FLOOD PLAN
COORDINATION
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(FPCO)

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BANK PROTECTION AND RIVER TRAINING (AFPM) PILOT PROJECT FAP 21/22

21

DRAFT FINAL REPORT PLANNING STUDY

VOLUME VIII

ANNEX 23: Preliminary Technical Study on Additional Test Sites

JANUARY 1993

CONSULTING CONSORTIUM FAP 21/22

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In association with:
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BANK PROTECTION AND RIVER TRAINING (AFPM) PILOT PROJECT FAP 21/22

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GERMAN-FRENCH COOPERATION WITH BANGLADESH

BANK PROTECTION AND RIVER TRAINING (AFPM) PILOT PROJECT FAP 21 / 22

FLOOD PLAN CO-ORDINATION ORGANIZATION (FPCO)

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February 09, 1993

Subj : **Submission of Draft Final Report on FAP 21: Additional Annex 23**

Dear Sir,

The Draft Final Report FAP 21/22 Planning Study consisting of Volume I A to Volume VII has already been submitted to you.

We have the pleasure in attaching 35 copies of **Volume VIII** comprising **Annex 23: Preliminary Technical Study on Additional Test Sites**. This is being presented as a further study in addition to Annex 22 submitted before.

We again take the opportunity of thanking you all for valuable guidance and excellent cooperation received by us.

Yours sincerely,

Dr H Brühl
Project Director

Encl: As mentioned

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PRELIMINARY TECHNICAL STUDY ON ADDITIONAL TEST STIES

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SUMMARY

In addition to the test areas selected in the Main Report, viz Kamarjani and Bahadurabad, two additional areas were investigated in more detail along the right bank of the Jamuna river at Sariakandi and Kazipur (see Fig. A.23-1), in order to be prepared for the case that one or both of the selected sites have to be abandoned due to morphological (or other) reasons.

For this purpose additional hydrographic and topographic surveys were carried out on a river stretch of about 6 km each north of Sariakandi and south of Kazipur and two-dimensional mathematical flow model investigations were performed. Furthermore, the models available in the River Research Institute in Faridpur for Kamarjani and Bahadurabad were modified and additional physical model tests carried out to simulate developments in the two additional areas. Use was also made of previous hydrological and morphological investigations, which were extended to the new areas.

Actual test sites within the areas have been selected using the criteria laid down in the Main Report Subsection 8.2.1, especially the "certainty-of-attack and the "something-to-defend" criterion. The results may be seen on Fig. A.23-50 and -51. It appears that the probability of current attack on the bankline north of Sariakandi, which was investigated because of the danger of break through to the Bangali river is only 25 % in the near future, whereas that south of Kazipur is in the range of 95 %.

Basically either of the structures selected in the Main Report can be accommodated at the additional test sites, viz 5 Nos. impermeable/permeable groyne combinations or 9 slope revetment types. The designs as specified in ANNEX 21 will be followed with certain modifications as resulting from topography and hydraulic loads.

At Sariakandi the structures as designed for Kamarjani (groyne field) or Bahadurabad (slope revetments), respectively, can be taken over without alteration (see Fig. A.23-65 and -66). Accordingly, the construction costs remain in the range of those in the Main Report.

At Kazipur the topographical conditions and higher hydraulic loads, require certain adaptations (see Fig. A.23-67 to -69), resulting in approximately 10% higher costs for a revetment and 22-25 % higher costs for a groyne solution, compared to those estimated in the Main Report. Since groyne test structures would occupy less inhabited land than the revetment test structure, a series of only 4 groynes may be considered which could be erected at the same total cost as considered in the Main Report for 5 groynes at Kamarjani.

1 INTRODUCTION

During elaboration of the Main Report a number of possible test areas were investigated along the Jamuna river and preselected areas assessed using applicable criteria. This process led to a ranking as shown in Table 8.1-1 (Subsection 8.1.2(4) therein), reproduced as follows:

1	Kazipur	(17)
2	Bahadurabad *	(14)
3	Sariakandi	(14)
4	Fulchari	(13)
5	Kamarjani *	(12)
6	Betil	(12)
7	Chandanbaisa *	(11)
8	Chauhali *	(10)
9	Nakalia *	(7)

The total scores are given in brackets. A "*" indicates that these areas are not taken up by FAP 1 for detailed design (or excluded by FAP 1 for being located on the left banks), although partly included in their priority list, thus not causing interference with FAP 21 activities. Areas without "*" were selected by FAP 1 in their report "BRTS Priority Works" (October 1991) for detailed design. As a consequence, Bahadurabad and Kamarjani were proposed as areas for FAP 21 test structures.

Following the discussion of the Interim Report in August/September 1992, the Consultant was requested to include two further areas in the list of possible test sites, in order to be prepared having alternatives in case coming morphological changes turn out not to justify the "certainty-of-attack" criterion for Kamarjani and/or Bahadurabad.

After discussions with FAP 1 it revealed that now only structures proposed by them for Sirajganj, Fulchari and Sariakandi south of Kalitola groyne will be processed for detailed design and tendering, due to fund restrictions. Accordingly, the areas at Kazipur and Sariakandi north of Kalitola groyne, being first and third in the ranking of Table 8.1-1 of Main Report, can be included as alternatives for test areas.

The present annex deals with selection of sites and possible test structures within the above mentioned two additional areas.

2 BASIC CONCEPTS

For investigating the possibility of test sites within the Kazipur and Sariakandi (north) areas, survey, hydrographic and hydraulic data must be available. On the other hand the short time, left until decision on starting final design for test structures must be made, did not allow for a complete investigation programme.

Use could be made of FAP 1 results to a certain extent, e.g. regarding soil conditions, surveys however were available from 1991 only. Accordingly, new topographic and hydrographic surveys were carried out. Furthermore, the evaluation of the hydrological (ANNEX 5) and the morphological study (ANNEX 11) were extended to the new areas and additional investigations were performed on the two-dimensional mathematical flow model.

For physical model tests, the available models in the River Research Institute for Kamarjani and Bahadurabad have been modified to cope with the changed river morphological situations and additional tests have been performed.

All studies carried out in the Main Report regarding feasible methods of bank protection and design concepts are equally applicable for the additional areas and the preliminary designs can be taken over, after minor adaptations to the specific local conditions have been made.

Investigations and studies on the environment and regarding socio-economy and agricultural development could not be performed within the short time given. However, basic conclusions drawn in the Main Report will also be applicable.

3 TECHNICAL INVESTIGATIONS

3.1 MORPHOLOGICAL STUDIES

3.1.1 General

For the two additionally selected sites morphological studies were carried out similar to what was done for the four sites selected earlier. This analysis was mainly based on recent satellite images and consisted first of all of assessing the morphological conditions near the proposed sites and secondly of making a prediction of the bank erosion over the coming years. Hereafter the results are summarized for Sariakandi and Kazipur, respectively.

3.1.2 Sariakandi

Sariakandi has been selected as one of the sites of FAP 1 because of the proximity of the Bangali River and the risk that further bank erosion may lead to a major avulsion of the Jamuna River into the Bangali. This danger exists the more as the flood levels of the Jamuna river are higher than those of the Bangali river, i.e. there exists a positive hydraulic pressure head, according to high water isolines in Interconsult (1991).

The river reach near Sariakandi is characterized by a relatively small width of some 10 km in total. It is one of the few reaches where the river has not widened over the period 1973-1992, but in fact there has been an inward movement of the left bank over a distance of several kms (see Figure 2.3-2 of ANNEX 2). Substantial erosion has happened along the right bank. It is assumed here, in line with the prediction made by FAP 1 (ANNEX 4 of the 2nd Interim Report), that over the coming decades there will a continued erosion along the right bank. This seems to be supported by the first results of another study the Consultant is doing into the importance of tectonic activities for the overall movement of the Brahmaputra/Jamuna river system.

The channel and char pattern near Sariakandi appears to be fairly stable over the last years. As can be observed from the 1992 channel pattern as presented in Fig. A.23-47, there are two channels that have an oblique angle to the river bank, one north of Sariakandi and one south of Sariakandi. The channel downstream of Sariakandi has caused substantial scour in the recent years, and at that location (actually Mathurapara) the structures proposed by FAP 1 will be located. The more northern channel has not been very active in eroding the river bank.

An assessment was made of the future bank line changes at Sariakandi. For the conditions **south of Sariakandi** it is important to point out the possibility of a cutoff near Madarganj (see Fig. A.23-47). If this occurs, then there is a possibility that the channel along the left bank will gain importance over the coming years. This may lead to a decrease of the bank erosion downstream of Sariakandi. It is expected, however, that this reduction will be of a temporary nature only, as in due time the bank erosion along the right bank will probably continue.

For the conditions **north of Sariakandi** it holds that the northern channel is only of secondary importance at present. There is a possibility that due to developments upstream the dimensions of this channel will increase. The possibility is estimated at some 25 % for the coming 2 years only, mainly because the angle between the channel axis and that of the main stream is fairly large. According to ANNEX 11, this is not favourable for an increase in conveyance on the short run. It is estimated that there is a probability of some 25% that there will be an erosion of a few hundred meters over the coming years (see Fig. A.23-47). In the long run, however, there will definitely be continued erosion in the reach upstream of Sariakandi. Hence river defence works at that location are well in line with an overall strategy for stopping the Jamuna River of moving in western direction.

The results of the above analysis are shown in Fig. A.23-47 in red colour, where the estimated future bank erosion after the floods in 1992, 1993 and 1994 is indicated as the bank line in February 1993, February 1994 and February 1995, respectively. In line with what was done for the originally selected sites, also the confidence interval is shown for

February 1995 bank line.

3.1.3 Kazipur

The river reach near Kazipur is characterized by a clear channel and bar pattern. This is shown in Fig. A.23-48, where the low flow channel and bar pattern in 1992 is presented as determined from the satellite image. This pattern is moving in downstream direction with a celerity of some hundreds meters a year. This regular pattern makes it easier to predict what the future developments over a period of a number of years will be.

In a first step the erosion pattern over the period 1989-1992 was examined. This was done by studying the satellite imagery, processed under this project (see ANNEX 11). An attempt was made to link the pattern of erosion to the migration of the system of bars and channels. Some results are presented in Fig. A.23-49, relating to the bank erosion and the movement of an island that is indicated by an "A" in Fig. A.23-48. Upon inspection of this figure it can be concluded that the location where bank erosion occurs is linked to the location of an island, that is gradually moving through the river system. According to Fig. A.23-49 it appears as if the island "A" has moved in the in upstream direction during the period 1990-1991. This did not happen in reality but is due to the exceptionally high water level on the 1991 image (see ANNEX 11).

Similar observations on the relation between island location and bank erosion could be made for other islands and bank erosion near Kazipur. This means that, at least in the present period, the bank erosion near Kazipur has a cyclic behaviour linked to the movement of islands through the system. The periodicity of the cycle is estimated to be about 8 to 10 years.

In a second step, this regular behaviour was used to predict bank erosion over the coming years. Therefore, firstly the location of island "A" over the coming years was estimated, and secondly the related location and extent of the erosion was predicted. The results of the above analysis are illustrated in Fig. A.23-48 in red colour, where the estimated future bank erosion after the floods in 1992, 1993 and 1994 is indicated as the bank line in February 1993, February 1994 and February 1995, respectively. For the February 1995 bank line also the confidence interval is shown. The inaccuracy anticipated is mainly due to the stochastic character of the floods in the Jamuna River: if the floods are exceptionally high over the coming years the bank erosion will continue over a larger distance. The probability that bank erosion will materialize as indicated in Fig. A.23-48 is quite high and has been indicated as 90 %. It is mentioned that the attached char (marked "B" in Fig. A.23-48), which is presently in front of the area that will be eroded, will also move in downstream direction together with the island marked "A".

It is stressed here that the bank erosion near Kazipur is apparently bank erosion downstream of Kazipur at present. It is interesting to note that according to the present evaluation, there may be renewed erosion at Kazipur in the period from around 1997 onwards. This depends, however, very much on the occurrence of a channel approaching at an angle to the bank line. More upstream the channels are more parallel, although more oblique channels may develop. The probability of bank erosion at Kazipur township itself is considerably smaller and is estimated at some 30 % around 1997. Also for the reason that this possible erosion is quite late compared to the duration of the project, it is preferred to locate the test structures downstream of Kazipur.

3.2 SELECTION OF TEST SITES

3.2.1 General

The decision for the location of the test structure within the larger test area (Sariakandi or Kazipur) has to take into account the criteria as laid down in Subsection 8.2.1 of the Main Report as well as the morphological changes expected in the near future, the subsoil conditions, environmental and socio-economic aspects etc.

In view of the above the following sites are foreseen for test structures.

3.2.2 Sariakandi Site

The site selected is marked on Fig.A.23-50. The map shows the topography and hydrography as surveyed in November 1992.

Since the area south and including the Kalitola groyne is taken care of by FAP 1, investigations were concentrated on the northern stretch. In this area the Bangali river is closest to the Jamuna (abt. 1.1 km) and with its general tendency to shift westward the danger exists of a breakthrough. This thread exists all the more as the Bangali river is attacking the embankment which is the last defence line towards the Jamuna flood plain with a dead arm of the old Dakuria river. The western slope of the embankment, facing the Bangali river, is presently reinforced through CC block, with 0.30 m side length. To prevent erosion from the Jamuna side this crucial place could be protected through a hard point or a set of groynes further north, e.g. at the Anterpara cross bar.

Accessibility from land is very poor for the whole area. Coming from Bogra/Gabtali the Bangali river has to be crossed by ferry with steep sandy banks at both sides. The roads in Sariakandi are narrow and generally without paving. Thus, the construction site would have to be approached from river side only. Works could be carried out at the flood plain, extending into the river bed.

The test structure at a location as shown Fig.A.23-50 will extend the number of hard points as planned by FAP 1 towards north in more or less equal distance. Any resistance by the population is not to be expected. The land used is mostly uncultivated, situated on the riverside of the embankments.

3.2.3 Kazipur Site

The site selected is marked on Fig.A.23-51. It gives the topography and hydrography as surveyed in November 1992.

The Jamuna right banks at Kazipur have been under continuous erosion for a long time. Embankments have been retired up to nine times. During the years 1988-1990 Government offices, a fertilizer godown, big market place high school, and other installations were washed away. The same fate reached the Meghai College in 1991, when the hospital was also evacuated precautionary. Erosion has progressed up to its boundary walls in the meantime.

In 1989 a groyne was built in extension of a cross-bar at Maijbari, which was washed away before completion by an early flood in June of same year. Local inhabitants believe that this incident caused accelerated erosion at the township and this was the reason why building a test structure at Kazipur was disregarded earlier (see Subsection 8.1.2 of the Main Report). Since, however, the main erosion area seems to move downstream (see Subsection 3.1.3) it is proposed to construct the test structures at Khudbandi, south of Kazipur township and west of the eroding char "B" (see Fig. A.23-48).

It is expected that Kazipur High School will have to be abandoned by the beginning of 1994. The test structure would, however, be able to protect Beara Bazar, mosque and primary school.

3.3 SUBSOIL CONDITIONS

No own subsoil investigations were executed in the additional areas. However, as stated in Section 8.3 of the Main Report, conditions of subsoil, as related to the construction of bank protection structures, do not alter significantly along the right banks of the Jamuna. According to the geotechnical investigations undertaken by FAP 1 along the right bank of the Jamuna, the vertical stratification and the soil properties for design works have been assumed as follows (see ANNEX 13):

Down to a depth of about 10 m clays and silts of low plasticity and non-plastic silts (group CL and ML), followed by non-plastic silty fine sand (group SM) down to about 20 m below surface prevail. Between a depth of about 20 to 30 m the soil was described as non-plastic slightly silty medium fine sand and medium fine sand (group SP-SM and SP). The sands are extremely uniform, generally with a coefficient of uniformity between 2 and 3, and are described as being slightly micaceous. The permeability is explained to be "consistent with SM/SP and SP soil". The bulk density of all layers recommended for use in the stability analysis is 19.5 kN/m^3 and the effective angle of internal friction $\varphi' = 28°$

for the layers down to 10 m depth, φ' = 32° for layers between 10 and 20 m and φ' = 33° for the third layer between 20 and 30 m depth, all without effective cohesion.

3.4 SURVEYS

3.4.1 General Approach

As basis for the studies on the additional test sites at Kazipur and Sariakandi appropriate maps showing the up-to-date situation of the areas had be prepared in addition to those of the main test areas, keeping the same standards. Thus, the Consultant engaged the same subcontractors who gained already experience from the former surveys. Field works were carried out by "The Surveyors & The Realtors" at Sariakandi and by "Hydroland Ltd." at Kazipur during the month of November 1992. Draft drawings of cross-sections were already handed over to the Consultant at the end of November, as to permit the preparation of physical models. All draft final drawings were received on December 15, 1992.

3.4.2 Scope of Work

Site and location of the areas to be surveyed had been selected mainly in view of the following aspects: certainty of attack, sufficient coverage, adequate for physical modelling and final site selection.

The very tight time frame required to limit the survey areas, compared with the size at the former areas, to a necessary minimum.

The following basic parameters were fixed for both places:

-	length of survey area	:	6 km
-	width of survey area = length of cross-sections (1 km on land, 1 km in the river approximately)	:	2 km
-	spacing of cross-sections	:	200 m
-	control stations (control pillars) to be established	:	12 numbers
-	scale of mapping	:	1:5000 for topographic maps and 1:2000/100 for cross-sections

3.4.3 Control Surveys and Accuracy

The control surveys had to be done according to the following specifications:

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(A) Horizontal Control

(1) connection of survey to BTM system by second order closed traverse survey;

(2) accuracy typical for engineering surveys, i.e. for unadjusted horizontal distances: 1 in 10000 and for unadjusted horizontal angles: $10\sqrt{N}$ sec, and

(3) reference control points and co-ordinates being provided by the Consultant.

(B) Vertical Control

(1) connection of heights to PWD datum, carried out as double levelling or closed back ont he starting point;

(2) accepted misclosure for a line not to exceed $\pm$ $12\sqrt{K}$ mm - where K is the length of circuit in kilometers, and

(3) reference BM points and values being provided by the Consultant.

3.4.4 Cross-section Survey

The cross-section survey had to be based on the following specifications:

(1) cross-sections extending on landside part being surveyed by terrestrial method, and on waterside part by hydrographical means;

(2) waterside profiles in line with those measured onshore; the connection of both being made properly in view of elevation and location;

(3) bathymetric survey being performed from a boat, and cross-sections being taken by echo-sounder;

(4) position fix being done by intersection and resection, or other appropriate means;

(5) temporary gauges placed at distances of about 2 km, and water levels recorded for proper connection to PWD datam; the gauges connected to PWD datum by levelling, and

(6) spot heights on land taken at 50 m distances at an average.

3.4.5 Execution of Works and Methodology

The works were carried out in a similar way and with a similar approach as described in detail in ANNEX 12 of the Main Report. Hence, only a brief description will be given in this subsection. The control points, consisting of reinforced concrete blocks were placed in the field at safe places and interconnected by closed traverses and double levelling, forming the basis for the topographic and hydrographic surveys. The cross-sections on the landside areas were surveyed by means of conventional techniques, whereas the bathymetric cross-sections were recorded by echo-sounders installed on country boats. The position fixing was done by the resection as well as by the intersection method. For proper connection of the soundings to PWD datum, the water levels were measured in regular intervals by means of temporary gauges, which were connected with bench marks located in the test area.

3.4.6 Results of Surveys

(A) Drawings

After evaluation of all field records, calculations, plotting etc. the following data and documents have been prepared.

(1) Sariakandi:

- 4 Nos. contour and sounding maps, 1:5000;
(see reduction in Fig. A.23-52 and -53)
- 30 Nos. cross-sections 1:2000/100;
(see location in Fig. A.23-52 and -53 and selected sections in Fig. A.23-54 and -55 at reduced scale).

(2) Kazipur:

- 4 Nos. contour and sounding maps, 1:5000;
(see reduction in Fig. A.23-56 and -57)
- 30 Nos. cross-sections 1:2000/100;
(see location in Fig. A.23-56 and -57 and selected sections in Fig. A.23-58 and -59 at reduced scale).

(B) Lists of Control Points

In the following tables, BTM co-ordinates and elevations (related to PWD datum) are compiled:

No. of Control Point	Co-ordinates (BTM)		Elevation m (PWD)
	Easting (m)	Northing (m)	
P1	457159.850	757332.620	17.96
P2	457518.928	756216.739	17.87
P3	457580.740	755041.040	16.93
P4	457400.716	753858.992	18.43
P5	457477.147	752676.889	17.41
P6	457691.680	751458.040	16.00
P7	457512.973	751413.065	19.91
P8	457345.017	752685.137	20.63
P9	456874.147	754125.335	20.40
P10	456869.290	755010.807	19.85
P11	457118.446	756232.487	17.08
P12	456648.379	757349.587	17.75
FMBM 7217	457737.608	751518.854	16.41

Table 3.4-1: Sariakandi- BTM co-ordinates and heights (PWD) of control points

No. of Control Point	Co-ordinates (BTM)		Elevation m (PWD)
	Easting (m)	Northing (m)	
P1	464611.900	728071.230	15.61
P2	464703.799	727469.627	18.22
P3	464826.300	726694.473	14.37
P4	465417.290	725602.690	16.77
P5	465840.435	725082.104	14.89
P6	465683.521	724306.963	14.30
P7	465542.580	723262.530	16.08
P8	465264.993	723964.996	19.92
P9	464654.780	725300.670	14.09
P10	464567.068	726329.225	14.95
P11	464272.500	726885.340	15.04
P12	464384.756	727693.844	18.19
FMBM 7209			15.16

Table 3.4-2: Kazipur- BTM co-ordinates and heights (PWD) of control points

It should be mentioned, that the above co-ordinate figures are given in tentative BTM terms (see ANNEX 12, Subsection 4.4.2). It is recommended to connect the pillars to FM GPS control points of FAP 18 at a later data when co-ordinates of FM GPS points are available and to adjust the tentative figures, if required.

3.5 HYDROMETRIC MEASUREMENTS

For the additional areas no hydrometric surveys in the field have been carried out for time reasons. However, some current velocities were measured by FAP 1 during August 1991, the results of which are reproduced below.

Point V_2 was located in front of the hospital, about 200 m from bankline. V_1, V_3, V_4 and V_5 represent a section about 300 m upstream and 100 m, 600 m, 800 m, 1000 m from bankline, respectively. V_6, V_7 and V_9 represent a section about 600 m downstream, 250 m, 500 m, 900 m from bankline, respectively.

The results of the current measurements, which were performed by FAP 1 on 10.08.91 until 13.08.91, are depicted on Fig.A.23-60. The velocities at that time were in the range of 0.8-2.0 m/s and 1.5-3.2 m/s at 100-150 m or 800-1000 m distance to bankline, respectively. There is no clear tendency in vertical direction, i.e. depending on the water depth. The values represent a snapshot of the flow pattern only.

According to figures recorded by BWDB the water level during the measurements was about 15.40 m PWD.

3.6 TWO-DIMENSIONAL MATHEMATICAL MODEL TESTS

3.6.1 Introduction

The future flow field near the test structures was computed with a two-dimensional mathematical model. The computed flow velocity field was used to determine the design flow velocities which are decisive for the design of these test structures. The computations were also used for the determination of the boundary conditions of the physical models of the test structures. The discharge distribution at the inflow of the physical models and the lateral boundary, which should follow a flow line, were determined from the computed flow field.

A description of the mathematical model TRISULA is given in Appendix 1 of ANNEX 6 Part B.

After a description of the characteristics of the mathematical model in Subsection 3.6.2 the schematization for the model and the results for the test structure near Sariakandi and Kazipur are discussed in Subsection 3.6.3.

3.6.2 Model Tests for Sariakandi and Kazipur

The mathematical model covers the outflanking channel over a length of about 5 km near Sariakandi and 5 km near Kazipur. These areas are drawn in a detail map of the planform of the Jamuna river in 1992, see Fig. A.23-2 and A.23-3 for Sariakandi and Kazipur respectively. The left boundary of the model is on a char where the discharge and the water depths are small and therefore the results of the computations are not sensitive for an accurate alignment of this left boundary. The upstream and the downstream boundary of the model area were designed to be perpendicular to the expected flow direction.

The total discharge is the discharge of the Jamuna river in a complete cross-section from right to left bank. The discharge in the channel of the mathematical model is estimated and is only a part of the total discharge (see Table 3.6-1).

Test area	Downstream water level (m + PWD)	Channel discharge (m^3/s)
Sariakandi	18.64	42,000
Kazipur	16.70	30,000

Table 3.6-1: Boundary conditions for mathematical simulations with a return period of 100 years

The curvi-linear grid was chosen to follow more or less the actual bank line between March to October 1992. The grid spacing varies from 50 m in the area of interest to

2 8

350 m in the inner bend which forms the left boundary at the char. A series of five groynes were simulated in the mathematical grid with two boxes for the length of a groyne, and three boxes for the spacing of the groynes in Sariakandi model and one box in Kazipur model, see Fig. A.23-4 and A.23-11. The grid point locations were referred to a system of coordinates with x-axis varying from 753500 m to 760000 m and the y-axis from 456500 m to 462000 m for Sariakandi model and for the Kazipur model the grid point locations are referred to a system of coordinates with x-axis varying from 726000 m to 730500 m and the y-axis from 464000 m to 469500 m. In all the graphs of Fig. A.23-4 to A.23-17 these axes are shown.

After the generation of the curvi-linear grid the bed level of the model was to be defined in the grid points. The river bed geometry which was measured during the field survey was combined with the actual bank lines. Permeable groynes were simulated as impermeable plates in the mathematical grid. The bank line between the groynes was the same as the assumed bank lines in the physical model. As part of the output of the TRISULA program, graphs with isolines of the bed geometry were plotted with the levels referring to PWD-datum. In the graphs the river bed below this datum is positive and the char land above this datum is negative.

The computations with the actual bank line were made with boundary conditions for a return period of 100 years, see Tables 3.6-2 and -3. A flow field with a return period of 100 years represents the design condition for a permanent structure. A part of the test structure will be designed as a permanent structure with the possibility that some minor parts will show some damage during the monitoring phase.

Return period	years	2	10	100
Chézy coeff. C	$m^{1/2}/s$	55 - 70	55 - 70	65 - 90
Manning coeff. n	$s/m^{1/3}$	0.021	0.021	0.017
Surface slope	-	$7. 10^{-5}$	8.10^{-5}	9.10^{-5}

Table 3.6-2: Estimated values of the Chézy and Manning coefficient and the water level gradient for Sariakandi model

Return period	years	2	10	100
Chézy coeff. C	$m^{1/2}/s$	55 - 65	55 - 65	75 - 85
Manning coeff. n	$s/m^{1/3}$	0.021	0.021	0.017
Surface slope	-	$7. 10^{-5}$	8.10^{-5}	9.10^{-5}

Table 3.6-3: Estimated values of the Chézy and Manning coefficient and the water level gradient for Kazipur model

The boundary conditions were the water level at the downstream boundary of the model and the estimated discharge distribution at the upstream boundary, see Table 3.6-1.

3.6.3 Results

For a return period of 100 years 4 graphs are presented of the model area with flow velocity isolines, flow velocity arrows indicating direction and magnitude of the flow velocities, flow lines and water level isolines. These graphs provide a good impression of the flow field in the whole model area for a selected channel alignment. For detail information close to the revetment some enlargements of these graphs are included.

These graphs show the following tendencies for Sariakandi:
- the flow lines are more or less parallel,
- the flow velocities have a tendency to increase in downstream direction.

These graphs show the following tendencies for Kazipur:
- the flow lines follow a curvature with a small radius near the downstream end of the model,
- the flow velocities have a tendency to increase in downstream direction.

It is remarked that near the downstream end of the model the accuracy of the computed flow field is somewhat less than in the middle of the model. This phenomenon may have influenced the above tendencies.

The maximum approach flow velocities without an influence of the series of groynes on the flow field are presented in Table 3.6-4.

Test Area	Approach Flow Velocity	Maximum flow velocities
	m/s	m/s
Kamarjani	1.90	2.0
Sariakandi	1.25 to 1.50	2.0 to 3.0
Kazipur	1.4 to 1.75	1.6 to 2.4

Table 3.6-4: Approach flow velocities and the maximum flow velocities for a series of groynes with a return period of 100 years

The discharge distribution used at the upstream boundary of the physical model is given in Table 3.6-5 for Sariakandi test area and in Table 3.6-6 for Kazipur test area according to Fig. A.23-2 and -3).

2Y

Row η	Grid Coordinates x	Grid Coordinates y	Distance Along η axis (m)	Discharge (m^3/s)
19	807581	462380		
20	807606	462420	47.3	165
21	807630	462460	46.6	380
22	807654	462499	45.5	548
23	807675	462536	42.6	603
24	807696	462574	43.9	660
25	807718	462613	44.7	645
26	807739	462654	45.7	597
27	807760	462695	46.4	546
28	807781	462737	46.7	521
29	807801	462780	47.4	530
30	807821	462823	47.8	573
31	807841	462867	48.4	635
32	807862	462915	52.0	746
33	807888	462971	62.2	981
34	807917	463035	70.4	1202
35	807952	463110	82.2	1465
36	807990	463189	87.7	1576
37	808028	463267	87.5	1468
38	808067	463346	87.4	1296
39	808106	463423	86.8	1230
40	808146	463500	86.5	1289
41	808190	463587	97.8	1443
42	808244	463696	121.6	1619
43	808310	463833	152.2	1879
44	808393	463999	185.4	2030
45	808480	464170	191.4	1783
46	808581	464373	227.3	1899
47	808704	464629	283.4	2313
48	808841	464916	318.8	2608
49	808975	465207	319.7	2676
50	809101	465502	321.0	2838
51	809222	465812	332.8	3264

Remark: the discharge allocated e.g. to row 20 corresponds to the section between rows 19 and 20.

Table 3.6-5: Sariakandi area. Bankline III'94 with protections. Suggested discharge distribution at the upstream boundary of the physical model

Row η	Grid Coordinates x	y	Distance Along η axis (m)	Discharge (m^3/s)
22	808122	462254	55.4	
23	808142	462307	56.2	104
24	808160	462358	54.7	466
25	808177	462409	53.5	652
26	808194	462459	52.6	633
27	808210	462508	52.0	578
28	808225	462557	51.4	627
29	808241	462606	51.1	648
30	808256	462654	50.8	669
31	808272	462703	50.6	711
32	808288	462750	50.5	745
33	808306	462803	56.1	854
34	808328	462864	64.5	1038
35	808354	462939	79.8	1339
36	808384	463022	87.2	1452
37	808412	463103	86.5	1256
38	808441	463184	85.8	1077
39	808470	463264	84.7	1054
40	808498	463343	84.1	1014
41	808534	463442	105.4	1103
42	808576	463556	121.5	955
43	808626	463695	148.3	929
44	808689	463867	182.7	1058
45	808754	464050	194.5	1072
46	808831	464273	235.7	1225
47	808921	464540	281.7	1456
48	809022	464844	320.7	1660
49	809123	465149	321.4	1715
50	809228	465455	322.8	1832
51	809342	465767	332.4	2071

Remark: the discharge allocated e.g. to row 23 corresponds to the section between rows 22 and 23.

Table 3.6-6: Kazipur area. Bankline III'94 with protections. Suggested discharge distribution at the upstream boundary of the physical model

3.6.4 Conclusion

The future flow field around the planned test structures near Sariakandi and Kazipur was computed with the two-dimensional mathematical model TRISULA. The test structures near Sariakandi and Kazipur were considered as a series of 5 groynes. The model area near Sariakandi and Kazipur covered an area of 6 km length and 5 km in width. In this area a schematized bed geometry based on five surveyed cross-sections was built in the model.

The results are computed flow fields which are presented in graphs with isolines of the flow velocities, isolines of the water levels, flow lines and an arrow presentation which indicates the magnitude and the direction of the flow.

The maximum approach flow velocity upstream of the series of groynes varies from 1.3 to 1.5 m/s for Sariakandi to 1.4 to 1.75 m/s for Kazipur. These approach flow velocities are lower than the approach flow velocities computed for Kamarjani and Kazipur.

The maximum flow velocities near the series of groynes north of Sariakandi vary from 2 m/s near the upstream groyne to 3 m/s for the downstream groyne. Near the series of groynes of Kazipur the maximum flow velocity increases from 1.6 m/s for the upstream groyne to 2.4 m/s for the downstream groyne.

The series of groynes were tested in the physical model (see Section 3.7) under conditions which represent a moderate attack of the flow on the bank. This was different from the strong attack of the flow on the bank in the mathematical simulations. Therefore, the discharge distribution and the flow lines in the physical and the mathematical model show some differences.

3.7 PHYSICAL MODEL TESTS

3.7.1 Introduction

For the design of the test structures the maximum depths of the expected scouring and the maximum flow velocities around these structures are design parameters which were investigated in a physical model. The layout of these structures was optimized in different tests regarding the scouring and the flow velocities.

In the River Research Institute two physical models were built, one for the test area near Kamarjani and one for the test area near Bahadurabad. These models were used for additional tests for the tests areas near Sariakandi and Kazipur. The layouts of these models were defined on the basis of the results of the field survey and those of the 2-dimensional mathematical model. From the channel cross-sections measured by the field survey an average cross-section was defined and built in the physical model. An average cross-section represents a moderate attack on the bank. The observed bankline was schematized to define the bank line in the physical models. The width of the physical models was not sufficient to accommodate a complete channel of the Jamuna river, therefore only 400 to 500 meter of the river channel width was moulded. The lateral boundary follows a flow line, which was computed with the mathematical model and also the discharge distribution at the upstream inflow boundary (see Section 3.6).

The scour pattern around the test structures was reproduced in the sand bed of the model. The size of the sand had almost the same size as the prototype sand, and to induce sufficient sediment transport in the model the discharge had to be higher than the discharge according to the Froude condition. Therefore, each test was divided into two parts with different discharges: first a relatively high discharge for the simulation of the scour pattern and secondly a model discharge according to the Froude condition to measure the flow velocities and the flow lines in the model. The possible scale effects by the relatively too high model discharge had a neglectable influence on the model results.

The flow velocities were measured in standard cross-sections at half of the water depth with small OTT-type flow propellers. After completion of the tests the average accuracy of the flow velocity measurements was estimated at only 5 % and that is less than expected. Nevertheless, these measurements were accepted and analyzed (see ANNEX 14). The flow lines were determined by following the track of some floats in the model. The scour depths were measured by a rule relative to a standard level which was indicated by a thread from one bank to the other bank of the model. During emptying the model the isolines of the sour holes were indicated with threads and a photograph of the scour hole was taken. The discharge was measured with a rectangular weir at the upstream side of the model. The water levels were read at about four point gauges along the bank of the model.

The test structures near Kazipur and Sariakandi were considered to be a series of groynes, which were investigated in some additional tests. The tests for the area near Sariakandi are described in Section 3.7.2 and those for the area near Kazipur in Section 3.7.3. A detailed report on the model tests T1 to T10 for Kamarjani and Bahadurabad is included in the report as ANNEX 14.

3.7.2 Model Tests for Sariakandi

In the undistorted model a stretch of about 2400 m of the right bank Jamuna river channel north of Sariakandi has been modelled at a length scale 1:75. In the model not the full width of the channel was considered but only a part with 400 to 500 m width. The analysis of the results of the test follows after a description of the layout and the geometry of the groynes.

(1) Test description

In test T10 for Kamarjani the bed geometry was the characteristic bed geometry with a curved bank for the test area near Kamarjani. The bed geometry in test T20 fore Sariakandi was a schematization of the river bed surveyed in November 1992 (vide Section 3.4). The shape of the cross-section near the groynes was the same as that in the Kamarjani model, only the depth was 1 to 2 m less. In the model this channel was schematized to a straight channel without the estimated 20 m bank erosion during construction period, see Fig. A.23-18 and A.23-19. From these figures it can be seen that the whole model was mirrored having the groynes on the left bank. This was done to minimize the reconstruction work in the model. For the presented results of the test this mirroring has no influence.

The main differences between the groynes in test T10 and the groynes in test T20 were the reduction of the length of the piles over a distance of 54 m, measured from the head of the groyne, as well as the direction of the groyne axis. The groynes were pointing in upstream direction and made an angle of 15 degrees with a line perpendicular to the bank line. The groynes had an impermeable part of 80 m at the flood plain and a permeable part of 61 m in the channel, see Table 3.7-1. From the flood plain the permeability increased gradually from 50 % up to 80 % near the head of the groyne in test T10, see Fig. A.23-20.

Length chn lnd	Spacing	Blockage	Length of Impermeable Part	Falling Apron
m m	m	%	m	
61 80	300	20/30/40/50	80	no

lnd = length of the groyne on the attached char in front of the embankment
chn = length of the groyne into the channel

Table 3.7-1: Characteristics of the groynes in test T20

(2) Results

The flow velocities near the groyne heads, the flow velocities along the bank between the groynes and the maximum scour depths were used for the determination of the design parameters. The results of test T20 are presented in Fig. A.23-21 to A.23-26 and Table 3.7-2.

Groyne	Maximum flow velocity near groyne head		Maximum flow velocity near the bank between the groynes		Maximum scour depth	
	T20	T10	T20	T10	T20	T10
	m/s	m/s	m/s	m/s	m	m
1	1.7	2.3	0.9 to 1.0	0.3 to 0.5	8	6.4
2	1.6	2.4			6	7.4
3	1.7	2.5	0.9 to 1.1	0.3 to 0.5	7	6.4

Table 3.7-2: Main results of T20 for test area near Sariakandi and of T10 for the test area near Kamarjani

The flow velocities and the flow lines which were measured in T20 are presented in Fig. A.23-21 to A.23-23. The flow velocities along the bank between the groynes were rather high in test T20, being 0.9 to 1.1 m/s, compared with less than 0.4 m/s in test T10. This is because of a difference of 20 m bank erosion in these tests. Therefore, these flow velocities in T20 should be compared with the flow velocities which were measured 20 m away from the bank in T10, viz. 1.1 to 1.8 m/s. It is concluded that if this bank erosion of 20 m is not acceptable, the length of the impermeable part of the groyne should be increased by about 20 m and the length of the permeable part should be kept constant. An alternative for the adjustment of the length of the groynes is to reduce the spacing between them.

The maximum flow velocity around the head of the groyne was measured within a distance of 20 m from the intersection of the water level and the groyne.
This maximum flow velocity was 1.6 to 1.7 m/s in test T20 which is lower than 2.3 to 2.5 m/s, measured in test T10. It is concluded that the maximum flow velocity near the head of the groyne is reduced if the length of the piles is reduced too. The different bed bathymetries in tests T20 and T10 had probably not much influence on these maximum flow velocities.

An example of the development of the maximum scour depth as a function of time is presented in Fig. A.23-24. From an extrapolation of that development the equilibrium scour depth is estimated. This is the maximum depth of a scour hole after the development of the scour hole has reached an equilibrium. This means that the scour hole does not increase significantly its size as a function of time. Some cross-sections of the river bed along the groyne axis, a cross-section through the head of the groyne and a cross-section downstream of the groyne are presented in Fig. A.23-25 to A.23-27 for the three different groynes.

The maximum local scour depth near the head of the groyne was 6 to 8 m below the initial bed level in test T20 and these depths are about the same as measured in test T10.

In the Sariakandi model the water depth is about 5 m less than in the Kamarjani model and therefore the scour depths in test T20 should be less than the scour depths in the Kamarjani model. This effect is compensated by the increase of the scour depths by an change in the orientation of the groyne axis in downstream direction, which was done for experimental reasons. It is concluded that the maximum local scour depth depends on the permeability near the head of the groyne and not on the length of the piles near the head.

Around the single pile row of the groyne no bed protection was applied and a scouring of 2 to 5 m close to the piles was observed in test T20. This scouring would increase through the local scour hole of the piles itself which has a maximum depth of about 2 to 3 times the pile diameter.

A further conclusion is that the results of the tests in the Kamarjani model and those with a revetment in the Bahadurabad model are valid also for a preliminary design of test structures near Sariakandi, if no high accuracy is required. The comparison of the cross-section in the Bahadurabad model with the schematized cross-section in the Sariakandi model shows that the waterdepth in Bahadurabad model is about 11 m (19.8 - 9 m + PWD) near the revetment and in the Sariakandi model about 8 % less, viz.: 17.5 - 7.3 = 10.2 m.

3.7.3 Model Tests for Kazipur

The physical model represents a stretch of 2500 m of a sharp bend in the channel near Kazipur, at the right bank of the Jamuna river. In the model not the full width of the channel was moulded but only a part with a width of 400 to 500 m (see Fig. A.23-3). The analysis of the results of the tests follows after a description of the layout and the geometry of the groynes.

