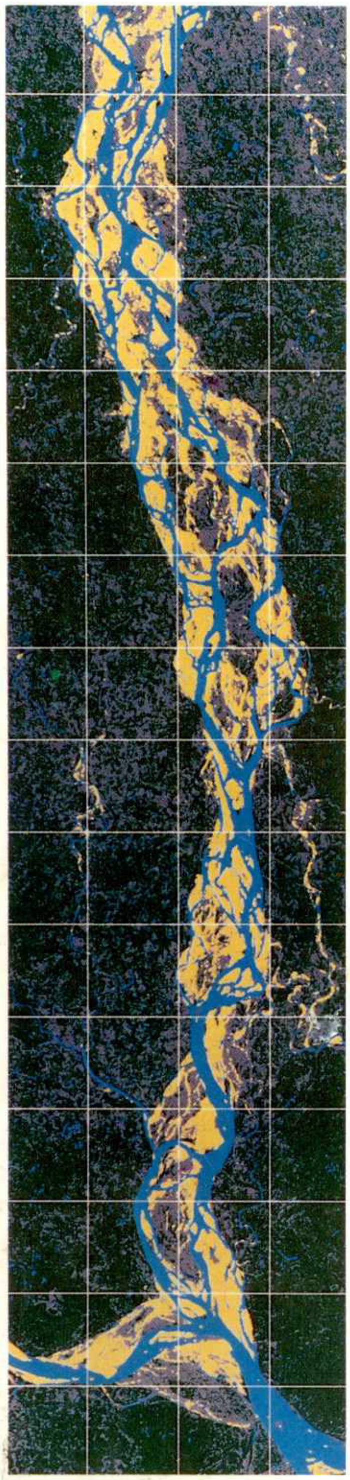
GOVERNMENT OF PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF WATER RESOURCES
WATER RESOURCES PLANNING ORGANIZATION

FEDERAL REPUBLIC OF GERMANY

KREDITANSTALT FÜR
WIEDERAUFBAU (KfW)

FRENCH REPUBLIC

CAISSE FRANCAISE DE
DEVELOPPEMENT (CFD)



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

TEST AND IMPLEMENTATION PHASE FAP 21

REPORT ON MONITORING AND ADAPTATION AT KAMARJANI TEST SITE

MONSOON 1998

DECEMBER 1999

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE
CONSULTING CONSORTIUM FAP 21/22

RHEIN-RUHR ING.-GES.MBH, DORTMUND/GERMANY
COMPAGNIE NATIONALE DU RHONE, LYON/FRANCE
PROF.DR. LACKNER & PARTNERS, BREMEN/GERMANY
DELFT HYDRAULICS, DELFT/NETHERLANDS

In association with:

BANGLADESH ENGINEERING & TECHNOLOGICAL SERVICES LTD. (BETS)
DESH UPODESH LIMITED (DUL)

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

TEST AND IMPLEMENTATION PHASE
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FAP 21/22

REPORT ON MONITORING AND ADAPTATION AT KAMARJANI TEST SITE

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LIST OF ABBREVIATIONS AND GLOSSARIES

AFPM	-	Active Flood Plain Management
BTM	-	Bangladesh Transverse Mercator
BWDB	-	Bangladesh Water Development Board
CFD	-	Caisse Francaise de Developpement
DGPS	-	Differential Global Positioning System
EDM	-	Electronic Distance Measurement
EGIS	-	Environmental Geographical Information System
FAP	-	Flood Action Plan
FPCO	-	Flood Plan Coordination Organization
G I	-	Galvanised Iron
GM	-	General Model
GoB	-	Government of Bangladesh
GPS	-	Global Positioning System
HW	-	High Water
KfW	-	Kreditanstalt für Wiederaufbau
Landsat	-	Land (Remote Sensing) Satellite
LW	-	Low Water
PWD	-	Public Works Department
RRI	-	River Research Institute
SLW	-	Standard Low Water
SPOT	-	System Probatoire d'Observation de la Terre
WARPO	-	Water Resources Planning Organization

1 INTRODUCTION

1.1 BACKGROUND

The Bank Protection Pilot Project is component 21 of the Flood Action Plan (FAP). It is jointly financed by Germany and France and was awarded by the Flood Plan Coordination Organization (FPCO) represented by the Kreditanstalt für Wiederaufbau (KfW) to the joint venture Rhein-Ruhr Ingenieur-Gesellschaft mbH as lead partner, Compagnie Nationale du Rhône, Prof. Dr. Lackner & Partners and Delft Hydraulics in association with Bangladesh Engineering and Technological Services Ltd. (BETS) and Desh Upodesh Ltd. (DUL).

As per Terms of Reference the Consultancy Services are to be performed in two phases, a Planning Study Phase (Phase I) followed by a Test and Implementation Phase (Phase II).

After submission of the Draft Final Planning Study Report in January 1993 a joint mission of KfW and CFD has carried out the project appraisal to proceed into Phase II of the Project. The Mission agreed to the overall concept of Phase II proposed by the Consultant the essence of which is the construction of a combination of permeable and impermeable groynes and of various types of revetments at two different test sites in two successive seasons.

The Test and Implementation Phase started on June 01, 1993 after the "Letter to Proceed" had been issued by FPCO on May 15, 1993.

The final design of the Groyne Test Structure at Kamarjani Test Site began in September 1993 and was finalised in February 1994 based on the preliminary design and construction methods of the Planning Study, supplemented by additional studies and investigations viz. morphological studies, geotechnical investigations, physical model tests in Bangladesh and France as well as topographic and hydrographic survey. The actual construction works started at the beginning of October 1994 and were substantially completed during the month of April 1995.

1.2 OBJECTIVES OF THE PROJECT

The objectives of the Project are to find improved solutions for bank protection works against erosion by designing, specifying and constructing different types of groynes and revetments using different materials and protective layers and investigating at the same time the suitability of local materials and construction methods. After construction of the test structures their behaviour is to be monitored for a period of at least three years. The final objective is to develop and optimise design criteria, cost-effective construction and maintenance methods, which shall serve as future standards, most appropriate for the prevailing conditions at the Jamuna and other rivers of Bangladesh. Hence, the test structures were to be designed in such a way and with such a level of safety that certain damages of the structures are allowed, are even required, because a test work which does not suffer any damage in the course of the monitoring and adaptation period may be oversized and therefore not be suitable to identify the limits and to develop new standards.

To achieve the above objectives, regular monitoring of the test structures is a must after their completion as well as preventive maintenance and adaptation of the structures taking into account the results and observations of each monitoring period. For the development of suitable adaptation measures, however, further studies and investigations are possibly required.

2 THE STRUCTURE

2.1 DESCRIPTION OF THE GROYNE TEST STRUCTURE

The test structure as per original design of 1993/94 comprised 6 groynes each of them a combination of an impermeable and a permeable section with increasing permeability towards the river. Three groynes (G-1 to G-3) were partly constructed off-shore and on-shore while the other ones G-B1, G-B2 and G-A were built on the flood plain. All six structures launch from and were built against an embankment constructed under the authority of the Bangladesh Water Development Board (BWDB) (see Fig. 2.1).

The main components of the groyne test field are the groynes G-1 to G-3, whereas G-B1, G-B2 and G-A, which were built upstream and downstream respectively from the main groynes are intended to supplement the functioning and effects of the latter in the coming years.

A detailed description of the test structure is given in the "Report on Monitoring and Adaptation" of September 1996.

2.2 DAMAGES

2.2.1 Damages during the Monsoon 1995

The structure was "tested" by the river for the first time during the flood season 1995, which was marked by five flood peaks of which three represented events with more than 10 years re-occurrence and a maximum water level on July 10, 1995 corresponding to a situation of about 25 years re-occurrence.

The first four flood peaks contributed to three major damage events within the test site area:

- destruction of the impermeable groyne head of groyne G-2 and loss of piles of the permeable section;
- breach of the main embankment about 80 m downstream from groyne G-2, and
- collapsing of the impermeable part of groyne G-3 at the downstream side and destruction of the impermeable groyne head.

For details reference is made to the "Report on Monitoring and Adaptation" of September 1996.

2.2.2 Damages during the Monsoon 1996

No damages to the individual groynes had been observed throughout the entire monsoon season 1996. Only the water sided slope of the main embankment above the berm at 21.0 m+PWD between groyne G-1 and G-2 as well as between G-2 and G-3, which was protected up to the crest at 23.50 m+PWD by Durba grass sods on Geo-jute soil saver, was damaged by wave action.

Moreover, during heavy rainfall in September and October 1996 the crest and the land sided slope of the main embankment were damaged by rain cuts. For details reference is made to the "Report on Monitoring and Adaptation" of September 1998.

2.2.3 Damages during the Monsoon 1997

Throughout the entire monsoon season 1997 no damages to the individual groynes and the embankment, from which they launch, have been observed.

The first half of the year was characterised by minor morphological changes of the riverbed in the test field area due to the char in front of the test structure. However, downstream from the test site in the area of Rasulpur and Syedpur severe bank erosion occurred.

The char in front of the test structure extended further southwards resulting in shifting of the main channel direction from west to south-west. The bathymetric surveys show the changes from 255° in May to 225° in July and 195° in August. The flow attack and bank erosion moved to the south concentrating in July on the area between Syedpur and Balashi Ghat, where flow velocities of 2.5 m/s were measured.

The southward extension of the opposite char continued also during the month of August, whereas the narrow channel just in front of the test structure continuously reduced its width and depth at the same time. It started to dry up in October and this process was completed in November, when no flow was observed. Moreover, the importance of the cut-off channel opposite the test site increased significantly in August.

North of Kharjani char a mid channel bar developed, which caused a movement of the main Kamarjani channel to the west and in November the Kamarjani channel divided into two channels, the western one of which was more dominant.

In the outer bend channel between Syedpur and Balashi Ghat severe erosion was observed and end of December 1997 also the last downstream groyne of the Kamarjani Test Structure came under attack again.

2.3 ADAPTATION WORKS

The initial findings of causes of damages in 1995 and the results of additional physical model tests performed in November/December 1995 at the River Research Institute at Faridpur had identified improvement and adaptation measures, which had to fulfil mainly the following conditions:

- to substantially reduce the magnitude of return currents and vortices within the groyne field in particular along the main embankment, and
- to further limit the development of severe return currents, turbulence and vortices.

For the design of adaptation and repair measures, the design parameters as per original design of the groyne structure were being maintained. Only the downstream part of the impermeable groyne heads received substantially increased launching aprons.

Since the main river attack during the monsoon season 1996 was expected downstream from groyne G-A threatening the main embankment near the Manos river estuary, it was decided to provide a new supplementary groyne G-A/2 about 200 m downstream from G-A.

The main adaptation and repair measures during the dry season 1995/96 were as follows:

- relocation of the main embankment starting about 30 m downstream from groyne G-1 up to about

150 m downstream from groyne G-3. The retired embankment is now 20 m behind the original one between groyne G-1 and G-2 and 50 m between groyne G-2 and G-3;

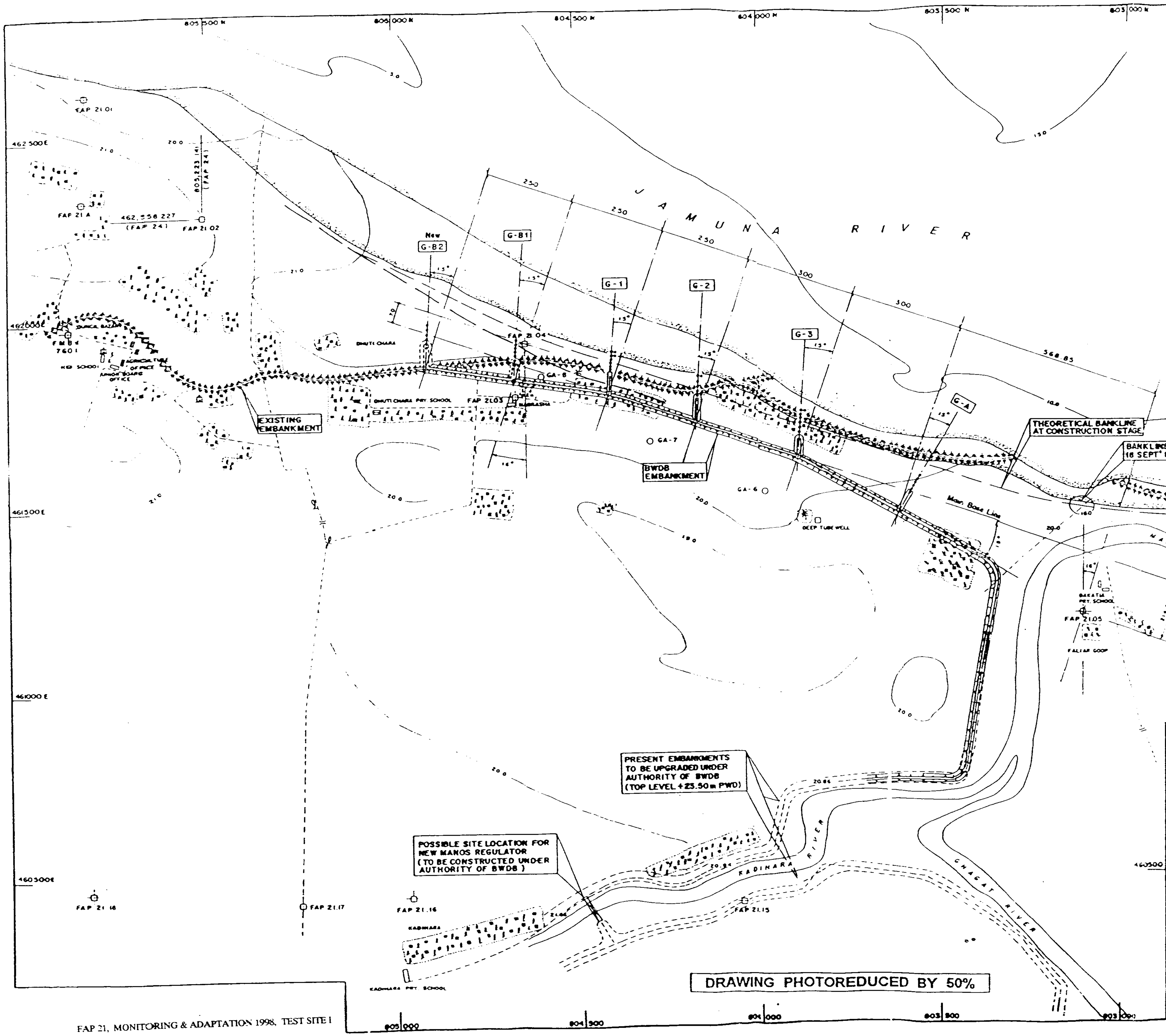
- slope protection by cc-blocks/boulders at the head of the steel sheet pile cofferdam of groyne G-1;
- driving of 44 Nos. tubular steel piles dia. 711 mm between the existing pile structure of groyne G-3 and the retired main embankment after removal of the remaining part of the impermeable groyne section;
- toe-protection of the retired embankment by cc-blocks upstream and downstream from the pile structure of groyne G-3;
- pile Nos. 21 to 24 (tubular steel piles Ø 711 mm) of groyne G-A were extended by 4.5 m and re-driven. Moreover, the pile structure was extended to the river side by 3 additional tubular steel piles Ø 1016 mm. Since 5 Nos. of totally 12 Nos. bored piles Ø 914 mm got lost during and after the monsoon season 1995 a row of additional 9 Nos. tubular steel piles Ø 711 mm have been installed 2.5 m upstream from the bored piles. The total length of the pile structure is now about 78 m;
- the new groyne G-A/2 consists of 20 Nos. bored piles Ø 914 mm and 14 Nos. tubular steel piles Ø 711 mm. The total length of the groyne is about 92 m from the centre of the main embankment;
- the river-sided slope of the retired embankment was protected between groyne G-1 and G-2 up to a level of 21.0 m+PWD by brick-mattresses and above up to the crest at 23.50 m+PWD by Durba grass sods on Geo-jute soil saver. The same holds for the section between groyne G-2 and G-3. Downstream from groyne G-3, between groyne G-A and G-A/2 as well as downstream from groyne G-A/2 the brick-mattresses are up to the crest of the embankment;

During the dry season 1996/97 the following adaptation and repair measures were carried out:

- replacement of grass sod protection in all areas by brick mattresses on geotextile filter up to the crest of the main embankment;
- repair of the crest and land sided slope of the main embankment, and
- driving of 23 Nos. steel piles Ø 711 mm and 32 m length at groyne G-2.

During the dry season 1997/98 the adaptation and repair works, which were required after the monsoon 1995, were completed by the construction of 12 Nos. reinforced in-situ concrete piles between the toe of the relocated main embankment and the pile structure of groyne G-2.

The general layout of the test structure after execution of adaptation and repair works is shown in Fig. 2.2.



Control. Point Schedule			
No. of Control Points	Co-ordinates (BTM) Easting	Co-ordinates (BTM) Northing	Elevation (m) (PWD)
FAP/21.01	462,627.053	805,806.859	21.418
FAP/21.02	462,291.196	805,502.408	21.600
FAP/21.03	461,792.210	804,651.047	21.552
FAP/21.04	461,935.686	804,621.661	20.677
FAP/21.05	461,202.019	803,095.930	21.562
FAP/21.14	460,095.848	803,167.593	21.653
FAP/21.15	460,414.972	804,038.757	22.051
FAP/21.16	460,435.320	804,952.676	21.496
FAP/21.17	460,417.153	805,240.781	21.773
FAP/21.18	460,448.563	805,787.523	21.135
FAP/21.A	462,336.863	805,815.424	21.511
FAP/21.D	461,118.195	802,222.598	22.226

LEGENT

- EMBANKMENT
- ROAD PUCCA, KACHA, FOOTPATH
- HIGH RIVER BANK
- HOUSE PUCCA, KACHA & TIN SHED
- TRAVERSE STATION & PILLAR
- HOMESTEAD
- MOSQUE
- BORING POINT

Notes.

1. Levels refer to ± 0.0 m PWD
2. Reference Drawings:
   - KA-003/1 Detailed Layout of Groynes
   - Survey drawings of Hydroland Survey Ltd Dhaka (1992/93)

REVISION	DATE	NAME	DESCRIPTION	APPROVED
2	07.8.95	ANOWAR	AS BUILD DRAWING	
1	13.10.94	ANOWAR	Implementation Layout	

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN COORDINATION ORGANIZATION (FPCO)

BANK PROTECTION PILOT PROJECT FAP-21

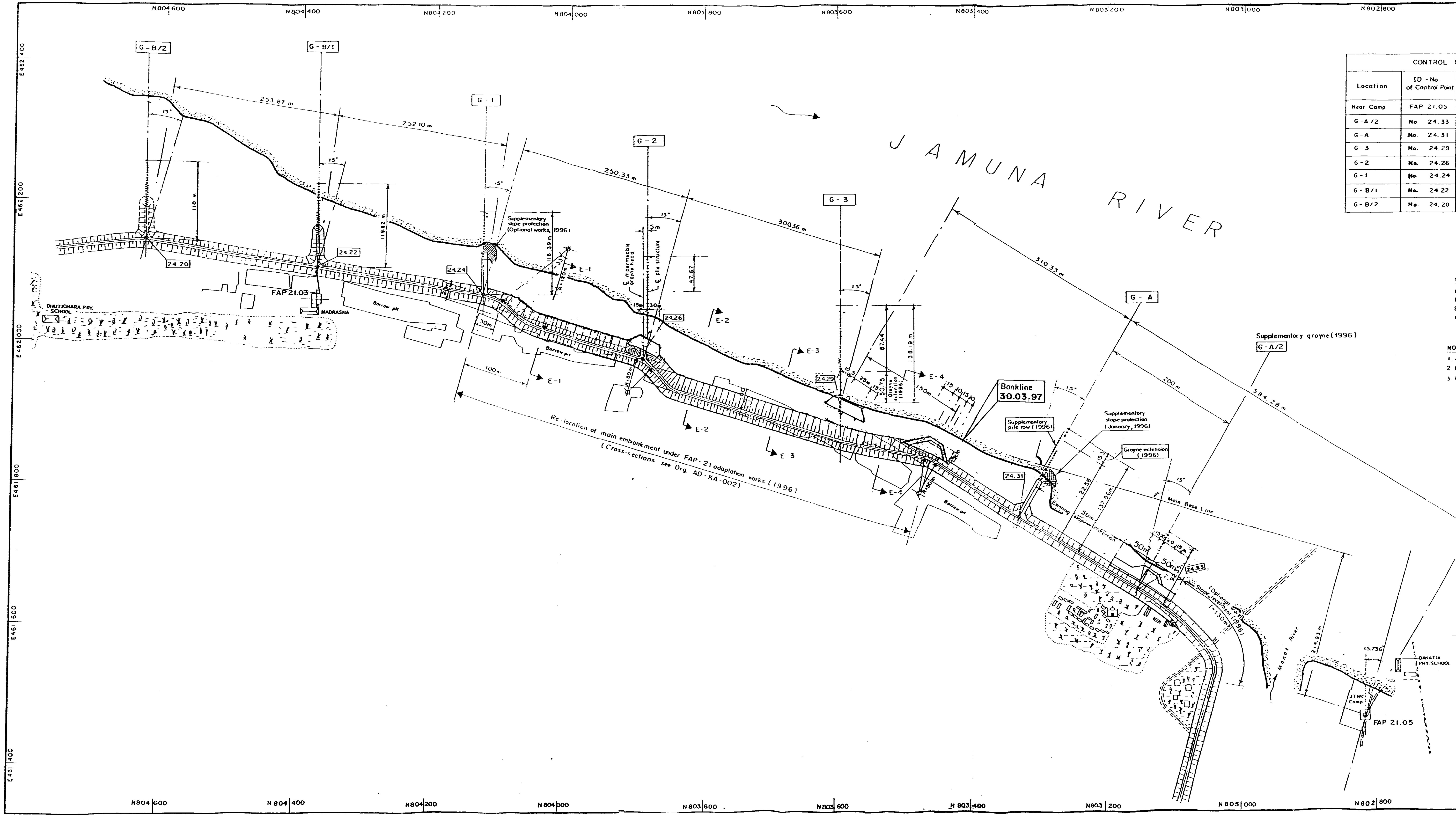
CONSULTING CONSORTIUM

TEST SITE I - KAMARJANI

GENERAL LAYOUT OF IMPLEMENTATION PROPOSAL

	NAME	DATE	SCALE: 1 : 5000
DRAWN	ANOWAR	22-09-94	
CHECKED		22/09/94	FIG. 2.1
APPROVED			REVISION 2

26



CONTROL POINT SCHEDULE

Location	ID - No of Control Point	Co-ordinates BTM (FAP 24) Easting	Northing	Elevation (m PWD)
Near Camp	FAP 21.05	461,479.517	802,817.795	+21.920
G-A/2	No. 24.33	(to be established)		
G-A	No. 24.31	461,763.470	803,328.440	+23.335
G-3	No. 24.29	461,922.160	803,595.130	+23.258
G-2	No. 24.26	462,003.780	803,884.190	+23.446
G-1	No. 24.24	462,071.690	804,125.130	+23.390
G-B/1	No. 24.22	462,106.970	804,374.750	+23.404
G-B/2	No. 24.20	462,142.470	804,626.130	+23.954

LEGEND

Homestead
Borrow pit
Bankline
Control points

NOTES

1. All measurements in meters.
2. Levels refer to ± 0.00 m PWD.
3. Reference Drawings:

AD-KA-002 Cross-Sections of Main Embankment
AD-KA-003 Main Embankment, Details of Revetment
AD-KA-010 Groyne G-1, General Layout Plan
AD-KA-020 Groyne G-2, General Layout Plan
AD-KA-030 Groyne G-3, General Layout Plan
AD-KA-040 Groyne G-A, General Layout Plan
AD-KA-050 Groyne G-A/2, General Layout Plan

0 50 100 200 m
Scale 1 : 2000

REVISION	DATE	NAME	DESCRIPTION	APPROVED
4	29.4.97	Anowar	Change of BANK LINE	
3	27.1.97	Anowar	As BUILT DRAWING (Adaptation works)	
2	8.8.96	ANOWAR	AS BUILT DRAWING	
1	28.01.96	ANOWAR	Revetment near G-A/2	

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
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FLOOD PLAN COORDINATION ORGANIZATION (FPCO)

BANK PROTECTION PILOT PROJECT FAP-21

JAMUNA TEST WORKS CONSULTANTS, JOINT VENTURE

TEST SITE I - KAMARJANI
-ADAPTATION WORKS-

ADAPTATION OF TEST STRUCTURES
GENERAL PROJECT LAYOUT

	NAME	DATE	SCALE: 1 : 2000
DRAWN	ANOWAR	10-01-96	
CHECKED		15-01-96	
APPROVED			

FIG. 2.2 REVISION 4

3 MONITORING OF THE TEST STRUCTURE

3.1 GENERAL

Since the final objective of this pilot project is to develop and optimise design criteria, cost-effective construction and maintenance methods, which will serve as future standards appropriate for the prevailing conditions at the Jamuna and other rivers of Bangladesh, regular monitoring of the structures after their completion till end of the project is one of the focal points of this pilot project.

Monitoring of the works undertaken at the test sites shall help to
- detect damages at an early stage;
- understand failing mechanisms, and
- plan suitable adaptation/repair works.

However, monitoring does not only refer to detecting damages of the structure but to observe their behaviour under load and to relate the loads to the structure's response. This requires on the one hand to monitor the loads (especially flow velocities, wave action etc.) and on the other hand to adapt the design rules. After adapting the design rules and the design, the works are to be adapted accordingly. Hence, the requirements of monitoring are to take care of the structures features as well as on the loads and natural effects, which may influence the structures. Records are therefore to be taken of
- the natural conditions acting at the structures (water level rise and fall, waves, currents, wind, precipitation etc.);
- the morphological changes of the river in the area of the test structures;
- the movements of structures and important structural parts in vertical and horizontal direction;
- the deterioration of materials used;
- the variations of the surrounding riverbed and bankline, and
- any damage by human and/or animal action.

Thereby it is of utmost importance for drawing right conclusions to record the above information with respect to
- exact location (referred to fixed points established in the hinterland);
- exact time of occurrence/survey;
- method of recording and equipment used;
- staff involved, and
- special observations etc.

All observations and data are entered in a Logbook developed for this particular purpose, which at the same time serve as a checklist for completeness of monitoring. Besides the results of regular hydrographic surveys, the Logbook is a basis for evaluation and selection of necessary measures to be taken. The Logbook and associated records enable to keep a continuous record of events showing the development of failure mechanisms and interrelation with acting forces.

Apart from daily routine observations, regular and periodic inspection programmes are carried out for each and every subject. However, time intervals have to be shortened in case deterioration is expected to increase not in line with the expectations and linear but at an accelerated pace. Additional inspections are required after extraordinary loading conditions, accidents etc.

The monitoring activities are subdivided into two main categories:

- survey of the properties and the behaviour of the structures, and
- reference measurements of physical phenomena that produce the loads on the structure.

The survey carried out under the monitoring programme is as follows:

- Logbook of activities and daily observations;
- Priority/alert information to FAP 21, Dhaka;
- Bathymetric surveys and recording;
- Water level recordings;
- Wind and wave recordings;
- Current measurements;
- Flow direction measurements;
- Topographic measurements;
- Bankline surveys;
- Groyne alignment, pile position;
- Meteorological measurements;
- Test pile recordings;
- Floating debris at groynes;
- Visual wave observations;
- Site processing quality control of data;
- Data transfer to FAP 21, Dhaka, and
- Detailed damage surveys during/after the flood period.

Final quality control of site data, final processing, presentation and evaluation is done in the office in Dhaka. The tasks are the following:

- Quality control of field monitoring;
- Final processing/presentation of survey results;
- Determination/confirmation of priority/alert situation;
- Initiation of emergency measures;
- Statistical evaluation of wind/wave records;
- Evaluation of water level recordings;
- Evaluation of current measurements;
- Comparison of results with applied design criteria, and
- Comprehensive annual report on results of field monitoring.

The organisation of the monitoring activities and adaptation of works have been explained in more detail in the "Report on Monitoring and Adaptation" of September 1996.

3.2 MONITORNG DURING THE MONSOON PERIOD 1998

3.2.1 Preliminary Remarks

During the dry season 1997/98 and the monsoon season 1998 the monitoring activities at Kamarjani Test Site were performed following the programme described in Section 3.1. Summaries of all activities have been reported in monthly monitoring reports. The progress of the whole project including the main results and observations of monitoring is reported in quarterly progress reports. In 1998 progress reports No. 19 to 22 have been published.

3.2.2 Bathymetry

Bathymetry surveys were done regularly to detect and record planform and riverbed changes and their influence on the stability of the test structure. The activities during the months of June to December 1998 are shown in Table 3.1. However, in the post-monsoon season after September 1998 bathymetry surveys within the groyne field were not possible due to sedimentation and the actual water levels.

The results of the main surveys from June to December are presented in Annex B and some differential models in Annex D.

3.2.3 Topographic Measurements

The topographic measurements were done by using **E**lectronic **D**istance **M**easurement (EDM) equipment and levelling instrument. During the period from June to December the following works were performed:

19/06	position of new Manors Regulator
07/07	waterline of Batkamari char
15/08	polygon survey from Kamarjani test site to Balashi Ghat
02/09	survey of Kamarjani market
22/09	survey of Kamarjani market
25/09 to 27/09	bankline from Kamarjani market to Balashi Ghat
28/09	survey of char opposite the groyne field
29/09	waterline of Kharjani char
29/10	bankline from groyne G-A to Rasulpur
17/11	bankline from Ghagot river to Balashi Ghat
23/12	bankline from Kamarjani market to Balashi Ghat
23/12 to 26/12	survey of char opposite the groyne field
28/12	bankline from Kamarjani market to Balashi Ghat
29/12	survey of char opposite the groyne field

3.2.4 Measurement by the Monitoring System

The monitoring system is located at groyne G-2 and recording water level information, wave heights and periods, test pile inclination and acceleration, wind speed and direction as well as other meteorological data like temperature, precipitation and relative humidity. Data are shown in the monthly reports on monitoring of the test structures.

Date	Survey Area						
	June 1998	July 1998	August 1998	September 1998	October 1998	November 1998	December 1998
01							
02							
03							
04							
05							
06							
07							
08		groyne field					
09			groyne field				
10							
11							
12							
13							
14							
15							
16							
17				groyne field			
18							
19							
20							
21							
22		main survey	main survey				
23	main survey	main survey	main survey	main survey		main survey	main survey
24	main survey	main survey	main survey	main survey		main survey	main survey
25	main survey	main survey	main survey	main survey		main survey	main survey
26	main survey	main survey	main survey	main survey	main survey	main survey	main survey
27	main survey		main survey	main survey	main survey	main survey	main survey
28	main survey		main survey	main survey	main survey		main survey
29	main survey		main survey		main survey		main survey
30	main survey	main survey			main survey		
31							

Table 3.1: Bathymetric survey at Kamarjani Test Site from June to December 1998

3.2.5 Measurement of Flow Velocity and Direction

Float track measurements were continued as well as measurements with the Valeport currentmeter. Results are presented in the monthly reports on monitoring of the test structures.

In addition, current measurements were carried out by a team of "Labor für Wasserbau" of Hochschule Bremen, Germany with drifter buoys using DGPS from mid June till end of July 1998. Results were presented in the report on "Current Measurements at Kamarjani, Katlamari and Bahadurabad" published in February 1999.

3.2.6 Observations

At the beginning of 1998 the water level was measured at 15.00 m+PWD, but continued to drop till about mid February. The minimum was recorded at 14.52 m+PWD on February 11, 1998. After a period with only minor fluctuations the seasonal rise started at about March 23 and at the end of March a water level of 16.06 m+PWD was measured. The peak of the first half of the year of 21.59 m+PWD was reached on June 14.

During the third quarter of the year the situation at the test site was characterised by exceptional high water levels, which remained from beginning of July till September 08 above 21.40 m+PWD. Three peaks were recorded viz. 22.14 m+PWD on July 26, followed by 22.22 m+PWD on August 19 and 22.46 m+PWD on September 07. The average water level in July was the highest one of July during the last 4 years and about 1 m higher than in July 1997. The total rainfall in July was 767 mm, which was significantly higher compared to the other years after 1995. Also in August 619 mm rainfall was recorded which was 370 mm more than in August 1997. And even in September 301 mm were measured.

The average water level in August was 1.9 m higher than in August 1997 and that one of September 1.45 m above the average in September 1997. The water level started to fall at the beginning of September and its changes during the month of October were rather unusual. In the first half of October water levels were measured, which were even below the minimum level observed in the period 1957 to 1989. After a sharp rise of about 2 m within 9 days only a peak at 19.89 m+PWD was measured on October 27. This water level was higher than ever observed during the period 1957 to 1989. The next day the water level started to fall and this drop continued till the end of the year. However, the curve remained above those of the years 1995 to 1997.

