ECONOMIC POLDER SIZE IN HALDA RIVER VALLEY - AN ALTERNATIVE APPROACH IN PLANNING AND DESIGN

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Certificate

This is to certify that this thesis work has been done by me and neither this thesis nor any part thereof has been submitted elsewhere for the award of any degree or diploma.

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entitled 'ECONOMIC POLDER SIZE IN HALDA RIVER VALLEY --- AN ALTERNATIVE APPROACH IN PLANNING AND DESIGN' be accepted as fulfilling this part of the requirements for the Degree of Master of Science in Engineering (Water Resources).

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ABSTRACT

For the flood protection of Halda river valley comprising an area of about 45,000 acres of cultivable land, IECO, Consultants of Bangladesh Water Development Board in 1974 proposed to construct two large polders as East and West Polders with embankments designed for flood of 50 year return period. Instead of constructing two large polders on the east and west banks of Halda river, five small polders can be planned using two existing roads i.e. Chittagong-Kaptai and Chittagong-Rangamati roads as embankment with the provision of a few drainage sluices at road crossings with channels. The advantage of the Small Polder Scheme is that if any breach in embankment occurs, only that smaller area will be affected and the remaining polders will be unaffected from flood inundation. On the other hand, with Large Polder Scheme a breach in embankment will inundate a larger area.

In the analysis, two alternative embankment plans of 50 and 25-year flood return periods were studied for the project area. The annual benefit for both the cases were assumed to be same and was derived from increased crop intensity as well as improved crop yields. The capital costs of embankment construction were found to be Tk. 76.58 and Tk.64.38 millions for embankment designed for 50-year and 25-year flood, respectively. Accumulated present worth of benefits considering 15% discount factor were found to be Tk. 549.37 and Tk. 517.94 millions, respectively. The benefit-cost ratios were calculated as 8.57 and 9.66 for embankment designed for 50 and 25-year floods, thus making the embankment plan of 25-year return period more economic.

In the analysis of Small Polder Scheme compared to Large Polder Scheme it was found that an additional capital cost of drainage sluices amounting to Tk. 20.16 millions is required for providing drainage facility to each of the three Small Polder-I, II and III of Large East Polder area. Similarly, another additional capital cost of drainage sluices amounting to Tk. 5.20 million is required to divide the Large West Polder area into two Small Polder-IV and Polder-V. The additional benefit for the Small Polder Scheme was derived from net crop damage. The net crop damage was obtained from four major storms of 1962, 1963, 1968 and 1969 considering with and without embankment conditions. The additional benefit which is the average of net crop damage of four storms of different cases of polder/polders affected by embankment breaching and protected from the flood was determined considering the two large polders separately. The additional annual benefits for each of the cases were obtained using probabilities of breaching of 0.4 and 0.25 in any year. The incremental benefit-cost ratios were calculated considering 25 year project life as the embankment plan of 25-year flood return period was found economic and selected for flood protection. The average incremental benefit-cost ratios of Small Polder Scheme for the project area were found as 8.32 and 5.20 for breaching probabilities of 0.40 and 0.25, respectively.

Analysing the engineering design and planning aspects, it has been concluded that the flood control by Small Polder Scheme having embankments of 25-year flood frequency is economically feasible and technically viable for Halda river valley. This embankment project can be recommended for implementation.

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LIST OF ABBREVIATIONS

BWDB	Bangladesh Water Development Board
EPC	Engineering and Planning Consultants Ltd.
EPWAPDA	East Pakistan Water and Power Development Authority
HYV	High Yield Variety
IBRD	International Bank for Reconstruction and Development
IECO	International Engineering Co. Inc.
JCHW	Justin - Courtney - Hohlweg - Watts
LLP	Low Lift Pump
O and M	Operation and Maintenance
PWD datum	Public Works Department datum
SOB datum	Survey of Bangladesh datum

CHAPTER – 1

INTRODUCTION

1.1 General

Human civilization developed near rivers and floodplains from the creation of the Earth, as adequate quantity of water for drinking and irrigation purposes, case of travel, trade etc. through waterways and the fertile agricultural land of the floodplains have attracted people to settle themselves. As civilization start in such places, man's life fall in tremendous hazard by occasional flooding of the floodplain. The uncontrolled flood causes not only damages to crop and property but also losses in livestock, damage to homesteads, disruption of transportation, other losses and untold suffering to the affected people. These hazards by flooding can be minimised by flood protection embankment.

Halda river valley is one of the largest floodplain of Karnafuli river system of which Halda river is a tributary. A location map of the project area is given in Figure 1.1. The average maximum flood depth is about six feet in monsoon in the lower Halda floodplain. Inundation of floodplain is due to the overbank flows from rivers and surface runoff from surrounding hills. The flood embankments can protect about 45,000 acres of cultivable lands and will ensure double cropping in most of the low lying areas which are now being cultivated for single crop. Overall protection from floods has a psychological effect on the minds of the farmers who are encouraged to raise crops freely without fear of flood damage.

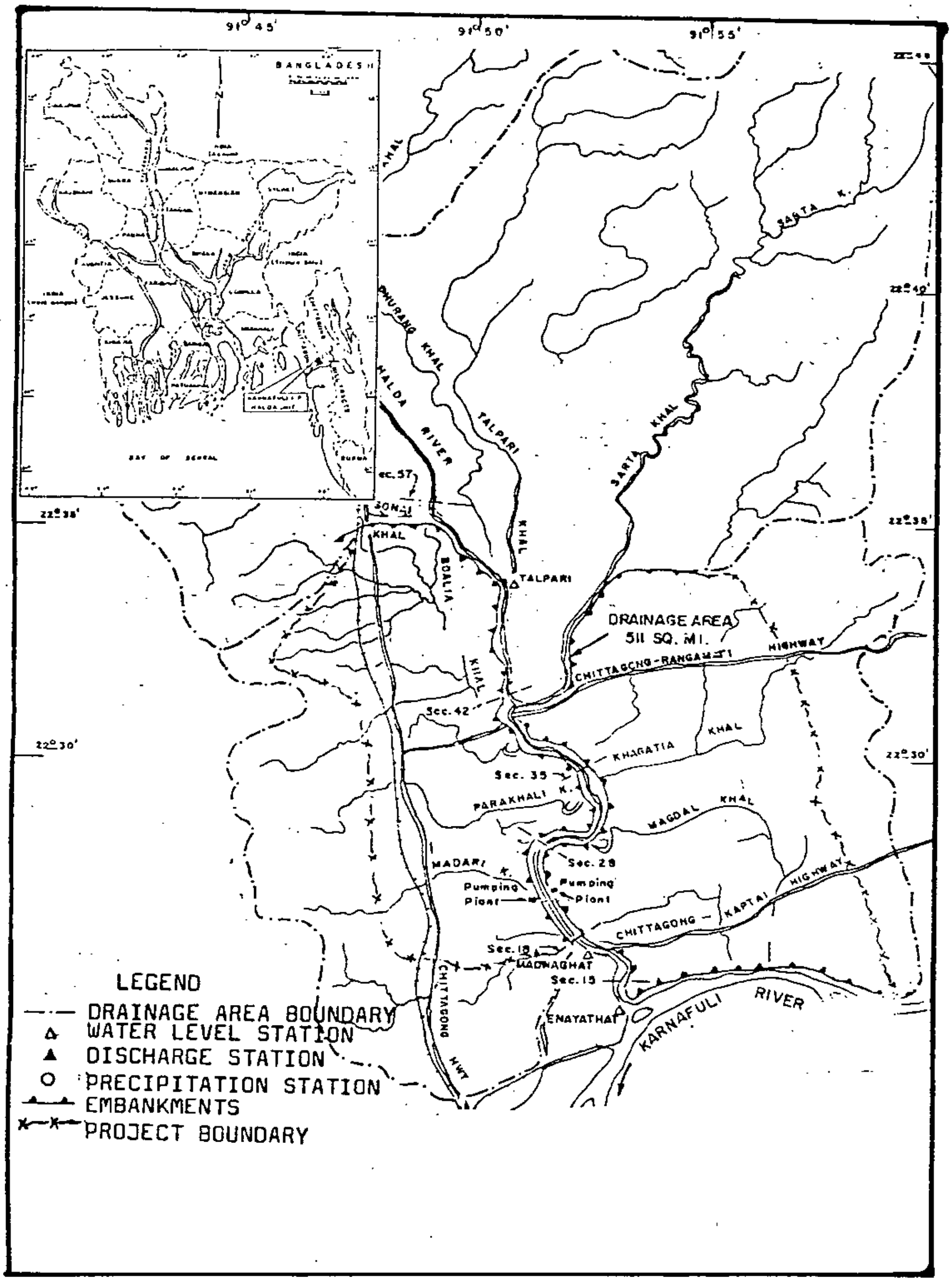


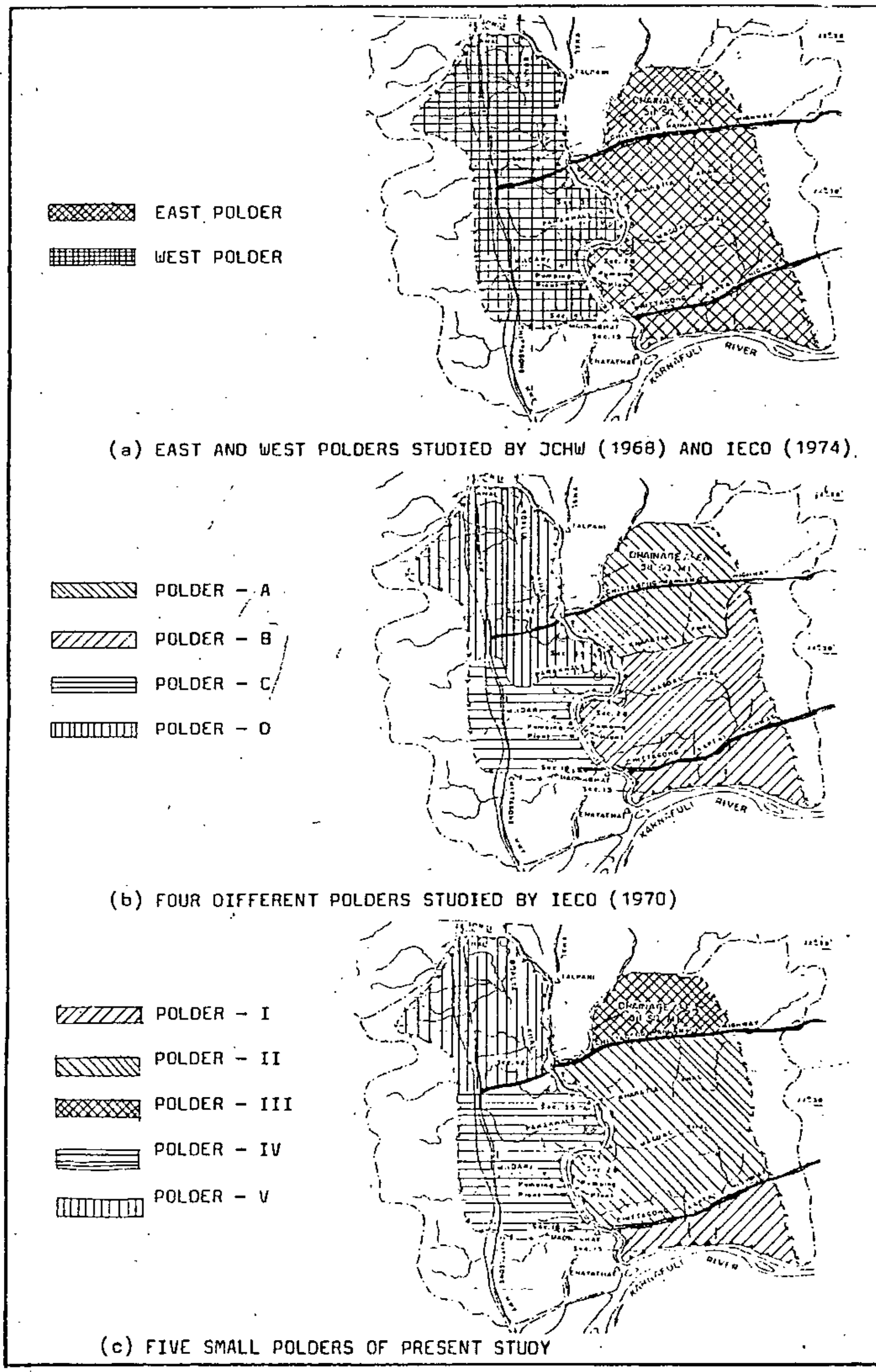
FIGURE 1.1 : LOCATION MAP OF THE PROJECT AREA

1.2 Previous embankment schemes for project area

Development of the whole Halda valley comprising of about 84,600 acres of cultivable land by irrigation, flood control and drainage was studied by Justin - Courtney - Hohlweg - Watts (JCHW), during the period 1965 to 1968 (JCHW, 1968). Their findings were presented in a feasibility report published in May, 1968. In that report a cost comparison was made between a proposed plan for irrigation by pumping from the Karnafuli river with a large pumping plant and an alternative plan which included the development of two storage reservoirs on the Halda river and the Dhurang khal. The irrigation by pumping alternative was found to be slightly more economical and recommended for implementation. JCHW also suggested construction of two large embankments on both sides of Halda river for the lower Halda valley comprising a cultivable area of about 45,000 acres. The two large polders are shown in Figure 1.2 (a).

In a subsequent review of the feasibility report, International Bank for Reconstruction and Development (IBRD) recommended that the report be updated in the light of additional available data and the new concepts of irrigation development in the country in the recent years (World Bank, 1975).

Between July 1970 and November 1970, another study was conducted by International Engineering Co. Inc.(IECO). In that study IECO proposed to provide embankment for lower Halda valley along the right bank of the Karnafuli river, on both banks of the Halda river, on south bank of Sonai khal and Sartakhal, and on both banks of the Khagatia khal as well as Parakhali khal (IECO, 1974 b). These embankments divided the lower Halda valley into four small polders as shown in Figure 1.2 (b).



(a) EAST AND WEST POLDERS STUDIED BY JCHW (1968) AND IECO (1974).

(b) FOUR DIFFERENT POLDERS STUDIED BY IECO (1970)

(c) FIVE SMALL POLDERS OF PRESENT STUDY

FIGURE 1.2: DIFFERENT POLDER SCHEMES FOR THE PROJECT AREA

During April 1973 through March 1974, a revised feasibility study was carried out by a joint venture of IECO and Rahman and Associates (IECO, 1974 b). In that study they proposed the most economic plan for irrigation on the lower Halda valley of 40,000 acres of irrigable land by surface water. The fresh water that enters through the existing khals during high tides will be stored in the khal by operating fifteen regulators. These regulators are located along the embankment on the khals. Irrigation water will be provided to most of the irrigable land by pumping this water using low lift pumps (LLP) for high yield variety (HYV) rice cultivation in dry season. The drainage would be accomplished by operating regulators along with improvement of drainage channels and by constructing two drainage pumping plants at the lower Halda valley. Finally for flood protection, the consultants proposed to embank the East Polder by right Karnafuli dyke and extended Halda east embankment along the south bank of Sarta khal and West Polder by the Halda west embankment extended along the south bank of Sonai khal (IECO, 1974 a).

The World Bank (1975) in an appraisal report on Halda river valley which was completed in December 1975, recommended that the main components of the project be based on the revised feasibility report of March 1974 of IECO. A summary of the appraisal is as follows (World Bank, 1975):

1) Construction of sixteen gated regulators at the outlets of khals to the Karnafuli and Halda rivers;

2) Construction of five cargo-transfer stations at selected regulator sites;

3) Improvement of about 41 miles of existing khals and the excavation of about 6.5 miles of new khals;

4) Twenty seven pumping stations with a total of 71 low lift, 2 cfs. pumps (or equivalent) to irrigate the higher areas;

5) Installation of about 710 low lift, diesel-powered 2 cfs. pumps (of which about 410 are for replacing the existing pumps) to raise water from the khals to adjacent low farm lands for irrigation;

6) Construction of small earthfill khal check structures; and

7) Construction of flood protection embankments of about 36 miles with some borrow pit areas to be used for drainage and water supply.

It should be noted here that, two pumping plants of 1200 cusec and 800 cusec in east and west side of Halda river respectively, located about 6,000 ft. upstream of the Chittagong Kaptai Bridge as proposed by IECO in 1974 for drainage as well as irrigation had not been provided in the Appraisal Report (Qasem, 1984).

As per Appraisal Report, project work started in the year 1975, and by 1982 almost all the major components of the project work was completed except 27 pumping stations and flood embankment on the right bank of Karnafuli and both banks of Halda river (Qasem, 1984). The proposed embankment designed for 50 year floods divide the project area into two large polders and involve huge construction costs and valuable land acquisition. The chain of villages along the river banks, highly developed with numerous pucca homesteads, fall along the proposed embankment alignment (Ahmed, 1983). As a result, the affected villagers opposed the construction of the embankment at the very inception of the project. As such the project authority had submitted a report to the World Bank Resident Mission in Bangladesh for deletion of the embankment, designed by the consultant and an alternative suggestion was given to construct an embankment of reduced height by connecting the existing village roads (Qasem, 1984). The roads will have to be redesigned and upgraded for this purpose. However, the modified alignment of the proposed embankment is in the proximity of the proposed earlier embankment alignment (Ahmed, 1983). In 1982, Irrigation Engineer of IDA Mission, Bangladesh, advised to conduct a survey along the village roads which may serve as embankment of less than 50 year flood. From this survey it has been found that with partial improvement, the existing village roads parallel to Halda river banks can be utilized as embankments along the east and west floodplains of Halda river to protect the area from overbank flows. The east and west floodplain of Halda at the lower reach of the river are also intersected by two motorable roads (Chittagong-Kaptai road and Chittagong-Rangamati road) running along the east-west direction. These roads divide the area into six small regions as shown in Figure 1.2(c). One of the small region on the right bank of Karnafuli river near Chittagong City is comparatively raised and rapid expansion of the Chittagong municipal area almost covers the whole compartment. That area can be left without any flood control embankment. The remaining five regions of huge cultivable land can be planned as individual small polders.

1.3 The importance of the study

The purpose of this research is to plan an economic flood embankment for a floodplain by several small polders instead of a large polder. This study will provide a helpful guideline in planning future flood control projects by a planner. This study will also provide a methodology of economic analysis of Small Polders Scheme compared to Large Polder-Scheme. In Bangladesh, the existing roads are generally above the normal flood level and if they cross a floodplain dividing the area into several small polders, these roads can be economically used as embankment with proper planning to get an economic flood embankment project.

1.4 Scope and objective of the study

Two reputed consulting firms have planned to provide flood protection for lower Halda valley. JCHW (1968) suggested two large polders to be constructed by embankments along the banks of Karnafuli and Halda river and IECO (1970) suggested four small polders using embankments along the banks of Halda river, Khagali khal and Parakhali khal. Naturally the investment cost for small polder system will be comparatively higher. This involve additional cost of earthwork and land acquisition for secondary embankments along the banks of khals. If the area is poldered into five small polders, as suggested in the present study two existing motorable roads can be utilised as the secondary embankments. This small polder system require a minor cost of a few drainage regulators at the road crossings with khals.

It is possible to build a large polder on each bank of the Halda river. Again several small polders may be built on each bank. The advantage of a large polder is economy in construction, but disadvantage is that if there is a breach in the embankment, a large area will be inundated. On the other hand, if several smaller polders are built in place of one large polder, the construction cost will be more but in case of breach in embankment a smaller area will be inundated. Thus it is likely that a Small Polder Scheme will be beneficial compared to a Large Polder Scheme because the extent of damage in terms of cropped area will be less for the former scheme.

The objective of the proposed research is to choose from two possible polder schemes: one consisting of two large polders and the other of five smaller polders in the lower Halda floodplain, the one that is economically most feasible and technically and socially viable. The specific objectives are as follows:

1) Economic analysis of the two flood protection schemes, one consisting of two large polders and the other of five small polders, in terms of benefit-cost ratio.

2) Economic analysis of embankments designed for 50-year and 25-year flood.

3) Planning of infrastructures, such as embankment and drainage sluices for both the polder schemes for flood control and drainage of the project area.

CHAPTER - 2

DESCRIPTION OF THE STUDY AREA

The Halda unit of Karnafuli Irrigation Project is to provide irrigation and drainage facilities and improved agricultural support services to farms in a net cultivable area of about 45,000 acres in the lower Halda valley. Irrigation water is to be provided by low lift pumps from an improved khal system. The khal system will retain the tidal recharge coming into the project area and water level will be maintained by the existing regulators. At present drainage is provided by the improved khals discharging into Halda and Karnafuli rivers. Almost all the major components of the project work was completed during the years 1975-1984 as proposed in the Appraisal Report of the project except flood embankments.

2.1 Location

The project area is located around the Halda tributary of the Karnafuli river in south east Bangladesh near the coast of the Bay of Bangal, some 130 miles from Dhaka. The project area comprises parts of the Rauzan and Hathazari Upazillas of Chittagong district. Latitudes and longitudes of the project area are $22^{0}25'-22^{0}35'$ and $91^{0}45'-91^{0}60'$ respectively. The project area is about 9 miles upstream of Chittagong City. The project location map is shown in Figure 1.1.

Two major motorable roads pass through the project area. These roads are above flood level and can be used as embankments for small polders. A paved highway from Chittagong to Kaptai cuts across the souther part of the project. Another paved highway, which connects Chittagong with Rangamati, extends 10 miles up the west side of the Halda valley to Hathazari where it turns east and crosses the valley. A minor upgrading of this road may be required to use it as an embankment.

2.2 Topography and Geology

The major part of the Halda valley is a wide, flat floodplain between the Sitakunda Range to the west and the Chittagong Hill Tracts to the east. In the southern part of the valley the lowest land is generally located about midway between the Halda river and the foot of the hills on each side. The slopes are gentle, almost flat. Elevation ranges from about 6 feet (SOB) in the low areas to about 14 feet (SOB) along the banks of the Halda and Karnafuli rivers. In the upper part of the valley the slopes are more irregular although the variations in elevations are generally small except near the hills. A large depression, the Boalia Bil, is located west of the Halda river and 10 miles north of the Karnafuli river. The valley floodplain narrows gradually upstream from the confluence of the Halda river and Dhurang khal.

The hills surrounding the Halda valley and the bedrock underlying the flood plain are formed by plio-pleistocene sediments consisting of soft friable sand stones, siltstones and shale. The alluvium in the flood-plain consists of stream-deposited sand, silt and clay. The thickness is unknown, but it probably reaches 300 to 400 feet or more in the south central part of the valley (IECO 1974 b).

2.3 River System

The Halda tributary of Karnafuli river is a meandering stream with a number of ox-bow-bends emerging from the hills which are located about 35 miles north of the Karnafuli river. The Halda river, located approximately in the middle of the valley, receives several tributaries. The major tributary khals as shown in Figure 1.1 on the eastern bank of Halda river are; Dabu khal, Khagatia khal, Magdal khal, Sakarda khal and Baruakhali khal. Uhalong khal and Had khal of the valley discharge into the Karnafuli river. Madari khal, Parakhali khal, Chenkhali khal and Boalia khal are major tributary khals on the western bank of Halda river. Sarta khal is just outside the project area. The average discharge of Halda river at Fatikchari gaging station is estimated to be 1,090 cusecs. The dry season discharges range from 10 to 100 cusecs in dry year and from 20 to 200 cusecs in the wet year. The lowest flows occur normally in April. The highest recorded discharge of 30,000 cusecs occured on July 10, 1968 and the corresponding river stage was 38.0 feet Survey of Bangladesh (SOB) datum. The Halda river finally discharge to Karnafuli river near Madana ghat about 8.5 miles upstream of Chittagong Port. The intrusion of saline water reached about four miles downstream of Halda and Karnafuli confluence. The location of different hydraulic gage stations are shown in Figure 1.1. Typical hydrographs of Halda river at Enayathat location is given in Figure 2.1.

2.4 Soils

Soils of the proposed project area are deep and nearly level. Where slight natural gradients occur, individual plots have been levelled to form terraces. Top soil textures range from loam to clay, with silty clay loam

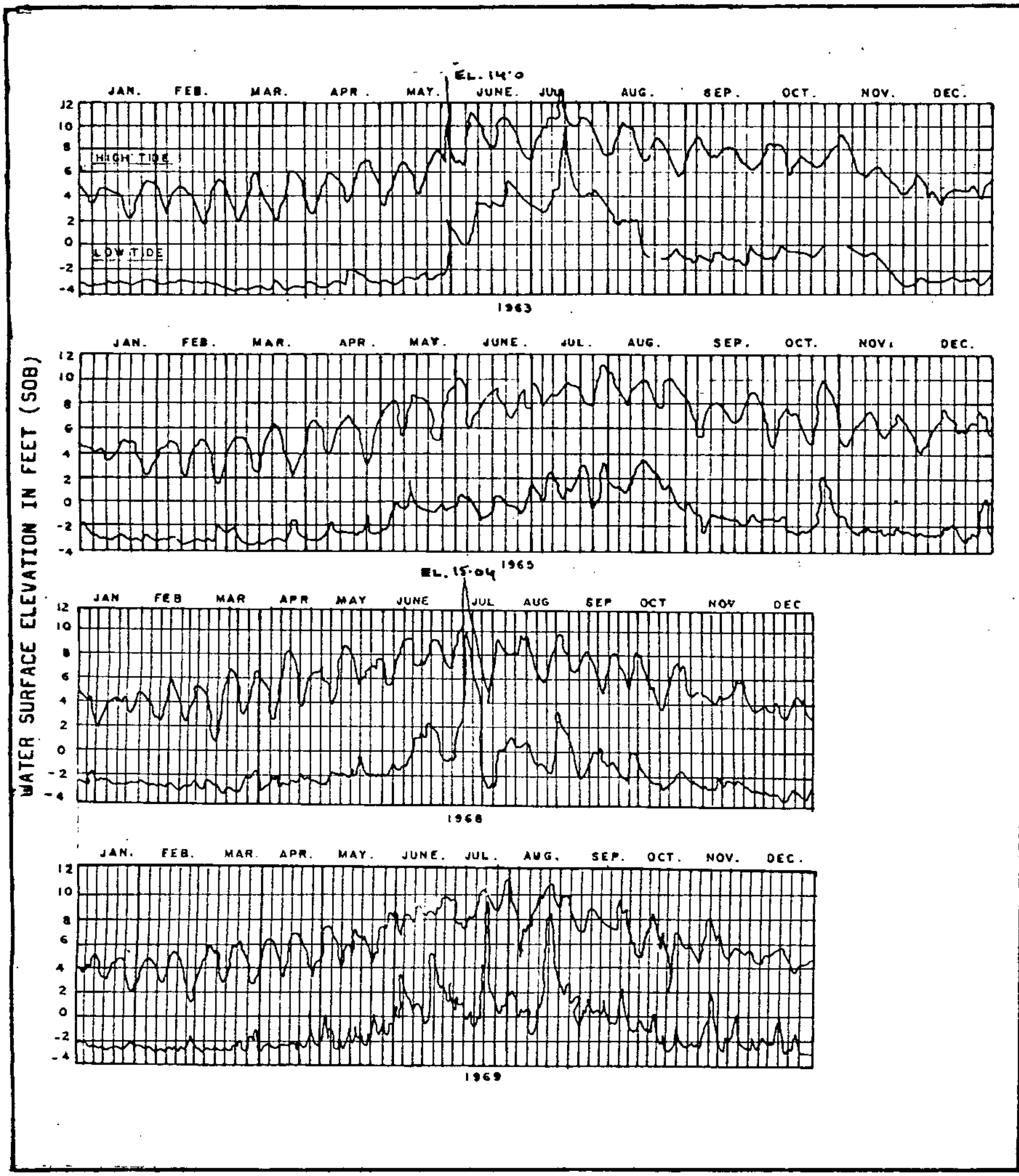


FIGURE 2.1: TYPICAL HYDROGRAPHS OF HALDA RIVER AT ENAYATHAT (AFTER IECO 1974 a)

and silty clay being the most common (JCHW, 1968 a). Soil permeability is low to moderate and is excellent for rice production. The area is seasonally flooded with depths seldom exceeding 4 feet (IECO, 1974 b). Most of the area is suitable for transplanted Aman during the wet season although the obtained yields are below optimum.

2.5 Climate

The project area has three main seasons: the monsoon from June to October, during which about 80% of total annual rainfall is recorded, the dry season from November to February, which has very little rainfall and the lowest temperature and humidities, and the pre-monsoon season from March to May, which has the highest temperatures and evaporation rates with occasional heavy rain storms. Cyclones, originating in Bay of Bangal in April-May and September-November, periodically cause severe damage along the coast, west of the project area. Mean monthly temperatures vary between 67° F in January and 83° F in May (IECO, 1974 b). The mean diuranal range in temperatures is about 20° F in the dry season, and 9° F in the rainy season. Relative humidity ranges from 65% to 85%. Annual rainfall averages about 110 inches. Evaporation ranges from 3 inches in January to 6 inches in May (IECO, 1974 b).

2.6 Existing Irrigation

Diuranal tidal fluctuations in the Bay of Bangal causes a back up of fresh water in the Karnafuli and into the Halda rivers and hence into the khals throughout the project area. At present this surface water is provided for irrigation by single lifting, using most of the purchased 800 LLP for HYV rice cultivation during dry season (Qasem, 1984).