(1) Test programme

The bed geometry and the bank lines in test T10 and T11 (Kamarjani) are represented in the cross-sections in Fig. A.23-28. The bed geometry in test T21 was a schematization of the bed geometry which was measured in a field survey near Kazipur, see some characteristic cross-sections of the field survey in Fig. A.23-29 and the schematized cross-sections in Fig. A.23-30. A qualitative comparison of these cross-sections with the cross-sections of the Kamarjani model shows similar tendencies and the water depth in test T21 (15.56 - (- 1.0) = 16.6 m) is slightly deeper (10 %) than the water depths in tests T10 and T11 (21.6 - 6.4 = 15.2 m) for Kamarjani. Furthermore, in test T21 the radius of the curvature of the bank line was smaller than this radius in tests T10 and T11.

The differences between the groynes in T10 on one the hand and the groynes in tests T11 and T21 on the other hand are the reduction of the pile lengths over a distance of 54 m from the head of the groyne and the orientation of the groyne axis, pointing in downstream direction with an angle of 15 degrees perpendicular to the bank line. A longitudinal section of the groynes and elevation of piles in test T10 is shown in Fig.A.23-31 and for tests T11 and T21 in Fig. A.23-32 and -41. The layout of model T11 is presented in Fig. A.23-33.

(2) Results

The flow velocities near the head of the groynes, the flow velocities along the bank between the groynes and the maximum scour depths are used for the determination of the design parameters. The results for test T11 are shown in Fig. A.23-34 to A.23-39. The layout of test T21 is presented in Fig. A.23-40, groyne longitudinal section in Fig. A.23-41 and the results for that test in Fig. A.23-42 to A.23-46 and Table 3.7-3.

Groyne	Maximum flow velocity near groyne head		Maximum flow velocity near the bank between the groynes		Maximum scour depth	
	T21	T11	T21	T11	T21	T11
	m/s	m/s	m/s	m/s	m	m
1	1.3	2.2	0.3 to 1.0	0.3 to 0.5	6.4	9.4
2	1.5	2.6			5.4	9.4
3	1.5	2.7	0.3 to 1.0	0.3 to 0.5	10.4	10.4

Table 3.7-3: Main results of T11 Kamarjani and T21 for Kazipur

The maximum flow velocities near the head of the groyne are relatively small in the Kazipur geometry (test T21). These low flow velocities can be explained by the flow lines and the flow velocities in Fig. A.23-42 for the discharge according to the Froude condition. In this graph the highest flow velocities are in the middle of a cross-section or at the inner bend, especially in cross-sections 10, 11 and 14.

The maximum flow velocities near the head of the groyne in test T11 are roughly the same as the maximum flow velocities in test T10, because of

- The direction of the groyne axis in T11 (pointing in downstream direction) results in a concentration of the discharge near the head of the groyne,
- This effect is compensated by the lowering of the piles near the groyne head.

This concentration of the discharge can be seen also from the comparison of the sketched flow lines in Fig. A.23-42 with the flow lines through the permeable groyne in test T11 in Fig. A.23-34.

It is concluded that the maximum flow velocity near the head of the groyne is reduced if

- the length of the piles is reduced;
- the direction of the groyne axis is perpendicular to the bank instead of pointing in

downstream direction, and
- the channel alignment is straight instead of an outer bend.

The flow velocities near the bank between the groynes are more or less equal in the tests T10, T11 and T21. The reduction of the length of the piles and changing the orientation of the groyne axis do not have a significant influence on the flow velocities along the bank. The groyne spacing was constant in these three tests.

The maximum scour depths in test T11 are more than the in test T10 because:
- The orientation of the groynes in downstream direction results in more scour depths,
- The length of the piles near the head of the groyne has no influence on the scour depths.

These maximum scour depths are measured 18 to 37 m in front of the head of the groyne.

The maximum scour depths are slightly deeper in test T21 (Kazipur) than in test T10 (Kamarjani, groynes perpendicular), but these scour depths are less deep than in test T11 (Kamarjani, groynes downstream inclined). This is because the water depths in the Kazipur model are about 10 % deeper, resulting in deeper scour depths in test T21 than in tests T10 and T11. On the other hand, the radius of curvature of the bankline in test T21 is smaller than in test T11 and T10, this resulted in a concentration of the flow velocities near the inner bank with smaller scour depths. These maximum scour depths are measured 19 m downstream of the groyne head.

General conclusion for the test area near Kazipur model: In a sharp bend a developed bend profile can be expected with the maximum flow velocities at the outer bend, not in the inner bend or in the middle of the cross section as observed in test T21. Therefore, 10 % deeper scour holes and 10 % higher maximum flow velocities are expected in the test area near Kazipur than measured in the Kamarjani model. Also the flow velocities measured near the revetment in the Bahadurabad model should be increased by 10 to 15 % for a revetment in the test area near Kazipur.

3.7.4 Conclusions

(1) Design values for groynes

The following conditions were investigated in the model tests:
- series of 5 groynes;
- spacing of groynes : 300 m;
- length of groynes : 80 m impermeable part on the flood plain and 61 m permeable part within the channel;
- permeability increase towards the groyne head in 4 steps, each 15 m long: 50-60-70-80 %;

- groyne axis perpendicular to the bank line;
- bed protection around groyne piles to prevent scouring, and
- pile heads above water level.

In the preliminary design a number of changes have been made against the above assumptions. These include:
- spacing of groynes is 200 - 250 m;
- pile length is reduced so that the permeable part of the groynes will be submerged during flood conditions;
- the impermeable part of the total groyne is 60 m, as is the permeable part, and
- the groyne axis is generally inclined towards the axis of the river flow by 15° in upstream direction.

The effect of the above changes has been estimated using the experience gained during earlier model tests as explained in ANNEX 14. Special reference is made in this connection to Fig. 14-38 and Fig. 14-80 therein.

The effect of a submerged permeable part of the groyne is probably a slight reduction on the design flow velocities for bed protection, whereas those for piles will not alter. The local scour depth used for design purpose is probably not influenced by shorter pile length. The reduction in groyne spacing was considered necessary for preventing a retreat of the bank line between them.

The design values for the maximum flow velocities and local scour depths considered for Sariakandi and Kazipur are listed below, applicable for moderate bank atack. Only in case confluence conditions have to be expected near to the test structures, a stronger attack with higher design values should be considered.

The design maximum flow velocity for piles will be 2.5 m/s at Sariakandi and 3 m/s at Kazipur, that for river bed protection will be 3 m/s at Sariakandi and 3.5 m/s at Kazipur. The design maximum local scour depths will be 5-7 m at Sariakandi and 10 m at Kazipur.

Due to the limited extend of investigations made for the additional test sites, the accuracy of the design values can not be as high as those for the series of groynes tested for Kamarjani. Therefore, however, a higher safety margin has been included.

(2) Design values for slope revetments

A slope revetment with the following conditions was investigated in the model tests:
- length of revetment: 1000 m;
- crest line radius of upstream termination: 400-450 m;
- slope of revetment: 1 in 3, and
- bed protection: falling apron 20-30 m wide.

The design maximum flow velocities for revetments will be 3.5 m/s at Sariakandi and about 4 m/s at Kazipur. The design maximum local scour depths will be about 10 m at Sariakandi and 14 m at Kazipur. The explanation given in the last para of (1) is also applicable here.

3.8 CONSTRUCTIONAL ASPECTS

The investigations made regarding construction materials, construction methods and equipment as well as contractor's capabilities, results of which are contained in ANNEX 19, are applicable for the additional test sites as well. Thus, the statements made in Section 9.2 of the Main Report remain valid.

4 PRELIMINARY DESIGN SOLUTIONS

4.1 DESIGN PARAMETERS

4.1.1 Water Levels

To obtain the water levels at Sariakandi and Kazipur the Hydrology Study (ANNEX 5) was evaluated again. The method is briefly explained again in the following.

For calculating the Jamuna river water levels between the gauging stations and for calculating the levels for defined return periods the general model (GM) was used. The FAP 25/GM model is a reduced version of the GM. With this model FAP 25/GM runs were made for a long period from 1965 to 1989 with a fixed bed, measured in 1986. At the time of the study the so called Run 6 of FAP 25/GM is considered as the final run for the existing situation with a recalibrated model. The calculated discharges were analyzed to determine the design discharges, see Fig. A.23-61 and -62.

With a frequency analysis of the available data the design water levels and the design discharges have then been determined for the test areas. The probability distributions, which are recommended by FAP 25, have been used in the hydrology study. The design water levels and the design discharges for selected return periods of 2, 5, 10, 25, 50 and 100 years are determined for representative cross-sections at the test areas, see Fig. A.23-63 and -64.

The design water levels should include a recommended safety margin which has to be added to the free board of the bank protection, accounting for wind set-up, wave run-up and others possible safety factors.

From the graphs (Fig. A.23-63 and -64) the following can be established (Table 4.1-1):

Water Level (m PWD)	Sariakandi	Kazipur
SLW	+ 11.00	+ 8.65
SHW	+ 16.70	+ 14.55
HFL (100 yr)	+ 18.65 (SLW + 7.65 m)	+ 16.70 (SLW + 8.05 m)
Design water level (25 yr)	+ 18.35 (SLW + 7.35 m)	+ 16.45 (SLW + 7.80 m)

Table 4.1-1: Water levels at Sariakandi and Kazipur test site

4.1.2 Hydraulic Loads

Wave data are taken from Section 9.3 of the Main Report as:

- significant wave length H_s = 1.0 m
- wave period T = 3 s

Design velocities as summarized in Subsection 3.7.4 have been found

- for Sariakandi in the same order of magnitude as for Kamarjani (for groynes) or Bahadurabad (for slope revetment), respectively, but
- for Kazipur to be increased by 10-15 %.

Thus, the design velocities would be

- for groyne piles at Sariakandi : 2.5 m/s
  at Kazipur : 3.0 m/s
- for river bed protection around groyne piles at Sariakandi : 3.0 m/s
  at Kazipur : 3.5 m/s
- for slope revetment
  at Sariakandi : 3.5 m/s
  at Kazipur : 4.0 m/s

4.1.3 Scour Depths

According to Subsection 3.7.4 the maximum local scour depths below river bed to be considered in the design would be:

- for groynes at Sariakandi : abt. 6 m at groyne head
  at Kazipur : abt. 10 m at groyne head
- for slope revetment at Sariakandi : abt. 10 m
  at Kazipur : abt. 14 m

4.1.4 Soil Conditions

In view of the findings recorded in Section 3.3 and in absence of any further subsoil investigations, soil properties are assumed as stated in ANNEX 21 for Kamarjani, viz.

γ/γ' = 18/8 kN/m^3
φ' = 27.5°
c' = 0 kN/m^2

ground water level abt. 2 m above SLW,
i.e. + 13.0 m PWD in Sariakandi
and + 10.70 m PWD in Kazipur

4.2 PRELIMINARY DESIGN OF GROYNES

Out of the alternatives investigated in ANNEX 20 a selection of 5 different groyne designs has been considered for execution in ANNEX 21 (Test Site Kamarjani). Principally, groyne test structures could be erected at both Sariakandi and Kazipur. Layout proposals have, therefore, be made for both areas in Fig. A.23-65 and -67, respectively. It is understood that adaptations are required after the exact course of bank line and actual river bed profile are available at the time of final design.

The general arrangements proposed for Kamarjani test site can also be followed in case either Sariakandi or Kazipur will be selected instead of Kamarjani. The 5 types (A-E) selected in ANNEX 21 for execution have been shown with their main features in Fig. A.23-70 and their location is indicated on the layout sketches Fig. A.23-65 and -67. Their main parts are listed in Table 4.2-1.

Type No.	Landsided impermeable part	Riversided permeable part	River bed pro-tection at toe
A	steel sheet pile cofferdam	steel piles	concrete blocks
B	concrete sheet pile cofferdam	steel piles	sand bags
C	earth dam	steel piles	sand blocks, chemically bound
D	earth dam	steel piles	none
E	earth dam	steel piles	sand bags

Table 4.2-1: Types of groynes to be tested

Further details can be obtained from ANNEX 21, Chapter 2.

For Sariakandi test site use will be made of the existing Anterpara groyne, which is in a deteriorated condition but can be upgraded to the impermeable part of groyne Type C. The earth dams of groynes Type D and E will be extended up to the existing parallel embankment and the cofferdams of Types A and B will be connected to earth dams also joining this embankment, see Fig. A.23-65. In this way a good combination of existing facilities and test structures can be achieved.

Ga

For Kazipur test site the more unfavourable hydraulic loads and deeper scour holes expected, will require heavier pile elements, which will have to be calculated during final design. Similar as for Kamarjani (Main Report) the new embankments connecting the groyne roots on landside are not considered to be erected by the Consultant (see Fig. A.23-67).

An alternative for Kazipur is shown on Fig. A.23-68. Instead of constructing the groyne Type E on low land down to level + 10 m PWD (corresponding to about 1.40 m above SLW) the whole groyne field is shifted upstream towards northwest. At the same time the line of defence has been shifted towards to expected new bankline. In this case groyne Type A consists of a short sheet pile cofferdam only, being close to the bank line (Type A1). The reduced groyne length requires reduction of groyne distance to about 200 m. The idea is to use as less inhabited land as possible for erecting the test structures, providing maximum protection. However, cost involved will be higher due to part of the structures being more in low laying ground with flowing water conditions. Final selection shall be made at the time when actual profiles are available for design.

4.3 PRELIMINARY DESIGN OF SLOPE REVETMENTS

Out of the alternatives investigated in ANNEX 20 a selection of 4 different slope sections (see Fig. A.23-71) with in total 9 types of revetment composition (see Table 4.3-1) has been considered for execution in ANNEX 21 and will also be applicable for the additional test sites in Sariakandi and Kazipur.

Details of the type of structures can be obtained from ANNEX 21, Chapter 4. In view of the higher hydraulic loads at Kazipur, individual components (e.g. of cover layer and toe protection) will have larger dimensions, to be calculated during final design.

Layout proposals are presented in Fig. A.23-66 for Sariakandi and in Fig. A.23-69 for Kazipur. Thereby, constructional requirements as per Chapter 5 of ANNEX 21 have been considered, leaving a protection dam towards the river during constructing the slope revetments. It is understood that adaptations are required after the exact course of bankline and actual river bed profile are available at the time of final design.

At Sariakandi the crest road of the structure can be directly connected to the top of the existing embankment, provided erosion has not progressed too far, (i.e. if construction takes not place later than 1993/94). In that case, however, this existing embankment could itself become part of the test structure.

At Kazipur connection to existing embankments is possible too, but is not necessarily required, especially at the downstream end. At the upstream end the necessity depends on the possible development of an embayment.

Protec-tion Type	Section No.	Cover layer/filter layer		Toe Protection
		Above water level	Below water level	
A	6 (BA-6)	V3 : Wire mesh gabions (boulders) A1 : Rip-rap (boulders) FA4: geotextile filter (multi layer)	B1 : rip-rap (boulders) FB3: geotextile sand mat	T1: boulders
B	6 (BA-6)	V2 : wire mesh gabions (bricks) A2 : rip-rap (chemically bonded sand blocks FA4: geotextile filter (multi layer)	B2 : rip-rap (chemically bonded sand blocks FB3: geotextile sand mat	T3: geotextile bags, par-tially filled with sand
C	5 (BA-5)	A4 : rip-rap (boulders with bitumen grout) FA1: granular filter	B9 : geotextile bags filled with sand FB1: geotextile filter (one layer)	T3: geotextile bags, par-tially filled with sand
D	5 (BA-5)	A6 : concrete blocks (regularly placed) FA4: geotextile filter (multi layer)	B5 : concrete blocks FB3: geotextile sand mat	T2: concrete blocks
E	5 (BA-5)	A3 : Rip-rap with cement grout FA2: lean sand asphalt	B5 : concrete blocks FB2: geotextile filter (multi layer)	T2: concrete blocks
F	2 (BA-2)	A8 : open stone asphalt FA2: lean sand asphalt	B10: tubular fabrics filled with sand/lean sand asphalt FB1: geotextile filter (one layer)	T5: tubular fabrics filled with sand or lean sand asphalt as extension of revetment
G	2 (BA-2)	A11: wire mesh gabions filled with boulders FA3: geotextile filter (one layer)	B12: wire mesh mattresses filled with boulders FB2: geotextile filter (multi layer)	T6: wire mesh mattresses filled with boulders
H	1 (BA-1)	B6 : cable connected blocks FA4: geotextile filter (multi-layer)	B6 : cable connected blocks FB3: geotextile sand mat	T4: cable connec-ted blocks as extension of revetment
K	1 (BA-1)	B7 : blocks connected to geotextiles FA3: geotextile filter (one layer)	B7 : blocks connected to geotextiles FB1: geotextile filter (one layer)	T7: scour preven-tion mat

Note: Markings in brackets within column 2 are from ANNEX 21

Table 4.3-1: Revetment composition selected for test structures

5 COST ESTIMATES

5.1 GENERAL REMARKS

All cost estimates in the following sections are based on the unit rates compiled in Section 9.3 of the Main Report. These costs are net working prices including cost of labour, materials and local equipment hire costs for execution of works. These costs are defined as Net Total Cost (NTC) in Subsection 10.3.2 of the Main Report. They do not contain:

- costs for mobilization;
- site installation costs;
- contractor's overheads and profit;
- purchase of equipment (or hire costs abroad);
- price escalation, and
- contingencies.

As for any details, reference is made to Tables A.21.6-1 to -5 for groynes and Tables A.21.6.-6 to -18 for slope revetments, contained in ANNEX 21.

5.2 GROYNES AT SARIAKANDI

The basic cost of a series of 5 groynes type A to E was estimated in Section 6.1 and Tables A.21.6-1 to -5 of ANNEX 21 to Tk 174,404,940 for Kamarjani.

The differences to the structures as shown on Fig. A.23-65 and -70 are as follows:

- flood plain level 6.00 m + SLW (instead 5.50 m);
- top of piles/gangway 7.35 m + SLW (instead 7.70 m), and
- groynes No. A, B and D have an earth dam extension up to the existing embankment, whereas for groyne No.C use will be made of the existing Anterpara groyne, thus no dam construction would be required. However, revetment and toe protection will have to be provided.

The above differences result in minor cost variations up and down and are within the margin of the estimate of ANNEX 21 Section 6.1, i.e. say:

Tk 174,500,000
========

5.3 GROYNES AT KAZIPUR

The basic cost of a series of 5 groynes type A to E was estimated in Section 6.1 and Tables A.21.6-1 to -5 of ANNEX 21 to Tk 174,404,940 for Kamarjani.

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The differences as shown on Fig. A.23-67 and -70 are as follows:

- flood plain level 5.60 m + SLW (instead 5.50 m);
- top of piles/gangway 7.80 m + SLW (instead 7.70 m);
- for groyne No.D use can be made of an existing cross-dam, so no earth dam section is to be built. However, revetment on the slopes will have to be provided, and
- groyne No.E will have to be erected on foreland lower than the flood plain. Apart from construction constrains will this result also in a higher earth dam (abt. 6.50 m instead of 2.20 m).

Furthermore, hydraulic loads are higher (see Subsection 3.7.4 (1)), resulting in stronger pile sections and heavier toe protection measures. This effect has been roughly calculated to result in 20% higher costs as compared with the estimates of ANNEX 21, Section 6.1.

The total cost of the 5 groynes (without connecting embankment at their root) at Kazipur has thereupon been estimated to:

ANNEX 21, Section 6.1	:	Tk 174,404,940
add additional cost for increased groyne type E	:	Tk 2,690,000
		Tk 177,094,940
add 20% for increased hydraulic loads, say		+ Tk 35,405,060
	Total:	Tk 212,500,000

This corresponds to an increase of 22 % against the cost of the solution proposed for Kamarjani.

If the downstream groyne, situated outside the higher flood plain and the to be protected inhabited area, is being omitted, costs can be brought back to those of the proposal in the Main Report. In that case, however, type D should be replaced by type E, having river bed protection on both sides.

The total cost of 4 groynes at Kazipur will than be in the range of:

ANNEX 21, Section 6.1	:	Tk 174,404,940
deduct type D	: -	Tk 27,740,130
deduct cost of earth dam using existing cross-bar after upgrading, approximately	: -	Tk 64,810
		Tk 146,600,000
add 20% for increased hydraulic loads	: +	Tk 29,300,000
	Total:	Tk 175,900,000

The cost for these 4 groynes is in the range of the cost for the solution proposed for Kamarjani.

Another alternative is shown in Fig. A.23-68 and explained in Section 4.2. Even if groyne type A1 is reduced to 90 m against type A, the reduction in length of the sheet pile section is less than the additional cost of longer piles near the bankline. Furthermore, groynes type B and E become more costly due to recession of bankline against standard section calculated in ANNEX 21. The estimated cost for this alternative is then as follows:

ANNEX 21, Section 6.1	:	Tk 174,404,940
groyne A1 instead of type A	: +	Tk 850,000
cost increase for type B	: +	Tk 3,698,000
cost increase for type E	: +	Tk 2,440,000
		Tk 181,392,940
add 20% for increased hydraulic loads, say	: +	Tk 36,307,060
	Total:	Tk 217,700,000

This corresponds to an increase of 25 % against the cost of the solution proposed for Kamarjani.

5.4 SLOPE REVETMENTS AT SARIAKANDI

The basic cost of 4 slope revetment sections with 9 different protection types was estimated in Section 6.2 and Tables A.21.6-6 to -18 of ANNEX 21 to Tk 193,170,710 for Bahadurabad.

The differences to the structure as shown on Fig. A.23-66 and -71 are as follows:

- crest level 7.35 m + SLW (instead 7.80 m), and
- the crest road can be directly connected to the existing embankment, having a top level of 8.70 m + SLW.

The flood plain level is the same as in Bahadurabad.

The total cost of the revetment test structure at Sariakandi, considering the reduction in total height against Bahadurabad test site, has been estimated as follows:

ANNEX 21, Section 6.2	:	Tk 193,170.710
reduction for reduced crest height appr.	: -	Tk 1,170,710

	Total:	Tk 192,000,000
		=========

The cost is nearly the same as for the structure in Bahadurabad.

5.5 SLOPE REVETMENTS AT KAZIPUR

The basic cost of 4 slope revetment sections with 9 different protection types was estimated in Section 6.2 and Tables A.21.6-6 to -18 of ANNEX 21 to Tk 193,170,710 for Bahadurabad.

The differences to the structure as shown on Fig. A.23-69 and -71 are as follows:

- flood plain level 5.60 m + SLW (instead 6.00 m), and
- hydraulic loads are higher (see Subsection 3.7.4 (1), resulting in heavier underwater revetments and toe protections. This effect has been roughly calculated to result in 10 % higher costs as compared with the estimates of ANNEX 21, Section 6.3.

The crest level is the same as in Bahadurabad.

The total cost of the revetment test structure at Kazipur, considering the higher loads, has been estimated as follows:

ANNEX 21, Section 6.2	:	Tk 193,170,710
add 10 % for increased hydraulic loads, say	: +	Tk 19,329,290

	Total:	Tk 212,500,000
		=========

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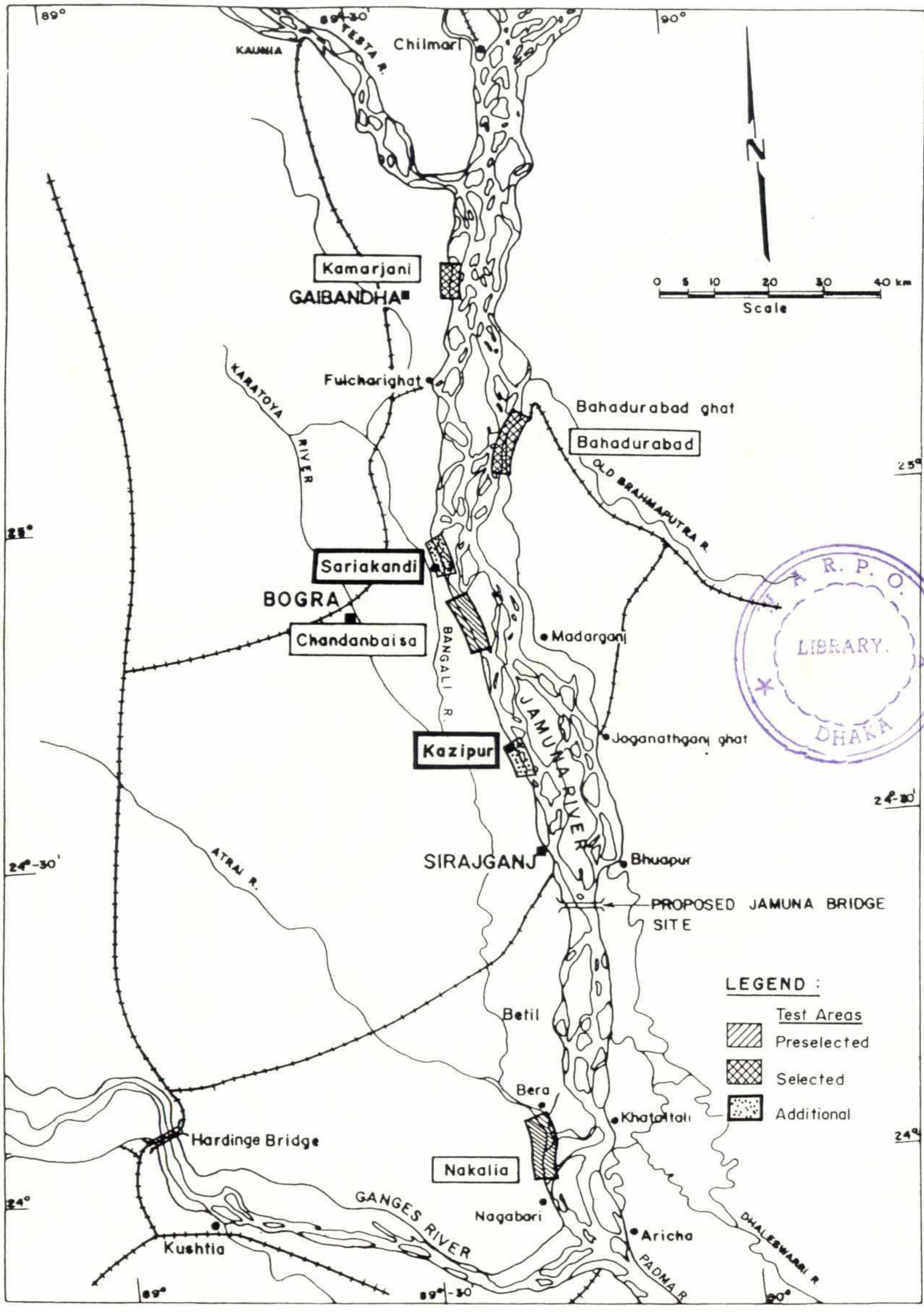
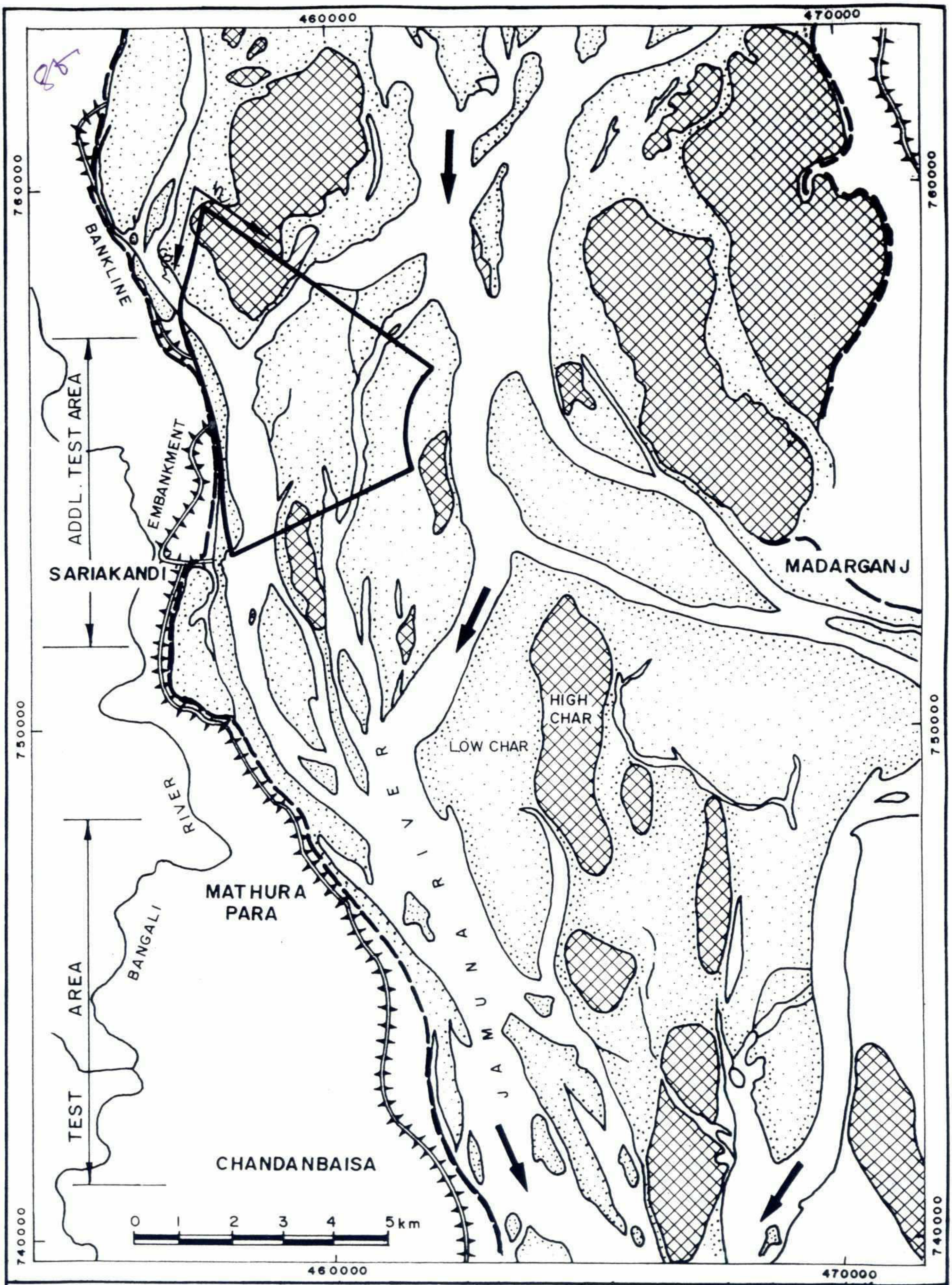
Delft Hydraulics, (1991)	TRISULA: A simulation program for hydrodynamic flows and transports in 2 and 3 dimensions - User Guide, release 1
FAP 1, (Oct.1991)	River Training Studies of the Brahmaputra River, Report on Priority Works
Interconsult, (1991)	Determination of Standard Low Water and Standard High Water Levels in Bangladesh, Vol.II: Technical Report
Mosselman, E., (1992)	Mathematical modelling of morphological processes in rivers with erodible cohesive banks, Communications on Hydraulic and Geotechnical Engineering, Faculty of Civil Engineering, Delft University of Technology; also personal communication

FIGURES



ADDITIONAL TEST AREAS	**FAP - 21/22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-1



SARIAKANDI

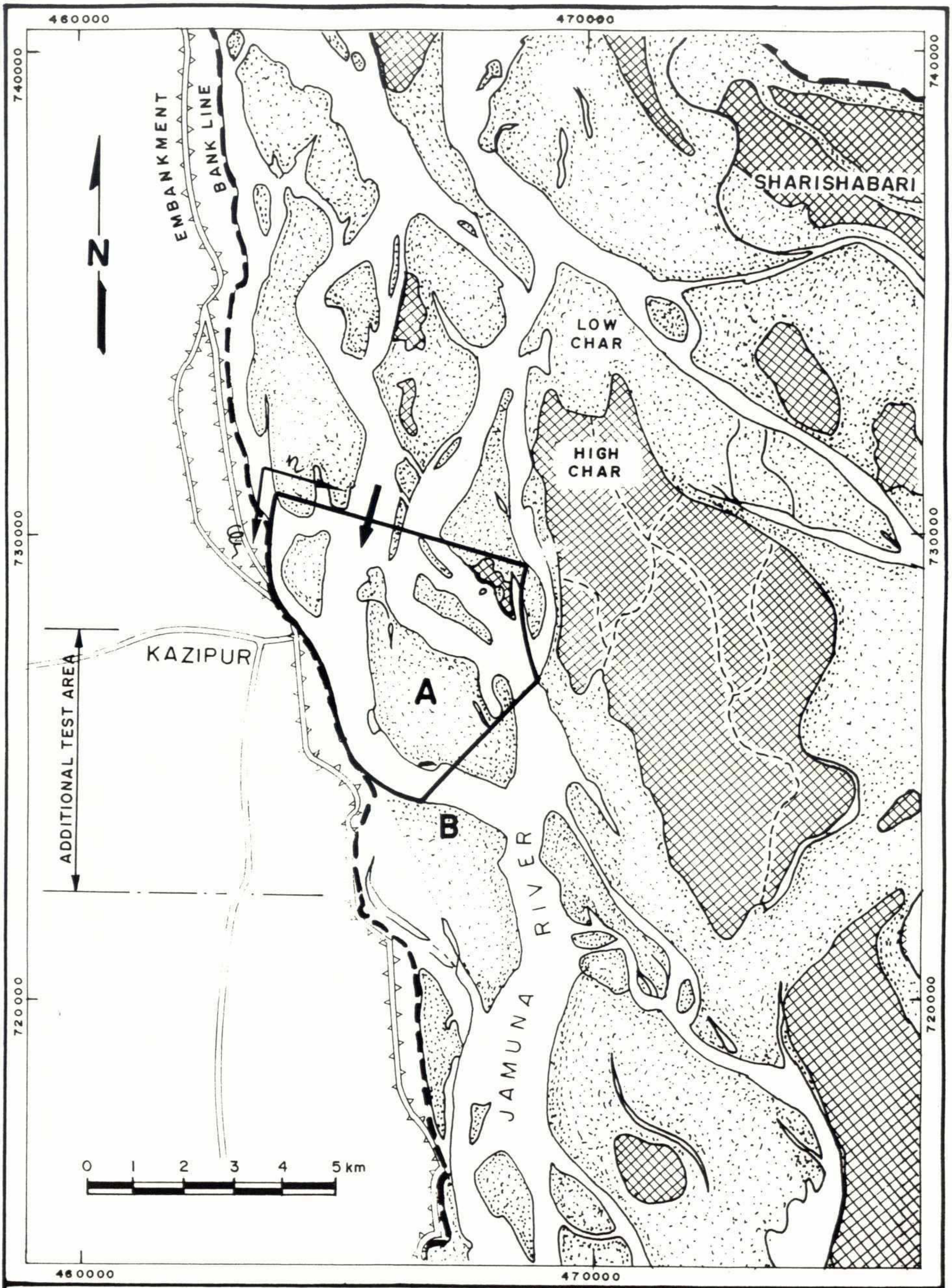
MATHEMATICAL MODEL BOUNDARIES

FAP - 21/22

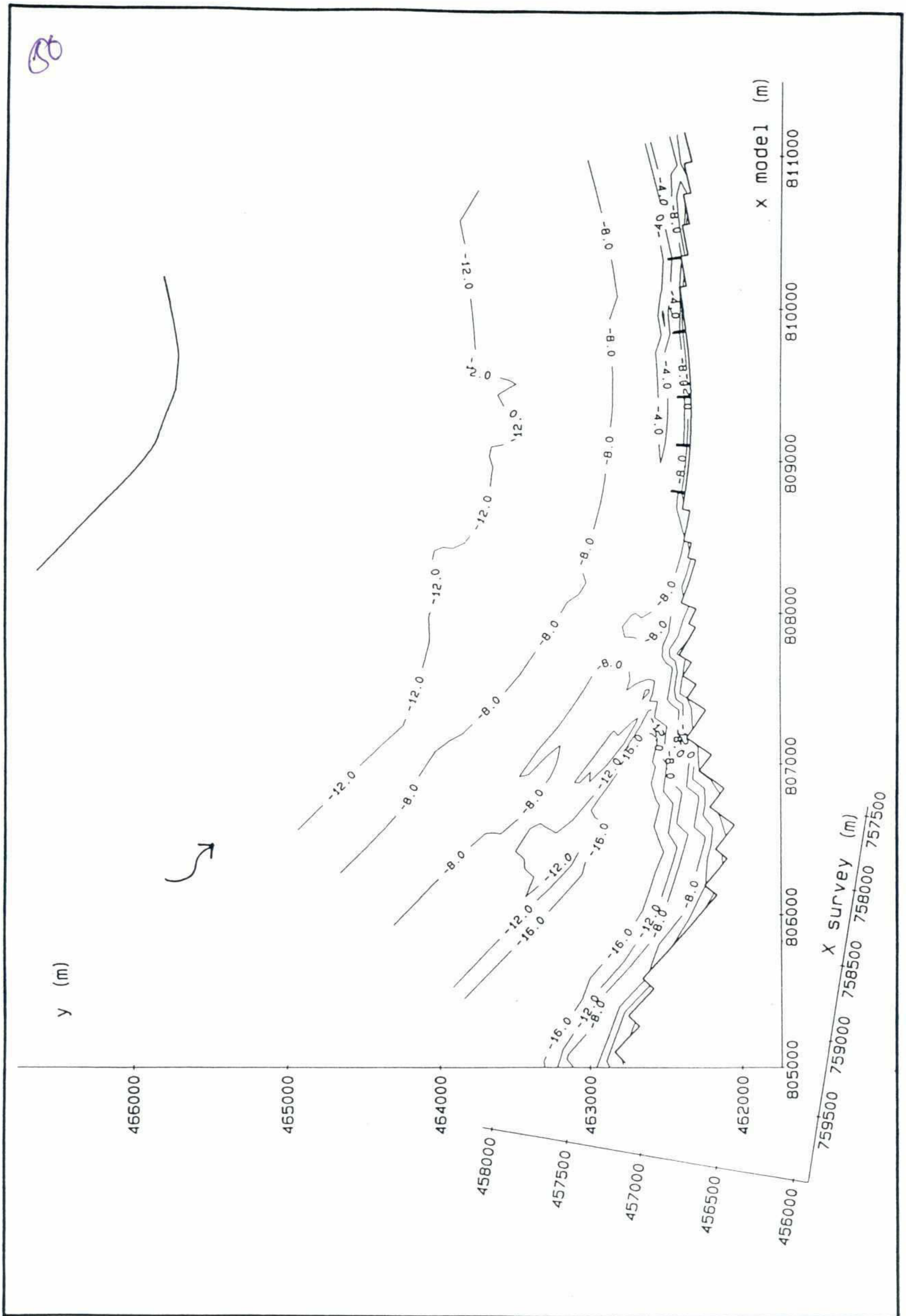
BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT

FINAL REPORT

FIG. A.23-2



KAZIPUR MATHEMATICAL MODEL BOUNDARIES	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A. 23 – 3

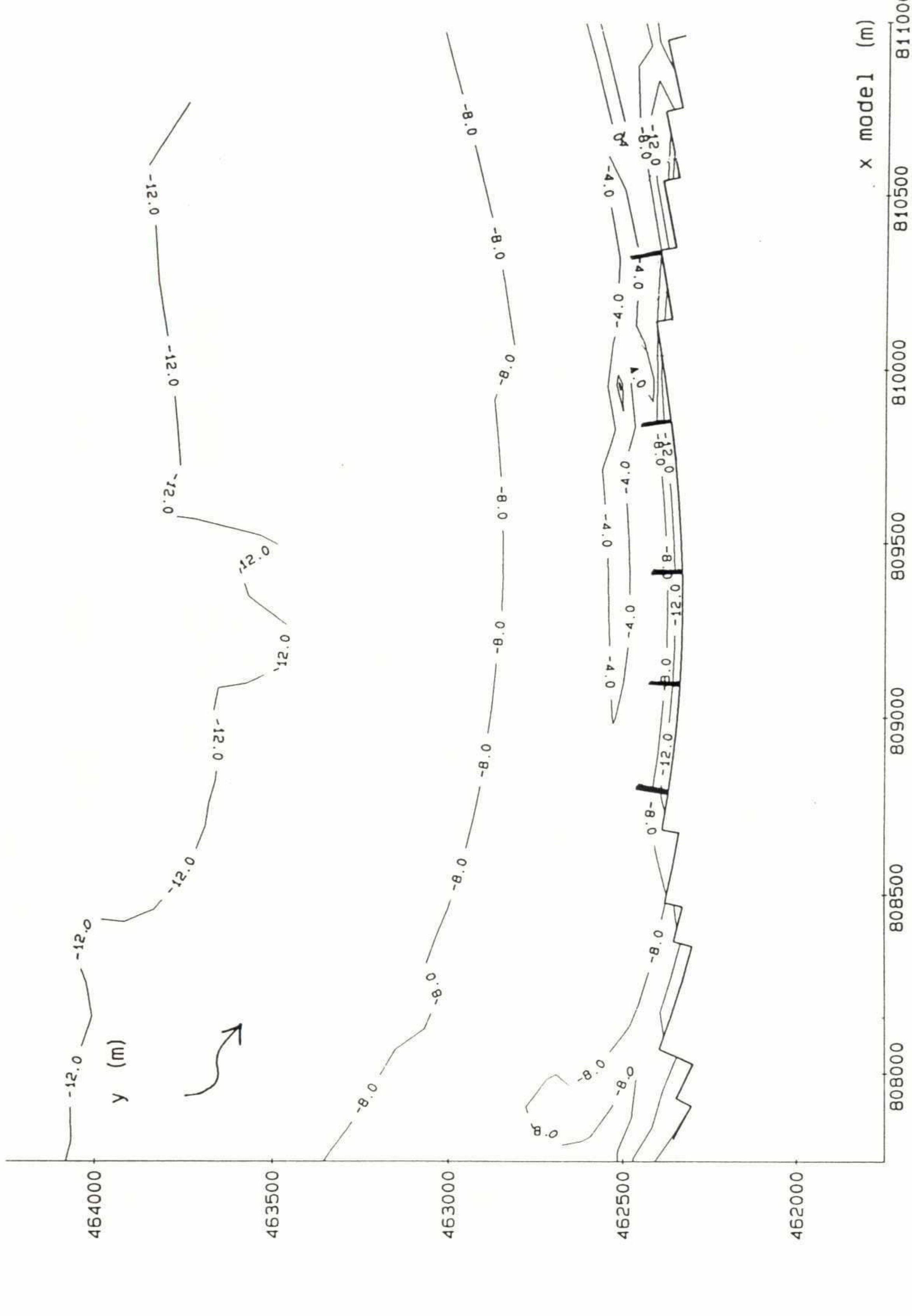


SARIAKANDI MATH. MODEL
BANK LINE III'94 WITH PROTECTIONS
BED LEVEL ISOLINES [-(+m PWD)]