The following observations have been recorded for the period June to December 1998:

06/06	slow bank erosion due to wave action from old camp to further 500 m downstream
10/06	wind speed of 8-10 m/sec moving from east to south-east. Wave heights of 0.5 m observed
13 to 14/06	reverse flow observed downstream from G-1
14/06	Excessive suspended materials by river flow comparing to previous years. 120x40x0.4 m floating debris found at G-2 200x100x0.15 m floating debris found at G-3
07 to 14/06	significant amount of floating debris observed during this period
06/07	floating debris stuck into the groynes G-1, G-2, G-3 and G-A

09/07	new considerable amount of floating debris stuck into the groynes G-2, G-3 and GA
17/07	Manos regulator opened to discharge water from countryside
19/07	From 8:00 a.m. 112 mm rainfall (measured) within 24 hours
23/07	Heavy wave activity on the river, wave heights of 0.5 to 0.7 m are observed u/s from Balashi ghat
03/08	floating debris stuck into the groyne G-1, G-2 G-3 and G-A
06/08	heavy wave and wind activity in the river, wave heights of 0.2 to 0.3 m and wind of 2 to 5 m/s from south-east observed
11/08	wind speed 7 m/s, wind direction 121°
15/08	wind speed 3 m/s, wind direction 14°
	floating debris stuck into the groynes G-1, G-2and G-A
17/08	floating debris stuck into the groynes G-B1, G-B2, G-1, G-2, G-3 and G-A
19 to 31/08	considerable amount of floating debris observed all over the groyne field area
01 to 30/09	continuous erosion at Kharjani char
	Kundarapara cut-off channel getting deeper and wider
	slow bank erosion from Rasulpur to 200 m d/s from Balashi ghat
02/09	heavy rainfall of 112 mm recorded
	floating debris stuck into the groynes G-1, G-2, G-3, G-A and G-A/2
04 to 12/09	considerable amount of floating debris observed at G-B1, G-1, G-2 G-3 and G-A/2
12/09	wind speed 5 m/s; wind direction 124°
15/09	wind speed 9 m/s; wind direction 195°
24/09	wind speed 5 m/s; wind direction 356°
26/09	wind speed 3 m/s; wind direction 214°
01 to 30/10	slow bank erosion from Rasulpur to Balashi ghat
01/10	floating debris stuck into groynes G-1, G-2, G-3, G-A and G-A/2
20/10	wind speed 6 m/s; wind direction 20°
21/10	wind speed 7 m/s; wind direction 346°
	due to local scour little bank erosion about 25 m u/s and 20 m d/s from G-1
23/10	bank erosion observed just d/s from the confluence of the Ghagot and the Jamuna river
26/10	huge floating debris (grass and banana tree) observed all over the test site
01 to 30/11	slow bank erosion from d/s from Syedpur to Balashi ghat
19 to 30/11	slow char erosion in front of groyne field
01/12	slow bank erosion from d/s from Syedpur to Balashi ghat
02 to 17/12	huge bank erosion from Rasulpur to Balashi ghat
03/12	wind speed 3 m/s; wind direction 326°
18 to 31/12	slow bank erosion from Syedpur to Balashi ghat

The events during the year 1998 can be summarised as follows:
During the first quarter of the year severe erosion continued in the outer bend channel between the confluence with the Manos river and Balashi ghat. In the area of Syedpur flow velocities of more than 1.9 m/s were measured in January and more downstream about 1.6 m/s resulting in a serious threat of the embankment, which was only about 250 m away from the river. This process continued also in February when maximum erosion of 60 m was measured, but slowed down during the month of March.

However, at the same time the flow velocities and the erosion increased at the char in front of the Groyne Test Structure.

During the months April and May slow bank erosion continued downstream from the groyne field up to Balashi ghat. This erosion process slowed down when the Kundarapara cut-off channel continued to develop in June. No attack on the groyne field had been observed during the second quarter of 1998.

The site surveys at the test site showed only shallow water with maximum scour depths downstream from groyne G-1 and G-2 of 10 m in July and 7 m in August. The bank erosion process between the test site area and Balashi ghat continued. At the same time the depth and the width of the Kundarapara channel continued to increase.

However, during the last quarter of the year the Kundarapara channel was declining. Discharge calculation showed that in December the Kundarapara channel was carrying 14 % of the total flow only whereas it had been 32 % in November and 44 % in October. At the same time bank erosion continued from Rasulpur to Balashi ghat. The progress of shifting of the bankline downstream from the structure for the period December 1995 to December 1998 is presented in Annex E. It shows that since February 1998 a maximum erosion of about 300 m occurred in the area of Rasulpur.

3.2.7 Physical Model Tests

From September 1997 to end of January 1998 ten additional physical model tests were performed in the River Research Institute in Faridpur, the objective of which was

- to investigate the causes of damages observed in 1995, and
- to gain more information/knowledge of the behaviour of the groynes/groyne field in order to be in a position to formulate design rules at the end of the Project and to work out guidelines and manuals for their application.

The tests have shown that the impermeable groyne head always lead to the creation of considerable eddies d/s from the structure and return currents along the bank between two successive groynes. The bank velocity was locally about 1.5 m/s, which was too high to avoid further bank erosion. It was not possible to reduce this bank velocity by increasing the length of the impermeable section. Furthermore, the development of a scour hole at the downstream side of the impermeable groyne section was confirmed. Since it is difficult to protect efficiently this part of the groynes, it was recommended on the basis of the test results to use permeable groynes only without any impermeable sections. They are more efficient to limit the flow velocity along the bank and to avoid the generation of eddies and return currents.

The ratio between the spacing of the groynes and the total length from the embankment to the groyne head is recommended between 2 and 2.5. The slope of the embankment should be protected by a revetment to resist a flow velocity of about 1 m/s and in order to limit the risk of blockage by floating debris it is recommended to built submerged or gradually submerging groynes only.

Details of the investigations and recommendations are presented in the Technical Report No. 6 of April 1998.

4 ANALYSIS OF THE MONITORING SURVEYS

4.1 INTRODUCTION

The monitoring of the Kamarjani test site in 1998 followed basically the same set-up as in the previous years. The main aspects of the monitoring described in this chapter are the meteorological conditions (Section 4.2), the characteristic maximum hydraulic load on the test structure by water levels, flow velocities, waves and floating debris piled up against the groynes (Section 4.3).

4.2 METEOROLOGICAL CONDITIONS

The rainfall intensity had been measured at the camp daily and registered in the logbooks (see Fig. 4.1). A high rainfall intensity of 142 mm had been measured on May 25. Also October 20 and 21 were rainy days with 310 mm rainfall in total. A comparison of the rainfall measured in Kamarjani and in Bahadurabad shows significant differences, which illustrates the local character of rainfall.

The wind speed and the wind direction were estimated daily at a certain time. Therefore, the values are not necessarily representative for the whole day. During 1998 the maximum wind speed is 10 to 11 m/s and only seven times a wind speed higher than 6 m/s was measured (see Fig. 4.2). The wind direction varied widely during most of the year, but from April to July it was remarkably constant from south-east direction (see Fig. 4.2).

The meteorological station at G-2 had been out of order from March 22 until July 02. But even after that date the operation of this monitoring station had been interrupted frequently for various reasons. The wind threshold parameter was set to 20 m/s to keep continuos normal mode data logging. The monitoring system had registered a maximum wind speed of 11 m/s on July 03, but in the logbook only 6 m/s had been mentioned on the same day. Also on October 20 a maximum of 10 m/s was registered and in the logbook only 6 m/s were mentioned. This indicates that the manual observations might underestimate the daily maximum wind speed.

4.3 HYDRAULIC LOAD

4.3.1 Introduction

The hydraulic load on the groynes by the river has the following components:

- maximum water levels,
- maximum flow attack and
- maximum wave attack.

The water levels have been measured on a daily basis throughout the whole year (Subsection 4.3.2) and the flow velocities in different ways during special surveys (Subsection 4.3.3). The hydraulic load on the groynes and the embankment by waves was very small in 1998, see Subsection 4.3.4.

4.3.2 Water Levels

The water level was measured at two staff gauges, which were located near G-A and upstream from G-1. The reading of the staff gauges was scheduled normally at 8.00, 13.00 and 17.00 hours daily. In general, the readings at G-A from 8.00 hours were used as a daily averaged value presented in hydrograph (see Fig. 4.3). The accuracy of the reading is estimated at ± 0.01 m.

The hydrograph observed at the test site during the 1998 monsoon had 5 peaks above 21 m+PWD, similar to the hydrograph measured at Bahadurabad. The peak flows in July and August were observed about 0.5 day earlier in Kamarjani than in Bahadurabad, which is a more downstream gauge station. However, the maximum water levels in the peak flows were all below the design water level of 22.50 m+PWD, which corresponds about to a 25 years return period (see Table 4.1). The maximum peak level of 22.44 m+PWD was slightly higher than the maximum peak level of 22.38 m+PWD observed in 1995.

During the receding limb of the hydrograph an unexpected local peak water level at 19.89 m+PWD had been measured on October 27, probably because an upstream dam had released discharge. This peak discharge had been smaller and later in 1995 and 1996 (see Fig. 4.3) and it did not occur in 1997.

Peak flow	Date	Time reading	Gauge GA	Estimated return period
			m+PWD	years
1	June 14 June 15	17.00 08.00	21.63 21.57	2
2	July 14 July 15	17.00 08.00	22.11 22.09	5 to 6
3	July 26	08.00	22.14	6 to 7
4	August 19	08.00	22.22	7 to 8
5	September 07 September 08	13.00 08.00	22.46 22.44	20 to 25

Table 4.1: Maximum peak water levels

The duration curve of the water levels shows that the water level was above the bankfull level of 20.5 to 21 m+PWD for an extreme long period of about 3 months (Fig. 4.4). During this period the floodplain had been inundated almost permanently. In the previous years the low water levels from January to March were very close to each other, but in 1998 these water levels were about 0.1 to 0.2 m higher, probably because of changes in the planform of the river. It is interesting to compare the duration curve of Kamarjani with the duration curve of Bahadurabad, where the low water levels were about 0.1 to 0.2 m lower than the previous years. This tendency is just contrary as seen in Kamarjani. The comparison of the peak levels shows that in Bahadurabad the maximum water level in 1998 was below the maximum in 1995 and in Kamarjani the same comparison shows that the maximum water level in 1998 was higher (only 0.06 to 0.08 m) than the maximum in 1995. In a braided river like the Jamuna the planform can have some influence on the peak levels and this has been studied in detail by the River Survey Project (1996) to explain the yearly differences in the stage-discharge relation in Bahadurabad.

The daily reading at G-A had been made without any interruption throughout the year. The upstream water levels had been read at the gauge upstream from G-1 from January 01 to March 24. At the landside of the embankment near G-A the water level had been read from July 05 to December 01 when the floodplain had been inundated (see Fig. 4.5). The water level on the floodplain was below the water level in the river before July 16. After that date the water level at the landside gradually becomes higher than in the river. In October and November this difference increased up to 1.5 to 2 m. This means that during the end of the monsoon flood the water level at the landside was about 0.5 to 1.5 m higher than in the river. This causes generally a groundwater flow through the embankment towards the river and this might reduce the stability of the protection layers of the embankment. However, this was not at all the case during the 1998 monsoon flood.

The rise and fall of the water level in G-A had been determined from May 01 to October 01 (see Fig. 4.6). During the rising limb of the hydrograph the water level raised maximum 0.02 to 0.04 m per hour. A maximum rise of 0.78 m per day had been recorded on May 27 and the next day the water level raised with 0.85 m. This rise was extremely high and had not been observed in a 25 years period from 1965 to 1990 in Bahadurabad. The heavy rainfall a few days earlier might have contributed to this sharp rise of the water level. On May 23 and 25 a 130 and 142 mm rainfall had been recorded in Kamarjani. Although the maximum water level rise was about 0.16 m per hour in Bahadurabad during the same period, the maximum daily rise was 0.72 m on May 27 and 0.69 m the next day. These extreme rises of the water level after 1994 indicate a systematic change in the hydrograph. Probably this is due to the construction of the Jamuna Bridge.

4.3.3 Flow Velocities

In April the Kamarjani channel flew with a velocity of 0.5 to 0.6 m/s close to groyne G-A and it exerted small flow attack on G-A/2. In May all the groynes stood in stagnant water, only the outer piles of GA-2 experienced low flow velocities, but in the period from May 17 to 28 water started to flow in the channel in front of the groyne field. Labor für Wasserbau (LfW) of Hochschule Bremen made float tracking in the groyne field from June 19 to 23. From June 30 to July 06 the flow velocities measured by float tracking varied from 1.0 to 1.2 m/s in front of the groynes, however, upstream the channel was more shallow and the flow velocities were higher, namely 1.3 to 1.4 m/s (see Fig. 4.7). In the small channel in front of the groynes float tracking were also made from July 17 to 27, September 29 and October 29 (see Table 4.2). Most float tracks were in the channel and passed the groynes at a short distance of 10 to 70 m from the outer piles.

Flow velocity verticals have been measured near the groynes by Valeport in July and August. The depth averaged flow velocity in the channel varied from 0.9 to 1.1 m/s in the scour holes where the depth varied from 5 to 10 m during the second peak flow on July 11 and 13 (see Fig. 4.8 and 4.9). The depth averaged flow velocity varied from 1.3 to 1.5 m/s in the flow line passing the outer piles where the water depth varied between 3.5 to 5 m during the rising limb of the fourth peak flow on August 16 and 17 (see Fig. 4.10 and 4.11). In Fig. 4.12 these flow velocities are compared with the hydrograph and preliminary curves have been sketched to show the overall tendency in the flow velocities. The maximum flow velocity (about 1.6 m/s) is much lower than the design flow velocity.

Date	Flow velocity out of outer piles by float tracking (m/s)	Flow velocity in groyne field by Valeport (m/s)
May 20-22	0	0
June 19-23	LfW	LfW
June 30-July 06	1.0 to 1.2	
July 11-13		0.9 to 1.1
July 17–27	1.4	
August 16-17		1.3 to 1.5
September 29	1.1 to 1.4	
October 29	0.8 to 1.0	
November 23-27	0	0

Table 4.2: Measured flow velocities near the groyne field

4.3.4 Wave Attack

Maximum wave heights did not coincide with the maximum wind speed, probably because of the sheltered location of the monitoring station at G-2, where a maximum wave height of 0.73 m was measured on September 06 (see Table 4.3). In the Logbook sometimes visual observations had been mentioned. For example, on June 10 the wave height in the channel was estimated at 0.50 m and on August 08 and 13 at 0.20 to 0.30 m with wind from south-east. The measured wave heights were lower than the design wave height, but still relatively high in the shallow channel in front of the groynes.

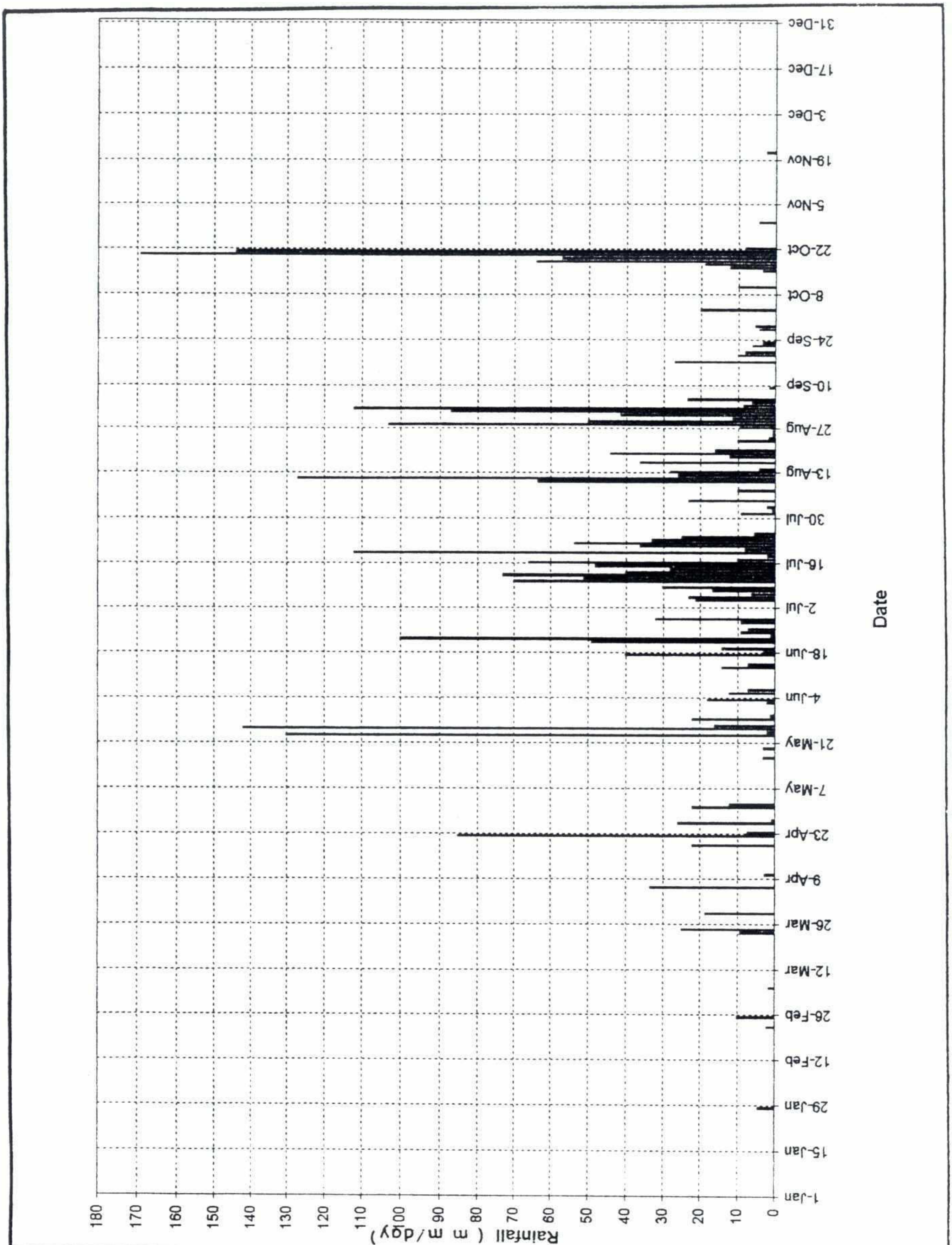
Date	Time	Wave height (m) (>0.2 m)	Wind speed (m/s) (>10 m/s)
03/07/98	14:51	0.20	-
03/07/98	18:01	-	11
11/07/98	05:24	0.25	-
13/07/98	08:20	0.23	-
13/07/98	09:10	0.20	-
13/07/98	10:20	0.21	-
13/07/98	10:50	0.21	-
13/07/98	17:20	0.20	-
13/07/98	18:00	0.23	-
13/07/98	20:10	0.21	-
14/07/98	22:30	0.22	-
19/07/98	16:16	-	10
21/07/98	21:25	-	10
06/08/98	14:42	0.20	-
06/09/98	04:56	0.73	-
08/09/98	06:39	0.70	-
08/09/98	18:19	0.67	-
08/09/98	20:49	0.59	-
09/09/98	01:31	0.20	
20/09/98	10:38	0.24	-
18/10/98	14:40	-	10
18/10/98	15:10	-	11
20/10/98	07:16	-	10
20/10/98	07:56	-	10
20/10/98	08:06	-	10
20/10/98	08:36	-	10
20/10/98	08:46	-	10
20/10/98	09:37	-	10
20/10/98	09:47	-	10
20/10/98	10:17	-	10
20/10/98	10:47	-	10
20/10/98	11:07	-	10
20/10/98	12:27	-	10
20/10/98	12:37	-	10
20/10/98	13:57	-	10

Table 4.3: Maximum wave height and maximum wind speed from July to October 1998

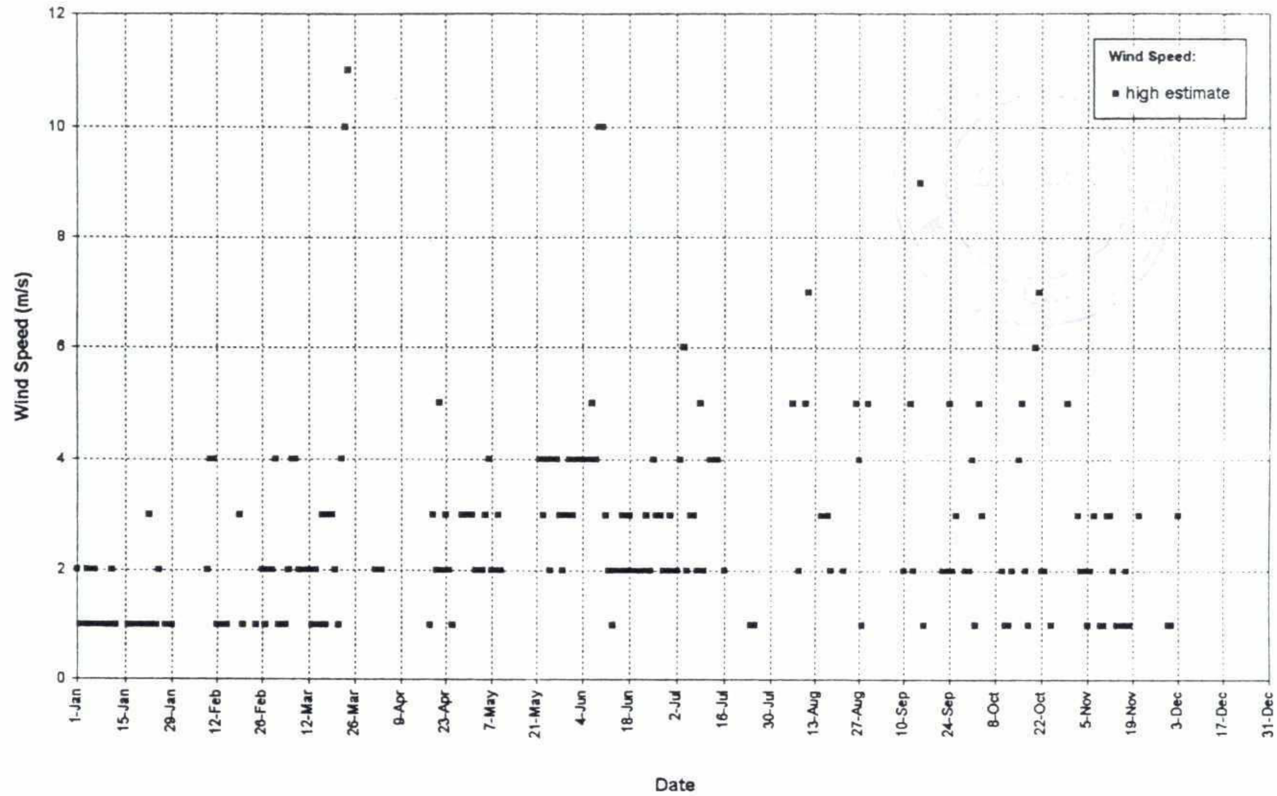
4.3.5 Floating Debris

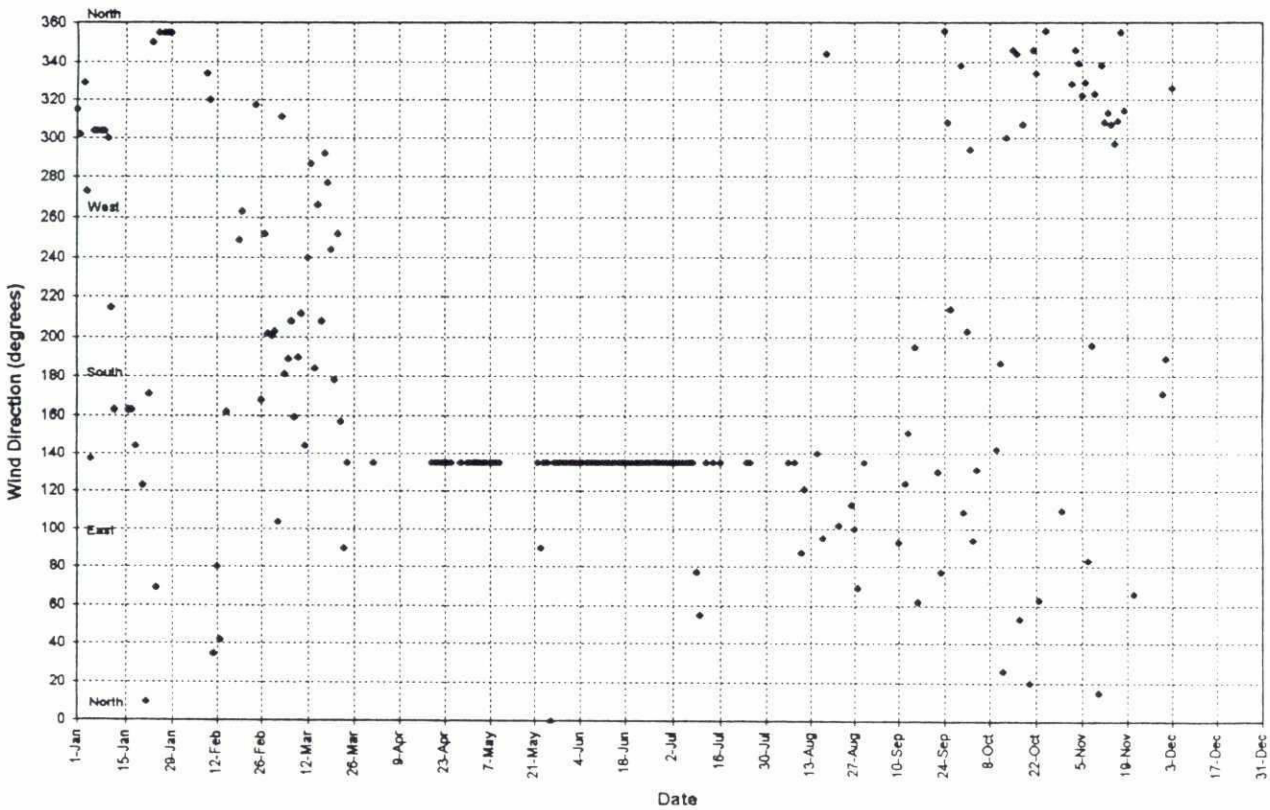
Floating debris of grass, water hyacinth and banana tree trunks had been observed from June to beginning of October (see Fig. 4.13 to 4.18) where the daily estimated thickness and area of debris are shown for each groyne.

On September 05 the thickness of a 5,000 m^2 layer of floating debris upstream from G-1 had been estimated 4.5 m and this is by far the largest thickness observed in the groyne field. It was much more than the 2 m thickness assumed in the design of the groynes. The maximum areas of debris upstream from G-2 and G-3 were 20,000 m^2. Although the channel in front of the groynes was small and shallow, the amount of floating debris was high. The area of floating debris as function of the water level in Fig. 4.19 shows that floating debris occurs if the water level is higher than 19.5 m+PWD. This has also been observed in the previous years.

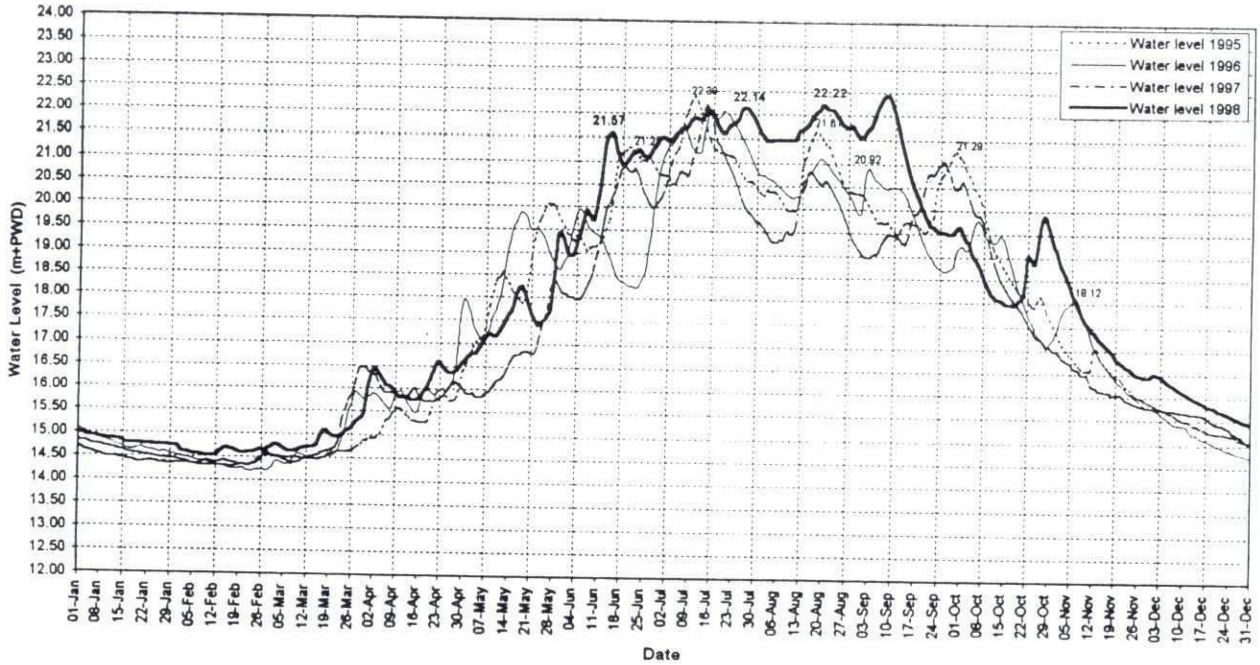


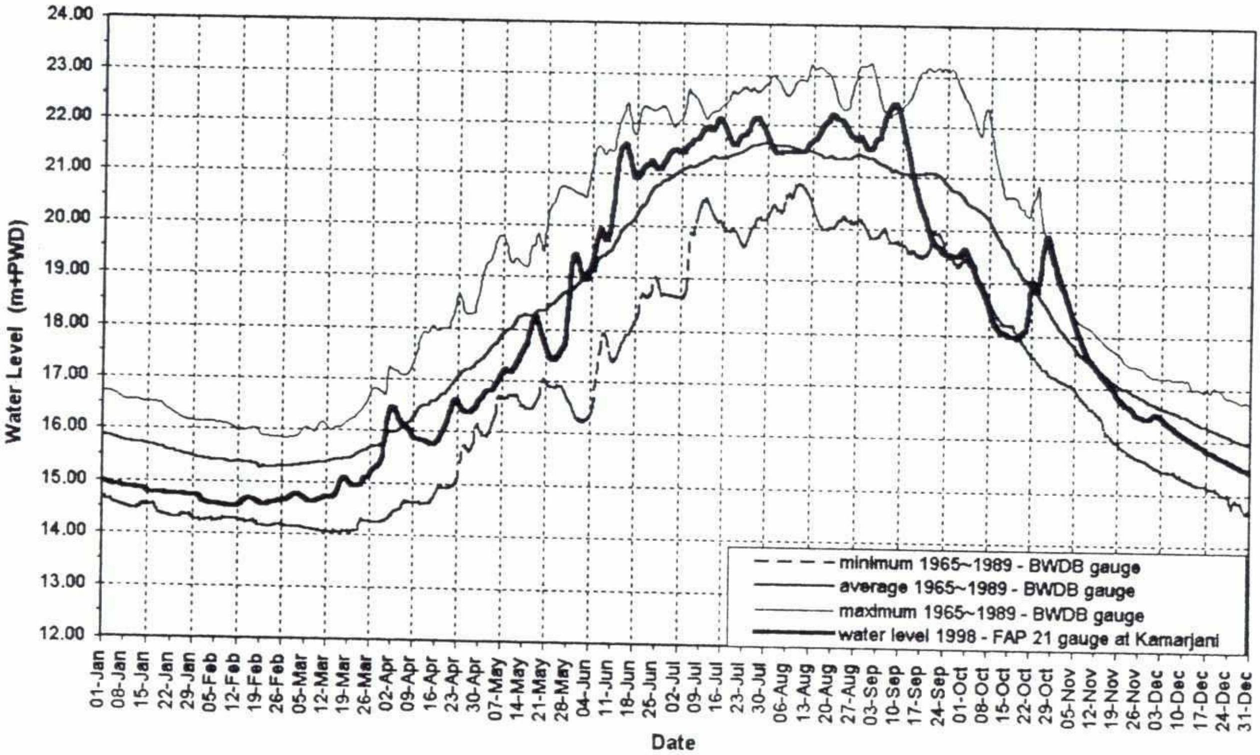
KAMARJANI TEST SITE **RAINFALL INTENSITY**	**FAP – 21** BANK PROTECTION PILOT PROJECT FIG. 4·1



