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GOVERNMENT OF BANGLADESH
FLOOD PLAN COORDINATION ORGANIZATION

FAP 24 RIVER SURVEY PROJECT

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1° Interim Report
Volume II
Annexures on survey work

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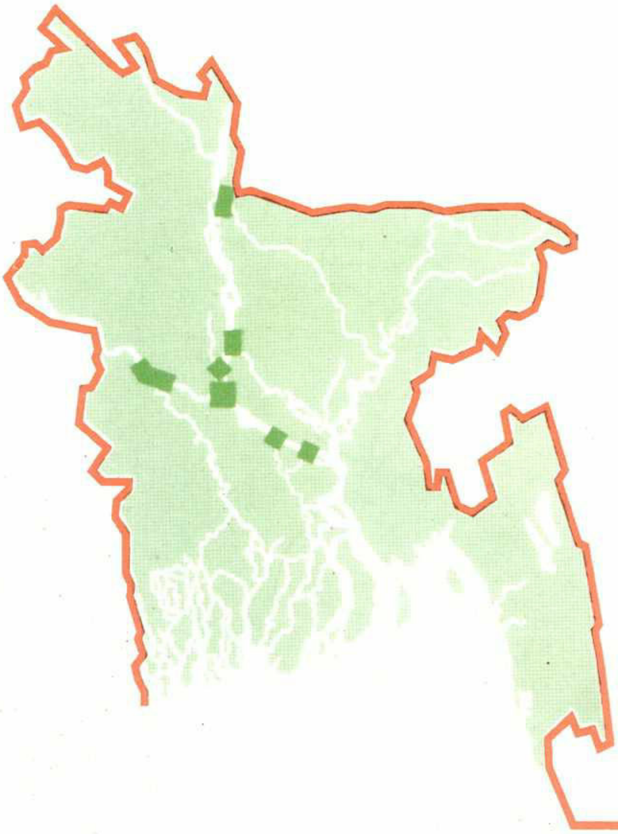

DELFT HYDRAULICS
DANISH HYDRAULIC INSTITUTE
OSIRIS
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Project ALA/90/04 — Commission of the European Communities

1° Interim Report

Volume II

Annexures on survey work

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CONTENTS OF THE INTERIM REPORT

8

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INTERIM REPORT
(Volume II)
Annexures on survey work

Contents Volume II

Annexure 1

Introduction

1.1 General

The first interim report comes into three volumes:

Volume	I	:	Main report
	II	:	Annexures on survey work
	III	:	Annexure on studies, etc.

The annexures have been divided into two volumes in order to get a separate volume on survey activities only. The set-up of this volume II is such, that it can be read separately. Consequently the review of the 1992 survey activities and the planning for 1993 described already in the other volumes are repeated here in the following sections.

1.2. Review of activities

The main activities of the River Survey Project are given in the following schedule:

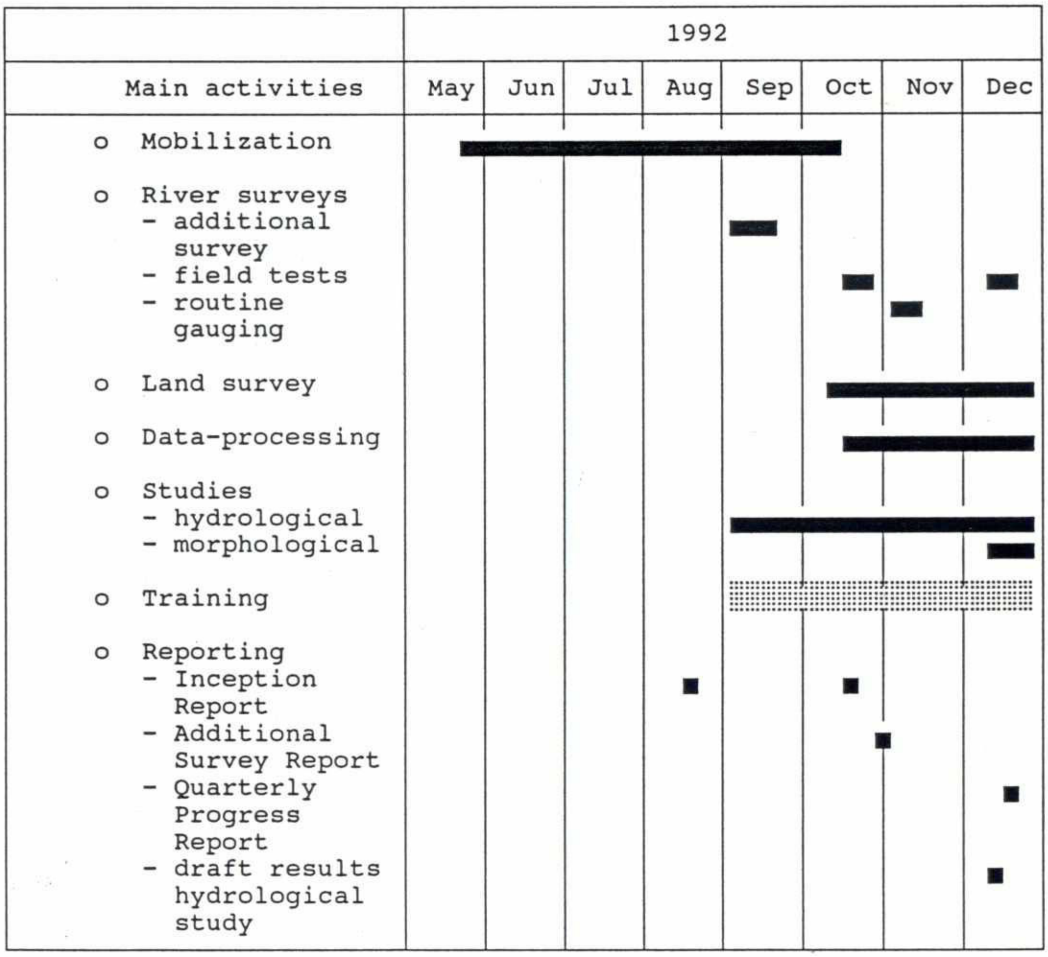

Figure 1.1 Main activities

1.2.1 Mobilization

Mobilization started just after the award of the contract. In Europe the main mobilization activities comprised the procurement of equipment including instruments and vessels. In Bangladesh the former MPO office (House No. 96, Road No. 23, Banani, Dhaka) was rented to be used as workshop, data-processing office, general office and staff residence. Also a field office in Gaibandha was put into operation. In the Netherlands a coastal patrol vessel was modified for survey purposes and in Singapore a new catamaran-type of boat was constructed. The vessels were transported on board of cargo vessels to Chittagong and sailed on their own keel to Narayanganj, where the survey equipment was installed at a yard. The end of the installation marked the end of the mobilization for Phase 1.

Some mobilization milestones are:

o	Award of Contract	May 22, 1992
o	Inception of Phase 1	June 9, 1992
o	Arrival of equipment in Bangladesh	August 4, 1992
o	Arrival survey vessel (DHA)	August 22, 1992
o	Release of equipment	September 7, 1992
o	Release of vessels	September 22, 1992
o	End of installation	October 15, 1992

For more details reference is made to the Revised Inception Report (FAP 24, 20 October 1992).

1.2.2 River Surveys

The river surveys executed in 1992 are:

- o Additional survey done in September with rented equipment and vessels (Anwesha with two tender boats) on the Jamuna near Bahadurabad
- o Test measurements in October near Bahadurabad
- o Routine gaugings in October/November near Bahadurabad
- o Additional test measurements in December on the Lower Meghna

The results of the additional survey have been elaborated in "Additional Survey September 1992" (FAP 24, 31 October 1992). Probably the most important conclusions of this report are:

(quote)
6) The significant difference between the presently measured discharge and the discharge according to BWDB rating curve of 1989 could not be explained.
7) It is observed that the flow directions vary considerably within one cross-section. Therefore detailed and accurate measurements of the flow direction are prerequisite to avoid considerable errors.
(unquote)

These observations asked for further analysis and therefore "Analysis of the Anwesha Survey Results" was made a study topic in the hydrological study programme (ref. Annexure 6).

In this volume the results of the tests measurements (of October and December) and the routine gaugings of November are presented (ref. Annexure 2).

1.2.3 Land survey

The land survey started with levelling between bench-marks and staff gauges at both sides of the Jamuna near Fulcharighat and Bahadurabad. For a description of the work done so far see Annexure 2.

1.2.4 Data-processing

By mid November the installation of the data-processing office was completed in terms of hardware, system software, standard DELFT-DHI and general software. Special software for FAP 24 was written and tested by the end of the year. Further quality checking and reporting demands will lead gradually to the final methods and formats for processing and reporting.

The sediment laboratory started in November and executed the following type of analysis:

- o Concentration of suspended sediments
- o Particle size, dry sieving
- o Particle size, settling tube

For results see Annexure 2.

1.2.5 Studies

Two types of studies are distinguished:

- o The hydrological study
- o The morphological study

Both types of studies started with collecting data and reports. The hydrological study started early September and the morphological study started by the end of the year.

The established study programmes and the main results have been summarized in Chapter 5 and 6 of the main report. For more details reference is made to Volume III.

1.2.6 Training

As defined in the ToR (FAP 24, 20 October 1992, Subsection 4.2.c and 4.3.c) the training should be given to:

- o BWDB staff
- o BIWTA staff (where applicable)
- o Staff of associated local consultants and contractors

Consequently, training is given both as an internal training (for FAP 24 staff, including associated staff) and as an external training (BWDB, BIWTA, etc.). Training, given by expatriate staff, in 1992 comprise:

- o Ship handling, maintenance and manoeuvering
- o Data-processing
- o Sediment analysis
- o Surveying

For the last three items staff from other organizations were invited via FPCO. The survey work was attended by BWDB staff. For further information on training reference is made to Chapter 7 of Volume I and Annexure 8 of Volume III.

1.2.7 Reporting

The Inception Report of August 1992 was revised in October. Comments on the Revised Inception Report (FAP 24, 20 October 1992) have been received from various sources and are presented and discussed in Volume III, Annexure 5.

The comments received on the Additional Survey Report (FAP 24, 31 October 1992) are also presented and discussed in Annexure 5 of the Volume III.

The first Quarterly Progress Report (FAP 24, 19 December 1992) has been published in draft. The report, mainly a supporting document for the external invoicing, covers the period of September to November 1992.

The first preliminary results of the hydrological study were assessed to be so important that an intermediate reporting was undertaken in December. The results are summarized in Chapter 5 of Volume I and elaborated in Volume III, Annexure 6.

1.3 Workplan

For various reasons it is proposed to change the workplan. The revisions envisaged are indicated in Chapter 8 of the Volume I, and further elaborated in Volume III. The scope of the revisions is listed below:

- The Phase 1 measurements are not affected. Gaugings missed in 1992 are shifted into the subsequent seasons.
- Between phase 1 and phase 2 viz. June 1 and October 31, 1993 a transition phase of five months is proposed with a mixed survey programme comprising:
  - HW test gauging
  - HW routine gaugings at all sites but with a lower frequency (about monthly at the main stations instead of fortnightly). At the end of this phase the final survey spread configuration will take place
- Phase 2 starts with a mobilization period and covers possibly three years, with a hardly affected measuring programme (which means that the first LW measurements need to be done with phase 1 equipment only). During the last monsoon the possible routine gaugings aim at catching the rising phase and peak of the flood only (in 1996)

The main revisions can be summarized as follows:

- Shifting the comparative test gaugings from 1992 to 1993
- About halving the HW routine gaugings and corresponding bed load measurements in 1993
- Shifting the remaining HW routine gaugings of 1993 to 1996
- If desired, extending the project period with 5 months (about 3 months survey and 2 months demobilization provided that resources will be available)

The results of these revisions are reflected in the following figures :
- the revised overall survey workplan
- the detailed workplan.