FAP – 21/22
BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT

FINAL REPORT

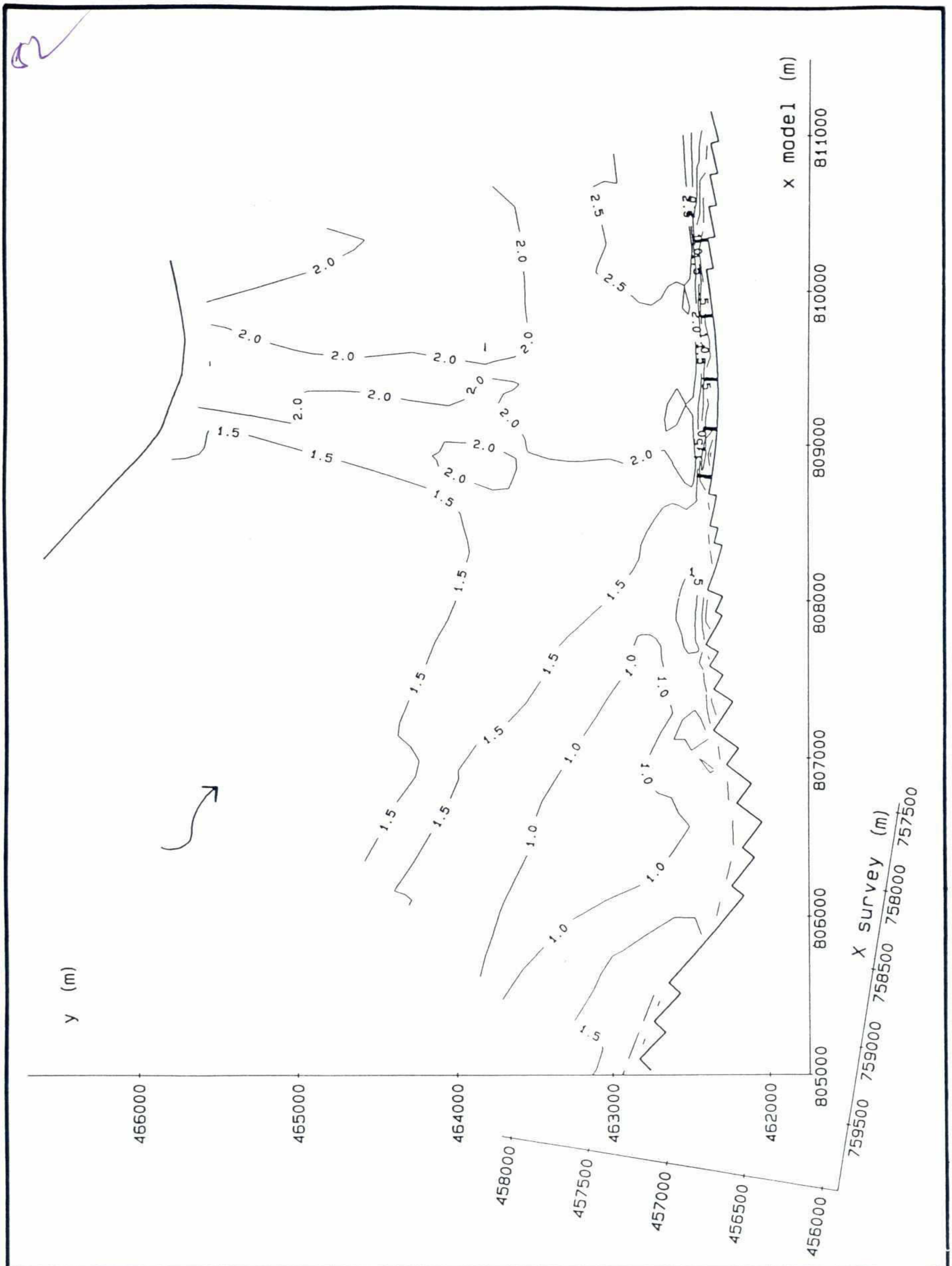
FIG. A.23-4



SARIAKANDI MATH. MODEL
BANK LINE III'94 WITH PROTECTIONS
BED LEVEL ISOLINES [-(+m PWD)](DETAIL)

FAP - 21/22
BANK PROTECTION AND RIVER TRAINING/
(AFPM) PILOT PROJECT

FINAL REPORT | FIG. A.23-5



SARIAKANDI MATH. MODEL

BANK LINE III'94 WITH PROTECTIONS

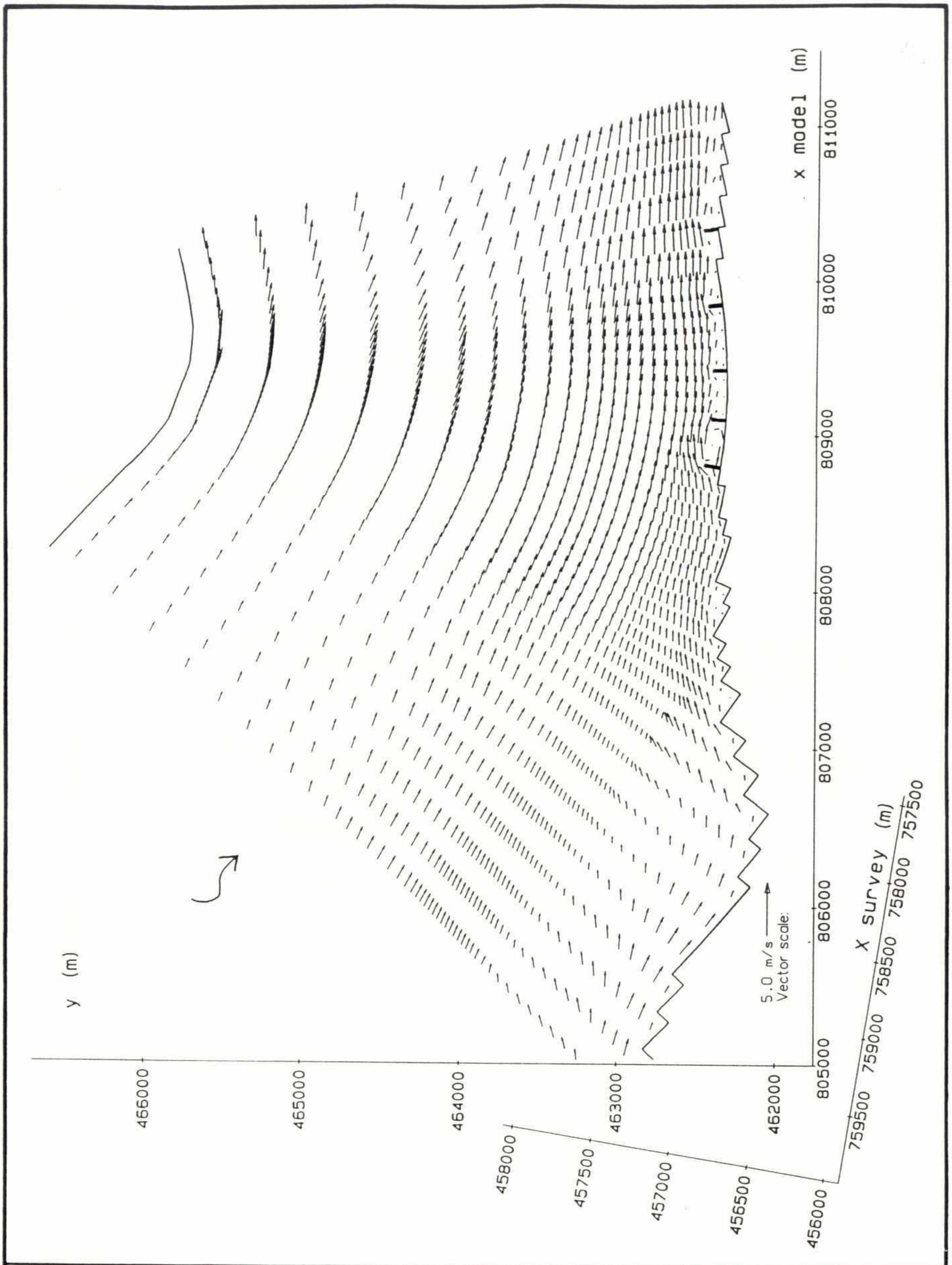
Tr = 100 YEARS - VELOCITY ISOLINES (m/s)

FAP - 21/22

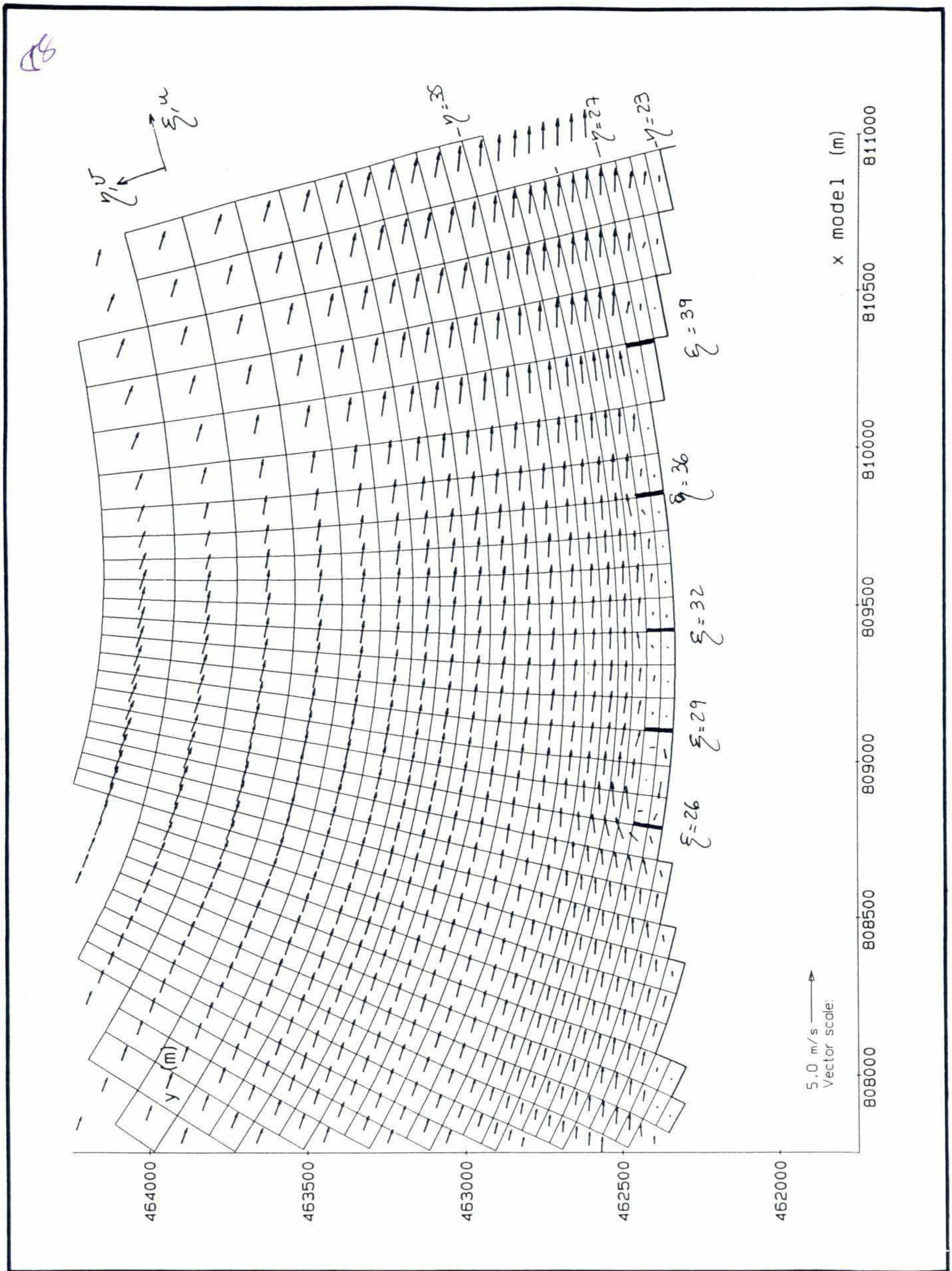
BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT

FINAL REPORT

FIG. A.23-6



SARIAKANDI MATH. MODEL BANK LINE III'94 WITH PROTECTIONS Tr = 100 YEARS - FLOW FIELD	**FAP - 21/22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-7



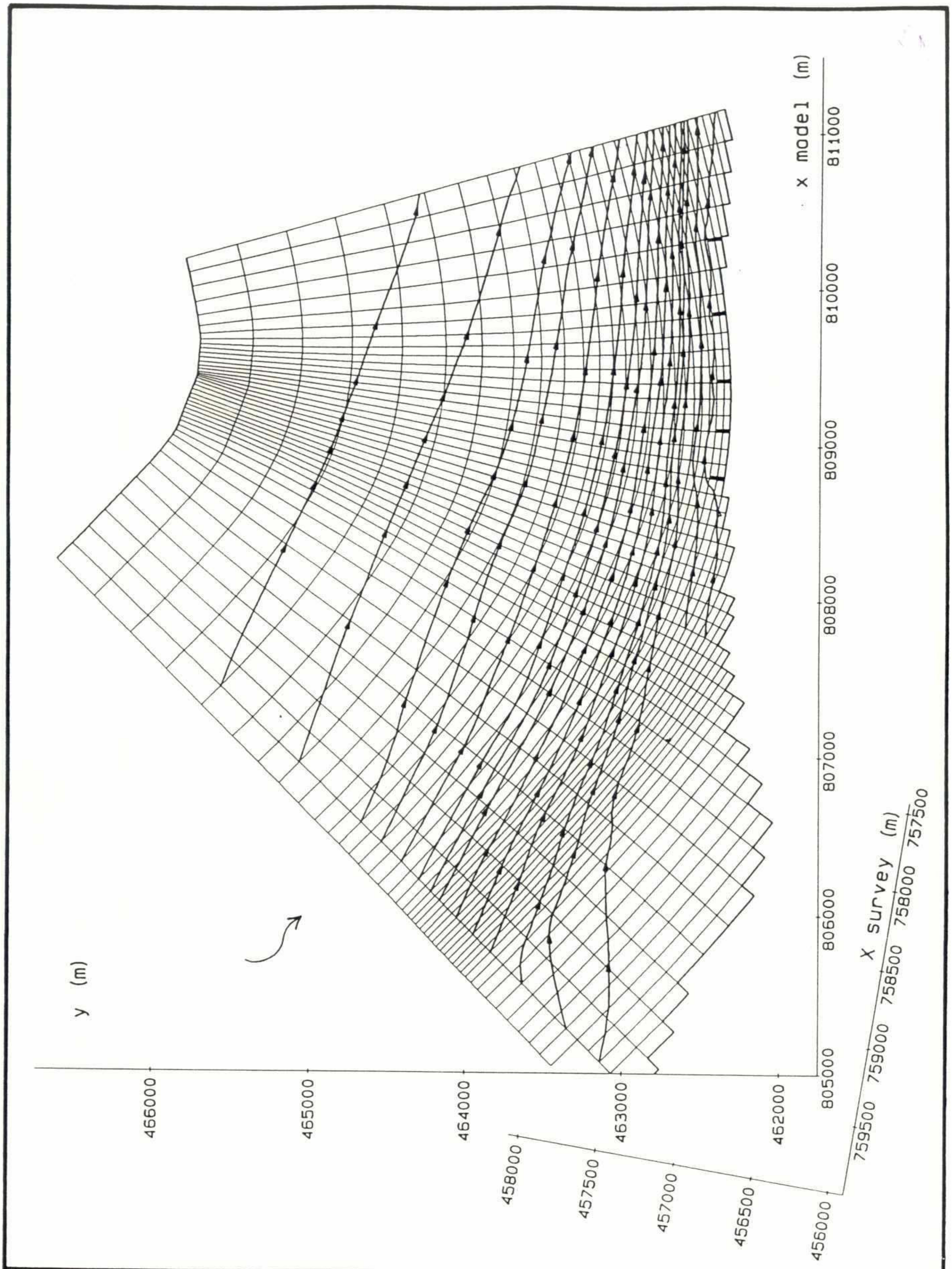
SARIAKANDI MATH. MODEL

BANK LINE III'94 WITH PROTECTIONS
FLOW FIELD (DETAIL)

FAP – 21/22

BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT

FINAL REPORT	FIG. A.23-8

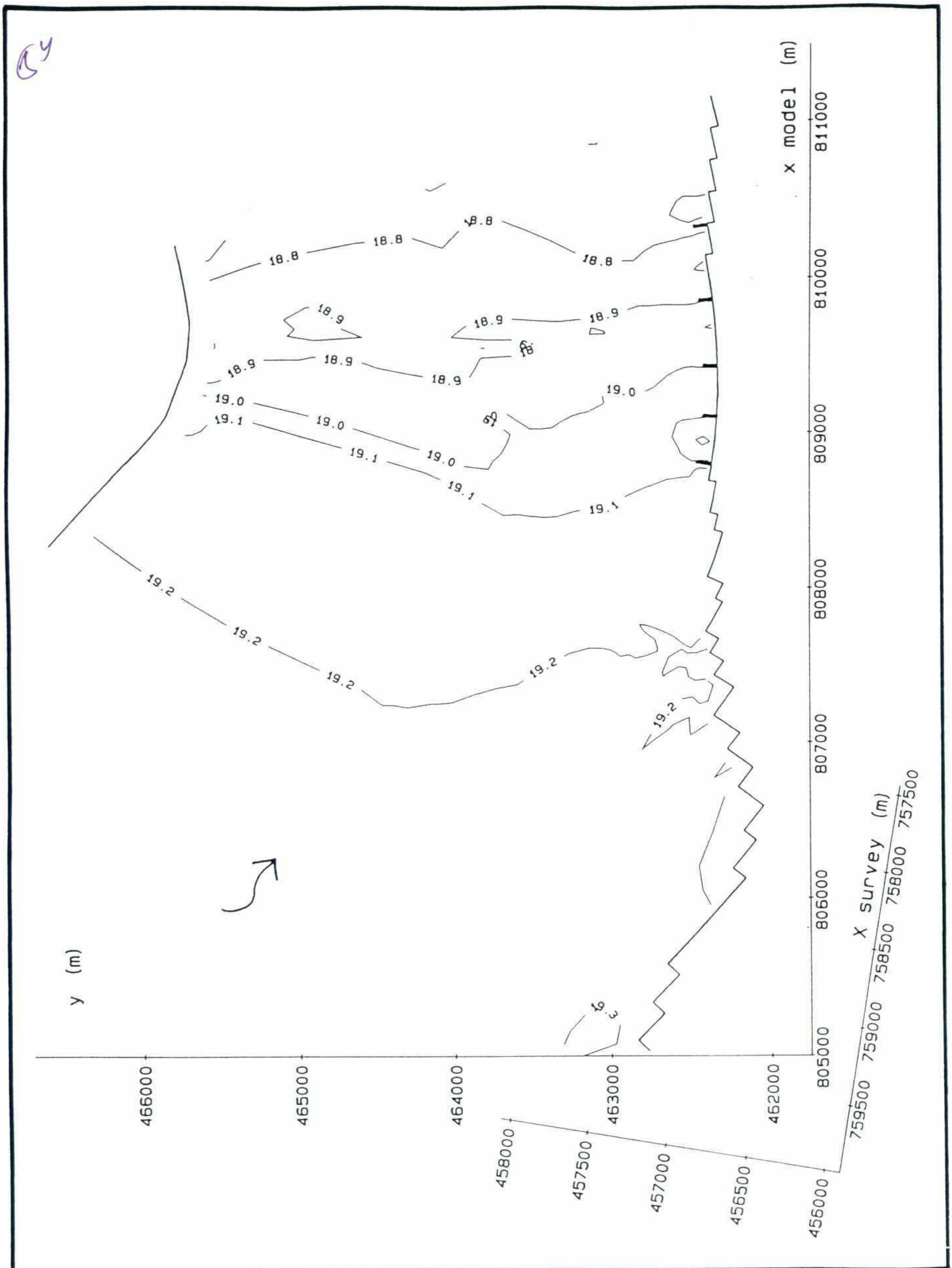


SARIAKANDI MATH. MODEL
BANK LINE III'94 WITH PROTECTIONS
Tr. = 100 YEARS – STREAM LINES

FAP – 21/22

BANK PROTECTION AND RIVER TRAINING/
(AFPM) PILOT PROJECT

FINAL REPORT | FIG.A.23-9



SARIAKANDI MATH. MODEL

BANK LINE III' 94 WITH PROTECTIONS

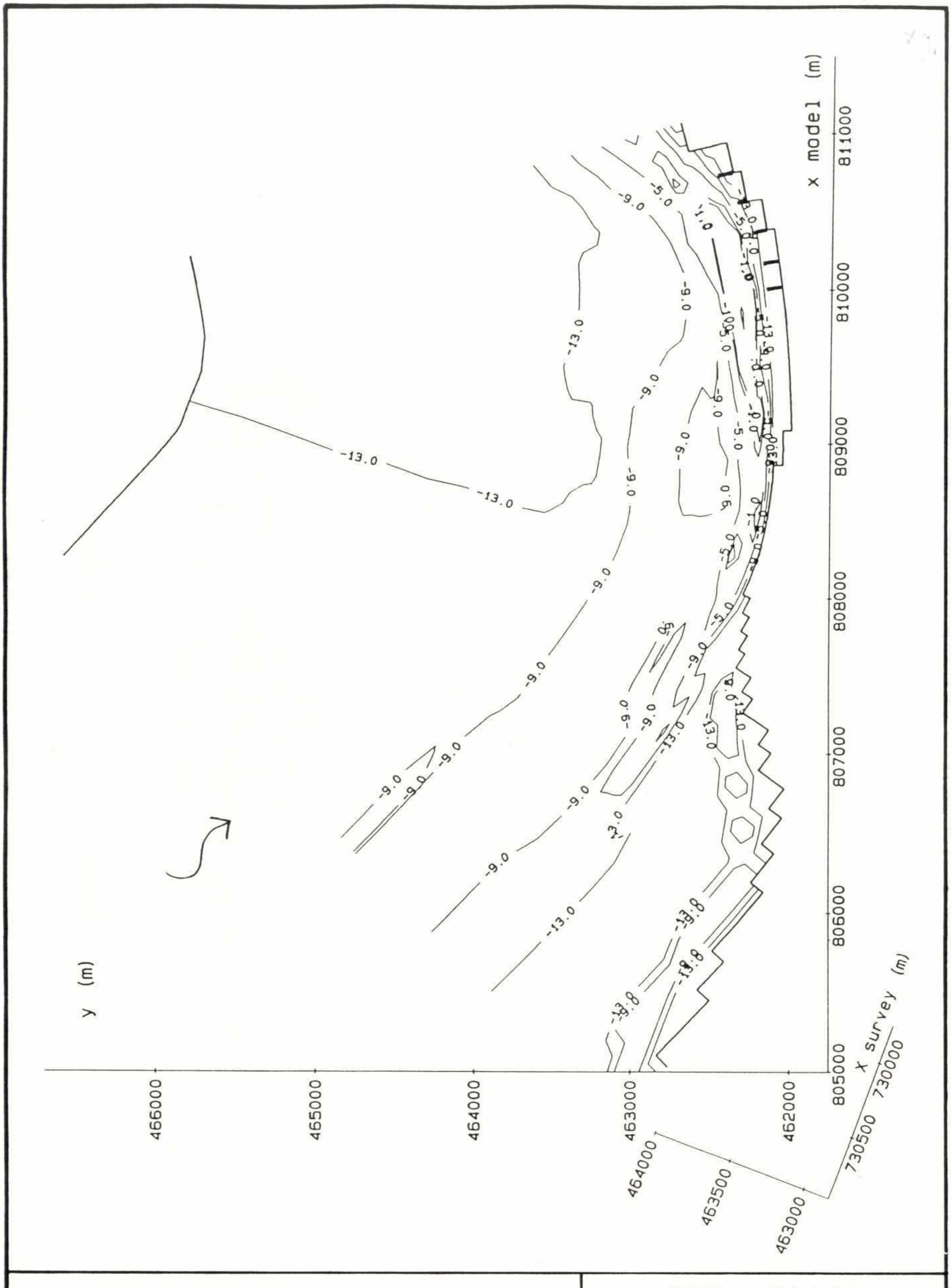
Tr = 100 YEARS – WATER LEVEL ISOLINES(+m PWD)

FAP – 21/22

BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT

FINAL REPORT

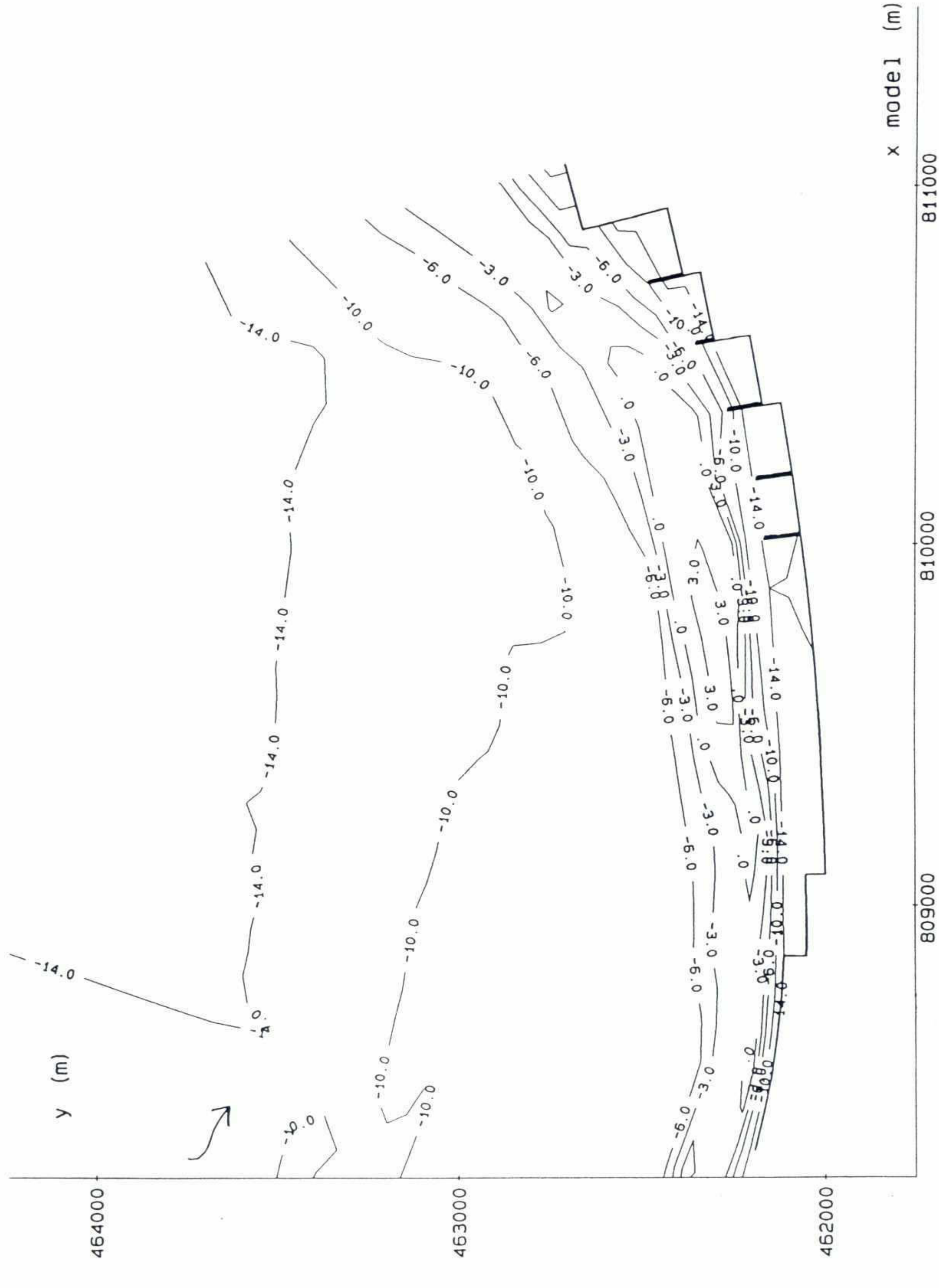
FIG. A.23-10



KAZIPUR MATH. MODEL
BANK LINE III'94 WITH PROTECTIONS
BED LEVEL ISOLINES [-(+m PWD)]

FAP - 21/22
BANK PROTECTION AND RIVER TRAINING/
(AFPM) PILOT PROJECT

FINAL REPORT | FIG. A.23-11



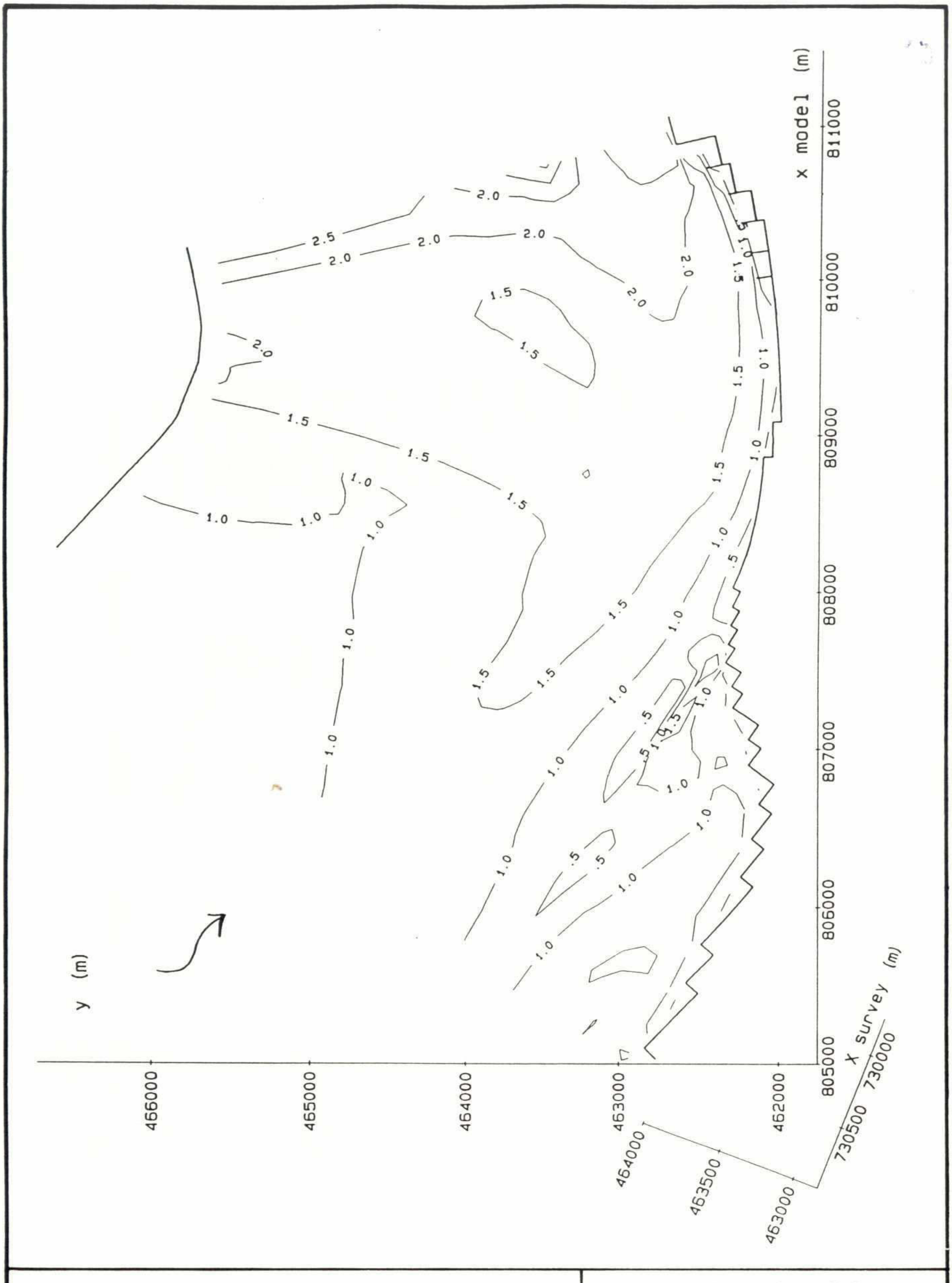
KAZIPUR MATH. MODEL
BANK LINE III'94 WITH PROTECTIONS
BED LEVEL ISOLINES [-(+m PWD)](DETAIL)

FAP - 21/22

BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT

FINAL REPORT

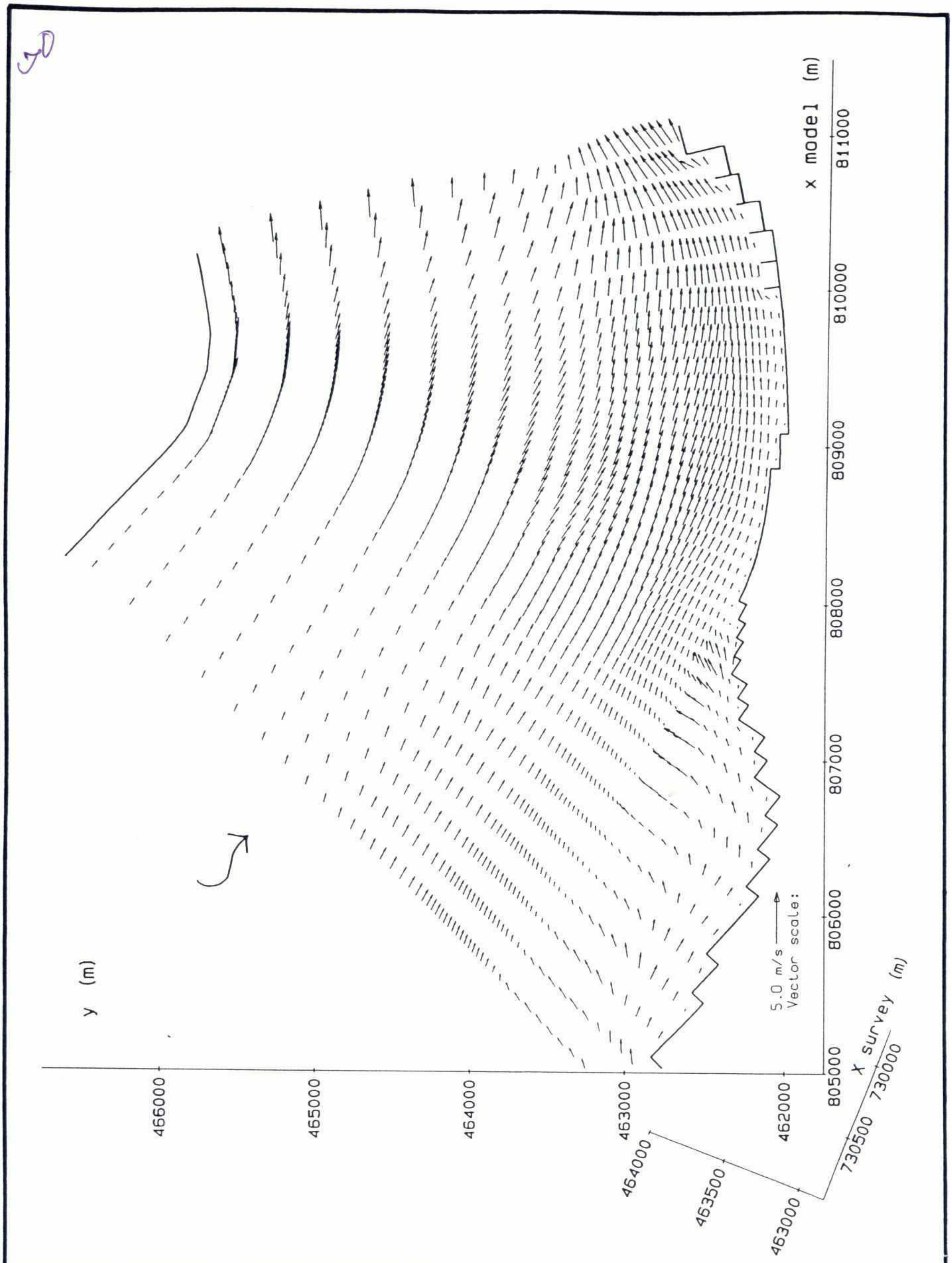
FIG. A. 23-12



KAZIPUR MATH. MODEL
BANK LINE III'94 WITH PROTECTIONS
Tr = 100 YEARS - VELOCITY ISOLINES (m/s)

FAP – 21/22
BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT

FINAL REPORT | FIG. A .23-13



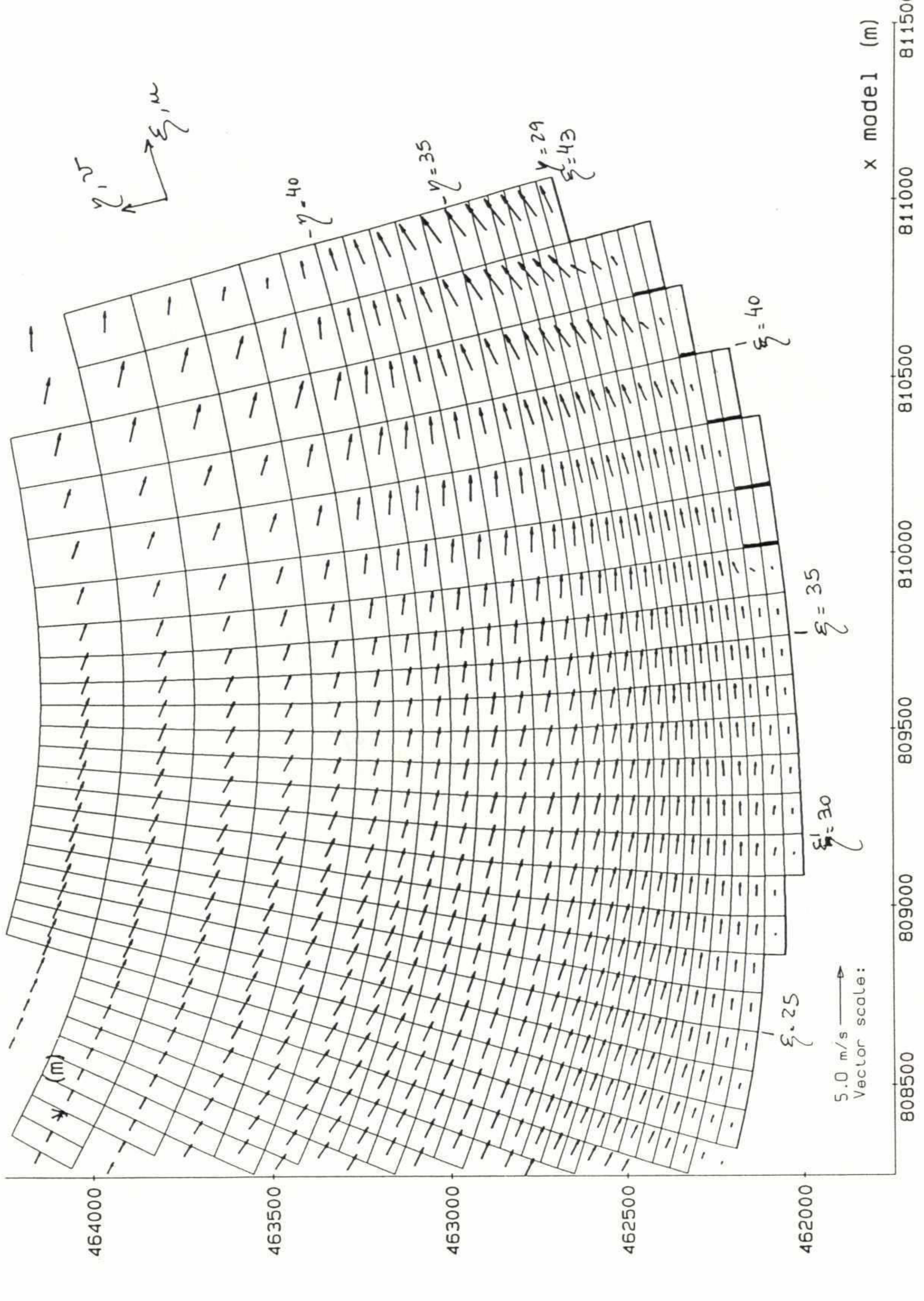
KAZIPUR MATH. MODEL
BANK LINE III'94 WITH PROTECTIONS
Tr = 100 YEARS - FLOW FIELD