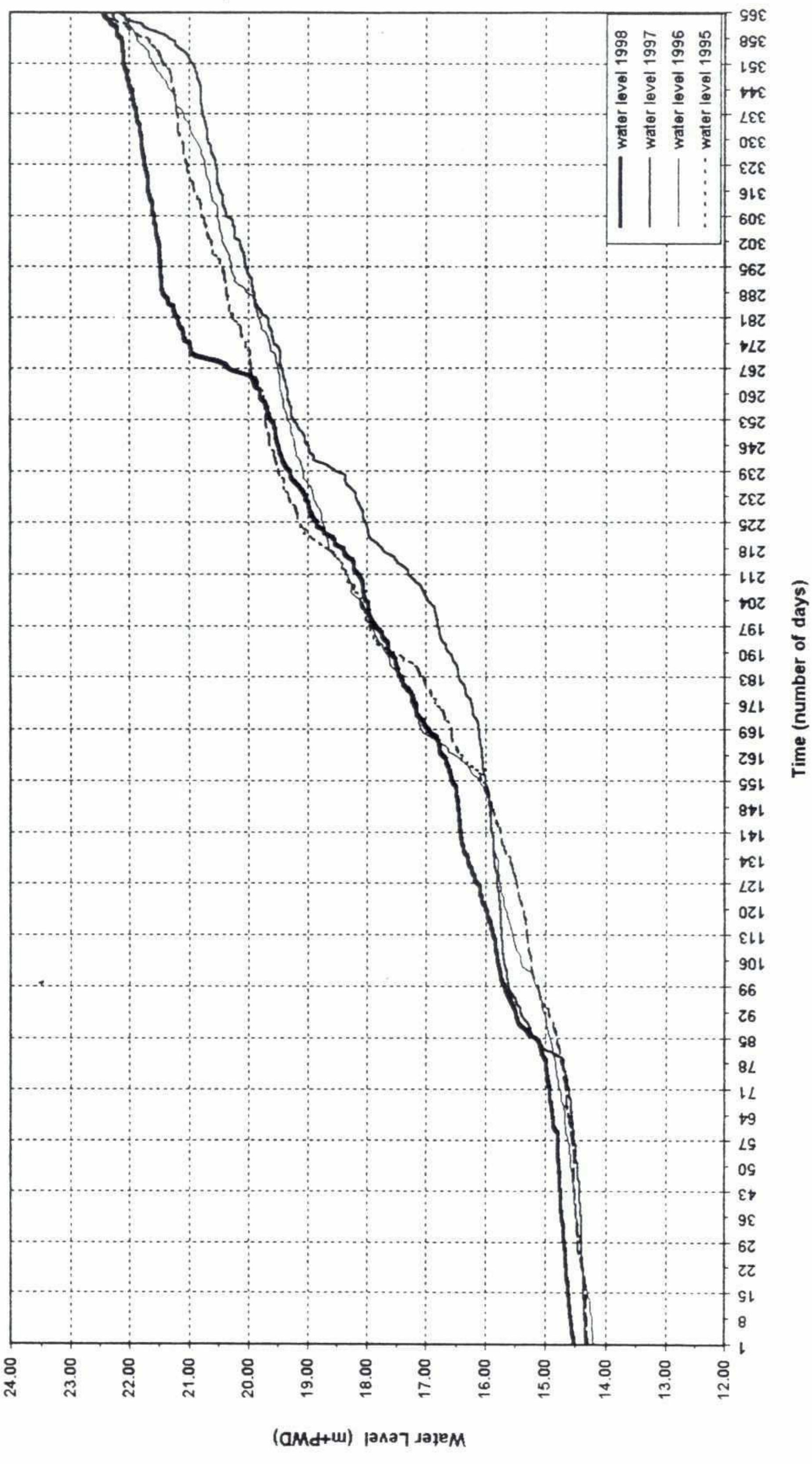


KAMARJANI TEST SITE WIND SPEED AND DIRECTION	**FAP – 21** BANK PROTECTION PILOT PROJECT FIG. 4.2





KAMARJANI TEST SITE HYDROGRAPHS FROM 1995 to 1998	**FAP – 21** BANK PROTECTION PILOT PROJECT FIG. 4.3



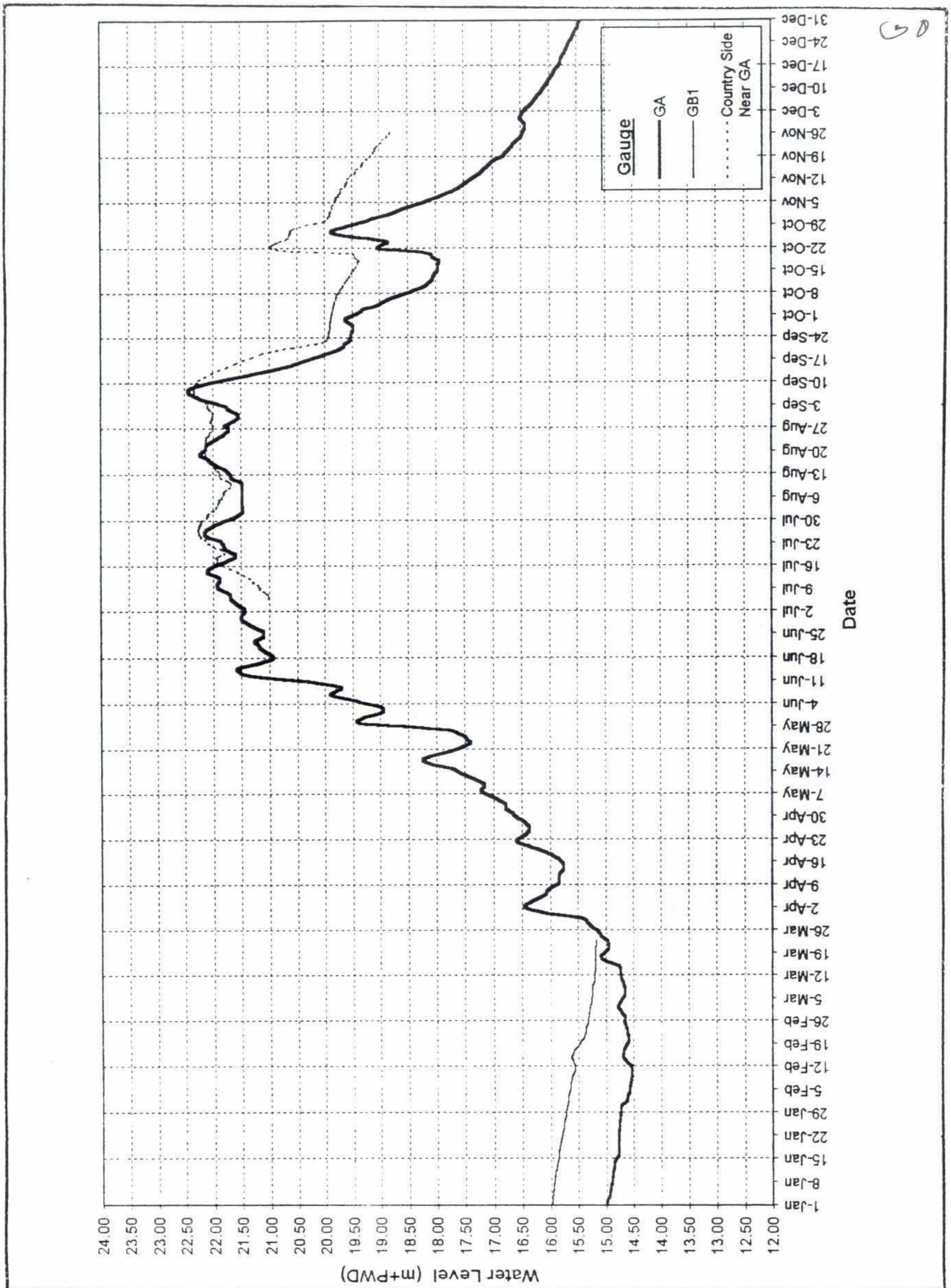
KAMARJANI TEST SITE

DURATION CURVES OF WATER LEVELS FROM 1995 to 1998

FAP – 21

BANK PROTECTION PILOT PROJECT

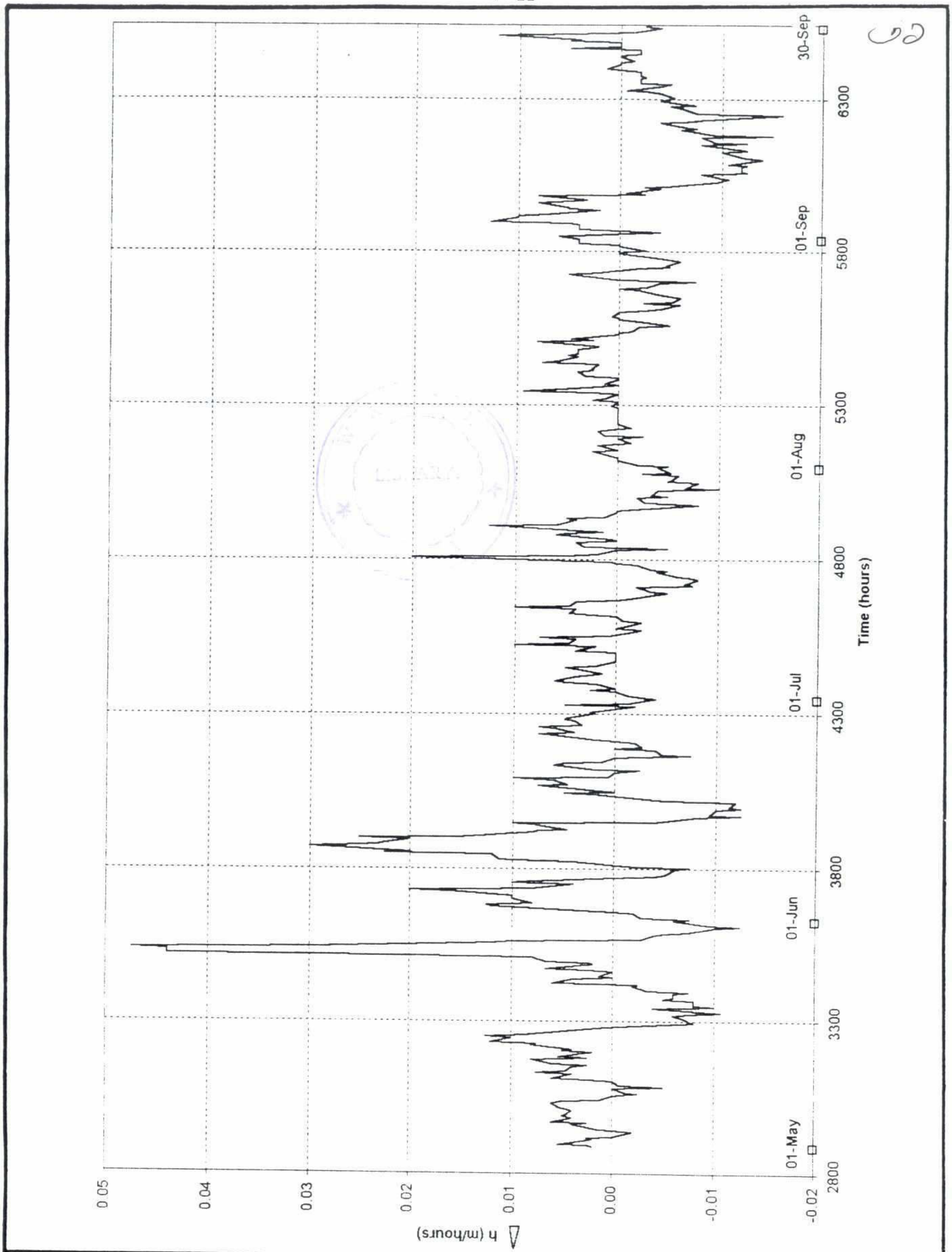
FIG. 4.4



KAMARJANI TEST SITE
WATER LEVELS UPSTREAM G-1 AND ON FLOOD PLAIN

FAP - 21
BANK PROTECTION PILOT PROJECT

FIG. 4.5



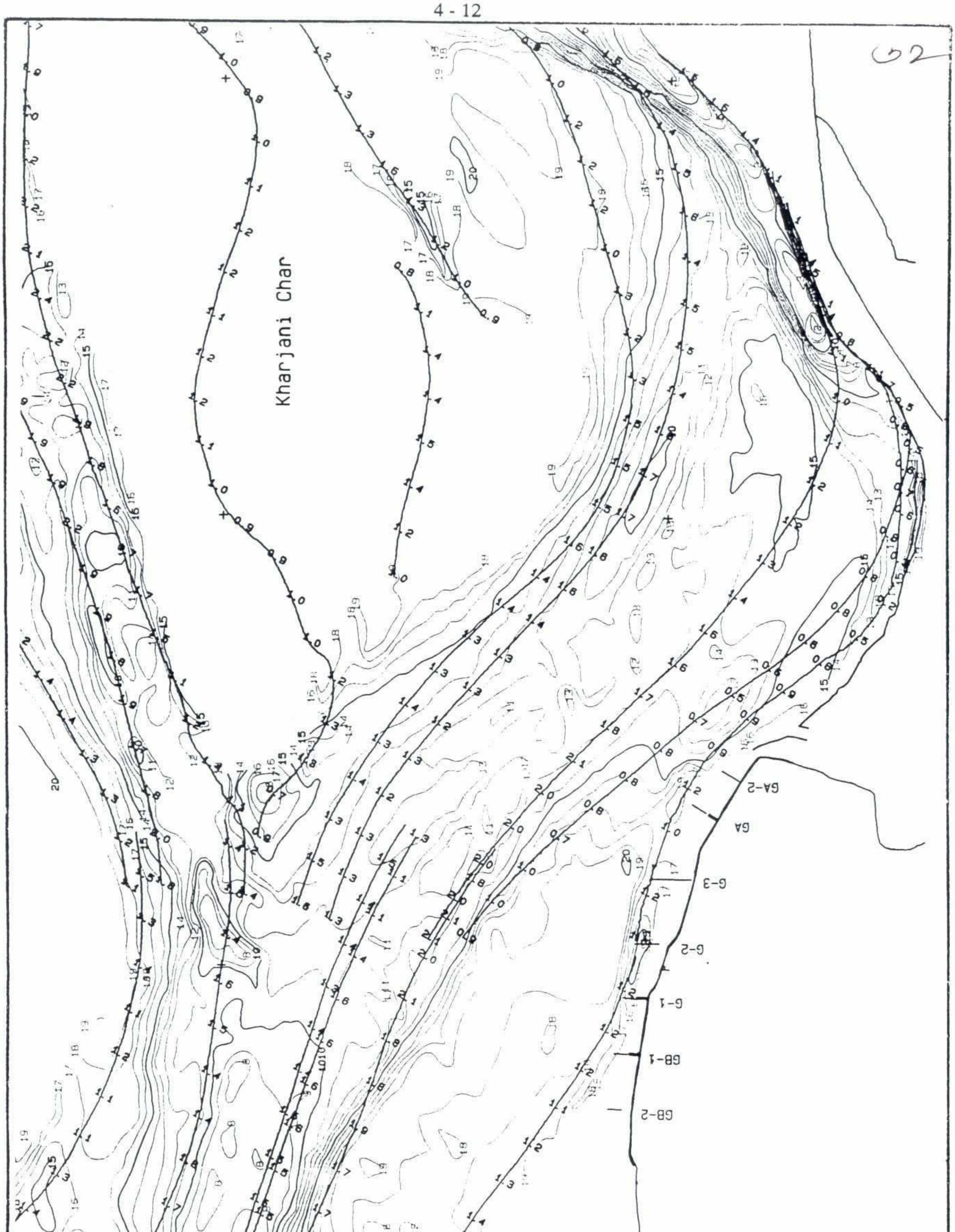
KAMARJANI TEST SITE

RATE OF RISE AND FALL OF WATER LEVEL

FAP – 21

BANK PROTECTION PILOT PROJECT

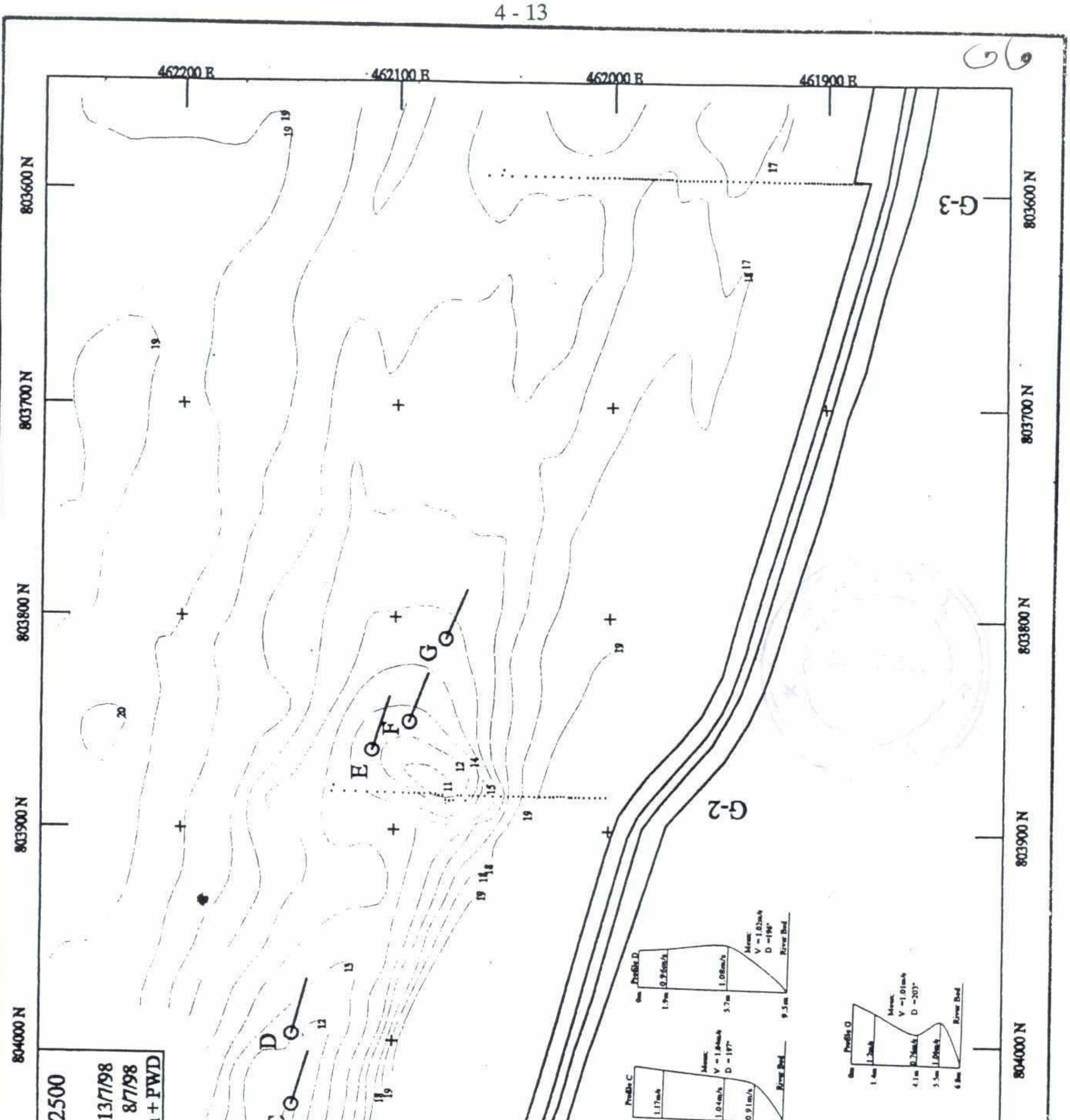
FIG. 4.6



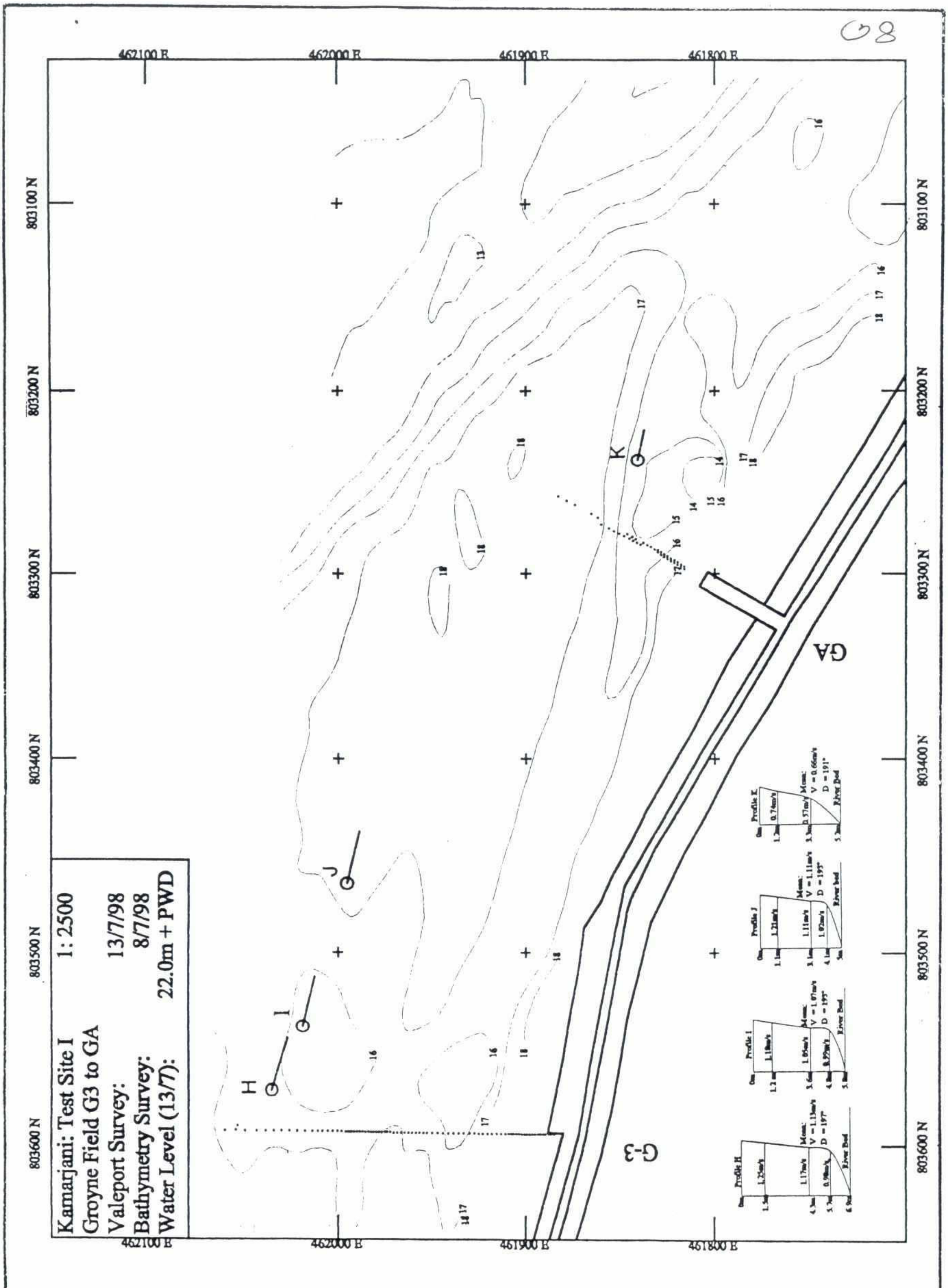
KAMARJANI TEST SITE
FLOAT TRACKING
30 JUNE - 6 JULY'98

FAP - 21
BANK PROTECTION PILOT PROJECT

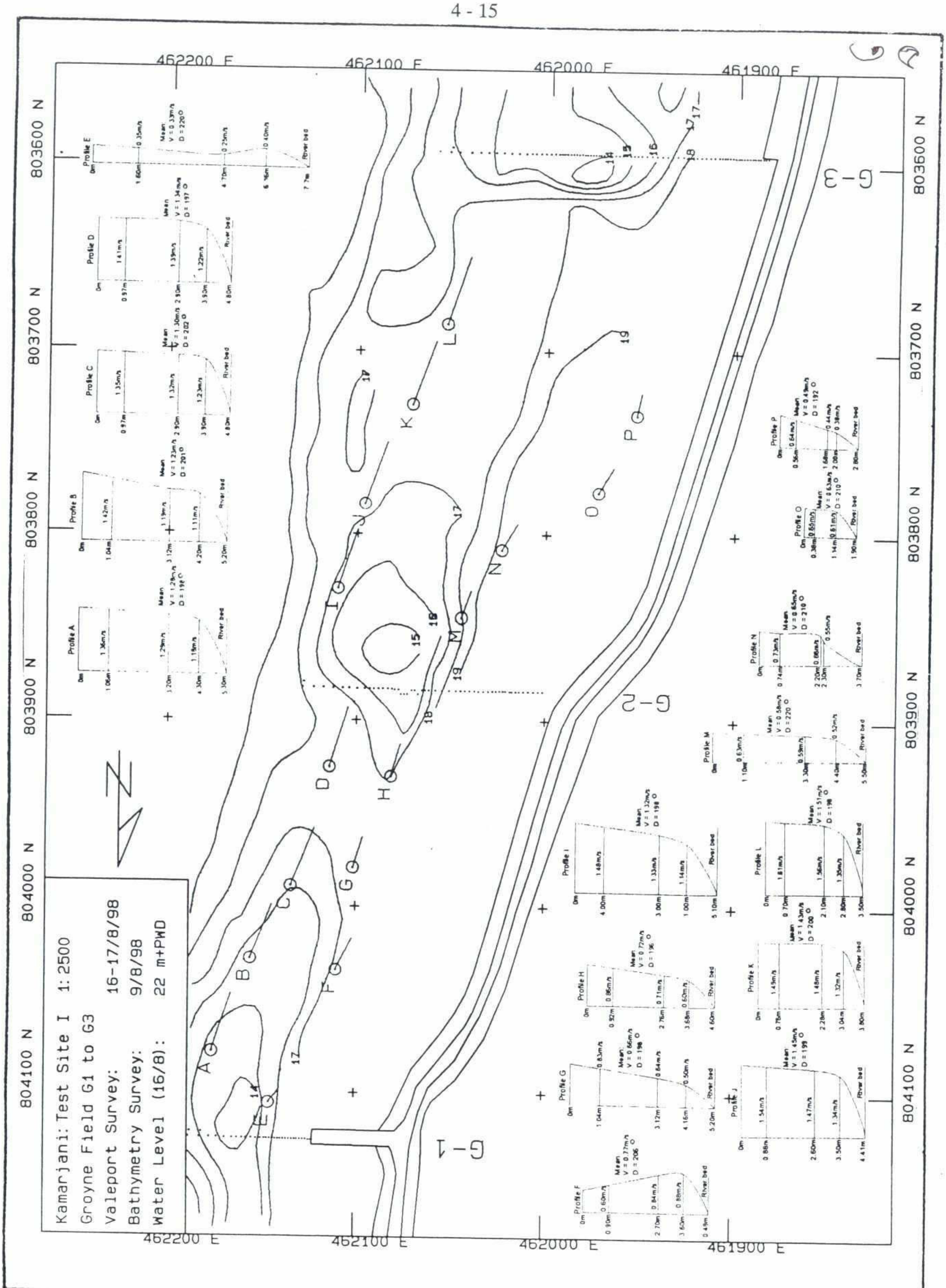
FIG. 4.7



KAMARJANI TEST SITE FLOW VELOCITY VERTICALS 11 - 13 JULY 1998	FAP - 21 BANK PROTECTION PILOT PROJECT FIG. 4.8



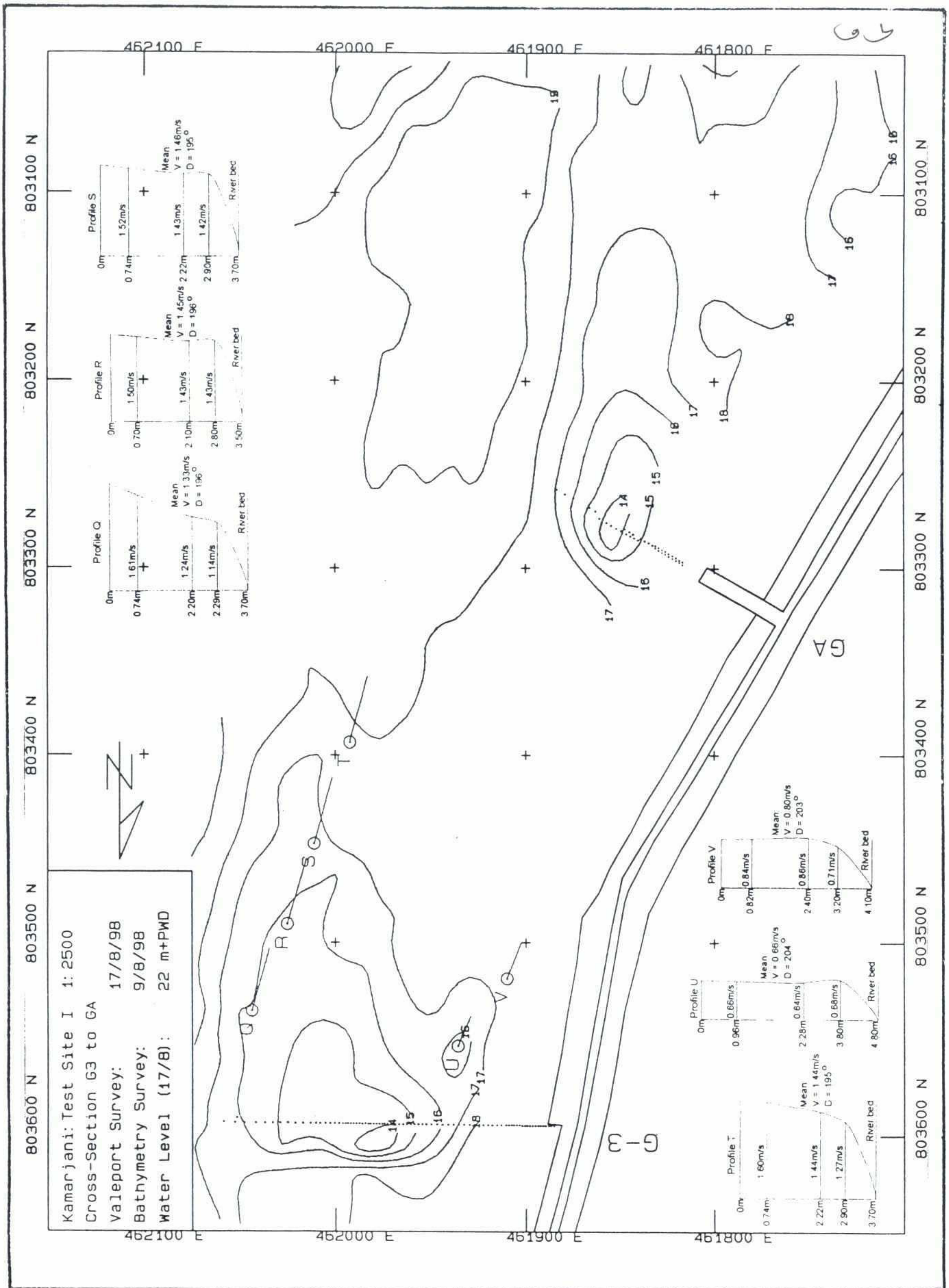
KAMARJANI TEST SITE FLOW VELOCITY VERTICALS 13 JULY 1998	FAP - 21 BANK PROTECTION PILOT PROJECT FIG. 4.9