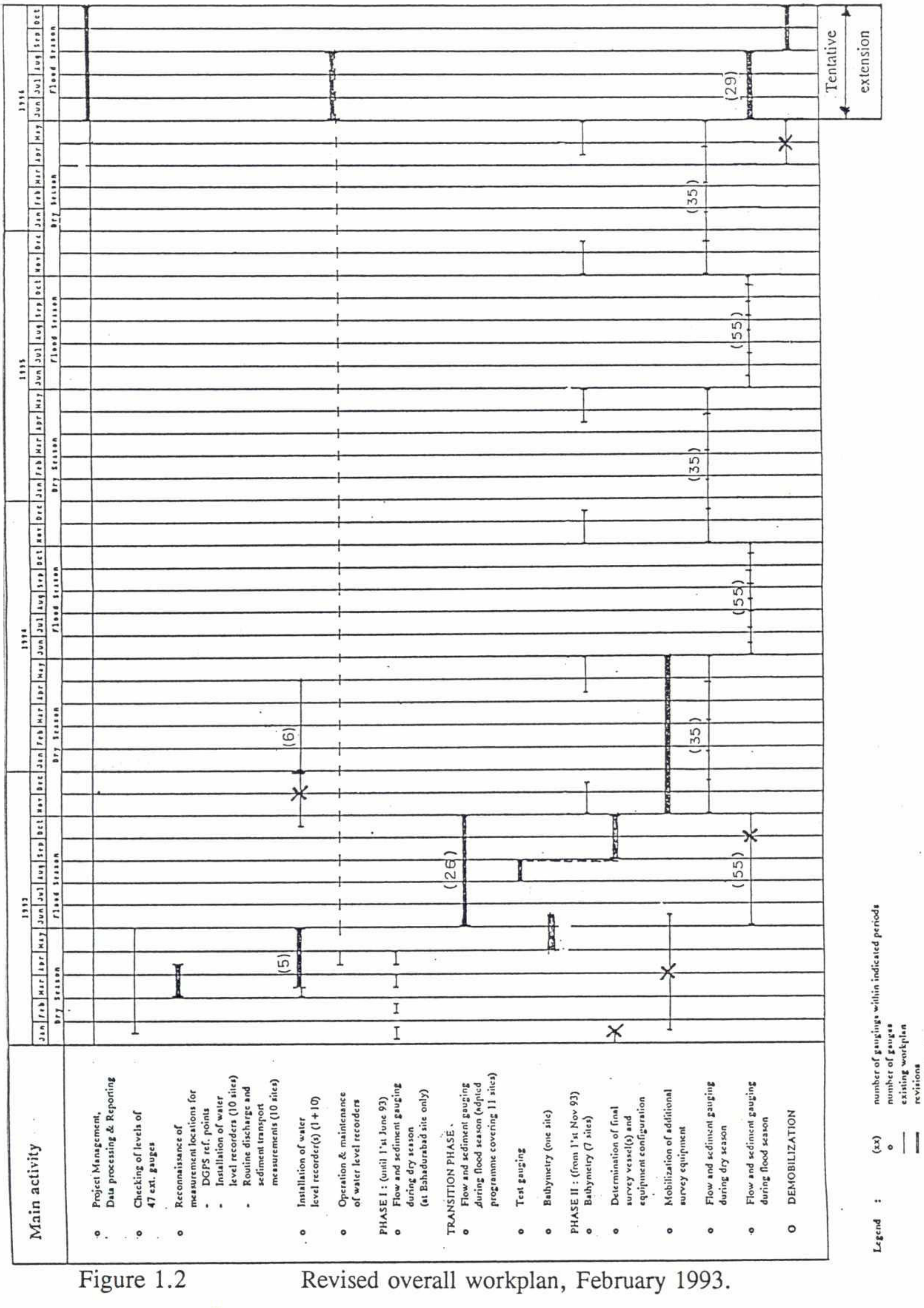

Figure 1.2 Revised overall workplan, February 1993.

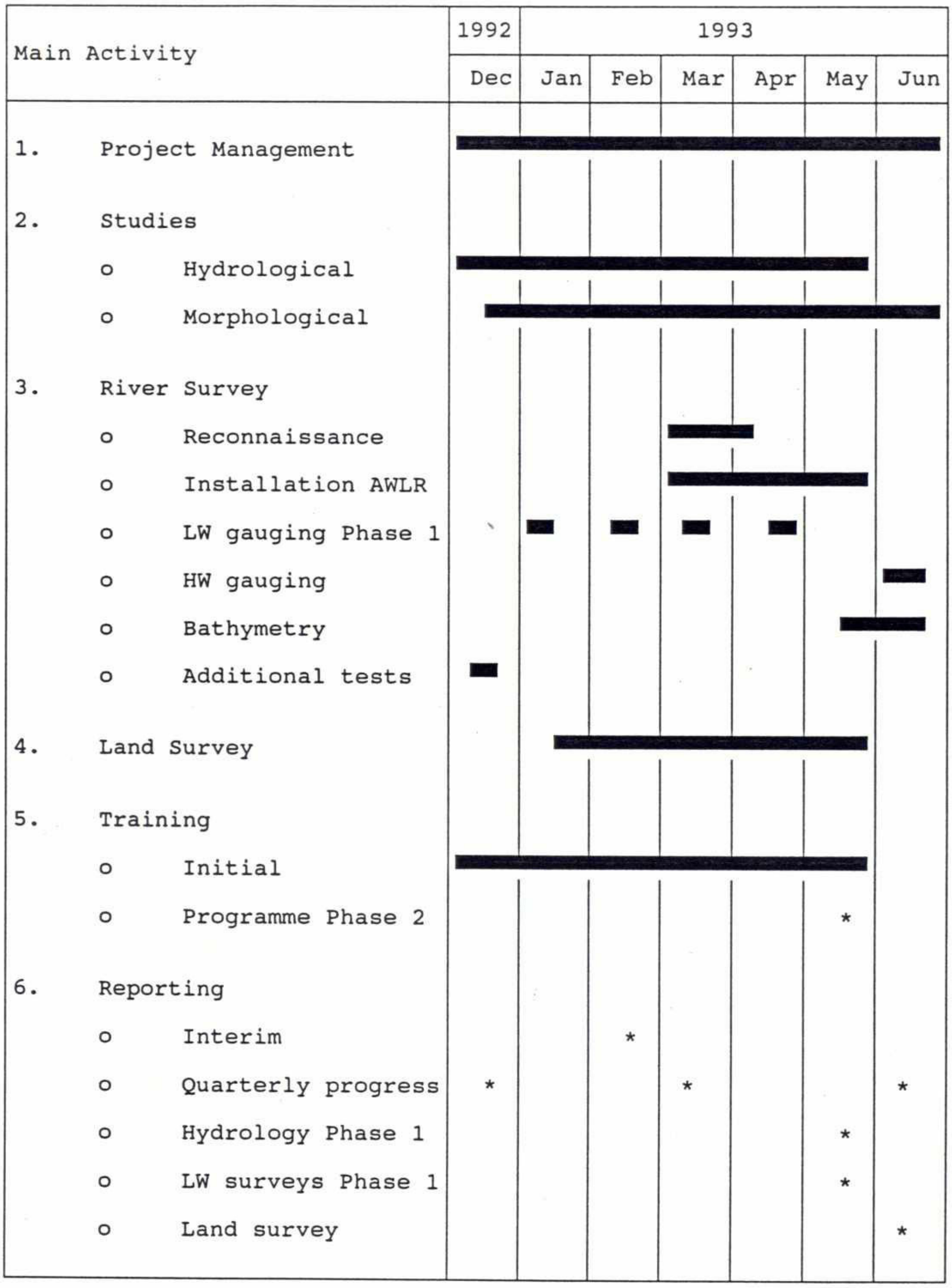

Figure 1.3 Detailed workplan (second half Phase 1)

1.4 Type of river surveys

The quantity of survey work on the rivers can be divided in different ways.

The first way is to distinguish :

- o Test measurements
- o Routine measurements
- o Special measurements

The test measurements are aiming at selecting the appropriate survey techniques. The routine measurements are summarized in a predescribed programme aiming at collecting reliable data over the project years. The special measurements are not programmed. An example is the Anwesha survey, organized to collect HW flow data in 1992 before the project equipment became operational. Other examples are the supplementary surveys envisaged to support a certain study topic, see section 3.1 of ToR (FAP 24, 20 October 1992).

A second way of distinguishing the measurements is per type:

- o Flow measurements
- o Sediment measurements
- o Hydrographic measurements (bathymetric survey)

To the first type belong the measurements of water levels, velocity and flow direction. This leads with some cross-sectional profiling to the discharge measurements.

The sediment measurements consists of suspended load and bed load measurements and bed material sampling. The hydrographic measurements consists of sounding the river configuration.

Type of test measurements

The test measurements comprise different type of tests. During and after the installation of equipment (instruments, winches, on-line computer systems) aboard the survey vessel, testing of equipment start. First electronic testing is done to check the various hardware components, comparing the actual behaviour with the existing specifications. Thereafter the so-called test measurements start ; testing the instruments in the river. The test measurements comprise various types of tests depending on the objective as indicated in the following table:

Objective	Type of tests
o Check of equipment	o Performance tests - detailed performance of instruments - inter-calibration (e.g comparing results of different type of instruments
o Improve operational procedures	o Trials - trials with survey boats - anchoring procedures
o Optimize measuring methods	o Optimization tests - varying sampling periods - varying spatial and temporal densities
o Find the appropriate technique(s)	o Overall tests - covering a full channel or river profile.

Table 1.1 Type of test measurements (or test gauging)

Remarks

1 In fact the first three objectives are the components which should result in the fourth objective : finding the appropriate technique(s)

2 The appropriate technique(s) mean that the best solution may vary
- in different part of one cross-section
- between sites
- per season

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1.5 Definitions

In an attempt to avoid confusion in reporting and discussions about surveying activities some further definitions/descriptions are given below.

Techniques.
With survey techniques is meant a combination of:

- o equipment (see below)
- o operational particulars
- o measuring methods

Equipment
Equipment is used in general as a combination of

- o survey instruments (for measuring and recording)
- o winches, cable, etc
- o survey vessel

Type of techniques
A distinction is made between various type of survey techniques viz. :

- o the reference techniques
- o the improved reference techniques
- o the recommended techniques
- o the FAP 24 techniques
- o the final techniques.
- o the sustainable techniques

The various techniques listed here are elaborated below

Reference techniques
The reference survey techniques are the more traditional techniques described in the TS and various standards (such as WMO and ISO standards). These techniques are used by both BWDB and BIWTA.

Improved reference techniques
As part of the project the consultant will review the reference techniques applied in Bangladesh and, if appropriate, will make suggestion for for improvements.

Recommended techniques
These are the techniques proposed by the consultant to replace as far as feasible the reference techniques envisaged for the routine measurements. Those are typically the techniques which will be tested in the August 1993 survey for use under the heaviest conditions

FAP 24 techniques
Based on the tests/surveys in August 1993 final decisions will be taken as to which (combination of) techniques will be applied during phase 2 of the River Survey Project FAP 24.