FAP – 21/22

BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT

FINAL REPORT

FIG. A.23-14



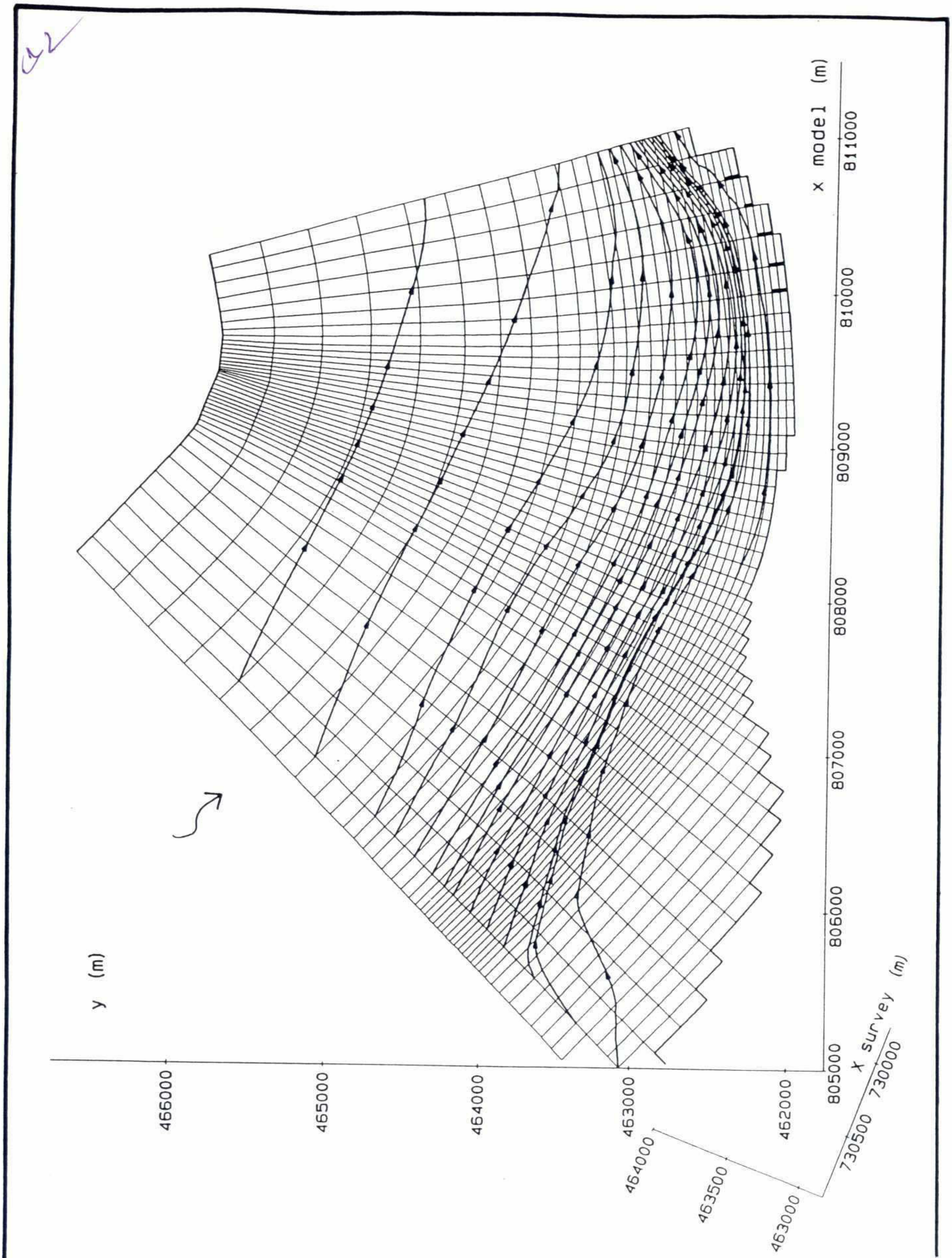
KAZIPUR MATH. MODEL
BANK LINE III'94 WITH PROTECTIONS
FLOW FIELD (DETAIL)

FAP – 21/22

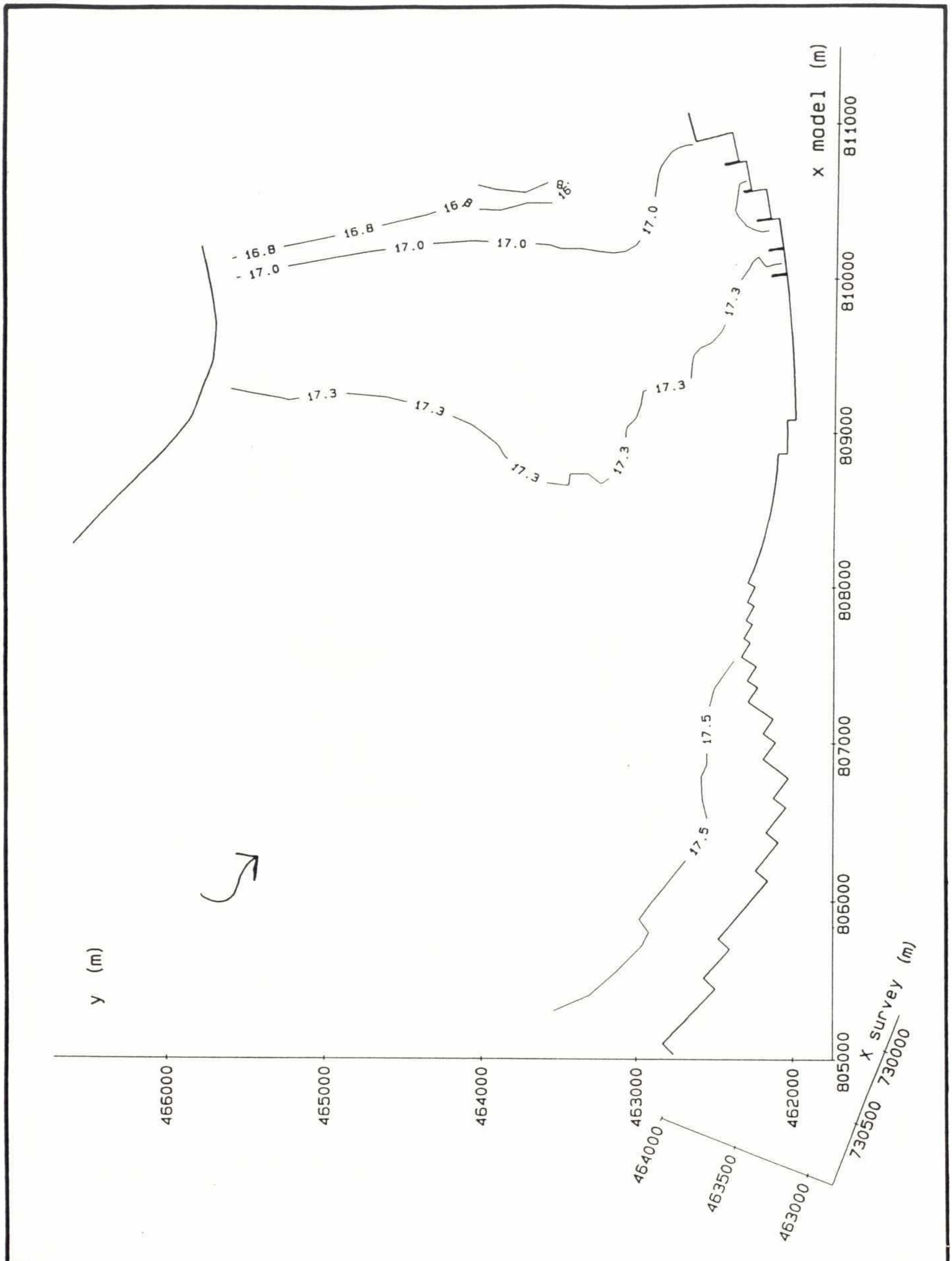
BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT

FINAL REPORT

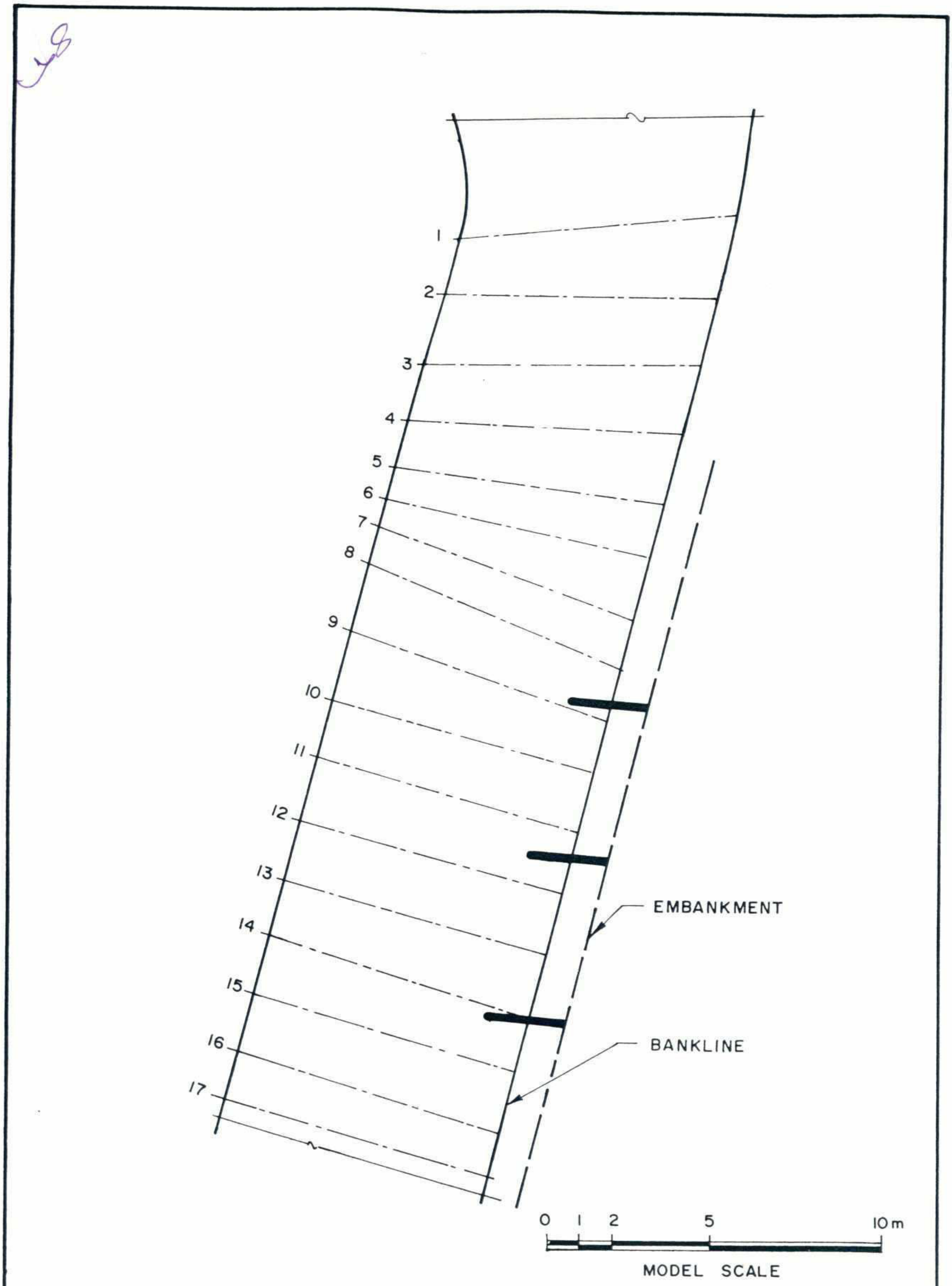
FIG. A. 23-15



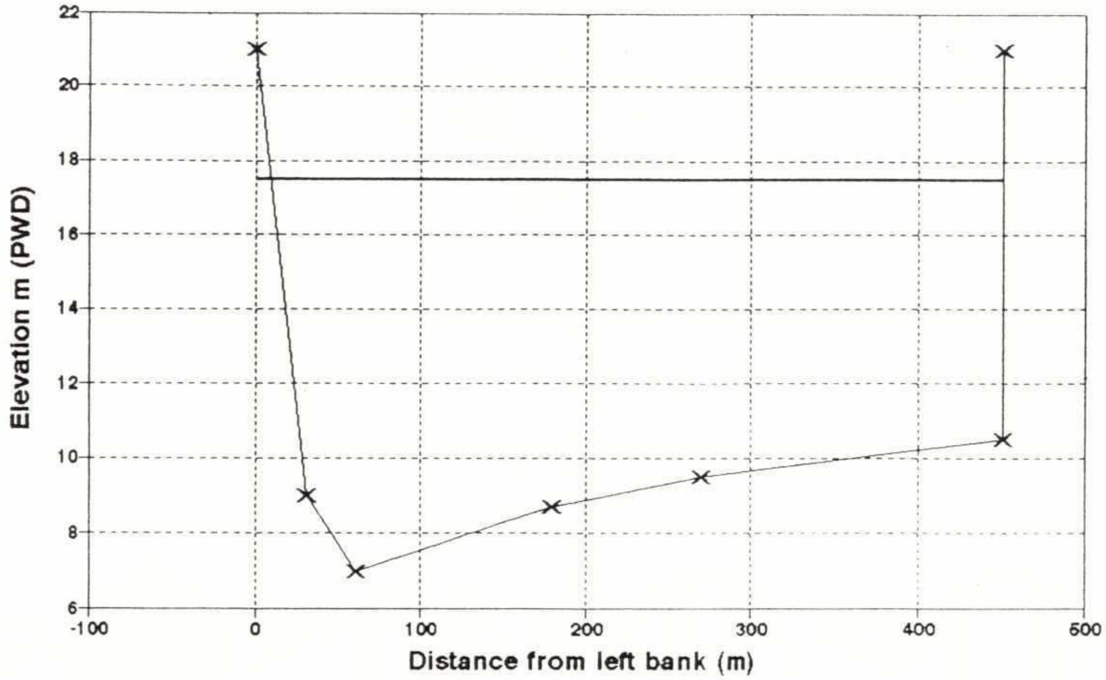
KAZIPUR MATH. MODEL BANK LINE III'94 WITH PROTECTIONS Tr = 100 YEARS -STREAM LINES	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT FINAL REPORT FIG. A.23-16



KAZIPUR MATH. MODEL BANK LINE III'94 WITH PROTECTIONS Tr = 100 YEARS – WATER LEVEL ISOLINES (+ m PWD)	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-17



SARIAKANDI MODEL LAY OUT PLAN OF TEST: T 20	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-18

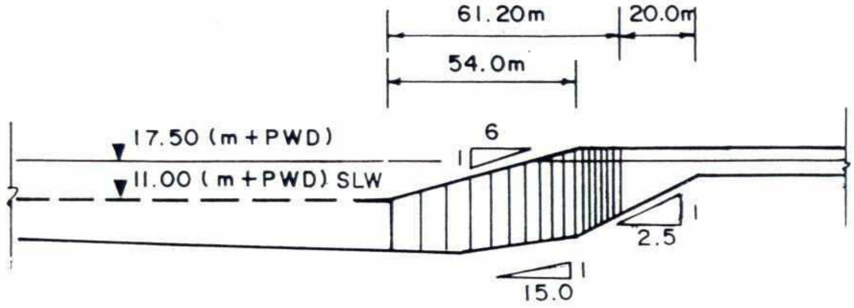


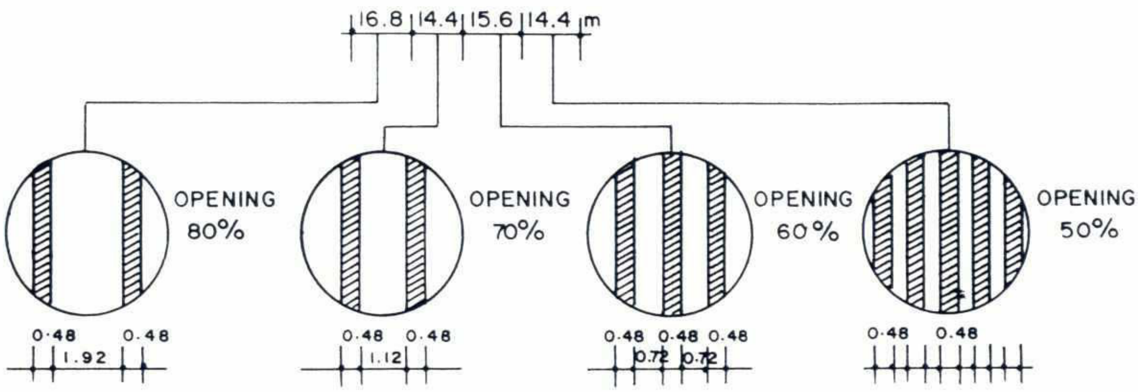
LEGEND

BED ELEVATION

WATER LEVEL

SARIAKANDI MODEL CROSS — SECTION TEST: T 20	FAP — 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-19





DETAILED ELEVATION OF PILES

SARIAKANDI MODEL PERMEABLE GROYNE TEST T-20	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A. 23 - 20

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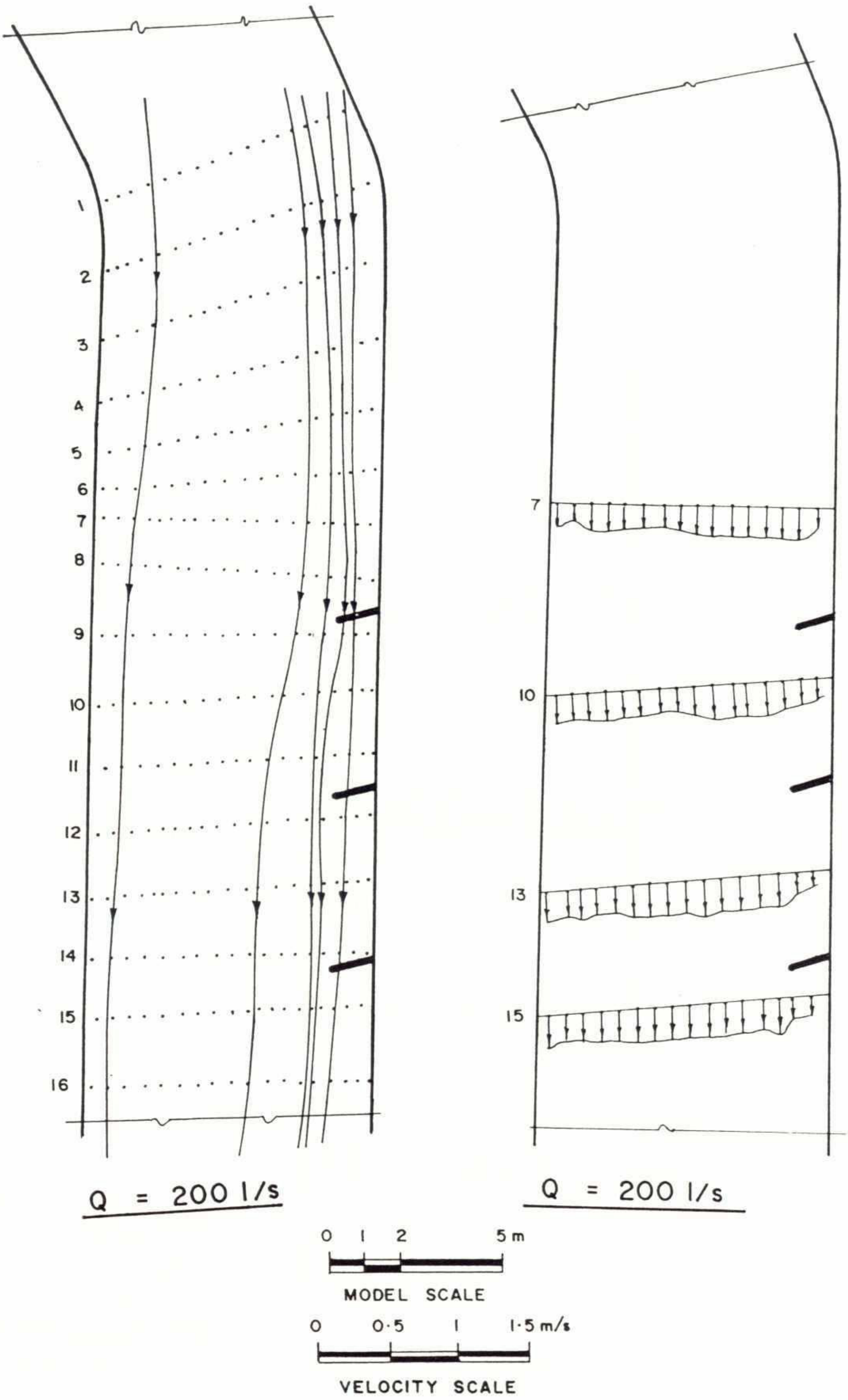
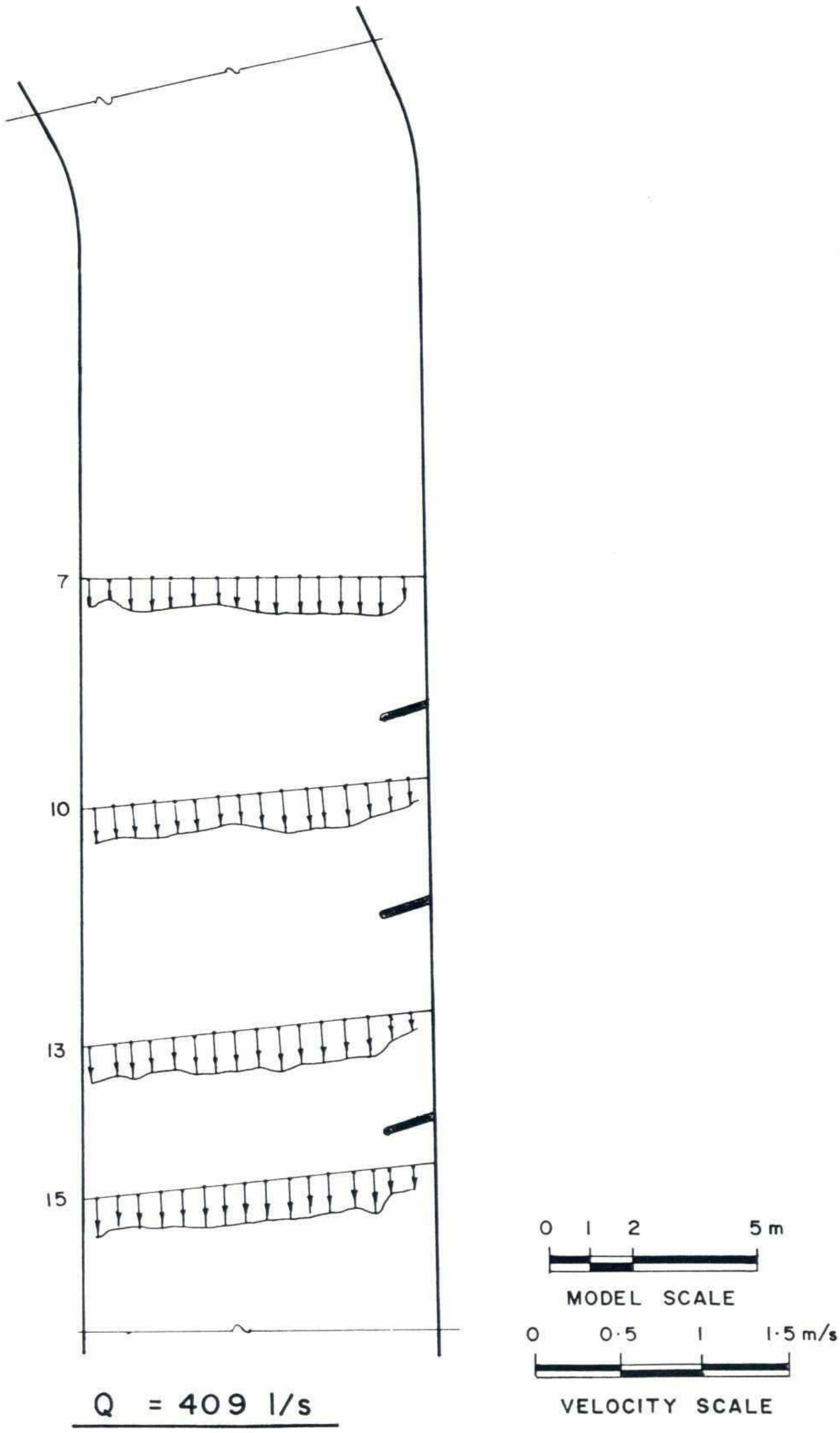
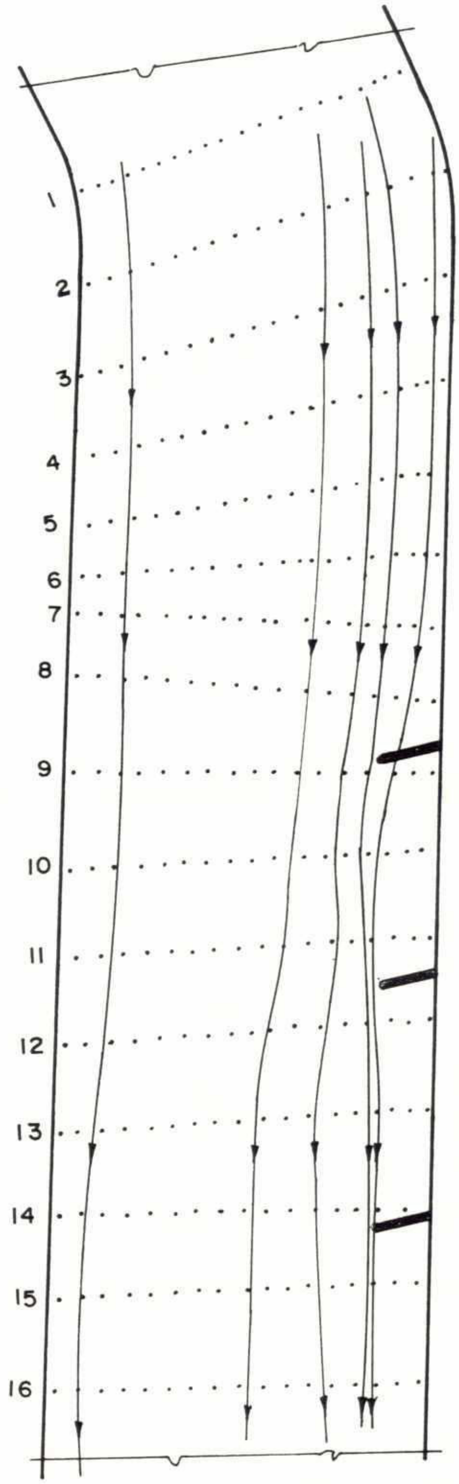


SARIAKANDI MODEL **FLOW LINES AND VELOCITY PROFILE** **TEST: T 20**	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A. 23 - 21



SARIAKANDI MODEL VELOCITY PROFILE TEST : T 20	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-22

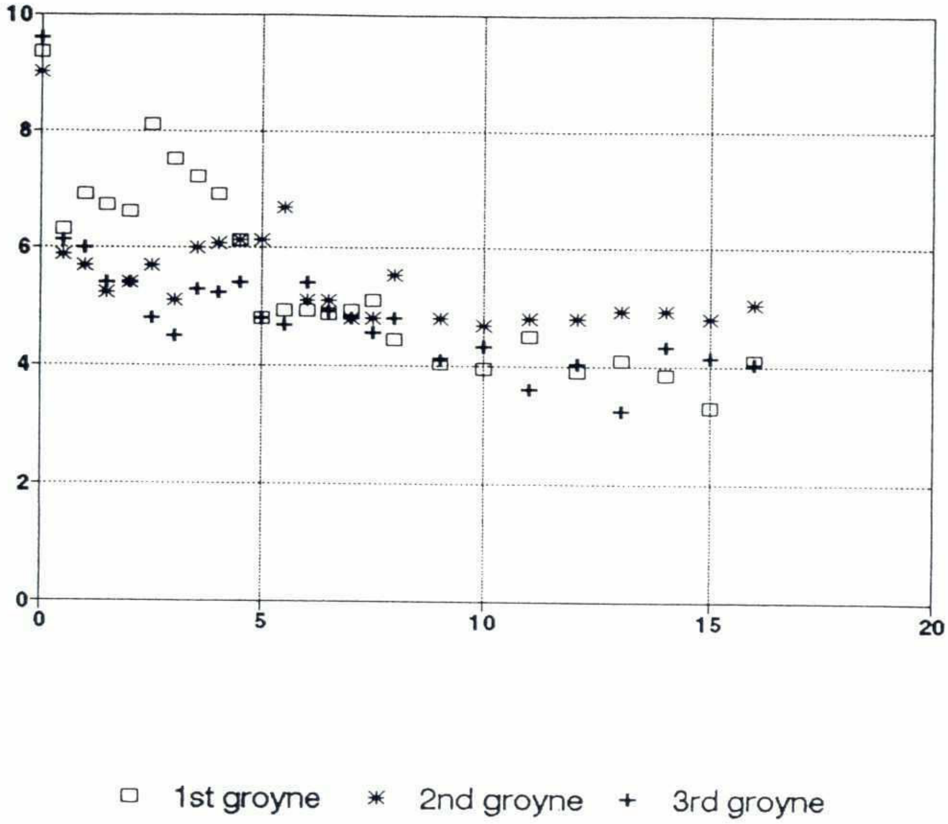


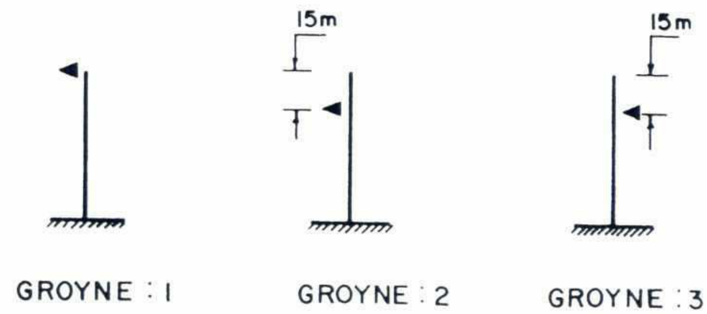
Q = 409 l/s

0 1 2 5 10m

MODEL SCALE

SARIAKANDI MODEL FLOW LINES TEST T-20	FAP - 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-23



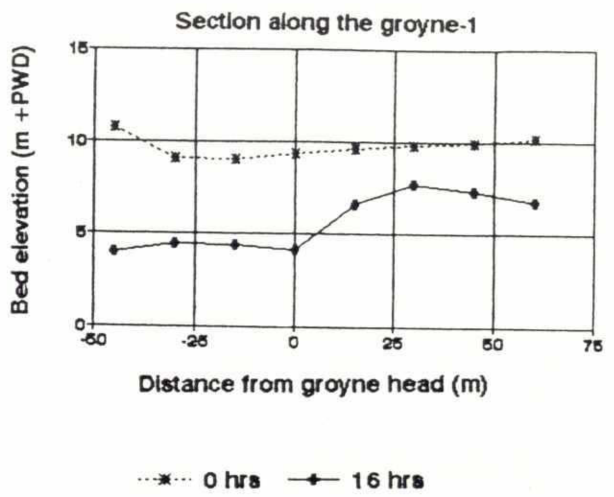


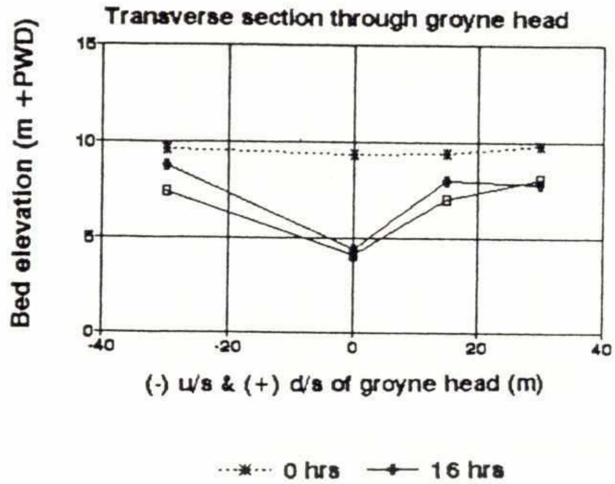
LEGEND

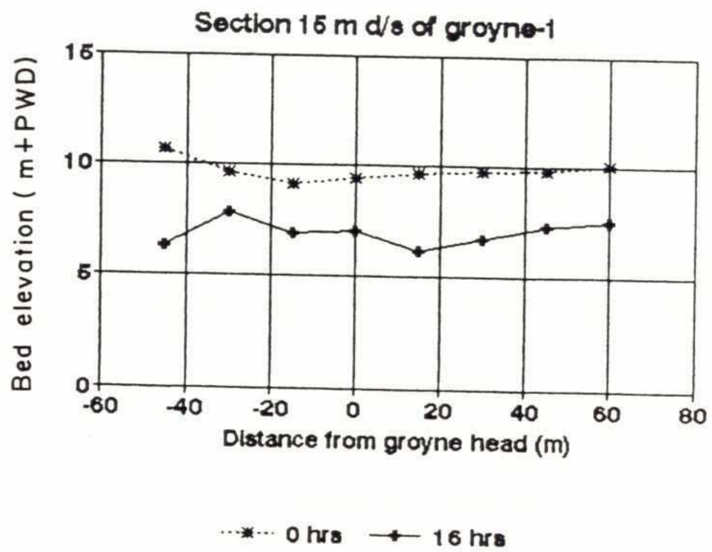
LOCATION OF
DEEPEST POINT ... ...

SARIAKANDI MODEL SCOUR VS TIME NEAR GROYNE **TEST T-20**	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT
	FINAL REPORT — FIG. A. 23-24

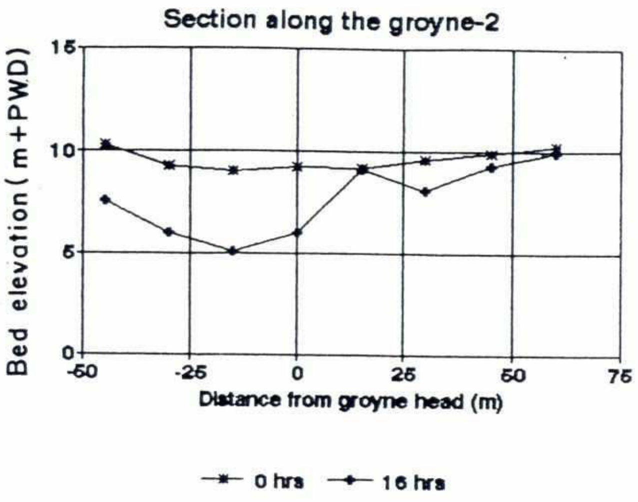
90

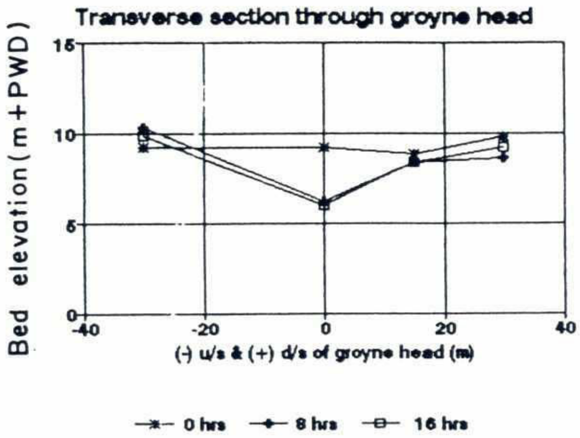


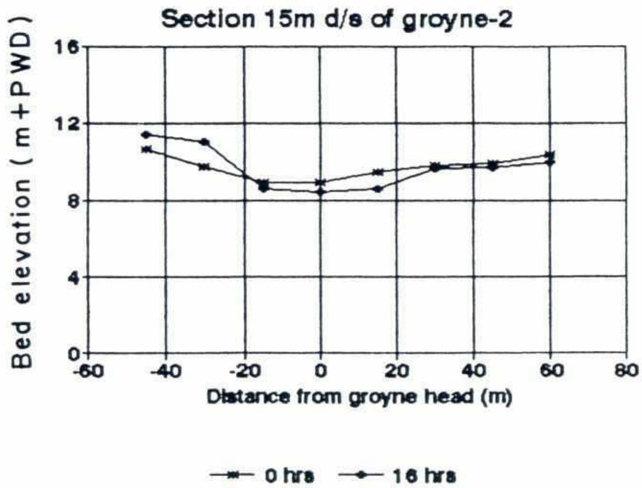




SARIAKANDI MODEL LONGITUDINAL AND CROSS SECTION OF THE SCOUR HOLE NEAR GROYNE I **TEST T-20**	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT FINAL REPORT — FIG. A.23-25

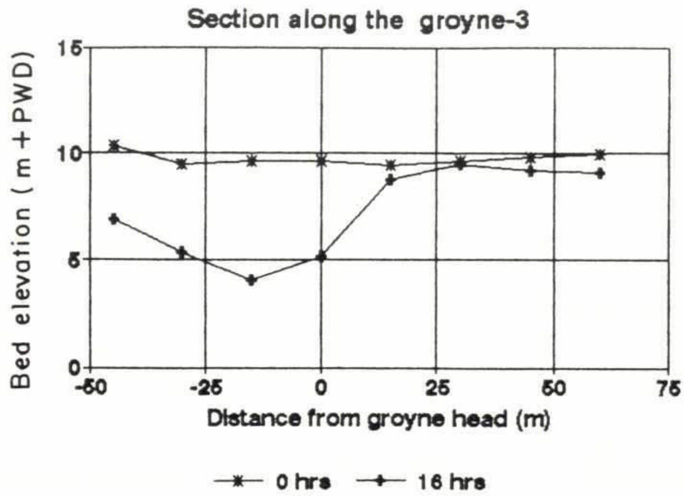


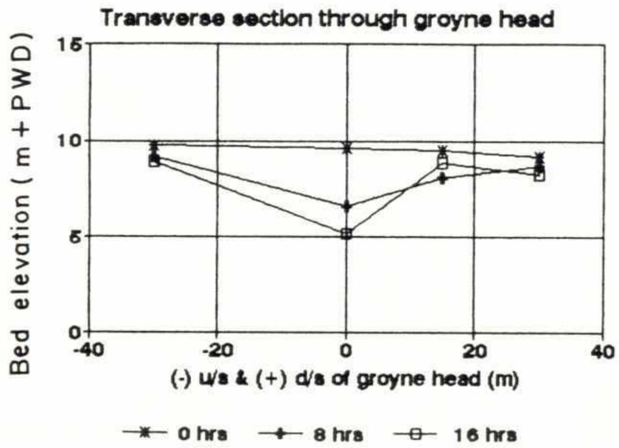


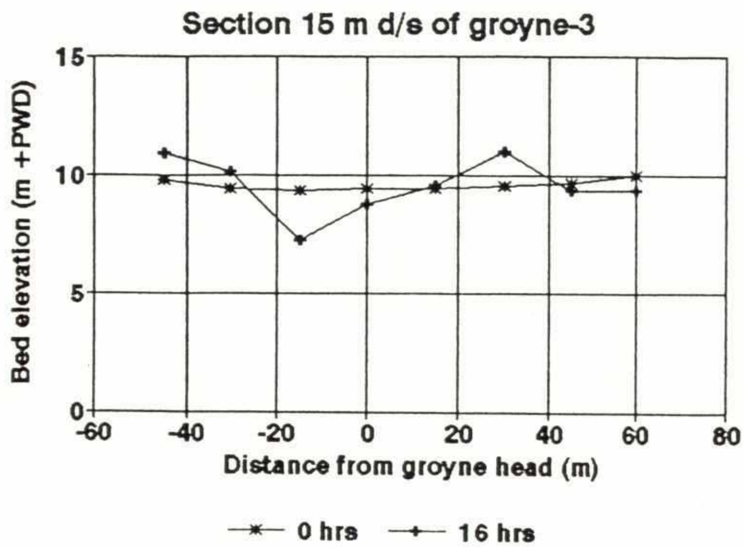


SARIAKANDI MODEL LONGITUDINAL AND CROSS SECTION OF THE SCOUR HOLE NEAR GROYNE 2 **TEST T-20**	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT FINAL REPORT — FIG. A.23– 26