KAMARJANI TEST SITE
FLOW VELOCITY VERTICALS
16-17 AUGUST 1998

FAP - 21
BANK PROTECTION PILOT PROJECT

FIG. **4.10**

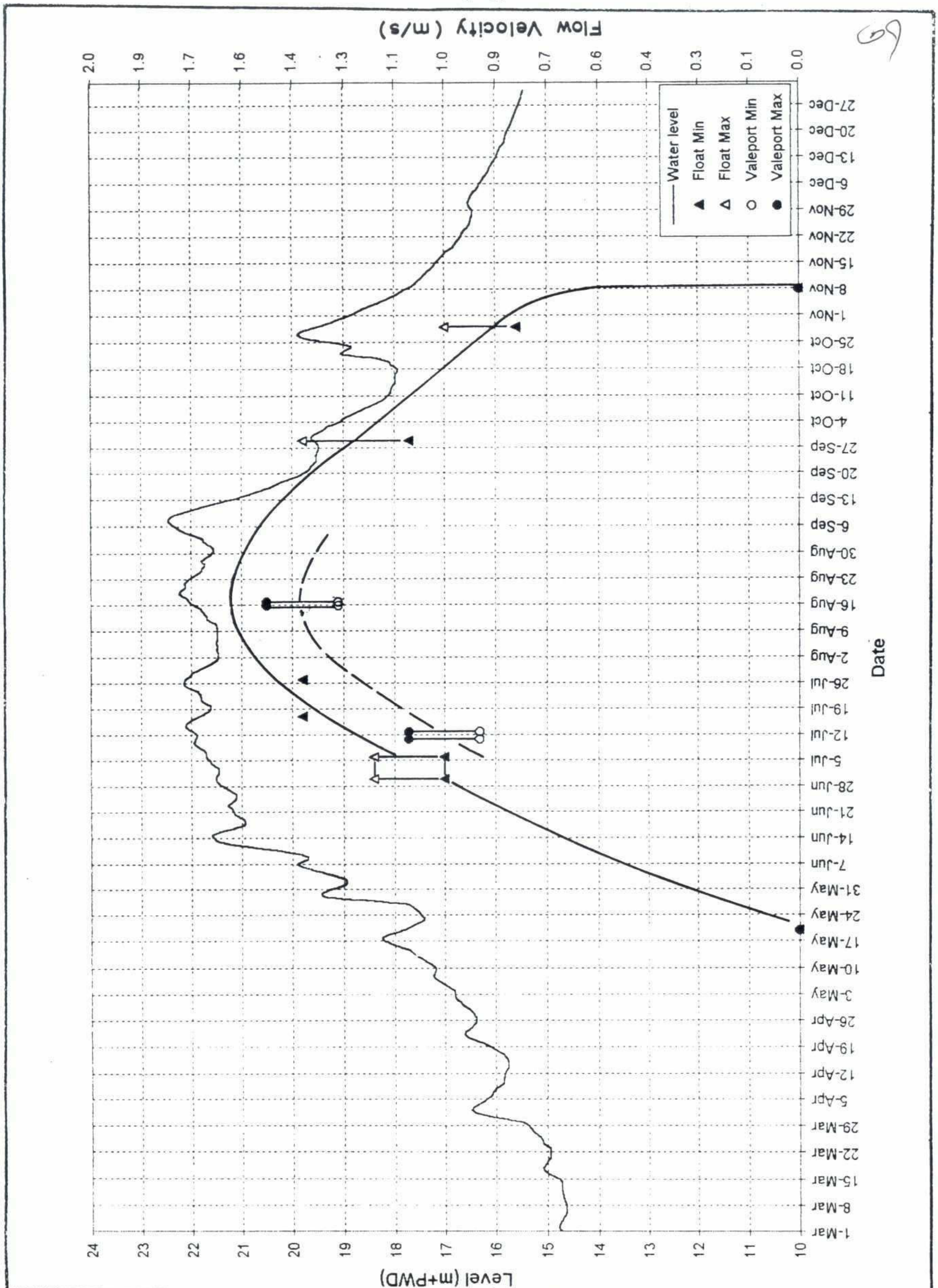


KAMARJANI TEST SITE
FLOW VELOCITY VERTICALS
17 AUGUST 1998

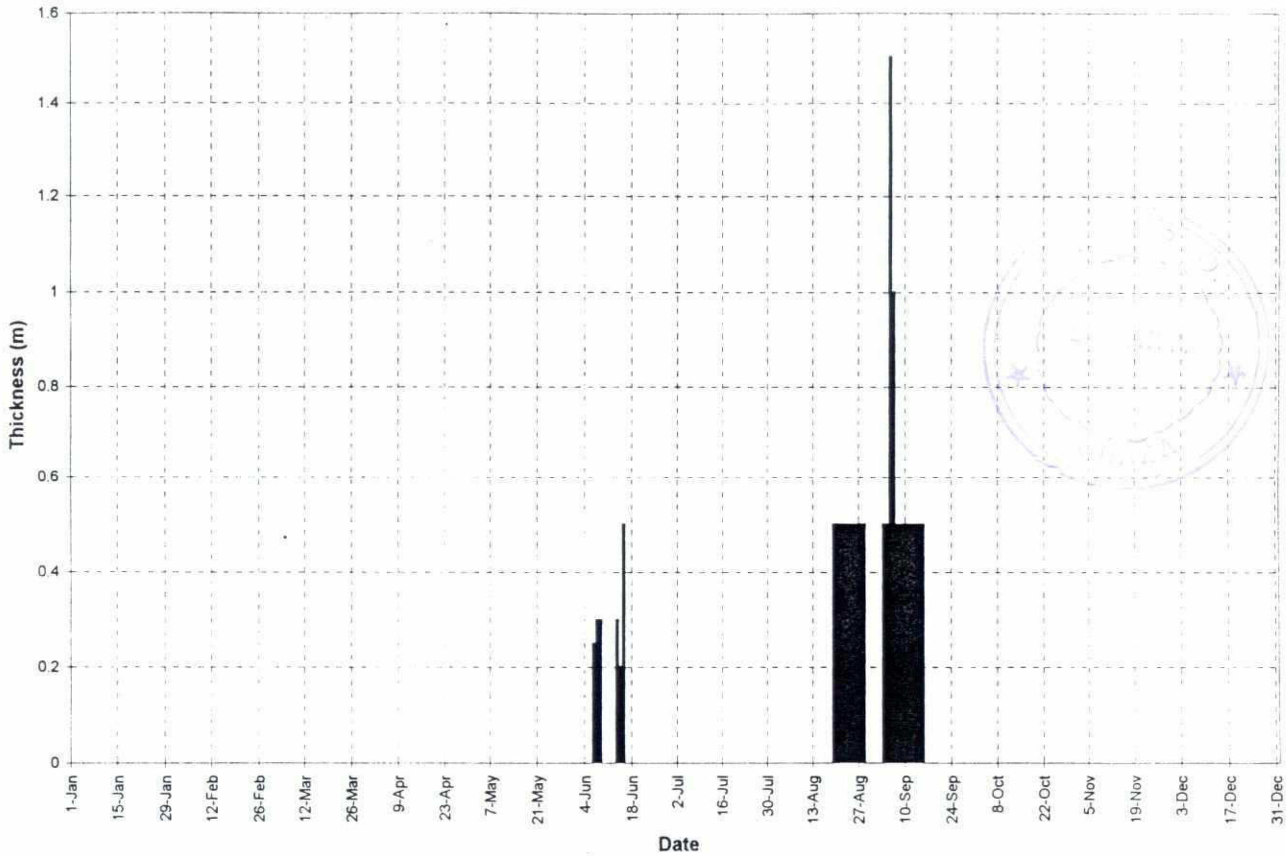
FAP - 21

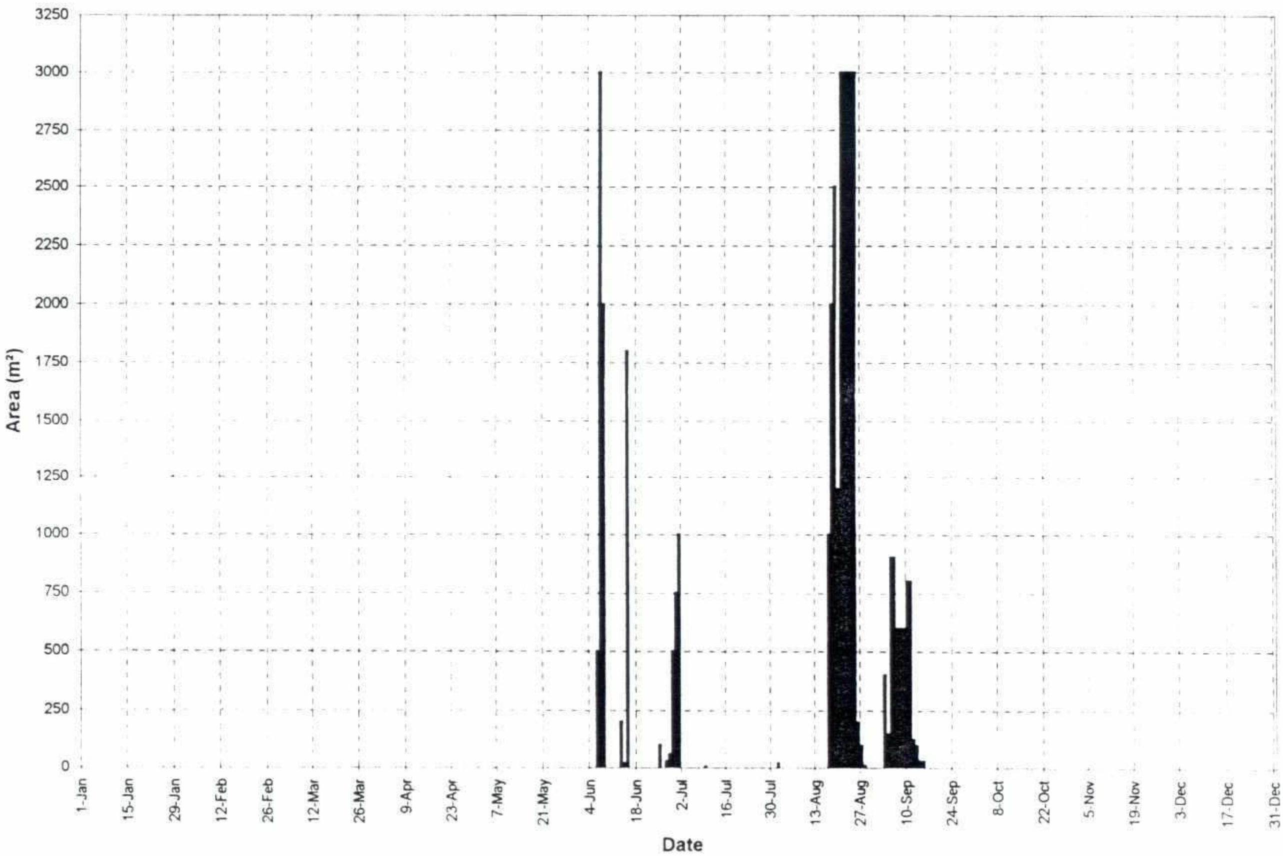
BANK PROTECTION PILOT PROJECT

FIG. **4.11**



KAMARJANI TEST SITE **FLOW VELOCITIES AND THE HYDROGRAPH NEAR THE GROYNE FIELD**	**FAP – 21** BANK PROTECTION PILOT PROJECT FIG. **4.12**





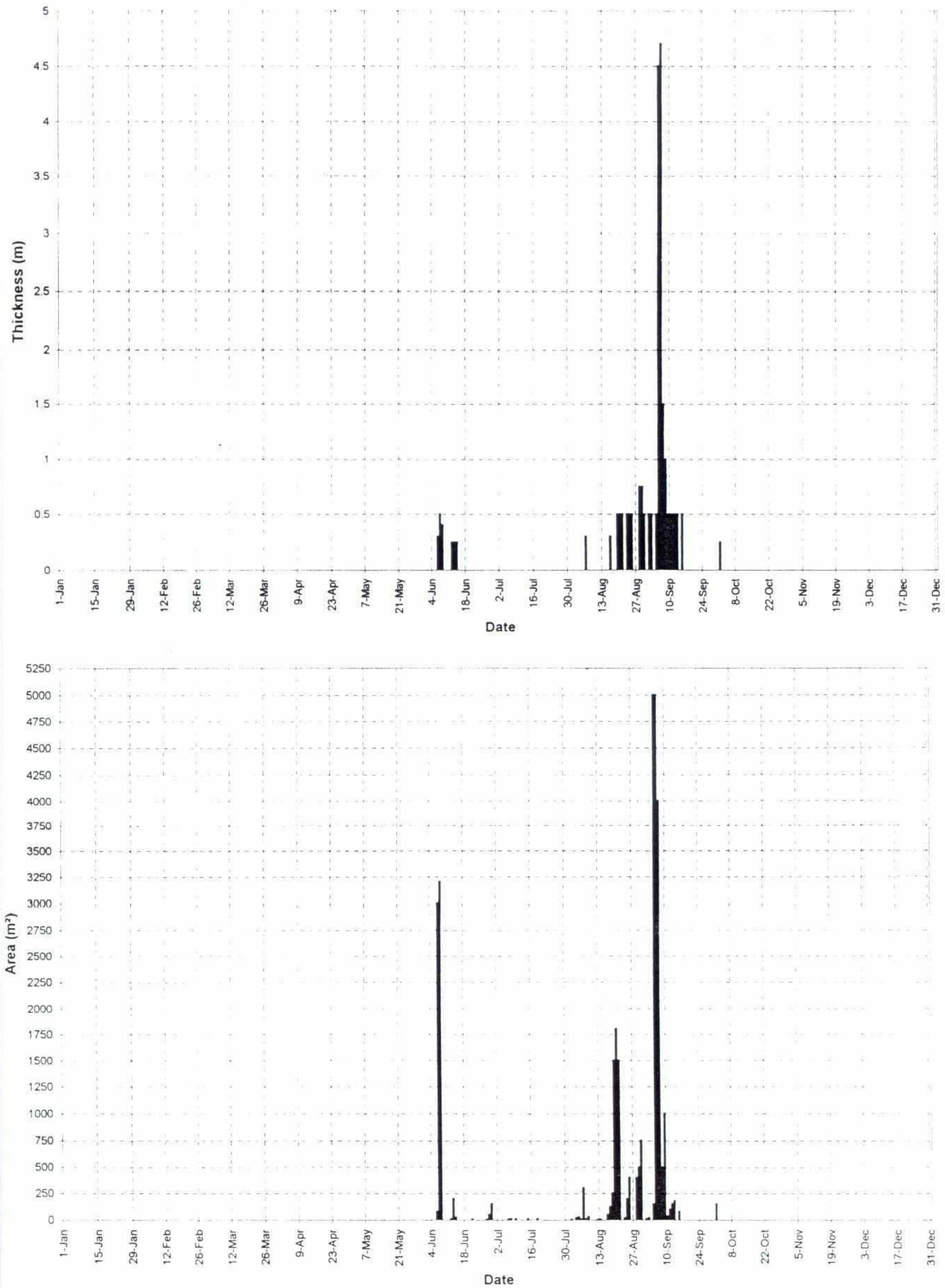
KAMARJANI TEST SITE

THICKNESS AND AREA OF FLOATING DEBRIS AT UPSTREAM GROYNE G-B1

FAP - 21

BANK PROTECTION PILOT PROJECT

FIG. 4.13



KAMARJANI TEST SITE

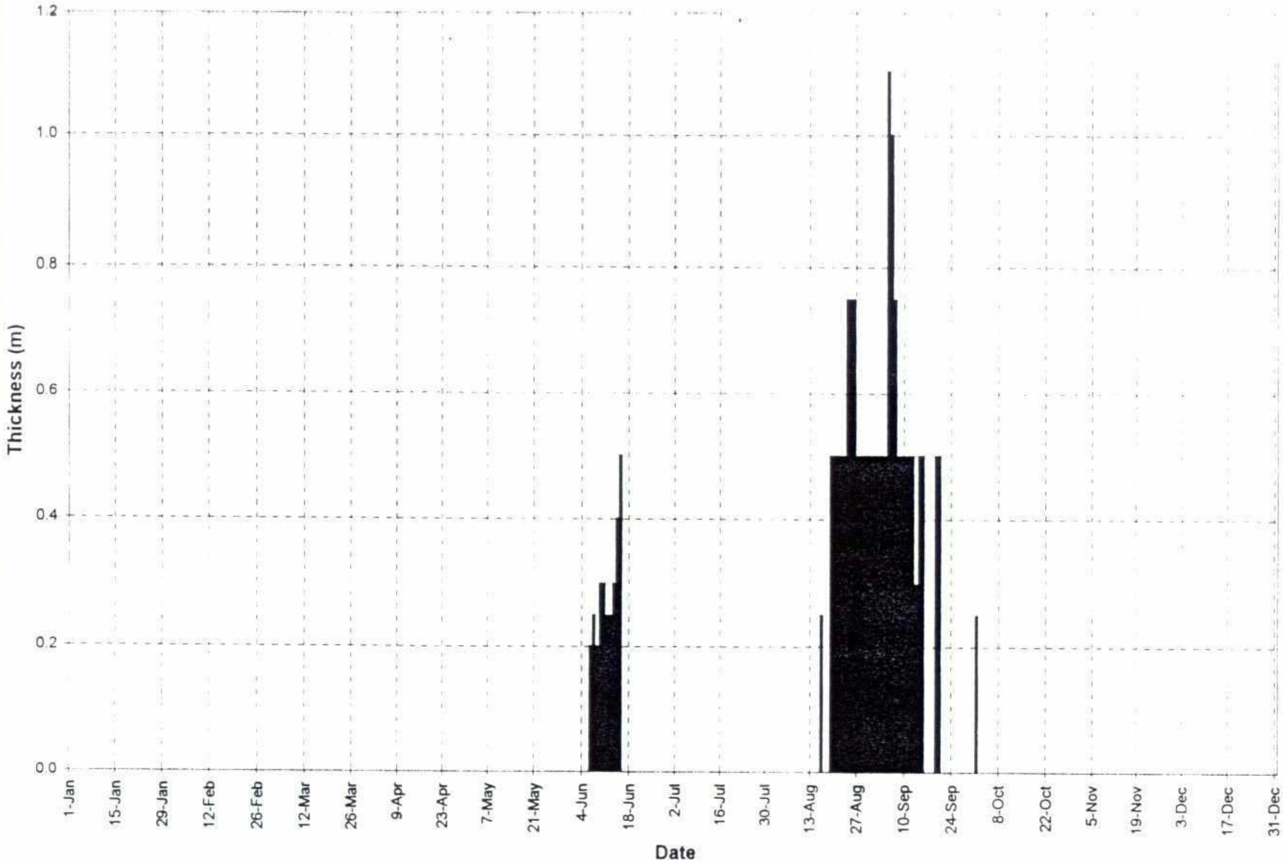
THICKNESS AND AREA OF FLOATING DEBRIS AT UPSTREAM GROYNE G-1

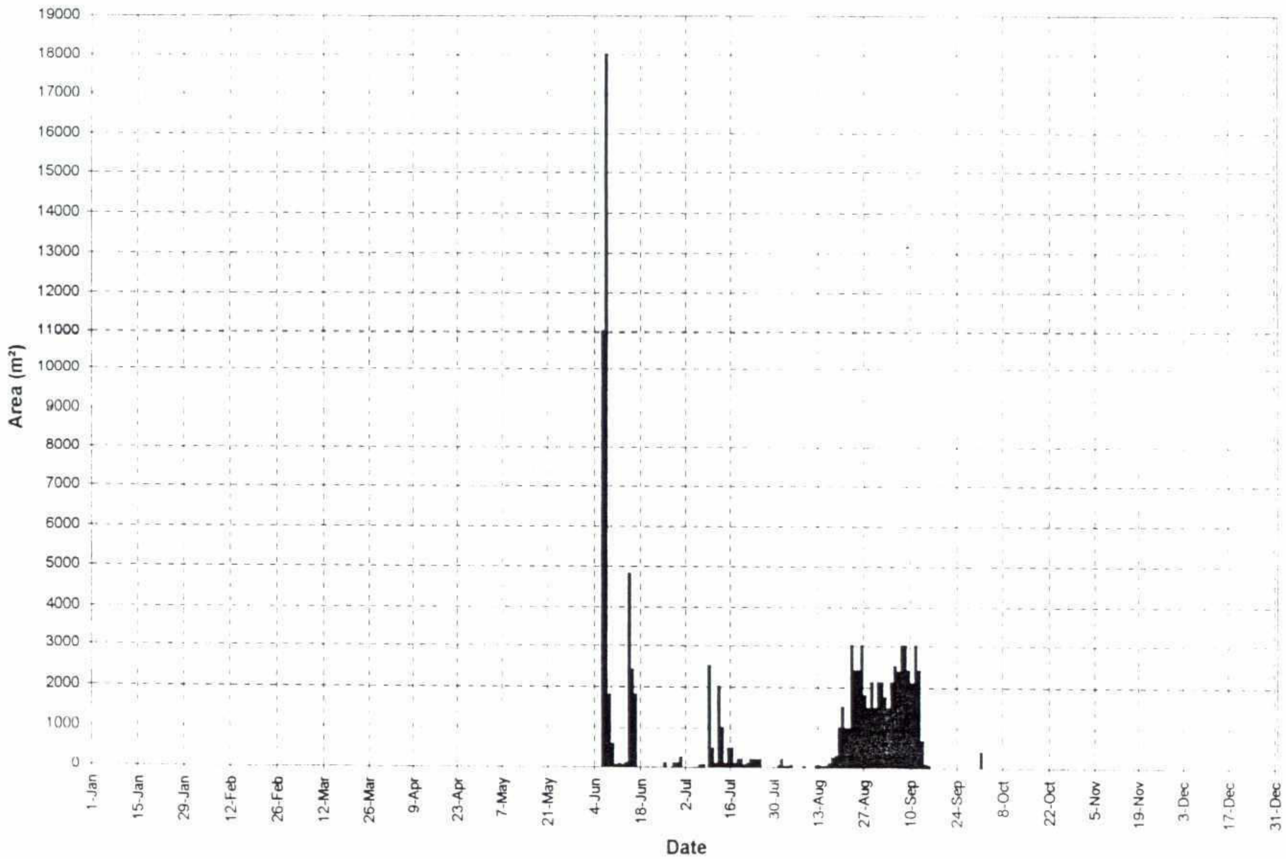
FAP - 21

BANK PROTECTION PILOT PROJECT

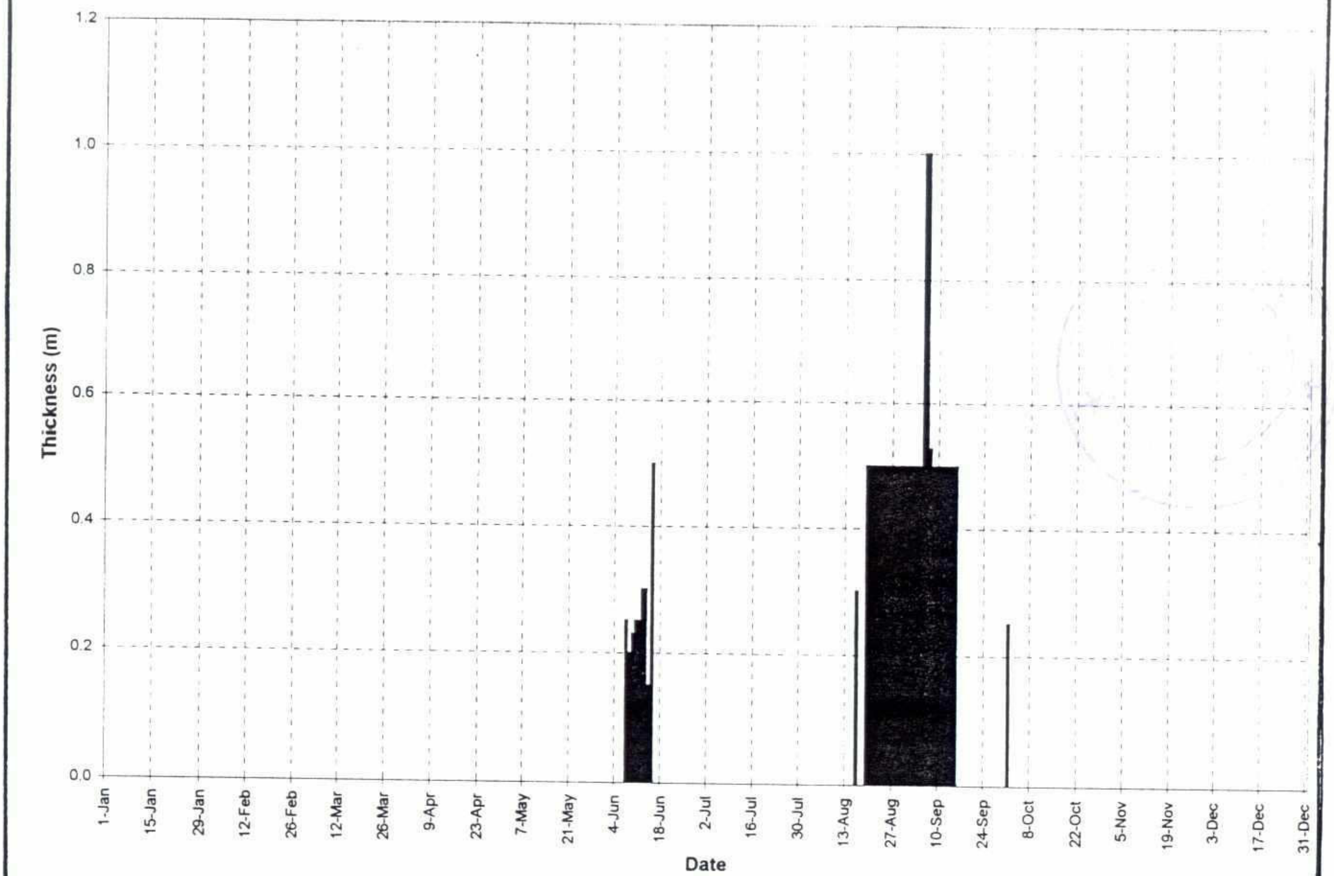
FIG. 4.14

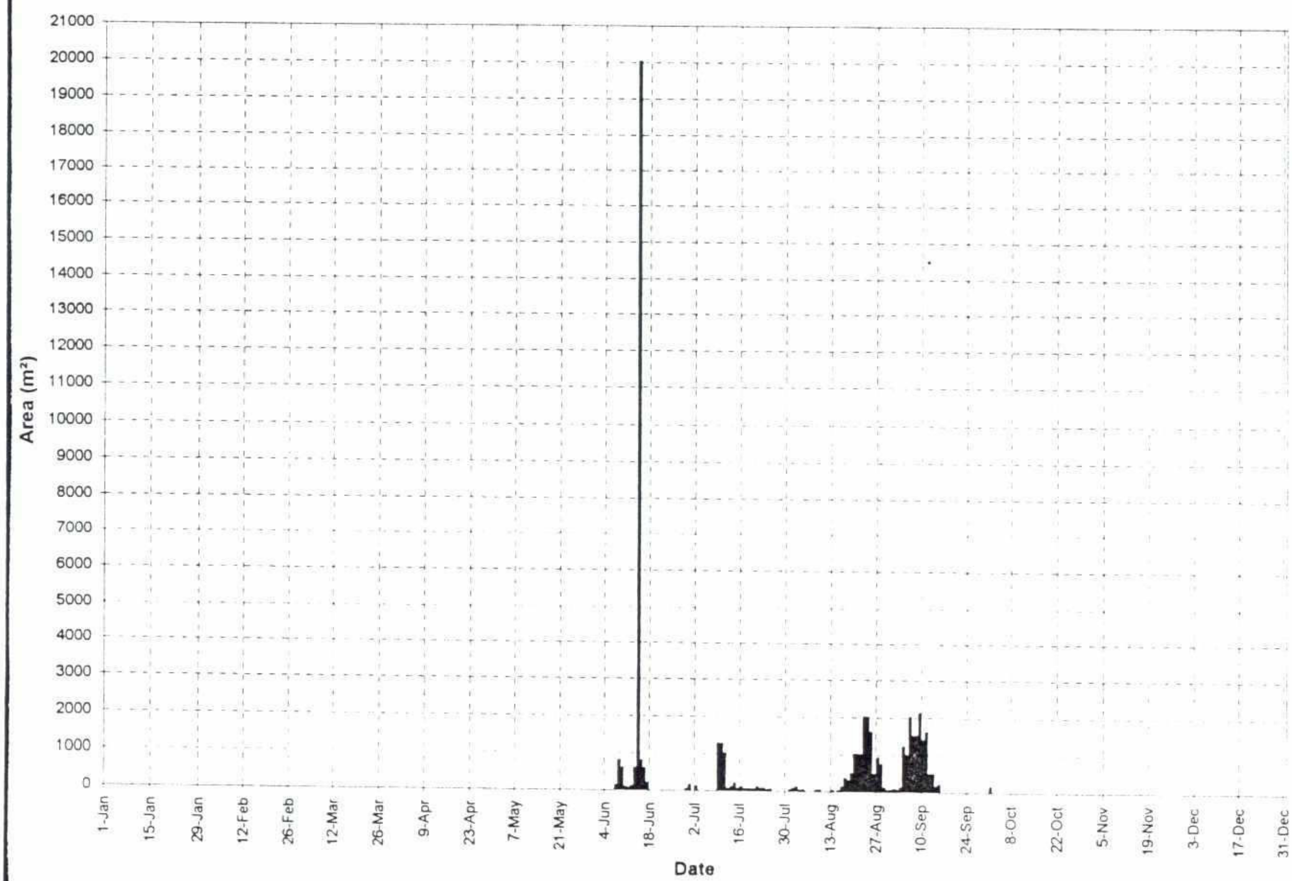
80





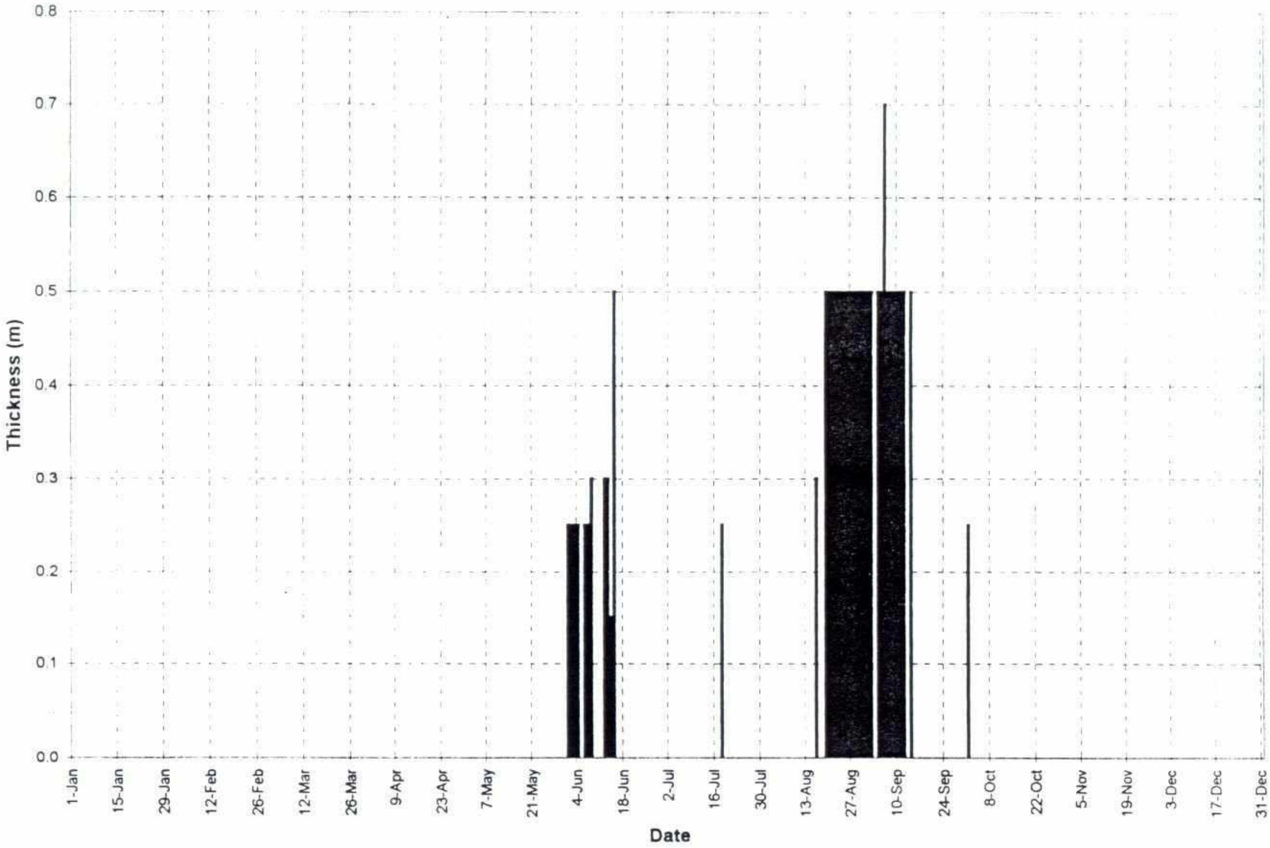
KAMARJANI TEST SITE THICKNESS AND AREA OF FLOATING DEBRIS AT UPSTREAM GROYNE G-2	FAP – 21 BANK PROTECTION PILOT PROJECT FIG. 4.15