The water is obtained from existing khal network where high tide water level is maintained by the operation of 15 gated regulators at the outfall of khals to Karnafuli and Halda river along proposed embankment alignment. Average command area per 2-cusecs pump is about 40 acres. About 25,000 acres of low lying land near the khal network is being irrigated by water from the khals. About 3,000 acres of higher lands are also being irrigated by ground water using shallow/deep tubewell (STW/DTW) in dry season.

2.7 Existing Drainage

Drainage in the project area is rudimentary. Khals convey excess water to the principal rivers, which are backed up during high tides. Large areas are thus flooded several times during a monsoon season with consequent reduction of crop yields. The water levels in the khals are low during dry season since there is practically no rainfall from November through April. Therefore drainage during dry season normally does not present any problem in the project area.

2.8 Agricultural development

The economy of the Halda valley is very much dependent on agriculture. Presently existing crops and cropping patterns are dictated almost entirely by flooding and drainage conditions in wet season and by lack of moisture in the higher land in dry season.

Rice is the main crop in the project area. There are three varieties of rice - Aus, Aman and Boro. Aus, a crop with a short growth period. is usually broadcast with the early rains in March - April and harvested in July-August. Aman, the main crop, is almost always transplanted.

Broadcasted Aman (B.Aman) is sown generally in June – July and Transplanted Aman (T.Aman) is transplanted a month later; and both are harvested in November – December. However, in some low lying areas, transplanting (Aman) is delayed until the monsoon flood recedes or if flood depths in July – August destroy the young plants before they become well established. Boro, which is cultivated with irrigation, is sown in December – January, transplanted a month later and harvested in May – June. The yields of local varieties are relatively low: 0.5 tons/acre for Aus; 0.8 tons/acre for Aman and 0.9 tons/acre for Boro (World Bank, 1975). The HYV Aus, Aman and Boro presently give yields of about 1.0, 1.2 and 1.7 tons per acre respectively. During dry season Rabi crops like Potato, Pulses, Oilseeds and Vegetables etc. are grown utilizing residual moisture after the harvesting of the rice crop. No jute is grown in this area.

2.9 Present cropping pattern without embankment

The most common cropping pattern in the project area is the cultivation of HYV–Boro as a single crop. This is grown in medium to medium low lands by surface water irrigation in dry season. Most of the low lying lands do not allow to go for second crop (Aman). Remaining land of relatively less flood depth is used for T. Aman as a chance crop. HYV–Boro is also cultivated in the higher land by ground water irrigation as these lands are comparatively flood free. These lands can be used for second crop in the monsoon for growing Aman rice.

The next important pattern is the growing of Aman (Transplanted) followed by Aus in the same field. This is grown in medium high to medium lands. Some times it is also practiced on the medium low lands, but in that case Aus is generally grown transplanted.

The third important pattern in the project area is the growing of transplanted Aman and Rabi crops in the same field. The fourth major pattern is the cultivation of three crops in a single field in a year. The crops grown in this pattern are Aus, Transplanted Aman and various Rabi crops.

Present cropping pattern is shown in Table 2.1 and cropping calendar is shown in Figure 2.2. This crop calendar represents the agricultural data published in Upazila Statistics of recent years (BBS, 1985). The present cropping intensity of the proposed project area is 181%.

PRESENT CROPPING PATTERN

TOTAL CULTIVABLE AREA 45,000 ACRES

TABLE - 2.1

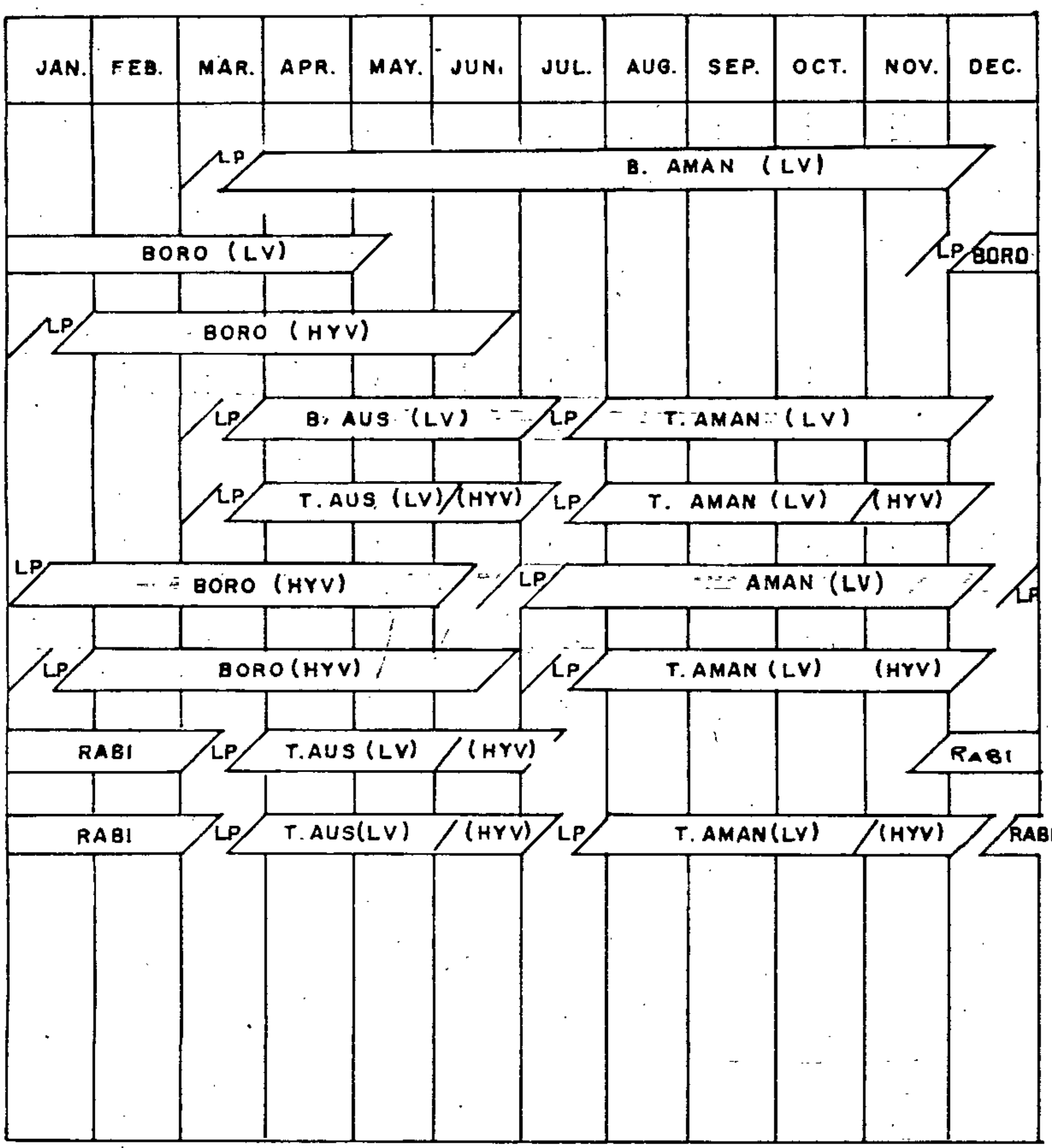
(AREA IN ACRE)

ELEVATION (FT. SOB)	BORO(LV/HYV)		AUS(LV/HYV)		AMAN(LV)		RABI		REMARKS
	EAST POLDER	WEST POLDER	EAST POLDER	WEST POLDER	EAST POLDER	WEST POLDER	EAST POLDER	WEST POLDER	
	500(LVS)	500(LVS)			800(LVSB)	700(LVSB)			
5 - 8	5,500(HYVS)	3,500(HYVS)							Boro irrigation
	8,500(HYV)	4,500(HYV)			8,500(LVB)	4,500(LVB)			by surface water
	2,000(HYV)	1,000(HYV)			2,000(LVB)	1,000(LVB)			"
8 - 10			2,000(LVB)	2,000(LVB)	2,000(LVT)	2,000(LVT)			
	1,000(HYV)	2,000(HYV)			1,000(LVT)	2,000(LVT)			
10 - 20			1,000(LVT)	2,000(LVT)	1,000(LVT)	2,000(LVT)			Boro irrigation
			2,000(LVT)	1,000(LVT)	2,000(LVT)	1,000(LVT)	2,000	1,000	by ground water
			2,700(LVT)	1,800(LVT)			2,700	1,800	
	500(LVS)	500(LVS)	2,000(LVB)	2,000(LVB)	11,3000(LVB)	6,200(LVB)			
TOTAL	17,000(HYV)	11,000(HYV)	5,700(LVT)	4,800(LVT)	6,000(LVT	7,000(LVT)	4,700	2,800	

LV - Local Variety, HYV - High Yield Variety, B - Broadcast rice, T- Transplanted rice and S - Single crop

EAST POLDER : (1) Single crop - 6,800 acres, (2) Double crop - 17,200 acres and (3) Triple crop - 2,000 acres

WEST POLDER : (1) Single crop - 4,700 acres, (2) Double crop - 13,300 acres and (3) Triple crop - 1,000 acres



LP – LAND PREPARATION
LV – LOCAL VARIETY
LVT– LOCAL VARIETY TRANSPLANTED
HYV– HIGH YIELD VARIETY

FIGURE 2.2: CROPPING CALENDAR

CHAPTER - 3

REVIEW OF PREVIOUS FLOOD AND DRAINAGE STUDIES

Flood and drainage studies of the project area were done by JCHW (1968) and IECO (1974). To provide flood protection, JCHW proposed to construct embankments of 10 year return period along the east and west bank of Halda river. To solve the resulting drainage congestion of West Polder area, they suggested a large drain (West Main drain) for the lower area west of the Halda river starting from Chittagong-Rangamati Highway to enter the Halda river just above the Chittagong-Kaptai Highway (JCHW, 1968 a). JCHW also proposed to re-excavate the other major channels to drain the East Polder area. They proposed to construct only five drainage structures at the embankment crossing with Had khal, Magdal khal, Khagotia khal, Dabua khal and West Main drain. Two storage reservoirs upstream the project area can reduce the peak flow which can be used for dry season irrigation were also proposed in their development plan.

IECO (1974) in their study also recommended the same embankments as suggested by JCHW for flood protection but the embankment was designed for 50-year flood return period. To solve drainage problem, IECO proposed to re-excavate all the existing channels. They suggested to construct 15 drainage sluices at the outfall of khals. The irrigation water is to be lifted from existing khal net work by LLPs in dry season.

According to the IECO's proposal, the channels re-excavation and drainage sluices construction were completed during the period 1975 to 1982.

Major drainage channels and sluices were implemented as per IECO's design. The present study is the extension of IECO's study, as such IECO's studies on flood control and drainage are described in the subsequent articles.

3.1 Flood studies

The flood studies of the project area were done by IECO in 1974 (IECO, 1974 a). These studies were done to get the flood water surface profiles of Halda river for different flood frequencies. IECO analysed hydrological records of different stations that were available upto 1969.

3.1.1 Flood frequency analysis of Halda river at Fatikchari

The flood water surface profile of 50-year recurrence interval was obtained from 50-year precipitation record. The precipitation of 1968 was taken as 50-year precipitation. Other profiles for 25 and 10 year recurrence intervals were obtained from the linear ratios of discharge of 50-year to 25-year and 50-year to 10-year at Fatikchari (from Figure 3.1). IECO computed the annual peak discharges of Fatikchari considering channel flows as well as overland flows from 1954 to 1969 (IECO, 1974 a). Over land flow was considered as the flow over floodplain for a sectional area across the length of Halda river at Fatikchari. Annual peak discharges and recurrence intervals of Halda river at Fatikchari is shown in Figure 3.1.

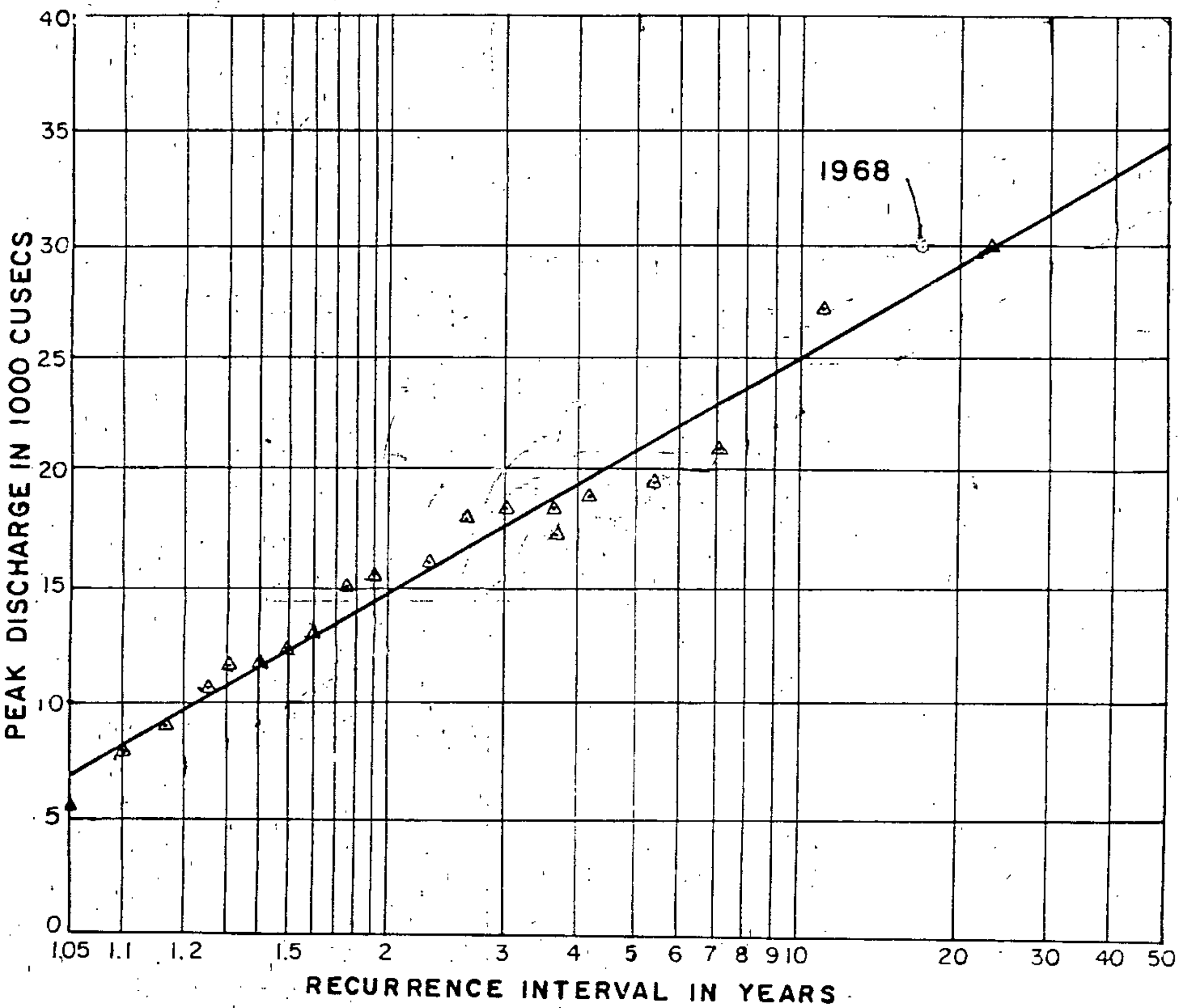


FIGURE 3.1: FLOOD FREQUENCY ANALYSIS OF HALDA RIVER AT FATIKCHARI (AFTER IECO, 1974 a)

3.1.2 Design discharges

The 50-year flood was computed by IECO (1974 a) from a 50-year precipitation considering the drainage areas of the tributaries of Halda river as given below. The computed 50-year flood of Halda river at Fatikchari, Sonai and Sartakhal locations were 31,900, 67,670 and 77,650 (without ponding) cusecs, respectively.

Tributary	Drainage area (sq. miles)
Halda river at Fatikchari	225.00
Durang khal at Fatikchari	90.00
Sua khal	35.40
Talpari khal	76.50
Sonai khal	16.50
Sarta khal	67.80
Total Halda river at Sarta khal	511.20

The proposed embankments along the lower Halda river will cause a back water effect from Sarta khal location (Figure 1.1) to upstream. The out flow from Sarta khal location was assumed to be controlled by the river stage as estimated from back water computations starting at the Karnafuli river (IECO, 1974 a). A modified flood flow was considered above the Sarta khal. The modified flow was considered with embankments, which will confine all the flow of wide floodplain to a single channel flow of Halda river at Sarta khal location. The hydrograph of the modified flood discharge (50-year flood frequency) at the mouth of Sarta khal was plotted and is shown in Figure 3.2. The peak discharge of 70,000 cusecs was assumed to remain constant from Sartakhal to the mouth of Halda river.

The flood hydrographs for 25 and 10 year return period at Sarta khal were first computed from the unadjusted flows using the ratios at Fatikchari of the 50-year flood peak to the 25-year flood peak as taken from recurrence interval in Figure 3.1 (IECO,1974 a). The unadjusted flow was considered with no embankment for the area. These floods were than routed through storage above Sarta khal to determine the modified flows (IECO,1974 a). The estimated peak discharges for 50, 25 and 10 years return period at various points along the Halda river were as follows:

PEAK DISCHARGES IN THE HALDA RIVER (IECO,1974 a)

RECURRENCE INTERVAL	LOCATION			
	FATIKCHARI	SONAI	SARTA KHAL	
			WITHOUT PONDING	MODIFIED*
50-year	31,900	67,670	77,650	70,000
25-year	28,000	59,000	68,500	63,500
10-year	22,700	48,000	55,500	50,000

* These discharges are assumed to remain unchanged through the entire reach from Sarta khal to the mouth of Halda river.

3.1.3 Flood water surface profiles

The water level in Karnafuli river with a recurrence interval of 50-year would be about 17.5 feet SOB, as obtained from Figure 3.3 (IECO, 1974 a). Of this, about 3 feet rise was considered to be caused

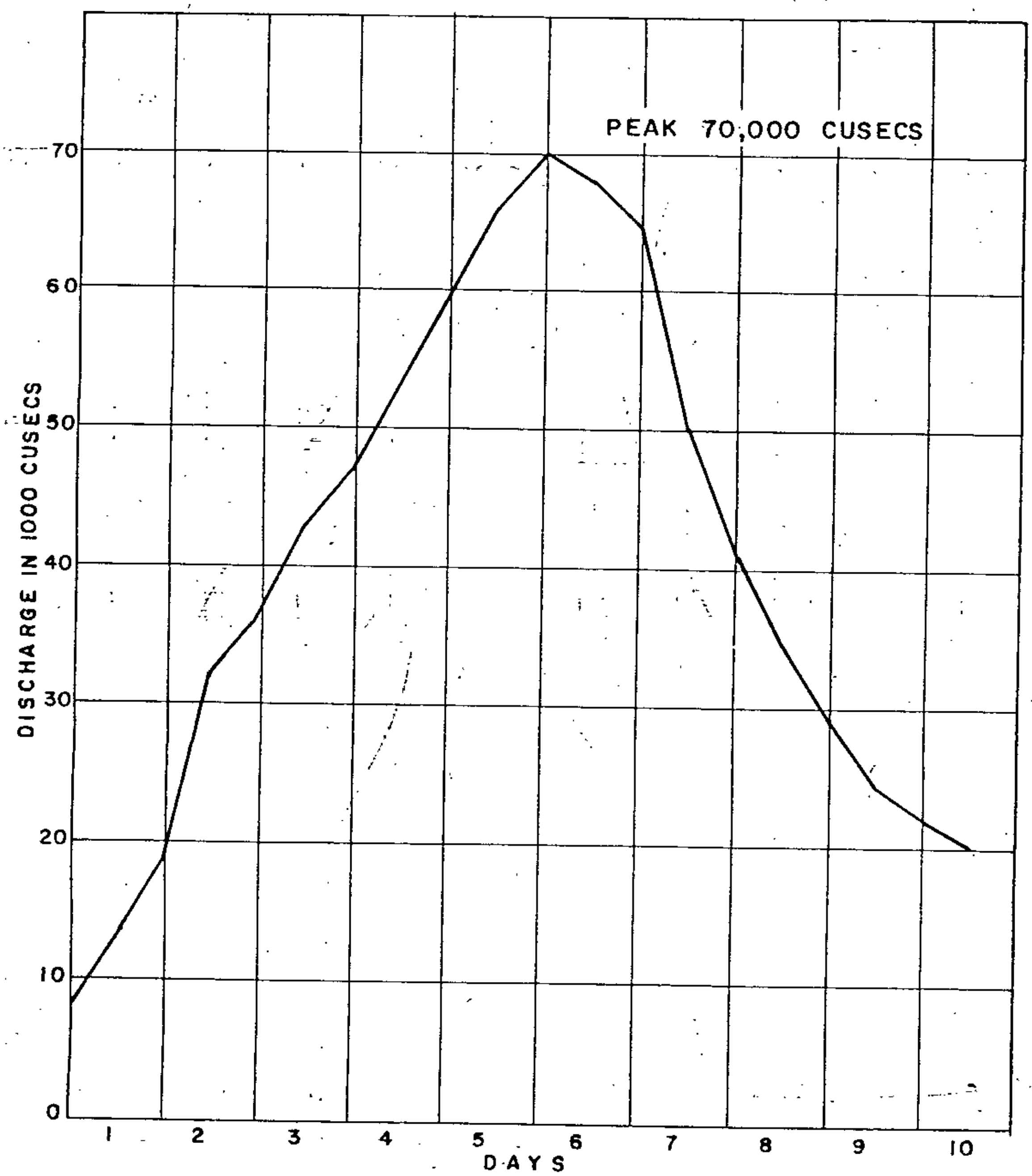


FIGURE 3.2: 50-YEAR DESIGN FLOOD OF HALDA RIVER AT SARTA KHAL LOCATION (AFTER IECO, 1974 e)

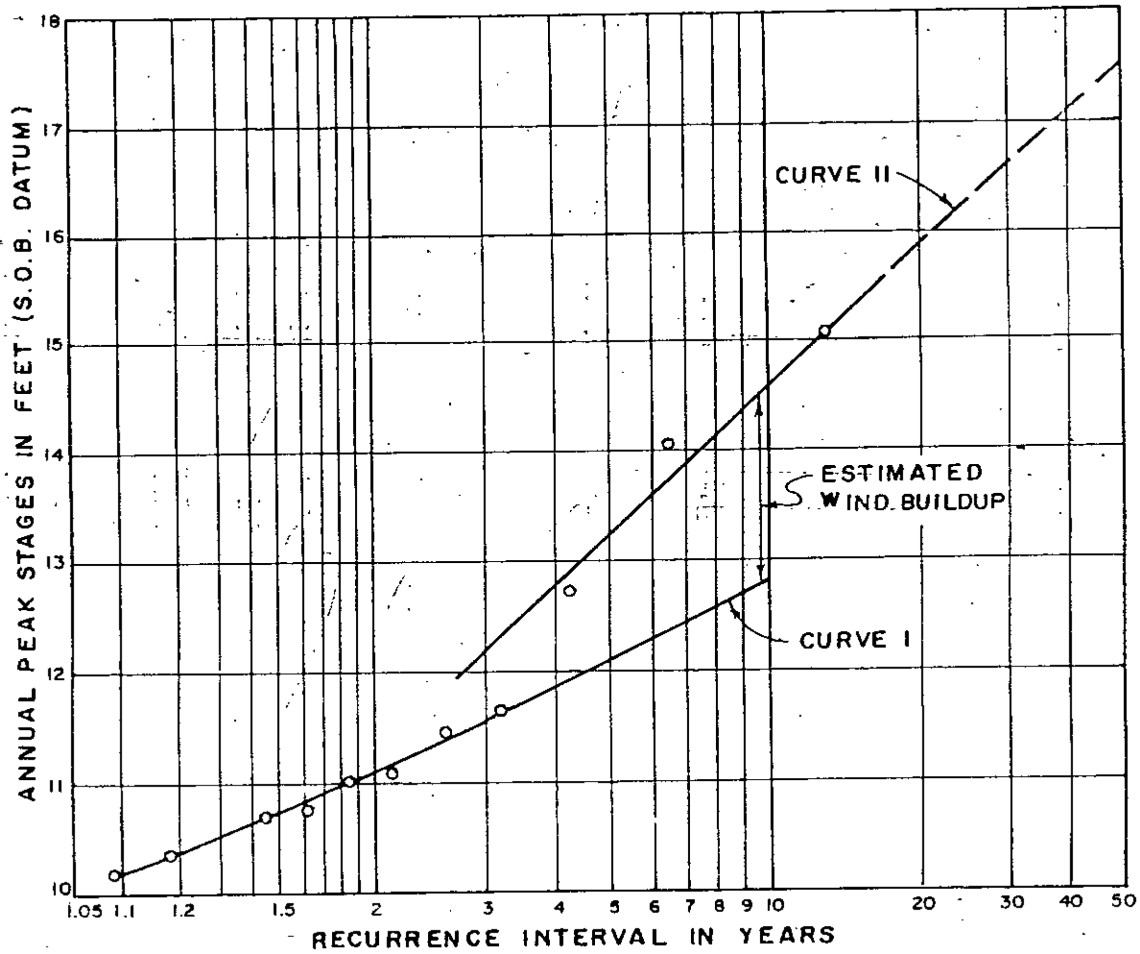


FIGURE 3.3: ANNUAL PEAK STAGES OF HALDA RIVER AT ENAYATHAT LOCATION (AFTER IECO, 1974 a)

by wind build-up and storm surges on the Bay of Bangal. The top of embankment in the lower reaches of the Halda (Chittagong-Kaptai Highway downstream) and the Karnafuli river was selected at elevation 18.5 feet for 50-year recurrence interval (Figure 3.3) with the provision of about 1 feet free board. It will provide 3 feet of free board with a discharge of 350,000 cusecs in the Karnafuli river with spring tide, but no wind build-up. Embankment heights for other flood frequencies are shown in Figure 3.4.

The water level of Halda river upstream of the Chittagong-Kaptai Highway was based on the stage of Karnafuli river. Considering the Karnafuli river stages for different flood frequencies as starting elevations, the backwater studies were made by IECO for Halda river starting from Chittagong-Kaptai Bridge. The different parameters for 50, 25 and 10-year recurrence intervals are as follows:

FLOOD RECURRENCE INTERVAL	STARTING ELEVATION IN THE KARNAFULI RIVER	HALDA LOSSES THROUGH CHITTAGONG-KAPTAI BRIDGE	ANNUAL PEAK DISCHARGE (CONSTANT FROM SARTA KHAL TO MOUTH OF HALDA RIVER
50-year	14.50 feet	0.5 feet	70,000 cusecs
25-year	14.30 feet	0.3 feet	63,500 cusecs
10-year	13.70 feet	0.1 feet	50,000 cusecs

The results of flood water surface profiles obtained from backwater studies for Halda river are presented in Figure 3.4. Embankment heights at different points along the alignment can be obtained from that figure after addition of a 3 feet freeboard for 50,25 and 10 years flood frequencies.

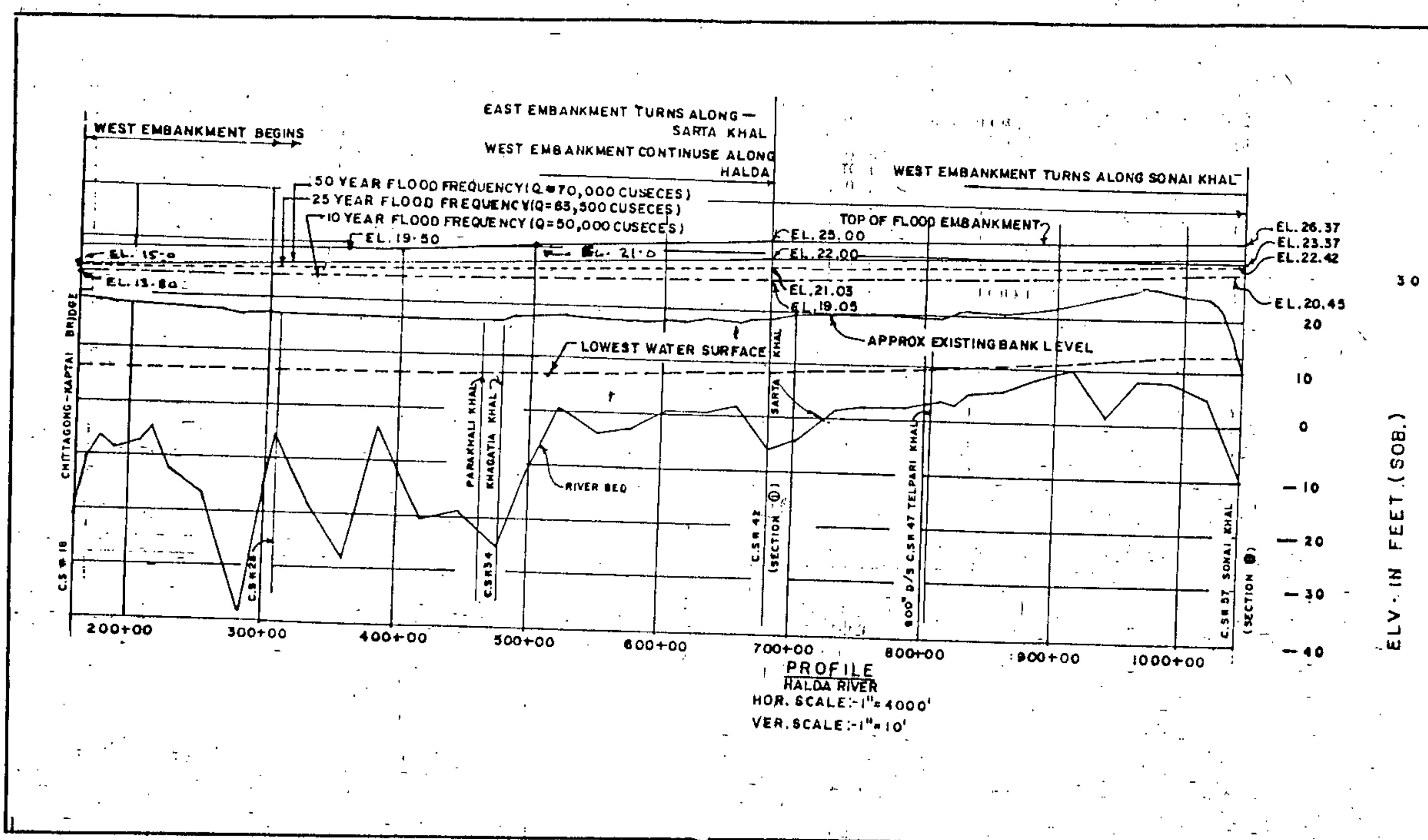


FIGURE 3.4: FLOOD WATER SURFACE PROFILES OF HALDA RIVER
(AFTER IECO, 1974 a)

3.2 Drainage studies

The drainage studies of the project area were done by IECO in 1974 (IECO, 1974 a). These studies were made to determine the economic feasibility of providing flood control and drainage for the development of the project. These studies provide the time, depth and duration of floods (Figure 3.6) of different flood frequencies.