96

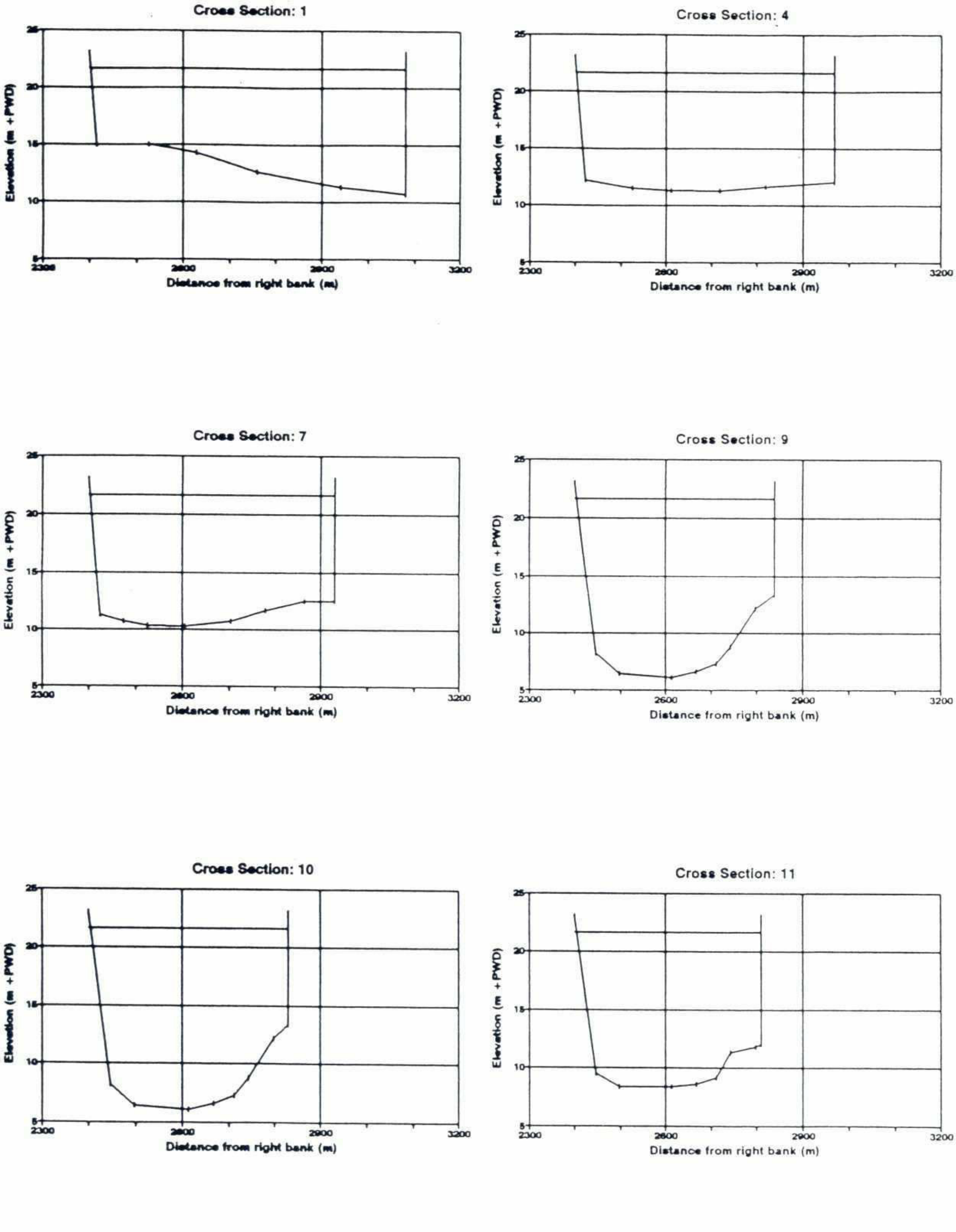






SARIAKANDI MODEL LONGITUDINAL AND CROSS SECTION OF THE SCOUR HOLE NEAR GROYNE 3 TEST T - 20	FAP - 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A. 23 - 27

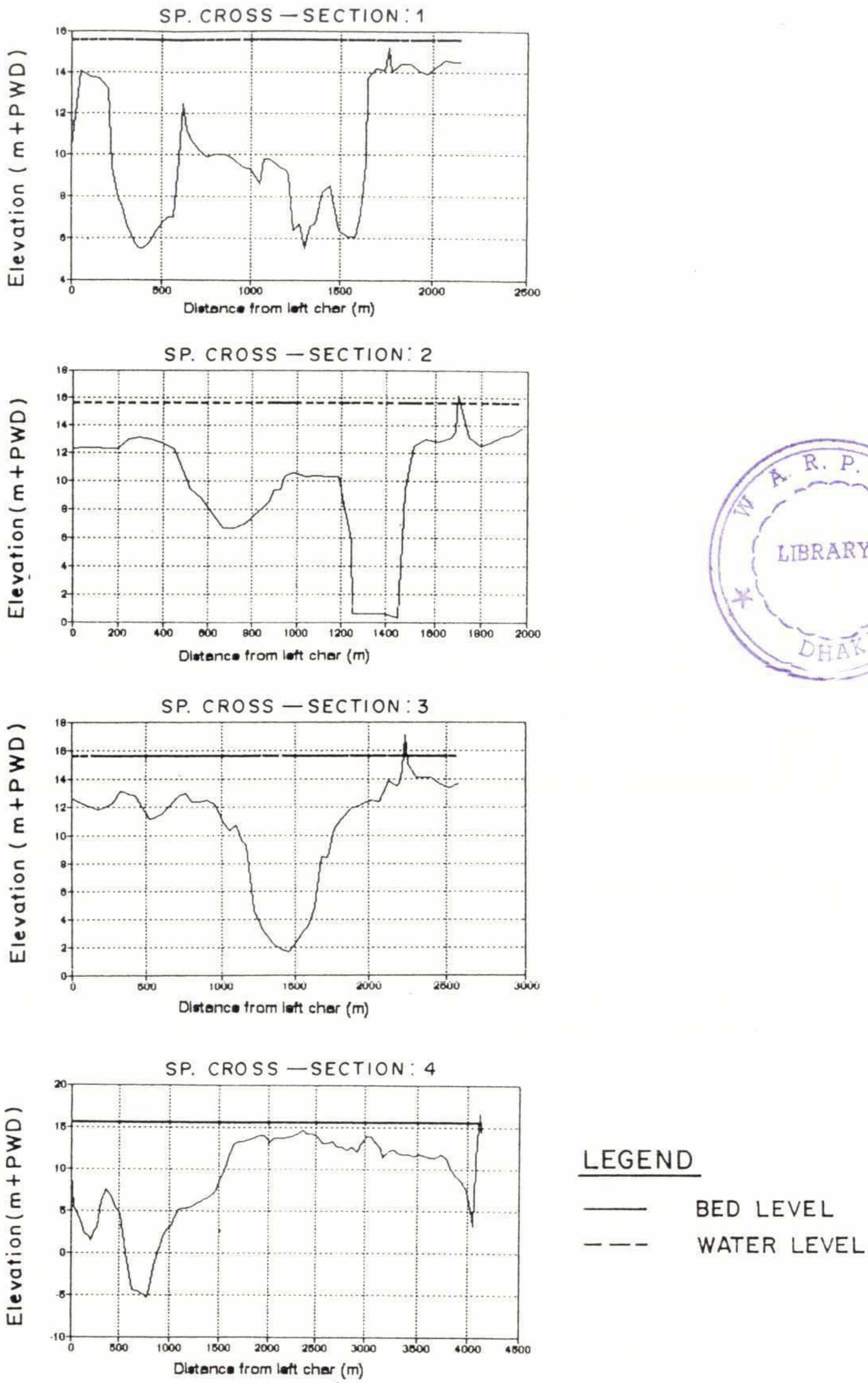
98



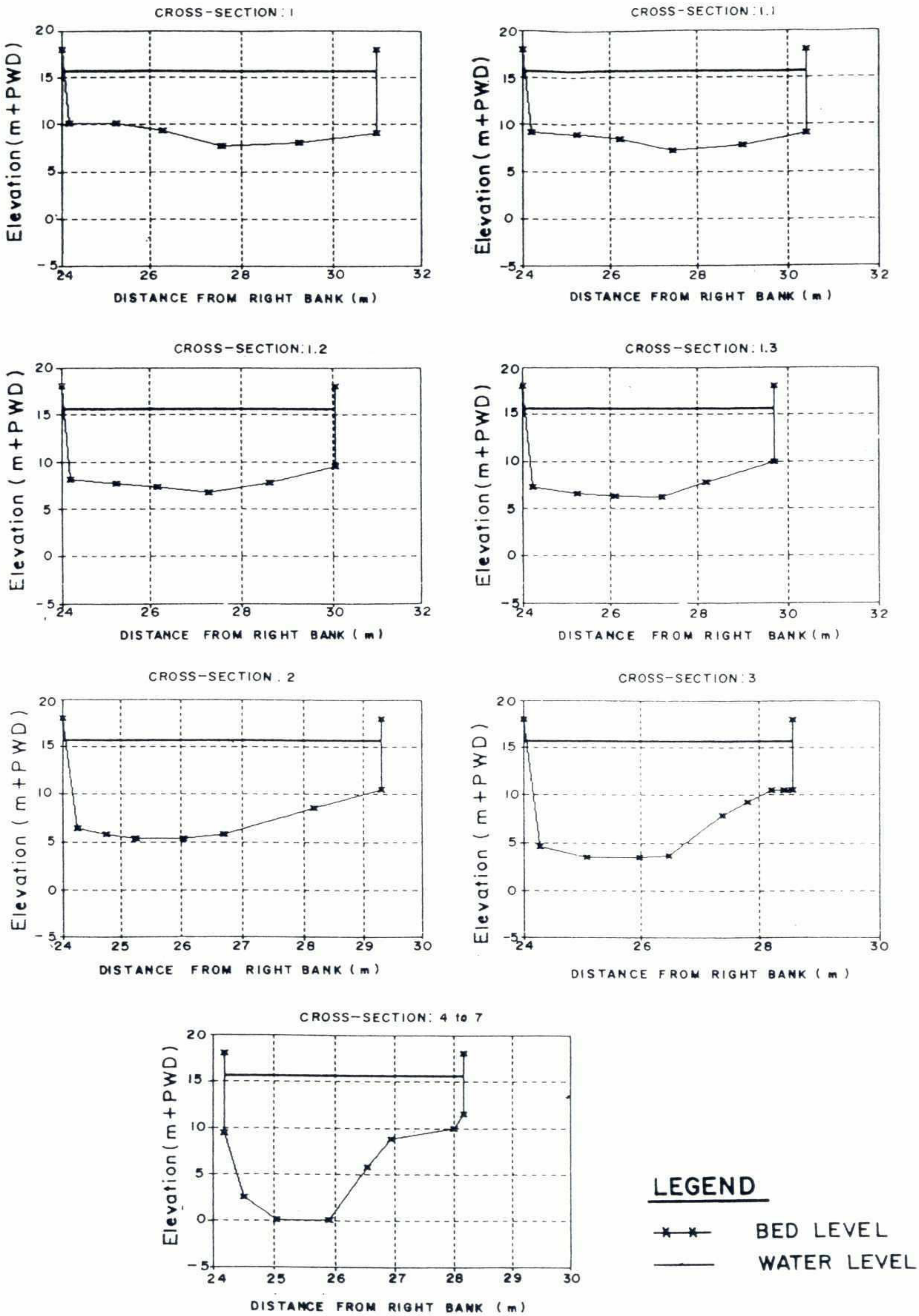
KAMARJANI MODEL
TYPICAL CROSS SECTION
TEST T 11

FAP – 21/22
BANK PROTECTION AND RIVER TRAINING/
(AFPM) PILOT PROJECT

FINAL REPORT | FIG. A.23 – 28

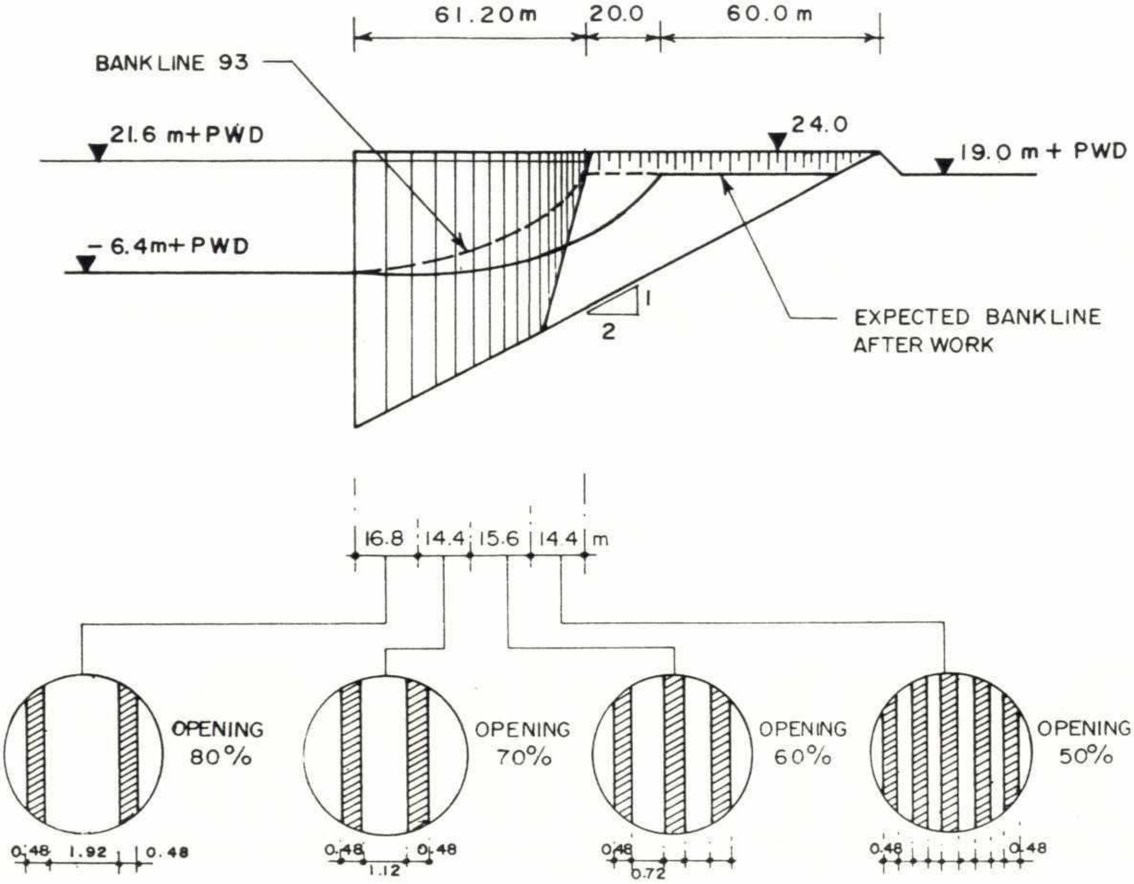


KAZIPUR SITE CROSS-SECTIONS SURVEYED IN NOVEMBER 1992	FAP - 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A. 23-29



KAZIPUR MODEL **TYPICAL CROSS SECTION** **TEST T 21**	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT
	FINAL REPORT | **FIG.A.23-30**

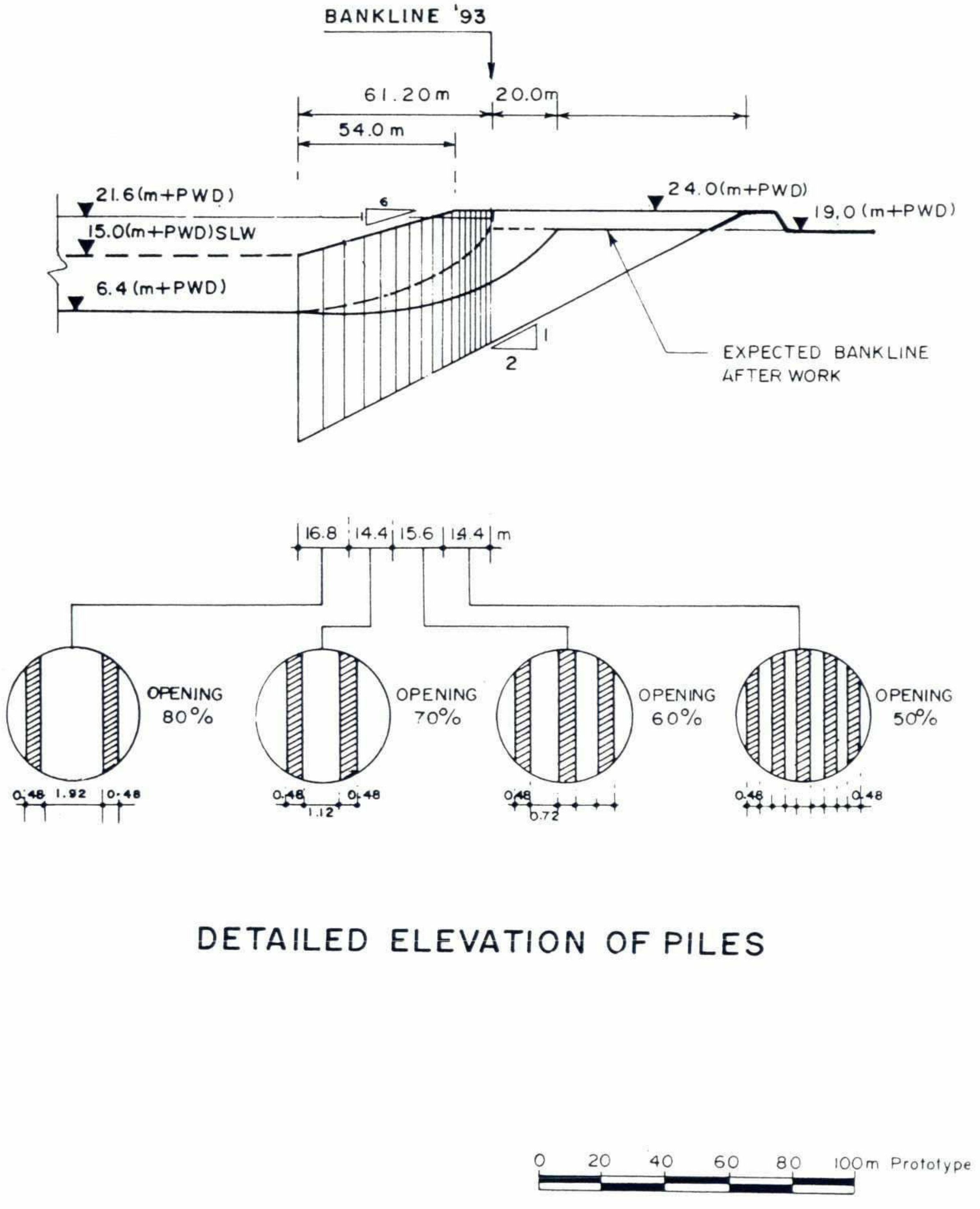
97



DETAILED ELEVATION OF PILES

KAMARJANI MODEL TEST T-10	FAP - 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-31

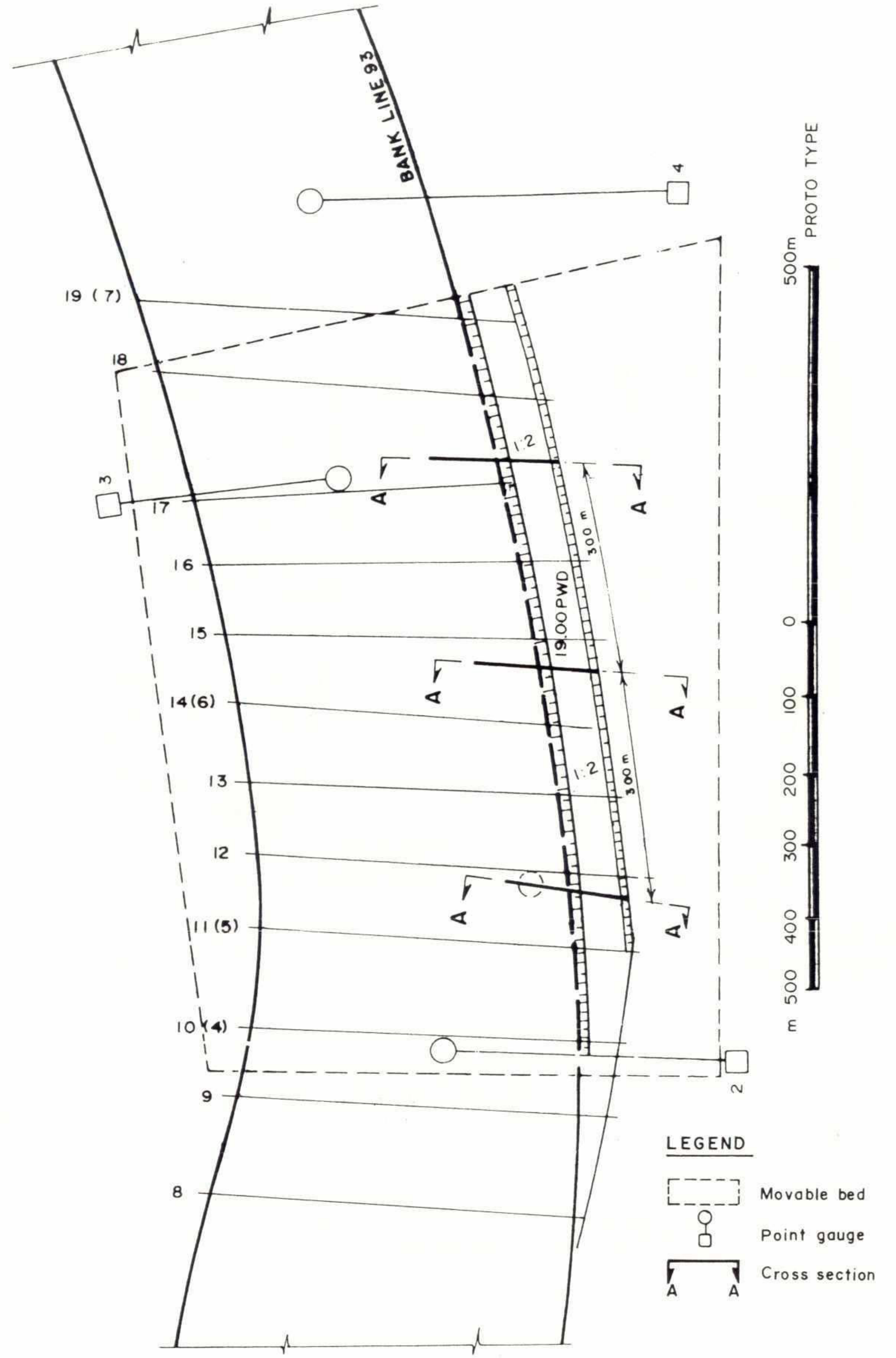
98



DETAILED ELEVATION OF PILES

GROYNES IN T II KAMARJANI MODEL AND IN T 21 KAZIPUR MODEL	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT FINAL REPORT — FIG. A. 23 – 32

80

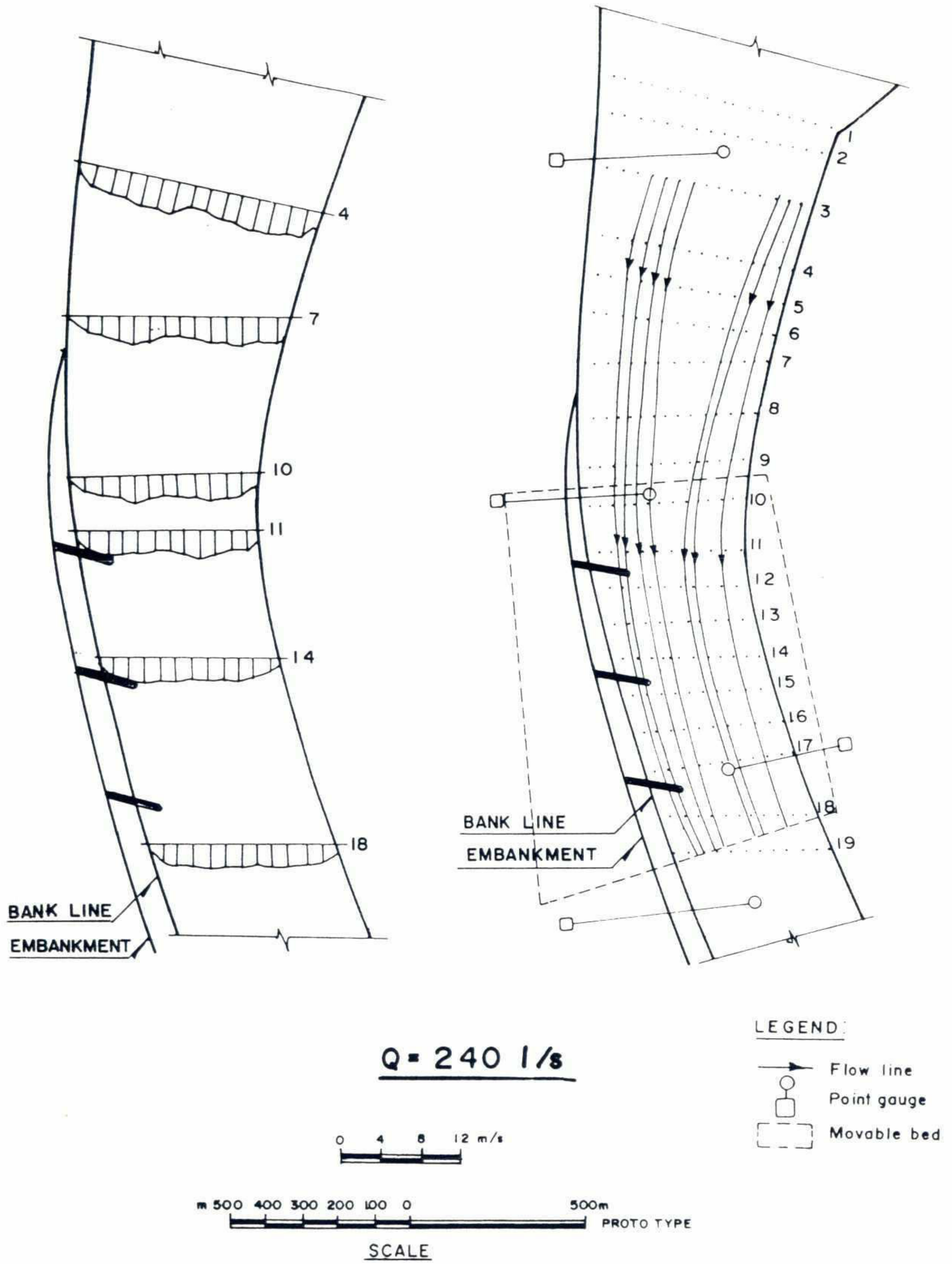


LAYOUT MODEL KAMARJANI
TEST T 11

FAP – 21/22
BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT

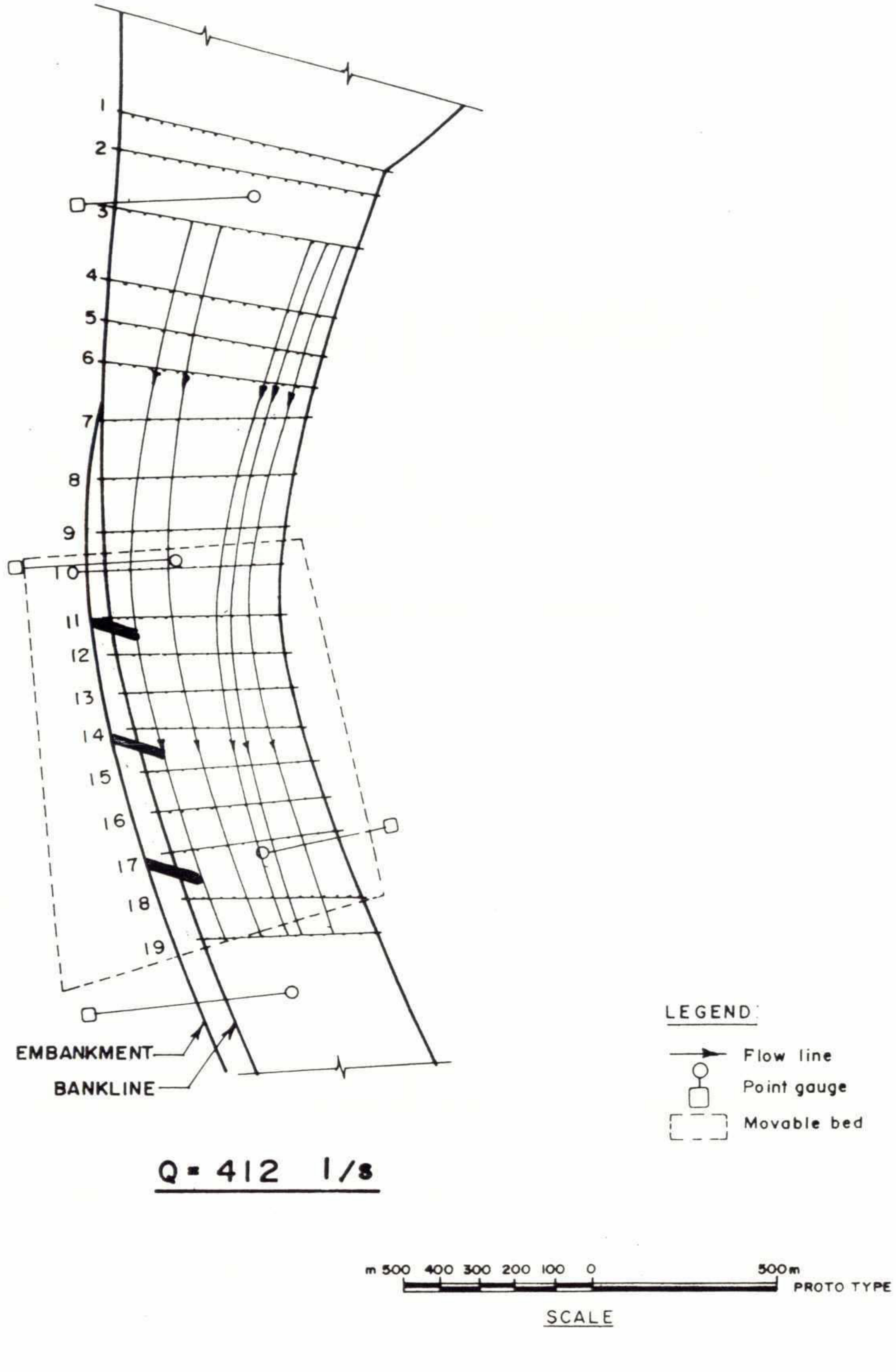
FINAL REPORT

FIG.A.23–33

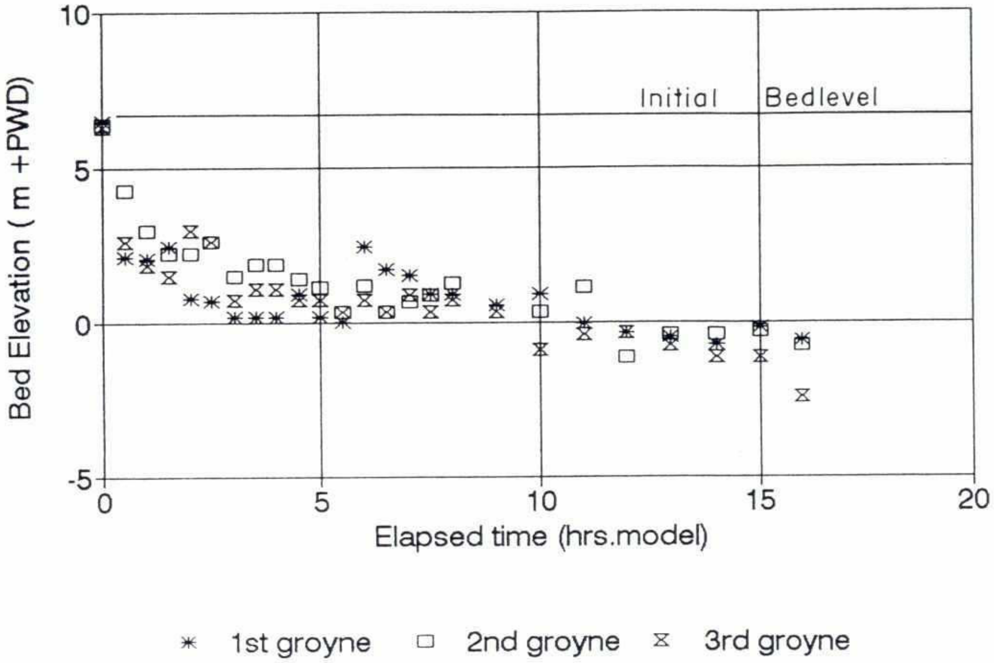


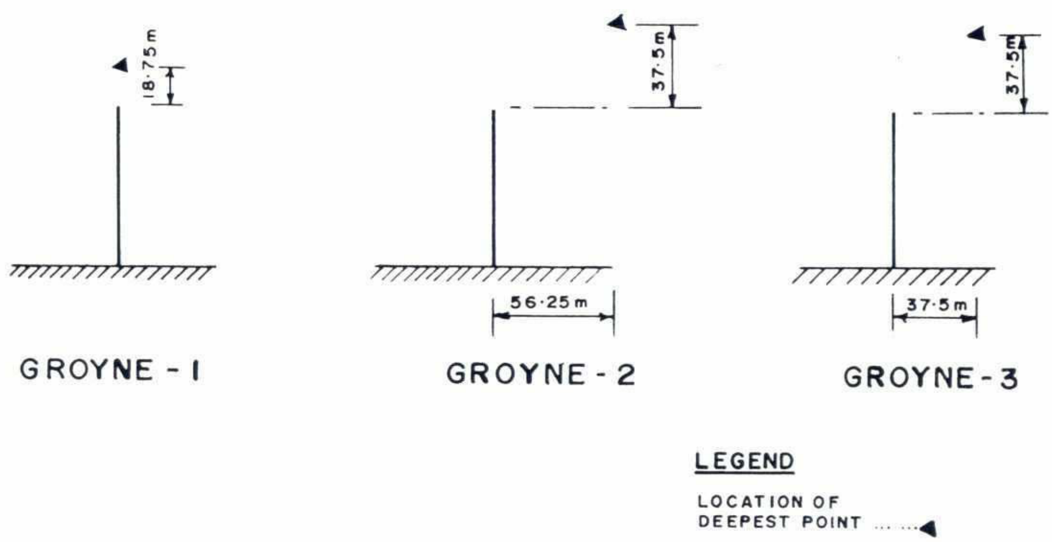
KAMARJANI MODEL **TEST T II** **FLOW LINE & VELOCITY PROFILE**	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT
	FINAL REPORT — FIG. A.23 – 34

80

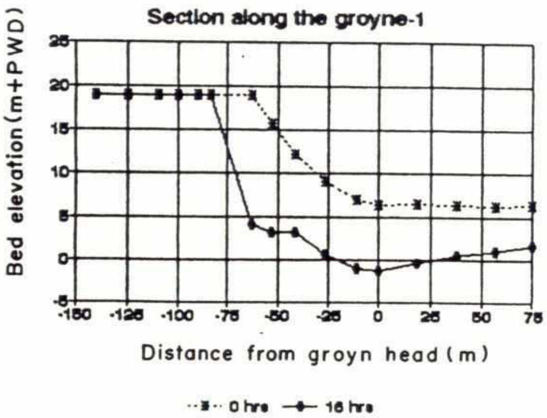


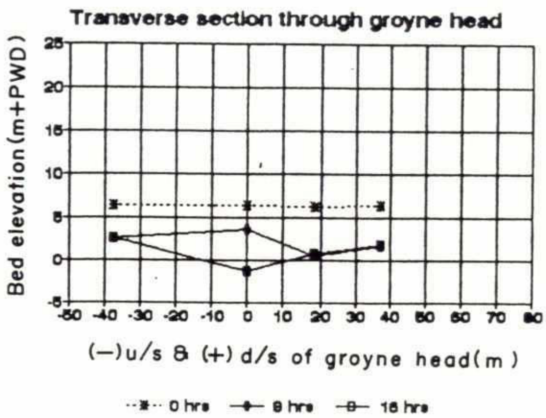
KAMARJANI MODEL TEST T 11 FLOW LINES	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG.A.23-35

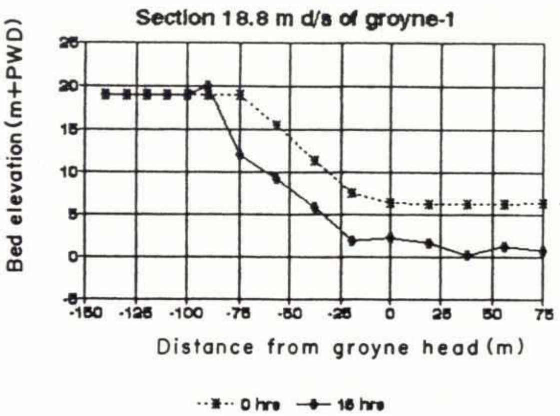




KAMARJANI MODEL DEEPEST POINT OF SCOUR HOLE TEST : T 11	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT
	FINAL REPORT / FIG.A.23– 36

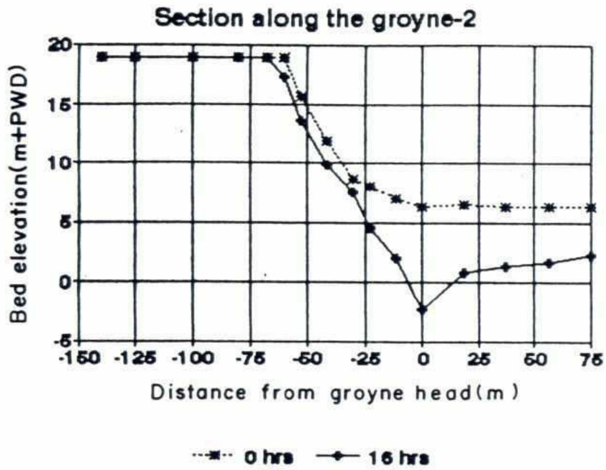


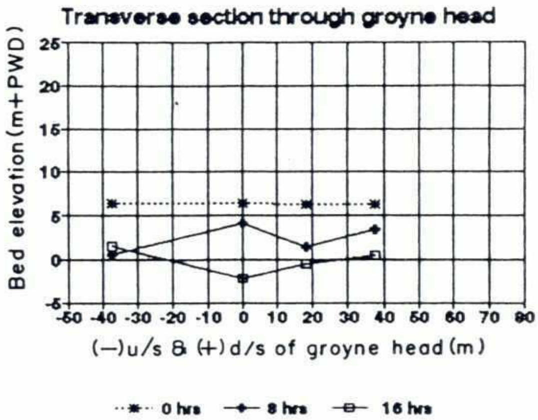


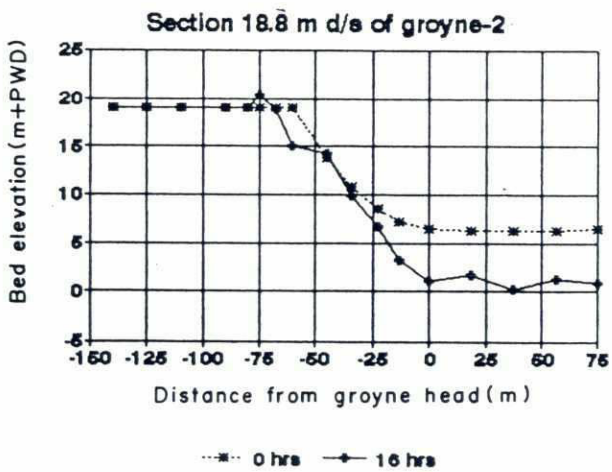


KAMARJANI MODEL TEST T 11 GROYNE NO. I LONGITUDINAL AND CROSS SECTION	FAP — 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT FINAL REPORT — FIG. A. 23-37