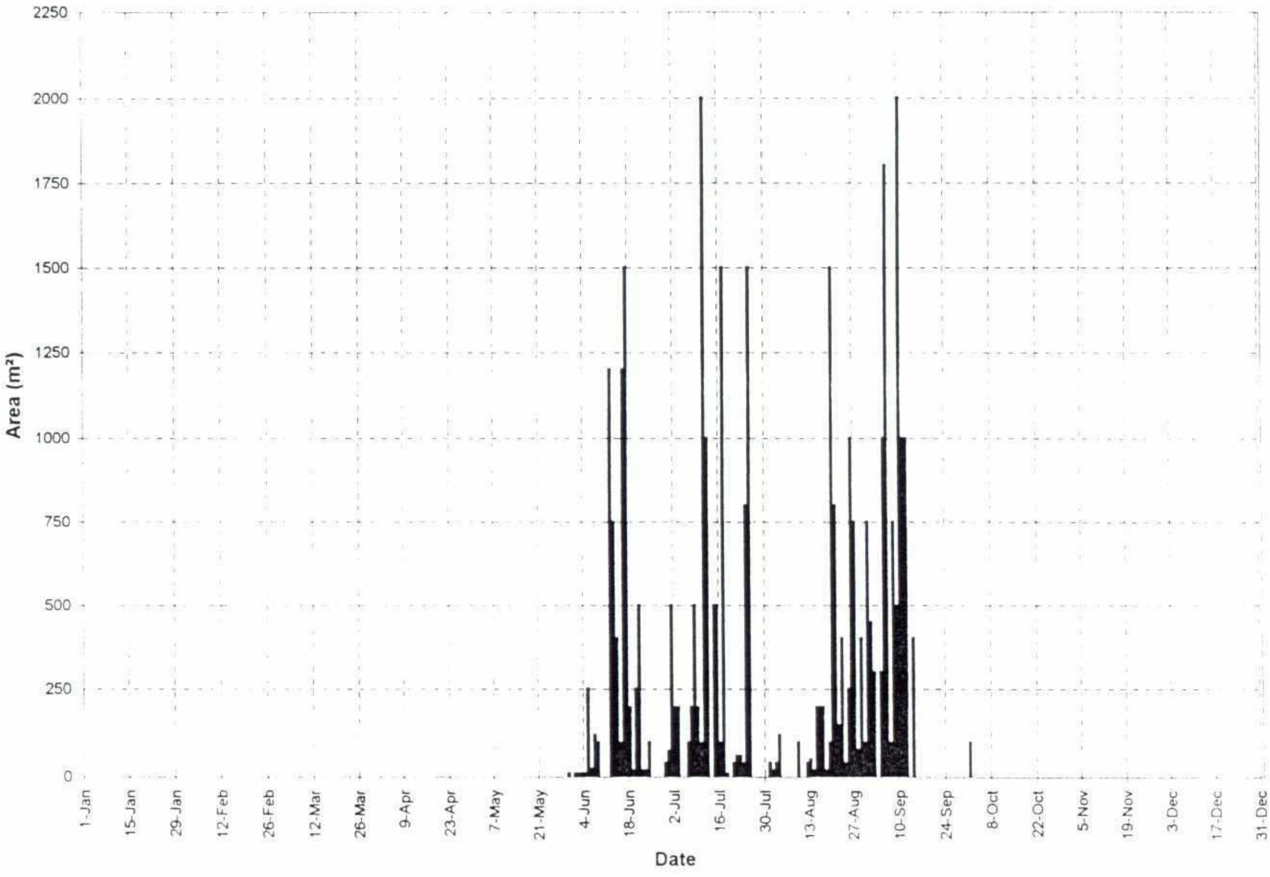




KAMARJANI TEST SITE THICKNESS AND AREA OF FLOATING DEBRIS AT UPSTREAM GROYNE G-3	FAP – 21 BANK PROTECTION PILOT PROJECT FIG. 4.16

82





KAMARJANI TEST SITE

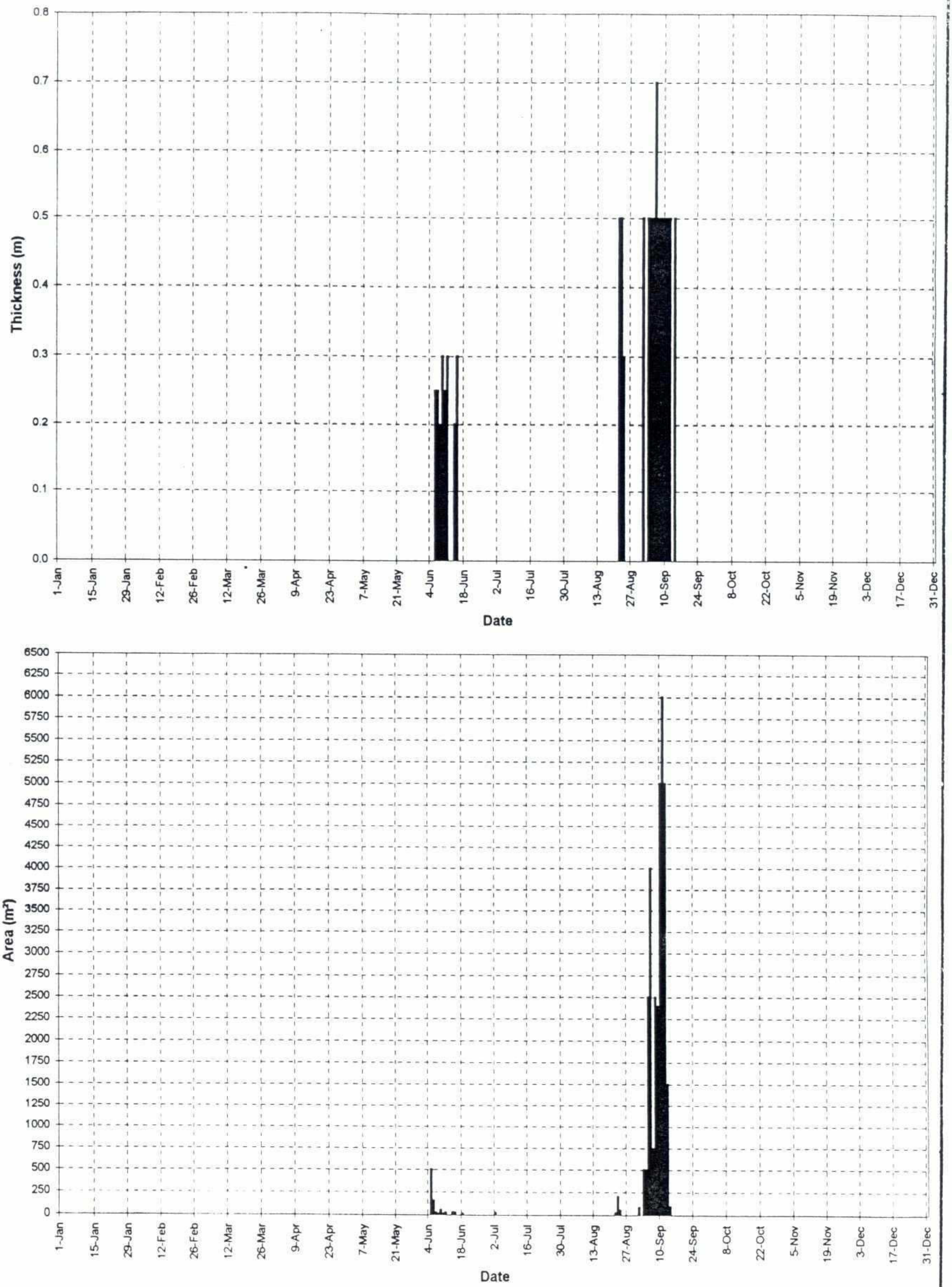
THICKNESS AND AREA OF FLOATING DEBRIS AT UPSTREAM GROYNE G-A

FAP - 21

BANK PROTECTION PILOT PROJECT

FIG. 4.17

86



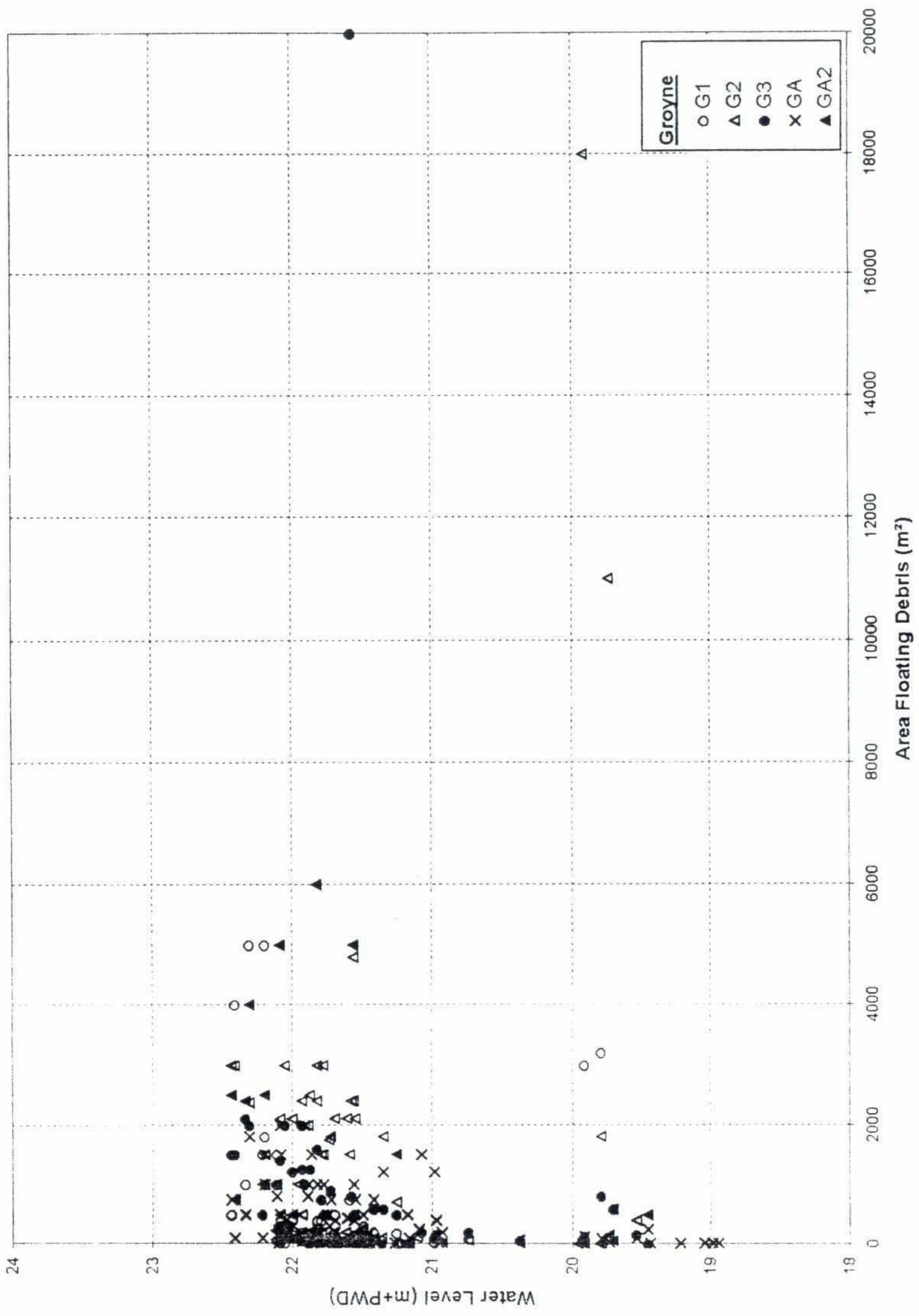
KAMARJANI TEST SITE

THICKNESS AND AREA OF FLOATING DEBRIS AT UPSTREAM GROYNE G-A/2

FAP – 21

BANK PROTECTION PILOT PROJECT

FIG. **4.18**



KAMARJANI TEST SITE
AREA FLOATING DEBRIS AS FUNCTION OF WATER LEVEL

FAP - 21
BANK PROTECTION PILOT PROJECT

FIG. **4.19**

5 MORPHOLOGY

5.1 MORPHOLOGICAL DEVELOPMENT AT KAMARJANI IN 1997-98

The bankline remained constant upstream from the groyne field and in the groyne field itself during the whole monsoon (see Fig. 5.1 and Annex E). However, downstream from the groyne field near the camp the bank eroded about 75 m from January to March. After that the bankline was stable in that stretch. A pronounced embayment had developed just downstream from the groyne field, probably due to the attraction of the main channel by the scour holes near the groyne field. It might have caused the main channel to attack the bank locally. Near Syedpur the BWDB had constructed a retired embankment over a length of almost 2 km. Further downstream from Syedpur to Rasulpur the bank erosion was severe in 1998, up to 450 m near Rasulpur, as the Kamarjani channel tend to migrate in downstream direction. For further details see pages B-2, B-4 and B-7 of Annex B.

The cut-off channel of the Kamarjani bend, which had been first identified during the 1996 monsoon, continued its growth. Nonetheless, the channel along the bank of Rasulpur remained dominant, producing deep outer bend scour through a combination of impinging flow and a confluence.

5.2 SCOUR HOLES

A small channel developed in front of the groynes during the highest stages of the 1998 monsoon. The scour holes near the groynes were small and only surveyed from July to October (see Tables 5.1 to 5.3) namely on July 08, August 09, September 17 and from October 26 to 30. In July small scour holes had been surveyed with a maximum depth of 1 to 3 m. The maximum depths were about 5 m near G-3 in August (see Fig. 5.2) and 5 m near G-1 in September. However, all were below the design scour depths.

The location of the scour holes was not downstream from the tip of the groyne as generally develops under severe flow attack, but in the middle and close to the pile row (see Fig. 5.2 to 5.4), which is shown by the bathymetry of August 09 and September 17. The bed level in the channel was very high. The bed protection was covered by sediments and the outer piles of G-3 were just above the river bed. The scour hole developed near the section with a 30 and 40 % blockage. The survey lines in these figures show that the deepest point of a small scour hole can be missed easily by the survey vessel. These surveys show that in a shallow channel when the bed protections are covered by sediments the scour hole shifts towards the bank, compared with the scour holes developed in a deep channel with exposed bed protections in 1995. This shift had obviously attracted the thalweg of the small channel close to the bank. In the initial stage with the very small scour holes this attraction might have been very small, but the 5 m deep scour holes had certainly the capacity to attract the channel.

The bed levels, the maximum scour depths near the groynes and the hydrograph are shown in Fig. 5.5 for G-1, G-2 and G-3 and in Fig. 5.6 for G-A and G-A/2. The bed level raised gradually to 18 m+PWD upstream from G-A and G-A/2. These graphs show that the small channel was only active during the monsoon. In the dry season it was filled with stagnant water or even dry.

Groyne	bed level	water depth	scour depth	
	(m+PWD)	(m)	(m+PWD)	(m)
G-1	13 to 14	8.0	10.8	2.8
G-2	14	7.5	10.8	3.2
G-3	17	4.75	15.8	1.2
G-A	16	5.75	13.8	2.2

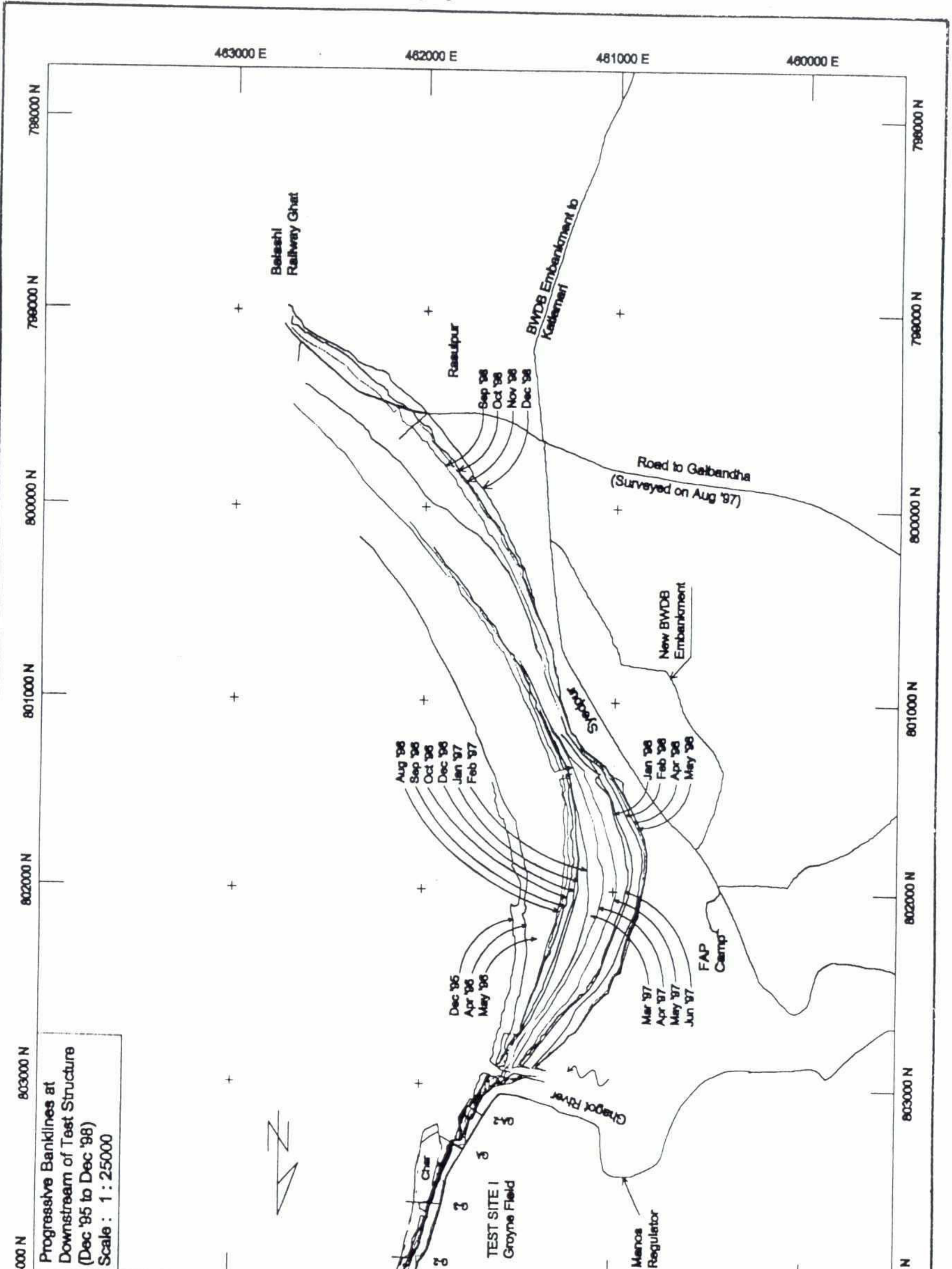
Table 5.1: Scour depths surveyed on July 08, water level at 21.75 m+PWD

Groyne	bed level	water depth	scour depth	
	(m+PWD)	(m)	(m+PWD)	(m)
G-1	17	4.5	13.4	3.6
G-2	17 to 18	4.0	14.0	3.5
G-3	17 to 18	4.0	12.7	4.8
G-A	17 to 18	4.0	13.7	3.8
G-A/2	17	4.5	16.0	1.0

Table 5.2: Scour depth surveyed on August 09, water level at 21.47 m+PWD

Groyne	bed level	water depth	scour depth	
	(m+PWD)	(m)	(m+PWD)	(m)
G-1	16	4.0	10.0	6.0
G-2	16	4.0	13.7	2.3
G-3	15.5	5.0	12.5	3.0
G-A	18	2.0	14.0	4.0
G-A/2	18	2.0	17.0	1.0

Table 5.3: Scour depth surveyed on September 17, water level at 20.34 m+PWD



KAMARJANI TEST SITE BANK LINE 1995-98	FAP – 21 BANK PROTECTION PILOT PROJECT
	FIG. 5.1

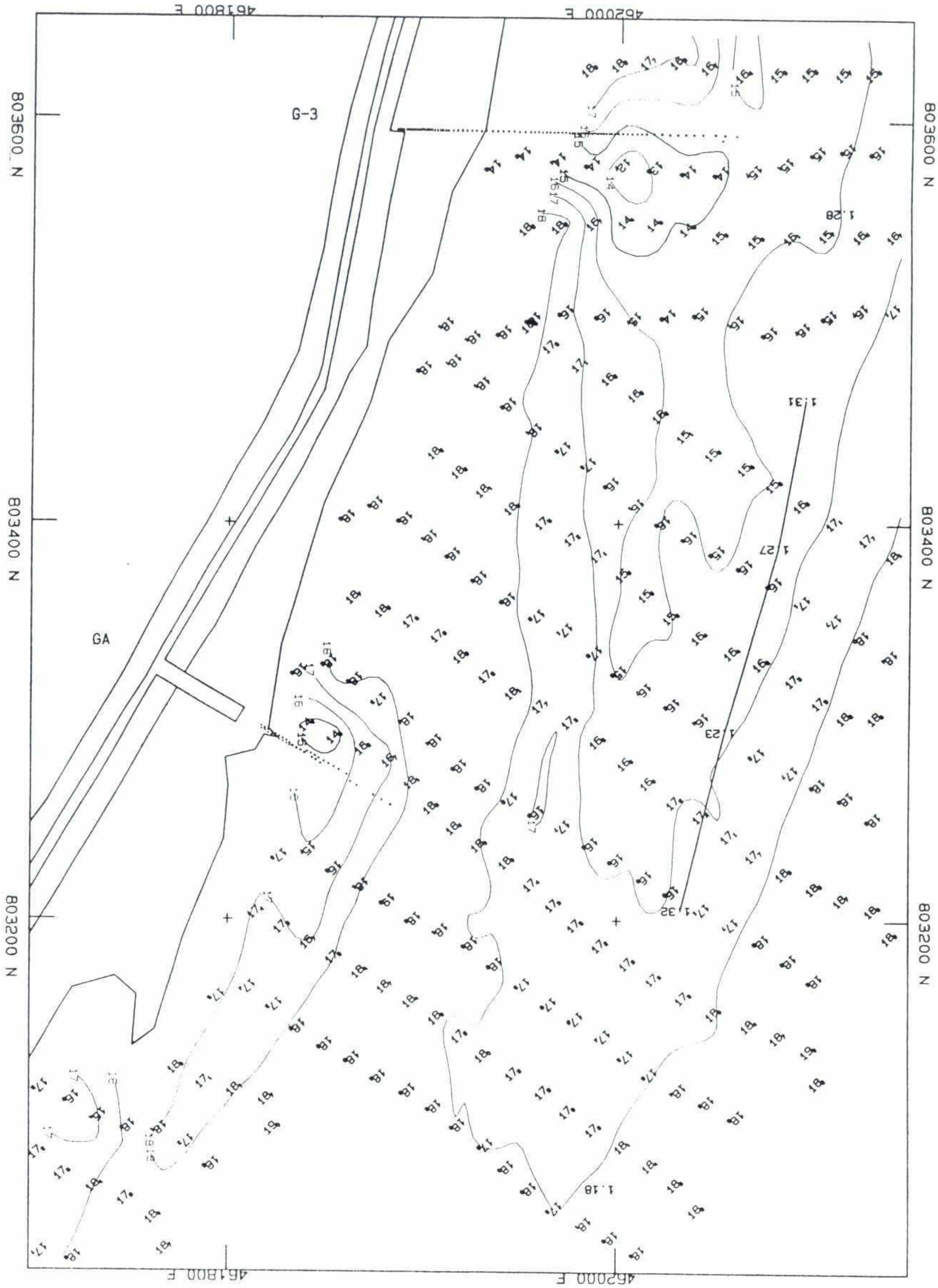
KAMARJANI TEST SITE

BATHYMETRIC SURVEY 09 AUGUST 1998

FAP – 21

BANK PROTECTION PILOT PROJECT

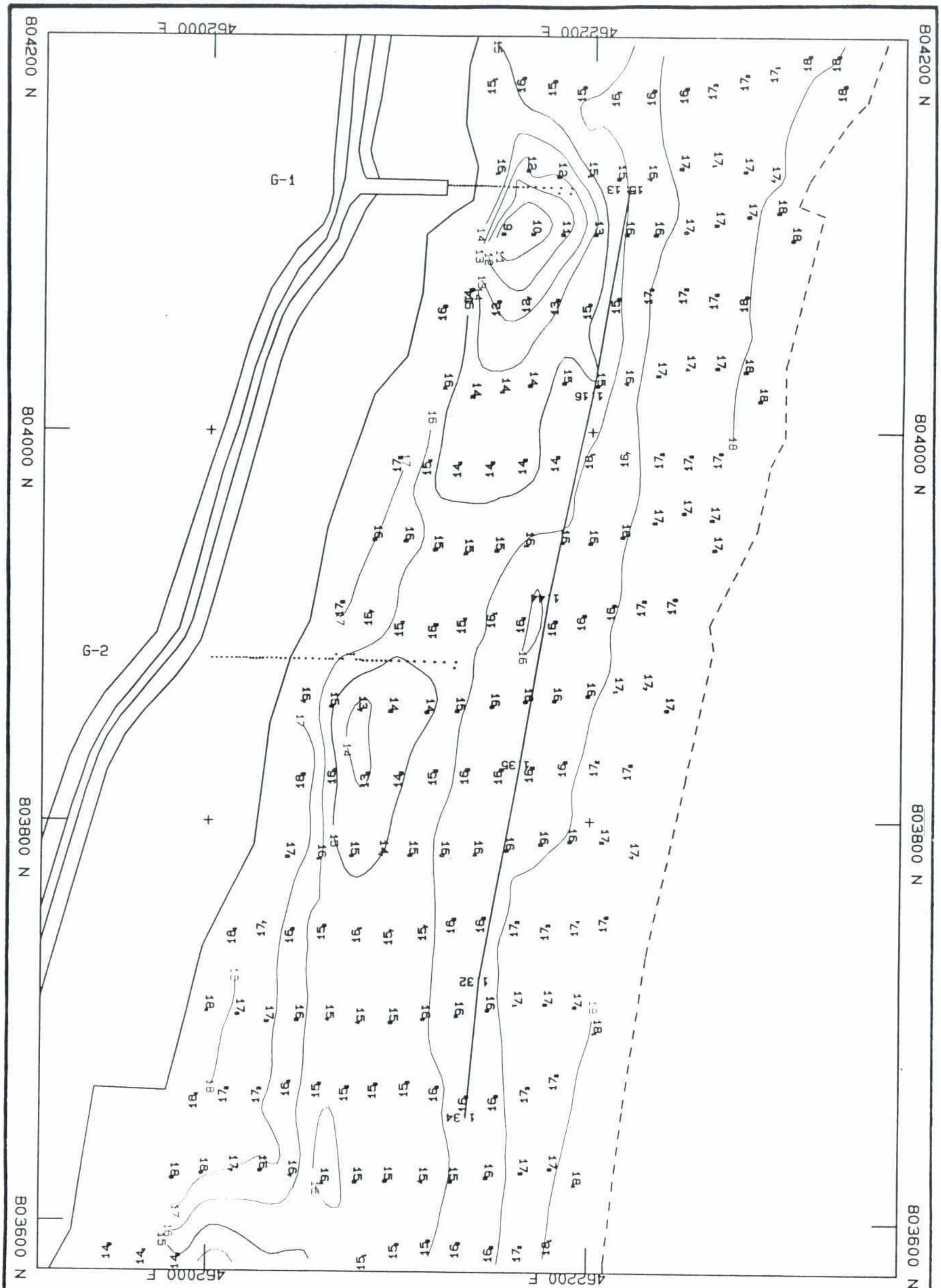
FIG. 5.2



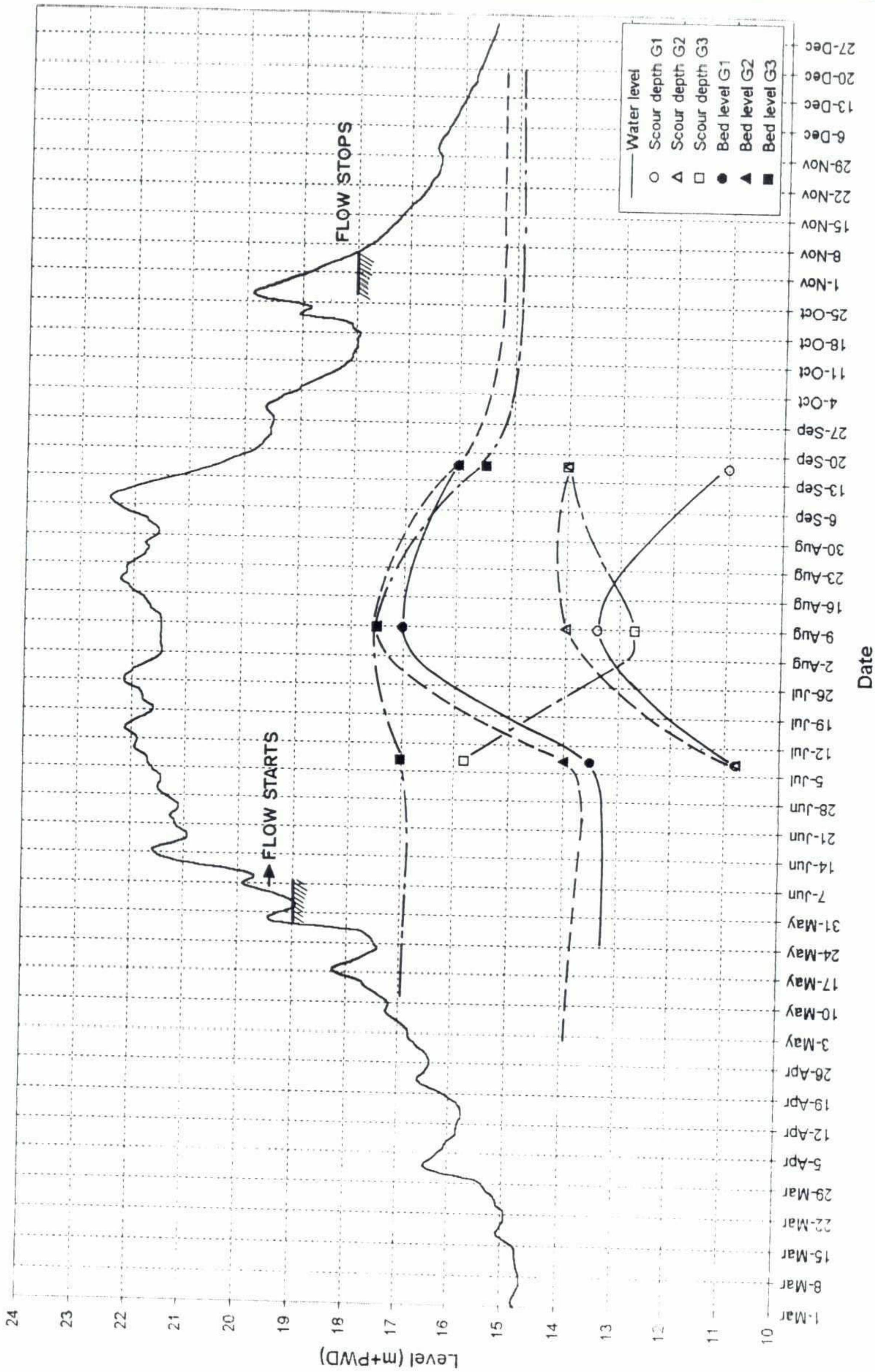
KAMARJANI TEST SITE
BATHYMETRIC SURVEY AT G-3 AND G-A
ON 17 SEPTEMBER 1998

FAP – 21
BANK PROTECTION PILOT PROJECT

FIG. 5.3



KAMARJANI TEST SITE BATHYMETRIC SURVEY AT G-1 AND G-2 ON 17 SEPTEMBER 1998	FAP – 21 BANK PROTECTION PILOT PROJECT
	FIG. 5.4

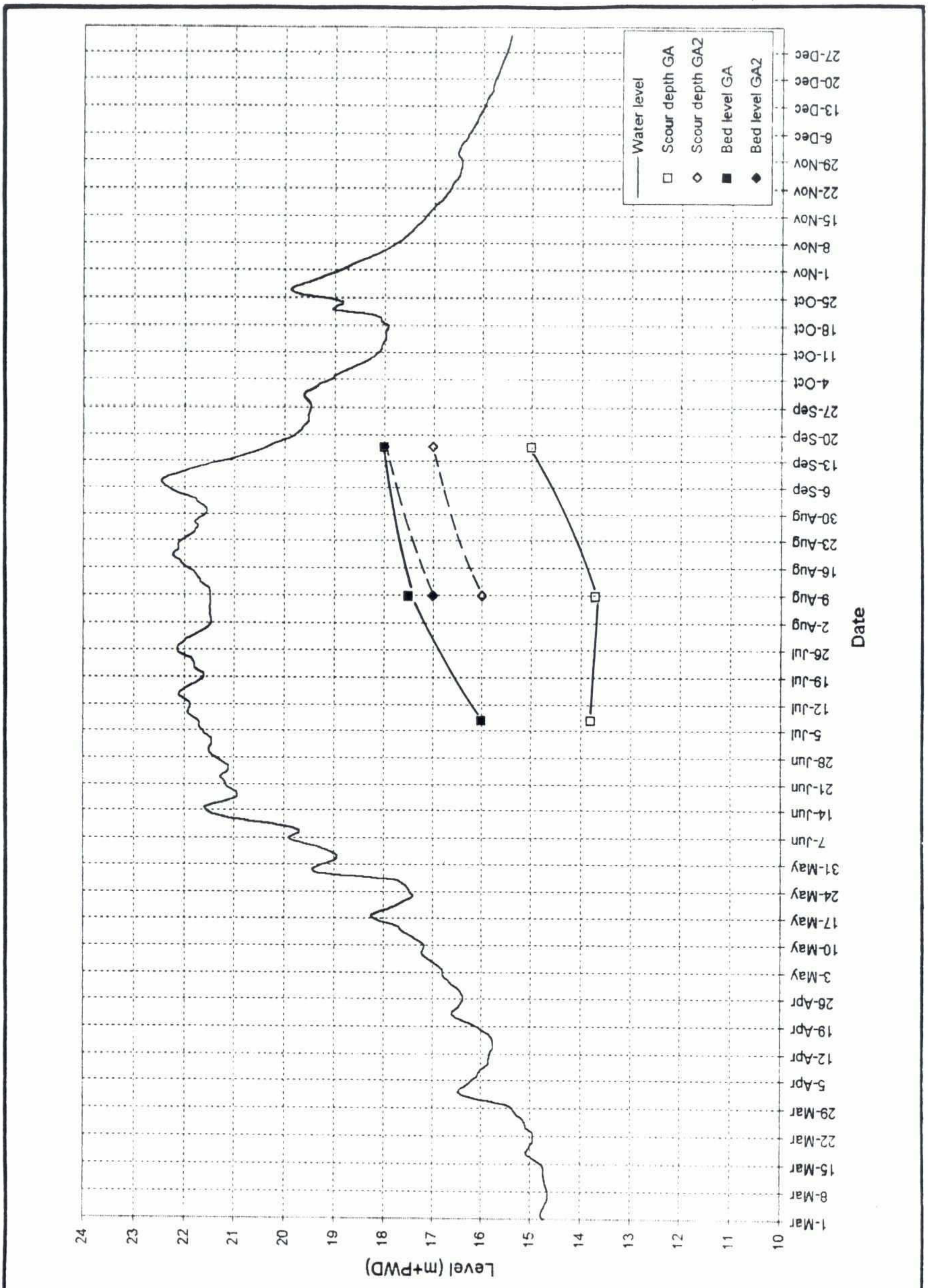


KAMARJANI TEST SITE
HYDROGRAPH, BED LEVELS UPSTREAM OF GROYNES AND DEEPEST POINT IN SCOUR HOLES AS FUNCTION OF TIME

FAP – 21

BANK PROTECTION PILOT PROJECT

FIG. 5.5



KAMARJANI TEST SITE HYDROGRAPH, BED LEVELS UPSTREAM OF GROYNES AND DEEPEST POINT IN SCOUR HOLES AS FUNCTION OF TIME	FAP – 21 BANK PROTECTION PILOT PROJECT FIG. 5.6

6 STRUCTURE OBSERVATIONS - DAMAGES

During the flood season 1998 no damages of the test structure have been observed.