Final techniques
During the years (of phase 2) further developments are possible as a consequence of for instance:

- o the experience gained on the river
- o the further insight obtained in the physics of the rivers by further studying and with the aid of the sophisticated instruments available on the survey vessel
- o further development in instrumentation

Obviously the final techniques to be applied in Bangladesh in the future can only partly be implemented during phase 2. The final techniques will be recommended at the end of the project.

Sustainable techniques
These are the survey techniques that will emerge from further studies and experience with the FAP 24 techniques. Just like the improved reference techniques the consultant will recommend on the technical and operational aspects of this technique, to be used outside the project, probably after the project.

The final selection of the sustainable techniques are considered to be no part of this project. For such a selection the following aspects need to be elaborated.

- o the economy of the techniques
- o the maintenance and repair situation including the availability of and access to spare parts
- o the timing of implementation
- o the training requirements

For a great deal this selection will be organization specific and as such needs to be done by the organization itself.

The various techniques mentioned here can also be seen as a development over the years:

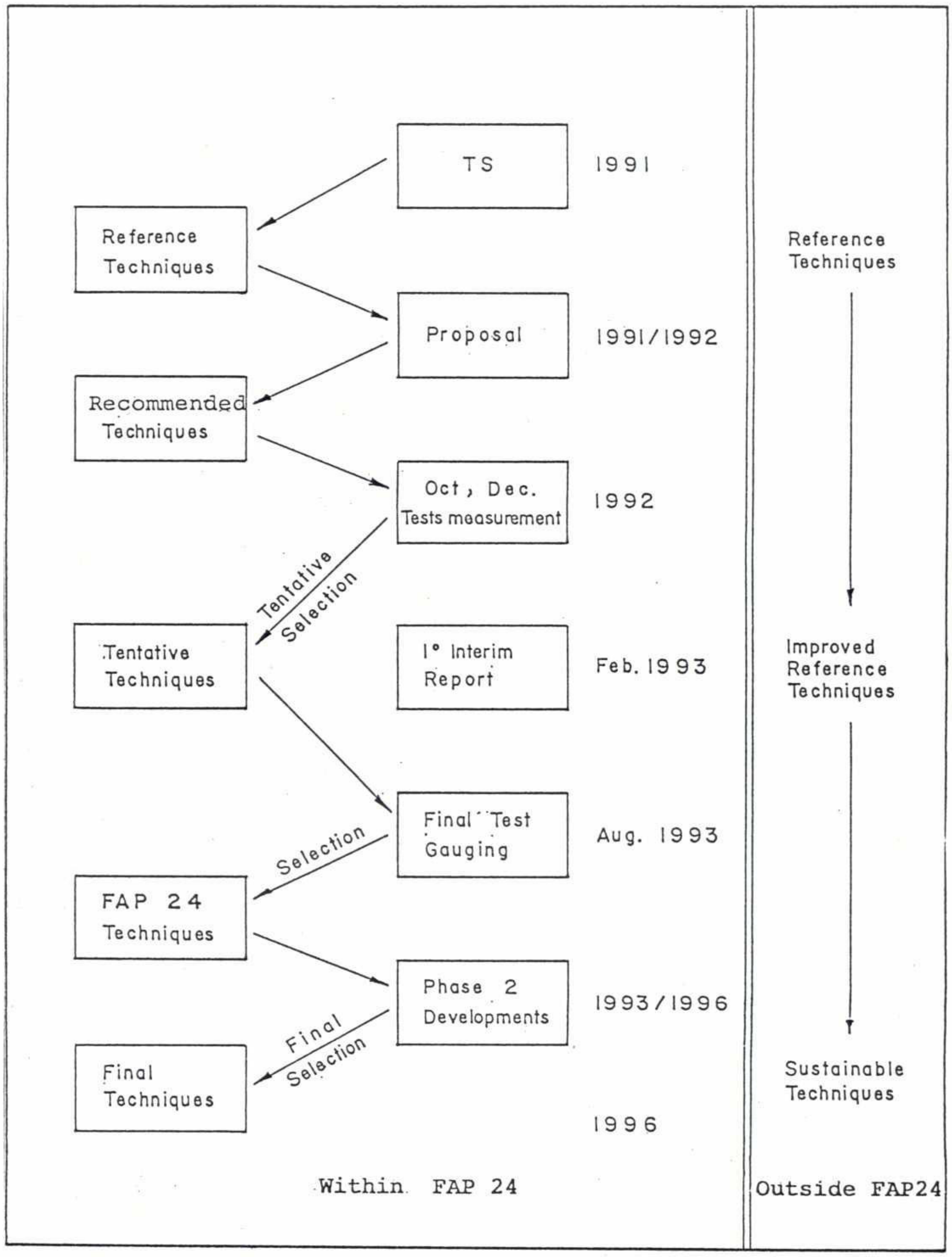

Figure 1.4 Development of survey techniques.

Further details on a tentative selection of survey techniques are provided in Chapter 4 in Volume I and in this Annexure 4 of Volume II.

The selection will be supported by studies in phase I and phase 2 respectively, as further described in Annexure 4 of this report.

Annexure 2

Survey activities

2.1 Background

In general the test measurements and test gaugings carried out in Jamuna River at Bahadurabad comprised:

- o Performance tests (to check equipment)
- o Trials (to check operational procedures)
- o Optimization tests (to optimize measuring methods)
- o Overall tests (to determine the appropriate technique)

The overall tests are a verification of the total procedure as a result of the other individual and more detailed tests.

Because of the late project start, the first measurements in the River Survey Project turned out to be the test gauging foreseen in the BoQ. However, the extremely low monsoon discharges in October 1992 impeded the realization of a complete test gauging programme and a reduced programme covering the right river channel only at Fulcharighat was carried out instead as described in Chapter 2.6.

Due to these low conditions, additional tests were performed in December 1992 on the Lower Meghna aiming at assessing the performance of equipment in higher current velocities and sediment concentrations.

Still the conditions were not satisfactory and final testing now is envisaged in August 1993 in high flood flow conditions. The following sections summarizes the tests of October and December as well as the single routine gauging carried out in between by the end of October and beginning of November 1992.

2.2 Description of survey area

General

The general configuration of the Jamuna River at Bahadurabad is shown in Fig.2.1. The map is based on a satellite images taken in March 1992. The following characteristics are noted:

- o At a stage of approximately 18 m above PWD datum the Jamuna River in the concerned area consists of two major channels in the following referred to as Left Channel in front of Bahadurabad ghat and Right Channel near Fulcharighat separated by a vast inhabited island (further called Central Island). This means that a full discharge gauging involves measurements in two separate cross-sections.

- o A major connection between both channels is situated about 10 km North or upstream of Fulcharighat. This connection is rather stable and has been used for many years by the Bangladesh Railway Ferry Service. (Ferry channel shown in Figure 2.1)

- o Opposite of Bahadurabad ghat two minor creeks were identified. Both were in the beginning of October conveying water from Left to Right channel, but at the actual stage their capacity was very limited. The northernmost creek was almost dry. During the dry season the creeks become dry.

- o The actual high water banks are hard to identify. Consequently it is not possible to assess the total width at the top of high water. On the other hand the average hydrograph for Bahadurabad (1964-1990) shows that the maximum stage is about 19.2 m/PWD which is only 1.5 m higher than the present observed lowest river stage and on the average equal to the level of the observed river banks. Significant parts of the Central Island are also 1.5 to 2.0 m above the present water-level. Therefore the identified coastline coincides rather well with the bankfull situation. Only sandbars will be (partly) submerged.

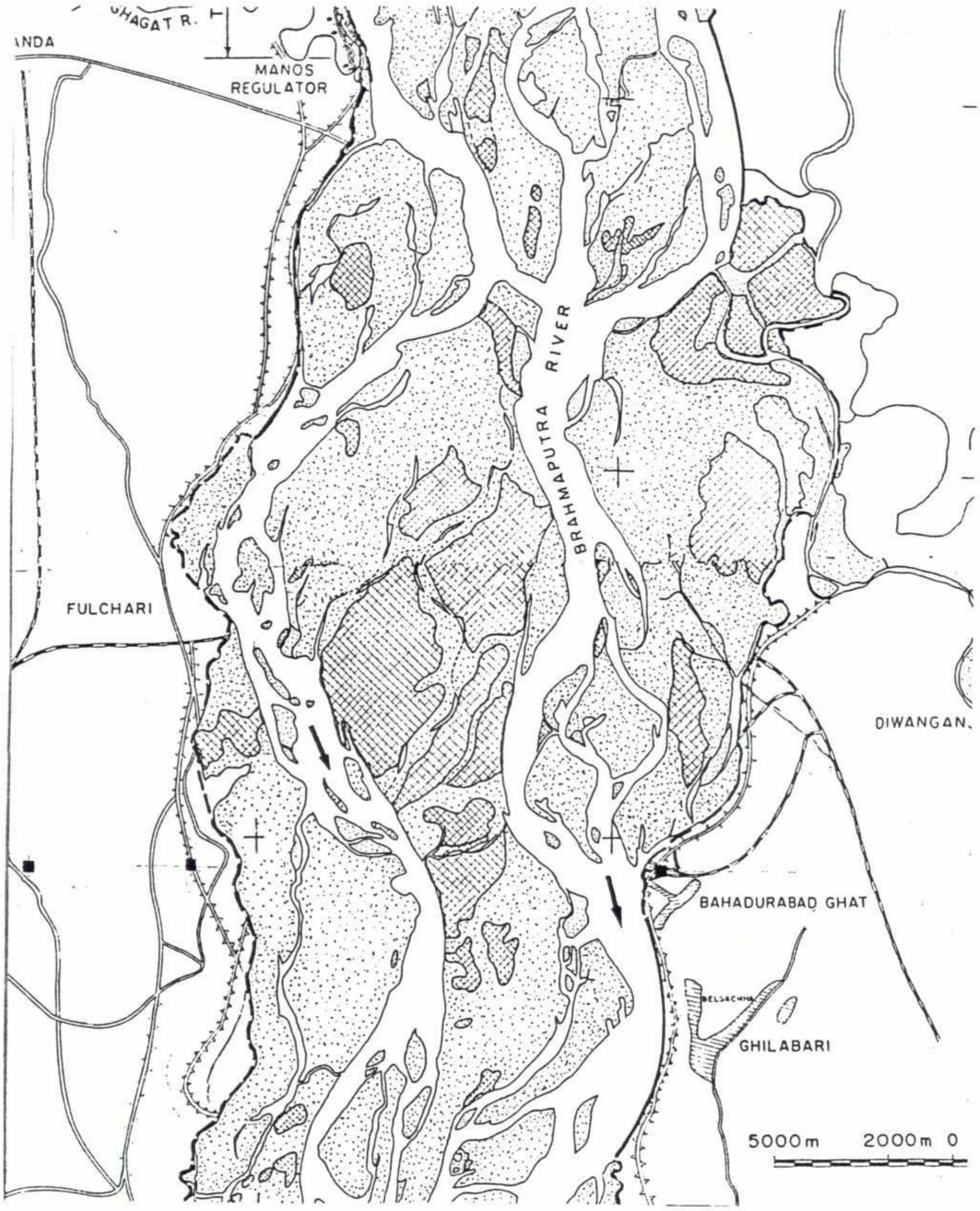

Figure 2.1 Key map for Bahadurabad site.