3.2.1 Drainage area and surface run-off

The drainage areas which dictate the East and West Polder are shown in Figure 3.5. The drainage area for East Polder is 70.5 sq.miles which consists of Drainage Polder-I (35.4 sq. miles), Drainage Polder-II (21.7 sq.miles) and the Khagatia khal area (13.4 sq.miles). The drainage area for the West Polder is 74.4 sq.miles which consists of Drainage Polder-IV (30.0 sq.miles), Drainage Polder-V (37.2 miles) and the Parakhali area (7.2 sq.miles). Boundary of drainage areas are shown in Figure 3.5.

Considering rainfall, evapo-transpiration, infiltration and retention etc. the peak runoffs for the 3 major storms were calculated and are presented as follows (from IECO, 1974 a).

ESTIMATED PEAK RUNOFF

PERIOD	RETURN PERIOD	POLDER	NUMBER OF DAYS	TOTAL RAINFALL (IN INCHES)	TOTAL RUNOFF (IN INCHES)	PEAK RUNOFF (CUSECS)
July, 1963	7.52	East	8	24.26	22.39	10,760
		West	8	22.25	20.20	11,850
July, 1968	50.00	East	7	42.33	40.68	18,400
		West	7	43.74	41.55	15,270
August, 1969	5.47	East	6	18.36	17.40	11,540
		West	6	18.14	17.05	10,610

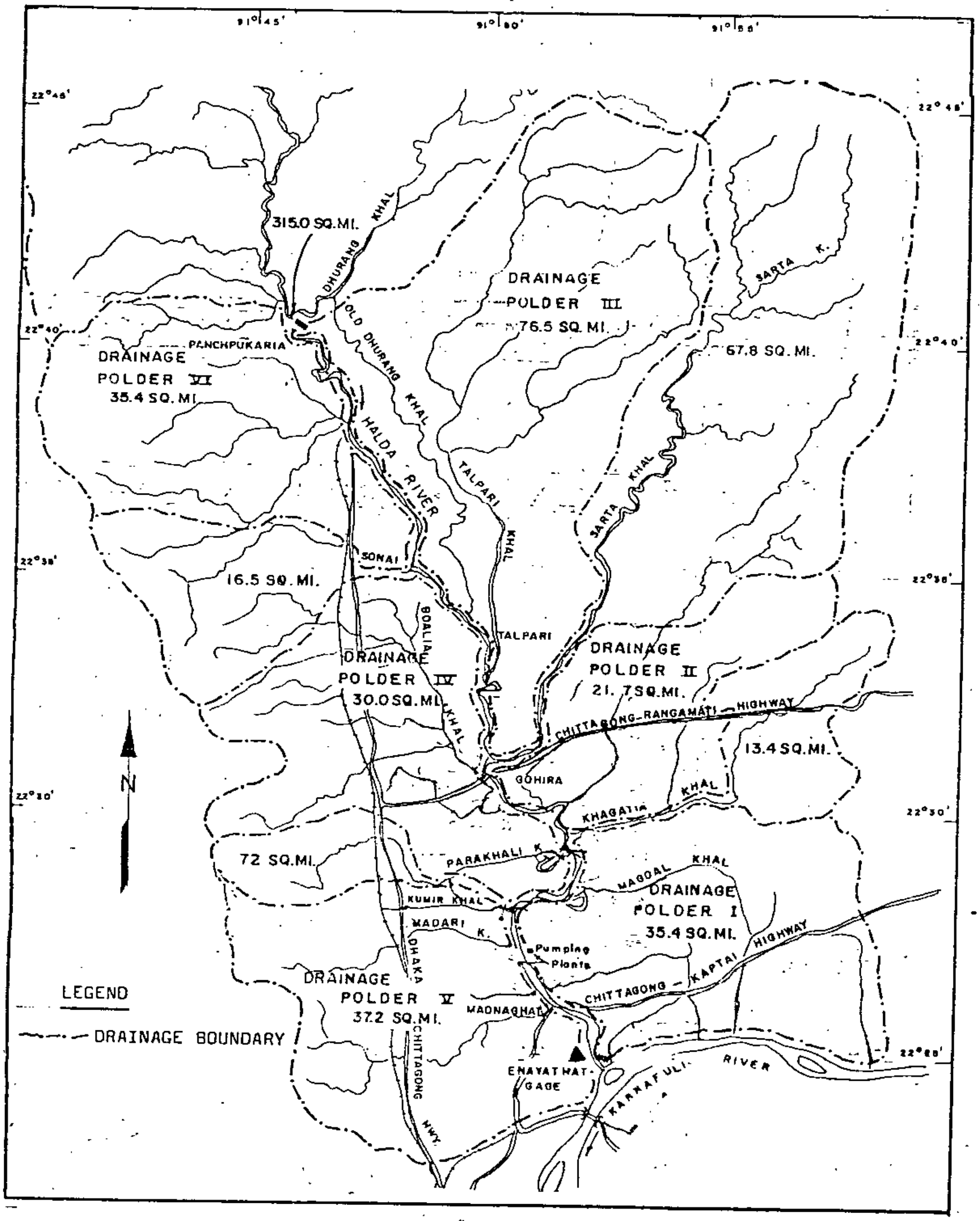


FIGURE 3.5: MAP SHOWING THE BOUNDARY OF DRAINAGE AREA
(AFTER IECO, 1974 a)

3.2.2 Interior drainage operation studies

Drainage operation studies for the East and West Polder were also done for the year 1962 through 1968 by IECO (1974 a). In planning the drainage operation system the following factors were considered

(a) Storm runoff into the ponding area,

(b) River stages,

(c) Ponding area-capacity relationships, and

(d) Discharges capacity of pumping plants and/or drainage sluices

In total, 37 and 34 vents (size 5 feet x 6 feet) of gated sluices were planned to accomplish the gravity drainage for East and West Polders respectively. For pump drainage, different numbers of pumping plants were considered in addition to the drainage sluices (shown in Figure 3.6). The river stages used in the study (IECO,1974 a), were the records of daily maximum and minimum water-levels of Halda river at Enayathat. That stage station was used as an average for all levels in the Halda and Karnafuli river, for the East and West Polders in the drainage operation study.

Considering all these factors, IECO presented detail information of drainage studies made for East and West Polders. Four major storms of different flood return periods were analysed to determine the interior flooding pattern that was later used to find the crop damage. The interior drainage operation for the storms 1962, 1963, 1968 and 1969 are presented in Figure 3.6(a – d).

EAST POLDER, 37-5x6 (WxH) REGULATORS
JUNE 1, 1962 THROUGH SEPTEMBER 30.1962

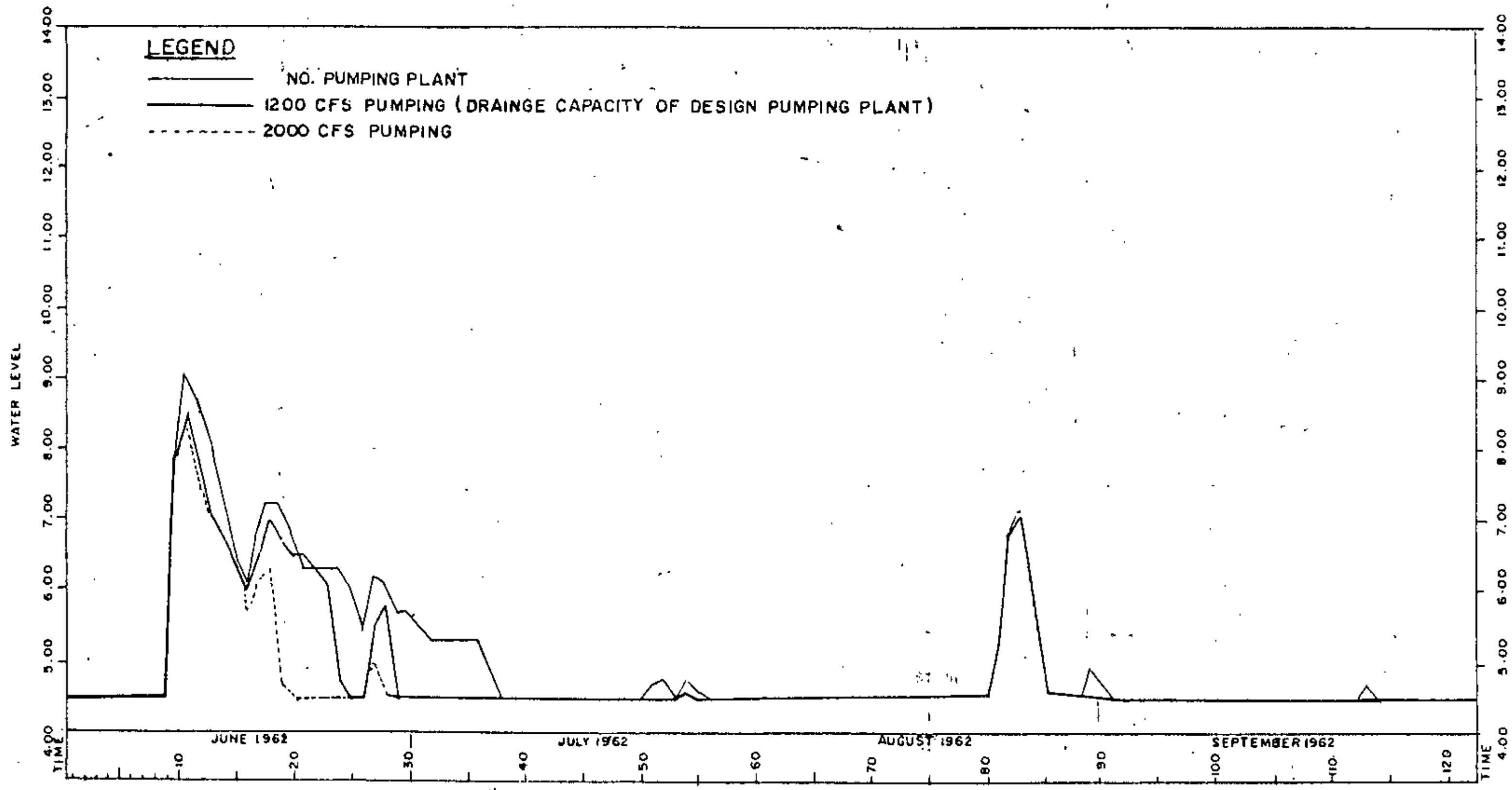


FIGURE 3.6 a: INTERIOR DRAINAGE OPERATION STUDIES
(AFTER IECO, 1974 a)

EAST POLDER, 37-5x6 (WxH) REGULATORS
JUNE 1, 1963 THROUGH SEPTEMBER 30, 1963

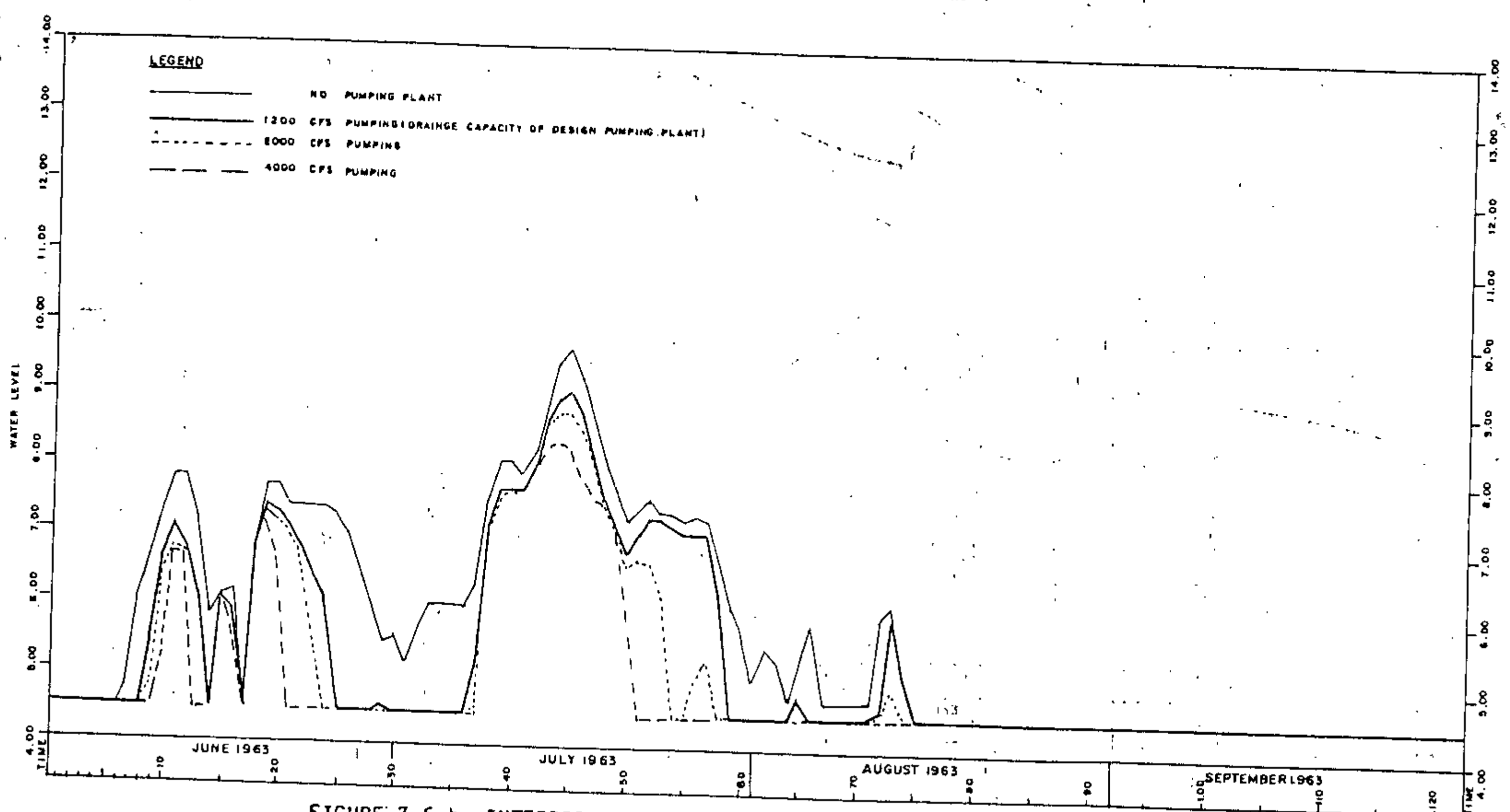


FIGURE 3.6 b: INTERIOR DRAINAGE OPERATION STUDIES
(AFTER IECO, 1974 a)

EAST POLDER, 37-5x6 (WxH) REGULATORS
JUNE 1. 1968 THROUGH SEPTEMBER 30.1968

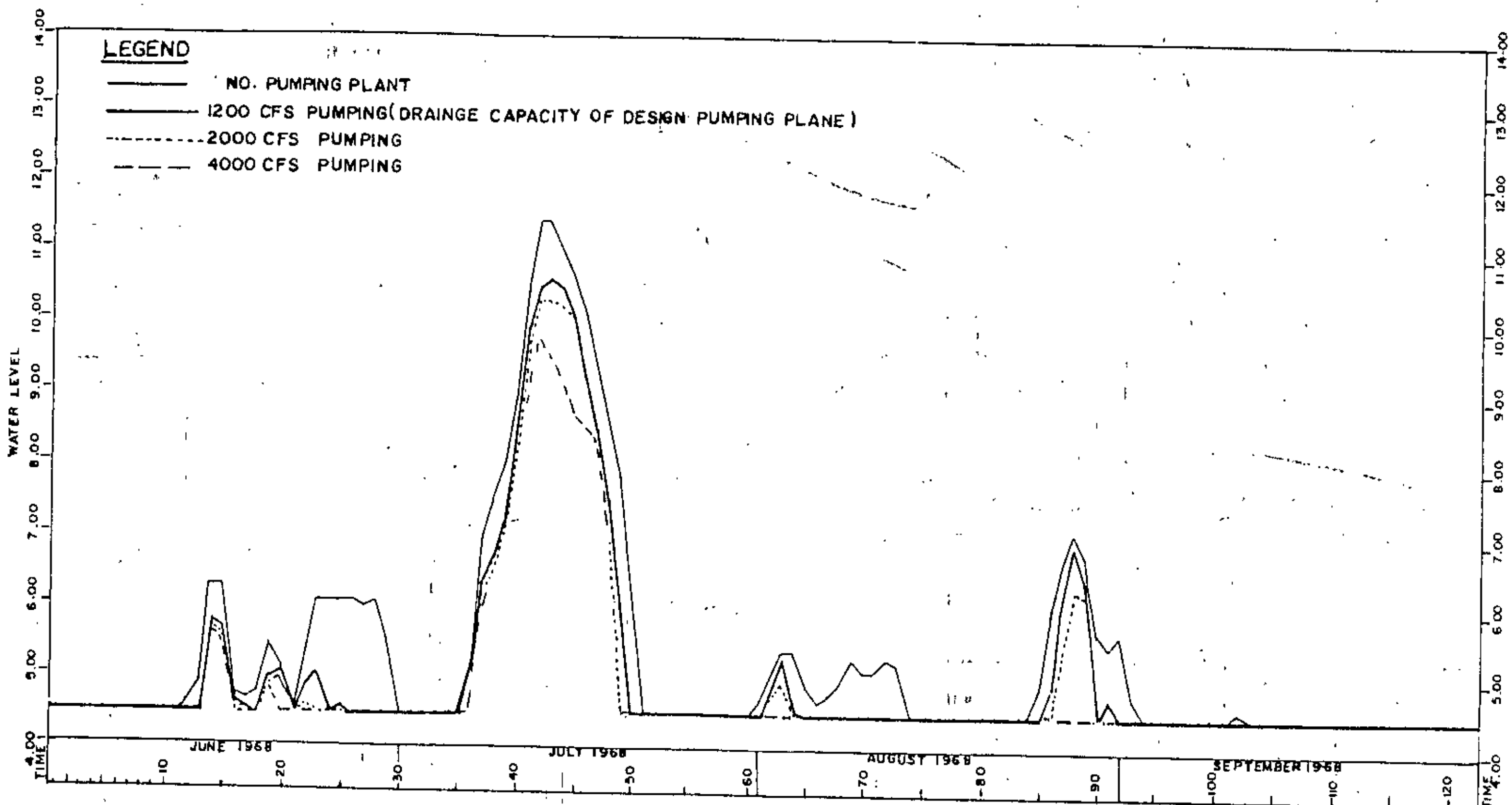


FIGURE 3.6 c: INTERIOR DRAINAGE OPERATION STUDIES
(AFTER IECO, 1974 a)

EAST POLDER, 37-5x6 (WxH) REGULATORS
JUNE 1. 1969 THROUGH SEPTEMBER 30.1969

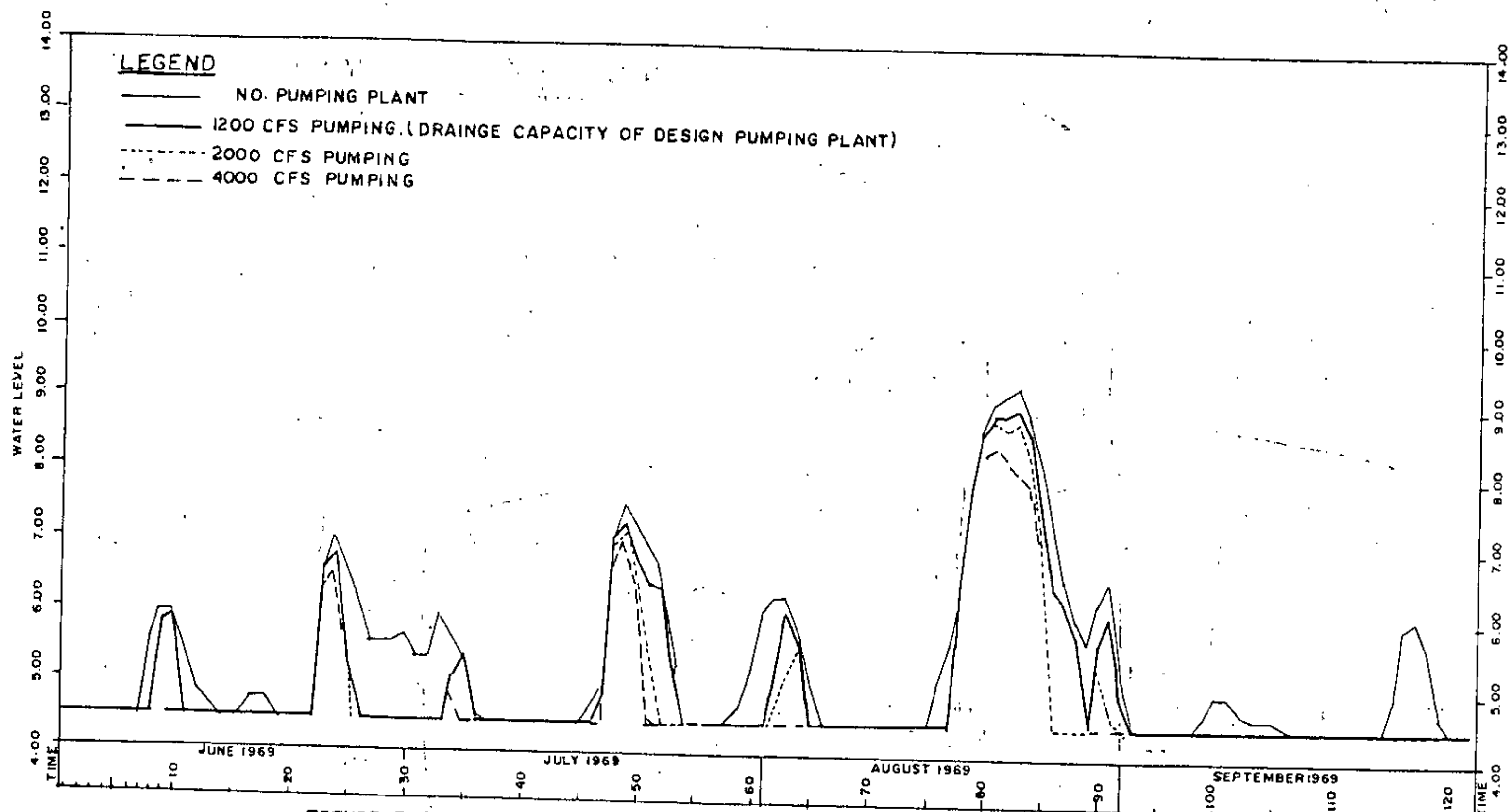


FIGURE 3.6 d: INTERIOR DRAINAGE OPERATION STUDIES
(AFTER IECO, 1974 a)

CHAPTER - 4

METHODOLOGY OF ANALYSIS

In this chapter the methodology of economic analysis of different flood protection alternatives are discussed. Firstly, the economic analysis of two embankment plans of 25 and 50 year flood frequencies was done. This analysis required the costs of embankment construction including land acquisition and turfing; and the benefits which are derived from incremental crop production considering with and without embankment conditions. The selection of the economic embankment plan was based on the higher benefit-cost ratio. Secondly, the economic analysis of small polder scheme compared to the large polder scheme was done. In this analysis an additional cost of drainage sluices at road crossings with drainage channels were considered. Since the existing roads were used as embankments in constructing the small polders, the additional cost of poldering was minimal. Additional benefits for small polder scheme were derived from net crop damage which comes from flood unaffected small polder/polders in case of breach in embankment in one polder. The selection of the economic polder scheme was based on the incremental benefit-cost ratio of small and large polders. The methodology of analysis is briefly discussed below.

4.1. Analysis of embankment plans

4.1.1 Cost of embankments

The alignment of the embankments were along existing village and motorable roads. The embankments sections were designed as per Bangladesh practice. The embankments heights for 50 and 25 year flood frequencies were obtained from the flood water surface profiles done by IECO (1974), after adding necessary freeboards The seepage line of the embankment section was drawn using Casagrands method and the stability of design embankment section was checked by Swedish slip Circle method. The net volume of earthwork of embankments for 50 and 25 year flood frequencies were calculated considering the designd section and the existing village roads. Total costs of embankments (structural cost) including land acquisition and turfing were calculated for both the embankment plans on the basis of the present schedule of rates used by BWDB.

4.1.2 Net incremental annual benefit

Considering the land elevations, flooding depth and availability of irrigation water, the present and future cropping patterns were prepared. Field informations and agricultural data of Upazila Statistics were used to prepare the present cropping pattern. Gross production values with and without embankment conditions were calculated on the basis of crop acreage, and yield . The cost of production was calculated based on the cost of labour (man and animal), seeds or seedling, fertilizers and insecticides. Incremental annual benefit was obtained after subtracting the annual benefit without embankment condition from the annual benefit with embankment condition. Net incremental annual benefit was obtained after subtracting a normal annual flood damage from incremental annual benefit. With embankment condition, the interior drainage congestion would occur and cause crop damage. This damage is considered as the normal annual flood damage. Net incremental annual benefit was assumed to be same for both the cases of embankment plans of 50 and 25 year flood frequencies.

4.1.3 Benefit-cost ratio

The capital costs of embankments plans of 50 and 25 year flood frequencies were obtained considering a contingency of 10% of capital cost and Engineering and administrative cost of 15% of capital and contingency costs. In this analysis a three year construction period and 15% discount factor were assumed. The operation and maintenance cost was considered as 2% of the capital cost from 4th year of the project life. Considering the above facts, the present worth of accumulated costs were calculated for both the embankment plans.

The benefits for both the embankment plans were considered same and derived from the net incremental annual benefit. The pattern of benefit build-up was considered 18%, 33% and 67% in the 4th, 5th and 6th year of project life. Full benefit was assumed from 7th year of the project life. Considering the discounting factor and project life, the present worth of accumulated benefits were calculated for both the embankment plans.

Benefit-cost ratios were obtained from the ratio of present worth of accumulated benefits to its corresponding present worth of accumulated costs for both 50 and 25 year flood embankment plans. The feasible embankment plan was selected on the basis of the higher benefit-cost ratio.

4.2 Analysis of small polder scheme

4.2.1 Cost of drainage sluices

Cost of drainage sluices are the additional cost (structural costs) of small polder scheme. The costs were calculated for east and west polder area separately. By operating the drainage sluices of an flood inundated polder, other small polder/polders can be protected from flood inundation. The number of vents of a drainage sluice were selected on the basis of the drainage area which is to be drained by the respective sluice. The sill and crest elevations of a drainage sluice were selected considering the respective channel bottom elevation and motorable road's top elevation. The cost of a drainage sluice was calculated from existing BWDB schedule of rates.

4.2.2 Net crop damage

Four storms of 1962, 1963, 1968 and 1969 were used to estimate the crop damage. Interior flooding hydrographs with embankment condition were developed by IECO (1974) for the period 1962 through 1969. The study indicate that the mentioned four storms can cause flood damage to crop due to interior drainage congestion. In this study, these four storms were used for crop damage calculation with embankment and with any breach of embankment conditions. The recurrence intervals of four storms were calculated by using Gumbel's asymptotic frequency distribution method. The interior flooding hydrographs developed by IECO (1974) for different storms were used in the estimation of crop damage with embankment condition.

For the calculation of crop damage by different storms with any breach of embankment, the Halda river stage was used. For each polder, a representative nodes with known water level was used. The flood depths and duration at these representative nodes for different storms were used in crop damage estimation. The water level of representative nodes were obtained from the water levels of gauging stations Talpari and Enayathat considering the slope of the water surface profile and linear interpolation.

The net crop damage by different storms for each of the small polder area is the difference between the crop damage with embankment and with any breach of embankment conditions. The average net crop damage from four storms for each small polder area was then calculated.

If there is a breach of embankment in the small polder then the other small polders are saved from flooding. The average net crop damage that would have occured to these flood protected polders without the small polder scheme was considered as benefit of this scheme. This benefit was then considered in the analysis of the incremental benefit-cost ratio of small and large polder scheme.