7 ADAPTATION AND REPAIR WORKS

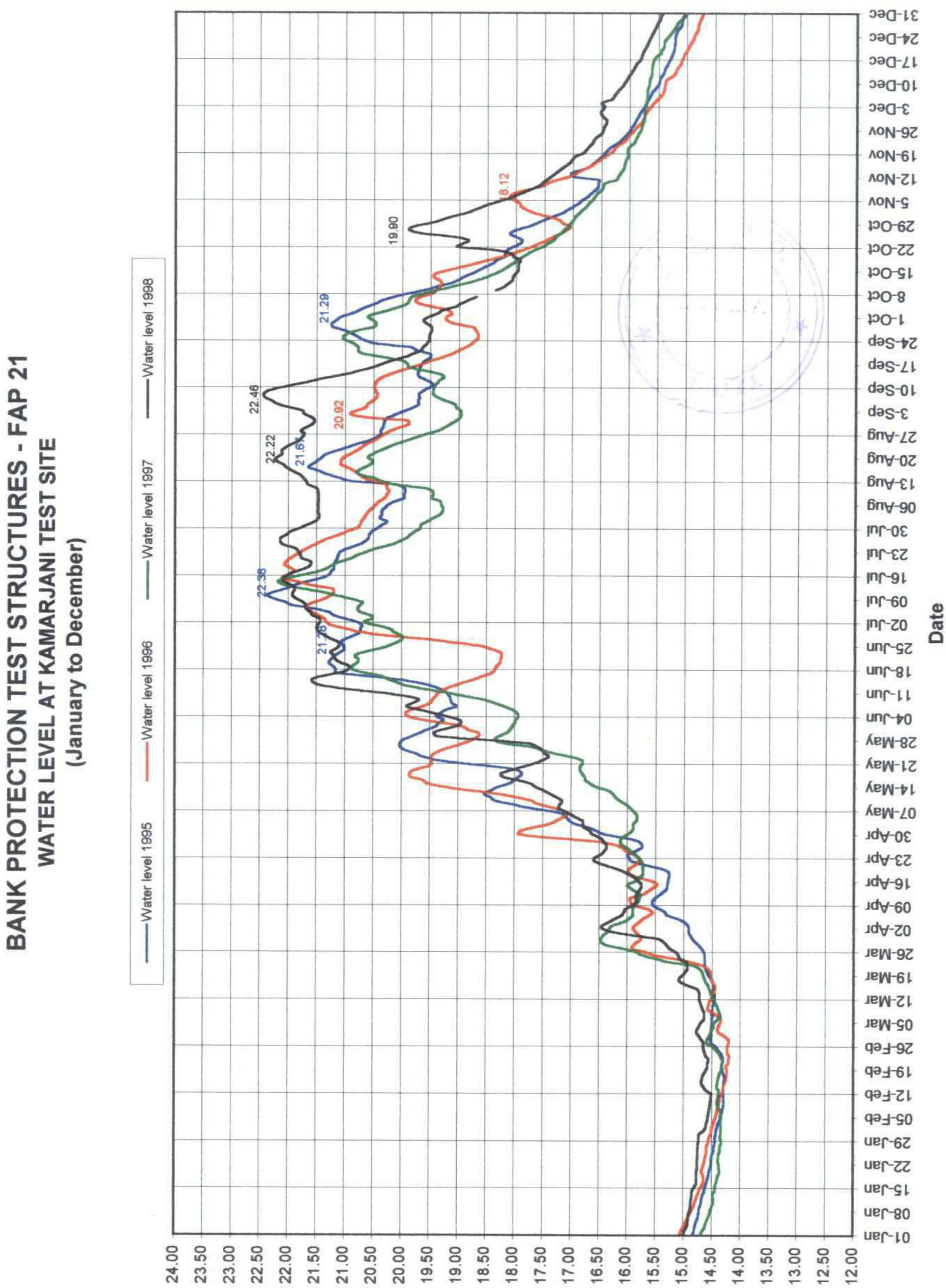
No adaptation or repair works of the test structure have been carried out in 1998.

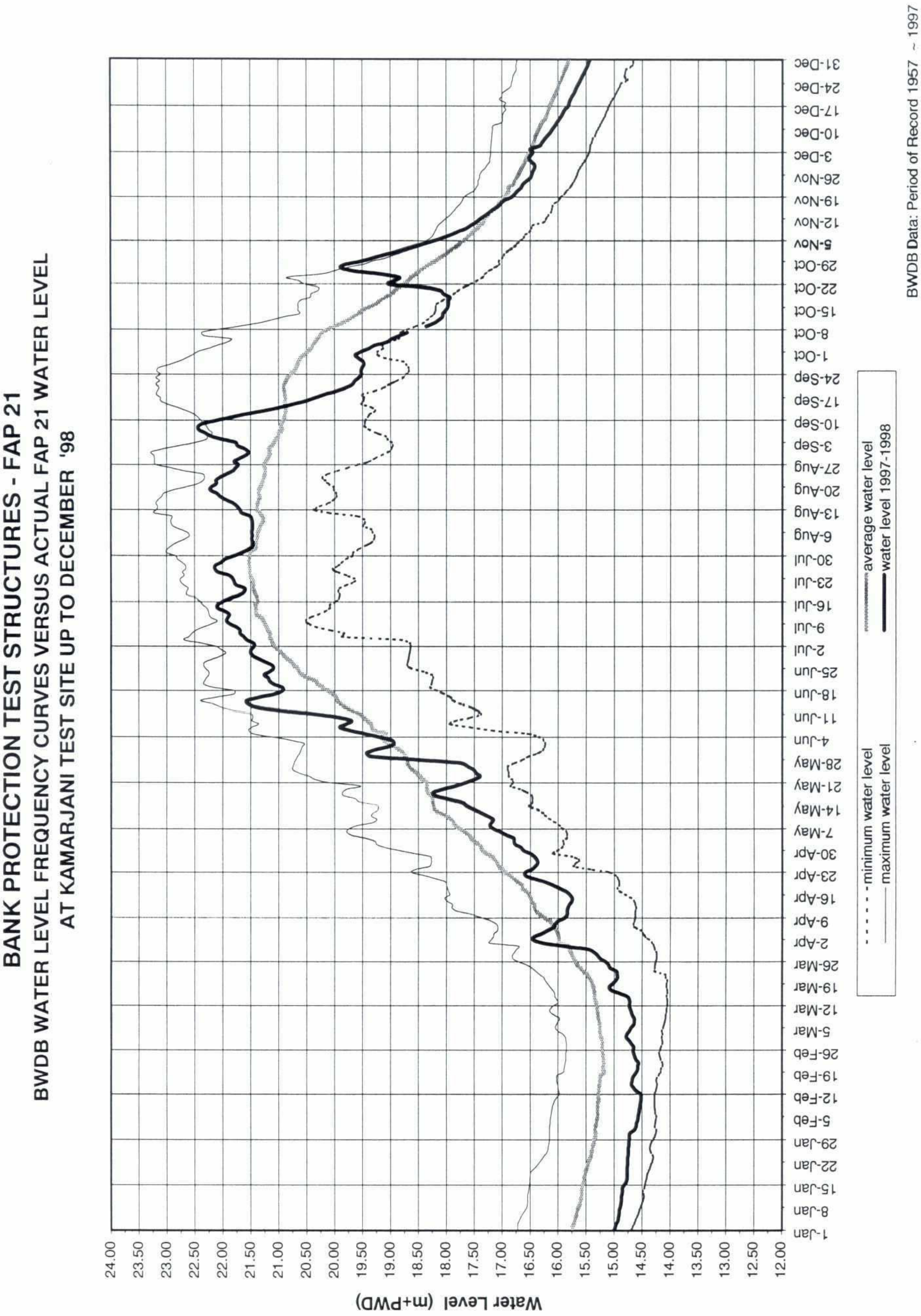
REFERENCES

AUTHOR / DATE	TITLE / PUBLISHER
Consulting Consortium FAP21/22 (September 1996)	Report on Monitoring and Adaptation at Kamarjani Test Site, Monsoon 1995
Consulting Consortium FAP21/22 (September 1998)	Report on Monitoring and Adaptation at Kamarjani Test Site, Monsoon 1996
Consulting Consortium FAP21/22 (March 1999)	Report on Monitoring and Adaptation at Kamarjani Test Site, Monsoon 1997
Consulting Consortium FAP21/22 (February 1999)	Current Measurements at Kamarjani, Katlamari and Bahadurabad
Consulting Consortium FAP21/22 (April 1998)	Additional Model Tests Technical Report No. 6
River Survey Project (RSP) FAP 24 (1996a)	Water Level Slopes Study Report No. 10

ANNEX A

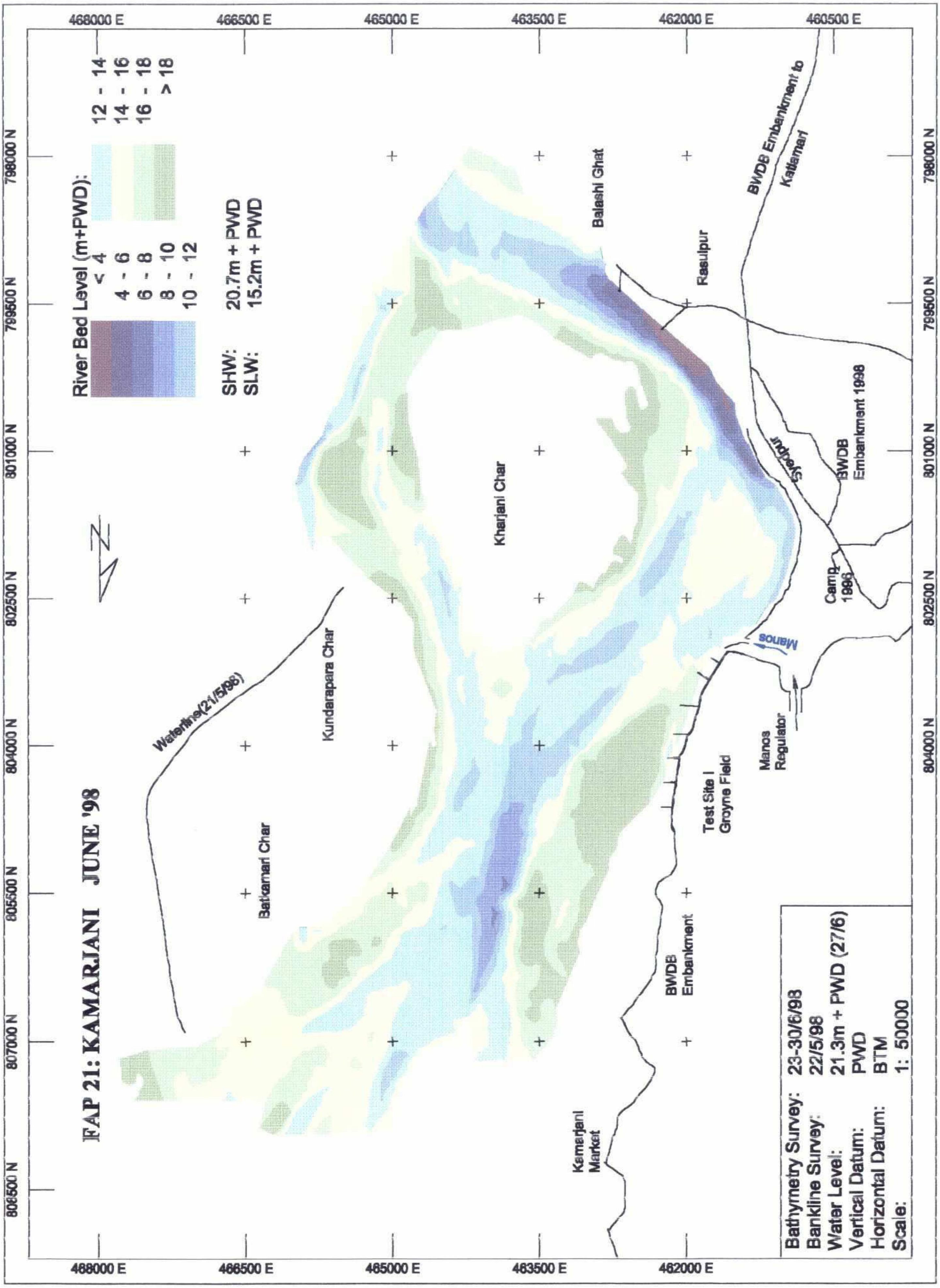
Water Level

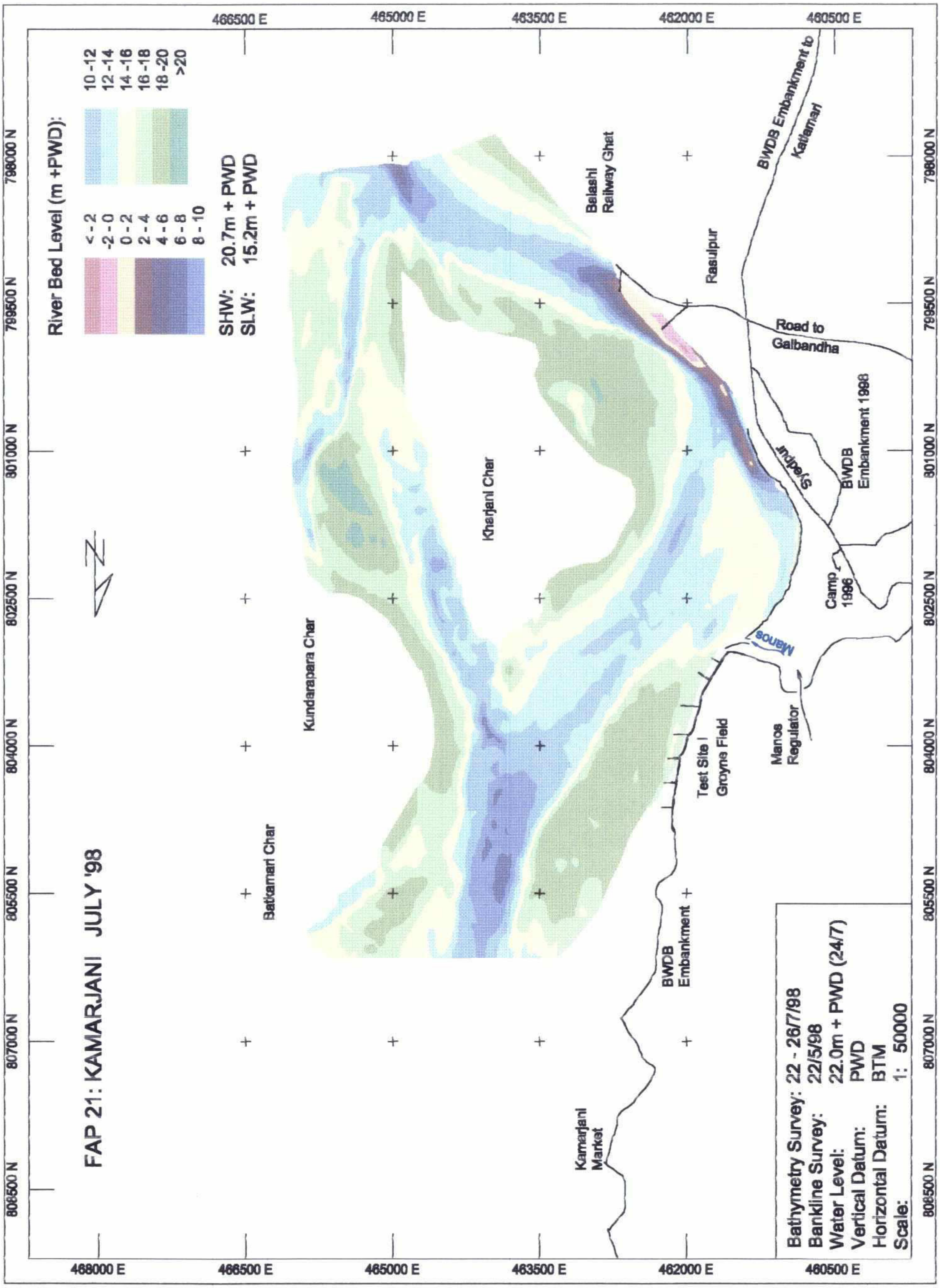

BANK PROTECTION TEST STRUCTURES - FAP 21
WATER LEVEL AT KAMARJANI TEST SITE
(January to December)
Water level 1995
Water level 1996
Water level 1997
Water level 1998
Water Level (m+PWD)
Date
22.46
22.22
21.67
22.38
21.78
21.29
20.92
19.90
18.12

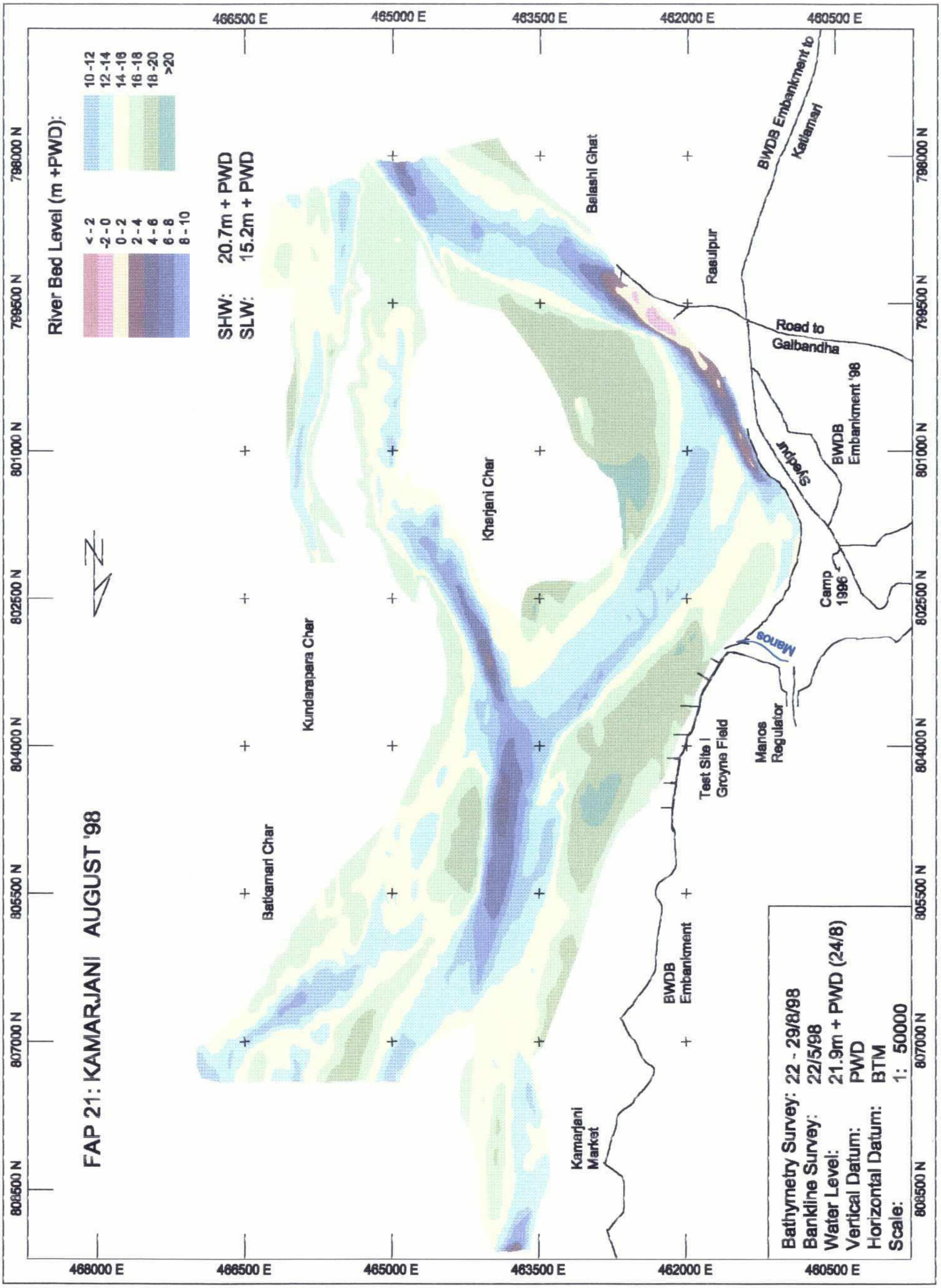

BANK PROTECTION TEST STRUCTURES - FAP 21
BWDB WATER LEVEL FREQUENCY CURVES VERSUS ACTUAL FAP 21 WATER LEVEL
AT KAMARJANI TEST SITE UP TO DECEMBER '98
Water Level (m+PWD)
24.00
23.50
23.00
22.50
22.00
21.50
21.00
20.50
20.00
19.50
19.00
18.50
18.00
17.50
17.00
16.50
16.00
15.50
15.00
14.50
14.00
13.50
13.00
12.50
12.00
1-Jan
8-Jan
15-Jan
22-Jan
29-Jan
5-Feb
12-Feb
19-Feb
26-Feb
5-Mar
12-Mar
19-Mar
26-Mar
2-Apr
9-Apr
16-Apr
23-Apr
30-Apr
7-May
14-May
21-May
28-May
4-Jun
11-Jun
18-Jun
25-Jun
2-Jul
9-Jul
16-Jul
23-Jul
30-Jul
6-Aug
13-Aug
20-Aug
27-Aug
3-Sep
10-Sep
17-Sep
24-Sep
1-Oct
8-Oct
15-Oct
22-Oct
29-Oct
5-Nov
12-Nov
19-Nov
26-Nov
3-Dec
10-Dec
17-Dec
24-Dec
31-Dec
minimum water level
maximum water level
average water level
water level 1997-1998
BWDB Data: Period of Record 1957 ~ 1997

ANNEX B

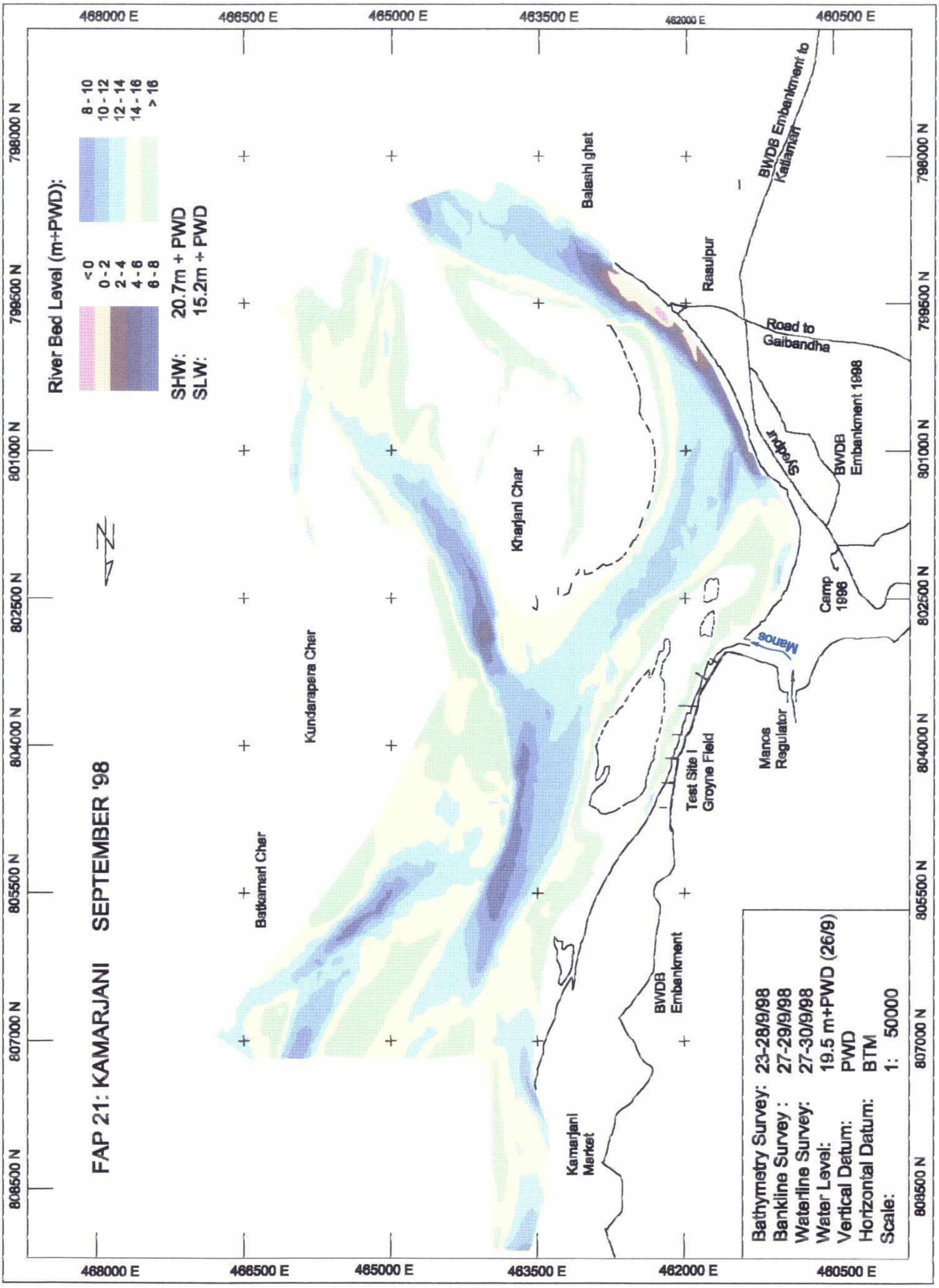
Bathymetric Survey

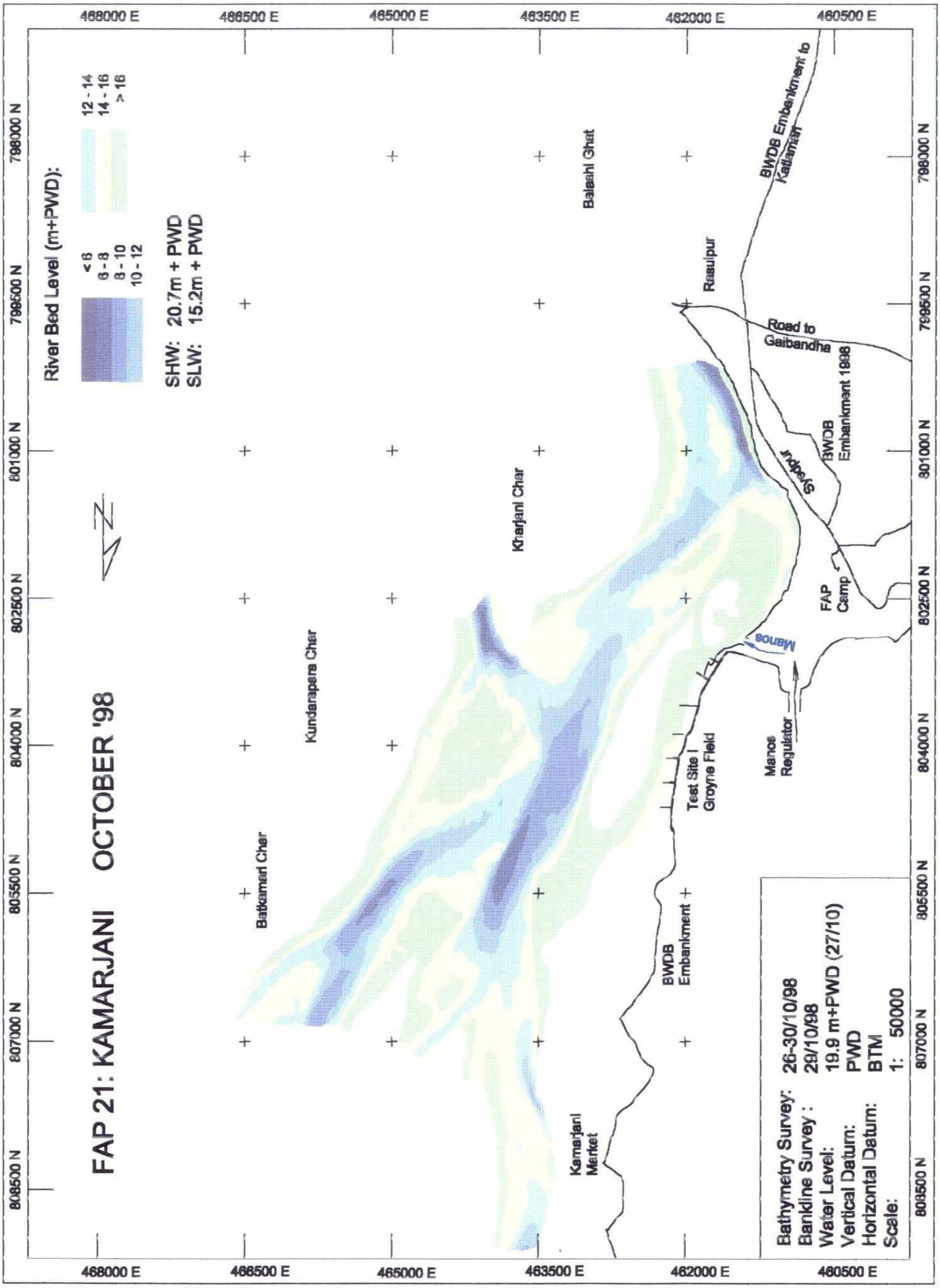

FAP 21: KAMARJANI JUNE '98
River Bed Level (m+PWD):
< 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
> 18
SHW: 20.7m + PWD
SLW: 15.2m + PWD
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N
Balashi Ghat
BWDB Embankment to Katlamari
Rasulpur
Kharjani Char
Syedpur
BWDB Embankment 1998
BWDB Embankment
Camp 1996
Manos
Manos Regulator
Kundarapara Char
Waterline(21/5/98)
Test Site I Groyne Field
Batkamari Char
Kamarjani Market
Bathymetry Survey: 23-30/6/98
Bankline Survey: 22/5/98
Water Level: 21.3m + PWD (27/6)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000