Site reconnaissance

Upon arrival at the site a general reconnaissance was carried out on land for location of suitable fix points for positioning as well as on the river itself to search for areas with reasonable smooth bottom configuration and flow conditions with no eddies or flow from secondary channels.

As a result supplementary fix points had to be constructed close to the river bank on both side of the river - south of Fulchari and Bahadurabad - respectively and their levels measured relative to PWD datum.

Selection of suitable cross-sections

Left Channel

The area u/s of Bahadurabad ghat where the BWDB permanent cross-section is located is very wide and shows many channels and sandbars. Only 1 km d/s of the railway station a river section was found, which consists of only one major channel and a shallow parallel creek at the western edge. Sounding of cross-sections showed a reasonably good profile with only one deep pool at some 600 m to Left Bank (LB) ref. Fig. 2.2.

Further downstream the river would widen again and bifurcate into some wide shallow channels. It was initially decided to select an almost straight East to West line following 25°07'15" North as an acceptable location for velocity/discharge measurements.

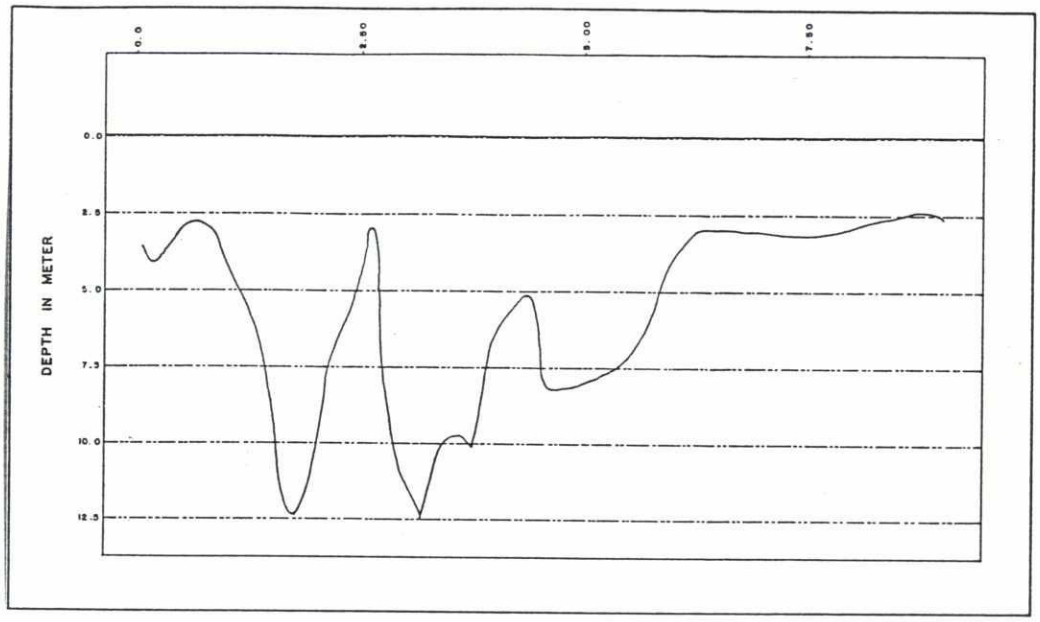

Figure 2.2 Echo-sounder cross profile of left river channel d/s of Bahadurabad.

Right Channel

A bankline survey and general observations made it clear that an acceptable location for discharge measurements could be found d/s of Fulcharighat.

Apparently 2 km d/s of the railway station a river section was found, which consisted of one major channel following the right bank and a more shallow creek towards the left bank. Sounding of cross-sections showed a reasonable cross profile for discharge measurements as shown in Fig. 2.3

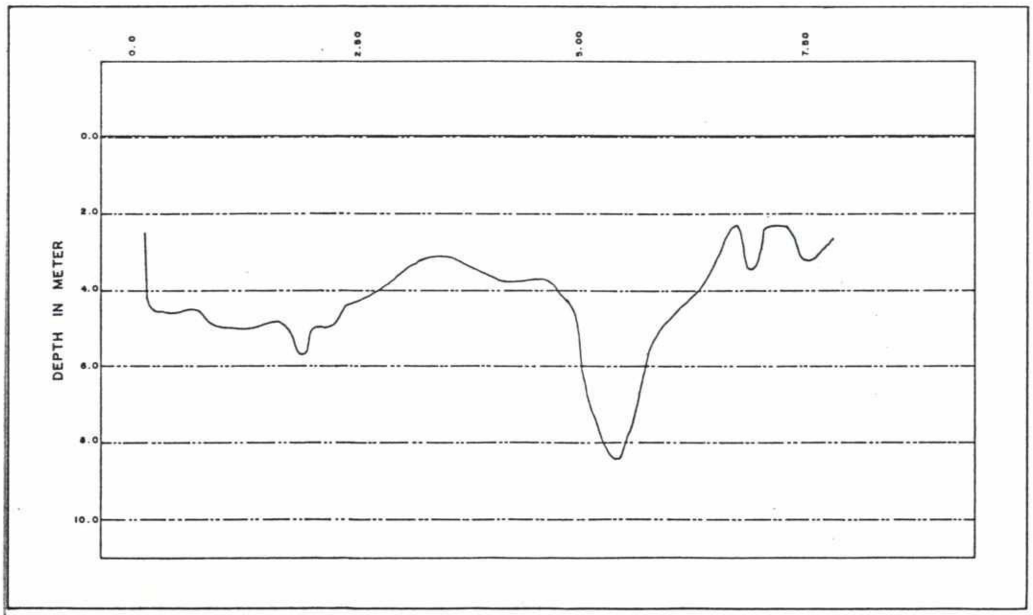

Figure 2.3 Echo-sounder cross profile of right river channel d/s of Fulcharighat.

2.3 Coordinate system and bench-marks

For navigation and annotation of positions for all measurements carried out on the rivers a differential satellite positioning system (DGPS) is used. Operating the system requires transmission of distance correction values by a UHF radio link between a master station installed in a know fix point - bench-mark - on land and the mobile survey vessels.

Therefore actual operation of DGPS calls for a reference point in form of a bench-mark with known coordinates based on the so-called World Geodetic System (WGS 84).

It was understood at the proposal stage, that FAP 18 on behalf of the SoB was establishing GPS bench-marks in Bangladesh and that the River Survey Project would be provided with accurate co-ordinates based on the WGS 84 ellipsoid in order to operate their proposed DGPS system.

The consultant has until now not been able to obtain any reliable co-ordinates for the bench-marks established by FAP 18 in the Bahadurabad area or elsewhere in Bangladesh.

Investigations and contacts with other FAP projects indicate that Survey of Bangladesh (SoB) intends to release co-ordinates on the bench-marks in the near future.

However, it is also indicated that those co-ordinates will be given based on an, at present unknown, Everest ellipsoid.

As GPS always measures with respect to the WGS 84 ellipsoid, the co-ordinates released by SoB must be converted to WGS 84 co-ordinates by means of some kind of co-ordinate transfer calculations - a "datum shift".

The consultants are not able to carry out this datum shift, due to lack of information regarding the geometric definition of the Everest ellipsoid to be used by SoB.

This means that the consultants cannot establish an accurate positioning annotation of the survey data in the applicable system until this problem is solved.

The following fix points have been applied for the measurements at Bahadurabad cross-section.

Location	Bench-mark	BTM co-ordinates		Elevation (PWD datum)
		x	y	
Kamarjani north of Manos	FMBM 7603 FMBM 7604			20.57 m 22.60 m
Bahadurabad	GPS 764 FMBM 5244	471089.58 m	2778134.75 m	20.31 m 19.86 m
Gaibandha	FMBM 7507 FMBM 7601 GPS 7	 454149.20 m	 2800728.61 m	21.62 m 20.80 m 21.97 m
Fulcharighat	FMBM 7305 FMBM 7401 GPS 765	 452530.93 m	 2782540.83 m	18.54 m 19.17 m 20.36 m

Notes: All values are preliminary.

Conversion to Mean Sea Level datum can be made by subtracting 0.4599 m from the PWD datum levels indicated in the table.

Source: BIWTA and Finnmap Oy.

Table 2.1 Bench-marks for Bahadurabad cross-section

2.4 Survey equipment (see also Appendix 1A)

The present survey spread configuration of survey equipment and vessels is summarized in Table 2.2 below.

EQUIPMENT	VESSEL A	VESSEL C	ALU CRAFT
Positioning System:			
* DGPS	x	x	x
Current and discharge measurement:			
* MBM using EMF and ADCP	x		
* Current recording:			
OTT recorder	x		
S4 recorder	x	x	x
* Float tracking	x	x	x
Echo Sounding:			
* Elac Laz 4420	x		
* Simrad EA 300 P		x	x
Side Scan Sonar:			
* EG & G Model 260	x		
Suspended sediment measurements:			
* Sampling into bottles	x	x	(x)
* Integrated bottom sampler	x		
* Turbidity recordings (MEX 3)	x		
Bed load transport measurements			
* Helley Smith trap samples	x		
* Sand dune tracking by echo sounding	x	x	x
River bed sampling			
* Van Veen Grab	x	x	(x)
Communication			
* VHF Radios	x	x	
* Walkie Talkies	x	x	x

Table 2.2 Survey spread matrix

A detailed description and technical specifications of the individual instruments are provided in the original Technical Proposal and summarized in Appendix I.

2.5 Survey procedures

General

The individual measurement disciplines involved in the River Survey Project are described below in general terms. More specific and detailed survey procedures will be elaborated during the course of surveys and will form an integral part of the overall Project Quality Plan outlined in Chapter 3.3

Water-level measurements

Installation of automatic water-level recorders is awaiting a clarification of technical alternatives in form of an acoustic or a pressure cell instrument. The final location also has to be decided awaiting some further reconnaissance on the site.

Until then manual staff readings related to the newly constructed levelling points are carried out on both sides of the river.

Requirements to possible water-level slope measurements also have to be determined.

Discharge measurements by ADCP and EMF (moving boat method)

Conventional discharge measurements by a series of manual profiling across the river (velocity-area method) can be accurate if properly organized and performed. However, the method is time consuming and resource demanding in terms of manpower and boats. This leads in general to a comprise between spatial density and time (duration of sampling and total measurements). Measurements lasting days may become inaccurate when flow conditions change markedly during the measurements, which quite often may be the case in the rivers of Bangladesh.

In order to overcome these problems the Acoustic Doppler Current Profiler (ADCP) concept was introduced in combination with the EMF which is installed in a fixed level of 0.5 m - 1.0 m in the front of the vessel. This instrument configuration constitutes the consultant's alternative method for "instantaneous" discharge gauging in the main channels.

"Instantaneous" means that the measuring time equals the travel time of the vessel crossing the river at a survey speed of 3 - 5 knots. The optimum survey speed of a vessel with ADCP in a possibly pulsating flow will be further investigated.

In summary the Acoustic Doppler Current Profiler (ADCP) methodology in the main channels is considered to provide the most accurate discharge measurement, as well as the highest data coverage within the shortest measuring period.

The principle instrument installation is illustrated in Figure 2.4. Actual measurements are carried out by crossing the rivers from one bank and during sailing the system will record high resolution vertical profiles for every 5 - 10 m along the transect and continuously present the profiles and calculate the discharge by integrating the velocity normal to the path taken by the survey vessel.