88

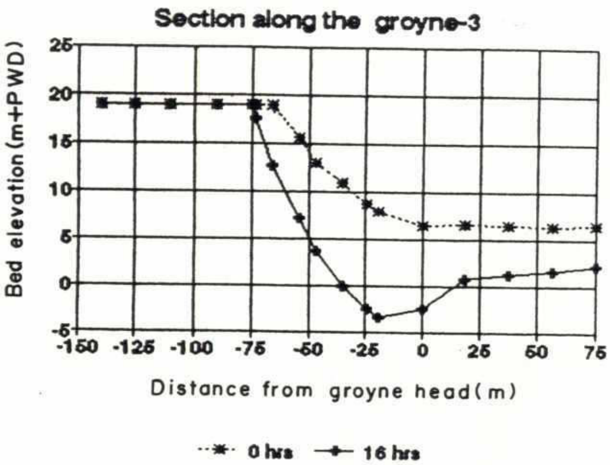


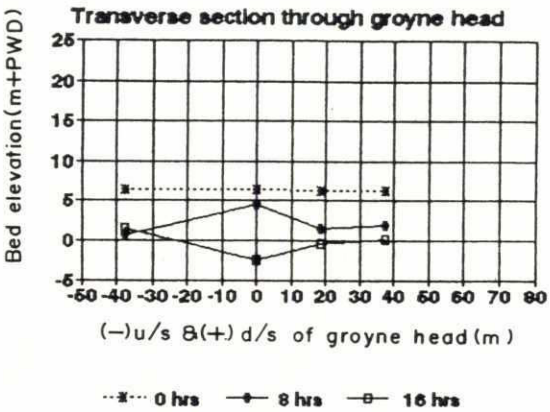


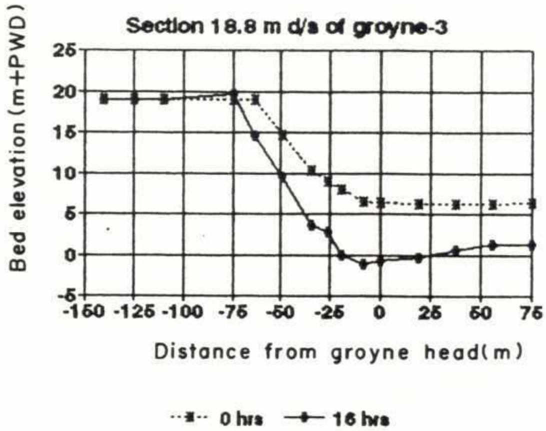


KAMARJANI MODEL **TEST T 11** **GROYNE NO. 2** **LONGITUDINAL AND CROSS SECTION**	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT FINAL REPORT — FIG.A.23–38

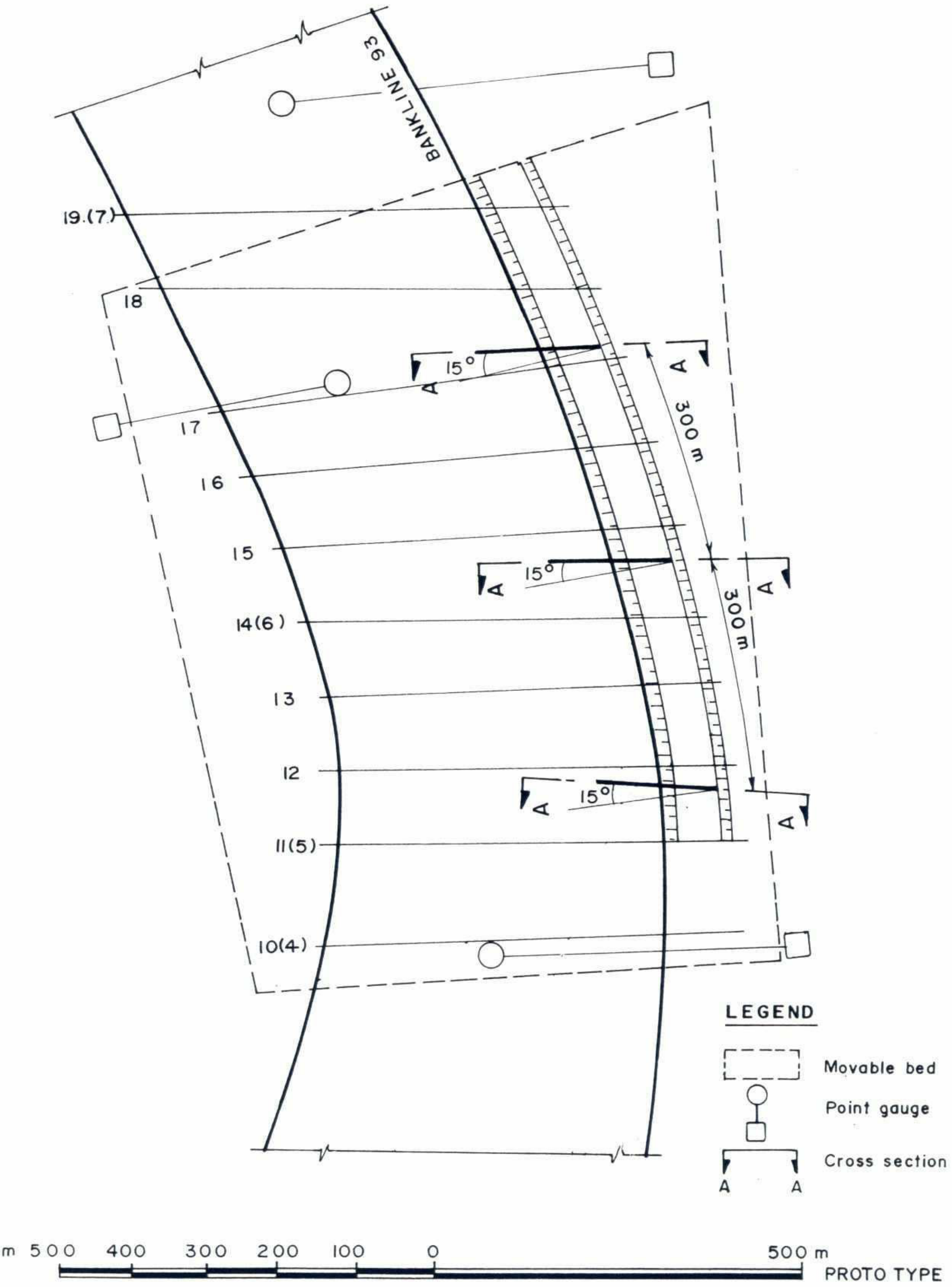
68





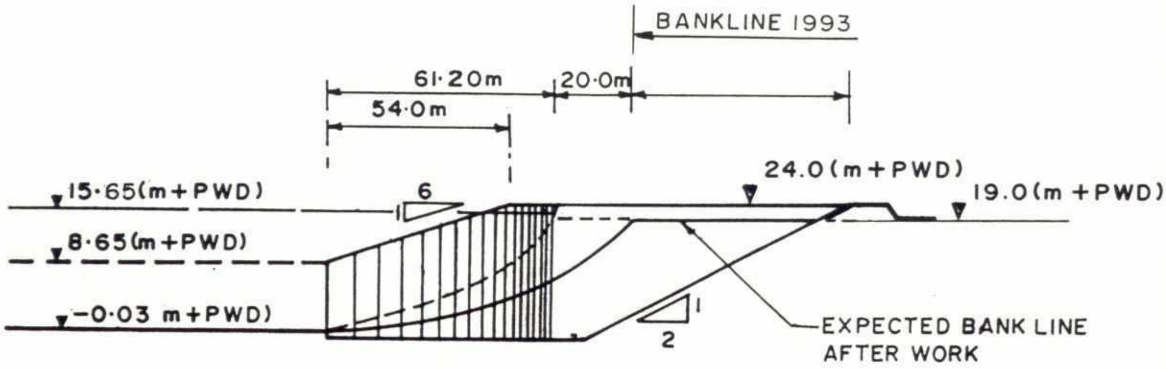


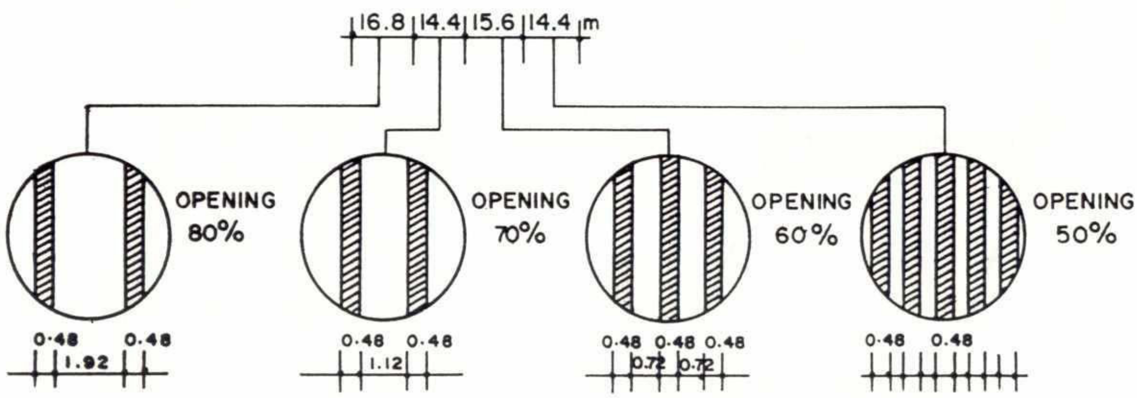
KAMARJANI MODEL TEST T 11 GROYNE NO. 3 LONGITUDINAL AND CROSS SECTION	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT
	FINAL REPORT | FIG. A.23-39



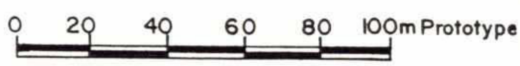
KAZIPUR MODEL TEST : T 21	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT
	FINAL REPORT | FIG.A.23–40

69

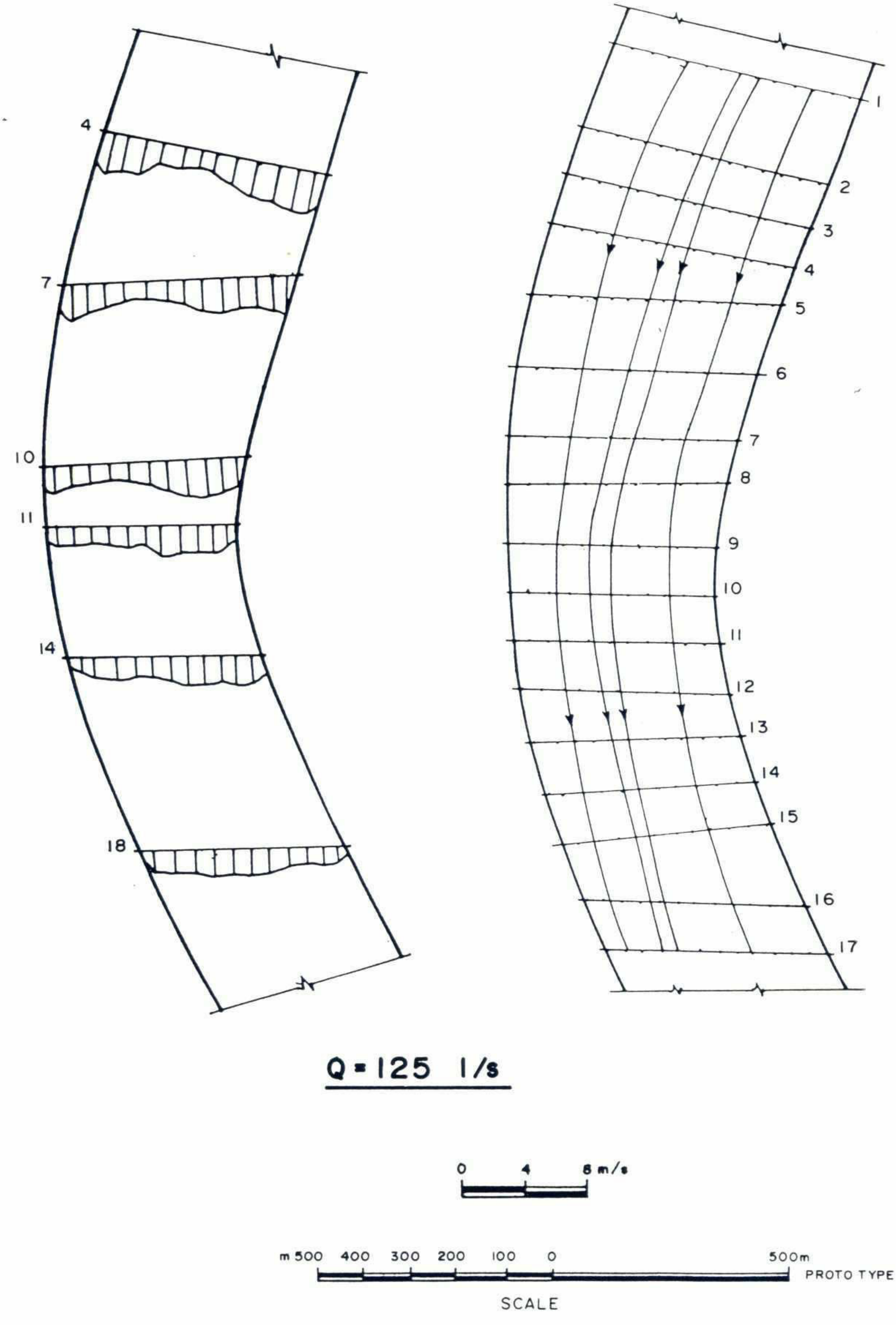




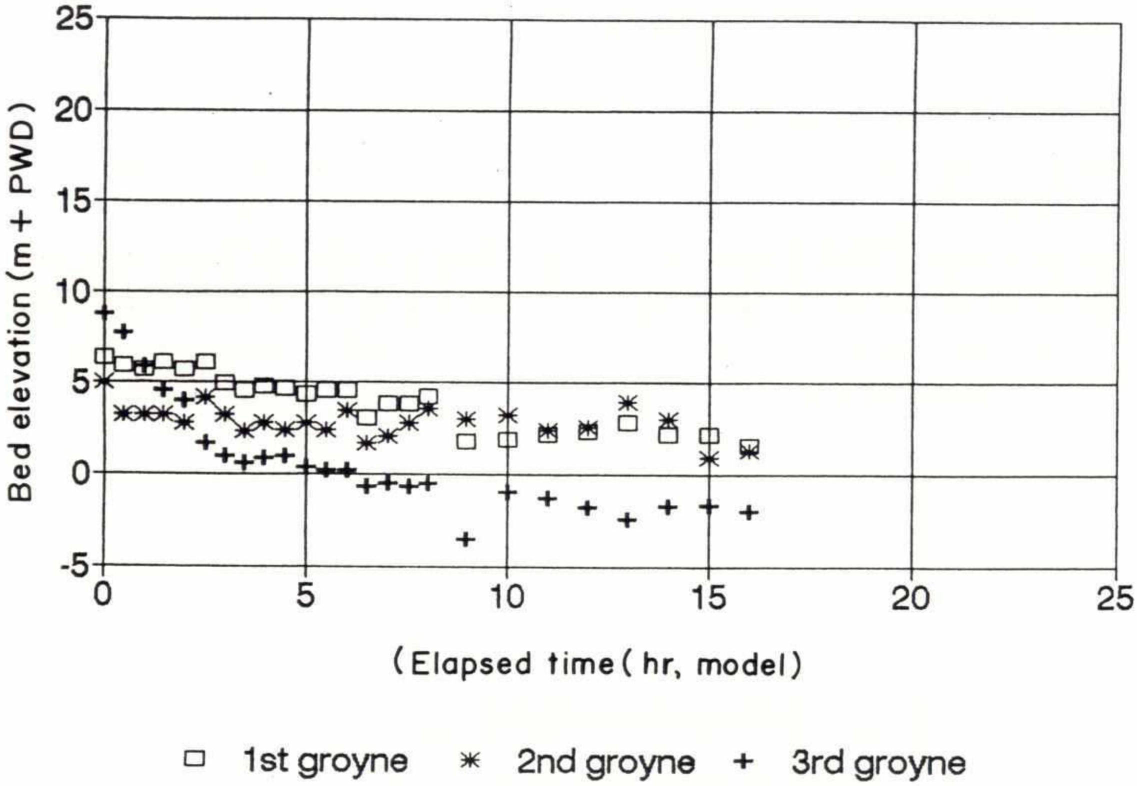
DETAILED ELEVATION OF PILES

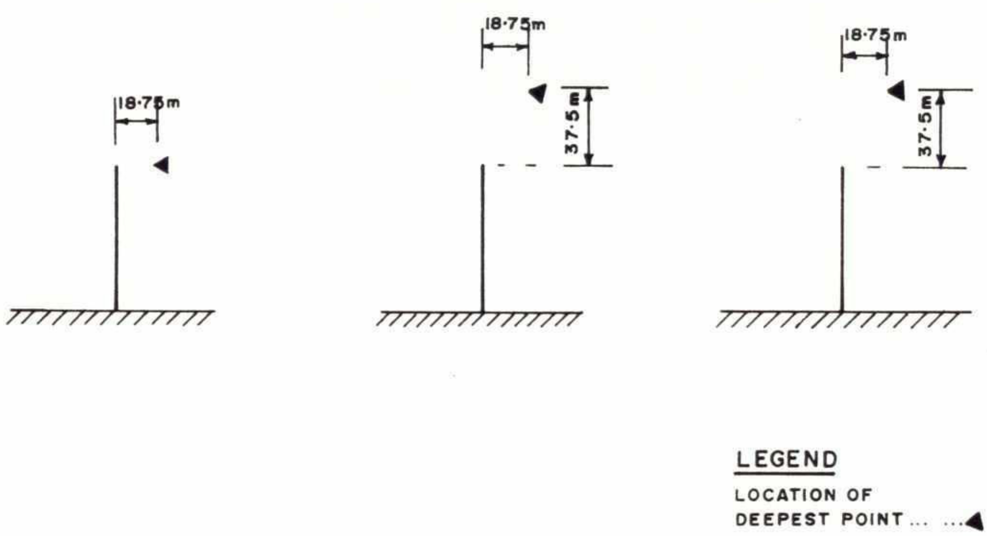


KAZIPUR MODEL **PERMEABLE GROYNE** **TEST T21**	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	**FIG. A.23-41**

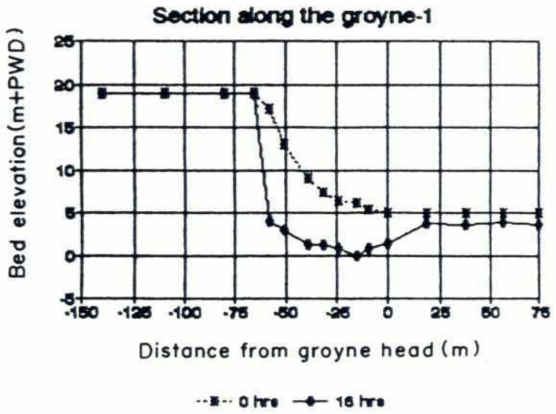


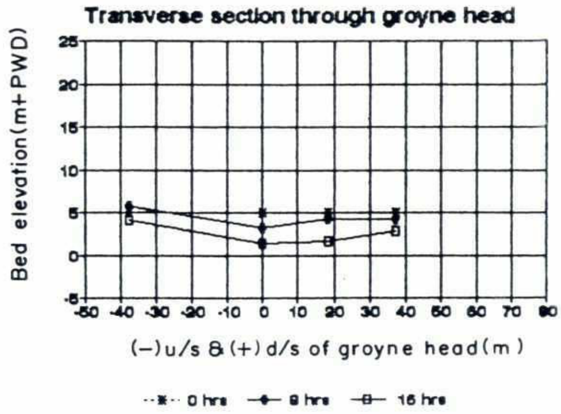
KAZIPUR MODEL **TEST T 21** **FLOW LINE & VELOCITY PROFILE**	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT
	FINAL REPORT | FIG. A. 23- 42

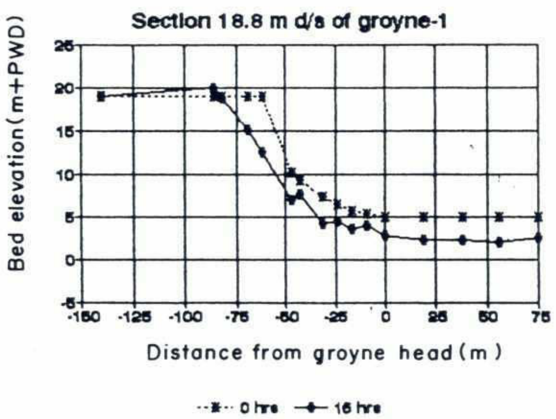




KAZIPUR MODEL DEEPEST POINT OF SCOUR HOLE TEST : T21	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT
	FINAL REPORT — FIG. A.23-43

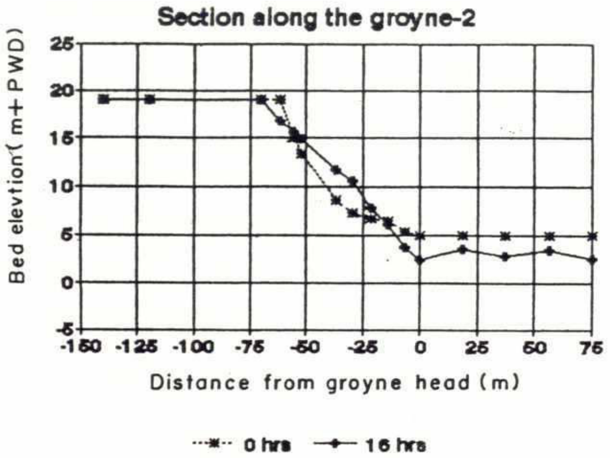


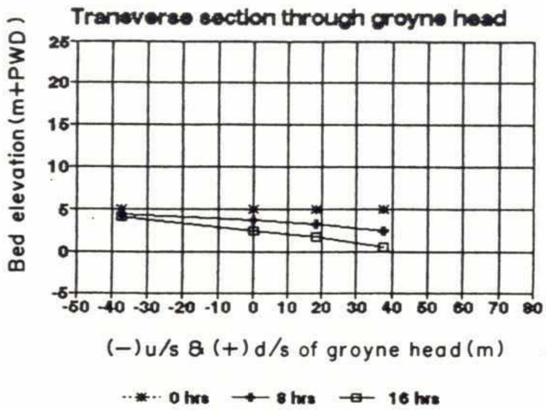


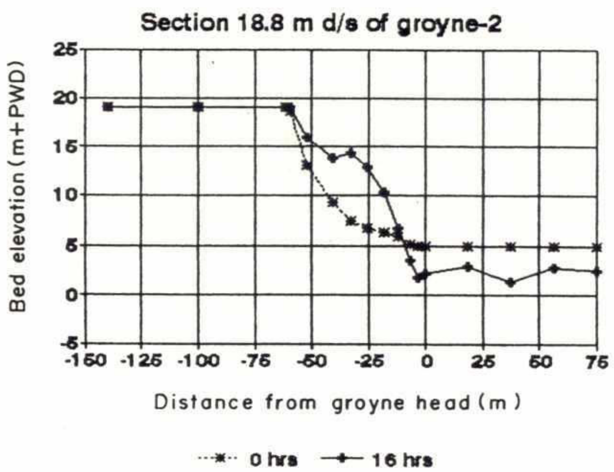


KAZIPUR MODEL **TEST T 21** **GROYNE NO. I** **LONGITUDINAL AND CROSS SECTION**	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT FINAL REPORT — FIG. A. 23 – 44

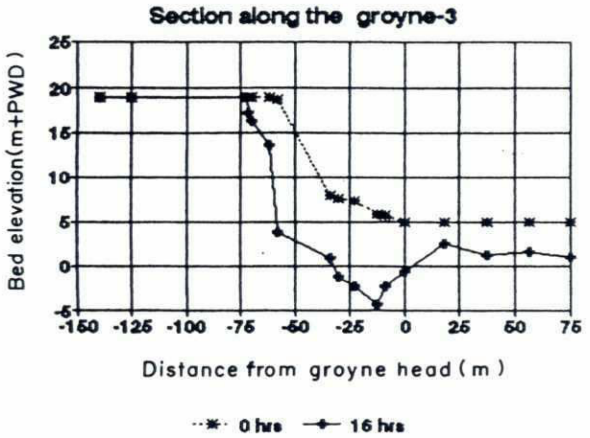
22

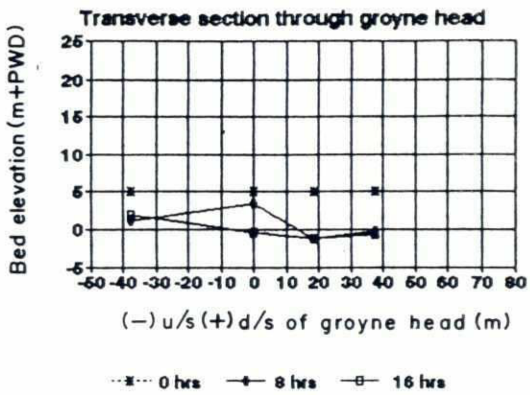


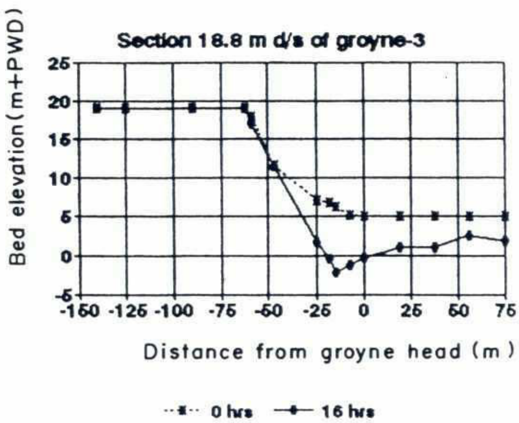




KAZIPUR MODEL **TEST T21** **GROYNE NO. 2** **LONGITUDINAL AND CROSS SECTION**	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT FINAL REPORT — FIG. A.23-45







KAZIPUR MODEL

TEST T21

GROYNE NO. 3

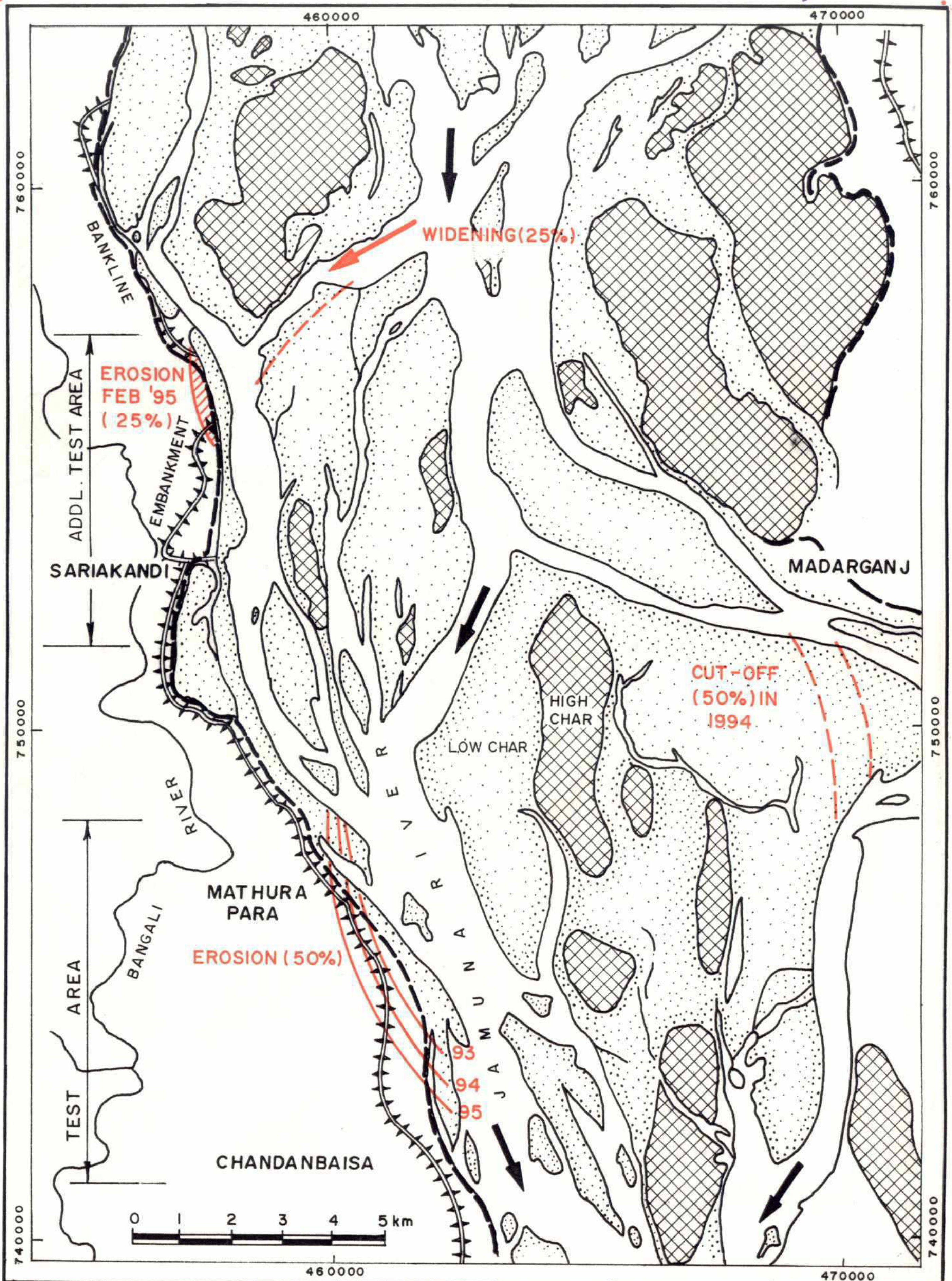
LONGITUDINAL AND CROSS SECTION

FAP – 21/22

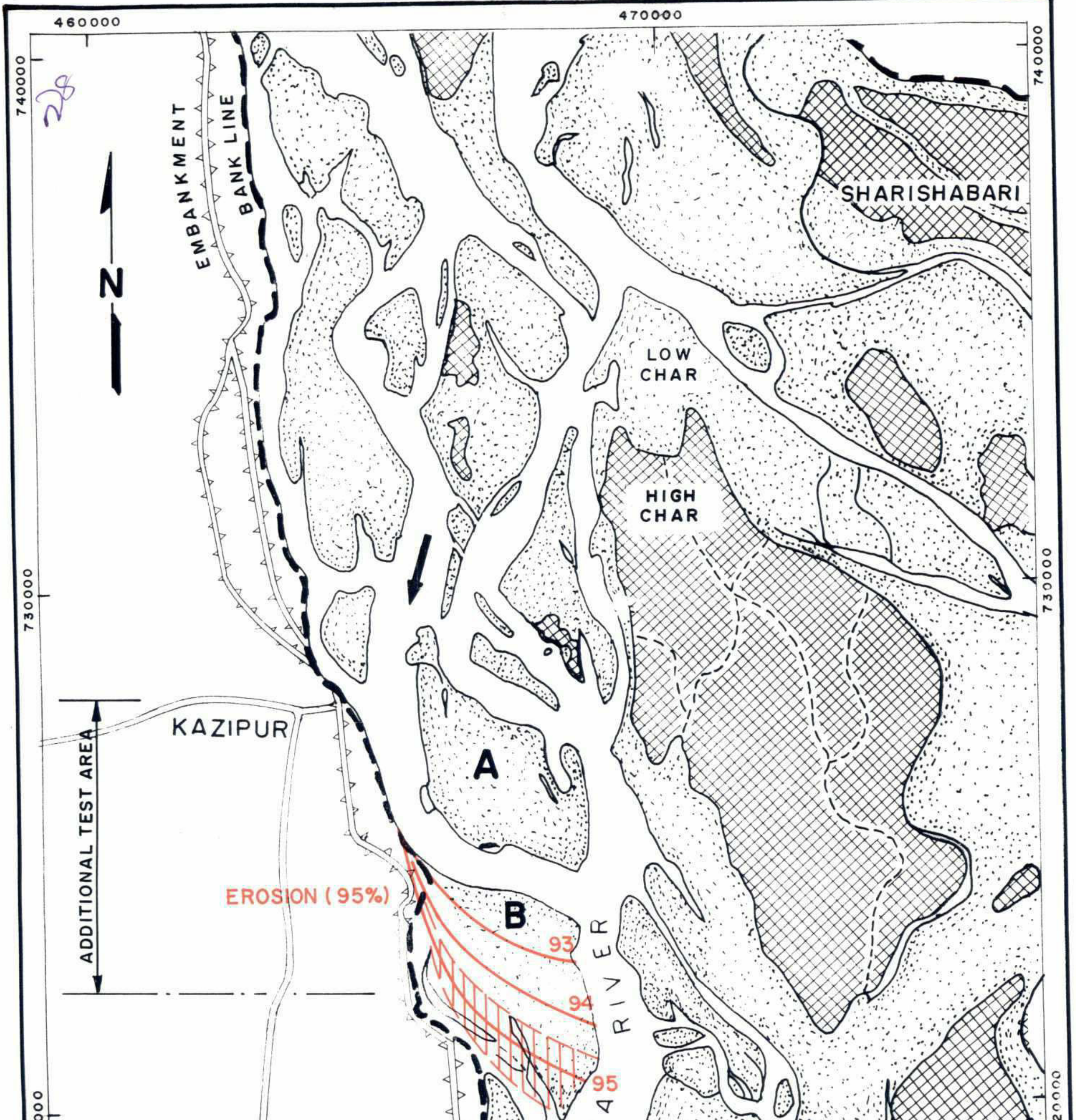
BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT

FINAL REPORT

FIG.A.23–46



SARIAKANDI AREA **EXPECTED BANK EROSION** CHAR PATTERN BASED ON LANDSAT IMAGE III' 1992	**FAP – 21/22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-47