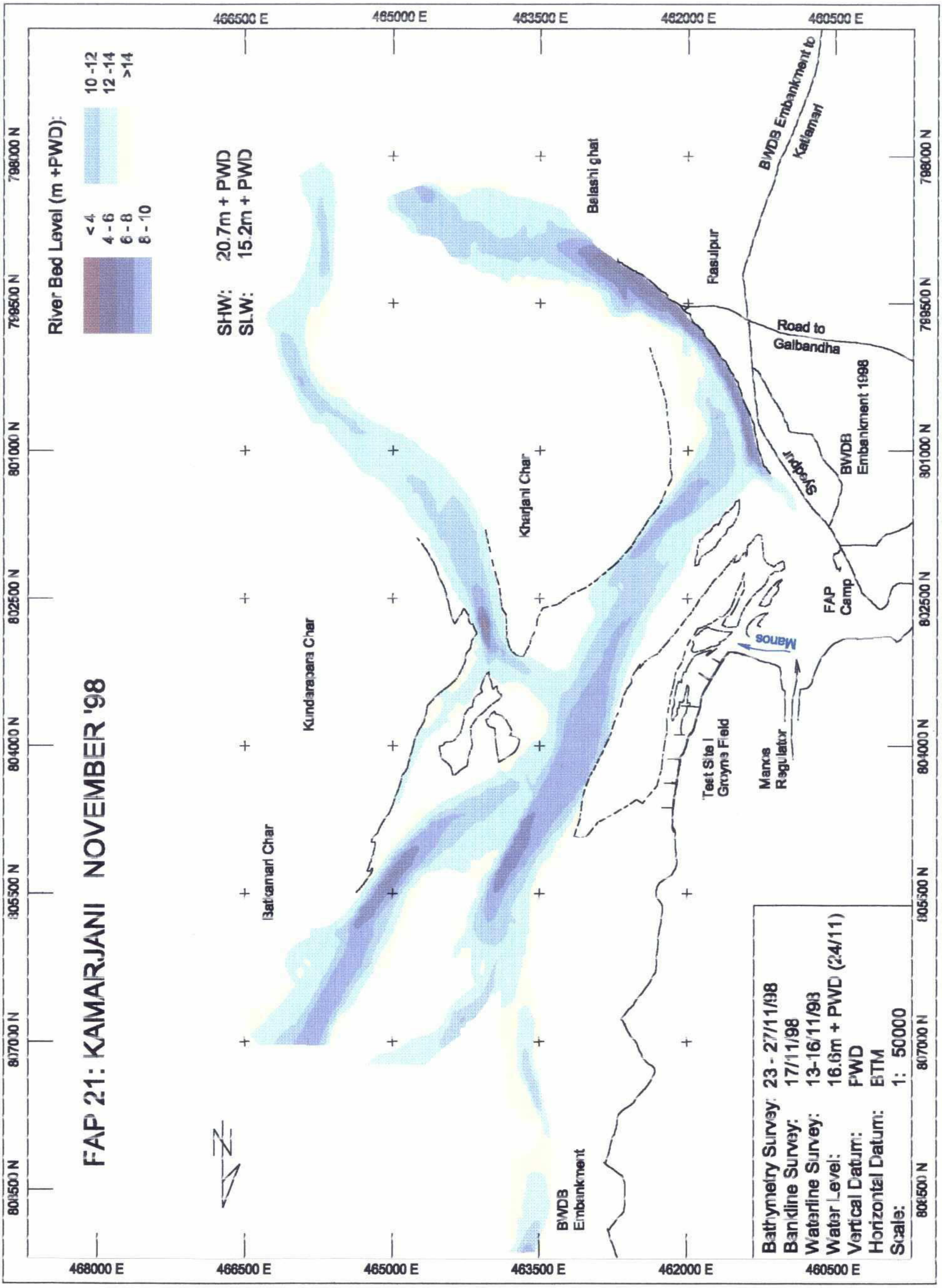

FAP 21: KAMARJANI JULY '98
River Bed Level (m +PWD):
< -2
-2 - 0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
18 - 20
>20
SHW: 20.7m + PWD
SLW: 15.2m + PWD
Bathymetry Survey: 22 - 26/7/98
Bankline Survey: 22/5/98
Water Level: 22.0m + PWD (24/7)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000
Kharjani Char
Kundarapara Char
Batkamari Char
Belashi Railway Ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment 1998
Syedpur
BWDB Embankment
Camp 1996
Manos
Manos Regulator
Test Site I Groyne Field
BWDB Embankment
Kamarjani Market
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N

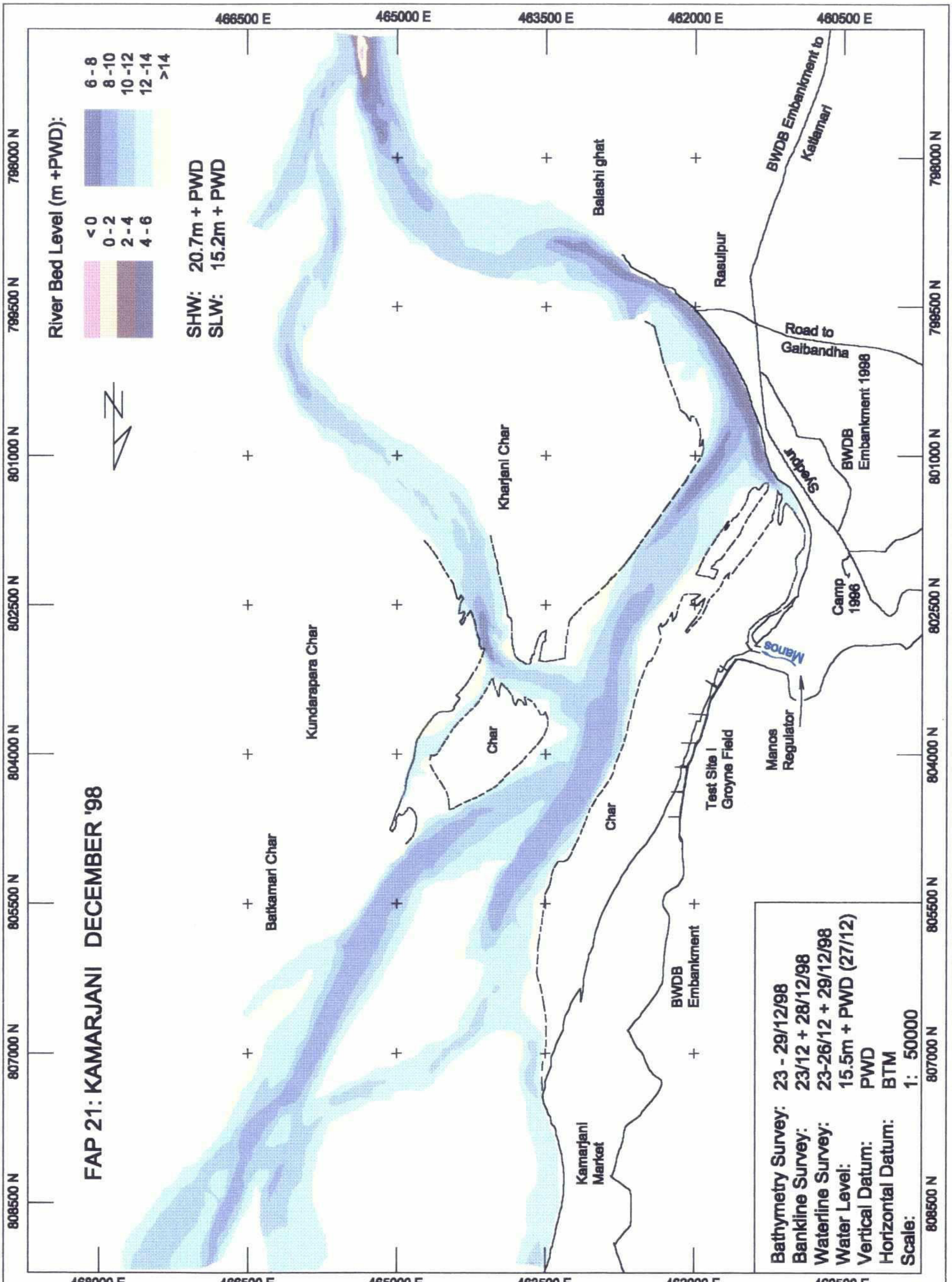


FAP 21: KAMARJANI AUGUST '98
River Bed Level (m +PWD):
< -2
-2 - 0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
18 - 20
>20
SHW: 20.7m + PWD
SLW: 15.2m + PWD
N
Bathymetry Survey: 22 - 29/8/98
Bankline Survey: 22/5/98
Water Level: 21.9m + PWD (24/8)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N
Balashi Ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment '98
Syedpur
BWDB Embankment
Kharjani Char
Camp 1996
Manos
Manos Regulator
Kundarapara Char
Test Site I Groyne Field
Batkamari Char
BWDB Embankment
Kamarjani Market


FAP 21: KAMARJANI SEPTEMBER '98
River Bed Level (m+PWD):
< 0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
> 16
SHW: 20.7m + PWD
SLW: 15.2m + PWD
N
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N
Balashi ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment 1998
Syedpur
BWDB Embankment
Kharjani Char
Camp 1998
Manos
Manos Regulator
Kundarapara Char
Test Site I Groyne Field
Batkamari Char
BWDB Embankment
Kamarjani Market
Bathymetry Survey: 23-28/9/98
Bankline Survey : 27-29/9/98
Waterline Survey: 27-30/9/98
Water Level: 19.5 m+PWD (26/9)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000

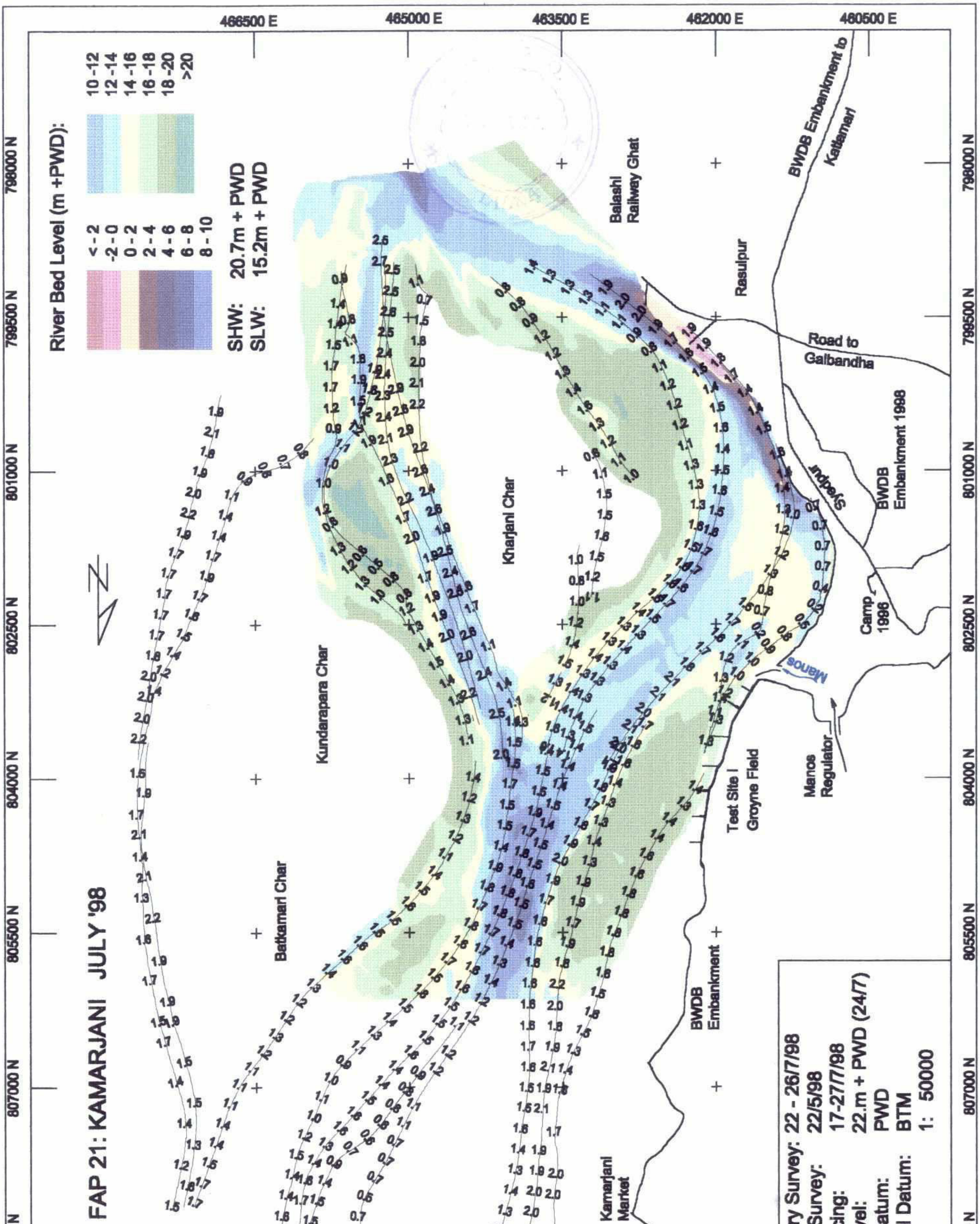

FAP 21: KAMARJANI OCTOBER '98
River Bed Level (m+PWD):
< 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
> 16
SHW: 20.7m + PWD
SLW: 15.2m + PWD
Bathymetry Survey: 26-30/10/98
Bankline Survey : 29/10/98
Water Level: 19.9 m+PWD (27/10)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000
Batkamari Char
Kundarapara Char
Kharjani Char
Balashi Ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment 1998
BWDB Embankment
Syedpur
FAP Camp
Manos
Manos Regulator
Test Site I Groyne Field
BWDB Embankment
Kamarjani Market
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N

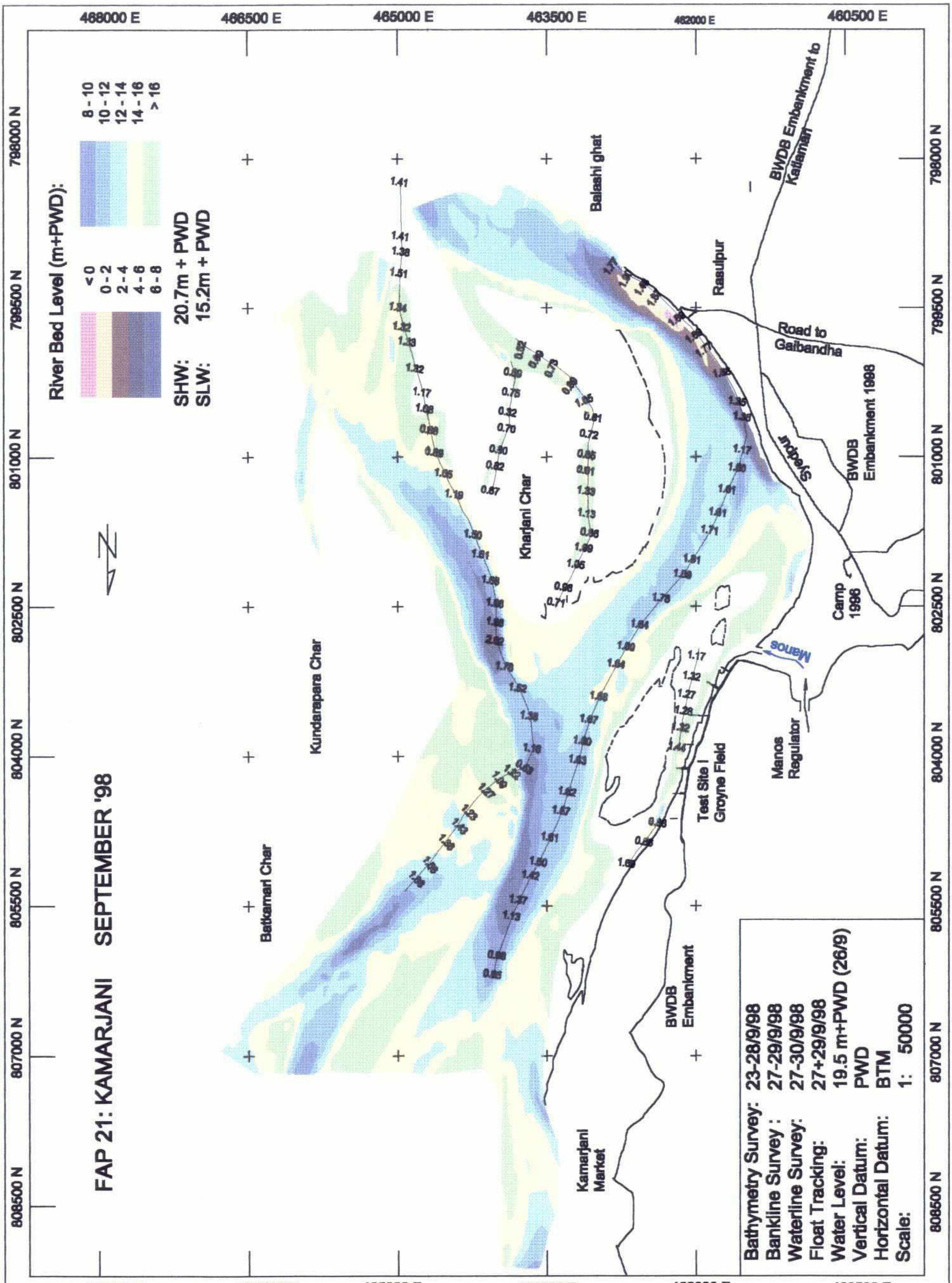

FAP 21: KAMARJANI NOVEMBER '98
River Bed Level (m +PWD):
<4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
>14
SHW: 20.7m + PWD
SLW: 15.2m + PWD
Belashi ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment 1998
Syedpur
Kharjani Char
Kundarapara Char
Batkamari Char
FAP Camp
Manos
Manos Regulator
Test Site I Groyne Field
BWDB Embankment
Bathymetry Survey: 23 - 27/11/98
Bankline Survey: 17/11/98
Waterline Survey: 13-16/11/98
Water Level: 16.6m + PWD (24/11)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N


FAP 21: KAMARJANI DECEMBER '98
River Bed Level (m +PWD):
< 0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
>14
SHW: 20.7m + PWD
SLW: 15.2m + PWD
N
466500 E
465000 E
463500 E
462000 E
460500 E
468000 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N
Balashi ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment 1998
Syedpur
BWDB Embankment
Kharjani Char
Camp 1996
Manos
Manos Regulator
Kundarapara Char
Char
Test Site I Groyne Field
Batkamari Char
BWDB Embankment
Kamarjani Market
Bathymetry Survey: 23 - 29/12/98
Bankline Survey: 23/12 + 28/12/98
Waterline Survey: 23-26/12 + 29/12/98
Water Level: 15.5m + PWD (27/12)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000

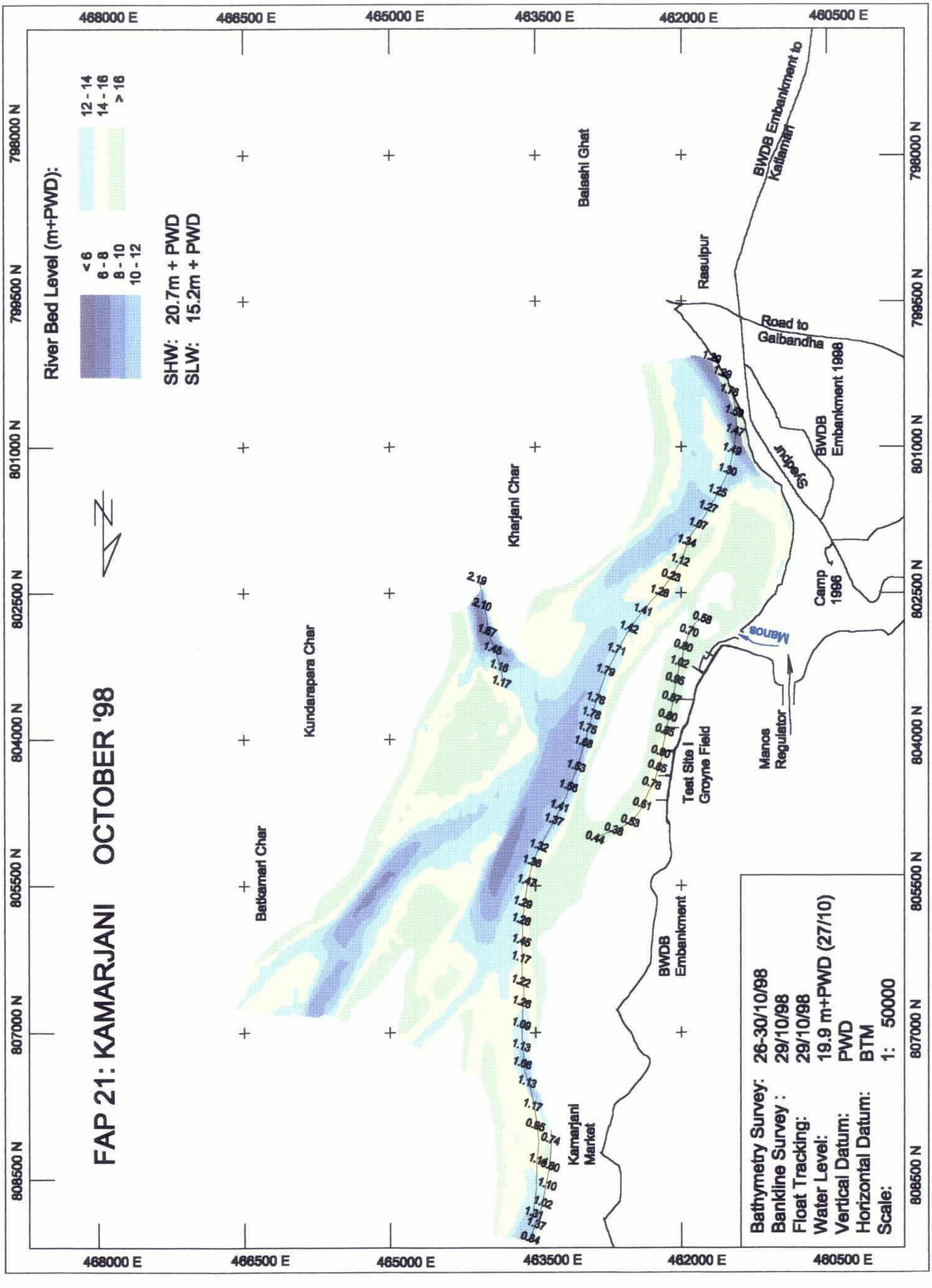
ANNEX C

Flow Lines


FAP 21: KAMARJANI JULY '98
River Bed Level (m +PWD):
< -2
-2 - 0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
16 - 18
18 - 20
>20
SHW: 20.7m + PWD
SLW: 15.2m + PWD
Balashi Railway Ghat
BWDB Embankment to Katlamari
Rasulpur
Road to Gaibandha
BWDB Embankment 1998
Syedpur
BWDB Embankment
Camp 1996
Manos
Manos Regulator
Test Site I Groyne Field
Kharjani Char
Kundarapara Char
Batkamari Char
Kamarjani Market
BWDB Embankment
Bathymetry Survey: 22 - 26/7/98
Bankline Survey: 22/5/98
Float Tracing: 17-27/7/98
Water Level: 22.m + PWD (24/7)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N


FAP 21: KAMARJANI SEPTEMBER '98
River Bed Level (m+PWD):
<0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
> 16
SHW: 20.7m + PWD
SLW: 15.2m + PWD
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N
Balashi ghat
BWDB Embankment to Katlamari
Rasulpur
Road to Gaibandha
BWDB Embankment 1998
Syedpur
BWDB Embankment
Kharjani Char
Camp 1996
Manos
Manos Regulator
Kundarapara Char
Test Site I Groyne Field
Batkamari Char
BWDB Embankment
Kamarjani Market
Bathymetry Survey: 23-28/9/98
Bankline Survey: 27-29/9/98
Waterline Survey: 27-30/9/98
Float Tracking: 27+29/9/98
Water Level: 19.5 m+PWD (26/9)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000

90


FAP 21: KAMARJANI OCTOBER '98
River Bed Level (m+PWD):
< 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 16
> 16
SHW: 20.7m + PWD
SLW: 15.2m + PWD
Balashi Ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment 1998
Syedpur
BWDB Embankment
Camp 1996
Manos
Manos Regulator
Test Site I Groyne Field
BWDB Embankment
Kamarjani Market
Kharjani Char
Kundarapara Char
Batkamari Char
Bathymetry Survey: 26-30/10/98
Bankline Survey : 29/10/98
Float Tracking: 29/10/98
Water Level: 19.9 m+PWD (27/10)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
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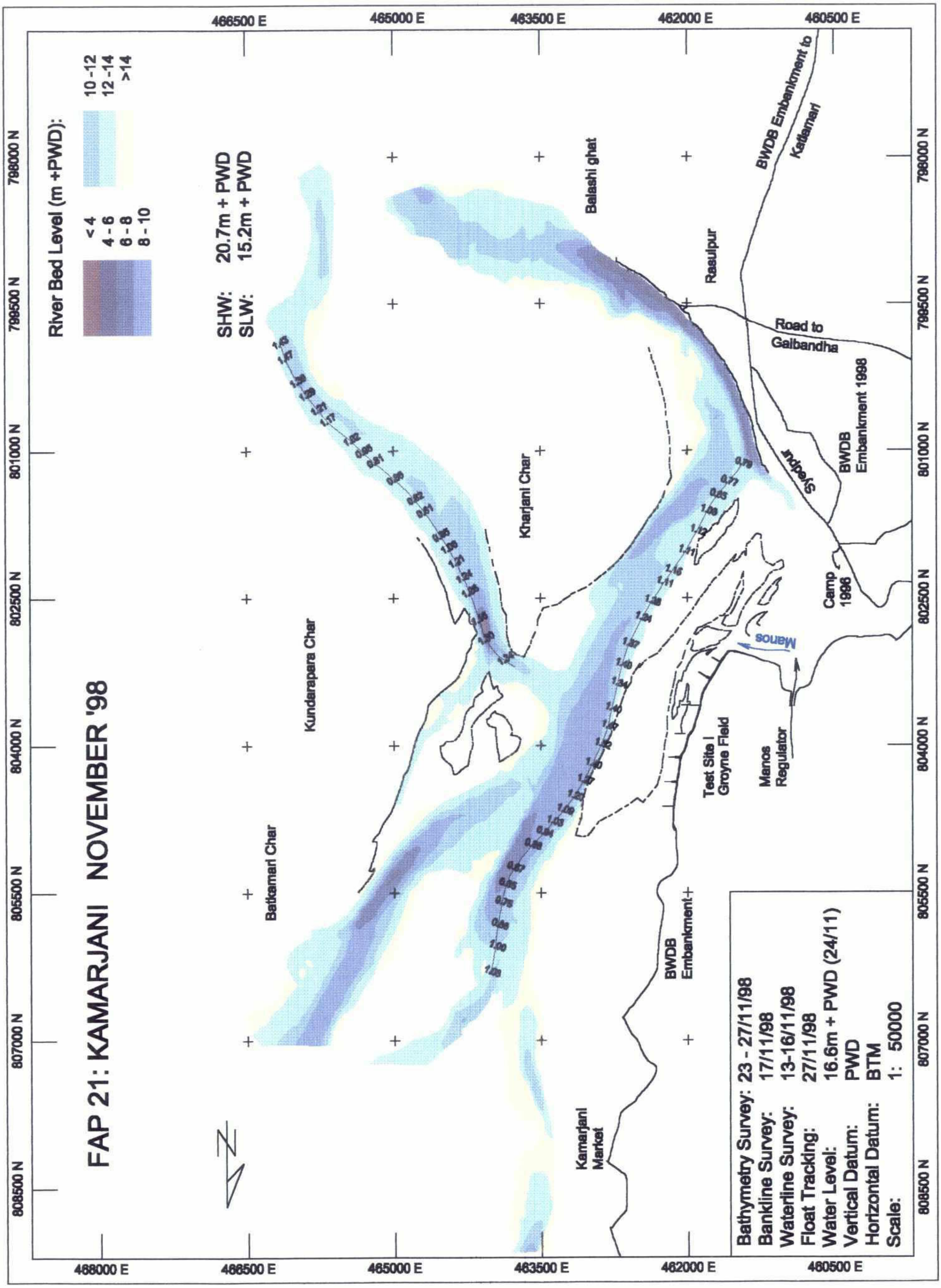
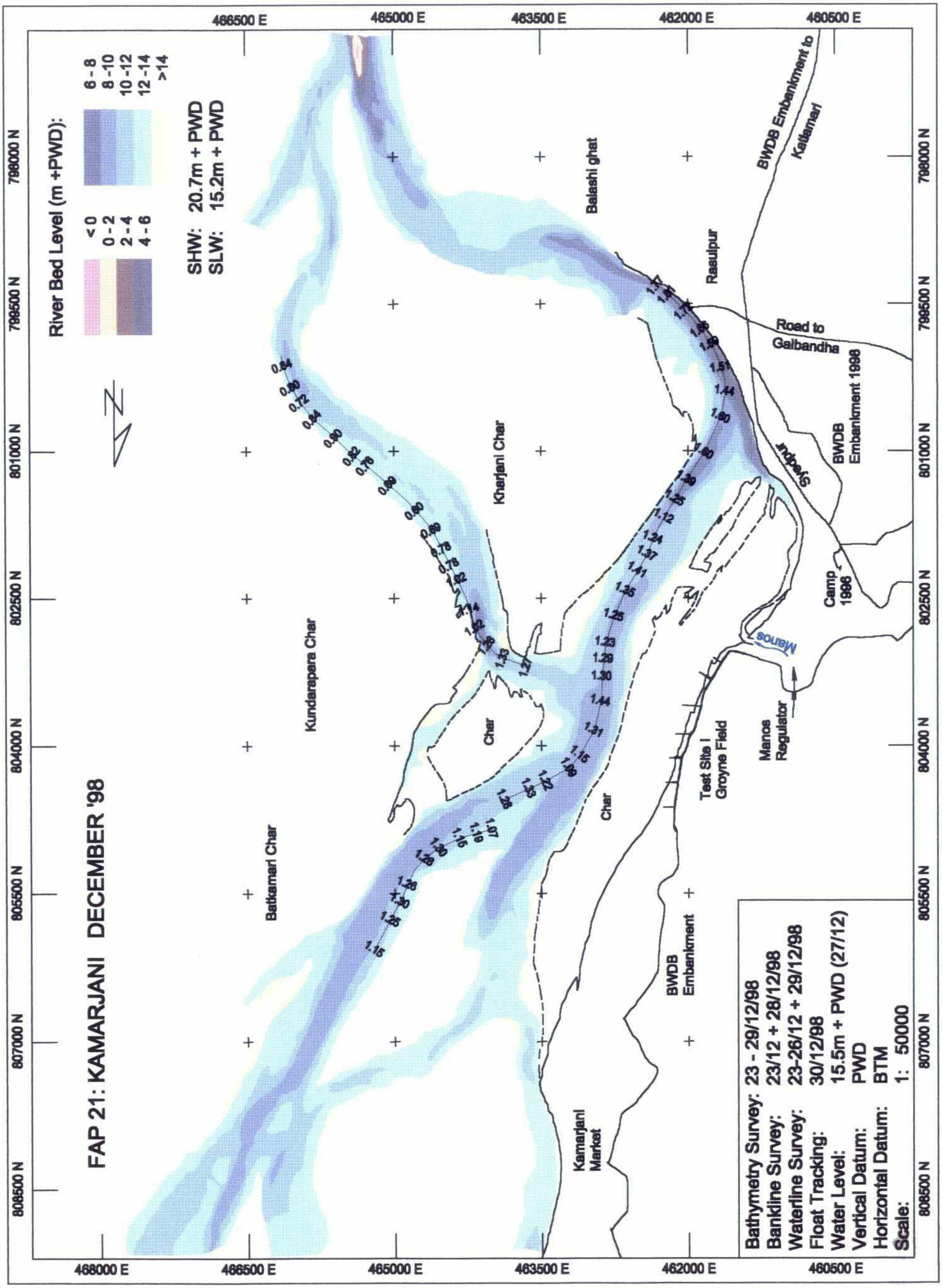
805500 N
807000 N
808500 N


FAP 21: KAMARJANI NOVEMBER '98
River Bed Level (m +PWD):
< 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
>14
SHW: 20.7m + PWD
SLW: 15.2m + PWD
Balashi ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment 1998
Syedpur
BWDB Embankment
Camp 1996
Manos
Manos Regulator
Test Site I Groyne Field
Kharjani Char
Kundarapara Char
Batkamari Char
BWDB Embankment
Kamarjani Market
Bathymetry Survey: 23 - 27/11/98
Bankline Survey: 17/11/98
Waterline Survey: 13-16/11/98
Float Tracking: 27/11/98
Water Level: 16.6m + PWD (24/11)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N


FAP 21: KAMARJANI DECEMBER '98
River Bed Level (m +PWD):
<0
0 - 2
2 - 4
4 - 6
6 - 8
8 -10
10 -12
12 -14
>14
SHW: 20.7m + PWD
SLW: 15.2m + PWD
Bathymetry Survey: 23 - 29/12/98
Bankline Survey: 23/12 + 28/12/98
Waterline Survey: 23-26/12 + 29/12/98
Float Tracking: 30/12/98
Water Level: 15.5m + PWD (27/12)
Vertical Datum: PWD
Horizontal Datum: BTM
Scale: 1: 50000
BWDB Embankment to Katlamari
Balashi ghat
Rasulpur
Road to Gaibandha
BWDB Embankment 1998
Syedpur
Kharjani Char
Kundarapara Char
Batkamari Char
Char
Camp 1998
Manos
Manos Regulator
Test Site I Groyne Field
BWDB Embankment
Kamarjani Market
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N