The ADCP can't measure the velocity close to the river-bed, due to transducer side loops, nor the velocity close to and above the immersion depth of the transducer. Close to the river-bed the velocity profile is extrapolated using hydraulic calibration and extrapolation at the surface is based on the EMF measurements. Further refinement of the off-line computation is envisaged based on additional measurements and analysis of the lower current profile

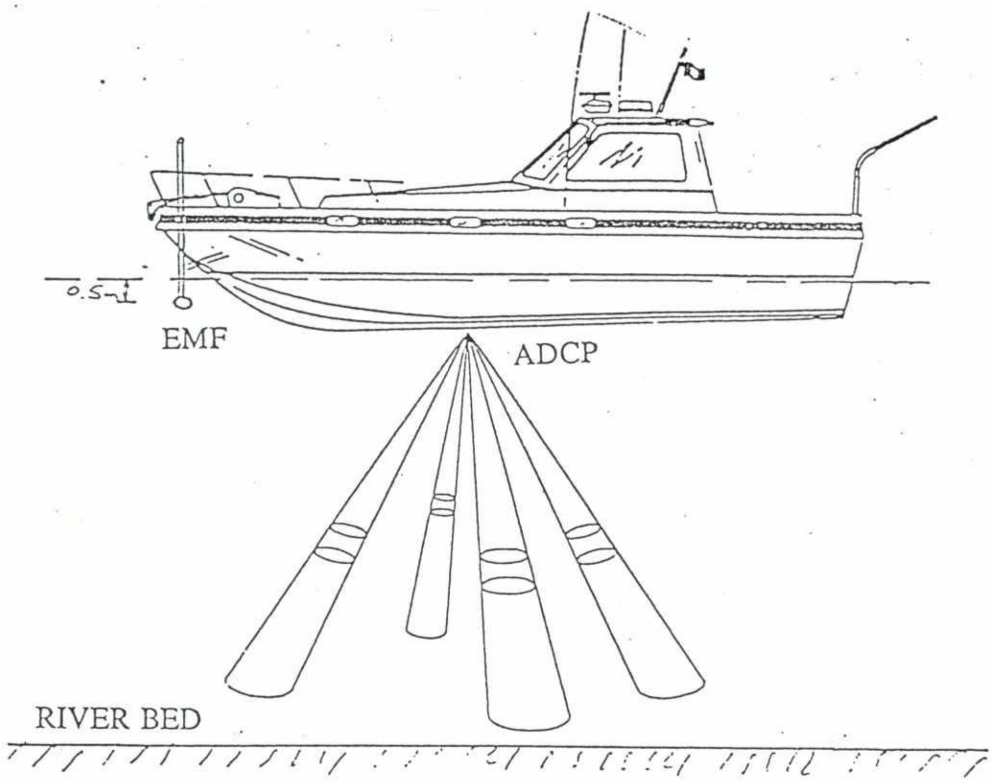

Figure 2.4 Principle sketch of instrument installation for the recommended method with EMF and ADCP

An example of a typical record showing the detailed current distribution in the measured cross-section is shown in Figure 2.5 and 2.6 below

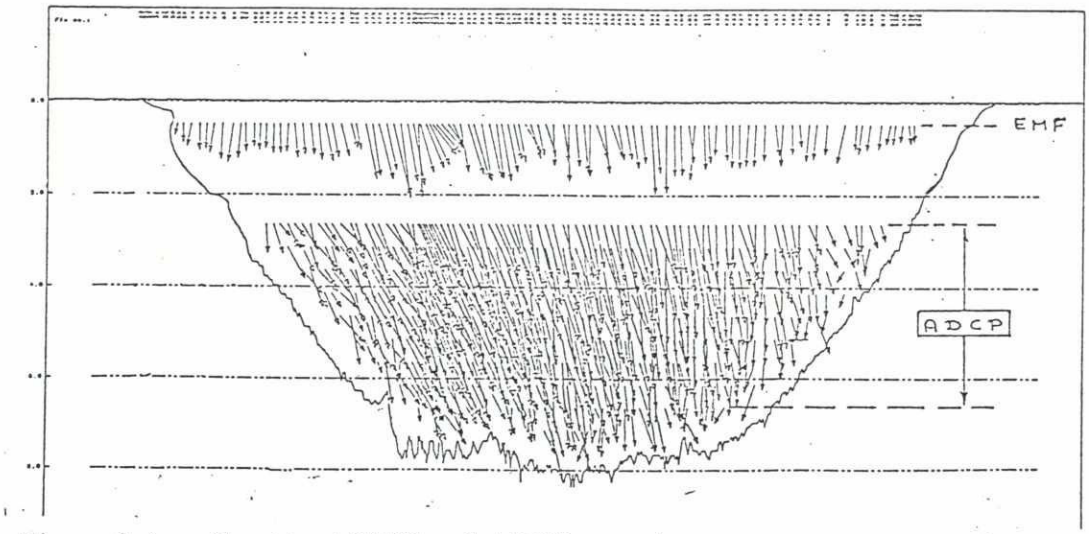

Figure 3.4 Combined EMF and ADCP record

Figure 2.5 Combined EMF and ADCP record.

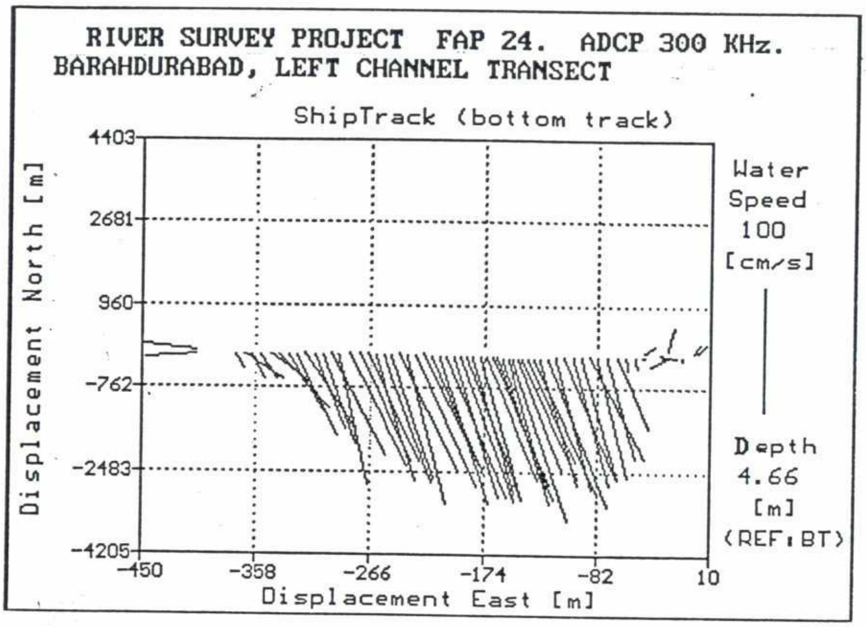

Figure 2.6 Example on horizontal current distribution at a certain predefined level (at 4.16 m depth).

Velocity and suspended sediment measurement by manual profiling (velocity-area method)

Measurements of suspended sediment concentrations are an integral part of the overall field investigation programme and are very time consuming and resource demanding.

The current velocity and suspended sediment profiling is carried out in a simultaneous operation using the combined sediment suction and velocity measurement device as shown in Figure 2.7.

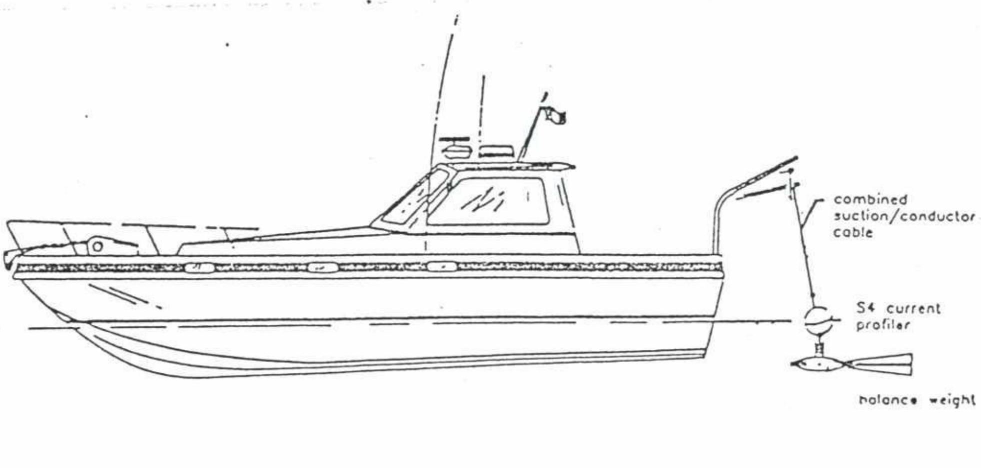

Figure 2.7 Principle sketch of equipment installation for combined current profiling and suspended sediment sampling

The measuring depth is recorded by a pressure cell included in the current meter and is monitored continuously during operation.

During the test gauging phase and generally in the beginning of the project, the distances between profiles in the river cross-section as well as the numbers of measurements in each profile are determined by the contract specifications.

Later on the sampling operation shall be optimized in terms of coverage densities and selection of locations for profiling will be based on evaluation of recorded ADCP cross-profiles including the back-scatters density record showing the relative variation of suspended sediment concentrations in the water.

During sampling the boat is normally anchored in the selected position. In situations where anchoring becomes difficult - not to say impossible - dynamic positioning will be established relative to a light marking buoy which is deployed temporarily during the measurements or by using the DGPS based navigation system on board. In how far dynamic positioning can be applied during near river-bed measurements needs further to be sorted out.

Alternatively, as a contingency procedure during extreme flow conditions, it can be required to allow for a drifting of the boat during the sampling, in order to reduce the current force on the submerged part of the sampling device, and also in order to reduce the ratio between the current velocity and the nozzle intake velocity. If so, the boat will be relocated in between each sampling. Near river-bed measurements cannot be done in this case.

Up to now a sediment sampling integration time of 5 minutes (e.g. 6 x 50 seconds) has been employed. Samples have been collected in 0.5 l bottles. Supplementary 25l samples have been collected at the lowest suction level for Andreasen settling tube determination of grain-size distribution.

During suspended sediment sampling turbidity measurements are carried out simultaneously and in the same points (on the A vessel only).

<u>Mapping of river-bed configuration for detection of sand dune patterns.</u>

A side scan sonar system has been installed on board on a temporary basis until the final need has been clarified.

The system consists of a pair of transducers mounted in a fish being towed behind the survey vessel during operation. The recorder is installed in the data-processing room on board. Side scan sonar survey is carried out in longitudinal lines covering the areas of interest for sand dune tracking. The records show

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details of the general river-bed configuration including sand dune lengths and indicative heights.

A typical example of record is shown in Figure 2.8 below.