4.2.3 Probability of breaching of embankment

The probability of breaching of embankments for the Halda river valley was estimated and later used to calculate the annual benefits of small polder scheme.

To get an average probability of breaching of embankment for Halda river valley, the statistics on breaching of a few embankment projects in Bangladesh were collected. For this study, three embankment projects were selected. These projects are (a) Gumti Flood Embankment Project (2) Brahmaputra Right Bank Embankment Project (3) Khowai River Project.

For probability estimation, field visits were made to the respective embankment projects. The information on breaching of the embankment recorded by site Engineer were collected. After analysing the breaching of embankments of different projects, an average probability of breaching was calculated for each project. Considering these breaching probabilities, a representative value was selected for Halda river valley for further analysis.

4.2.4 Reduction of water level at downstream polders due to breach in embankment

It was assumed that with any breach of embankment of an upstream small polder the discharge at the representative nodes of other polders will be reduced by the net storage capacity of the inundated small polder. If the peak flow at the representative node is assumed to be Q_1 then the inflow to the breached polder to fill the respective storage volume is Q_2. The volume of Q_2 was computed by assuming a 48 hour time period to fill the available storage. The effect of the reduced discharge, (Q_1-Q_2) with its corresponding lowered water level on other downstream small polders was studied.

4.2.5 Incremental benefit-cost ratio

The additional capital cost of small polder scheme was calculated considering a contingency cost of 10% of capital cost and Engineering and Administrative cost of 15% of capital and contingency costs. The project life was taken on the basis of the selected economic embankment plan as discussed in Article 4.1.3. A two year construction period and 15% discount factor were assumed in the analysis. The operation and maintenance cost was assumed as 1% of the additional capital cost from 3rd year of the project life. Considering the above assumptions, the present worth of accumulated additional cost was calculated.

The additional benefit of the small polder scheme depends upon the crop damage that would have occured in polder protected from flood when a breach occurs in one polder. The additional annual benefits were calculated after multiplying the benefits by an average probability of breaching of embankment. The present worth of accumulated additional benefits were calculated considering 15% discount factor.

Incremental benefit-cost ratio was calculated considering the present worth of accumulated additional benefits and accumulated additional costs. The selection of economic polder scheme for flood protection of Halda river valley was based on the calculated incrmental benefit-cost ratio.

CHAPTER - 5

THE PROBABILITY OF BREACHING OF EMBANKMENTS

To get an average probability of breaching of embankments for Halda river valley the statistics on breaches of a few embankment projects in Bangladesh were collected. For this study three old embankment projects were selected. These projects are (1) Gumti Flood Embankment Project, (2) Brahmaputra Right Bank Embankment Project and (3) Khowai River Project. These three embankment projects were chosen because these projects are very old and provide much information regarding the embankment breaching. It is seen, that the embankment length of Gumti and Khowai embankment projects are similar to that of Halda River Valley Project. It is also seen that the breaching of of embankments of these two projects are caused by structural faults, human inference or flood water overtopping. But the breaching of Brahmaputra Embankment Project was mainly due to river shifting.

The records available for the embankment projects do not specify, however, wheather breaching of embankments were due to overtopping by flood flows, due to erosion of embankments by current action, due to changing of the river course or due to faulty design and lack of proper maintenance.

5.1 Analysis of breaching of embankments

5.1.1 Information collected on breaches

The breaching information was collected from BWDB's Head Office and from field offices. Annual Report of Flood in Bangladesh published by Flood Forecasting and Warnings Cell of BWDB (BWDB, 1974) provide the breaching information along with flood damages. The last Annual Report on Flood was published in 1974 which contained the breaching information upto 1974.

To collect the upto-date data on breaches of Gumti and Khowai embankment projects, field visits were made to the office of the Executive Engineer of Comilla O and M Division and Habiganj O and M Division in Comilla and Habiganj district. No field visit was made to the site office of Brahmaputra Right Bank Embankment Project. The length of embankment of this project is about four times greater than the embankment length of Halda river valley. Moreover, the breaching of Brahmaputra Right Bank Embankment Project are mainly because of river shifting as such nature of breaches of Brahmaputra Right Bank Embankment Project were considered different from that of Halda river valley. To calculate the probability of breaching of embankment for Brahmaputra Right Bank Embankment Project, the information available upto 1974 in Annual Report on Flood was used. The probability of breaching of embankment for Gumti Flood Embankment Project and Khowai River Project was calculated based on the data available upto 1986, collected after field visit.

5.1.2 Probability analysis of breaching of embankments

5.1.2.1 Gumti Flood Embankment Project

About 317 years ago, circa 1669, embankments were first constructed on both sides of the Gumti River in Comilla district. The total embankment length is about 42 miles starting from upstream high grounds of Indian border to Jafargang (Ali,1983). Following the record flood of 1956, the embankments were strengthened,the river channel alignment was improved by shortening the courses of loops, and the flow section was increased through lowering of the channel bed by dredging. This work was completed in 1957 - 1958 (EPWAPDA, 1965). In 1976, the Dumbur Hydro-Electric Project was completed in India, which now completely controls the monsoon flood of Gumti (Ali,1983). The embankment sections were designed based on the 77 years flood records and 200-year flood frequency (EPWAPDA, 1965). The design sections of 14 feet crest width, 3:1 (H:V) side slopes on both sides, 1:0.00001 longitudinal slope and 5 feet free-board are maintained by proper yearly maintenance work (Ali, 1983).

Breachings of embankments during the 81-year period, starting from 1906 through 1986, occurred in 45 years (Ali, 1983). Breachings of the embankments during 53-year from 1906 through 1958 (resectioning completed in 1958) was a recurring feature and the probability of breaching in any year was 0.74 (Table 5.1). The probability of breaching in any year from 1959 to 1976 (completion of Dumbur Hydro-Electric Project in 1976) was 0.22(Table 5.1). The probability for the period of 10-year from 1977 through 1986 was 0.2. Considering the total project life the average probability of breaching is 0.56. But considering the period before the completion of Dumber Hydro-Electric Project, the average probability is 0.61.

5.1.2.2 Brahmaputra Right Bank Embankment Project

Construction of the Brahmaputra Right Bank Embankment Project was started in 1963-64 and was completed in 1967-68 (Rahman, 1984). Under this project an embankment having a length of 135 miles from Kaunia in the district of Rangpur to Bera in the district of Pabna was constructed along part of Teesta and Brahmaputra right bank. The embankment was designed for 100-year flood frequency with the crest width varying from 14 feet (52 miles of embankment downstream of Kaunia) to 24 feet (for the rest embankment). The side slopes for whole length of the embankment was taken as 3:1 (H:V). The free-board was taken as 3 feet for a distance of 23 miles of embankment downstream of Kaunia and 5 feet for the rest of the embankment length. Construction of 25 miles of new embankment (an upstream embankment in addition to 135 miles), 9.5 miles of retired embankment, 25 miles of drainage channels and 110 feet of protection work were completed during the period 1974 to 1978 (Rahman, 1984). Now the total length of embankment is 160 miles.

It seems that the breaching of the Brahmaputra Right Bank Embankment occurred in 1970, 1972 and 1973 (BWDB, 1974). The probability of breaching of embankment for 7-year period from 1968 through 1974 is 0.43 (Table 5.1).

5.1.2.3 Embankment of Khowai River Project

The embankments of Khowai River Project was planned on both banks of the river for a total length of 78 miles in the Habiganj district. In total about 38 miles of embankments were constructed during the 9-year period from 1971 through 1979 (Habiganj W.D. Division, 1986). The embankment was designed for 50-year flood frequency with a crest width of 14 feet, country side slope of 2 to 5:1, river side slope of 2 to 3:1, and free-board of 3 feet (Sarm Associates Ltd., 1974).

The breaching of the embankments occurred in 1982, 1983, 1984, 1985 and 1986 (Habiganj W.D. Division, 1986). The probability of breaching in any year for 8-year period from 1979 through 1986 is 0.63 (Table 5.1).

TABLE 5.1

PROBABILITY OF BREACHING IN ANY YEAR

(1) GUMTI FLOOD EMBANKMENT PROJECT

PERIOD OF RECORD	YEAR OF RECORDS	YEAR OF BREACHES	PROBABILITY OF BREACHING IN ANY YEAR	REMARKS
1906 – 1958	53	39	0.74	RESECTIONING COMPLETED IN 1958
1959– 1976	18	4	0.22	DUMBUR HYDRO-ELECTRIC PROJECT COMPLETED IN 1976 IN INDIA
1977 – 1986	10	2	0.20	
Average	81	45	0.56	

(2) BRAHMAPUTRA RIGHT EMBANKMENT PROJECT

1968 – 1974	7	3	0.43	

(3) KHOWAI RIVER PROJECT

1979 – 1986	8	5	0.63	

5.1.3 Selection of an average probability of breaching

From the analysis of the probability of breaching of three old embankments projects in Bangladesh (shown in Table 5.1), it can be seen that the lower and upper limits of average breaching probabilities are 0.43 and 0.63 respectively. Considering the past record of embankment breaches the minimum average probability of breaching was found as 0.4 approximately. This can be taken as the normal breaching probability of embankment in Bangladesh. From Table 5.1, it can be seen that with proper resectioning the probability of breaching of Gumti Embankment Project was 0.22. Hence with proper design and maintenance the probability of breaching can be taken as 0.25. These two probabilities were considered in the economic analysis of Halda river valley.

5.2 Reduction of water level at downstream polders due to breach in embankment

Failure of embankment depends not only on the hydraulic characteristics i.e. flood water overtopping but is also related on seepage action and structural faults etc. If an embankment is designed for 50-year flood recurrence interval, it means that the design height of embankment is equal to the height of a peak flood water-level of 50-year return period plus a free-board (almost 3 feet). Now, theoretically it can not be said that the embankment will fail due to overtopping by a flood of 50-year recurrence interval. The embankment may fail for a flood of more than 50-year return period which will be able to overtop the design embankment height including free-board. On the other hand, the embankment may fail for reasons like severe seepage action or structural faults etc. for a flood of less than 50-year return period.

The hydrographs for each of the tributary areas upstream of the mouth of Sartakhal for recurrence intervals of 50, 25 and 10-year were determined, using design precipitation and unit hydrograph of each tributary developed by IECO (1974). Floods from each of the tributary were combined to give the Halda flood discharges at Sartakhal. The discharges were estimated to be 70,000 cusecs, 63,500 cusecs and 50,000 cusecs for 50, 25 and 10-year recurrence intervals respectively. The water surface profiles of the peak discharges are shown in Figure 5.1.

Five small polders as proposed in this study with their net storage capacity may influence the flow of peak flood discharge of Halda river. Any breach of embankment of upstream Polder-III or Polder-V, just upstream of Sartakhal mouth, will withdraw a discharge for a time span. The occurrence of this event was assumed to happen at the peak discharge and that will reduce flood level for the subsequent downstream polders. This magnitude of flood flow reduction may be negligible or significant, depending mainly on the reservoir capacity of the inundated polder.

The study was limited only on the breach of embankment of upstream Polder-III or Polder-V. The reduced flood flow for all the downstream polders was analysed. Also this study was based on the water surface profile (Fig.5.1) for different peak flows.

5.2.1 Assumptions on flow characteristics of Halda river

Polder-III and Polder-V, located upstream of Sartakhal mouth were designated as upstream polders; and other polders were designated as downstream polders. The breach of embankment of upstream polder was considered. Net storage capacity of inundated polder is the water volume

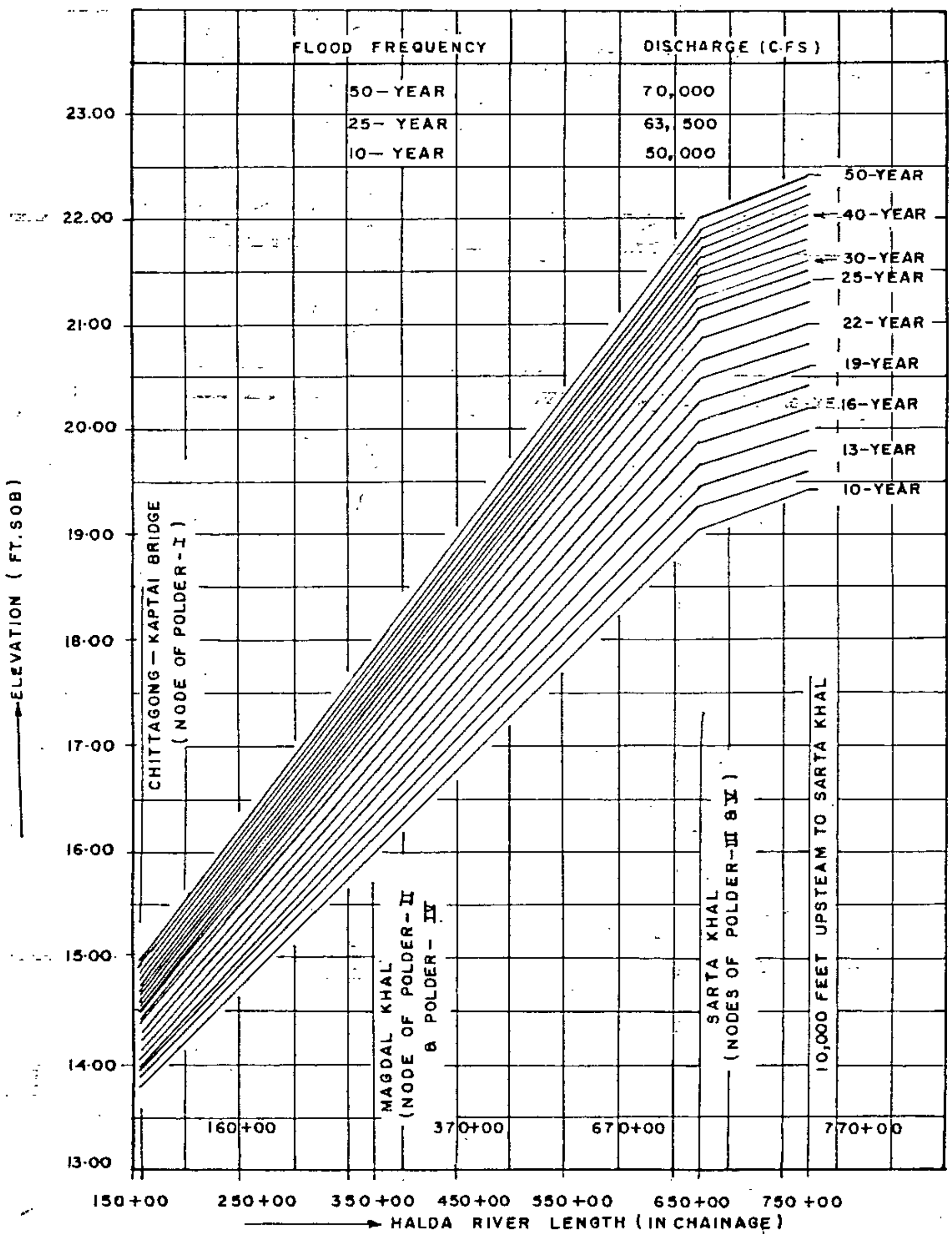


FIGURE 5·1: FLOOD WATER SURFACE PROFILES OF HALDA RIVER of that polder upto the equilibrium water level after any failure of embankment , considering polder interior normal water level before breaching . The following assumptions were made in analysing the effect of a flood for the downstream polders for any failure of embankment of any of the upstream polders.

1) A discharge of Halda river for any return period is assumed to remain constant, from Sartakhal mouth to the confluence of Halda river and Karnafuli river. Any reduction of discharge from this reach of the river will influence the subsequent downstream polders. An average flow is considered for 48 hours for Halda river which is the peak discharge (Q_1) of a particular return period.

2) Failure of embankment of any upstream polder will start at the time of peak discharge. Inflow to the polder will continue for 48 hours.

3) An average inflow (Q_2) to polder is considered based on the net storage capacity for an equilibrium water level. Downstream flow direction of Halda river is considered as a positive flow.

4) The reduced discharge ($Q_1 - Q_2$) will influence the downstream polder for their corresponding water level.

5) In no case the interior water level on inundated polder will be higher than the exterior water level (river stage) during selected 48 hours. That is, no return flow from polder is considered in analysis.

6) Net storage capacity of the inundated polder will never be less than the volume of water entering into the polder in the specified period.

5.2.2 Analysis of effect of breach

The effect of breach of embankment in upstream polder on downstream polders is presented by a set of sample calculation in this article. A breach of embankment of Polder-III (smallest upstream polder) by a flow of 50-year flood recurrence interval was used to analyse the effect of reduced flood discharge on downstream protected polders. It was considered that 70,000 cusecs (Q_1) peak discharge will flow (in Halda river) from Sartakhal mouth to the mouth of Halda river. From Figure 5.1, it can be seen that water level is 22.0 feet at the mouth of Sartakhal for the corresponding discharge of 70,000 cusecs. It was assumed that the embankment of Polder-III will fail at the time of peak discharge of 70,000 cfs. The inflow to Polder-III will start at the peak discharge and continue for 48 hours. The interior water level before breaching of Polder-III at the time of peak discharge was found (from Figure 3.6, 3 of 4) to be about 12.5 feet. The elevation of the storage volume of water in Polder-III, should be less than 22.0 feet otherwise backflow will occur.

As a trial the equilibrium water level was assumed to be 21.0 feet. After a breach when no flow occurs from river to polder or vice versa, the corresponding water level has been defined as equilibrium water level. The storage capacity of Polder-III for 12.5 feet and 21.0 feet elevation are 12,000 acre-ft. and 54,000 acre-ft. (from 7.3). The net storage capacity of Polder-III is 42,000 acre-ft. Therefore, inflow discharge to Polder-III, Q_2 is 10,588 cusecs. The net downstream flow is (Q_1-Q_2) 59,413 cusecs. The corresponding water level at the mouth of Sartakhal is about 20.50 feet (from Figure 5.1) which corresponds to a discharge of less than 25-year flood recurrence interval. The flood of 25-year recurrence interval is

63,500 cfs. and the corresponding water level is 21.05 feet. With further trial the actual equilibrium water level can be achieved. It can be observed that the residual flood discharge with any breach of embankment of Polder-III will be the flood of less than 25-year recurrence interval. The water levels for the representative nodes (obtained from Figure 5.1) of downstream polders are given in Table 5.2 with corresponding flood recurrence intervals. With the similar procedure, the water levels for the representative nodes of downstream polders with the failure of embankment of Polder-V were calculated and given in Table 5.2.

The analysis indicates that with any breach of embankment of Polder-III the flood of 50-year recurrence interval will be reduced to a flood of 25-year recurrence interval for the downstream polders. That is the chance of failure of embankments of downstream polder is reduced by 50 percent. Similarly with any breach of embankment of Polder-V, the flood of 50-year recurrence intervals will be reduced to a flood of 18-year recurrence intervals for downstream polders. That is the chance of failure of downstream polder embankment is reduced by 36 percent.

REDUCTION OF WATER LEVEL AT DOWNSTREAM POLDERS DUE TO BREACH IN EMBANKMENT

TABLE 5.2

1) WITH ANY BREACH OF EMBANKMENT OF UPSTREAM POLDER-III (SMALLEST POLDER)

	HALDA RIVER AT SARTA KHAL			AT REPRESENTATIVE NODE OF POLDER-II (OUTFALL OF MAGDAL KHAL)			AT REPRESENTATIVE NODE OF POLDER-IV (OUTFALL OF MAGDAL KHAL)			AT REPRESENTATIVE NODE OF POLDER-I (CHITTAGONG-KAPTAI BRIDGE)			AT REPRESENTATIVE NODE OF POLDER-V (HALDA RIVER AT SARTAKHAL)		
STORM	FLOOD FREQUENCY (YEAR)	DISCHARGE (CUSECS)	WATER ELEVATION (FT. SOB)	FLOOD FREQUENCY (YEAR)	DISCHARGE (CUSECS)	WATER ELEVATION (FT. SOB)	FLOOD FREQUENCY (YEAR)	DISCHARGE (CUSECS)	WATER ELEVATION (FT. SOB)	FLOOD FREQUENCY (YEAR)	DISCHARGE (CUSECS)	WATER ELEVATION (FT. SOB)	FLOOD FREQUENCY (YEAR)	DISCHARGE (CUSECS)	WATER ELEVATION (FT. SOB)
50-YEAR FLOOD FREQUENCY	50	70,000	22.00	25	63,500	17.25	25	63,500	17.25	25	63,500	14.60	Less than 50	-	-
25-YEAR FLOOD FREQUENCY	25	63,500	21.05	17.5	56,750	16.65	17.5	56,750	16.65	17.5	56,750	14.20	Less than 25	-	-

2) WITH ANY BREACH OF EMBANKMENTS OF UPSTREAM POLDER-V

	HALDA RIVER AT SARTA KHAL			AT REPRESENTATIVE NODE OF POLDER-II (OUTFALL OF MAGDAL KHAL)			AR REPRESENTATIVE NODE OF POLDER-IV (OUTFALL OF MAGDAL KHAL)			AT REPRESENTATIVE NODE OF POLDER-I (CHITTAGONG-KAPTAI BRIDGE)			AT REPRESENTATIVE NODE OF POLDER-III		
50-YEAR FLOOD FREQUENCY	50	70,000	22.00	18	56,900	16.70	18	56,900	16.70	18	56,900	14.25	Less than 50	-	-

CHAPTER - 6

PLANNING AND DESIGN OF EMBANKMENTS AND DRAINAGE SLUICES

The planning of embankments are based on the existing village road alignments and drainage sluices are based on the number of crossings of channels with existing Chittagong-Kaptai and Chittagong-Rangamati road. The embankments of 50 and 25-year flood were designed to provide the adequate sections to resist the corresponding peak floods.

6.1 Planning and design of embankments

6.1.1 Embankment alignment

The embankments alignment for lower Halda Floodplain was proposed by IECO in 1974. The proposed embankments for the lower Halda valley empolder Halda East Polder and Halda West Polder on east and west side of the Halda river respectively. A survey was done by BWDB along the existing village roads, which are in the proximaty of the proposed embankment alignment. This was done to reduce the cost of embankment, as because the modified alignment saves the cost of existing acquired lands and existing earth work volumes. From the survey data it is observed that the modified alignment is sufficiently far away from the existing stream line. The set back distance varies from 400 feet to 3,000 feet. The mofified alignment was based solely on the use of the existing village roads and hence reduce the cost of land acquisition and earth work volume.

The approximate crest elevations of Chittagong-Kaptai road and Chittagong-Rangamati road were found to be 20.25 feet and 24.0 feet (JCHW, 1968 b). Since the 50-year flood level at Enayathat is 18.0 feet, the

Chittagong-Kaptai road can safely be used as embankments of more than 50-year flood frequency. Considering the flood level (50-year) at Sartakhal as 22.00 feet the Chittagong-Rangamati road can also be used as embankment of 50-year flood frequency with an additional 2.0 feet height of free-board. The additional height of 1.0 feet of earth work is necessary to give a 3.0 feet free-board and will be required for about 2 miles. This earth work cost is ignored.

6.1.2 Design of embankment cross-section

6.1.2.1 Embankment crest profiles

The embankment crest profiles were obtained from flood water surface profiles of Halda river developed by IECO (1974), considering a free-board. The flood water surface profiles of 25 and 10-year flood return periods were obtained from the linear ratios of peak discharges of 50-year to 25-year and 50-year to 10-year at Fatikchari station. To update the analysis of IECO (1974) with recent data, a curve of recurrence intervals - annual peak discharge at Fatikchari on Halda river has been drawn. To draw this curve with recent data, a rating curve of discharge - elevation has been drawn (Figure 6.1) for the period 1954 through 1969 for Fatikchari. The peak annual discharges of channel and overland flows for the period 1970 through 1981 were obtained from the rating curve for their corresponding peak elevations. This was necessary because the available discharge data at Fatikchari consists of only the channel discharge and the overland flow could not be estimated. The present study was based on recent data after the construction of Kaptai dam in 1962 for the period 1962 through 1981. The recurrence interval of each annual peak discharge has been calculated and is given in Table 6.1. A curve for recurrence interval with the corresponding discharge has been drawn and is shown in Figure 6.2. This curve is slightly deviated (less than 10%) from the curve of IECO's study in the region of interest beyond 10 year recurrence interval . This deviation has not been considered significant to change the computed flood discharge and water surface profiles of Halda river for 50-year, 25-year and 10-year flood frequencies done by IECO (1974).

The embankments heights of 50, 25 and 10-year flood frequencies can be obtained after adding free-boards with corresponding flood water heights. As in Bangladesh the embankments are designed for 50 and 25 year flood frequencies, theee two alternatives were considered in this analysis.

6.1.2.2 Embankment crest widths, side slopes and free-boards

As the the embankment is the substitute of village roads, naturally it requires sufficient crest width that will provide vehicular movement. The widths were assumed to be 14 feet in both 25 and 50 year flood embankments. The side slopes were considered according to the Bangladesh practices, used in Coastal Embankment Project. For Karnafuli dyke the side slopes were taken as 1:2 (country side) and 1:3 (river side). Side slopes were taken 1:2 (country side and river side) for all other embankments.

The freeboard of Karnafuli dyke upto Madnaghat bridge was assumed to be 3.5 feet and the freeboards for all other embankments of Halda river dyke and other streams dykes were taken as 3.0 feet for both 50-year and 25-year flood frequencies.

ANNUAL PEAK DISCHARGE AND RECURRENCE INTERVALS OF HALDA RIVER AT FATIKCHARI

TABLE 6.1

YEAR	DATE	MAXIMUM WATER LEVEL (FT.SOB)	MAXIMUM WATER LEVEL (FT.PWD)	CHANNEL DISCHARGE (CUSECS)	CHANNEL PLUS OVERLAND DISC. CUSECS	RANK M	RECURRENCE INTERVAL *3 (YEARS)
1962	Jun.10	30.68	32.18	–	13,000 *1	13	1.62
1963	Jul.13	34.73	35.51	–	21,000	3	7.00
1964	Jul.30	30.42	31.92	–	11,700	15	1.40
1965	Jul.8	32.74	34.66	7,416	17,000	9	2.33
1966	Aug.25	32.54	34.66	8,899	18,000	8	2.63
1967	Jul.9	30.71	32.22	6,922	8,700	19	1.11
1968	Jul.10	37.99	39.35	9,535	30,000	1	21.00
1969	Jul.18	34.09	34.60	9,323	19,400	4	5.25
1970	Jul.24	34.15	35.65	16,880	18,300 *2	7	3.00
1971	Jun.28	31.23	32.73	–	12,000	14	1.50
1972	Jul.21	29.37	30.87	7,981	9,000	18	1.17
1973	Jun.18	28.06	29.56	5,403	7,200	20	1.05
1974	Jun.22	34.21	35.71	13,596	19,000	5	4.20
1975	Jul.28	36.99	38.49	14,585	27,000	2	10.50
1976	Jun.11	35.93	37.43	15,397	18,500	6	3.5
1977	Jun.29	33.05	34.58	14,903	16,000	10	2.1
1978	Sep.25	32.59	34.09	26,874	15,000	12	1.75
1979	Aug.21	32.85	34.35	6,886	15,500	11	1.91
1980	Jun.7	30.82	32.32	–	10,600	17	1.24
1981	Jul.5	31.11	32.61	–	11,500	16	1.31

*1 CHANNEL PLUS OVER-LAND FLOW FOR THE PERIOD 1962 THROUGH 1969 WAS CALCULATED BY CONSULTANTS (IECO, 1974 a).