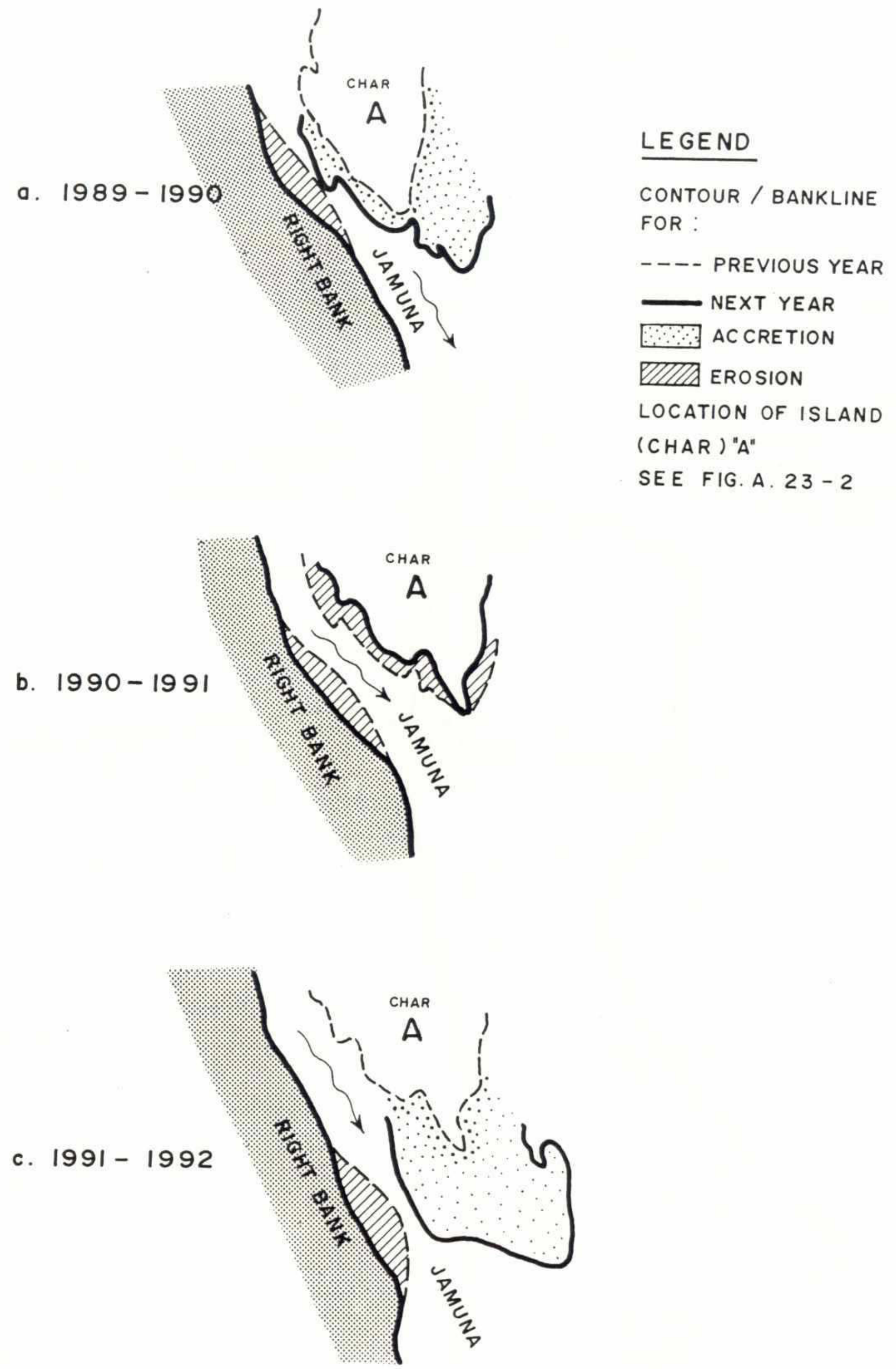
KAZIPUR AREA
EXPECTED BANK EROSION

CHAR PATTERN BASED ON LANDSAT IMAGE III' 1992

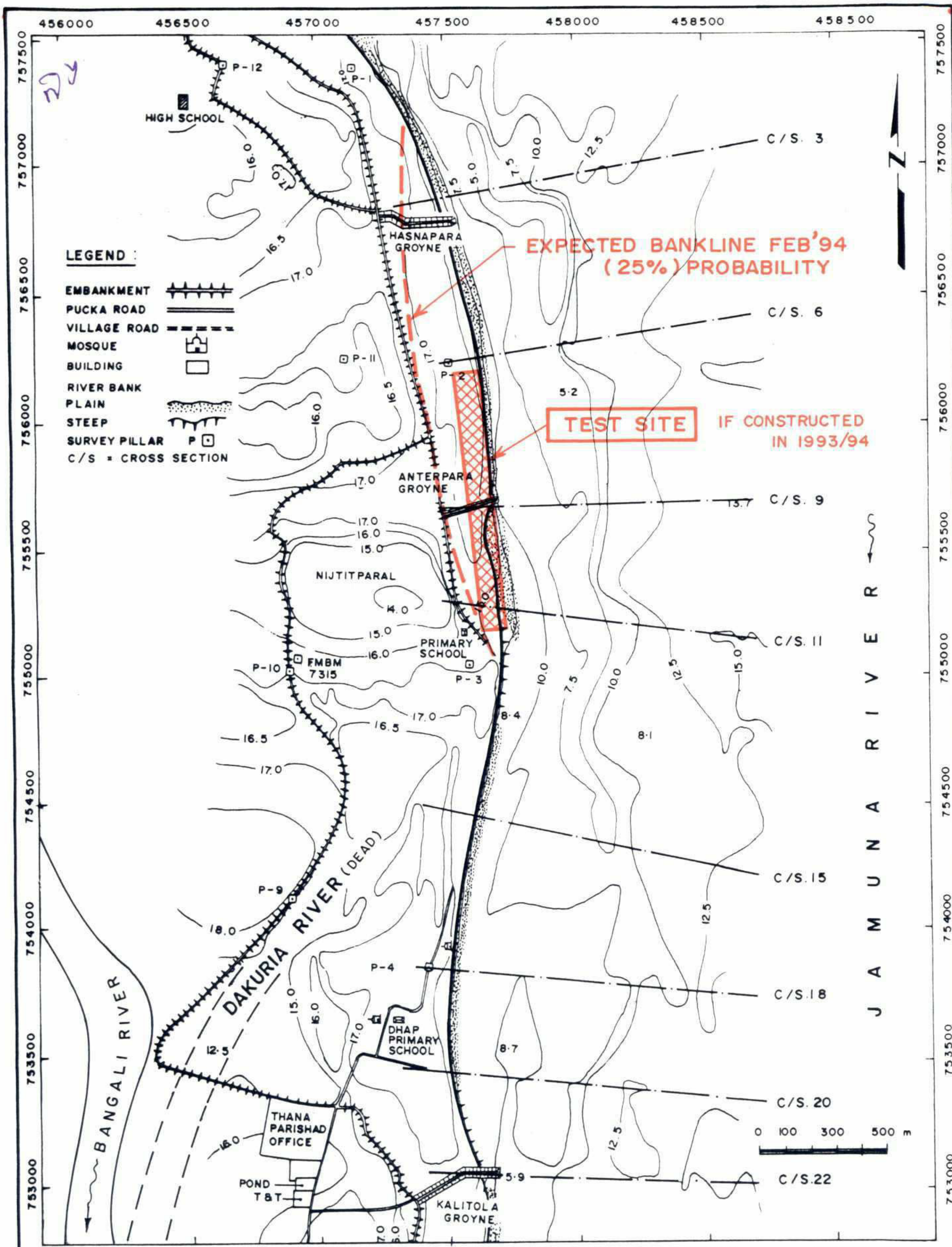
FAP — 21/22

BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT

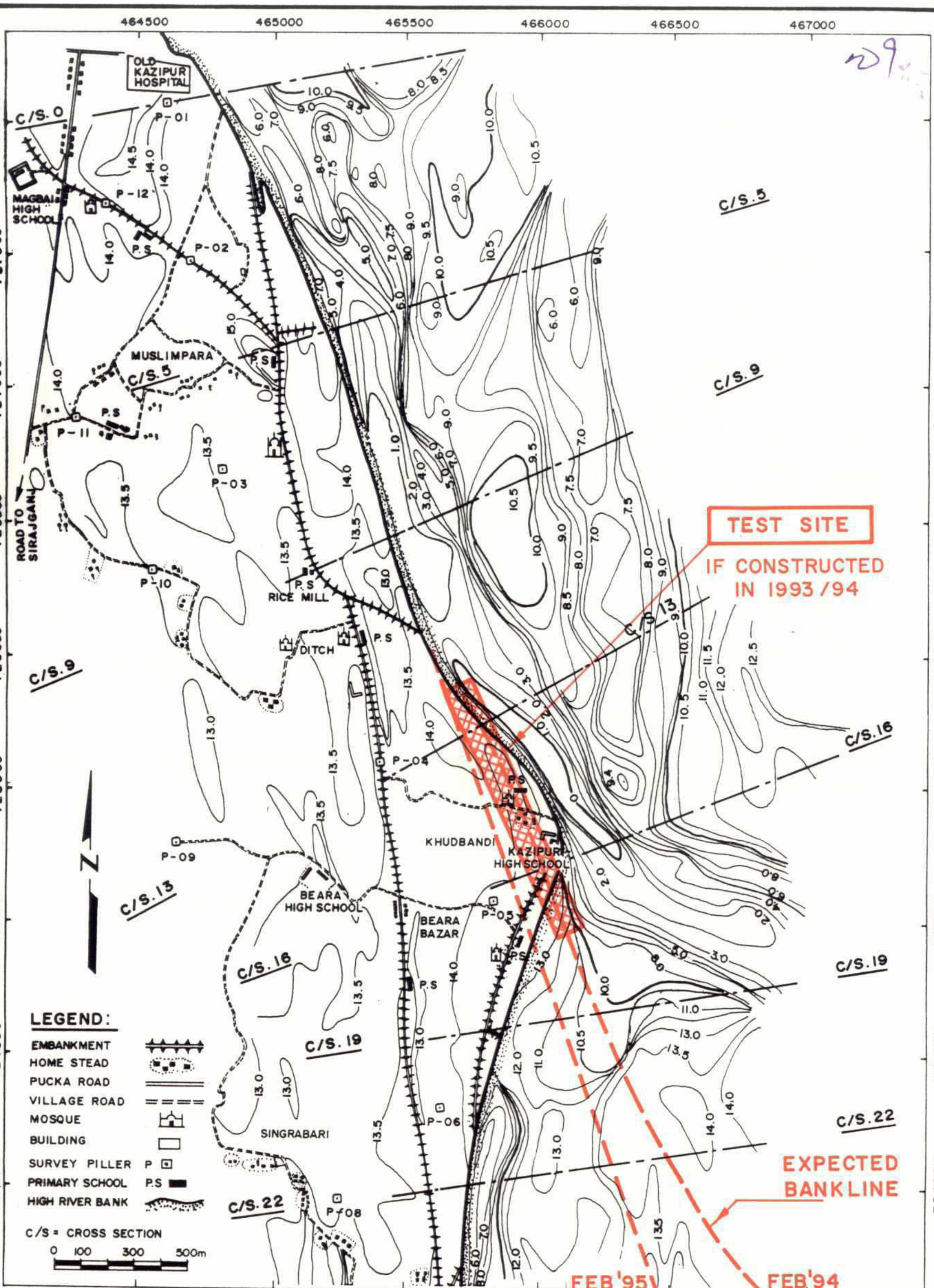
FINAL REPORT | FIG. A.23-48



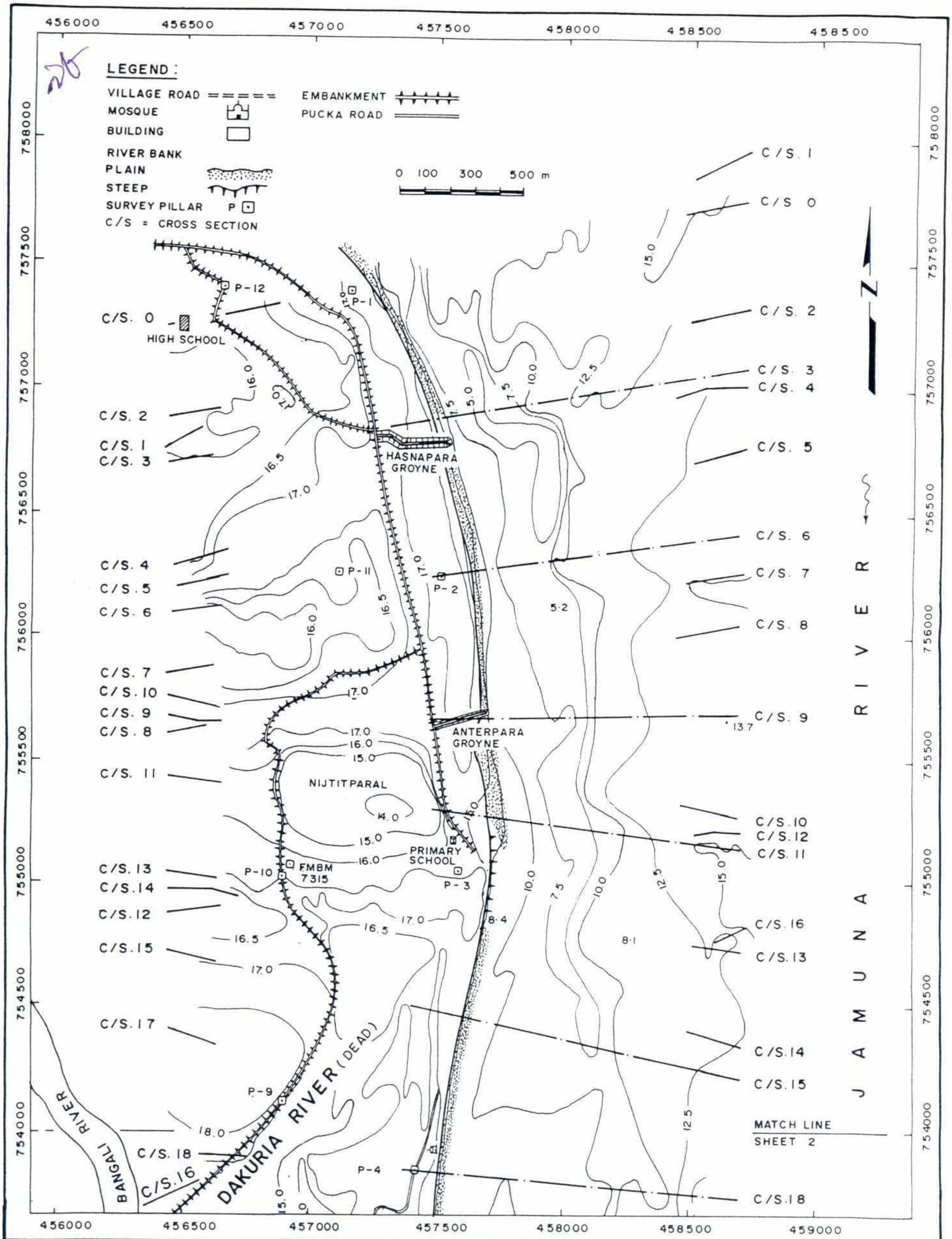
BANK EROSION AND LOCATION OF ISLAND A NEAR KAZIPUR DURING DIFFERENT PERIODS	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A. 23-49



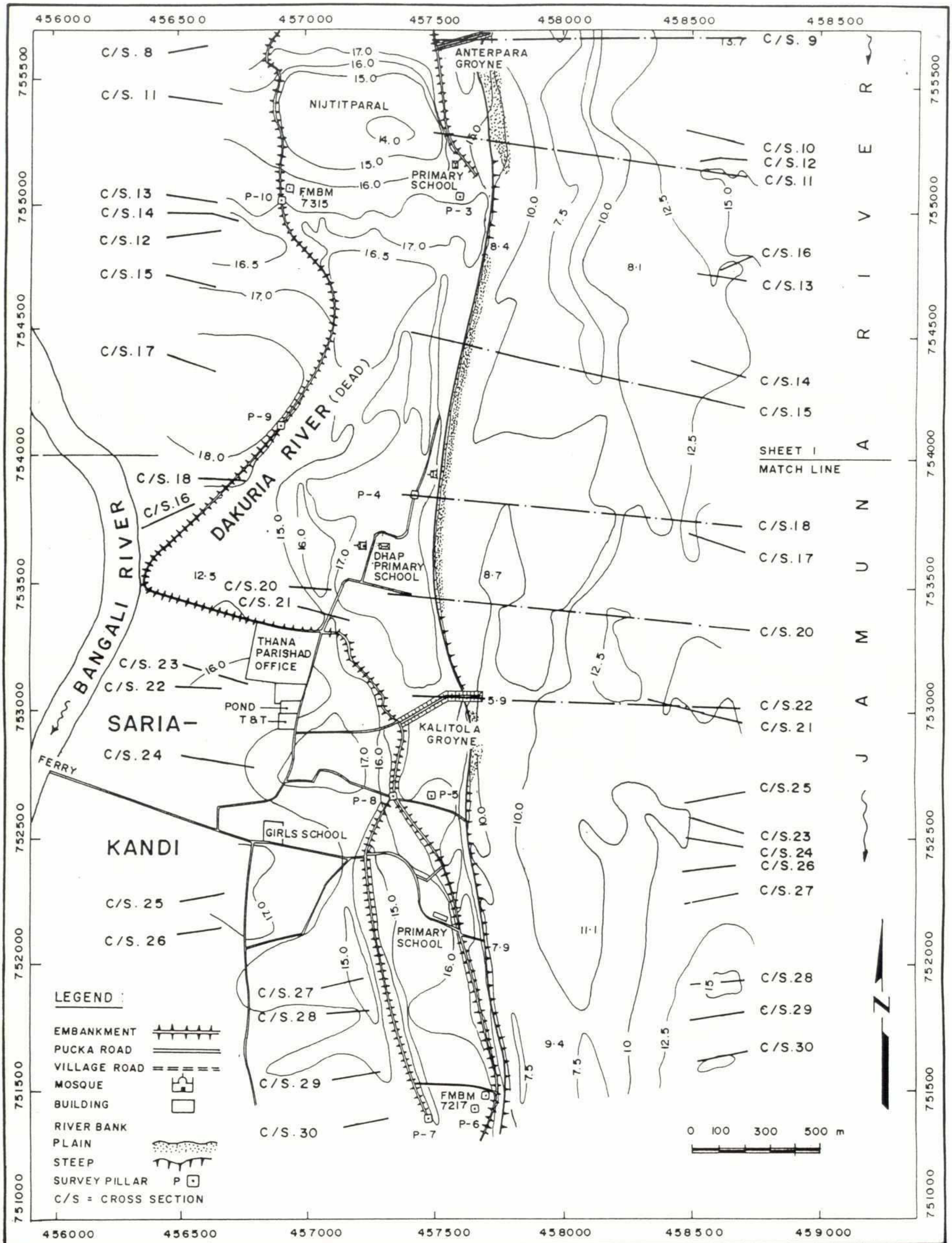
SARIAKANDI **LOCATION OF TEST SITE**	FAP - 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT
	FINAL REPORT | FIG.A.23-50



KAZIPUR LOCATION OF TEST SITE	**FAP - 21/22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT
	FINAL REPORT — FIG. A.23-51



SARIAKANDI TOPOGRAPHIC AND HYDROGRAPHIC SURVEY OF NOVEMBER 1992	FAP - 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
CONTOUR MAP SHEET 1	FINAL REPORT	FIG. A.23-52



SARIAKANDI

TOPOGRAPHIC AND HYDROGRAPHIC SURVEY OF NOVEMBER 1992

CONTOUR MAP SHEET 2

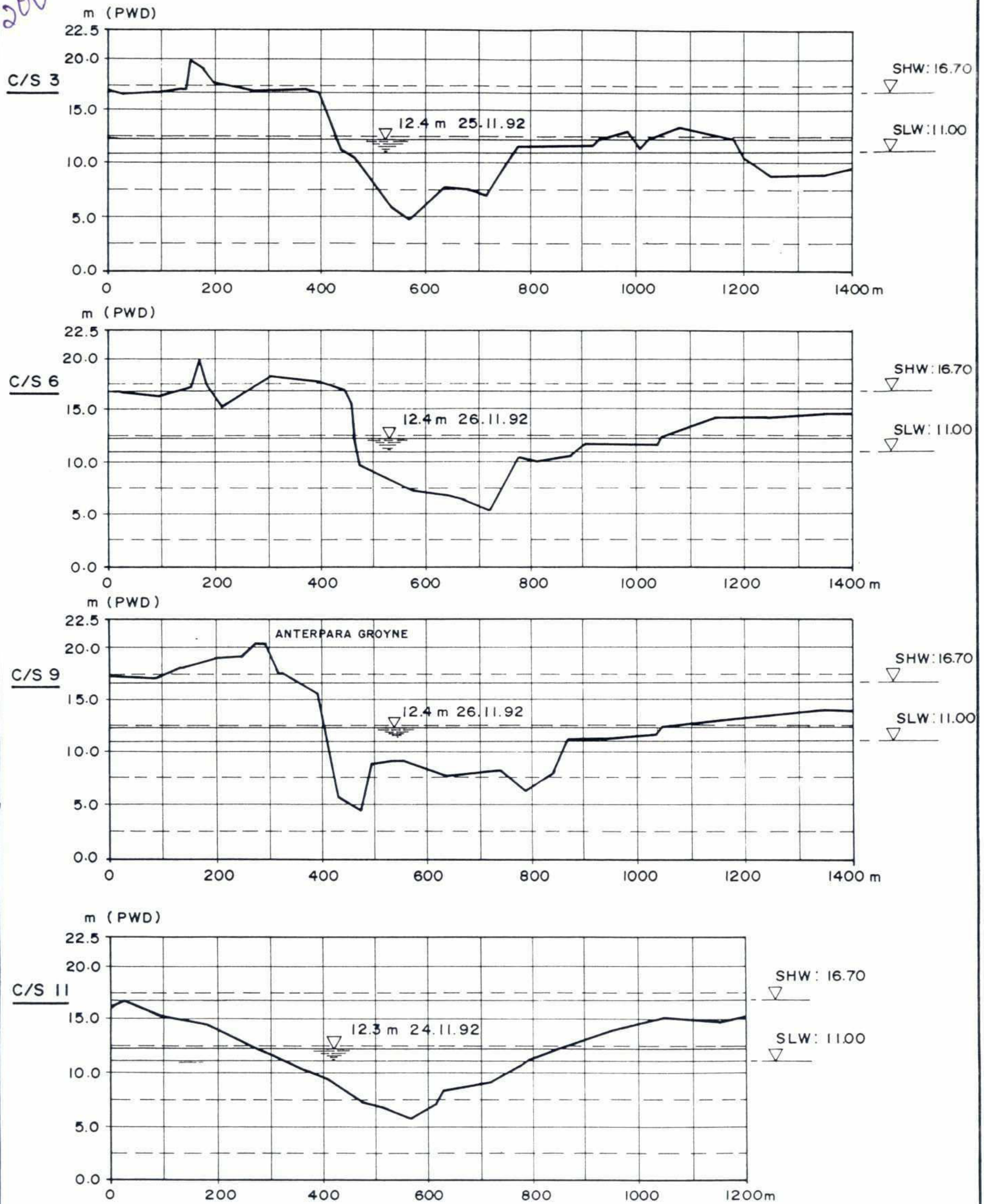
FAP - 21/22

BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT

FINAL REPORT

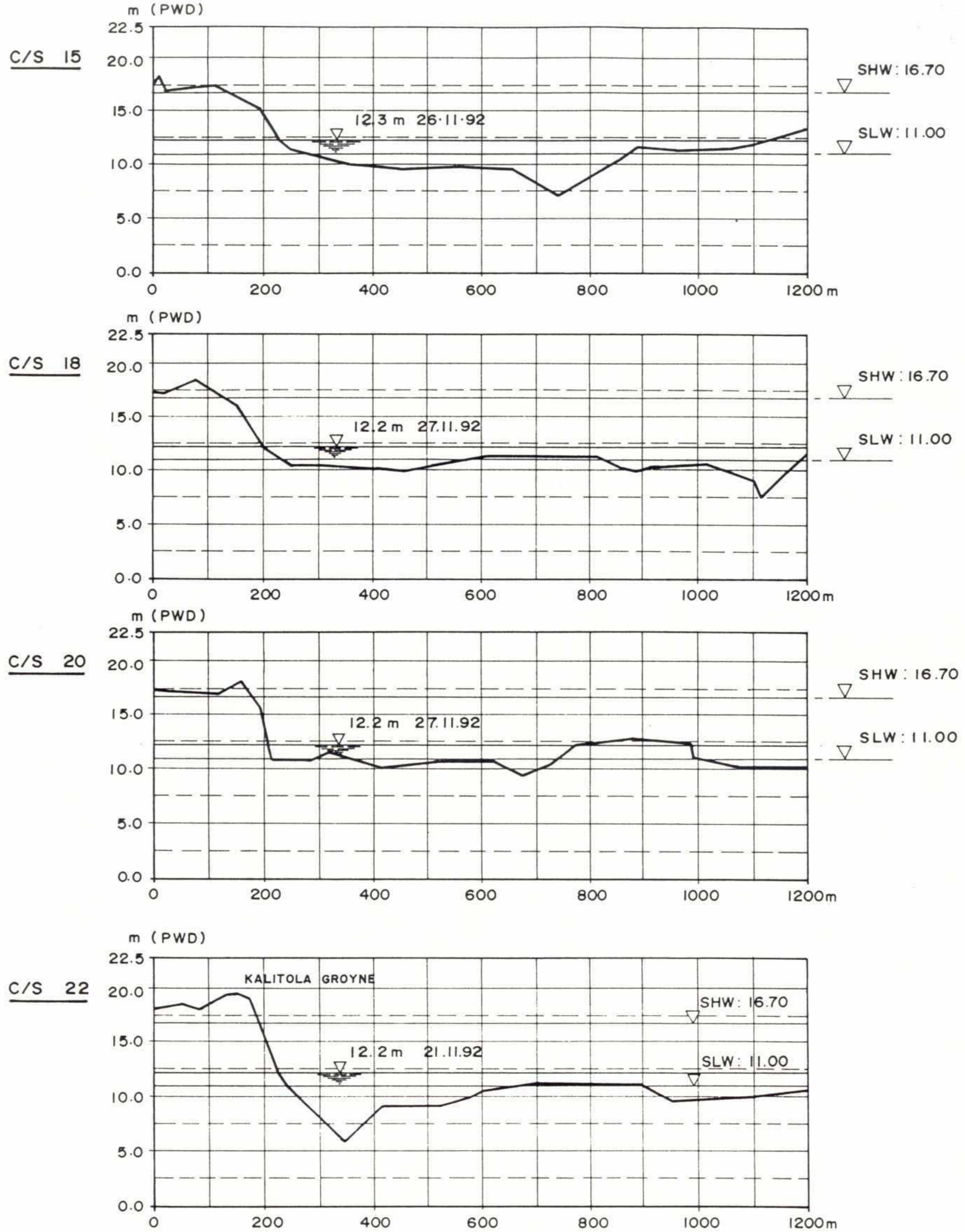
FIG. A.23-53

200



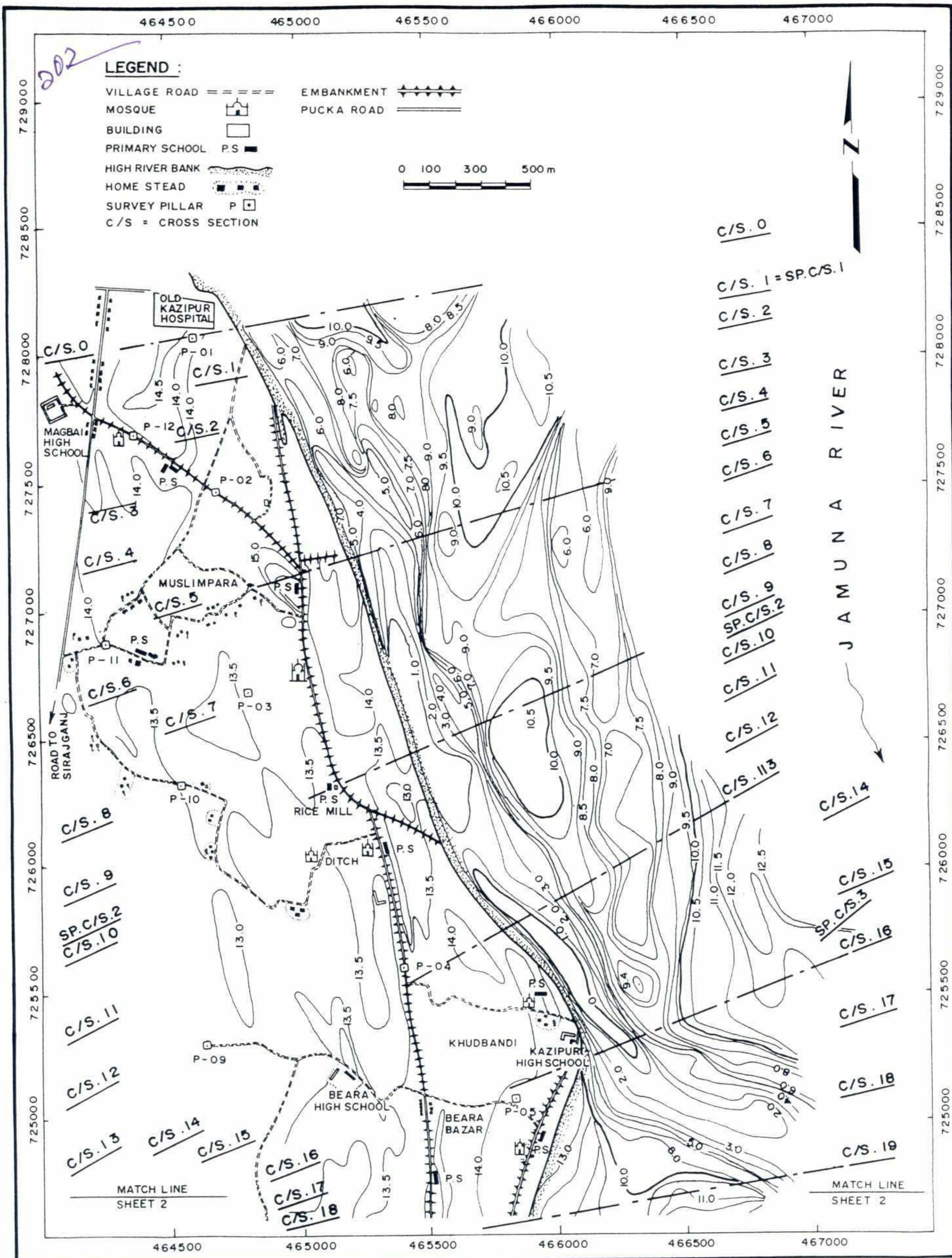
SARIAKANDI RIVER BED PROFILES C/S 3, 6, 9, 11	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT
	FINAL REPORT — FIG. A.23-54

202



NOTE :
LOCATION SEE FIG. A.23 -7

SARIAKANDI RIVER BED PROFILES C/S 15,18,20,22	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT
	FINAL REPORT | FIG. A.23-55



KAZIPUR

TOPOGRAPHIC AND HYDROGRAPHIC SURVEY OF NOVEMBER 1992

CONTOUR MAP SHEET 1

FAP – 21/22

BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT

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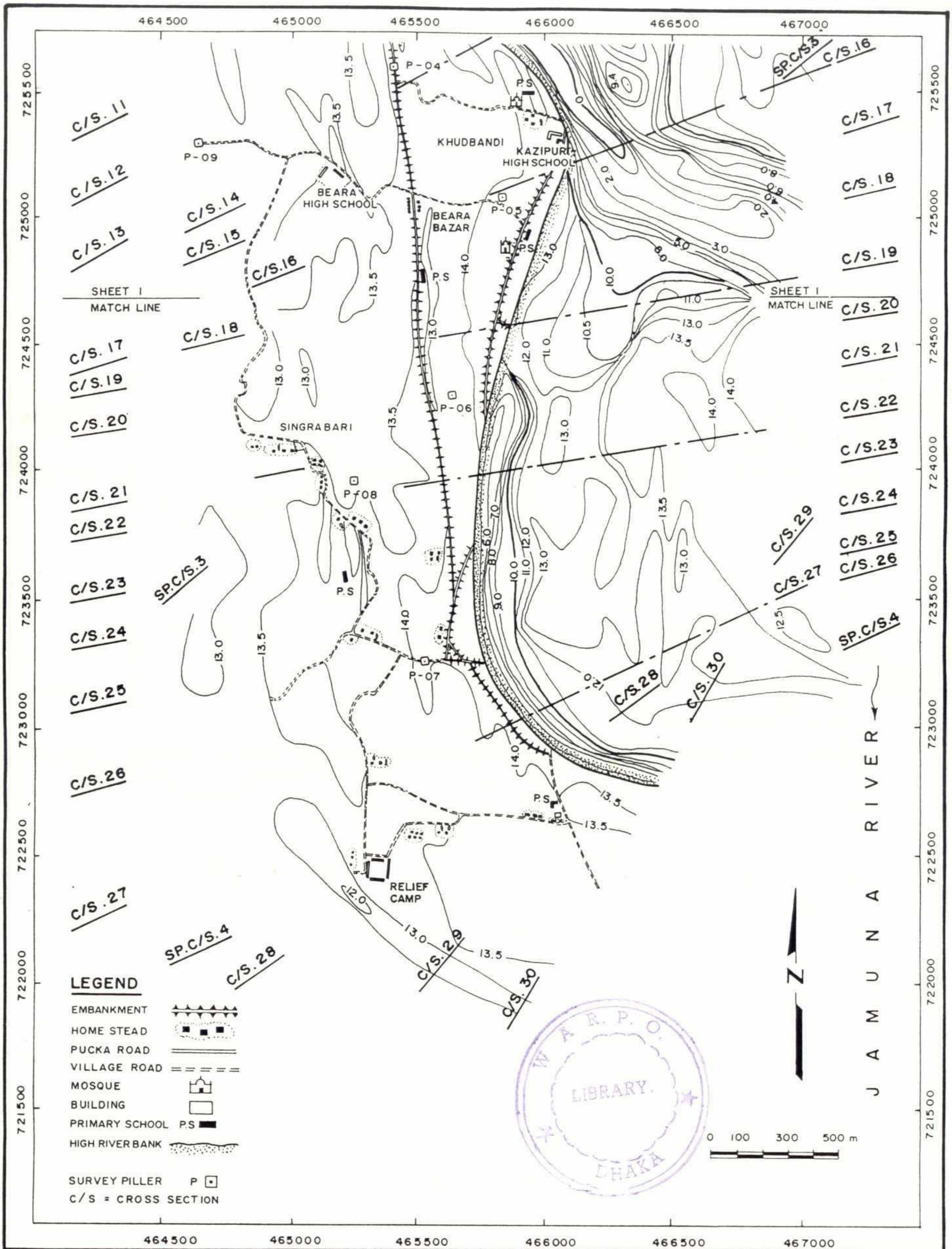
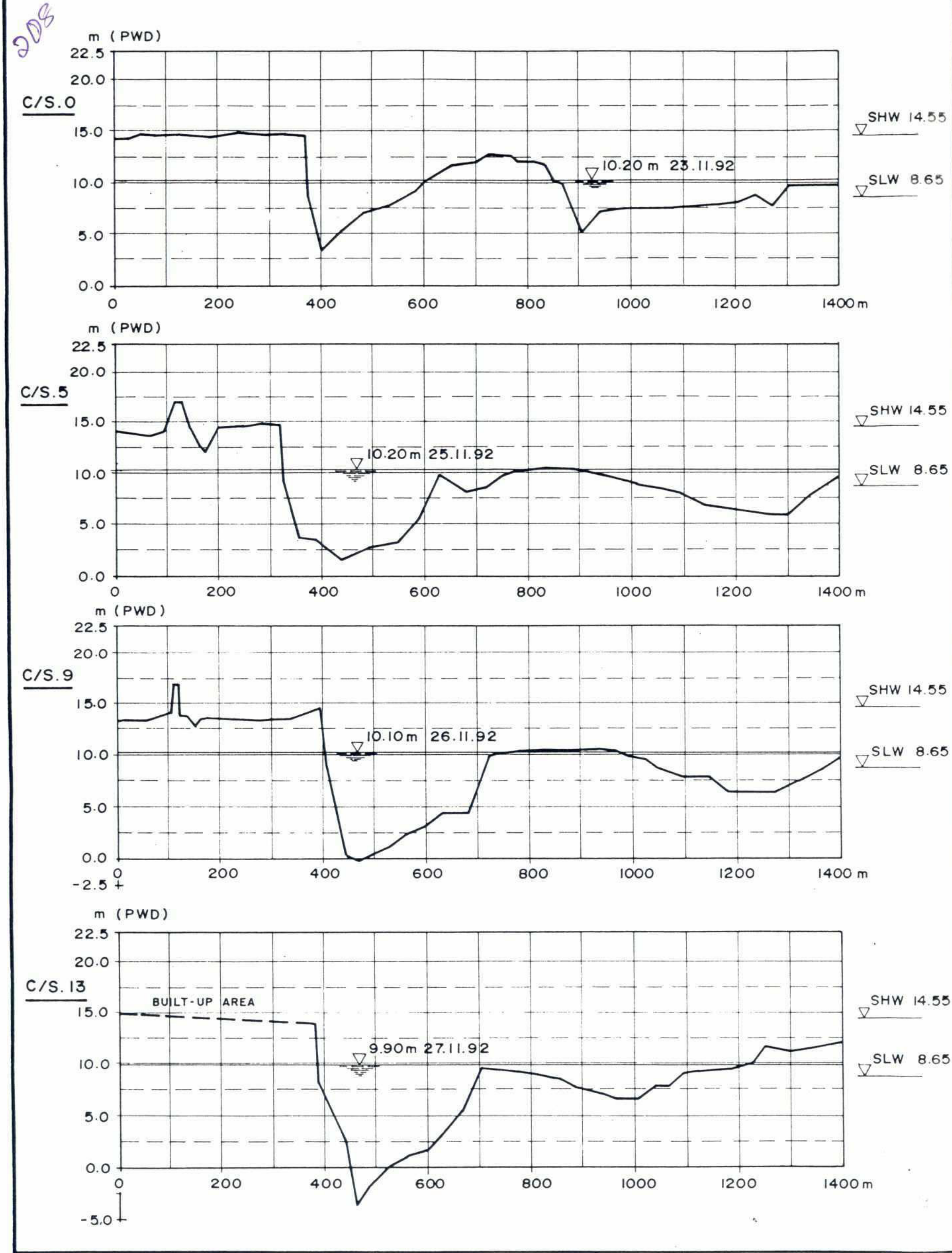
FIG. A.23-56

206



KAZIPUR TOPOGRAPHIC AND HYDROGRAPHIC SURVEY OF NOVEMBER 1992 CONTOUR MAP SHEET 2	FAP - 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-57



KAZIPUR
RIVER BED PROFILES
C/S 0, 5, 9, 13

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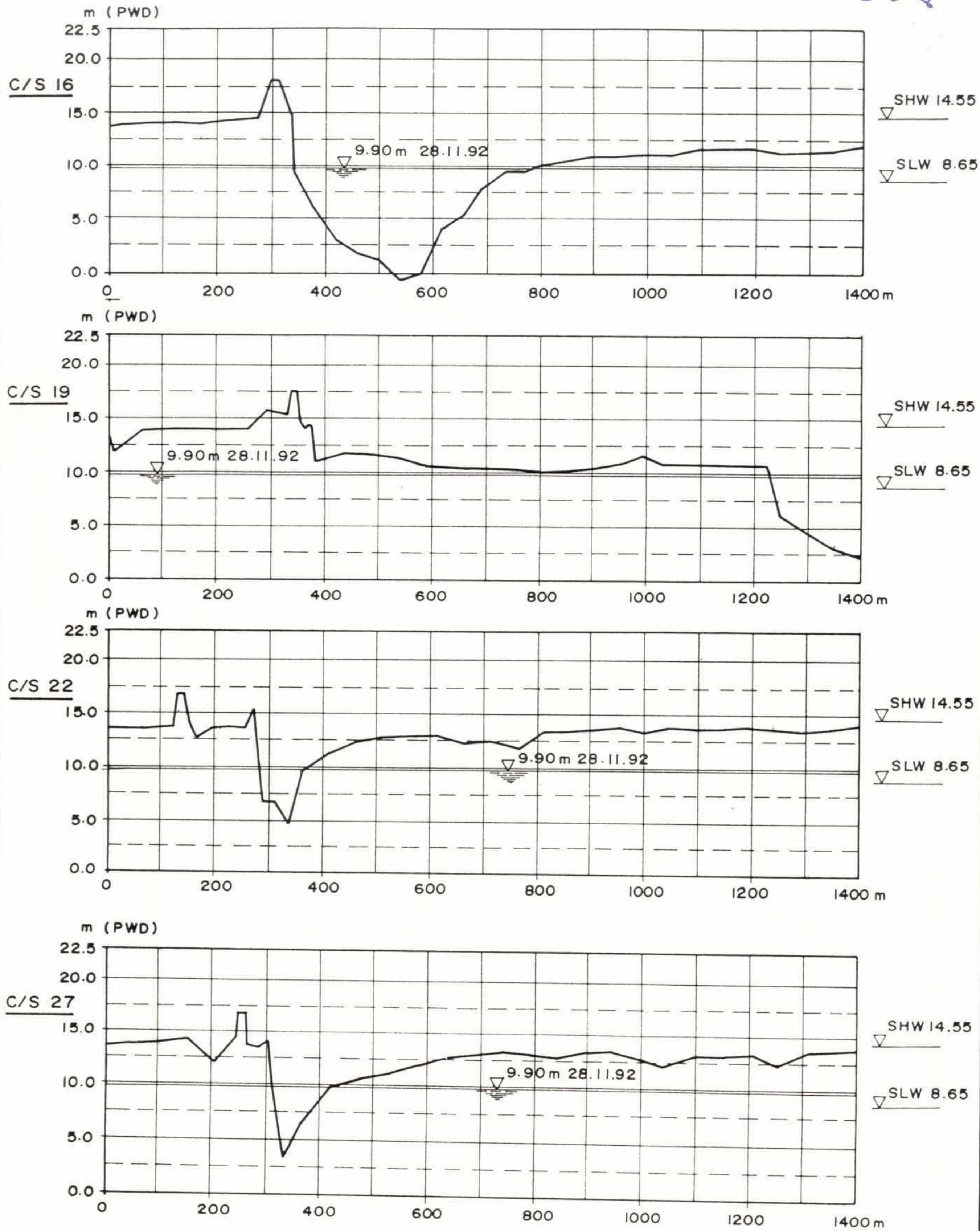
FIG. A.23-58

208



KAZIPUR
RIVER BED PROFILES
C/S 16, 19, 22, 27

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BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT

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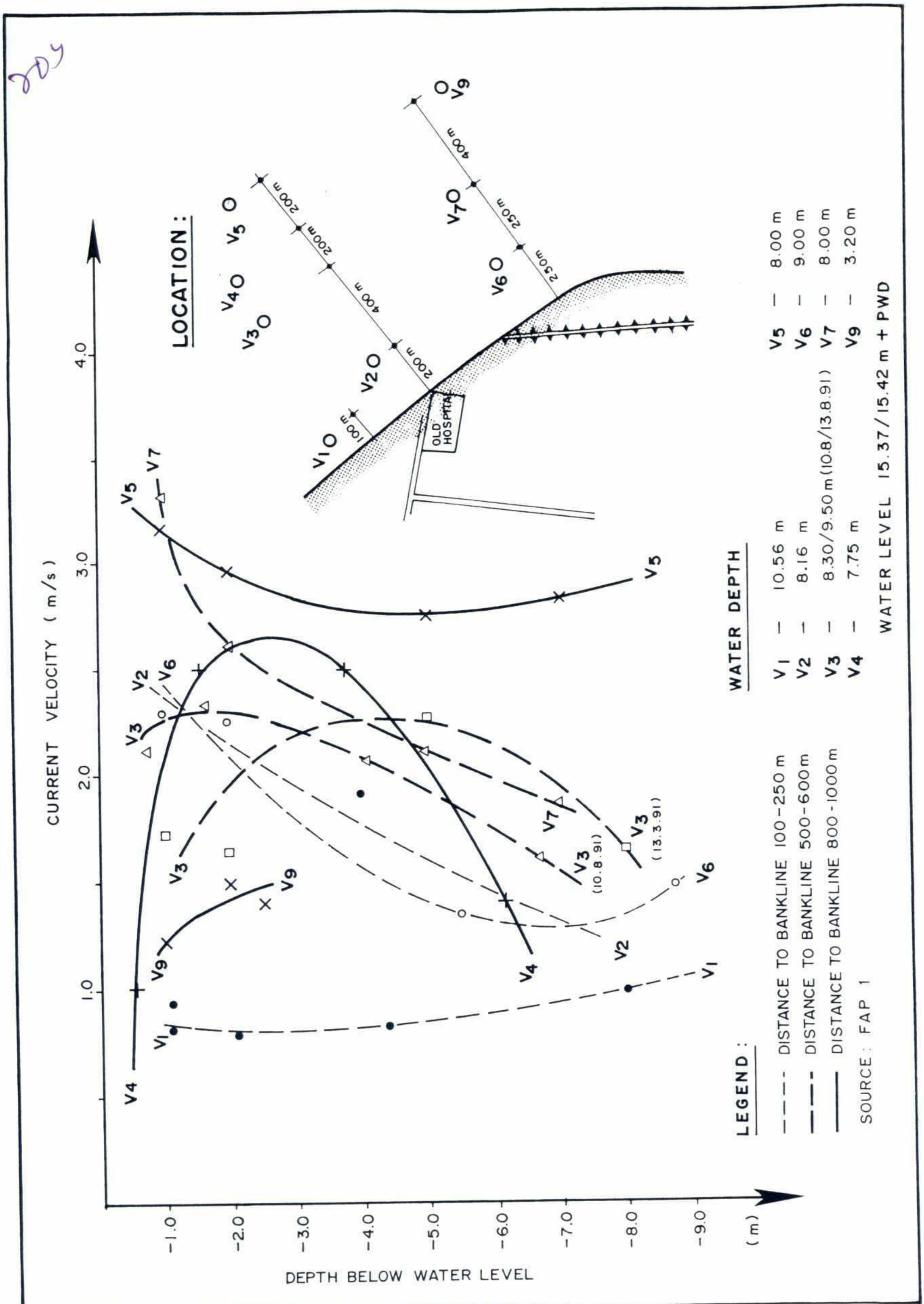
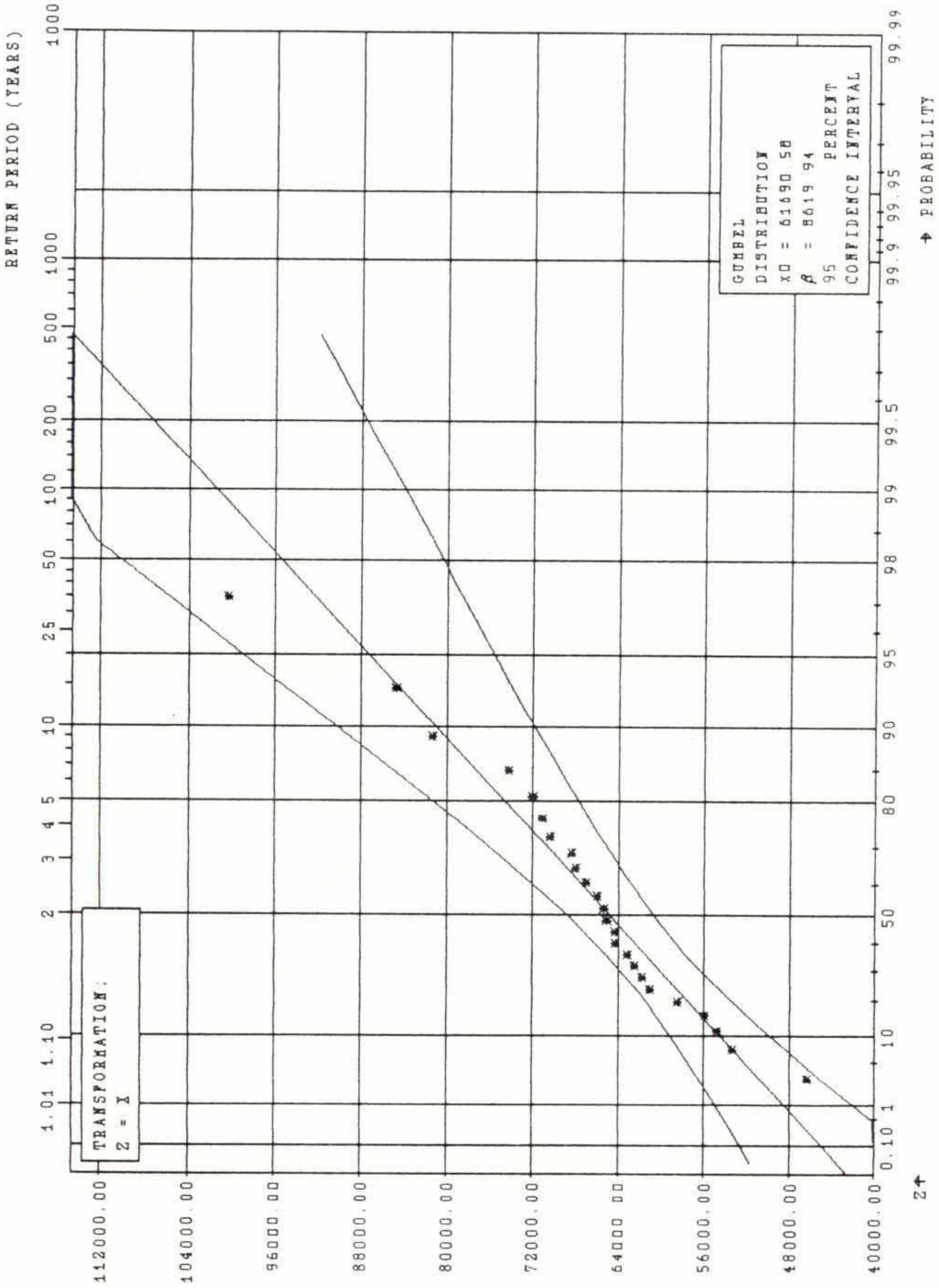
FIG. A.23-59