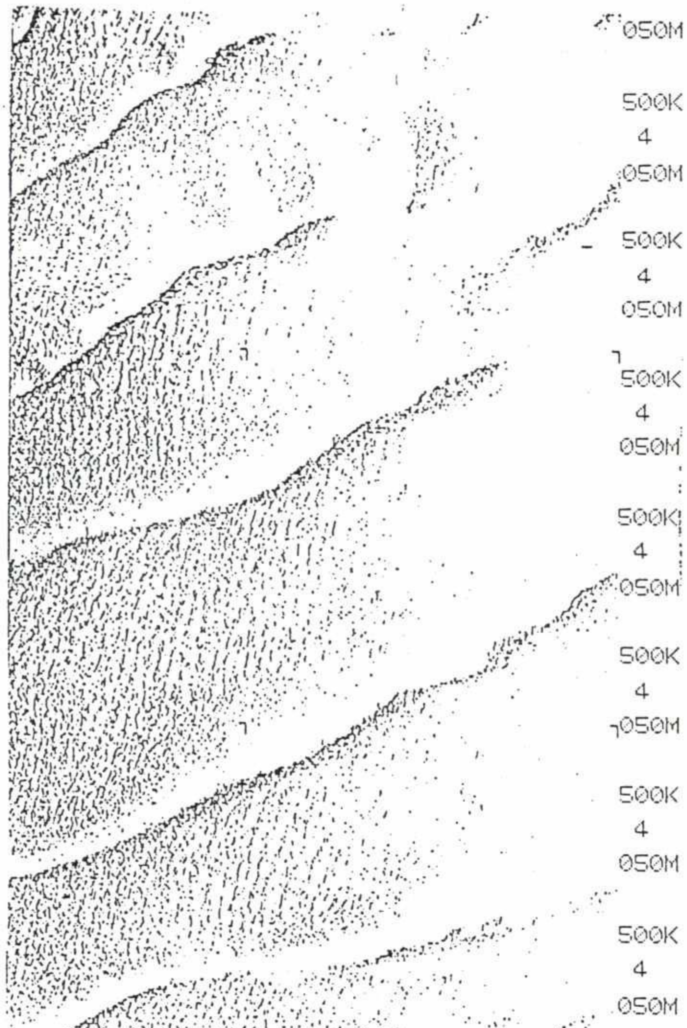


Figure 2.8 Side scan sonar record from Bahadurabad

Bed load transport measurements

During the test gauging bed load transport measurements have been carried out using the Helley-Smith trap sampler only. The samples were taken during the suspended sediment- and current-profiling, mentioned above. 2 minutes duration samples were collected 3 times at each location.

Due to the fact that flow conditions were low compared to normal peak flood level bed load transport measurements by monitoring of sand dune movements during intensive bathymetric survey campaigns of 1 - 2 days duration have been postponed into the coming flood season. Additional tests with some alternative, still to be defined, instruments should be foreseen.

Bed material sampling

This measurement discipline has to be further investigated and clarified. Up to now only a few grab samples have been collected from the river-bed. In addition to this a few samples have been taken from some shoals becoming dry during the falling water-level.

2.6 October test measurements

2.6.1 Objectives

The objectives of the test measurements scheduled for October 1992 at the Bahadurabad site were to:

- o Make an objective comparison between the standard testing of various types of equipment and the new, modern technology, especially in view of their use in peak flow conditions in terms of performance, reliability and accuracy
- o Optimizing the gauging procedures with respect to measurement sampling density and frequency

Prior to execution of any test measurements a site reconnaissance for selection of a suitable measurement cross-section was carried out as described in Chapter 2.2. An inter-calibration between the individual current meters and the ADCP was also made.

The testing programme has been described in details in the Inception Report (FAP 24, 20 October 1992, Appendix G) and a summary is provided in the following.

2.6.2 Testing programme

Upon arrival at the site it was realized that the water-level had fallen drastically since peak flow conditions and that the development continued with approximately 8 - 10 cm reduction per day. Based on this observation it was agreed that execution of the test gauging programme as originally planned would be unable to fulfil the objectives and that a reduced programme covering the right river channel at Fulcharighat only should be implemented.

In principle the testing programme included comparison of three different measurements methodologies for discharge gauging.

In order to gain time in the field, trials with suspended sediment transport gauging by point- and integrated-sampling technique were postponed for a few days. They were carried out simultaneously with the subsequent flood season routine gauging as described in Chapter 2.7 below.

Standard method

This is the method for discharge gauging or test gauging by velocity-area method with current meters.

For manual discharge gauging the selected river cross-section is classified into main and smaller channels as well as shallows (ref. Figure 2.9):

- o Main channels are 500 m to 2 km wide, (geometric width) maximum depths ranging from 5 m to 25 m, exceptionally amounting to 30 m or even more at intensive scouring places
- o Minor channels are here defined as having widths ranging from 100 m to 500 m and maximum depths between 3 m to 10 m
- o Bars and shallows are those zones without well defined minor channels as described before, but where depths exceed 3 m (as related to the water-level at the moment of the gauging)

The test gauging procedure shall comply with the following requirements:

- o In main channels
  - Maximum distance between verticals (stations) 100 m
  - Six-point method for each vertical
  - 300 seconds integration time for each velocity sampling (with record of sampling at each 50 seconds interval)
- o In smaller channels
  - Four verticals (stations)
  - Three-point method for each vertical
  - 100 seconds integration time for each velocity sampling (with record of sampling at 50 seconds)

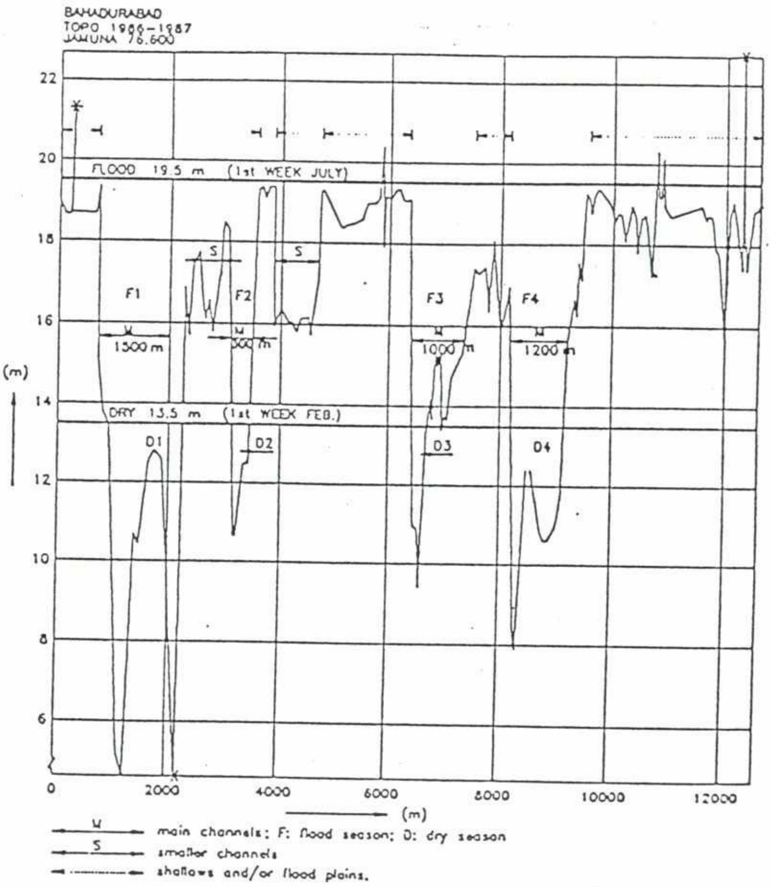


Figure 2.9 Typical cross-profile at Bahadurabad

Alternative methods (recommended method)

Two alternative methods have been included in our contract for testing i.e.:

- o Moving boat using EMF
- o Moving boat using EMF and ADCP in combination

Present test measurements focused on the second alternative. In order to increase the accuracy of the gauging and to obtain the optimum basis for the comparison between the standard and the recommended method it was decided to increase the number of discharge measurements using EMF and ADCP simultaneously. Complete crossings were made before and after each series of manual profiling.

Sediment transport gauging

Suspended sediment test gauging was carried out simultaneously with the flow test gauging using the velocity-area method as follows:

o Point sampling

- number of samples in water depths larger than 3 m was:
  close to surface as possible
  0.2 x D
  0.4 x D
  0.6 x D
  0.8 x D
  close to bottom as possible

- number of samples for depths less than 3 m was:
  0.2 x D
  0.6 x D
  0.8 x D

o Integrated sampling

In some of the verticals a depth-integrated sample of suspended sediments was taken for comparison. This exercise will be continued.

o Turbidity measurements

Suspended sediment sampling was supplemented with turbidity measurements for comparison.

In order to obtain more experience and a more comprehensive database, the measurements will be continued after the testing programme.

The prospect is to replace some of the relative time consuming suspended sediment sampling with the more efficient turbidity measurements.

o ADCP suspended sediment measurements

The manual suspended sediment sampling and turbidity profiling is also supplemented with back-scatter intensity measurements during the ADCP crossings.

The measurements give the relative variation of suspended sediment concentrations in the cross-section and may be used for planning of locations for suspended sediment sampling, thus allowing to optimize the gauging effort. The combined information on suspended sediment and flow distribution supports further analysis of sediment transport and related morphological processes in the river.

- Bed load transport measurements

  Trials were made with the side scan sonar to record the general river-bed configuration, showing sand dune patterns with lengths and orientation.

  It was also planned to measure the bed load transport by frequent monitoring of sand dune movements by echo-sounding in a relative dense grid of survey lines. Upon arrival at the site it turned out that the river-bed in the measurement cross-sections was smooth and that location of areas with well developed sand dune movements would be difficult to find in the existing river conditions with the water-level falling drastically. It was therefore decided to postpone these trials and maybe carry them out at another location.

  Bed load transport was measured using the Helley-Smith trap-type sampler.

- Laboratory analysis of sediments

  The following analysis have been carried out at the project laboratory in Dhaka:
  - suspended sediment concentration, by Millipore micro-filtering
  - grain size distribution of suspended sediments, by Andreasen settling tube test
  - grain size distribution of coarse river-bed sediment, by wet sieving
  - grain size distribution of fine river-bed sediments, by hydrometer testing

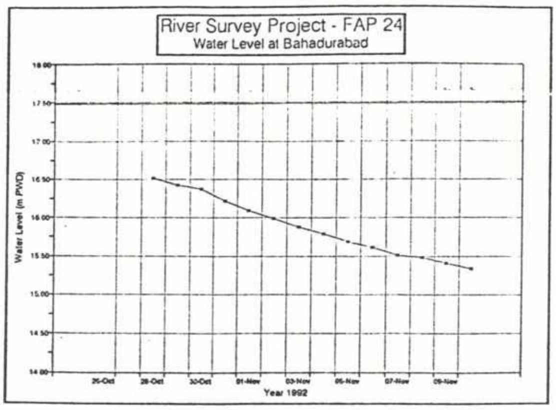
2.6.3 Measurement results (see also Appendix 1B)

All valid measurement data are compiled in Appendix 1B inclusive a quantitative summary. A few key results are further described in the following.

A more detailed data interpretation and comparison is discussed in Annexure 4, Section 4.4.

Water-levels

As mentioned earlier it was found that the water-level was falling drastically since peak flow conditions and that the situation continued with approximately 8-10 cm reduction per day. Water-levels recordings covering the measurement period are presented in Figure 2.10 below.



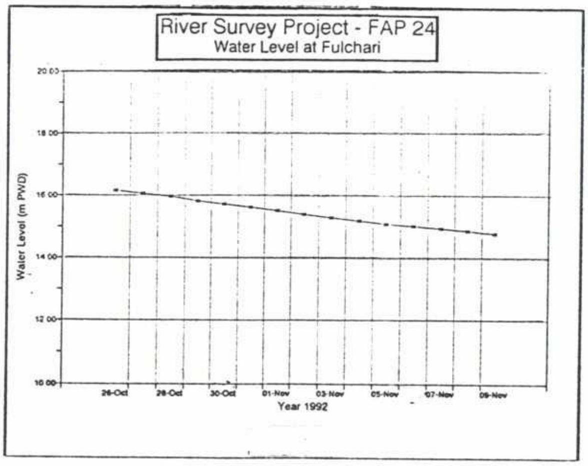


Figure 2.10 Water-level recordings at Bahadurabad and Fulcharighat respectively.