*2 CHANNEL PLUS OVER-LAND FLOW FOR THE PERIOD 1970 THROUGH 1981 OBTAINED FROM FIG. 6.1

*3 FORMULA FOR RECURRENCE INTERVAL = $\frac{N+1}{M}$

M = RANK OF DISCHARGE, THE LARGEST DISCHARGE GIVEN A RANK OF 1

N = NO. OF YEARS OF RECORD

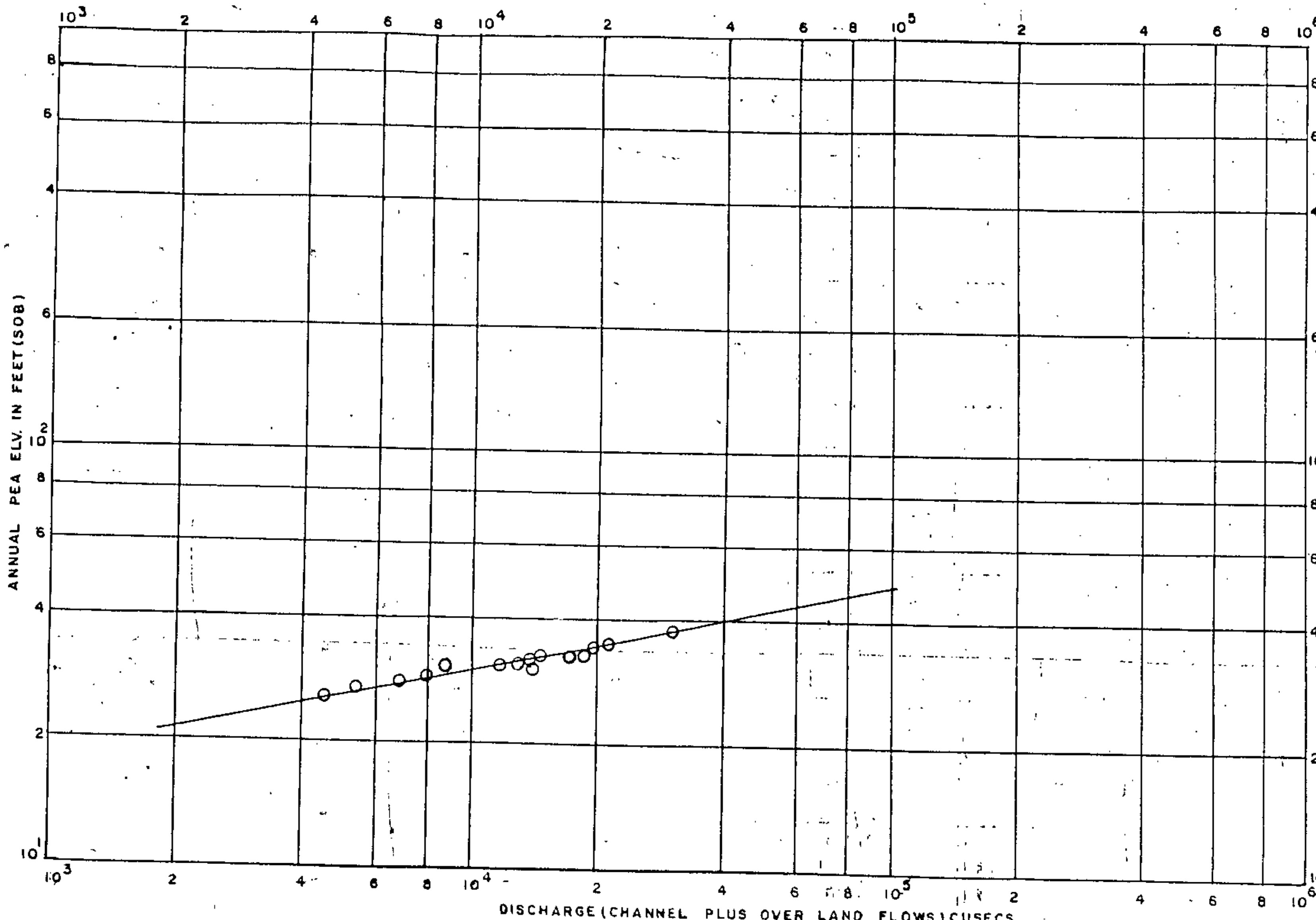
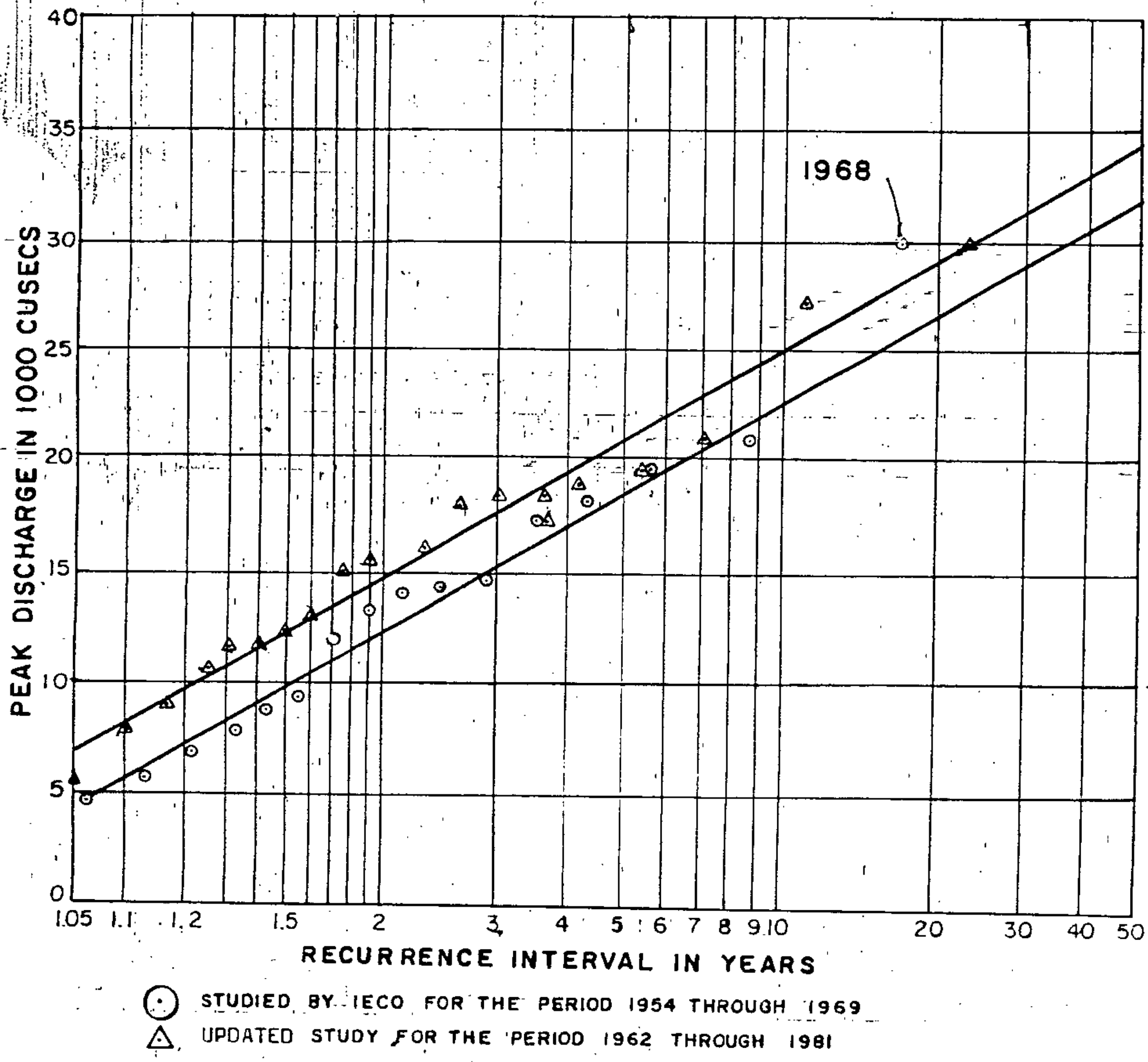


FIGURE 6·1: RATING CURVE OF HALDA RIVER AT FATIKCHARI



6.2 FLOOD FREQUENCY ANALYSIS OF HALDA RIVER WITH UPDATED DATA

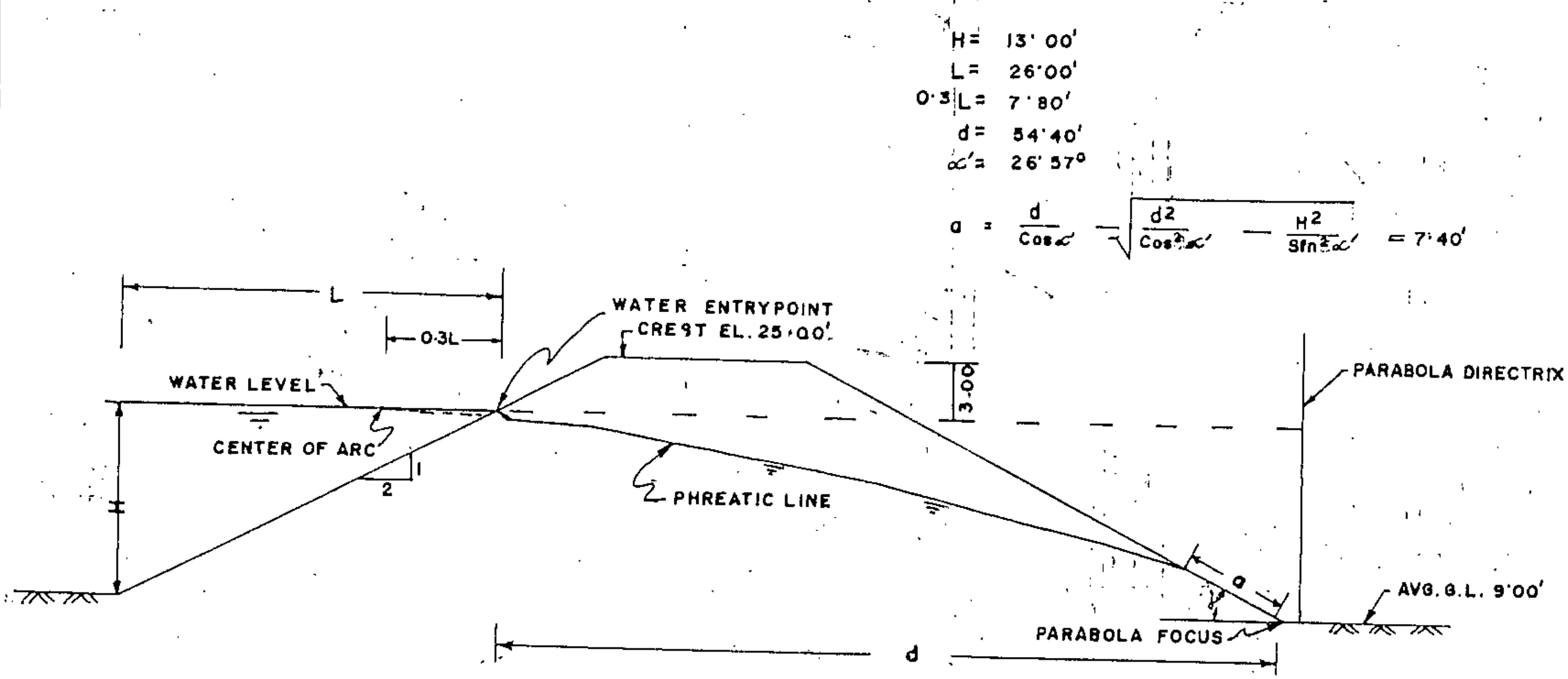
6.1.2.3 Seepage analysis of embanknent cross section

For the seepage analysis of the embankment, the average cross-section for most critical condition of H.F.L. of 50-year flood frequency was taken. The phreatic line of the embankment section is drawn using Casagrande's Method, assuming the phreatic line to be a base parabola with its focus at the downstream toe. The phreatic line must emerge out tangentially at some point above the downstream toe. The distance "a" between the exit point of phreatic line and the downstream toe is known as seepage discharge face and that zone always remains wet. The distance "a" was determined by Schaffernak's Analytical Method (Punmia, 1981). Phreatic line of the embankment cross-section is shown in Fig. 6.3.

6.1.2.4 Stability of embankment slopes

To test the slope stability, the generally accepted Swedish Slip Circle Method of stability analysis was used, (Punmia, 1981). In this method the potential failure surface is assumed to be cylindrical, and the factor of safety against sliding is defined as the ratio of the average shearing strength, as determined by the Coulomb's equation ($S=C+\sigma\tan\phi$) to the average shearing stress determine by statics on a potential sliding surface.

The locus of the slip circle was determined by using Fellenious Method (Punmia 1981). Considering the critical condition, a slip circle was drawn just touching the embankment toe on the land side. All calculations of slope stability based on Figure 6.3 and 6.4 are shown in Table 6.2. The factor of safety against sliding was found to be 1.82, which is considered sufficient.



NOTE :-

PARABOLA COORDINATES DETERMINATION BY CASAGRANDE METHOD

a— VALUE DETERMINATION BY SCHAFFERNAK'S ANALYTICAL METHOD

FIGURE 6·3: DETERMINATION OF PHREATIC LINE

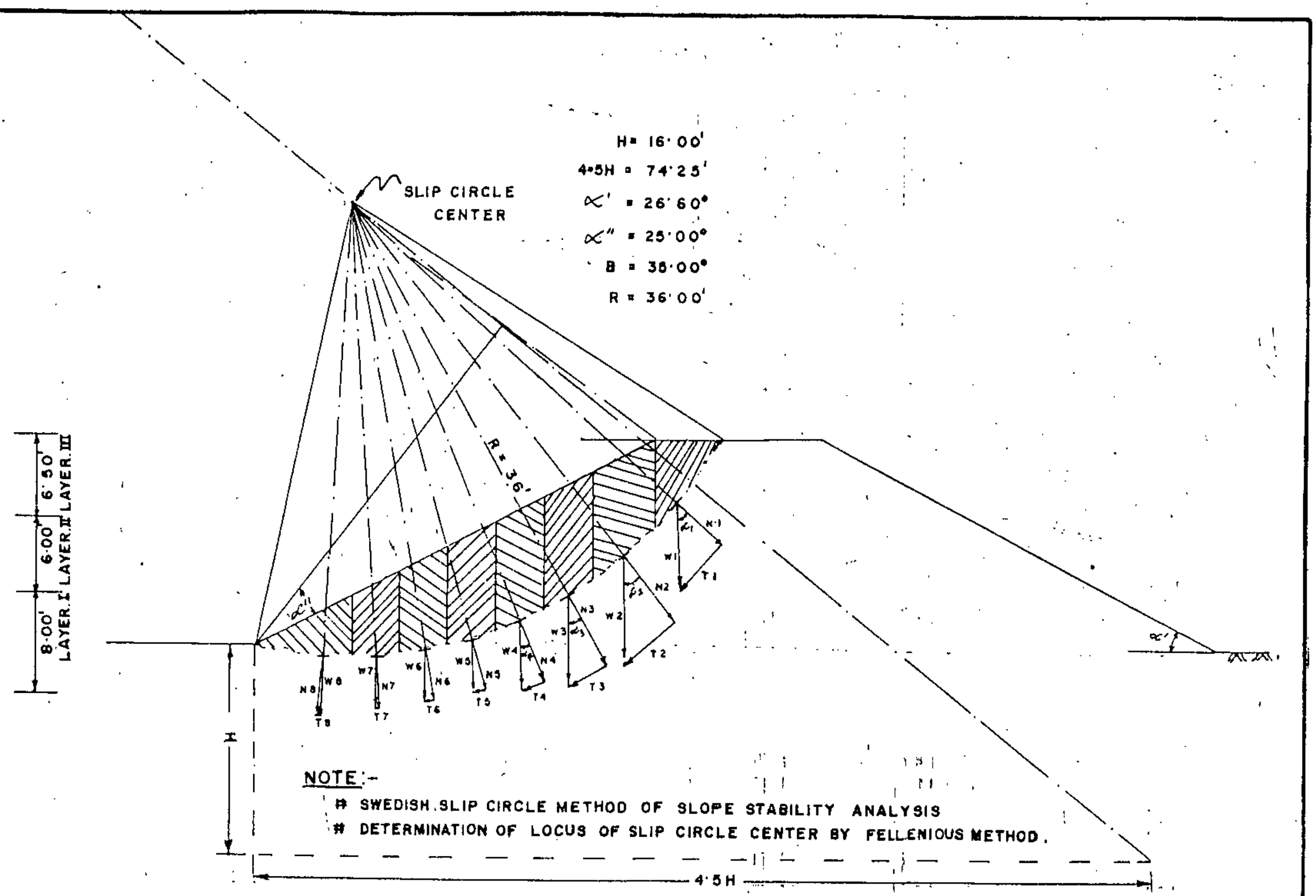


FIGURE 6.4 : SLOPE STABILITY ANALYSIS

SLOPE STABILITY ANALYSIS

TABLE 6.2

LAYER	SOIL UNIT WEIGHT γ,(LBS/FT^3)	SOIL UNIT COHESION C,(LBS/FT^2)	ϕ
LAYER-I	200	0	35°
LAYER-II	115	200	18°
LAYER-III	115	400	0°

LAYER NO.	SEGMENT NO.	VERTICAL FORCE, W	α	T (W Sin α)	N (W Cos α)	ϕ	N Tan ϕ	C	ΔL	C. ΔL
I	1	4032	48.58°	3023.52	2667.47	35°	1867.78	0	9.18	0
	2	4320	38.66°	2698.69	3373.34	35°	2362.04	0	–	0
	3	3200	29.90°	1595.16	2774.07	35°	1942.42	0	–	0
	4	800	22.62°	307.69	738.46	35°	517.08	0	–	0
II	2	1435	38.66°	896.44	1120.54	18°	364.09	200	6.80	1360.00
	3	2670	29.90°	1330.96	2314.61	18°	752.06	200	4.70	940.00
	4	2760	22.62°	1061.54	2547.69	18°	827.79	200	–	–
	5	2300	16.26°	643.99	2208.00	18°	717.42	200	–	–
	6	1380	9.46°	226.82	1361.23	18°	442.29	200	–	–
	7	460	2.86°	22.95	459.42	18°	149.27	200	–	–
	4	740	22.62°	284.62	683.08	0°	0	400	4.57	1828.00
	5	1475	16.26°	412.99	1416.00	0°	0	400	4.24	1696.00
	6	1935	9.46°	318.03	1908.69	0°	0	400	4.10	1640.00
	7	2118	2.86°	105.68	2115.36	0°	0	400	4.03	1612.00
	8	2208	3.81°	(–) 146.72	2203.12	0°	0	400	8.08	3232.00
				ΣT=12,782.36	Σ(N.Tanϕ) =9,942.24				Σ(C.ΔL)=13,308.00	

$$F.S = \frac{\Sigma(C.\Delta L) + \Sigma(N.Tan\,\phi)}{T} = \frac{23,250.24}{12,782.36} = 1.82$$

NOTE: SWEDISH SLIP CIRCLE METHOD OF SLOPE STABILITY ANALYSIS.
LOCUS OF THE SLIP CIRCLE CENTER BY FELLENIOUS METHOD.
SOURCE OF γ, C AND ϕ -VALUES FROM BANGLADESH – NETHERLANDS JOINT PROGRAMME, DELTA DEV. PROJECT, 1985.

6.1.3 Cost of embankment construction

6.1.3.1 Earth work in existing roads

The use of the existing village roads as embankments have reduced the amount of earth work of proposed embankment. A survey was done by BWDB along the alignment of existing village roads which modified the proposed alignment of the embankment as suggested by IECO. The earth work volume of the existing village roads were calculated with the available cross-sections and road profiles. These calculations are shown in Appendix-A. The total volume of earth work of the existing road is 85,12,000 cubic feet. It was also found that lengths of embankments for East Polder and West Polder were 22.76 miles and 19.89 miles respectively. Total length of embankment which needs to be developed is 42.65 miles.

6.1.3.2 Earth work in proposed embankments

The amount of earth work for the proposed embankments were calculated for flood frequencies of 50-year and 25-year. These calculations are based on the selected flood water surface profile, side slopes and free-board.

Earth work volume for 50-year and 25-year flood frequencies have been found to be 13,69,88,000 and 11,99,60,000 cft. respectively. The earth work volumes are shown in Appendix A. The net earth work volume for 50-year and 25-year flood frequencies of the proposed embankments are 12,84,76,000 and 11,14,48,000 cft. The cost of net earth work volume were based on the present schedule of rates (BWDB, 1986) used in Chittagong O and M Circle. The costs are shown in Table 6.3.

EMBANKMENT COST SUMMARY

TABLE 6.3

ITEM	QUANTITY		UNIT	UNIT COST (TK.)	COST (TK.)	
	50-YEAR FLOOD FREQUENCY	25-YEAR FLOOD FREQUENCY			50-YEAR FLOOD FREQUENCY	25-YEAR FLOOD FREQUENCY
EARTH WORK	12,84,76.440	11,14,48,560	Cft.	0.36	4,62,51,518	4,01,21,482
LAND ACQUISITION	140	104	Acre	95,000.00	1,33,00,000	98,80,000
TURFING	270	243	Acre	3,660.00	9,88,200	8,89,380
				Total	6,05,39,718	5,08,90,862

6.1.3.3 Land acquisition and turfing costs of embankments

It was reported by site Engineers that only 68 acres of additional land will be required for 100 feet right of way of embankment (Ahmed, 1983). That is, in total 517 acres of land is required for right of way (100 feet) of 42.65 miles embankment. Therefore, the above reporting indicates, that a net 449 acres of land will not be required to acquire for 100 feet right of way. The 449 acres of land is the right of way of existing village roads. The right of way of 25 and 50 year flood frequencies embankments were calculated on the basis of an average cross-section of embankment and an average cross-section of borrowpit. It was assumed that the fill section will be equal to the cut section. An average right of way of entire 42.65 miles length was calculated as 114 feet and 107 feet for embankment of 50-year and 25-year flood frequencies. A typical cut and fill section for embankment is shown in Figure 6.5. A total of 140 and 104 acres of land will have to be acquired for the embankments of 50-year and 25-year flood frequencies respectively (Table 6.3). The cost of land acquisition based on the present local price are Tk. 13.30 millions and Tk. 9.88 million for 50-year and 25-year flood frequency embankments.

Turfing was considered necessary to reduce the soil erossion on inclined sides of the embankments. The turfing areas are 270 acres and 243 acres for embankment of 50 and 25-year flood frequencies. These costs are also given in Table 6.3. Total costs of embankments construction are Tk. 60.54 millions and Tk. 50.89 millions for 50-year and 25-year flood frequencies.

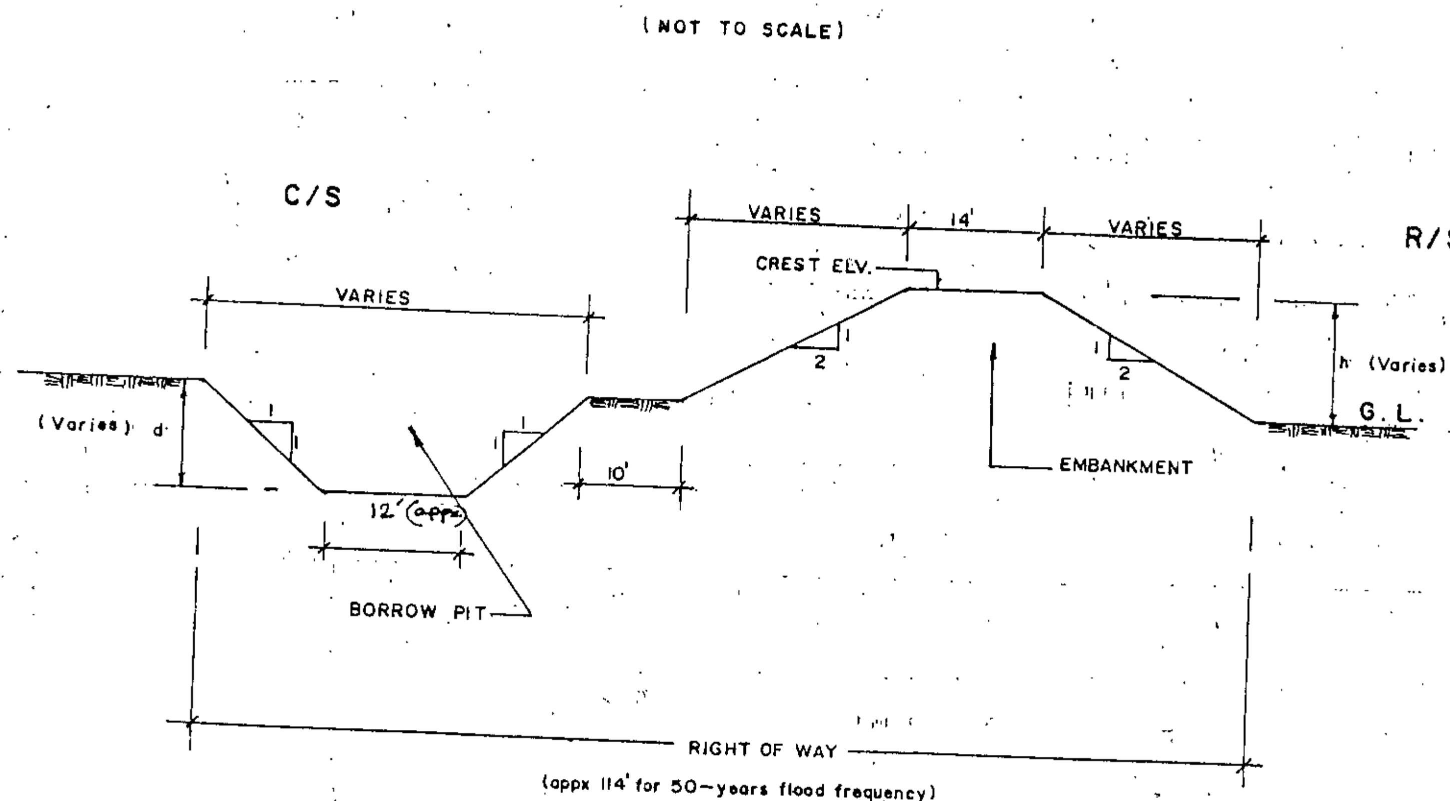


FIGURE 6.5: TYPICAL EMBANKMENT CROSS-SECTION

6.2 Planning of drainage sluices for small polder schemes

The Halda floodplain has a longitudinal slope towards the Karnafuli river. The floodplain is also laterally sloped towards the Halda river which flows through middle of the plain. Naturally drainage discharge of the floodplain are towards the Halda river as well as the Karnafuli river. Two motorable roads, Chittagong-Kaptai and Chittagong-Rangamati Highway, intersects Halda floodplain (lower reach) into six small zones. The proposed embankment along Halda river banks and the existing roads make 5 polders (excluding one zone under Chittagong municipality area) of cultivable lands. By providing drainage sluices of sufficient capacity at road crossings of the existing drainage canals, these 5 small polders can be made to function independently. With the proper operation of drainage sluices, the inundation of any small polder will not affect the others. East Polder consists of Polder-I (11.8 sq. miles drainage area), Polder-II (41.15 sq. miles drainage area) and Polder-III (17.55 sq. miles drainage area). West Polder consists of Polder-IV (52.4 sq. miles drainage area) and Polder-V (22.0 sq. miles drainage area) as shown in Figure 6.6.

6.2.1 Location of drainage sluices

In order to operate the small polders as independent units, six drainage sluices are required at the roads crossings of the existing drainage channels (Fig. 6.6). The drainage sluices at the Chittagong-Kaptai road crossings of Hadkhal and Uhalang khal were designated as R-1 (5 vent) and R-2 (3-vent) respectively. The drainage sluices at the Chittagong-Rangamati Road crossings of Gohira Mour khal, Dabuakhal, Berolia khal and Changkhali khal were designated as R-3 (2-vent), R-4 (3-vent), R-5 (1-vent) and R-6

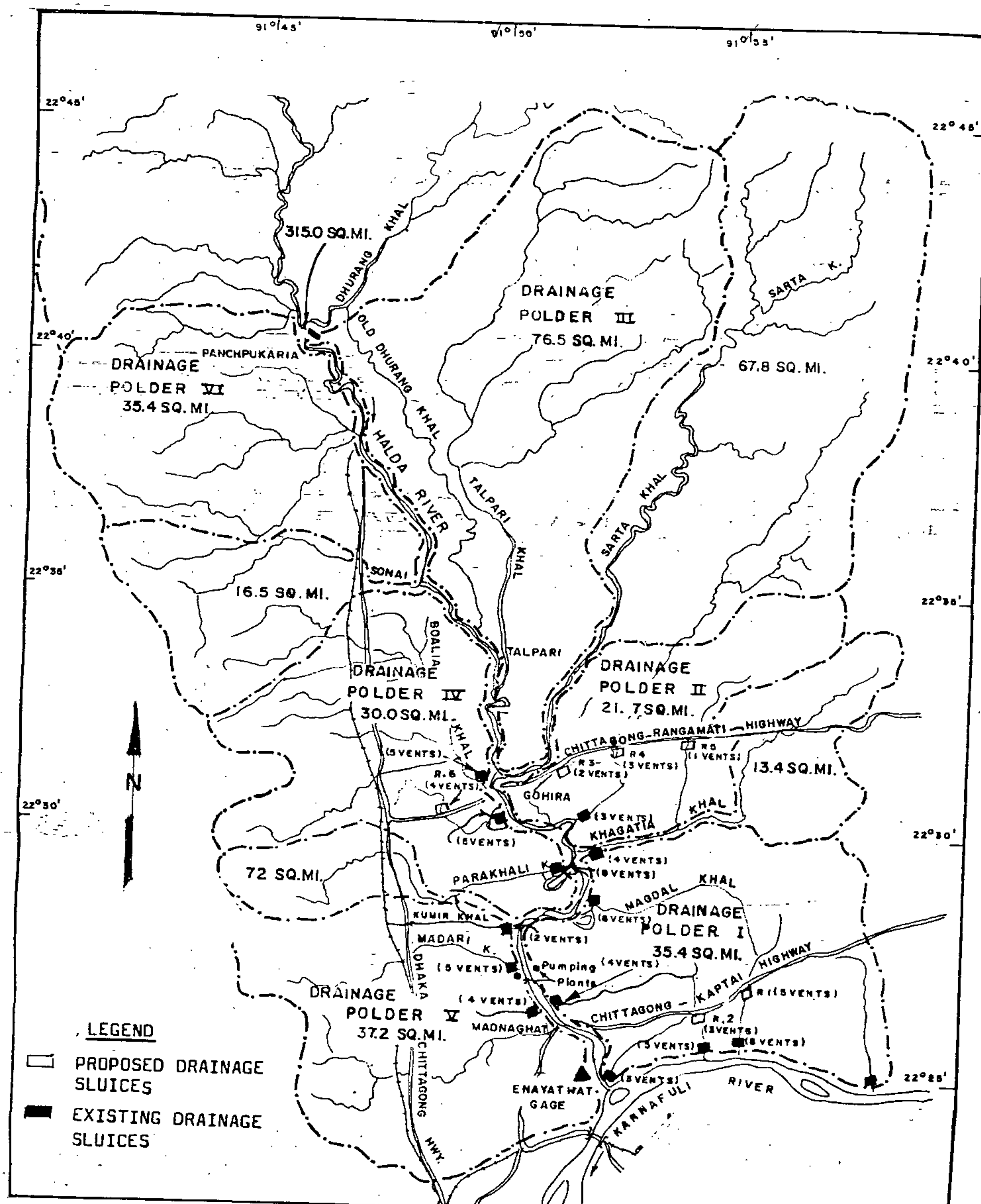


FIGURE 6.6: MAP SHOWING THE LOCATION OF DRAINAGE SLUICES

(4-vent) respectively. The locations of all these sluices are shown in Figure 6.6. Drainage sluices R-1 and R-2 will discharge to Polder-I which finally discharge into Karnafuli river. Drainage Sluices R-3, R-4 and R-5 will discharge to Polder-II which is ultimately diverted to Halda river. The R-6 Drainage sluice will discharge to Polder-IV which discharge into Halda river.