CURRENT VELOCITIES AT FIXED POINTS IN FRONT OF KAZIPUR HOSPITAL	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-60

209



ANNUAL MAXIMUM DISCHARGE DISTRIBUTION AT CHAINAGE 113 km (SARIAKANDI)

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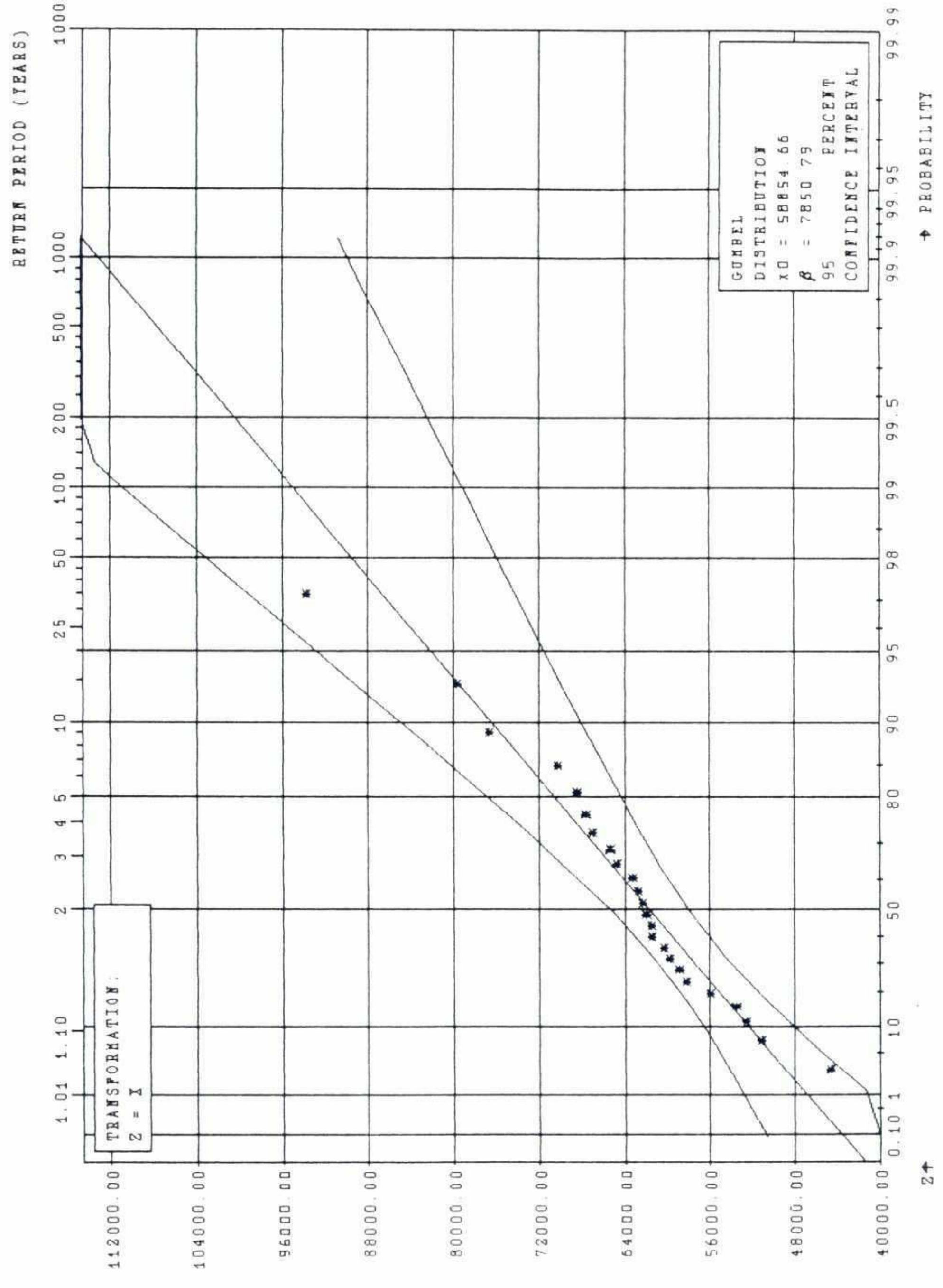
FIG. A.23-61

208



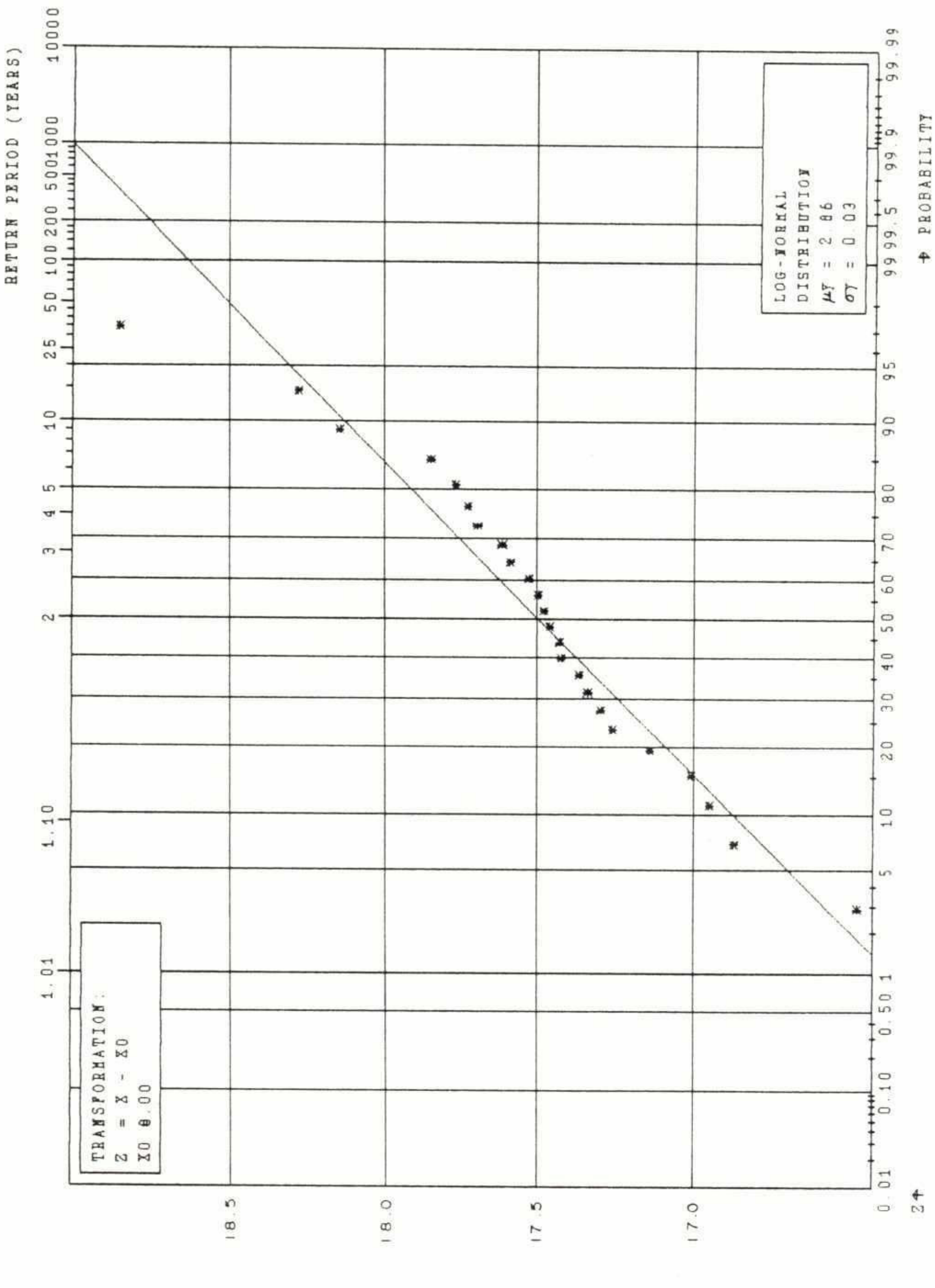
ANNUAL MAXIMUM DISCHARGE
DISTRIBUTION AT KAZIPUR

FAP – 21/22

BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT

FINAL REPORT	FIG. A.23-62

202



ANNUAL MAXIMUM WATER LEVEL DISTRIBUTION AT SARIAKANDI
(CHAINAGE 109 Km)

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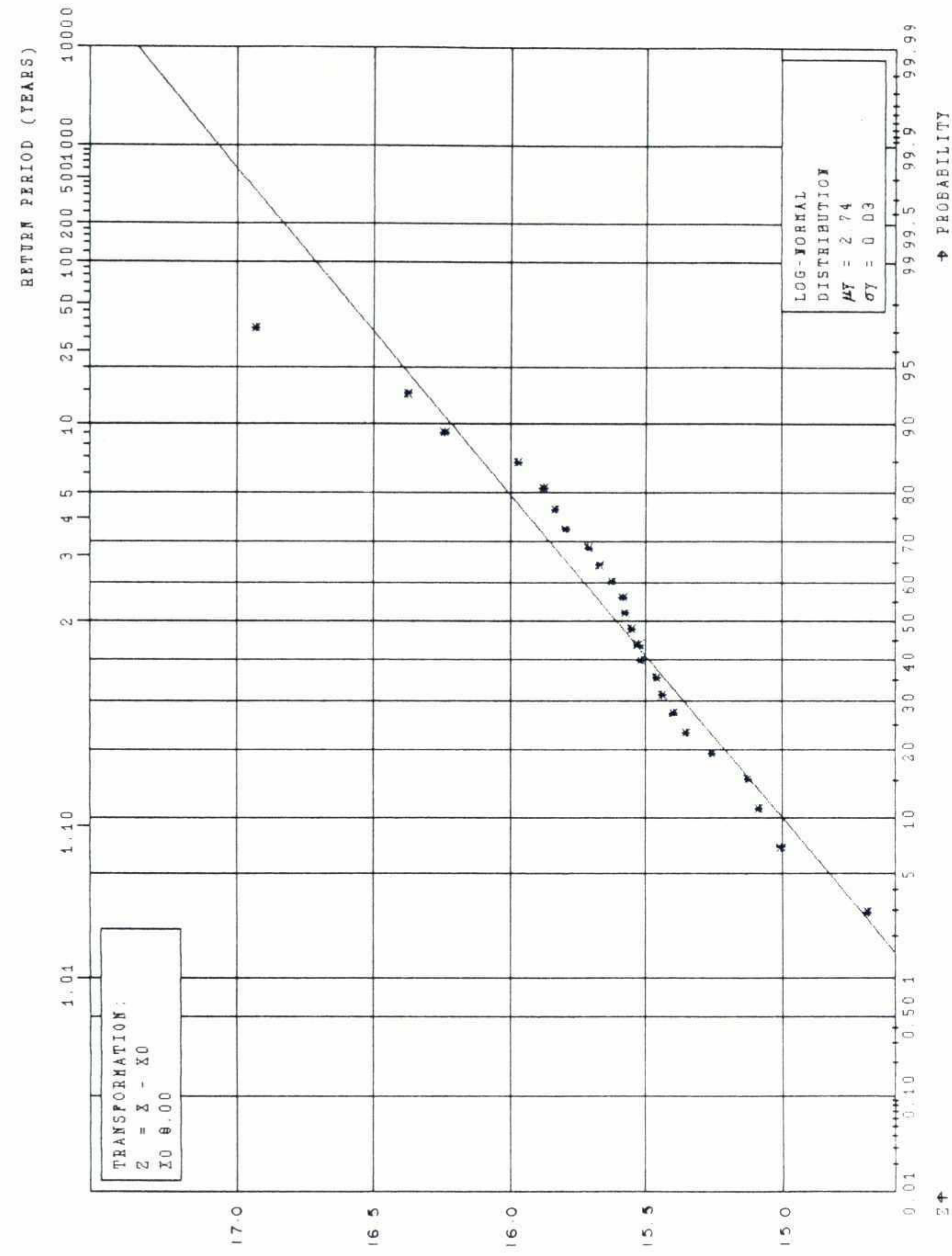
FINAL REPORT	FIG. A.23-63	

220



ANNUAL MAXIMUM WATER LEVEL
DISTRIBUTION AT KAZIPUR
(CHAINAGE 142 Km)

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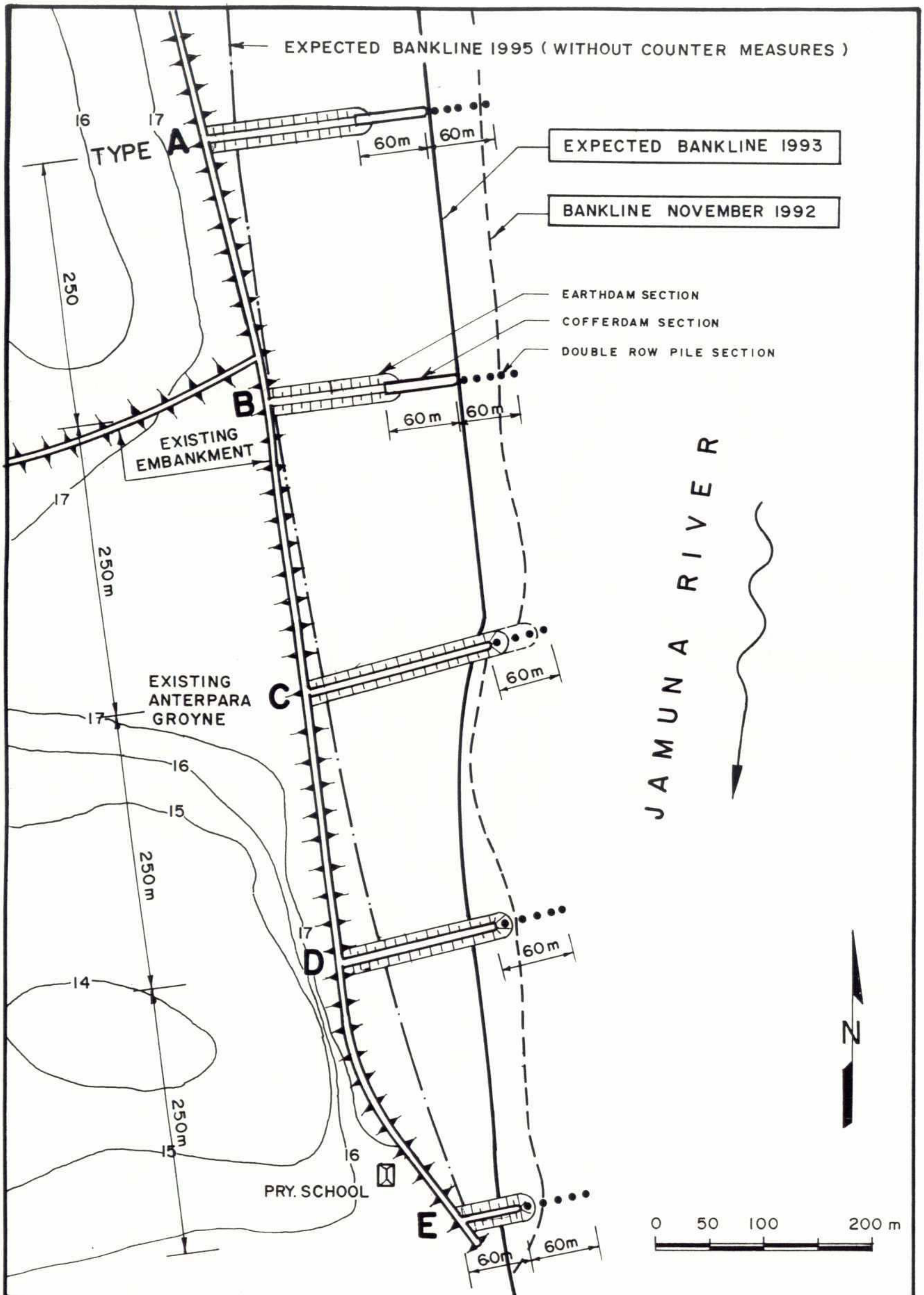
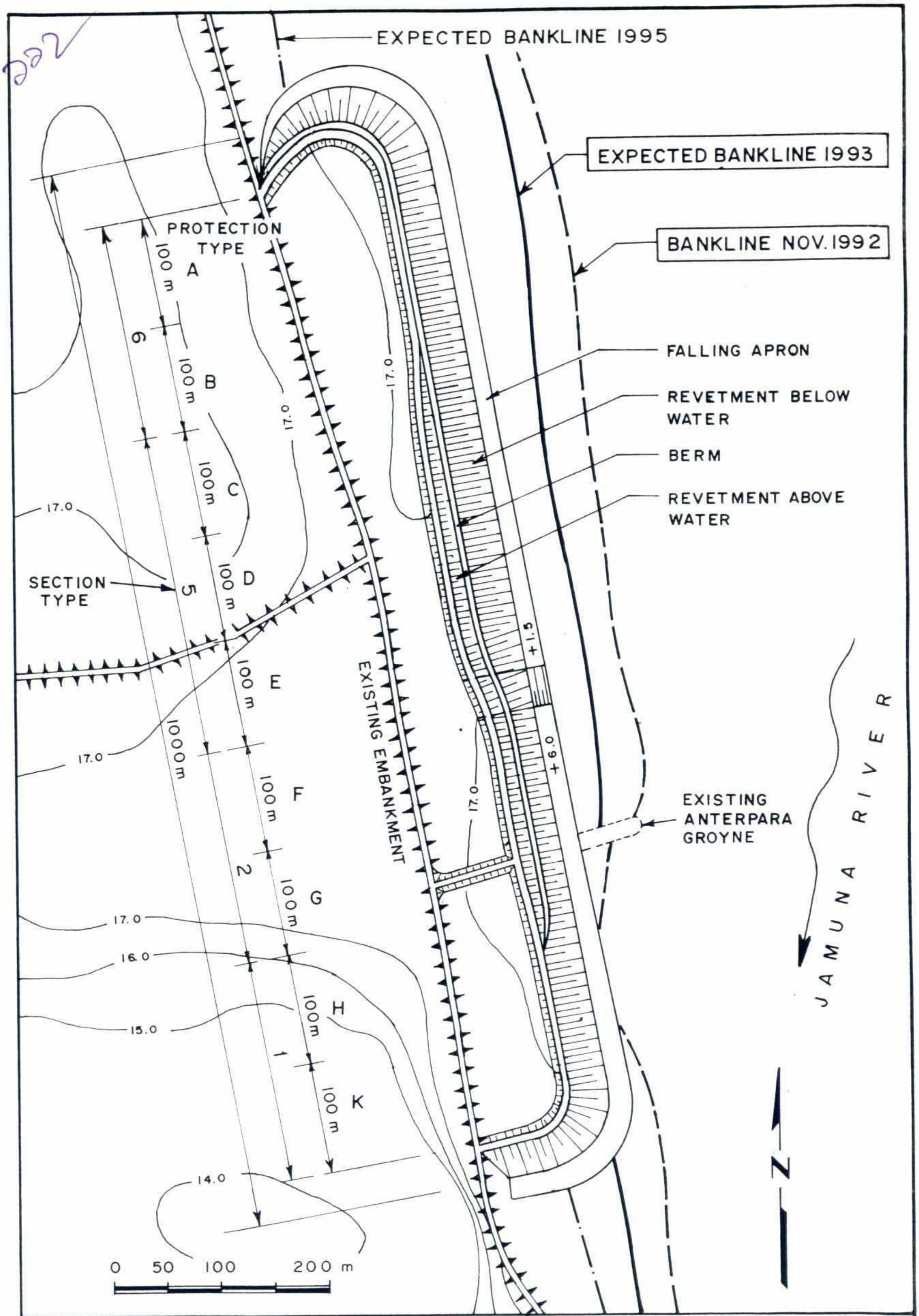
FIG. A.23-64



LAYOUT OF GROYNES AT SARIAKANDI TEST SITE	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT
	FINAL REPORT | FIG. A. 23- 65



LAYOUT OF SLOPE REVETMENT AT SARIAKANDI TEST SITE

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FIG. A.23–66

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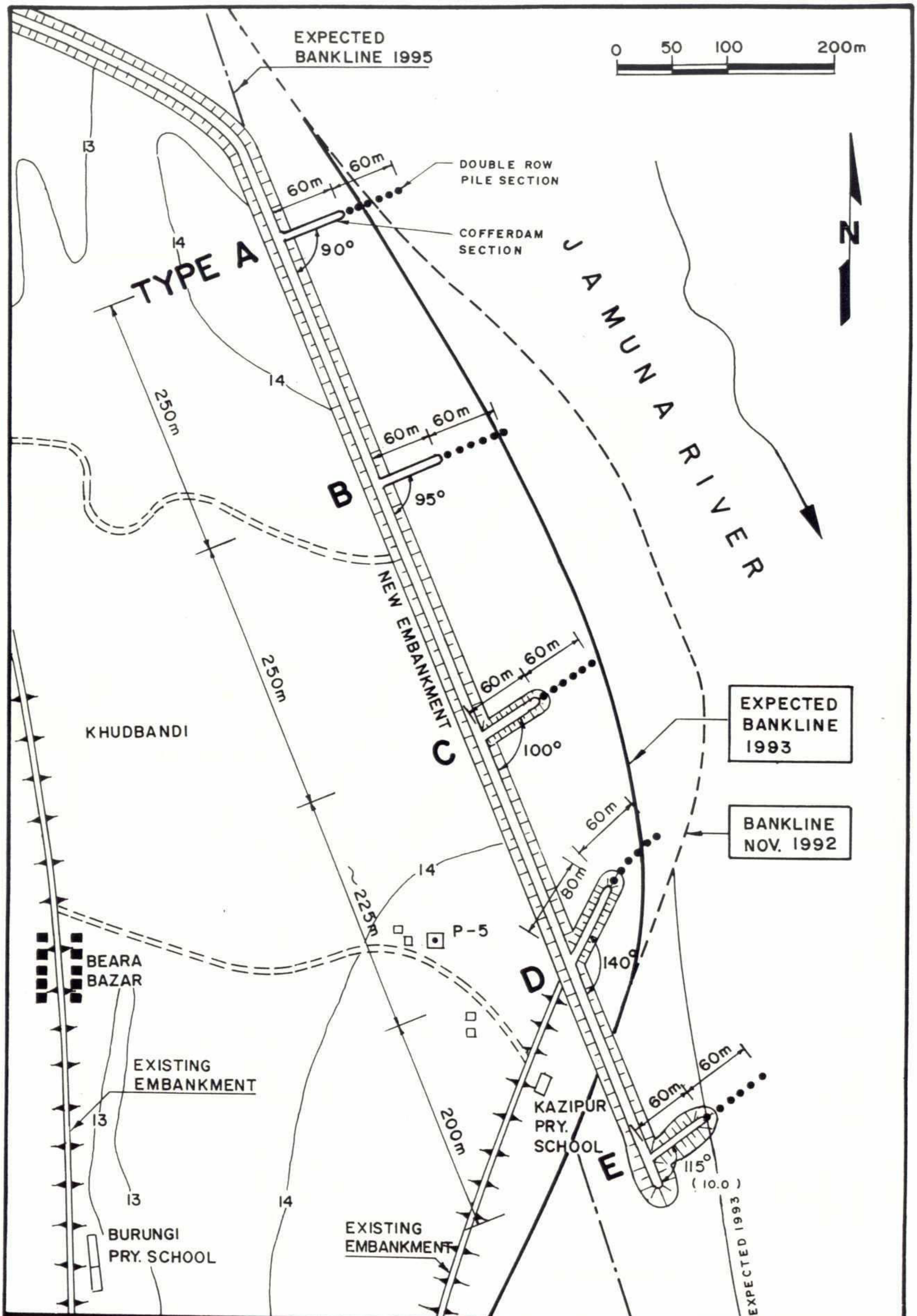

LAYOUT OF GROYNES AT KAZIPUR TEST SITE	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-67

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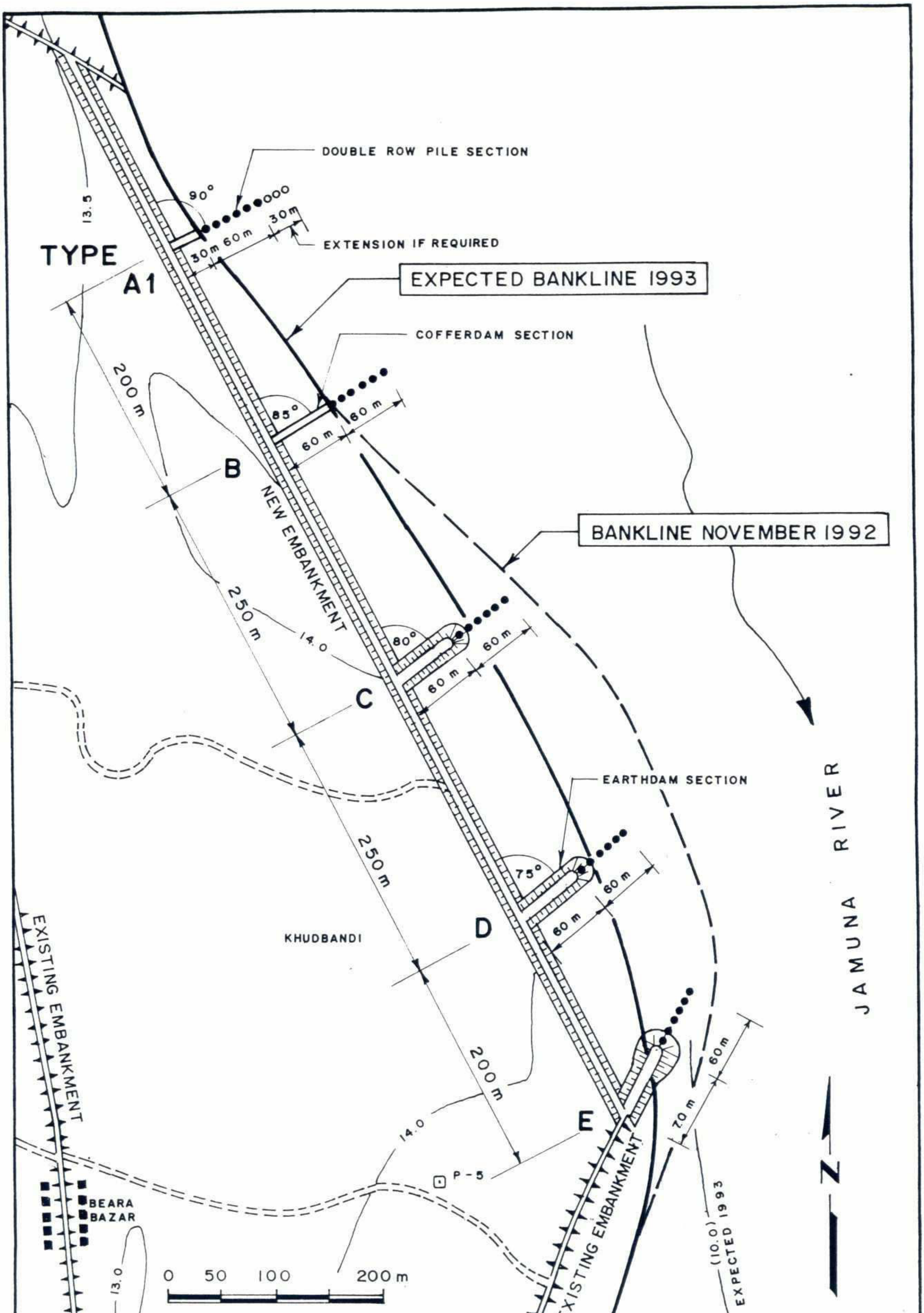

ALTERNATIVE LAYOUT OF GROYNES AT KAZIPUR TEST SITE

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BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT

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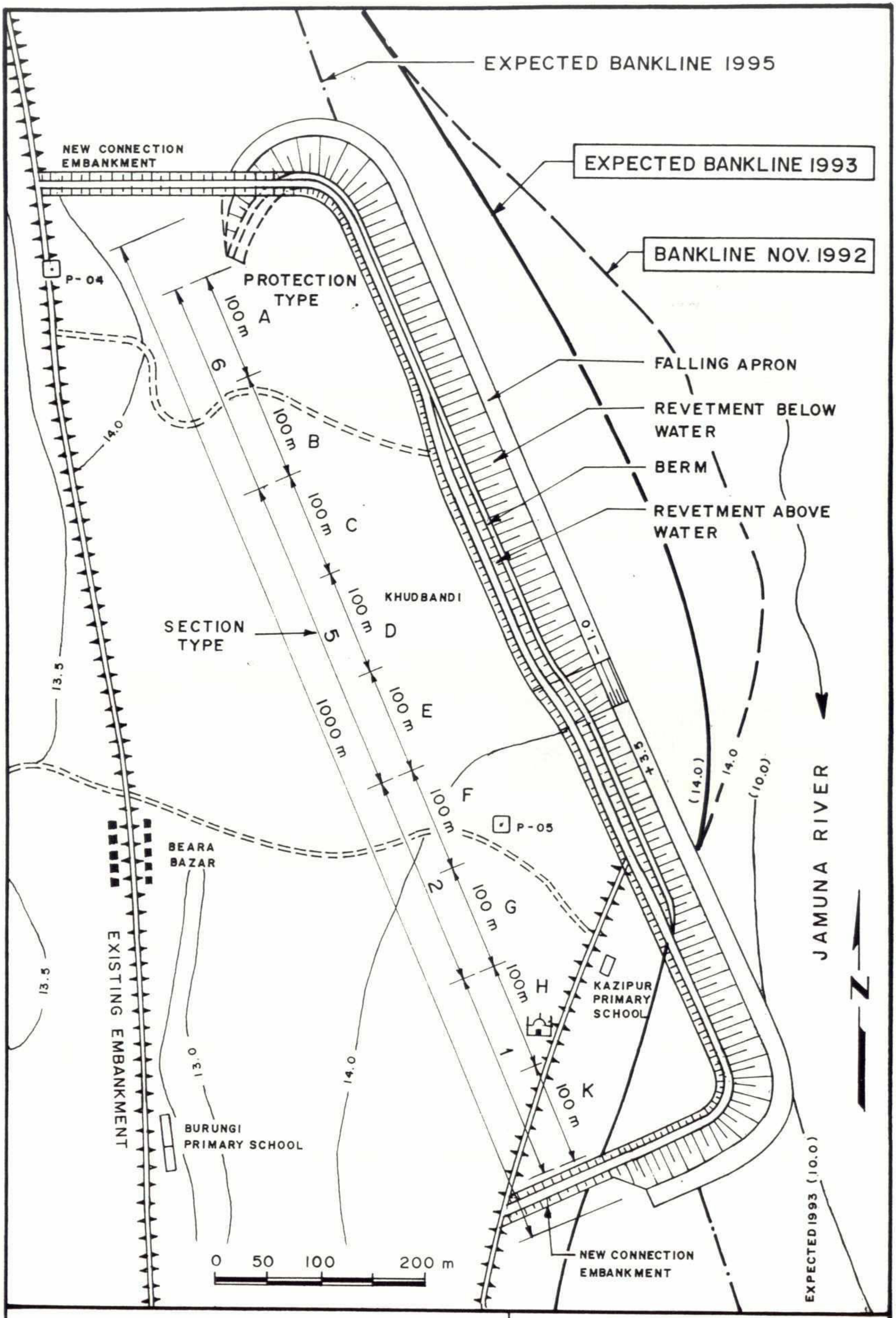
FIG. A.23-68



LAYOUT OF SLOPE REVETMENT AT KAZIPUR TEST SITE

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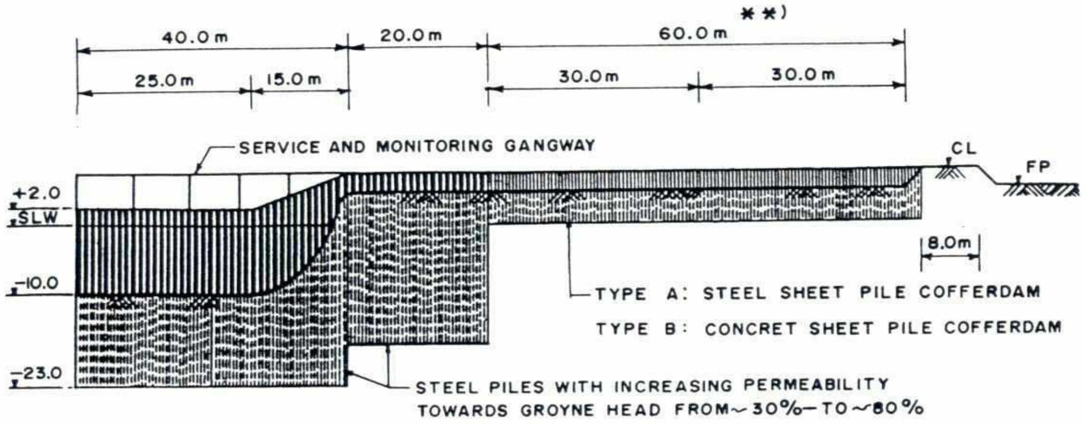
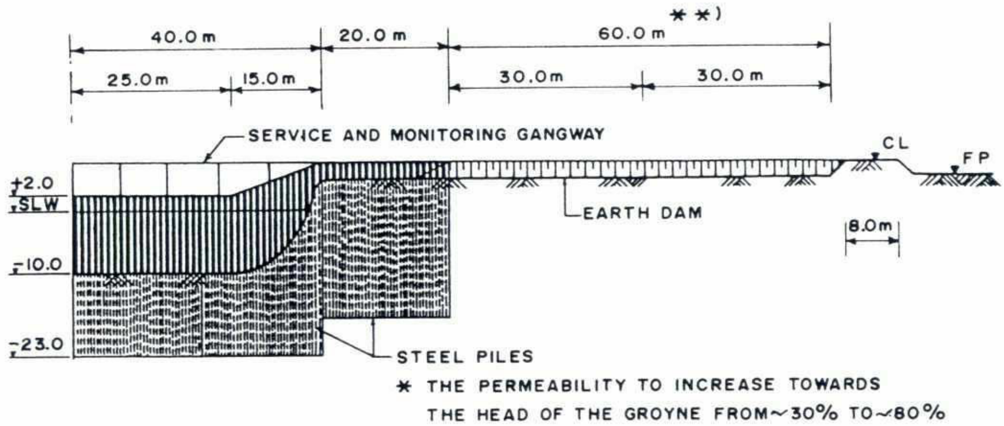
FINAL REPORT

FIG. A.23-69

GROYNE TYPE A + B



GROYNE TYPE C + D + E



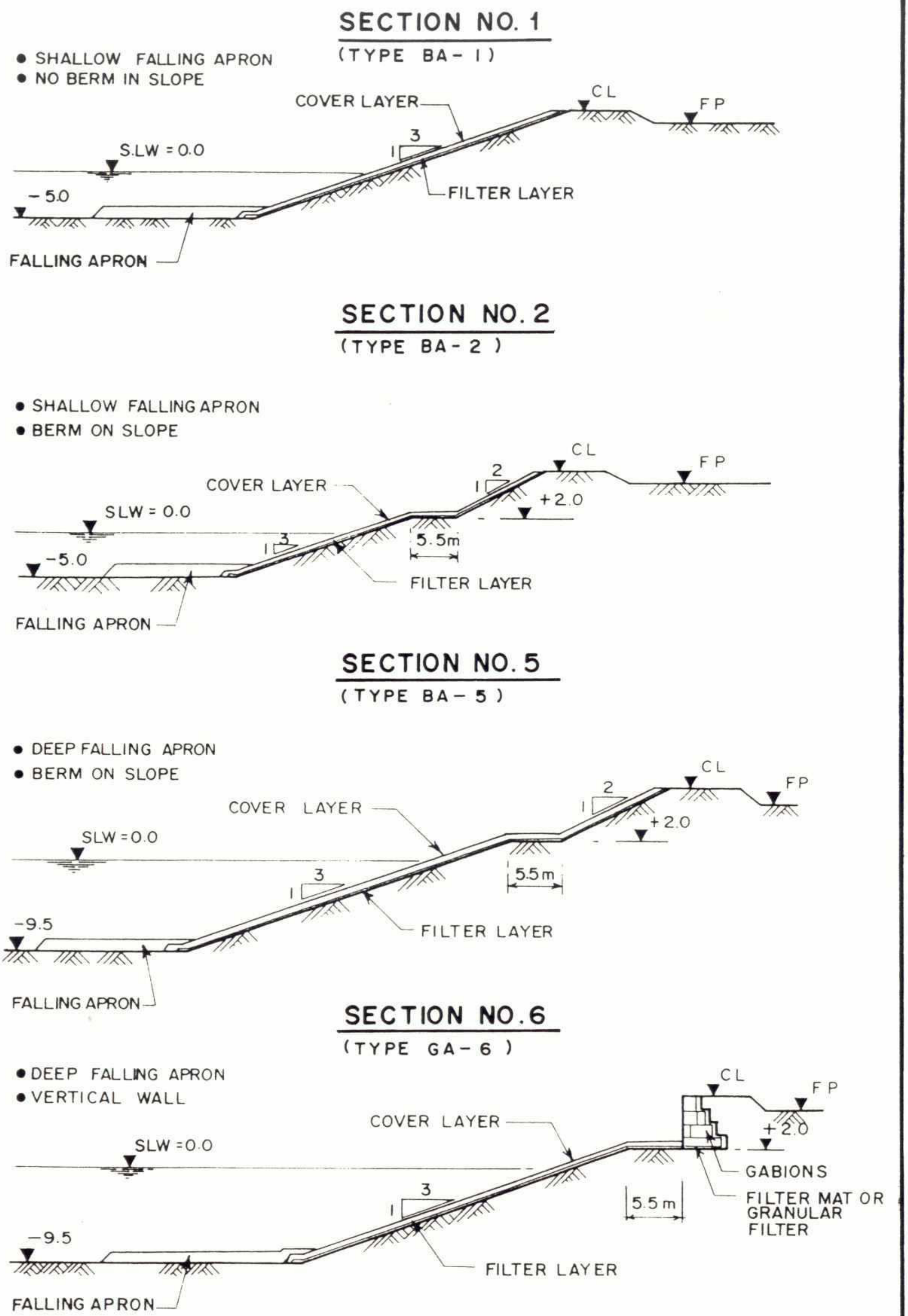
LEGEND	SARIAKANDI *)	KAZIPUR *)
CL = CREST LEVEL	+ 8.70 m (EXISTING EMBANKMENT)	+ 7.80 m
FP = FLOOD PLAIN LEVEL	+ 6.00 m	+ 5.60 m

*) LEVELS IN m above SLW

**) LENGTHS OF EARTH DAMS AT SARIAKANDI ARE DIFFERENT

FOR MORE DETAILS OF GROYNE DESIGN SEE ANNEX 21

SECTIONS OF GROYNE TEST STRUCTURES	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A. 23-70



LEGEND	SARIAKANDI	KAZIPUR
CL = CREST LEVEL	+ 7.35 m	+ 7.80 m
FP = FLOOD PLAIN LEVEL	+ 6.00 m	+ 5.60 m

SECTIONS OF SLOPE REVETMENT TEST STRUCTURES	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	FINAL REPORT	FIG. A.23-71