ANNEX D

Differential Models

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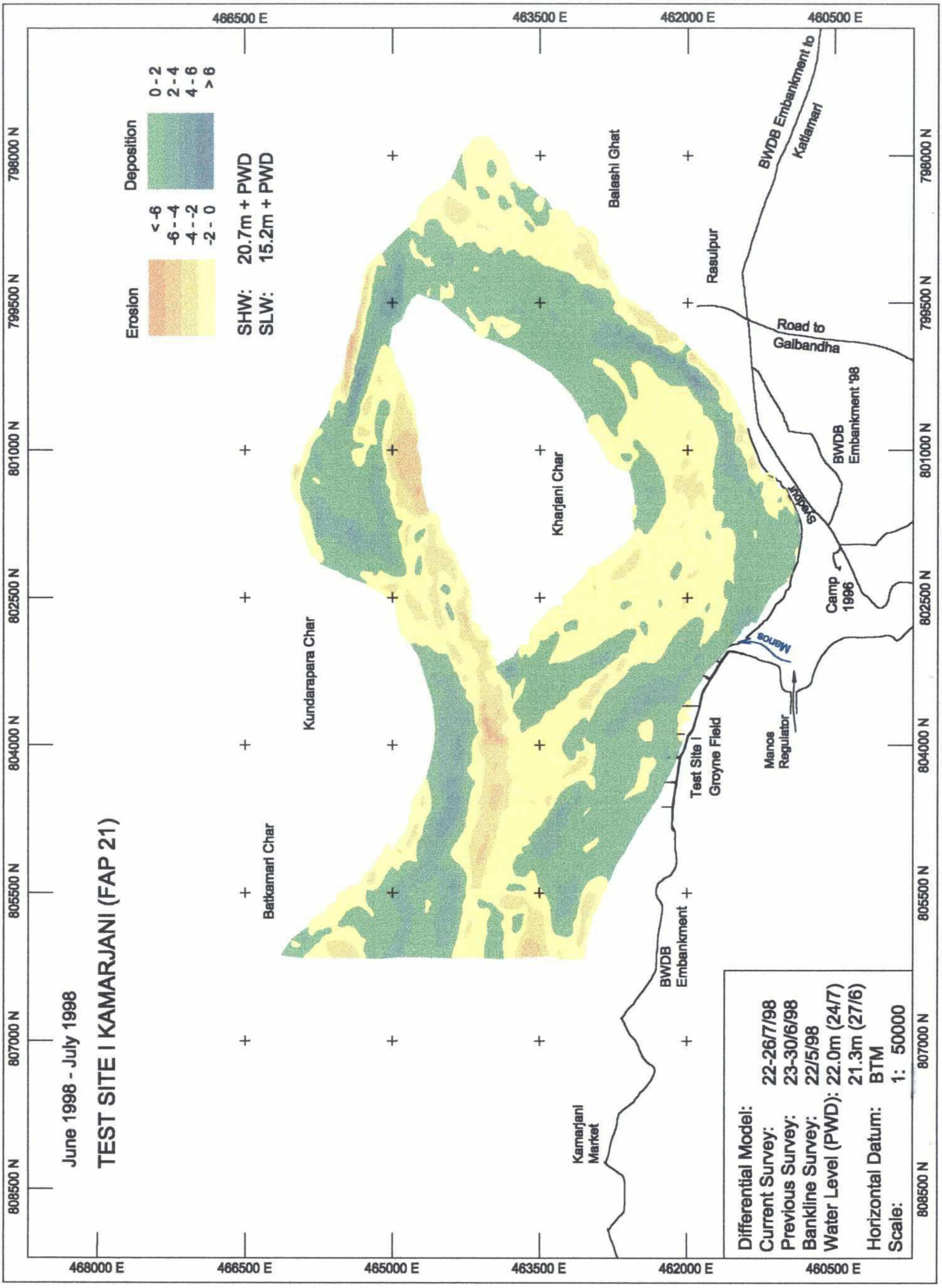
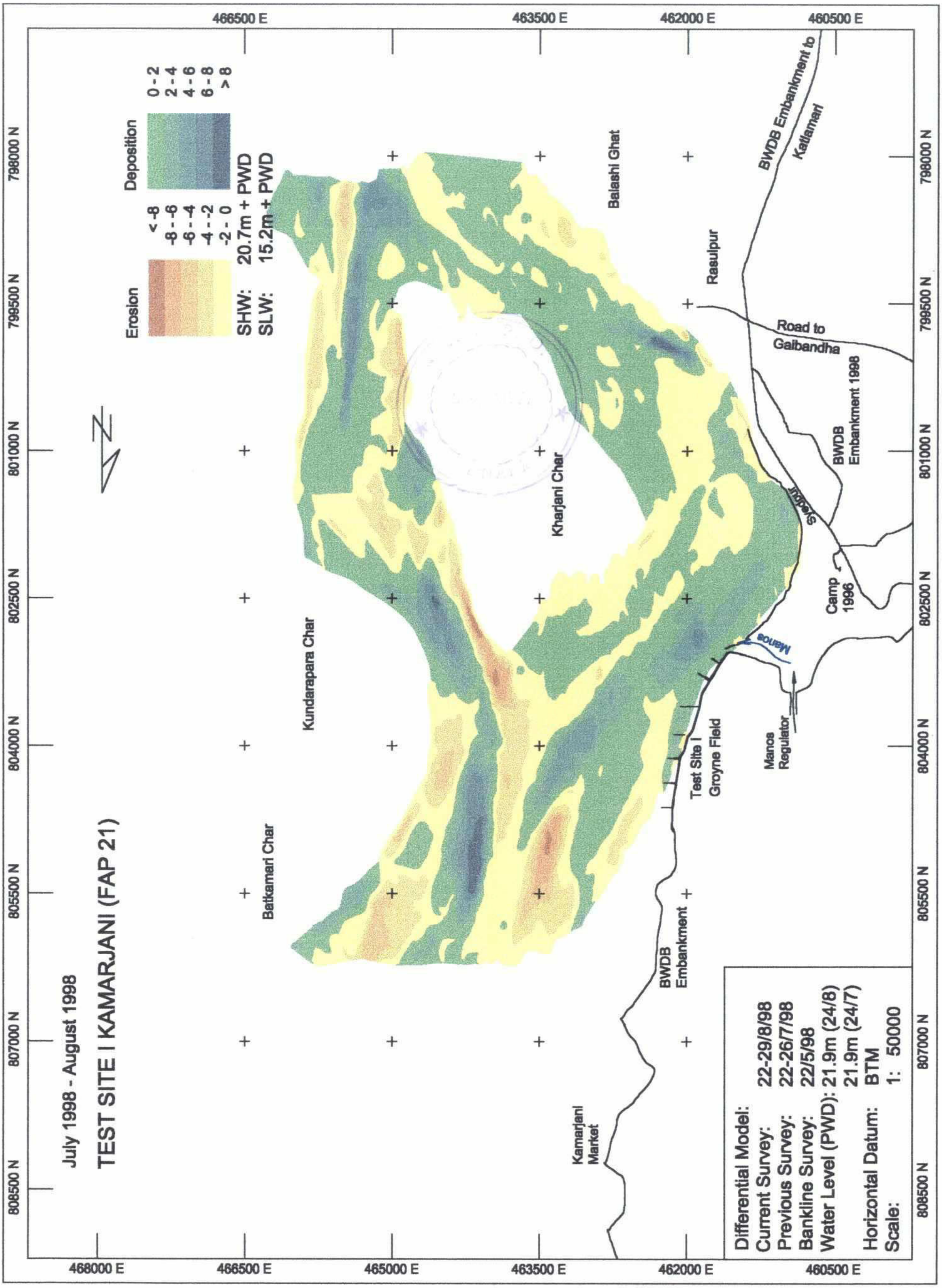
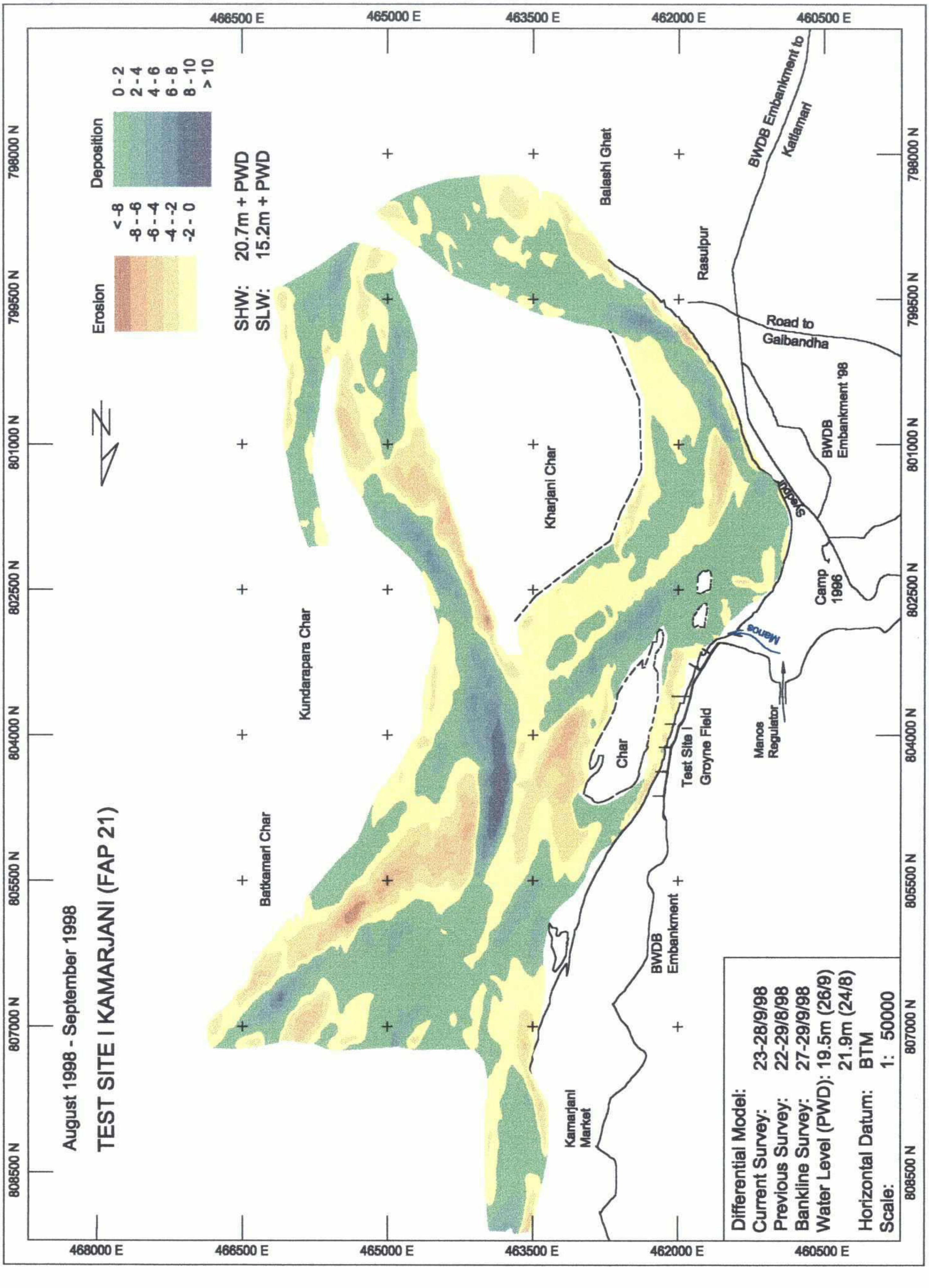

June 1998 - July 1998
TEST SITE I KAMARJANI (FAP 21)
Erosion
< -6
-6 - -4
-4 - -2
-2 - 0
Deposition
0 - 2
2 - 4
4 - 6
> 6
SHW: 20.7m + PWD
SLW: 15.2m + PWD
Balashi Ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment '98
BWDB Embankment
Spadow
Camp 1996
Manos
Manos Regulator
Test Site I Groyne Field
Kharjani Char
Kundarapara Char
Batkamari Char
BWDB Embankment
Kamarjani Market
Differential Model:
Current Survey: 22-26/7/98
Previous Survey: 23-30/6/98
Bankline Survey: 22/5/98
Water Level (PWD): 22.0m (24/7) 21.3m (27/6)
Horizontal Datum: BTM
Scale: 1: 50000
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N


July 1998 - August 1998
TEST SITE I KAMARJANI (FAP 21)
Erosion
< -8
-8 - -6
-6 - -4
-4 - -2
-2 - 0
Deposition
0 - 2
2 - 4
4 - 6
6 - 8
> 8
SHW: 20.7m + PWD
SLW: 15.2m + PWD
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N
Balashi Ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment 1998
BWDB Embankment
Kharjani Char
Kundarapara Char
Batkamari Char
Sleeping
Camp 1996
Manos
Manos Regulator
Test Site I Groyne Field
BWDB Embankment
Kamarjani Market
Differential Model:
Current Survey: 22-29/8/98
Previous Survey: 22-26/7/98
Bankline Survey: 22/5/98
Water Level (PWD): 21.9m (24/8)
21.9m (24/7)
Horizontal Datum: BTM
Scale: 1: 50000


August 1998 - September 1998
TEST SITE I KAMARJANI (FAP 21)
Erosion
< -8
-8 - -6
-6 - -4
-4 - -2
-2 - 0
Deposition
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
> 10
SHW: 20.7m + PWD
SLW: 15.2m + PWD
Batkamari Char
Kundarapara Char
Kharjani Char
Balashi Ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment '98
BWDB Embankment
Spadur
Camp 1996
Manos
Manos Regulator
Char
Test Site I Groyne Field
Kamarjani Market
Differential Model:
Current Survey: 23-28/9/98
Previous Survey: 22-29/8/98
Bankline Survey: 27-29/9/98
Water Level (PWD): 19.5m (26/9)
21.9m (24/8)
Horizontal Datum: BTM
Scale: 1: 50000
466500 E
465000 E
463500 E
462000 E
460500 E
468000 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N

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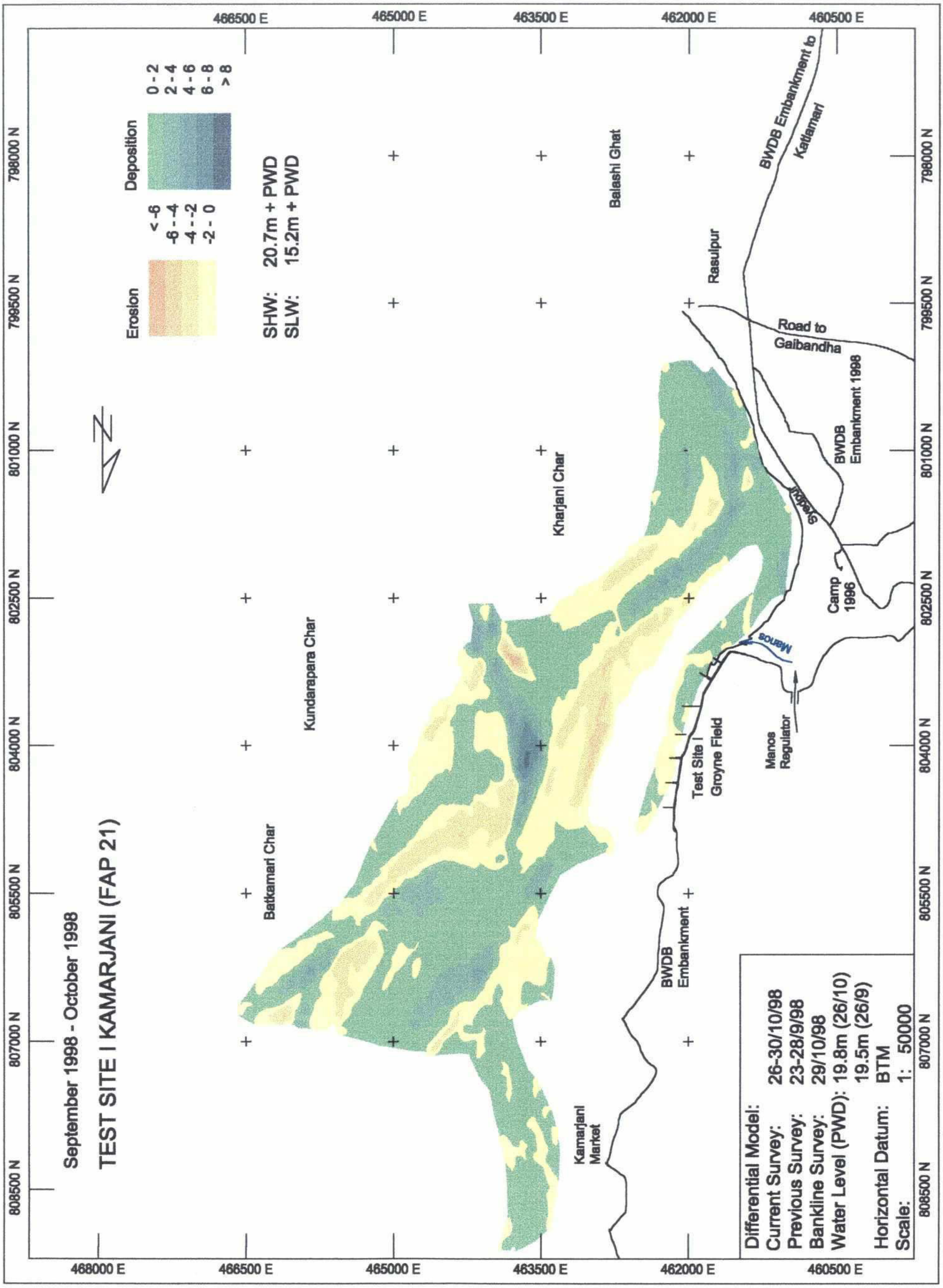

September 1998 - October 1998
TEST SITE I KAMARJANI (FAP 21)
Erosion
< -6
-6 - -4
-4 - -2
-2 - 0
Deposition
0 - 2
2 - 4
4 - 6
6 - 8
> 8
SHW: 20.7m + PWD
SLW: 15.2m + PWD
466500 E
465000 E
463500 E
462000 E
460500 E
468000 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N
Balashi Ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment 1998
BWDB Embankment
Spadkil
Camp 1996
Manos
Manos Regulator
Test Site I Groyne Field
Kharjani Char
Kundarapara Char
Batkamari Char
BWDB Embankment
Kamarjani Market
Differential Model:
Current Survey: 26-30/10/98
Previous Survey: 23-28/9/98
Bankline Survey: 29/10/98
Water Level (PWD): 19.8m (26/10)
19.5m (26/9)
Horizontal Datum: BTM
Scale: 1: 50000

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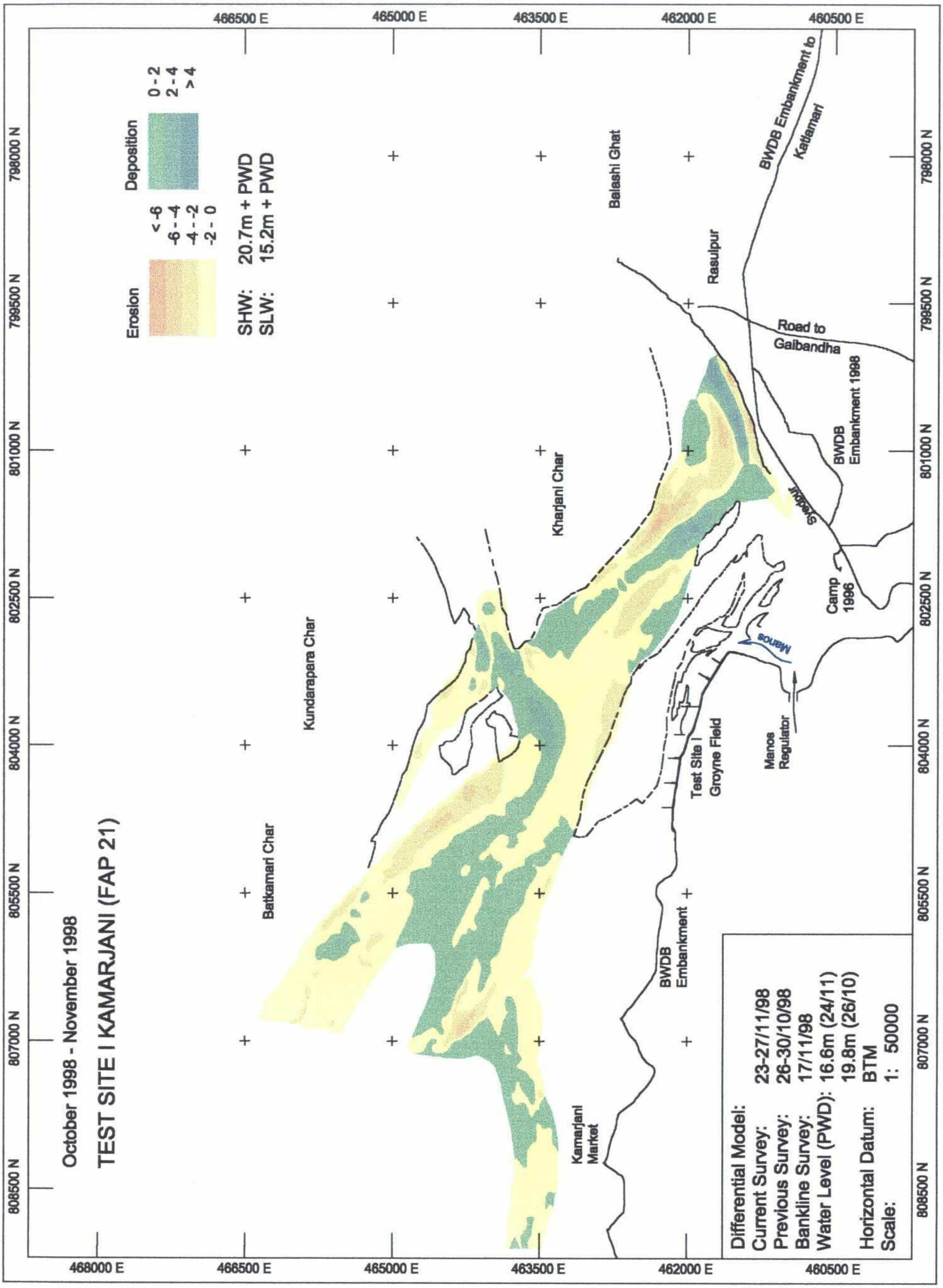
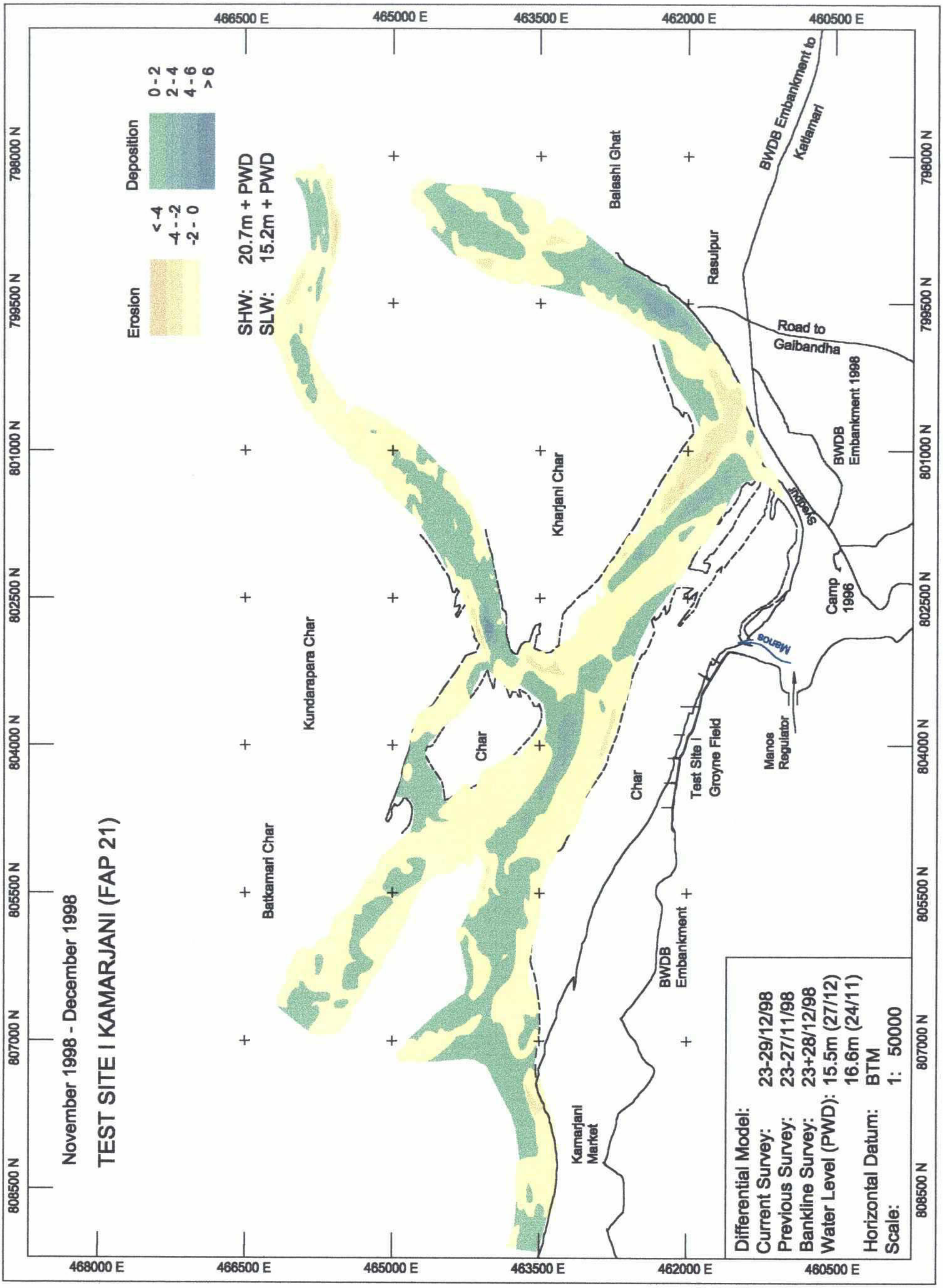

October 1998 - November 1998
TEST SITE I KAMARJANI (FAP 21)
Erosion
Deposition
< -6
-6 - -4
-4 - -2
-2 - 0
0 - 2
2 - 4
> 4
SHW: 20.7m + PWD
SLW: 15.2m + PWD
466500 E
465000 E
463500 E
462000 E
460500 E
468000 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N
BWDB Embankment to Katlamari
Balashi Ghat
Rasulpur
Road to Gaibandha
BWDB Embankment 1998
BWDB Embankment
Kharjani Char
Camp 1996
Manos
Manos Regulator
Test Site I Groyne Field
Kundarapara Char
Batkamari Char
BWDB Embankment
Kamarjani Market
Differential Model:
Current Survey: 23-27/11/98
Previous Survey: 26-30/10/98
Bankline Survey: 17/11/98
Water Level (PWD): 16.6m (24/11)
19.8m (26/10)
Horizontal Datum: BTM
Scale: 1: 50000



November 1998 - December 1998
TEST SITE I KAMARJANI (FAP 21)
Erosion
< -4
-4 - -2
-2 - 0
Deposition
0 - 2
2 - 4
4 - 6
> 6
SHW: 20.7m + PWD
SLW: 15.2m + PWD
Differential Model:
Current Survey: 23-29/12/98
Previous Survey: 23-27/11/98
Bankline Survey: 23+28/12/98
Water Level (PWD): 15.5m (27/12)
16.6m (24/11)
Horizontal Datum: BTM
Scale: 1: 50000
Batkamari Char
Kundarapara Char
Char
Char
Kharjani Char
Balashi Ghat
Rasulpur
BWDB Embankment to Katlamari
Road to Gaibandha
BWDB Embankment 1998
BWDB Embankment
Camp 1996
Manos
Manos Regulator
Test Site I Groyne Field
BWDB Embankment
Kamarjani Market
468000 E
466500 E
465000 E
463500 E
462000 E
460500 E
798000 N
799500 N
801000 N
802500 N
804000 N
805500 N
807000 N
808500 N

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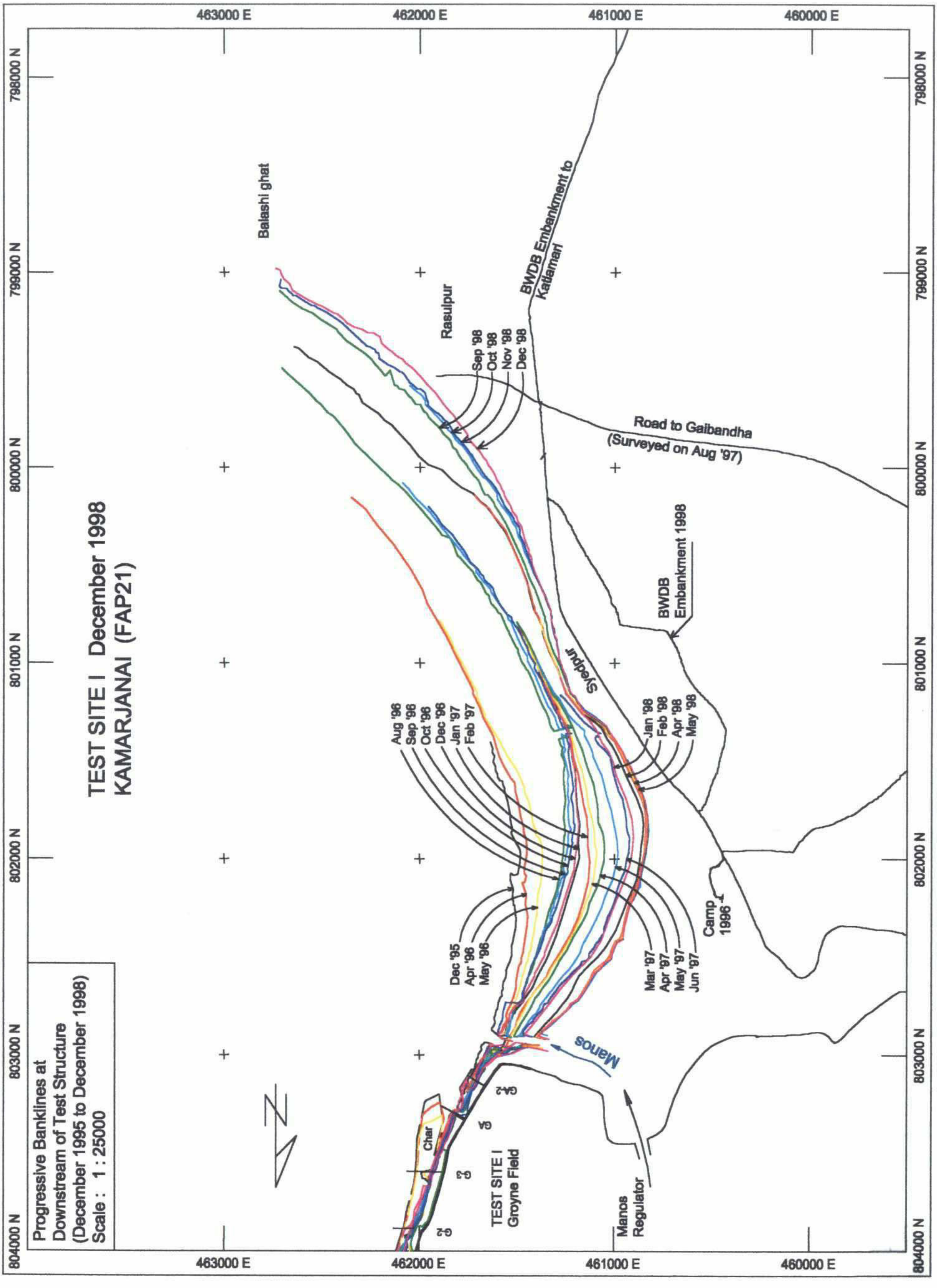
ANNEX E

Change of Bankline


TEST SITE I December 1998
KAMARJANAI (FAP21)
Progressive Banklines at
Downstream of Test Structure
(December 1995 to December 1998)
Scale : 1 : 25000
463000 E
462000 E
461000 E
460000 E
798000 N
799000 N
800000 N
801000 N
802000 N
803000 N
804000 N
Balashi ghat
Rasulpur
BWDB Embankment to
Kattamari
Sep '98
Oct '98
Nov '98
Dec '98
Road to Gaibandha
(Surveyed on Aug '97)
BWDB
Embankment 1998
Syedpur
Jan '98
Feb '98
Apr '98
May '98
Aug '96
Sep '96
Oct '96
Dec '96
Jan '97
Feb '97
Dec '95
Apr '96
May '96
Mar '97
Apr '97
May '97
Jun '97
Camp
1996
Manos
GA-2
GA
G-3
G-2
Char
TEST SITE I
Groyne Field
Manos
Regulator
N