6.2.2 Selection of number of vents of drainage sluices

Number of vents of drainage sluices depend on the discharge of drainage channel and head difference of water levels between the land and river side of a polder. This can be obtained by selecting the proper design discharge and head difference. For the planning purpose, the number of vents of sluices was selected based on drainage area. The standard dimension of vent used in Bangladesh is usually 5 feet width by 6 feet height.

Had Regulator (8-vent), Uhalang Regulator (5-vent), Sakarda Regulator (3-vent), Baruakhali Regulator (4-vent) and Magdal Regulator (8-vent) were designed by IECO (1974) to cover the drainage area of 35.4 sq. miles (Fig. 6.6). In total 28 vents were designed to drain 35.4 sq. miles of drainage area i.e. each vent drains about 1.26 sq. miles of drainage area. In total 16 vents of Had Regulator, Uhalang Regulator and Sakarda Regulator can cover 20.28 (i.e. 16 x 1.26) sq. miles of drainage area. The discharge of 8.48 (i.e. 20.28 - 11.8) sq. miles of drainage area belonging to Polder-II normally pass through Had khal and Uhalang khal at Chittagong-Kaptai road crossing. The discharge capacity at the road crossing of Had khal and Uhalang khal is in the ratio 8:5 according to their vent number as 8 vent and 5 vent respectively. Accordingly, the drainage area of 5.22 (i.e. 8 x 8.48/13) sq.

miles and 3.26 (i.e. 5 x 8.48/13) sq. miles will be covered by drainage regulator R-1 and R-2 respectively. The vent number of R-1 was determined as 4.14(5.22/1.26) and that of R-2 as 2.58 (3.26/1.26). Finally, 5 vents for R-1 and 3 vents for R-2 had been selected.

With similar procedure and assumption the number of vents of R-3, R-4 and R-5 had been selected as 2 vents, 3 vents and 1 vent respectively. These sluices are across the Gohira Mour khal, Dabua khal and Berolia khal at the Chittagong-Rangamati road crossing as shown in Figure 6.6. Similar procedure was adopted for the drainage sluice R-6 and number of vents selected was 4 vents.

6.2.3 Selection of sill elevations and crest elevations of drainage sluices

The sill elevations of the drainage sluices are selected based on the bottom elevations of their respective drainage channels. The crest elevations of the drainage sluices are based on the road's or embankment's crest elevation. These sill and crest elevations are required to get the height of structures and their costs.

Inspecting the drawings of drainage channels and embankments, presented in the Feasibility Study Report (JCHW, 1968 b), the sill and crest elevations were selected. The sill elevations of drainage sluice R-1 and R-2 was found to be (-) 1.40 m.PWD and (-) 1.00 m.PWD respectively. Their crest elevations matching with the top elevation of Chittagong-Kaptai road have been selected as 6.20 m.PWD. Similarly the sill elevations of R-3, R-4, R-5 and R-6 have been selected based on their respective channels bottom elevation, and crest elevations were selected considering the top elevation of Chittagong-Rangamati road. These are shown in Table 6.4.

6.2.4 Cost estimation of drainage sluices

The cost of drainage sluices were calculated at the present market price. PRC/ECI, Consultant of BWDB, made a Chart to calculate the cost of drainage sluices. Based on that chart (PRC/ECI,1985), the cost of different drainage sluices for different vent numbers and the heights of the structures have been calculated. The cost of each drainage sluice is shown in Table 6.4.

TABLE 6.4

DRAINAGE STRUCTURES COST SUMMARY

STRUCTURE	NUMBER OF VENT	SILL ELV. (METER PWD)	CREST ELV. (METER PWD)	COST (TK.)	REMARKS
R - 1	5	(-) 1.40	6.2	39,54,279.24	
R - 2	3	(-) 1.00	6.2	29,58,166.30	
R - 3	2	(-) 0.80	8.0	30,88,081.50	EAST POLDER AREA
R - 4	3	(-)0.80	8.0	35,58,920.50	
R - 5	1	(±) 0.00	8.0	23,81,083.10	
			Sub-total	1,59,40,531.00	
R - 6	4	(-) 1.00	8.0	41,12,912.90	WEST POLDER AREA
			Grand total	2,00,53,444.00	

CHAPTER - 7

BENEFIT-COST ANALYSIS OF DIFFERENT POLDER SCHEMES

Flood control planning requires determination and evaluation of all those plans which are technically sound and feasible. A number of engineering alternatives are analyzed to satisfy the overall objective of the flood control facility and then the most economic alternative is selected. Many times full flood protection may not be possible due to economic reasons and only partial protection is provided. Economics of the alternative flood control plans is a key to planning.

In designing the flood control embankment, two alternative designs for 50-year and 25-year flood recurrence intervals were proposed. These were also analysed for economic feasibility based on benefits derived from higher cropping intensity and improved crop yield with proposed project. In the flood control planning of lower Halda floodplain, one of the proposed plan was the poldering of the valley on each side of the Halda river and the other was of five small prolders instead of two large polders. The feasibility of these two alternative plans were compared on the basis of costs and benefits. The benefits were derived from the net flood damage for storms of different flood frequencies. The costs were derived from additional cost of drainage sluices for internal drainage of the polder.

7.1 Probability of occurrence of major storms

Detailed inspection of drainage studies for entire 8-year from 1962 through 1969, indicate that 4 major storms of 1962, 1963, 1968 and 1969 caused damage to crops. The recurrence intervals of these 4 storms were calculated using Gumbel's asymptotic frequency distribution method. The method is expressed with the following five equations as follows:

$$\alpha = (1.52933 + \ln n - 1/2n + 1/8n^2) / (P\ max. - P\ min.) \qquad (1)$$

$$u = (1.52933\ P\ max. + (\ln n - 1/2n + 1/8n^2)\ P\ min.) / (1.52933 + \ln n - 1/2n + 1/8n^2) \qquad (2)$$

$$Y = \alpha(x - u) \qquad (3)$$

$$\varphi(x) = e^{-e^{-Y}} \qquad (4)$$

$$T(x) = 1/(1 - \varphi(x)) \qquad (5)$$

Where, α and u = Two different parameters of distribution.

P max. = Probable maximum discharge with recurrence interval n years.

P min. = Probable minimum discharge with recurrence interval 1.01 year.

n = Recurrence interval of probable maximum discharge

x = Any discharge.

Y = A reduced variate.

T(x) = Recurrence interval for the corresponding discharge x.

$\varphi(x)$ = Another reduced varied.

Having obtained the parameters of the distribution α and u from equations (1) and (2), the recurrence interval of any discharge X can be calculated from equation (3), (4) and (5).

The annual peak discharge of Halda river at Fatikchari in 1968, was calculated 30,000 cusecs (from Fig. 3.1) which was exceptionally high. That flow was considered as probable maximum discharge with recurrence interval of 50-year. IECO, during their study on Halda Project also considered 50-year recurrence interval for the flood of 1968. The annual peak flow of the probable minimum discharge was assumed 5,000 cusecs (from Fig. 3.1) with recurrence interval 1.01-year which caused no damage to crop in the project area. Applying the Gumbel's asymptotic frequency distribution method, the recurrence intervals of different storms were calculated and is shown in Table 7.1.

7.2 Computation of Area-Elevation and the storage capacity-elevation curves

The four inches to a mile map prepared by Survey of Bangladesh (SOB) was used to determine the gross area. The gross area was planimetered for every one foot contour interval, upto 20 foot contour elevation. The net cultivable area was obtained after subtracting the homesteads, waterways and roads etc. The net cultivable area and gross area of different small polders are shown in (Table 7.2). The area-elevation and the storage capacity-elevation curves for different small polders are shown in Figures 7.1 through 7.5. These figures were used to determine the reservoir storage volume of different polders with any breach of embankment.

7.3 Proposed future cropping pattern with embankment

It is expected that rice would continue to be the dominant crop after completion of the flood protection scheme for the project area, but

TABLE 7.1

RECURRENCE INTERVALS OF MAJOR STORMS

STORM	ANNUAL PEAK DISCHARGE AT FATIKCHARI (cfs.), x	PARAMETERS		REDUCED VARIATES		RECURRENCE INTERVALS (YEAR), T(x)	PROBABILITY $\frac{1}{T(x)}$
		u	α	Y(x)	$\varphi(x)$		
June, 1962	13,000	12,039	2.17×10^{-4}	0.2087	0.4441	1.80	0.56
June, 1963	21,000	12,039	2.17×10^{-4}	1.9467	0.8669	7.52	0.13
July, 1968	30,000	12,039	2.17×10^{-4}	3.9019	0.9800	50.00	0.02
July, 1969	19,400	12,039	2.17×10^{-4}	1.5991	0.8170	5.47	0.18

POLDER-WISE LAND OF PROJECT AREA

TABLE 7.2

AREA IN ACRES

ELEVATION	POLDER-I		POLDER-II		POLDER-III		EAST POLDER		POLDER-IV		POLDER-V		WEST POLDER	
	GROSS AREA	CULTI-VABLE AREA	GROSS AREA	CULTI-VABLE AREA	GROSS AREA	CULTI-VABLE AREA	GROSS AREA	CULTI-VABLE AREA	GROSS AREA	CULTI-VABLE AREA	GROSS AREA	CULTI-VABLE AREA	GROSS AREA	CULTI-VABLE AREA
5' - 8'	2,228	1,863	15,690	13,119	380	318	18,298	15,300	7,175	5,470	4,893	3,730	12,068	9,200
8' - 10'	1,749	1,118	2,449	1,565	2,060	1,318	6,257	4,000	1,378	1,198	2,072	1,802	3,450	3,000
10'-20'	2,698	1,871	3,787	2,626	3,177	2,203	9,662	6,700	3,143	2,716	4,727	4,084	7,870	6,800
TOTAL	6,675	4,852	21,925	17,310	5,617	3,839	34,217	26,000	11,696	9,384	11,692	9,616	23,388	19,000

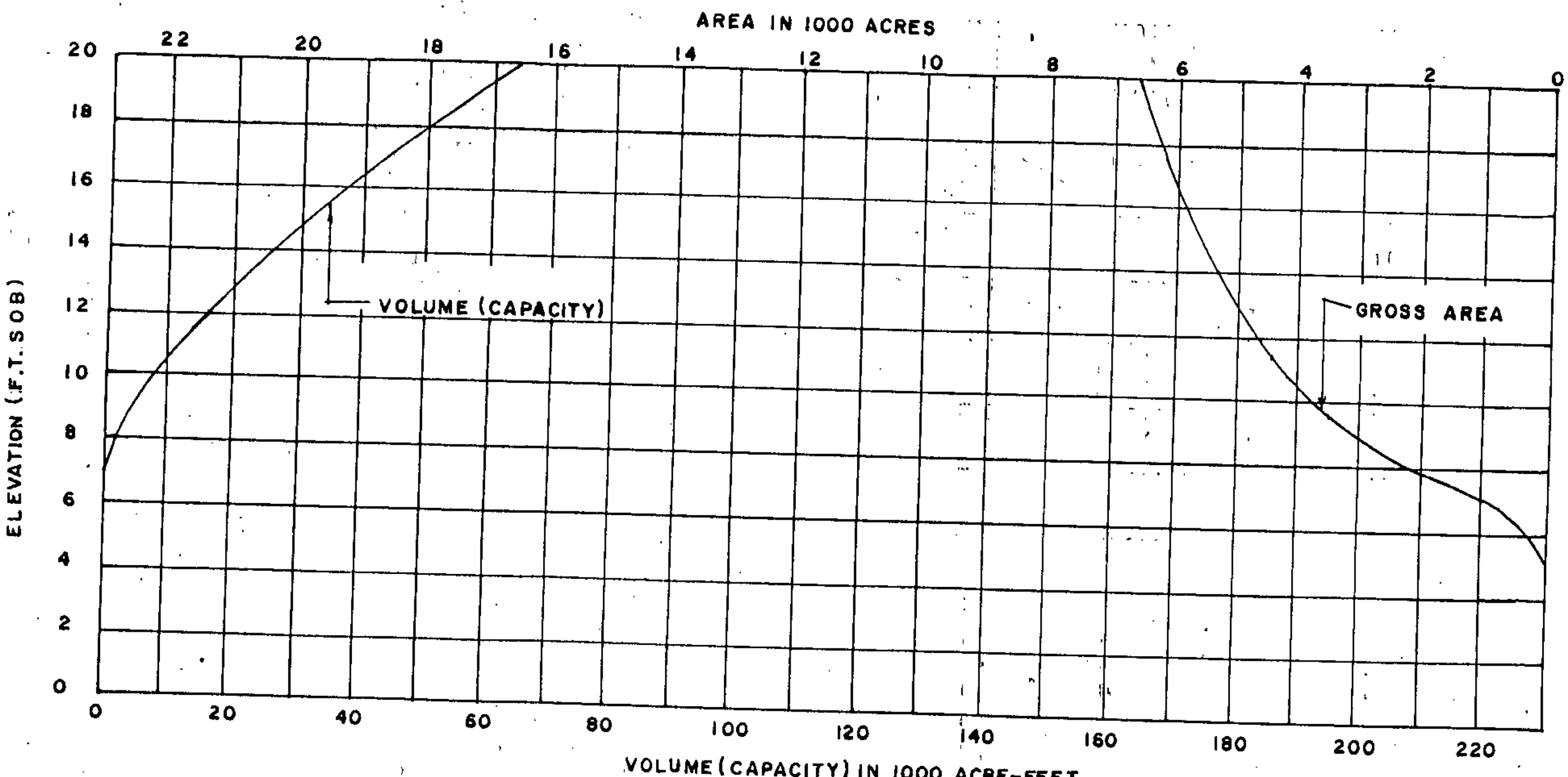


FIGURE 7·1 : AREA-ELEVATION AND VOLUME-ELEVATION CURVE OF POLDER-I

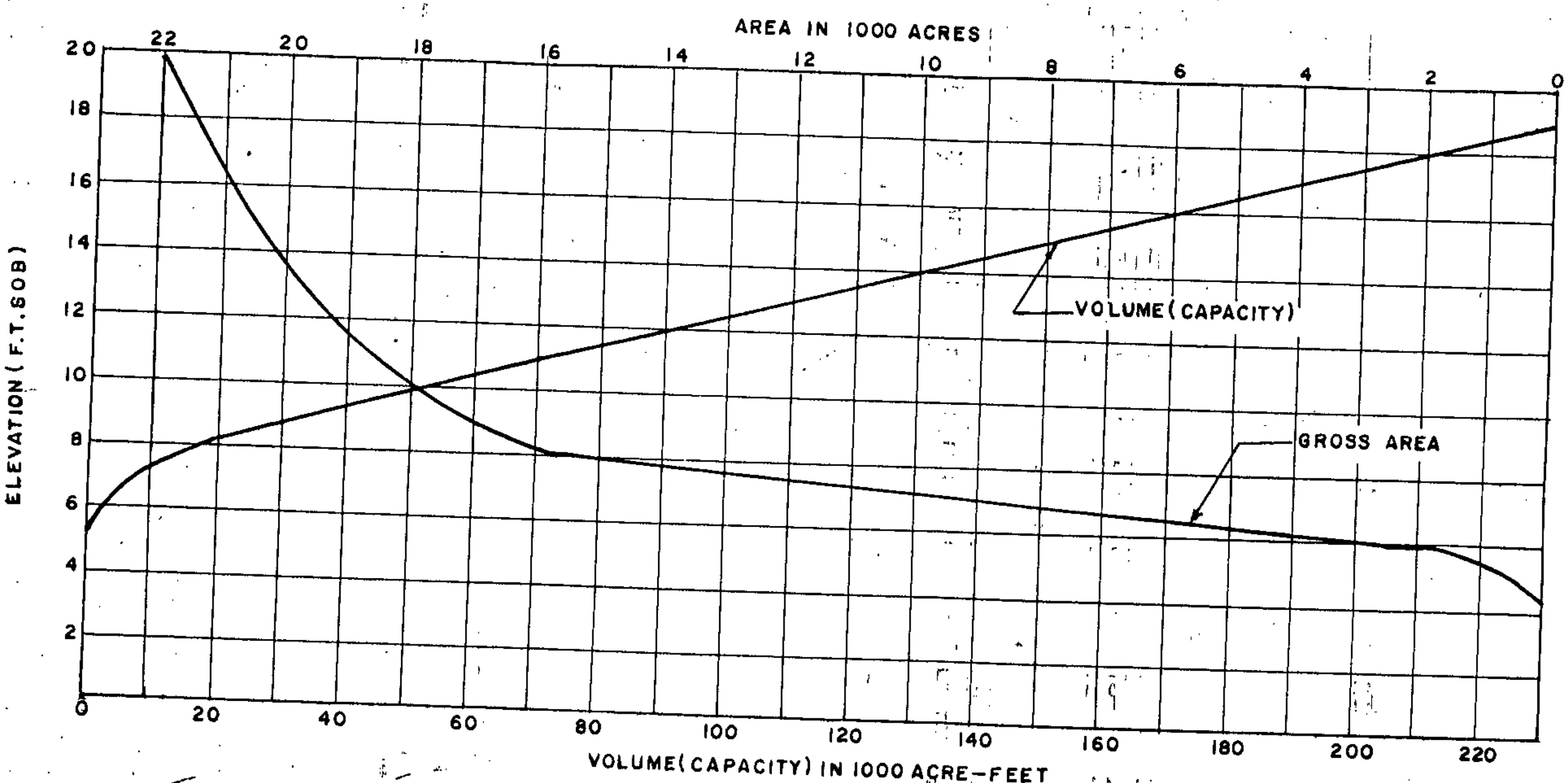


FIGURE 7·2: AREA-ELEVATION AND VOLUME-ELEVATION CURVE OF POLDER-II

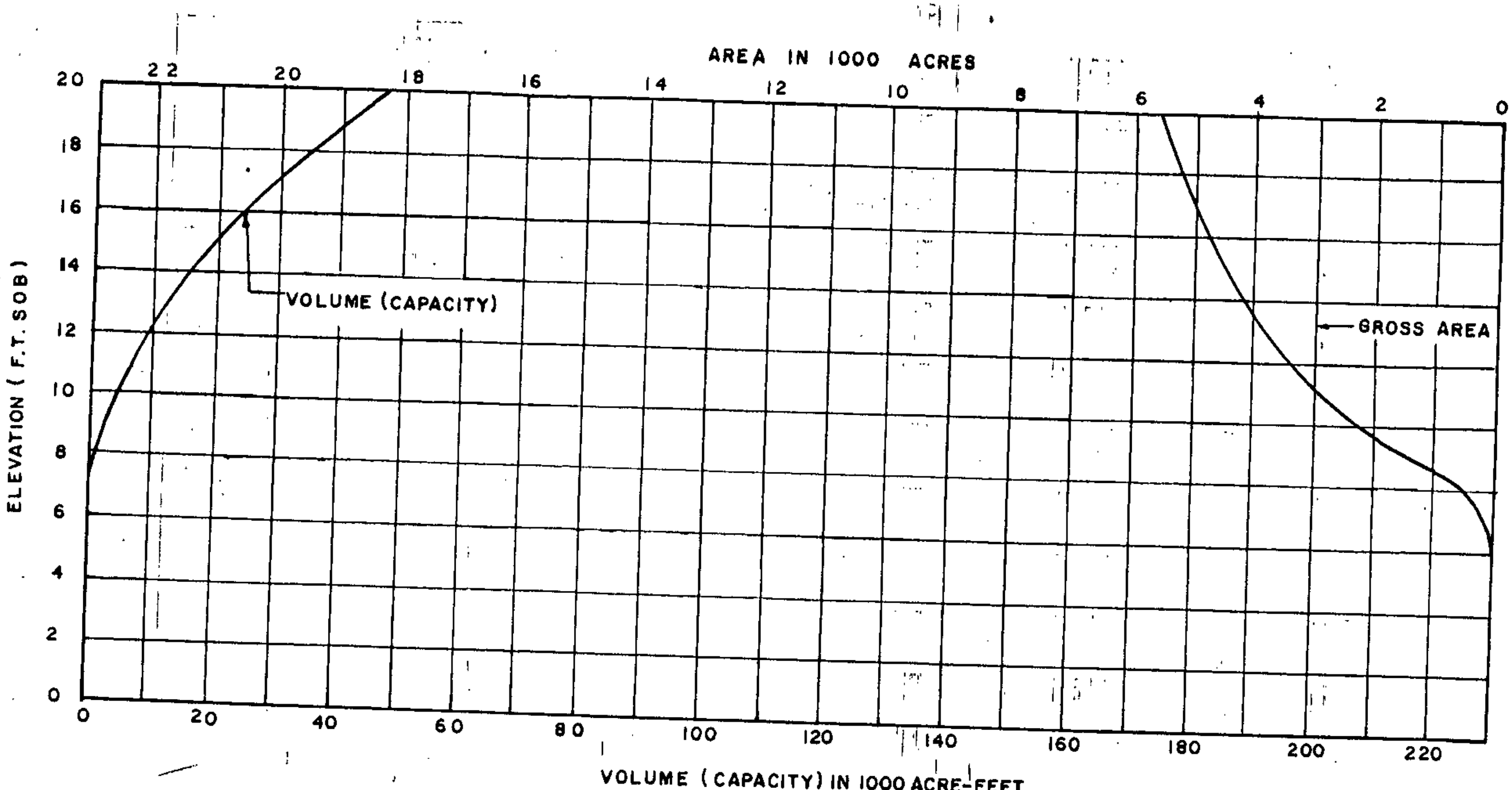


FIGURE 7·3: AREA-ELEVATION AND VOLUME-ELEVATION CURVE OF POLDER-III

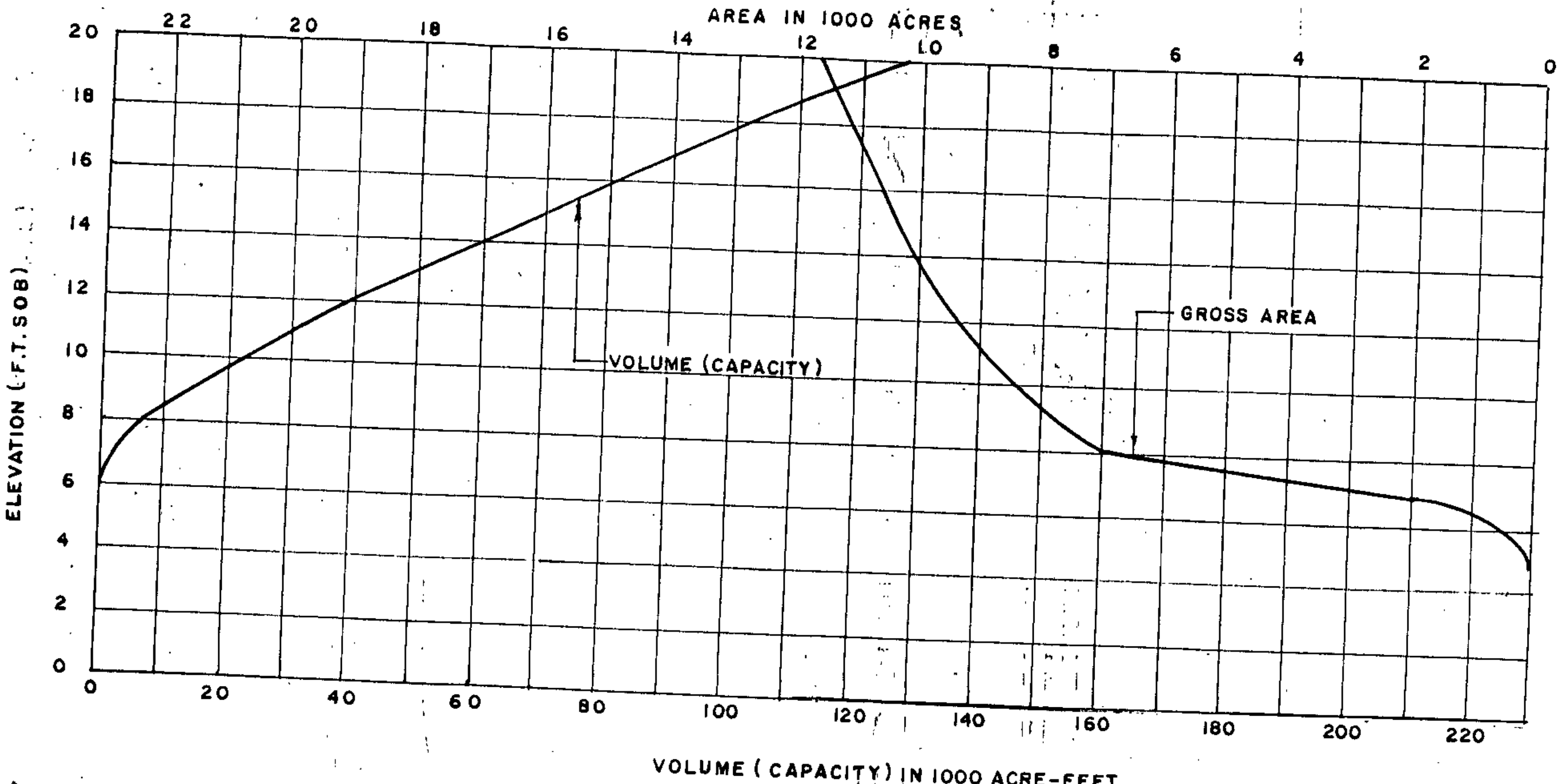


FIGURE 7.4 : AREA-ELEVATION AND VOLUME-ELEVATION CURVE OF POLDER-IV

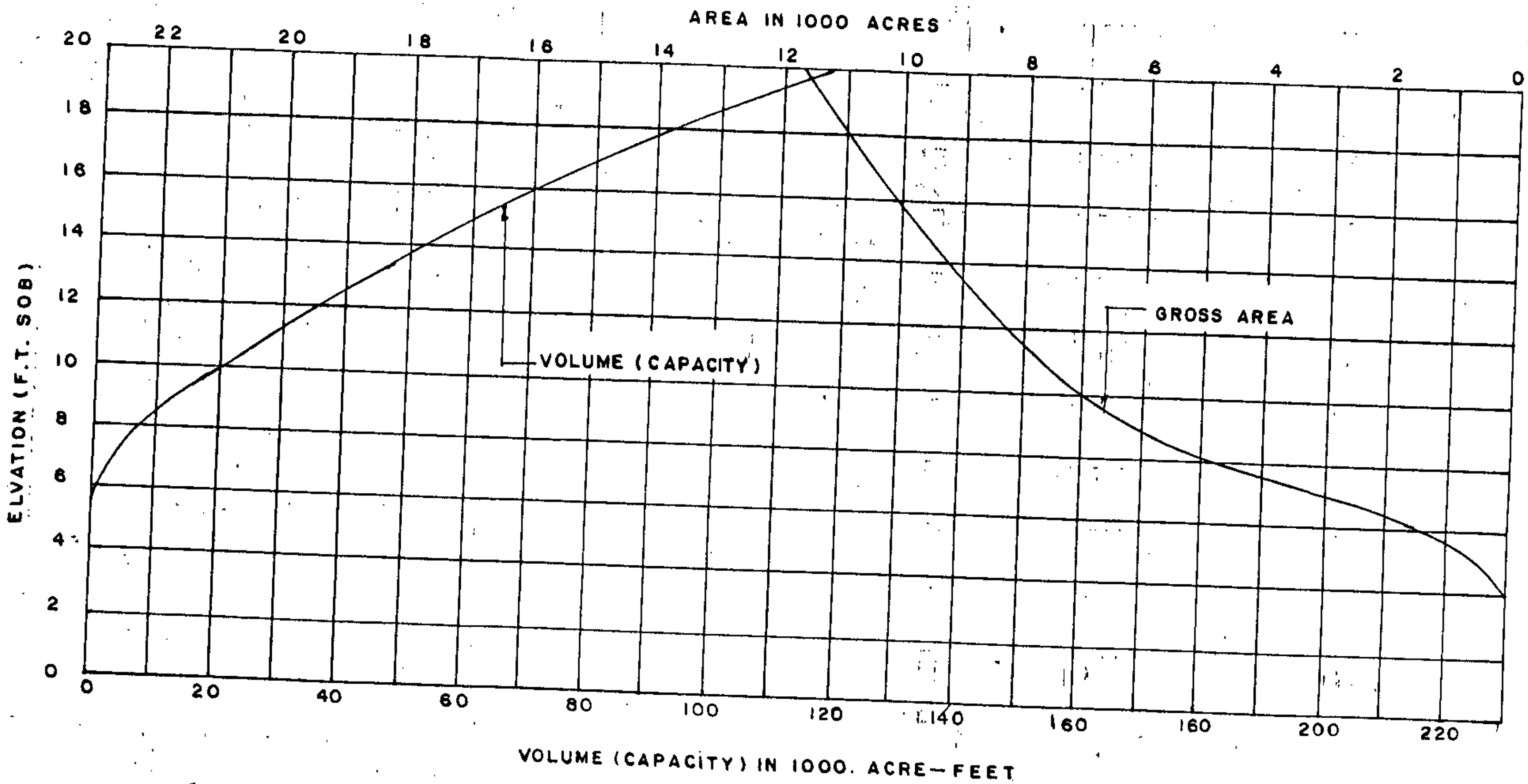


FIGURE 7·5: AREA-ELEVATION AND VOLUME-ELEVATION CURVE OF POLDER-V there would be considerable changes in the relative importance of various rice crops. With the irrigation facility, most of the low lying area is being cultivated for HYV Boro as a single crop replacing the single Local Aman crop. It is obvious that with the flood protection, these areas will be cultivated for double crop of HYV Aman followed by HYV Boro or HYV Aus. The acceptance of HYV rice by farmers will be due to its higher yielding nature than traditional local variety of rice. Therefore with flood protection, it can be assumed that local variety of rice will be replaced by the HYV of rice in all seasons.