Discharge measurements by ADCP and EMF (moving boat method)

During the test gauging in October 1992 in the right river channel 4 discharge cross-sections (trans-sects) were carried out using the combined instrument configuration of ADCP and EMF. The results are shown in Appendix 1B and listed as follows:

Date	Location	Discharge in m^3/s	
		*	**
26/10/92	Right Channel	7,353	4,690
	Right Channel	7,741	4,637
27/10/92	Right Channel	7,426	4,623
	Right Channel	7,000	4,565

Table 2.3 Discharge measurements by ADCP and EMF (EMF without differential GPS causing quite some scatter in the surface discharge component and a substantial difference in absolute discharge measurements).

* Off-line data-processing including EMF surface measurements
** On-line measurements based on ADCP only

The differences between the off-line (real) discharge measurements and the on-line (partly coverage) discharge measurements is caused by the contribution of the discharge through the shallow parts of the cross-section where the ADCP cannot measure. Obviously these differences are quite substantial due to the extreme low water levels of the moment.

Unfortunately the EMF measurement data are influenced by quite some inaccuracy caused by the lack of the differential mode when operating the GPS for positioning ; ref. Chapter 2.3

Velocity and suspended sediment measurements by manual profiling (velocity-area method)

Current velocity and suspended sediment concentration profiles are also included in Appendix 1B.

During the test measurements a complete cross-section was carried out in the right river channel by manual profiling and the following discharge was calculated.

Date	Location	No. of verticals in each cross-section	Discharge in m^3/s
26-27/10/1992	Right Channel	15 *	7,700

* Positioning by GPS only i.e. inaccurate positioning of vertical profiles

Table 2.4 Discharge calculations by velocity-area method

For results of sediment transport gauging see Chapter 2.7

86

2.7 November routine gaugings

2.7.1 Objectives

Due to the fact that the objectives of the test gaugings in October could not be fulfilled in the prevailing flow conditions it was decided to carry out a complete routine gauging covering both river channels and using various measurement methods i.e.

For the discharge:

- o The velocity area method by manual profiling
- o Moving boat method with ADCP and EMF

For suspended sediments:

- o Pump-bottle system
- o Optical turbidity
- o ADCP back-scatter
- o Depth integrating system

For the bed load transport:

- o Helley-smith trap sampler

The main objectives of this routine gauging is obviously:

- o Collect reliable data on discharge and sediment.

  However, due to the fact that various measuring techniques were used, the survey results serve also other purposes, see next points

- o Make an objective comparison between the moving boat method and the velocity area method.
- o Optimize the gauging procedures with respect to sampling density and frequency (based on survey result).

2.7.2 Measurement programme

The programme for the routine field campaign is summarized in table 2.5 below

Discharge gauging			Sediment gauging			
Depth	Activity	Measurement time	Depth	Activity		
Main			D>3m	Pumping into bottles	*Turbidity recordings	*Integrated sampling
Surface	Standard method with S4 current meter	300 seconds with record of sampling for every 50 secs.	Surface	x	x	
0.2 D			0.2 D	x	x	
0.4 D			0.4 D	x	x	
0.6 D			0.6 D	x	x	
0.8 D			0.8 D	x	x	
Bottom			Bottom	x	x	
Small						
0.2 D		100 seconds with record of sampling for every 50 secs.	0.2 D	x	x	
0.6 D			0.6 D	x	x	
0.8 D			0.8 D	x	x	
0 - 1 m	EMF	Selective	Bottom	Grab sample where possible		
2m - B	ADCP	Selective	2m - B	ADCP for relative measurements		
Distance between verticals * Main channels : 100 m ** Small channels : 4 verticals			Bed load	Sampling for Andreasen tube analysis		
				Trap sampling with Helley - Smith sampler		

* Partial activity

Table 2.5 Field measurement discipline matrix

The measurements were carried out in the left channel south of Bahadurabad on 29 - 31 October 1992 and in the right river channel south of Fulcharighat on 3rd November 92 employing the equipment listed in Table 2.2 and following the procedures described in Chapter 2.4.

A general description of the survey area is provided in Chapter 2.2. All together 10 valid moving boat discharge gaugings and one complete crossing by manual profiling were carried out.

2.7.3 Measurement results (see also Appendix 1C)

All valid measurement data are compiled in Appendix 1C inclusive a

quantitative summary. A few key results are further described in the following.
A more detailed data interpretation and comparison is discussed in Annexure 4, Section 4.4.

Water-levels

As mentioned earlier it was found that the water-level was falling drastically since peak flow conditions and that the situation continued with approximately 8-10 cm reduction per day. Water-levels recording covering the measurement period were presented in Figure 2.10 above.

Discharge measurements by ADCP and EMF (moving boat method)

During the flood season routine gauging in October/November 1992 covering both river channels several discharge cross-sections (trans-sects) were carried out using the combined instrument configuration of ADCP and EMF. The results are shown in Appendix 1C and listed as follows:

Date	Location	Discharge in m^3/s
29/10/92	Left Channel	11,744
	Left Channel	11,778
	Left Channel	11,859
30/10/92	Left Channel	10,768
	Left Channel	11,084
	Left Channel	11,413
31/10/92	Left Channel	10,789
	Left Channel	**10,218**
03/11/92	Right Channel	4,260
	Right Channel	4,072

Table 2.6 Discharge measurements by ADCP and EMF (EMF without differential GPS causing quite some scatter in the surface discharge component and a substantial difference in absolute discharge measurement. This matter is investigated further).

The discharge values reflect the falling water-levels.

Unfortunately the measurements are also influenced by quite some inaccuracy caused by the lack of the differential mode when operating the GPS for positioning ; ref. Chapter 2.3

Discharge by velocity-area method

Current velocity and suspended sediment concentration profiles are included in Appendix 1C.

During the measurement campaign one complete cross-section covering both river channels were carried out by manual profiling and the following discharges were calculated.

Date	Location	No. of verticals in each cross-section	Discharge in m^3/s
29-31/10/1992	Left Channel	15 * (**)	10,700
03/11/92	Right Channel	15 *	4,130

* Positioning by GPS only i.e. inaccurate positioning of vertical profiles
** Positioning by DGPS

Table 2.7 Discharge by velocity-area method

Suspended sediment concentrations

For the measurements of suspended sediment concentrations various measuring methods were applied in combination:

- o Pump-bottle
- o Optical turbidity
- o ADCP back-scatter
- o Depth integrating

The results of these measurements are summarized hereafter. For more details see Appendix 1C.

o Andreasen settling tube

Samples for determination of grain size distribution of suspended sediments have been collected in some of the profiles at the lowest sampling level close to the river-bed.

The results are summarized in table 2.8 below and grain size distribution curves as well as sampling locations are included in Appendix 1C.

Samp No.	Collect date	Collect time	Collect depth (m)	Total depth (m)	D35 (mm)	D50 (mm)	D65 (mm)	Stnd. dev.
136C	30/10/92	13:00	9.00	9.20	0.027	0.044	0.090	4.5
143C	30/10/92	15:05	9.00	9.20	0.015	0.032	0.060	4.5
150C	30/10/92	17:00	5.20	5.40	0.015	0.026	0.052	5.5
157C	31/10/92	11:30	9.50	10.0	0.013	0.026	0.048	3.8
27A	31/10/92	12:34	6.85	9.30	0.018	0.035	0.061	5.3
28A	31/10/92	16:07	9.80	11.80	0.021	0.033	0.045	2.8
203C	03/11/92	12:30	3.50	3.70	0.012	0.017	0.025	3.0
34A	03/11/92	13:30	8.10	8.30	0.051	0.069	0.090	3.0
211C	03/11/92	13:43	2.40	2.60	0.012	0.019	0.035	3.4
218C	03/11/92	14:49	2.70	2.90	0.017	0.029	0.041	3.6
225C	03/11/92	15:40	2.00	2.20	0.019	0.028	0.042	2.9
239C	03/11/92	17:22	1.60	1.80	0.010	0.015	0.020	5.1

Table 2.8 Grain size distribution of suspended sediment samples.

The standard deviation equals 0.5 (D50/D16 + D84/D50).

As also stated elsewhere the Andreasen sampling will continue also in order to study the vertical distribution of grain sizes.

o Depth integrated suspended sediment samples

So far only a few depth integrated samples have been collected for comparative analysis. The future need will be further investigated and more samples will be taken.

The results are shown in Figure 2.11 below.

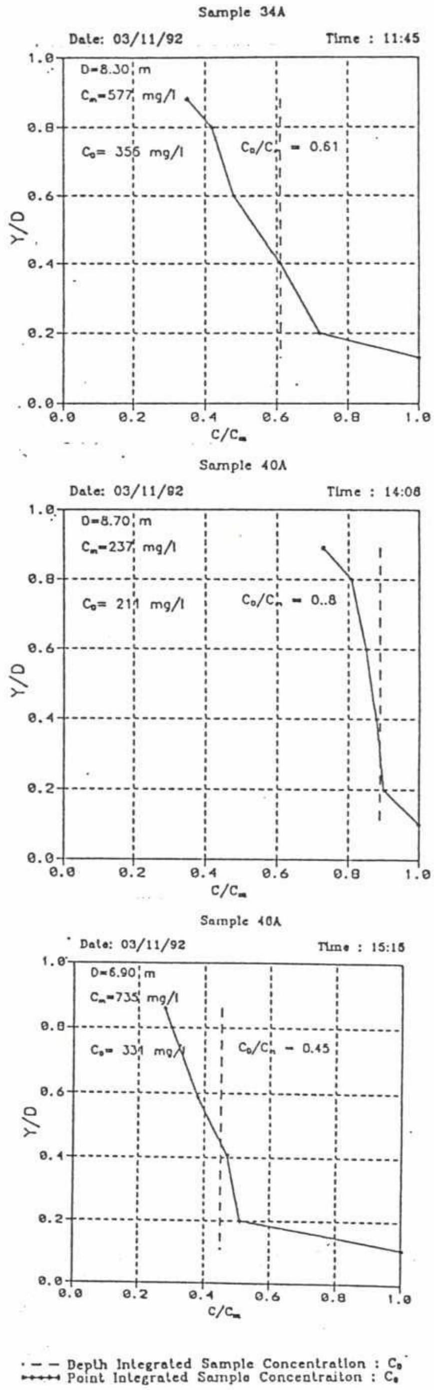


Figure 2.11 Depth integrated suspended sediment samples

Bed load measurements

o Helley-Smith bed load samples

Also bed load samples have been collected around some of the measuring verticals for analysis of bed load transport. Mostly three samples were taken around one vertical as indicated alongside Table 2.9.

The results are summarized in Table 2.9 below and the related grain size distribution curves are included in Appendix 1C.