The cropping calendar is presented in figure 2.2 and proposed future cropping pattern is shown in the Table 7.3. The future cropping intensity of the project area will be 208%.

7.4 Polder-wise proposed future land use

Proposed future land use was prepared for each of the small polder area. This was used to determine acreage of cropped land of different polders within a flood level, which was finally used to determine the crop damage. Polder-wise proposed future land use is shown in Table 7.4.

7.5 Flood damage

Only the agricultural damages were considered in the estimates. Property damages to buildings, homesteads, equipments etc. would be relatively minor and cannot be expressed interms of money easily. Moreover, no survey data of property damage was available in hand. These damages were ignored. The crop during the monsoon season is rice and the varieties planted are T. Aus (HYV), B. Aman and T.Aman (HYV).

PROPOSED FUTURE CROPPING PATTERN

TABLE 7.3

(TOTAL CULTIVABLE AREA 45,000 ACRES)

(AREA IN ACRE)

ELEVATION (FT.SOB)	BORO (HYV)		AUS (HYV)		AMAN(LV)/(HYV)		RABI		REMARKS
	EAST POLDER	WEST POLDER	EAST POLDER	WEST POLDER	EAST POLDER	WEST POLDER	EAST POLDER	WEST POLDER	
	500(HYVS)	500(HYVS)			300(LVSB)	200(LVSB)			
5 - 8	2,000(HYV)	1,000(HYV)			2,000(HYVT)	1,000(HYVT)			Boro irrigation
	9,500(HYV)	3,000(HYV)			9,500(HYVT)	3,000(HYVT)			by surface water
			3,000(HYVT)	3,000(HYVT)	3,000(HYVT)	3,000(HYVT)			
		1,500(HYV)				1,500(HYVT)			
	3,000(HYV)	2,000(HYV)			3,000(HYVT)	2,000(HYVT)			
8 - 10			1,000(HYVT)	1,000(HYVT)	1,000(HYVT)	1,000(HYVT)	1,000	1,000	"
	1,000(HYV)	2,000(HYV)			1,000(HYVT)	2,000(HYVT)			
10 - 20			1,000(HYVT)	2,000(HYVT)	1,000(HYVT)	2,000(HYVT)			Boro irrigation
			2,000(HYVT)	1,000(HYVT)	2,000(HYVT)	1,000(HYVT)	2,000	1,000	by ground water
			2,700(HYVT)	1,800(HYVT)			2,700	1,800	
	500(HYVS)	500(HYVS)			300(LVSB)	200(LVSB)			
TOTAL	15,500(HYV)	9,500(HYV)	9,700(HYVT)	8,800(HYVT)	22,500(HYVT)	16,500(HYVT)	5,700	3,800	

LV - Local Variety, HYV - High Yield Variety, B- Broadcast rice, T - Transplanted rice and S- Single crop
EAST POLDER : (1) Single crop - 800 acres, (2) Double crop - 22,200 acres and (3) Triple crop - 3,000 acres
WEST POLDER : (1) Single crop - 700 acres, (2) Double crop -16,300 acres and (3) Triple crop - 2,000 acres

TABLE 7.4

POLDER-WISE PROPOSED FUTURE LAND USE

CULTIVABLE AREA IN ACRES

CROP	POLDER-I			POLDER-II			POLDER-III			EAST POLDER	POLDER-IV			POLDER-V			WEST POLDER
	ELV. 5'-8'	ELV. 8'-10'	ELV. 10'-20'	ELV. 5'-8'	ELV. 8'-10'	ELV. 10'-20'	ELV. 5'-8'	ELV. 8'-10'	ELV. 10'-20'		ELV. 5'-8'	ELV. 8'-10'	ELV. 10'-20'	ELV. 5'-8'	ELV. 8'-10'	ELV. 10'-20'	
1. B.Aman(LV)	37	–	–	257	–	–	6	–	–	300	119	–	–	81	–	–	200
2. T.Aman(HYV)	1740	1120	1120	12470	1560	1560	290	1320	1320	22500	5015	1200	2000	3485	1800	3000	16500
3. T.Aus(HYV)	365	280	1952	2573	391	2234	62	329	1874	9700	1784	399	1917	1216	601	2883	8800
4. Boro(HYV)	1440	840	280	10320	1170	390	240	990	330	16000	3540	800	800	2460	1200	1200	10000
5. Rabi	–	280	1312	–	391	1842	–	329	1546	5700	–	399	1118	–	601	1682	3800

Floods occurring in June and first half of July cause damage to B. Aman and T. Aus (HYV). If it occurs in second half of July then it causes damage to B. Aman and T. Aman (HYV) (beginning of transplanting period) and also delays the retransplanting of T. Aman (HYV) in first half of August. Any flood in second half of August causes complete damage to submerged T.Aman (HYV). Considering the time of occurrences of floods the crop damages were calculated for proposed projects with embankment and with any breach of embankment conditions.

The flood damages resulting from different small polders are also dependent on flood depths, duration and frequency. It is evident that the duration as well as the depth of flooding has an important bearing on the crop damages. Also the crop damages depend on the time of the season when the flooding occurs.

7.5.1 Assumptions on calculation of crop damage by different storms

The drainage studies from 1962 through 1969 indicate that the 4 major storms in 1962, 1963, 1968 and 1969 affect the crops with proposed embankment. The storms of different flood return period were used to determine the crop damages in the project area.

To estimate the crop damage by different storms, it is necessary to know the catchment characteristices namely area, depth and duration of flooding for various flood intensities. The information of four storms of different flood frequencies are shown in Table 7.5. An average flood depth was used for the crop damage with embankment. Representative nodes of

FLOODING HEIGHTS WITH AND WITH ANY BREACH OF EMBANKMENT

TABLE 7.5

YEAR OF STORM	DATE OF MAXIMUM FLOODING	MAXIMUM FLOOD ELEVATION(FT.)		GROSS AREA AT MAXIMUM FLOODING (ACRES)		NUMBER OF DAYS OF FLOODING ABOVE ELV. 7 FEET		HALDA RIVER STAGES 1/		
		EAST POLDER	WEST POLDER	EAST POLDER	WEST POLDER	EAST POLDER	WEST POLDER	AT ENAYATHAT (NODE OF POLDER-I) (FT.)	AT OUTFALL OF MAGDAL KHAL (NODE OF POLDER II,IV) (FT.)	AT OUTFALL OF SARTA KHAL (NODE OF POLDER III AND V) (FT.)
1962	June,11	9.06	9.89	21,355	15,155	5.50	5.50	10.50	14.50	18.50
1963	June,11	7.86	7.69	17,290	10,055	4.00	3.50	10.70	14.25	17.80
	July,15	9.66	10.06	22,410	15,375	20.50	20.50	13.50	16.59	19.67
1968	July,12	11.42	12.85	24,650	18,465	12.50	12.50	15.00	18.45	21.90
1969	July,19	7.61	7.94	15,585	11,565	4.00	3.50	11.00	14.00	17.00
	Aug.,22	9.28	9.78	21,735	14,990	8.50	8.50	10.50	13.78	17.04

1/ SMALL POLDERS ARE ASSUMED TO BE INFLUENCED BY HALDA RIVER STAGES WITH ANY BREACH OF EMBANKMENT different small polders (in Table 7.5) with their flood depths based on Halda river stages were used to determine the crop damage with any breach of embankments.

The land at each elevation will have its unique flooding pattern and should be evaluated separately. However, this would involve extensive calculations which were not considered justified in this study. Therefore, the following simplified assumptions were made in estimating the crop damage:

1) The duration of submergence that could be tolerated by crop was assumed to be 7 days for B.Aman and 3 days for T. Aman (HYV).

2) The flooding elevations corresponding to the durations in (1) have been determined from the hydrographs of interior flooding depth with embankment condition from Figure 3.6 and Halda river flood water level with any breach of embankment condition from column 9, 10, 11 of Table 7.5.

3) The height of the different crops are assumed as follows:

   i) In the middle of June, the heights of B. Aman and T.Aus (HYV) will be 3 feet and 2.5 feet respectively.

   ii) In the middle of July, the heights of B.Aman, T.Aus (HYV) and T.Aman (HYV) will be 3.5 feet, 2.5 feet and 1 foot respectively.

   iii) In the 2nd half of August, the heights of B.Aman and T.Aman(HYV) will be 3.5 feet and 2.0 feet respectively.

   This height was substracted as appropriate from the elevations determined in (2).

4) The net areas subjected to damage have been determined by means of the area-elevation relation of individual crop for each polder, shown in Table 7.4. No damage was assumed for the crops grown at higher elevations.

5) Damage to T.Aus (HYV) during its harvesting period in the middle of June, depended on flood severity. The maximum damage has been assumed approximately 15% for low lands below 8 feet elevation with embankment condition.

6) Replanting was assumed for crops damaged in second half of July. Its cost have been calculated on the basis of the actual cost of replantation.

The procedures mentioned above were used to determine the area affected by different storms in the project with embankments and with any breach of embankments.

7.5.2 Per acre cost of different flood damaged crops

7.5.2.1 Crop damage with embankment

With embankment, some interior flooding would still occur due to drainage congestion inside the polders, that would cause crop damage. Flood damage to crop has been calculated on the basis of the present market price of rice. The yields of B.Aman, T.Aman (HYV) and T.Aus (HYV) per acre were assumed as 0.52 m.ton. (14 maunds), 1.31 m.ton.(35 maunds) and 1.31 m.ton. (35 maunds) respectively. The price of one m.ton (26.8 maund) rice was calculated as 4556 Taka.

In calculating the crop damage it has been assumed that from the middle of July the seedling of T. Aman (HYV) will be started. The flood affected T. Aman (HYV) area below the elevation of 7 feet (SOB) was assumed to be uncultivated and replanting was not possible. The remaining lands of comparatively higher elevations (about 7 ft. to 8 ft. elevation) could be replanted after recession of flood in the month of August. The replanting cost is obtained on the basis of actual labour cost, seed cost and fertilizer cost etc. Another cost added with the cost of replanting is the reduced gross income due to lower yield of the second crop. It was assumed that a 20% reduction in yield occurs for all replanted T.Aman (HYV) (IECO, 1971).

At present market price, per acre costs of damaged crop were calculated as Tk. 2380 and Tk. 5950 for B. Aman and T. Aus (HYV). Also the per acre costs of crop damage were Tk. 5950 and Tk. 3407 for T. Aman (HYV) and replanting T. Aman (HYV) respectively (EPC, 1986 a).

7.5.2.2 Crop damage with any breach of embankment

With any breach of embankment, affected polder or polders will be directly influenced by the Halda river stages. The flood affected area in that case was obtained from the area-elevation relation in Table 7.4 for the corresponding river stages. For the flood affected cropped land with any breach of embankment, no replantation was assumed for T. Aman (HYV) as the flood recession would not allow the replantation. Losses of crop damage per acre in different months at present market price were calculated as Tk. 2380, Tk. 5950 and Tk. 5950 for B.Aman, T.Aus (HYV) and T.Aman (HYV) respectively.

7.5.3 Flood affected cropped lands with embankments

The interior flooding hydrographs (shown in Figure 3.6) are considered representative for every polder. Considering the assumptions made in Article 7.5.1, the cropped lands affected by a flood were estimated. The flood affected cropped lands for every small polder is presented in Table 7.6. Two floods occuring in different months of a year were considered individualy to estimate the damaged cropped lands and the maximum area of the two for a particular crop was taken for analysis.

7.5.4 Flood affected cropped lands with any breach of embankment

A polder with a breach of embankment, will submerge the polder area upto elevation of Halda river stages and will cause a severe damage to crops due to the sudden rise of water level inside the polder. The representative nodes of different small polders (column 9, 10 and 11 of Table 7.5) with flood depths were used to determine the crop damage with any breach of embankments. These flood depths are based on the historical observed river stages at stations Talpari and Enayathat. It was assumed that the water level at outfall of Sarta khal is representative for Polder-III and Polder-V. Similarly, the water level at outfall of Magdal khal is representative for Polder-II and Polder-IV, and water level at Enayathat is representative for Polder-I. The water levels of Halda river at different representative nodal points were calculated by assuming the normal water surface profile between Talpari and Enayathat stations.

No replanting of T. Aman with any breach of embankment was considered as the recession of flood level will not allow such replanting.

7.5.5 Estimation of crops damaged by different storms

7.5.5.1 Estimation of crops damaged by different storms with embankment

The estimation of crop damaged by different storms for individual polder is the flood affected areas of land multiplied by per acre cost of damaged crop.

Polder-wise total loss for a particular crop for a specific storm is shown in Table 7.6. Total losses for different storms are shown in Table 7.7.

7.5.5.2 Estimation of crops damaged by different storms with any breach of embankment

Polder-wise total losses for a particular crop of a specific storm are shown in Table 7.8. Total losses for different storms are shown in Table 7.9 with any breach of embankment.

7.5.6 Benefits from the protection of crop damage

Total crop damage of different small polders due to interior flood depth with proposed embankment are shown in Table 7.7. Similarly total crop damage of each small polder for different storms with any breach of embankment of the respective small polder are shown in Table 7.9. Difference between the crop damages for the above two conditions is the net crop damage for the breach of embankment of a small polder. The net crop damage for each small polders is shown in Table 7.10.

TABLE 7.6

(1 OF 3)

ESTIMATE OF FLOOD DAMAGE (WITH EMBANKMENT)

EAST POLDER

(a) POLDER-I

STORM	CROP	MAXIMUM FLOODING EL.(SOB)	PLANT HEIGHT (FT.)	NET AREA DAMAGED (ACRES)	VOLUME OF LOSS PER ACRE(TK.)	TOTAL VOLUME OF LOSS (TK.)
Jun. 11,1962	(1) B.Aman	9.06	3.00	4	2380.00	9,520.00
	(2) T.Aus(HYV)	9.06	2.50	54	5950.00	3,21,300.00
Jun. 11,1963	(1) B.Aman	7.84	3.00	4	2380.00	9,520.00
	(2) T.Aus(HYV)	7.84	2.50	43	5950.00	2,55,850.00
Jul. 15,1963	(3)a T.Aman(HYV)	9.66	1.00	700	5950.00	41,65,000.00
	(3)b T.Aman(HYV)	9.66	–	1100	3407.00	37,47,700.00
Jul. 12,1968	(1) B. Aman	11.42	3.50	40	2380.00	95,200.00
	(2) T. Aus(HYV)	11.42	2.50	18	5950.00	1,07,100.00
	(3)a T.Aman(HYV)	11.42	1.00	700	5950.00	41,65,000.00
Jul. 19,1969	–	7.61	–	–	–	–
Aug. 22,1969	(1) B. Aman	9.28	3.50	4	2380.00	9,520.00
	(3)a T.Aman(HYV)	9.38	2.00	600	5950.00	35,70,000.00

(b) POLDER-II

STORM	CROP	MAXIMUM FLOODING EL.(SOB)	PLANT HEIGHT (FT.)	NET AREA DAMAGED (ACRES)	VOLUME OF LOSS PER ACRE(TK.)	TOTAL VOLUME OF LOSS (TK.)
Jun. 11,1962	(1) B.Aman	9.06	3.00	25	2380.00	59,500.00
	(2) T.Aus(HYV)	9.06	2.50	387	5950.00	23,02,650.00
Jun. 11,1963	(1) B.Aman	7.84	3.00	31	2380.00	73,780.00
	(2) T.Aus(HYV)	7.84	2.50	310	5950.00	18,44,500.00
Jul. 15,1963	(3)a T.Aman(HYV)	9.60	1.00	4930	5950.00	2,93,33,500.00
	(3)b T.Aman(HYV)	9.60	–	5545	3407.00	1,88,91,815.00
Jul. 12,1968	(1) B.Aman	11.42	3.50	250	2380.00	5,95,000.00
	(2) T.Aus(HYV)	11.42	2.50	129	5950.00	7,67,550.00
	(3)a T.Aman(HYV)	11.42	1.00	4930	5950.00	2,93,33,500.00
Jul. 19,1969	–	7.61	–	–	–	–
Aug. 22,1969	(1) B.Aman	9.38	3.50	25	2380.00	59,500.00
	(3)a T.Aman(HYV)	9.38	2.00	4300	5950.00	2,55,85,000.00

(3) a T.Aman (HYV) can not be replanted.
(3) b T.Aman (HYV) can be replanted.

TABLE 7.6
(2 OF 3)

(c) POLDER-III

STORM	CROP	MAXIMUM FLOODING EL.(SOB)	PLANT HEIGHT (FT.)	NET AREA DAMAGED (ACRES)	VOLUME OF LOSS PER ACRE(TK.)	TOTAL VOLUME OF LOSS (TK.)
Jun. 11,1962	(1) B.Aman	9.06	3.00	1	2380.00	2,380.00
	(2) T.Aus (HYV)	9.06	2.50	9	5950.00	53,550.00
Jun. 11,1963	(1) B.Aman	7.84	3.00	1	2380.00	2,380.00
	(2) T.Aus(HYV)	7.84	2.50	7	5950.00	41,650.00
Jul. 15,1963	(3)a T.Aman(HYV)	9.66	1.00	120	5950.00	7,14,000.00
	(3)b T.Aman(HYV)	9.66	–	605	3407.00	20,61,235.00
Jul. 12,1968	(1) B.Aman	11.42	3.50	10	2380.00	23,800.00
	(2) T.Aus(HYV)	11.42	2.50	3	5950.00	17,850.00
	(3)a T.Aman(HYV)	11.42	1.00	120	5950.00	7,14,000.00
Jul. 19,1969	–	7,61	–	–	–	–
Aug. 22,1969	(1) B.Aman	9.28	3.50	1	2380.00	2,380.00
	(3)a T.Aman(HYV)	9.28	2.00	100	5950.00	5,95,000.00

WEST POLDER

(a) POLDER-IV

Jun. 11,1962	(1) B.Aman	9.06	3.00	12	2380.00	28,560.00
	(2) T.Aus(HYV)	9.06	2.50	266	5950.00	15,82,700.00
Jun. 11,1963	(1) B.Aman	7.84	3.00	14	2380.00	33,320.00
	(2) T.Aus(HYV)	7.84	2.50	212	5950.00	12,61,400.00
Jul. 15,1963	(3)a T.Aman(HYV)	9.66	1.00	1635	5950.00	97,28,250.00
	(3)b T.Aman(HYV)	9.66	–	2035	3407.00	69,33,245.00
Jul. 12,1968	(1) B.Aman	11.42	3.50	120	2380.00	2,85,600.00
	(2) T.Aus(HYV)	11.42	2.50	89	5950.00	5,29,550.00
	(3)a T.Aman (HYV)	11.42	1.00	1635	5950.00	97,28,250.00
Jul. 19, 1969	–	7.61	–	–	–	–
Aug. 22,1969	(1) T.Aman	9.28	3.50	12	2380.00	28,560.00
	(3)a T.Aman (HYV)	9.28	2.00	1180	5950.00	70,21,000.00

TABLE 7.6
(3 OF 3)

(b) POLDER-V

STORM	CROP	MAXIMUM FLOODING EL.(SOB)	PLANT HEIGHT (FT.)	NET AREA DAMAGED (ACRES)	VOLUME OF LOSS PER ACRE(TK.)	TOTAL VOLUME OF LOSS (TK.)
Jun. 11,1962	(1) B. Aman	9.06	3.00	8	2380.00	19,040.00
	(2) T.Aus(HYV)	9.06	2.50	184	5950.00	10,94,800.00
Jun. 11,1963	(1) B.Aman	7.84	3.00	10	2380.00	23,800.00
	(2) T.Aus(HYV)	7.84	2.50	148	5950.00	8,80,600.00
Jul. 15,1963	(3)a T.Aman(HYV)	9.60	1.00	1115	5950.00	66,34,250.00
	(3)b T.Aman(HYV)	9.60	–	1715	3407.00	58,43,005.00
Jul. 12,1968	(1) B.Aman	11.42	3.50	80	2380.00	1,90,400.00
	(2) T.Aus(HYV)	11.42	2.50	61	5950.00	3,62,950.00
	(3)a T.Aman(HYV)	11.42	1.00	1115	5950.00	66,34,250.00
Jul. 19,1969	–	7.61	–	–	–	–
Aug. 22, 1969	(1) B.Aman	9.38	3.50	8	2380.00	19,040.00
	(3)a T.Aman(HYV)	9.38	2.00	820	5950.00	48,79,000.00

TABLE 7.7

SUMMARY OF FLOOD DAMAGE (WITH EMBANKMENT)

(LOSS OF CROP IN TAKA)

STORM	PEAK DISCHARGE AT FATIK-CHARI (CUSECS)	RECURRENCE INTERVAL	POLDER-I (TK.)	POLDER-II (TK.)	POLDER-III (TK.)	POLDER-IV (TK.)	POLDER-V (TK.)	WHOLE PROJECT AREA(TK.)
Jun.11,1962	13,000	1.80	3,30,820	23,62,150	55,930	16,11,260	11,13,840	54,74,000
Jun.11,1963	21,000	7.52	81,78,070	5,01,43,595	28,19,265	1,79,56,215	1,33,81,655	9,24,78,800
Jul.12,1968	30,000	50.00	43,67,300	3,06,96,050	7,55,650	1,05,43,400	71,87,600	5,35,50,000
Aug.22,1969	19,400	5.47	35,79,520	2,56,44,500	5,97,380	70,49,560	48,98,040	4,17,69,000

TABLE 7.8
(1 OF 3)

ESTIMATE OF FLOOD DAMAGE (WITH ANY BREACH OF EMBANKMENT)
EAST POLDER
(a) POLDER-I

STORM	CROP	MAXIMUM FLOODING ELV. FT.(SOB)	PLANT HEIGHT (FT.)	NET AREA DAMAGED (ACRES)	VOLUME OF LOSS PER ACRE(TK)	TOTAL VOLUME OF LOSS(TK.)	REMARKS
Jun. 11,1962	(1) B.Aman	10.50	3.00	37	2380.00	88,060.00	
	(2) T.Aus(HYV)	10.50	2.50	1980	5050.00	1,17,81,000.00	
	(3) T.Aman(HYV)	"	–	1900	5950.00	1,13,05,000.00	Out of Trans plantation
Jun.11,1963	(1) B.Aman	10.70	3.00	37	2380.00	88,060.00	
	(2) T.Aus(HYV)	10.70	2.50	1900	5950.00	1,13,05,000.00	
	(3) T.Aman(HYV)	10.70	–	1900	5950.00	1,13,05,000.00	Out of Trans plantation
Jul.12,1968	(1) B.Aman	15.00	3.50	37	2380.00	88,060.00	
	(2) T.Aus(HYV)	15.00	2.50	110	5950.00	6,54,500.00	
	(3) T.Aman(HYV)	15.00	1.00	2700	5950.00	1,60,65,000.00	
Aug.22,1969	(1) B.Aman	10.50	3.50	37	2380.00	88,060.00	
	(3) T.Aman(HYV)	10.50	2.00	3300	5950.00	1,96,35,000.00	-do-
						8,24,02,740.00	

(b) POLDER-II

STORM	CROP	MAXIMUM FLOODING ELV. FT.(SOB)	PLANT HEIGHT (FT.)	NET AREA DAMAGED (ACRES)	VOLUME OF LOSS PER ACRE(TK)	TOTAL VOLUME OF LOSS(TK.)	REMARKS
Jun.11,1962	(1) B.Aman	14.50	3.00	257	2380.00	6,11,660.00	
	(2) T.Aus(HYV)	14.50	2.50	3950	5950.00	2,35,02,500.00	
	(3) T.Aman(HYV)	14.50	–	9800	5950.00	5,83,10,000.00	Out of Trans plantation
Jun.11,1963	(1) B.Aman	14.25	3.00	257	2380.00	6,11,660.00	
	(2) T.Aus(HYV)	14.25	2.50	3950	5950.00	2,35,02,500.00	
	(3) T.Aman(HYV)	14.25		9800	5950.00	5,83,10,000.00	Out of Trans plantation
Jul.12,1968	(1) B.Aman	18.45	3.50	257	2380.00	6,11,660.00	
	(2) T.Aus(HYV)	18.45	2.50	260	5950.00	15,47,000.00	
	(3) T.Aman(HYV)	18.45	1.00	11400	5950.00	6,78,30,000.00	
Aug.22,1969	(1) B.Aman	13.78	3.50	257	2380.00	6,11,660.00	
	(3) T.Aman(HYV)	13.78	2.00	12000	5950.00	7,14,00,000.00	-do-
						30,68,48,640.00	

TABLE 7.8
(2 OF 3)

(c) POLDER-III

STORM	CROP	MAXIMUM FLOODING ELV. FT.(SOB)	PLANT HEIGHT (FT.)	NET AREA DAMAGED (ACRES)	VOLUME OF LOSS PER ACRE(TK)	TOTAL VOLUME OF LOSS(TK.)	REMARKS
Jun.11,1962	(1) B.Aman	18.50	3.00	6	2380.00	14,280.00	
	(2) T.Aus(HYV)	18.50	2.50	225	5950.00	13,38,750.00	
	(3) T.Aman(HYV)	18.50	–	800	5950.00	47,60,000.00	Out of Trans plantation
Jun.11,1963	(1) B.Aman	17.80	3.00	6	2380.00	14,280.00	
	(2) T.Aus(HYV)	17.80	2.50	200	5950.00	11,90,000.00	
	(3) T.Aman(HYV)	17.80	–	800	5950.00	47,60,000.00	Out of Trans plantation
Jul.12,1968	(1) B.Aman	21.90	3.50	6	2380.00	14,280.00	
	(2) T.Aus(HYV)	21.90	2.50	115	5950.00	6,84,250.00	
	(3) T.Aman(HYV)	21.90	1.00	900	5950.00	53,55,000.00	
Aug.22,1969	(1) B.Aman	17.00	3.50	6	2380.00	14,280.00	
	(3) T.Aman (HYV)	17.00	2.00	2050	5950.00	1,21,97,500.00	-do-
						2,03,42,620.00	

WEST POLDER
(a) POLDER-IV

STORM	CROP	MAXIMUM FLOODING ELV. FT.(SOB)	PLANT HEIGHT (FT.)	NET AREA DAMAGED (ACRES)	VOLUME OF LOSS PER ACRE(TK)	TOTAL VOLUME OF LOSS(TK.)	REMARKS
Jun.11,1962	(1) B.Aman	14.50	3.00	119	2380.00	2,83,220.00	
	(2) T.Aus(HYV)	14.50	2.50	3580	5950.00	2,13,01,000.00	
	(3) T.Aman(HYV)	14.50	–	3800	5950.00	2,26,10,000.00	Out of Trans plantation
Jun.11,1963	(1) B.Aman	14.25	3.00	119	2380.00	2,83,220.00	
	(2) T.Aus(HYV)	14.25	2.50	3500	5950.00	2,08,25,000.00	
	(3) T.Aman(HYV)	14.25	–	3800	5950.00	2,26,10,000.00	Out of Trans plantation
Jul.12,1968	(1) B.Aman	18.45	3.50	119	2380.00	2,83,220.00	
	(2) T.Aus(HYV)	18.45	2.50	205	5950.00	12,19,750.00	
	(3) T.Aman(HYV)	18.45	1.00	5450	5950.00	3,24,27,500.00	
Aug.22,1969	(1) B.Aman	13.78	3.50	119	2380.00	2,83,220.00	
	(3) T.Aman(HYV)	13.78	2.00	5968	5950.00	3,55,09,600.00	-do-
						13,03,32,370.00	

TABLE 7.8
(3 OF 3)

(b) POLDER-V

STORM	CROP	MAXIMUM FLOODING ELV. FT.(SOB)	PLANT HEIGHT (FT.)	NET AREA DAMAGED (ACRES)	VOLUME OF LOSS PER ACRE(TK)	TOTAL VOLUME OF LOSS(TK.)	REMARKS
Jun.11,1962	(1) B.Aman	18.50	3.00	81	2380.00	1,92,780.00	
	(2) T.Aus(HYV)	18.50	2.50	3570	5950.00	2,12,41,500.00	
	(3) T.Aman(HYV)	18.50	–	2800	5950.00	1,66,60,000.00	Out of Trans plantation
Jun.11,1963	(1) B.Aman	17.80	3.00	81	2380.00	1,92,780.00	
	(2) T.Aus(HYV)	17,80	2.50	3570	5950.00	2,12,41,500.00	
	(3) T.Aman(HYV)	17.80	–	2800	5950.00	1,66,60,000.00	Out of Trans plantation
Jul.12,1968	(1) B.Aman	21.90	3.50	81	2380.00	1,92,780.00	
	(2) T.Aus(HYV)	21.90	2.50	235	5950.00	13,98,250.00	
	(3) T.Aman(HYV)	21.90	1.00	3300	5950.00	1,96,35,000.00	
Aug.22,1969	(1) B.Aman	17.04	3.50	81	2380.00	1,92,780.00	
	(3) T.Aman(HYV)	17.04	2.00	5500	5950.00	3,27,25,000.00	-do-
						13,03,32,370.00	

TABLE 7.9

SUMMARY OF FLOOD DAMAGE (WITH ANY BREACH OF EMBANKMENT)

(LOSS OF CROP IN TAKA)

STORM	PEAK DISCHARGE AT FATIK-CHARI (CUSECS)	RECURRENCE INTERVAL	POLDER-I (TK.)	POLDER-II (TK.)	POLDER-III (TK.)	POLDER-IV (TK.)	POLDER-V (TK.)	WHOLE PROJECT AREA(TK.)
Jun.11,1962	13,000	1.80	2,31,74,060	8,24,24,160	61,13,030	4,41,94,220	3,80,94,280	19,39,99,750
Jun.11,1963	21,000	7.52	2,26,98,060	8,24,24,160	59,64,280	4,37,18,220	3,82,87,060	19,30,91,780
Jul.12,1968	30,000	50.00	1,68,07,560	6,99,88,660	60,53,530	3,39,30,470	2,12,26,030	14,80,06,250
Aug.22,1969	19,400	5.47	1,97,23,060	7,20,11,660	1,22,11,780	3,57,92,820	3,29,17,780	17,26,57,210

NET FLOOD DAMAGE FOR ISOLATED SMALL POLDER SYSTEM TABLE 7.10

(FLOOD DAMAGE COST IN THOUSAND TAKA)

STORM	FLOOD PROBA-BILITY	POLDER-I			POLDER-II			POLDER-III		
		WITH ANY BREACH OF EMBANKMENT	WITH EMBANK-MENT	NET FLOOD DAMAGE	WITH ANY BREACH OF EMBANK-MENT	WITH EMBANK-MENT	NET FLOOD DAMAGE	WITH ANY BREACH OF EMBANK-MENT	WITH EMBANK-MENT	NET FLOOD DAMAGE
Jun.11,1962	0.556	23174	330	22844	82424	2362	80062	6113	55	6058
Jun.11,1963	0.133	22698	8178	14520	82424	50143	32281	5964	2819	3145
Jul.12,1968	0.020	16807	4367	12440	69988	30696	39292	6053	755	5298
Aug.22,1969	0.183	19723	3579	16144	72011	25644	46367	12211	597	11614
TOTAL				65948			198002			26115
AVERAGE				16487			49501			6529

STORM	FLOOD PROBA-BILITY	POLDER-IV			POLDER-V			WHOLE PROJECT AREA		
		WITH ANY BREACH OF EMBANK-MENT	WITH EMBANK-MENT	NET FLOOD DAMAGE	WITH ANY BREACH OF EMBANK-MENT	WITH EMBANK-MENT	NET FLOOD DAMAGE	WITH ANY BREACH OF EMBANK-MENT	WITH EMBANK-MENT	NET FLOOD DAMAGE
Jun.11,1962	0.556	44194	1611	42583	38094	1113	36981	5474	193999	188525
Jun.11,1963	0.133	43718	17956	25762	38287	13381	24906	92478	193091	100613
Jul.12,1968	0.020	33930	10543	23387	21226	7187	14039	53550	148006	94456
Aug.22,1969	0.183	35792	7049	28743	32917	4898	28019	41769	172657	130888
TOTAL				120475			103945			514482
AVERAGE				30119			25986			128621

If any of the small polder (say, Polder-III of large East Polder), will be inundated due to its embankment breach, other small polder (Polder I and II of East Polder) may be saved from inundation by operating the gated drainage sluices which makes other small polders independent. In this case, losses are the net crop damage of that small polder (Polder-III) only and benefits are the net crop damage of other unaffected polders (Polder I and II). On the other hand, the same breach of embankment will inundate the whole large polder (East Polder) and losses are the net crop damages of all small polders (Polder I, II and III). The isolated small polders system can earn the benefits from their other unaffected small polders if one polder is affected by a breach in the embankment. Analysis of these benefits will help in determining the feasibility between the alternatives of small and large polders schemes.

7.6 Benefit-cost analysis

Two alternative embankments of 50-year and 25-year flood frequencies for flood protection of the project area were considered.The economic alternative is selected on the basis of costs and benefits. In this economic study, the costs are the function of proposed embankments cross-section. The costs are related to the embankments along Karnafuli river and on both banks of Halda river extended upto high grounds. The benefits will be derived from net crop production considering the project "Without Embankment" and The Project "With Embankment".

After selection of the embankment alternative, a second study was done on the plans of two different polder sizes (large polders and small polders). In this case, the cost will include the cost of embankment and construction costs of a few drainage sluices. The construction cost of embankment in both the alternative plans will remain same as no cost for existing motor roads development is required. The benefit is the function of crop damage with and without any failure of embankments of polder.

7.6.1 Analysis of embankment plans

7.6.1.1 Benefits, costs and financial returns

The present and proposed land uses are shown in Table 2.1 and 7.3. The crop acreages, yields and production values of the project "without embankment" and the project "with embankment" are shown in Table 7.11 and 7.12. Yields and unit prices are based on the present condition (EPC,1986 a). The benefit of the project is the increased value of agricultural production.

7.6.1.2 Benefits of the project

The gross production values of the project "without embankment" and the project "with embankment" are Tk. 309.88 millions and Tk. 549.16 millions respectively (Table 7.11 and 7.12). The production costs were calculated on the basis of BWDB present price index (EPC,1986 a). Production costs for the project "with embankment" and "without embankment" are shown in Table 7.13. The incremental annual benefit (Table 7.14) was found to be Tk. 165.53 millions. A normal annual crop damage has been considered,which is equivalent to the flood damage by storm of 2-year flood recurrence interval. The normal annual loss is about 5.47 millions (Table 7.7). The net incremental annual benefit was found to be Tk. 160.06 millions (Table 7.14)

TABLE 7.11

CROP ACREAGE, YIELD AND PRODUCTION VALUE FOR
PROJECT WITHOUT EMBANKMENT

SL. NO.	NAME OF THE CROPS	ACREAGE	YIELD		TOTAL PRODUCTION		UNIT RATE		GROSS PRODUCTION VALUE('000 TK.)
			TON/ ACRE	MAUND/ ACRE	TON	MAUND	TK/ TON	TK/ MAUND	
1	B. Aman -LV	17,500	0.522	14	9142	245,000	4556	170	41,650
2	T. Aman -LV	13,000	0.560	15	7276	195,000	4556	170	33,150
3	B.Aus -LV	4,000	0.373	10	1493	40,000	4556	170	6,800
4	T. Aus -LV	10,500	0.634	17	6660	178,500	4556	170	30,345
5	Boro - LV	1,000	0.634	17	634	17,000	4556	170	2,890
6	Boro - HYV	28,000	1.306	35	36567	980,000	4556	170	166,600
7	Wheat - HYV	130	0.746	20	97	2,600	4342	162	421
8	Potato	1,275	4.030	108	5138	137,700	1606	60	8,262
9	Pulses	1,150	0.224	6	257	6,900	5360	200	1,380
10	Oilseeds	1,275	0.224	6	285	7,650	8040	300	2,295
11	Vegetables	3,510	2.015	54	7072	189,540	2144	80	15,163
12	Chillies	160	0.672	18	107	2,880	8576	320	922
			TOTAL =						309,878

NET AREA = 45,000 ACRES   CROPPING INTENSITY = 181%

TABLE 7.12

CROP ACREAGE, YIELD AND PRODUCTION VALUE FOR PROJECT WITH EMBANKMENT

SL. NO.	NAME OF THE CROPS	ACREAGE	YIELD		TOTAL PRODUCTION		UNIT RATE		GROSS PRODUCTION VALUE(000'Tk.)
			TON/ ACRE	MAUND/ ACRE	TON	MAUND	TK/ TON	TK/ MAUND	
1	B. Aman -LV	500	0.522	14	261	7,000	4556	170	1,190
2	T. Aman -HYV	39,000	1,306	35	50934	1365,000	4556	170	232,050
3	T. Aus -HYV	18,500	1.306	35	24160	647,500	4556	170	110,075
4	Boro - HYV	26,000	1.306	35	33956	910,000	4556	170	154,700
5	Wheat - HYV	165	0.821	22	135	3,630	4342	162	588
6	Potato	1,615	4.851	130	7834	209,950	1608	60	12,597
7	Pulses	1,450	0.336	9	487	13,050	5360	200	2,610
8	Oilseeds	1,615	0.373	10	602	16,150	8040	300	4,845
9	Vegetables	4,465	3.060	82	13663	366,150	2144	80	29,290
10	Chillies	190	0.746	20	142	3,800	8576	320	1,216
				TOTAL					549,161

NET AREA = 45,000 ACRES   CROPPING INTENSITY = 208%

COST OF PRODUCTION TABLE 7.13

	ITEM	UNIT	QUANTITY USED W	QUANTITY USED W1	RATE (TK/UNIT)	TOTAL COST ('000 TK.) W	TOTAL COST ('000 TK.) W1
1.	Man-labour	Man-days	5358 550	7395 607	20	107 171	147 911
2.	Animal-labour	Pair-days	815 850	968 371	35	28 555	33 893
3.	Seed/Seedling:						
	a) Paddy	Tons	3815	1619	4985		
		Maunds	102 250	43 400	186	19 019	8 072
	b) Wheat	Tons	5	6	4020		
		Maunds	130	165	150	20	25
	c) Potato	Tons	476	603	2010		
		Maunds	12 750	16 150	75	956	1 211
	d) Pulses	Tons	17	22	6700		
		Maunds	460	580	250	115	145
	e) Oilseeds	Tons	8	10	7370		
		Maunds	204	258	275	56	71
	f) Vegetables	Tons	26	33	4985		
		Maunds	702	893	186	131	166
	g) Chillies	Tons	0.18	0.22	30016		
		Maunds	5	6	1120	6	7
4.	Fertilizer:						
	a) Urea	Tons	2039	5568	4985		
		Maunds	54 653	149 213	186	10 165	27 754
	b) T.S.P	Tons	1195	3590	4744		
		Maunds	32 023	96 200	177	5 668	17 027
	c) M.P.	Tons	241	1291	4020		
		Maunds	6 452	34 610	150	968	5 192
5.	Insecticides	Lbs	11 200	49 292	134	1 500	6 605
					TOTAL =	174 330	248 079

W = WITHOUT PROJECT
W1= WITH PROJECT

TABLE 7.14

SUMMARY OF BENEFITS

(In 10^5 Taka

A.	PROJECT WITH EMBANKMENT:	
	1. Gross value of production	5491.61
	2. Cost of production	2480.79
	3. Benefit	3010.82
B.	PROJECT WITHOUT EMBANKMENT:	
	1. Gross value of production	3098.78
	2. Cost of production	1743.30
	3. Benefit	1355.48
C.	INCREMENTAL ANNUAL BENEFIT (3010.82 - 1355.48)	= 1655.34
D.	NORMAL ANNUAL FLOOD DAMAGE (TABLE 7.7)	= 54.74
E.	NET INCREMENTAL ANNUAL BENEFIT (C-D)	= 1600.60

7.6.1.3 The costs of project

Capital cost estimates have been prepared on the basis of the 1985 schedule of unit prices applicable to the BWDB Chittagong O and M Circle (BWDB,1985). A contingency of 10% of structural cost and Engineering and Administration cost of 15% of structural cost including contingency have been included, as shown in Table 7.15. The capital cost for two alternative embankments for 50-year and 25-year flood frequencies are Tk. 76.58 millions and Tk. 64.38 millions respectively.

7.6.1.4 Assumptions for economic analysis

(a) Operation and maintenance cost

Annual O and M costs were taken as 2% of the capital cost for the flood embankment and 1% of the capital cost for drainage structures (EPC, 1986 b). Annual O and M cost was considered after implementation of the project and will be continued throughout the project life.

(b) Construction period

It was assumed that the implementation of the flood control project would take three years (EPC, 1986 c). A three year construction period for drainage structures was also considered.

(c) Benefit build-up

Full benefit of flood control is expected to accrue from the seventh year of the project life. The pattern of benefit build-up assumed in the analysis is presented below (EPC, 1986 c):

Pattern of benefit build-up

Year	% of full benefit
1	–
2	–
3	–
4	18
5	33
6	67
7–50 or 7–25	100

(d) Discount rate

Most of analysis under BWDB is done at the discount rate of 15% (PRC/ECI,1985), as such the discount rate in the economic analysis considered was 15%.

(e) Capital cost break-down

Considering three years construction period of the embankments, the capital cost break-down is presented below which is similar to other projects under BWDB.

Pattern of capital cost break-down

Year	% of capital cost
1	20
2	50
3	30
4–50 or 4–25	–

TABLE 7.15

CAPITAL COST ESTIMATE OF EMBANKMENT

1. EMBANKMENT FOR 50-YEAR FLOOD FREQUENCY (50 YEAR PROJECT LIFE)

Embankment (including land acquisition and turfing)	:	Tk. 6,05,39,718
Physical contingency (10%)	:	Tk. 60,53,972
Sub-total	:	Tk. 6,65,93,690
Engineering and Administration (15%)	:	Tk. 99,89,054
Capital cost	:	Tk. 7,65,82,744

2. EMBANKMENT FOR 25-YEAR FLOOD FREQUENCY (25 YEAR PROJECT LIFE)

Embankment (including land acquisition and turfing)	:	Tk. 5,08,90,862
Physical contingency (10%)	:	Tk. 50,89,086
Sub-total	:	Tk. 5,59,79,948
Engineering and Administration (15%)	:	Tk. 83,96.992
Capital cost	:	Tk. 6,43,76,940

7.6.1.5 Benefit-cost ratio

A project life of 50 years and 25 years were assumed for the embankments of 50-year and 25-year flood frequencies respectively. Capital cost of the first alternative i.e. embankment for 50-year flood frequency is Tk. 76.58 millions and the capital cost of second alternative is Tk.64.38 millions as shown in Table 7.15.

Considering the assumptions for economic analysis in article 7.6.1.4, the present worth of cost and benefit for first alternative have been found to be Tk. 64.08 millions and Tk. 549.37 millions respectively. This making a benefit cost ratio as 8.57 (Table 7.16). Using the same assumption, the benefit cost ratio for the second alternative has also been calculated as 9.66 (Table 7.17). Hence the second alternative of 25-year flood frequency embankment is economically more feasible.

7.6.2 Analysis of small polder schemes

The polder schemes of different polder sizes are proposed for the flood protection of the project area. The proposed first plan is to construct two large polders on both sides of Halda river valley and second plan is to construct five small polders.

As the cost of upgrading of existing roads proposed to be used as embankment was ignored, the cost of embankment for both the above cases are similar for the designed flood frequency. An additional capital cost of five drainage sluices of Tk. 20.16 millions (Table 7.18) will be required for the drainage of the large East Polder when acting as three small polders

TABLE 7.16

COMPUTATION OF BENEFIT-COST RATIO OF EMBANKMENT FOR 50-YEAR FLOOD

50 YEAR PROJECT LIFE (IN THOUSAND TAKA)

YEAR	CAPITAL COST	O AND M COST	TOTAL COST	DISCOUNTING FACTOR	PRESENT WORTH OF COST	NET INCREMENTAL ANNUAL BENEFIT	PRESENT WORTH OF BENEFIT
1	1,53,17	-	15317	0.869	13318	-	-
2	3,82,91	-	38291	0.756	28953	-	-
3	2,29,74	-	22974	0.657	15106	-	-
4	-	1532	1532	0.571	875	28810	16450
5	-	1532	1532	0.497	761	152819	26251
6	-	1532	1532	0.432	662	107240	46328
7-50	-	1532	1532	2.876	4406	160060	460337
				TOTAL	64081		549366

$\therefore$ Benefit-cost ratio $= \dfrac{549366000}{64081000} = 8.57$

TABLE 7.17

COMPUTATION OF BENEFIT-COST RATIO OF EMBANKMENT FOR 25-YEAR FLOOD

25 YEAR PROJECT LIFE (IN THOUSAND TAKA)

YEAR	CAPITAL COST	O AND M COST	TOTAL COST	DISCOUNTING FACTOR	PRESENT WORTH OF COST	NET INCREMENTAL ANNUAL BENEFIT	PRESENT WORTH OF BENEFIT
1	12875	-	12875	0.869	11195	-	-
2	32188	-	32188	0.756	24340	-	-
3	19313	-	19313	0.657	12698	-	-
4	-	1288	1288	0.571	735	28810	16450
5	-	1288	1288	0.497	640	52819	26251
6	-	1288	1288	0.432	556	107240	46328
7-25	-	1288	1288	2.679	3451	160060	428907
				TOTAL	53615		517936

∴ Benefit-cost ratio = $\frac{517936000}{53615000} = 9.66$

(Polder-I,II and III). Similarly the additional capital cost of a drainage sluice of Tk. 5.20 millions (Table 7.18) will be required for the large West Polder to act as two small polders (Polder-IV and V).

Any failure of embankment of a large polder will inundate the whole area and will cause large crop damage. On the other hand, that failure will inundate only one/more small polder/polders and other small polder/polders will remain unaffected, for the plan of small polders system. The benefit is derived from the savings of crop of flood unaffected small polder/polders. This is the additional benefits for the plan of small polders.

7.6.2.1 Assumptions for benefit-cost analysis

1) Additional capital cost of drainage sluices were estimated on the basis of schedule of rates of Chittagong O and M Circle (BWDB,1985). Ten percent of structural cost for physical contingency and 15% of structure cost including contingency for Engineering and administration were included in the analysis. Cost estimation is shown in Table 7.18.

2) Annual O and M cost was assumed as 1% of the additional capital cost of drainage structures. This cost is considered constant from the implementation of structures and will be continued throughout the project life.

3) A 25 years project life was considered.

TABLE 7.18

ADDITIONAL COST ESTIMATE

(A) EAST POLDER: DRAINAGE STRUCTURES COST FOR INDEPENDENTLY FUNCTIONING POLDER-I, POLDER-II AND POLDER-III

Drainage structures (R-1, R-2, R-3, R-4 and R-5)	:	Tk.	1,59,40,531
Physical contingency (10% of structure cost)	:	Tk.	15,94,053
Sub-total	:	Tk.	1,75,34,584
Engineering and administration (15%)	:	Tk.	26,30,187
Additional capital cost	:	Tk.	2,01,64,771

Additional present worth of cost (considering 15% discount factor):

1) In the 1st year construction period (30% of capital cost)	:	Tk.	52,60,374
2) In the 2nd year construction period (70% of capital cost)	:	Tk.	1,06,73,229
3) O and M cost (annually 1% of capital cost for 3rd year through 25th year of project life)	:	Tk.	9,75,660
Total additional present worth of cost	:	Tk.	1,69,09,263

(B) WEST POLDER: DRAINAGE STRUCTURE COST FOR INDEPENDENTLY FUNCTIONING POLDER-IV AND POLDER-V

Drainage structure (R-6)	:	Tk.	41,12,913
Physical contingency (10% of structure cost)	:	Tk.	4,11,291
Sub-total	:	Tk.	45,24,204
Engineering and administration (15%)	:	Tk.	6,78,631
Additional capital cost	:	Tk.	52,02,835

Additional present worth of cost (considering 15% discount factor):

1) In the 1st year construction period (30% of capital cost)	:	Tk.	13,57,261
2) In the 2nd year construction period (70% of capital cost)	:	Tk.	27,53,865
3) O and M cost (annually 1% of capital cost for 3rd year through 25th year of project life)	:	Tk.	2,51,736
Total additional present worth of cost	:	Tk.	43,62,862

4) A two year construction period was assumed. About 30% and 70% of construction work was assumed to be completed in the first and second year of the project life.

5) Additional annual benefit derived from crop damages was based on the average of four storms of 1962, 1963, 1968 and 1969 (from Table 7.10).

6) Two probabilities of breaching of embankment (0.4 and 0.25) were considered in the analysis.

7.6.2.2 Incremental benefit-cost ratio

Considering the assumptions in article 7.6.2.1, incremental benefit-cost ratios of different cases of polder/polders affected by embankment breaching (Col. 1 of Table 7.19) and protected from the flood (Col. 2 of Table 7.19) were calculated. Incremental benefit-cost ratios are shown in Table 7.19. A average additional annual benefit (average of crop damage of four storms) was calculated from Table 7.10 for each case of polder/polders with or without embankment breaching. The average incremental benefit-cost ratios of East and West Polder were found as 5.55 and 16.64 (Table 7.19) for an average probability of breaching of 0.40 in any year. Similarly the average incremental benefit-cost ratios of East and West Polder were found as 3.47 and 10.40 (Table 7.19) for an average probability of breaching of 0.25. The average incremental benefit-cost ratios of whole project area for Small Polder Scheme were calculated as 8.32 and 5.20 for 0.4 and 0.25 breaching probabilities respectively.

TABLE 7.19

ESTIMATION OF BENEFIT-COST RATIO FOR ECONOMIC STUDY OF SMALL POLDER SCHEME

POLDER AFFECTED BY BREACHING OF EMBANKMENT	POLDER PROTECTED FROM THE BREACHING OF EMBANKMENT	ANNUAL BENEFIT (AVG. OF NET FLOOD DAMAGE FROM TABLE 7.10 (TK.)	DISCOUNT FACTOR	PRESENT WORTH OF BENEFIT (TK.) FOR PROBABILITY OF BREACHING IN ANY YEAR		CAPITAL COST (TK.)	PRESENT WORTH OF COST (TK.)	BENEFIT-COST (B/C) RATIO FOR PROBABILITY OF BREACHING IN ANY YEAR		REMARKS
				0.4	0.25			0.40	0.25	
POLDER-I	POLDER-II AND POLDER-III	56030000	6.46415	144874510	90546580	20164771	16909263	8.56	5.35	EAST POLDER
POLDER-II	POLDER-III AND POLDER-I	23016000	"	59511541	37194719	"	"	3.52	2.20	
POLDER-III	POLDER-I AND POLDER-II	65988000	"	170622510	106639080	"	"	10.10	6.31	
POLDER-I AND POLDER-II	POLDER-III	6529000	"	16881771	10551109	"	"	0.99	0.62	
POLDER-II AND POLDER-III	POLDER-I	16487000	"	42629770	26643610	"	"	2.53	1.58	
POLDER-III AND POLDER-I	POLDER-II	49501000	"	127992740	79995472	"	"	7.57	4.73	
POLDER-IV	POLDER-V	25986000	"	67190950	41994350	5202835	4362862	15.41	9.63	WEST POLDER
POLDER-V	POLDER-IV	30119000	"	77877482	48673433	"	"	17.86	11.16	

CHAPTER – 8

CONCLUSION AND RECOMMENDATION FOR THE FURTHER STUDY

8.1 Conclusion

The main objective of the study was to find an economic flood protection scheme for the Halda river valley on engineering considerations.

In the embankment design consideration, two alternatives of 50–year and 25–year flood frequencies were studied. The capital costs of two embankment plans of 50–year and 25–year flood frequencies were found to be Tk. 76.58 and Tk. 64.38 millions respectively. The benefit–cost ratios of these embankment plans were 8.57 and 9.66. It is thus seen, that the embankment project of 25–year flood frequency is comparatively more economic.

In planning consideration, another alternative of Small Polder Scheme compared to Large Polder Scheme was analysed for the same area. Considering the Large East Polder consisting of three small polders and West Polder consisting of two small polders separately, it was seen that the average incremental benefit-cost ratios of Small Polder Scheme for Large East and West Polder areas were 5.55 and 16.64 respectively for 0.4 breaching-probability in any year. Similarly, the average incremental benefit-cost ratios of Small Polder Scheme for both the large polder areas were found to be 3.47 and 10.40 respectively for a breaching probability of 0.25. The average incremental benefit-cost ratios of Small Polder Scheme for the whole project area were 8.32 and 5.20 for breaching probabilities of 0.4 and 0.25 respectively. It is seen that the construction of two small polders for Large West Polder area is more economic. Considering the probability of breach in embankment, it can be concluded that the Small Polder Scheme is more beneficial than Large Polder Scheme.

Considering the engineering design and planning concepts, finally it can be concluded that embankment section of 25-year flood frequency with five small polders can provide optimum flood protection for the project area. The Small Polder Scheme with embankment of 25-year flood frequency is the economically feasible and technically viable flood protection project for Halda River Valley.

8.2 Recommendation for further study

Considering the experience gained while working on this research project the following items of works can be recommended for further study.

(1) A mathematical model of Halda river is necessary to study the flow and flood characteristics and to analyse the effect of any breach of embankment in any small polder on other small polder/polders (upstream/downstream).

(2) The upstream hilly areas of the project can be planned as storage reservoir to control the flood in monsoon and to provide irrigation during the dry season. A detailed study in this respect, would include a topographical survey of hilly areas, possible reservoirs sites and their capacities and reservoir operation policy. Such reservoir project could also be used for hydro-power generation. An economic comparison of such a project with the presently planned schemes could bring out

the best mode of development of water resources in the area.

(3) A-detailed study on the breaches of embankment, the nature of the breaches and damages as direct and indirect caused by such breaches is lacking. Such a field study on breaches is necessary to evaluate the impact of embankments on flood control polder schemes.

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COMPUTATION OF EARTHWORK VOLUME

APPENDIX A

EMBANKMENT	LENGTH (FT.)	CREST ELV. (FT.SOB)	GROUND ELV. (FT.SOB)	HEIGHT (FT.)	WIDTH (FT.) TOP	WIDTH (FT.) BOTTOM	LONGITUDINAL SLOPE	SIDE SLOPE	VOLUME (0/00 CFT)	REMARKS
A. EARTHWORK VOLUME OF EXISTING VILLAGE ROADS										
KARNAFULI RIGHT BANK EMBANKMENT UPTO CHITTAGONG-KAPTAI BRIDGE	46000	8-15	6-8	2-9	4-9	8-35	-	-	2399.65	EAST POLDER
CHITTAGONG-KAPTAI BRIDGE TO SARTAGHAT BRIDGE	47200	9-13	6-8	1-5	3-14	4-22	-	-	1134.85	
SARTAGHAT BRIDGE TO HIGH LAND	27000	11-17	8-10	3-7	6-10	8-24	-	-	1202.40	
CHITTAGONG-KAPTAI BRIDGE TO BOALIA REGULATOR	56000	9-15	7-9	2-4	4-20	4-48	-	-	2165.05	WEST POLDER
BOALIA REGULATOR TO HIGH LAND	49000	10-15	9-13	1-6	2-14	4-80	-	-	1610.10	
								TOTAL =	8512.05	
B. EARTHWORK VOLUME OF EMBANKMENT DESIGN FOR 50-YEAR FLOOD										
KARNAFULI RIGHT BANK EMBANKMENT UPTO CHITTAGONG-KAPTAI BRIDGE	46000	18.50	6-8	10-12	14	66-76	0.000	C/S 1:2 R/S 1:3	22304.83	EAST POLDER
CHITTAGONG-KAPTAI BRIDGE TO SARTAGHAT BRIDGE	47200	18.50-25	6-8	13-17	14	56-75	0.00026	C/S 1:2 R/S 1:2	26427.53	
SARTAGHAT BRIDGE TO HIGH LAND	27000	25-26	8-10	16-17	14	76-81	0.000037	"	21265.18	
CHITTAGONG-KAPTAI BRIDGE TO BOALIA REGULATOR	56000	18.50-25	7-9	10-16	14	54-79	0.000086	C/S 1:2 R/S 1:2	30482.30	WEST POLDER
BOALIA REGULATOR TO HIGH LAND	49000	25-26.40	9-13	13-17	14	67-83	0.000038	"	36508.65	
								TOTAL =	136988.49	
C. EARTHWORK VOLUME OF EMBANKMENT DESIGN FOR 25-YEAR FLOOD										
KARNAFULI RIGHT BANK EMBANKMENT UPTO CHITTAGONG-KAPTAI BRIDGE	46000	17.50	6-8	9-11	14	61-71	0.000	C/S 1:2 R/S 1:3	19165.41	EAST POLDER
CHITTAGONG-KAPTAI BRIDGE TO SARTAGHAT BRIDGE	47200	17.50-24	6-8	9-16	14	52-78	0.00026	C/S 1:2 R/S 1:2	23310.92	
SARTAGHAT BRIDGE TO HIGH LAND	27000	24-25	8-10	14-16	14	72-78	0.000037	"	19142.88	
CHITTAGONG-KAPTAI BRIDGE TO BOALIA REGULATOR	56000	17.50-24	7-9	9-15	14	52-75	0.000086	C/S 1:2 R/S 1:2	26955.64	WEST POLDER
BOALIA REGULATOR TO HIGH LAND	49000	24-25.40	9-13	11-15	14	59-77	0.000038	"	31385.76	
								TOTAL=	119960.61	