Collect date	Collect Time	Total weight (g)	Transport rate (kg/ms)	D35 (mm)	D50 (mm)	D65 (mm)	Stnd. dev.
30/10/92	15:30	124	0.0067	0.280	0.325	0.350	1.5
	15:35	336	0.0370	0.158	0.191	0.232	1.6
	16:00	690	0.0377	0.213	0.268	0.326	1.5
31/10/92	11:45	41	0.0022	0.300	0.350	0.400	1.3
	12:00	57	0.0031	0.300	0.350	0.400	1.3
	12:10	486	0.0265	0.142	0.164	0.190	1.4
31/10/92	16:15	361	0.0197	0.319	0.357	0.399	1.3
	16:30	437	0.0238	0.313	0.351	0.394	1.3
	16:45	43	0.0023	0.315	0.352	0.393	1.3
03/11/92	12:50	96	0.0052	0.089	0.108	0.137	1.9
	13:00	13	0.0010	0.199	0.269	0.330	1.7
03/11/92	14:40	875	0.0478	0.280	0.324	0.374	1.5
	14:45	598	0.0327	0.304	0.346	0.395	1.3
	14:50	143	0.0078	0.288	0.329	0.376	1.3
03/11/92	16:30	42	0.0050	0.208	0.275	0.333	1.7

Table 2.9 Grain size distribution of bed load material

In spite of a very careful and accurate performance of the measurements the results show a large scatter. The reasons for these differences will be further investigated and more samples will be needed to achieve any firm conclusion.

2.8 Tests gauging in December 1992

2.8.1 Background

Due to the fact that the test gaugings in October were done in moderate flow and could not be executed completely, problems were encountered to select the final and complete field equipment configuration for Phase 2. In an attempt not to delay the project more than necessary, the consultant proposed to carry out some additional field tests in the lower sections of River Meghna. Here the tidal conditions were expected to generate high currents and thereby high suspended sediment concentrations during spring tide, which might be comparable with the conditions at Bahadurabad in monsoon flow conditions.

During the test gauging in October it turned out that one of the critical parameters in the survey operation was the performance of the combined current string/suction cable (umbilical) which had showed strong tendencies of vibration in the prevailing flow conditions. The consultant expects to solve the problem by adding some kind of fairing which eliminates the vortexes inducing the oscillations.

According to experience from other countries the ADCP performance is expected to become critical in terms of acoustic contact with the river bottom in high sediment concentrations.

Therefore the test gauging in December focused on the performance of the ADCP in high sediment concentrations.

A brief proposal on additional testing was forwarded on 28 November 1992 and the measurements were carried out on 14 - 24 December 1992.

2.8.2 Objectives

The main objective of the additional field tests was to support decisions regarding final selection of survey equipment configuration.

A timely selection of hardware was desired to avoid substantial delays in the measuring programme as mentioned earlier. It was questionable whether these decisions could be taken from the results of the field tests of October 1992 (no high flow). Waiting for the results of the final field tests during the 1993 monsoon (high flow conditions) would cause considerable delays. Hence, the additional field tests were proposed, attempting to overcome these problems.

Conditions on site

A testing site should be found where the flow conditions would be comparable with the specified high flow conditions. Velocities up to 3 m/s and sediment concentrations up to 2000 ppm were sought. These conditions could not fully be met. However, in the tidal rivers, especially the desired sediment concentrations were expected to be found.

2.8.3 Measurement Programme

The original test measurement programme contained in principle the same measurement disciplines as the original programme carried out in Jamuna River at Bahadurabad cross-section by the end of October but should this time focus on detection of areas with high sediment concentrations. It also involved the entire survey spread including the survey vessels DHA and DHC.

The programme included:

- a rather detailed bathymetric survey for determination of a suitable test gauging cross-section
- some preliminary ADCP crossings covering a river stretch of 1-2 km in order to obtain a size of order of prevailing current velocities and distributions
- a test gauging including current profiling by S4 and suspended sediment profiling by sampling and turbidity measurements. The number of verticals would be selected on site based on distributions within the cross-section recorded by the EMF and ADCP
- function test with the side scan sonar in an alternative area with some sand dunes
- during the tests the anchoring procedure would be monitored closely especially with respect to recovery of anchors. Alternative anchors and supplementary moorings may have to be introduced

Upon arrival at the sites in the middle of the spring tidal period, again the flow conditions turned out to be lower than expected and the planned programme had to be changed drastically covering a much wider area and thereby most of the operation time was actually spent on reconnaissance type measurements.

2.8.4 Measurement procedures

Individual measurement procedures were the same as applied in the previous test gauging in October and described in Chapter 2.4

The December campaign covered the Lower Padma and Meghna between the existing BWDB discharge cross-section at Mawa and 60 km downstream of Chandpur.

Altogether 7 cross-sections were measured and some of them several times in order to catch the peak flow conditions (tidal). Suspended sediment samplings, turbidity readings and manual current profilings were carried out in selected critical areas.

2.8.5 Measurement results (see also Appendix 1D)

All valid measurement data is compiled in Appendix 1D. A few key results are further described in the following.

A few selected measurement results are summarized in the following.

As also mentioned above most of the measurement programme was spent on reconnaissance for locations with high sediment concentrations, which would disturb the acoustic signals from the ADCP causing loss of bottom track.

Some critical conditions were encountered on 21 December during maximum outflow conditions in a well developed sand-dune area when navigating along the sand-dune propagation direction.

Several ADCP profiles were recorded when drifting slowly across the sand-dune area in order to record sufficient data for further special analysis. A long series of data with no bottom track were actually recorded.

Two conventional 0.5 l suspended sediment samples and two 25 l samples for Andreasen tube analysis were collected as close at the bottom as possible. Maximum current velocity was recorded to 1.5 m/s and maximum suspended sediment concentrations were 1300 - 1700 mg/l. Other typical concentration data is listed below:

Field No.	Collect. date	Collect. time	Collect. depth	Dry filter wt.(gm)	Volume (m)	Total filter wt. (gm)	Concentration (mgll)
1	19/12/92	1710	3.00	0.0943	51.5	0.1077	260.19
2	19/12/92	1735	14.70	0.0948	52.5	0.1234	544.76
3	20/12/92	1130	2.70	0.0909	56.5	0.1198	511.50
4	20/12/92	1145	7.80	0.0918	55.5	0.1181	473.87
5	20/12/92	1230	13.00	0.0972	55.5	0.125	500.90
7	20/12/92	1745	8.25	0.0997	60.0	0.1816	1365.00
8	21/12/92	0745	6.00	0.091	5505	0.1647	1327.93
9	21/12/92	0820	1.50	0.0932	56.0	0.1389	816.07
11	21/12/92	1850	4.50	0.0894	63.0	0.2008	1768.25
12	21/12/92			0.0933	58.0	0.159	1132.76

Table 2.10 Concentration of suspended sediment.

18

2.9 Land survey

2.9.1 Horizontal positioning by dynamic DGPS

Also for land surveying the differential satellite positioning system (DGPS) is used and as mentioned earlier operating this system required transmission of distance correction values by an UHF radio link between a master station installed in a known fix point - bench-mark on land and the new location to be positioned.

GPS always measures with respect to the World Geodetic System (WGS 84) and therefore the coordinates to be released by SoB must be converted to WGS 84 coordinates by means of some kind of coordinate transfer calculations - a "datum shift".

The consultants are not able to carry out this datum shift, due to lack of information regarding the geometric definition of the Everest ellipsoid to be used by SoB.

This means that the consultants cannot establish an accurate positioning annotation in the applicable system until this problem is solved.

Further details are provided in Chapter 2.3.

2.9.2 Levelling of bench-marks across the river channels.

In December 1992 bench-marks were created for gauging stations near to Bahadurabad on the left bank of the river. For the coming measuring campaign in May/June additional bench-marks will have to be created. Locations for these bench-marks not only include the left bank of the Jamuna near Bahadurabad but also the chars in the middle of the river. Bench-marks on the left bank can simply be connected by traditional levelling to the existing network of FINNMAP bench-marks. Transfer from this network to the char in the middle of the river is rather problematic. Three methods have been considered as follows:

1) Hydrostatic levelling
   The water-level of the river is assumed to be perpendicular to the vertical. By taking simultaneous gauge readings on both banks the level can be transferred. This is the traditional solution.

2) Trigonometric levelling
   With a theodolite the vertical angle between the bench-marks on

both sides of the river is measured. The slope distance between the two bench-marks is also measured. Difference of height can now be calculated.

3) Levelling by GPS.
A network of GPS baselines is measured between several points having known coordinates and height and the point to be determined. By fitting this local network into the known positions coordinates of the unknown point can be calculated.

Local experience shows that the traditional method by simultaneous gauge readings at both banks of the river over a longer period has given bad results in the past.

It is at this initial stage suggested that all three methods will be considered for transferring the level to the char.

Comparison of the results will enable the selection of the most suitable method for other sites and campaigns where similar problems may arise in the future.

2.9.3 <u>Levelling of the dry part of the Bahadurabad site.</u>

Measurements can be split into vertical and horizontal measurements.

Vertical measurements (z coordinate)

For the vertical measurements three methods will be discussed and should be evaluated with regard to productivity and applicability in the local environment:

1) Traditional levelling
Slow, but local knowledge is sufficient to start these measurements without any prior training. However the method requires relatively a lot of horizontal positioning. All necessary equipment is available.

2) Levelling by rotating laser
Fast method, requires little training as the method is very similar to traditional levelling. Some effort for horizontal positioning required for traditional levelling. No equipment available.

3) Tachymetric levelling

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Fast method. A considerable training of local personnel is required. The required effort for horizontal positioning is limited in comparison to the other methods because part of the positioning comes automatically with the levelling. Equipment is available. Integration of measuring results in HYDROPAC is very simple and fast compared to the other methods.

Horizontal measurements (x,y coordinates)

The levelled topo-spots should be positioned to be able to draw maps of the spot area. A regular covering of the area with measured spots is required. The obtained map should link up properly with the bathymetric charts of the adjacent channels. To achieve this, temporary points should be marked on the shore to locate the sailed lines.

Doing this work with traditional land survey methods is very time consuming and unnecessarily accurate. A faster method is to use a mobile DGPS receiver for the positioning work. Additional advantage is that positioning for the water survey is the same as for the land survey thus avoiding any discrepancies. For this purpose a portable DGPS spread should be compiled from the available equipment.

From the technical point of view it is a disadvantage that the available receivers are not able to present results in a map projection as land survey calculations can only conveniently be done in grid coordinates, however, this problem can be overcome by converting latitudes and longitudes to grid coordinates.

Recommendation/conclusion

- o Trials should be performed with the tachymetry method. In case of positive results this method is to be preferred above the others for reasons of:
  - productivity
  - integration of horizontal and vertical positioning
  - easy interfacing of results to HYDROPAC

- o Alternatives need to be investigated aiming at minimizing the amount of topographical work. Possibilities are for instance
  - measuring water-levels at various water-level slopes.
  - using additional information from remote sensing techniques such as areal photographs, satellite images and/or radar pictures.

2.9.4 Verification zero levels of BWDB gauges

The total number of gauges to be verified is 47. The gauges are listed in Table 2.11, and their locations are shown in Figure 2.12. The zero level of gauges is determined by levelling the gauge to FPCO approved bench-marks. The checking consists of comparing the thus obtained zero level with the zero level as used by the gauge reader.

Four stages can be distinguished for this checking:

1) Site visit to check if the information of the FPCO supplied bench-marks corresponds with the situation in the field.

2) If bench-marks are found to be in accordance with the description as supplied by FPCO and in a good condition, levelling between bench-mark and gauge is carried out.

3) In all other cases a proposal is sent to the FPCO on how to improve the situation either by replacement, re-levelling or construction of new bench-marks.

4) After consensus between FAP 24, FPCO and BWDB, the proposed work will start on these stations.

Data sources

Survey of Bangladesh (SoB)
During site visits throughout the country SoB pillars were found which have been established under the Survey of Bangladesh project "Strengthening of Capability of Survey of Bangladesh in Geodesy" in cooperation with Japan. In many cases these bench-marks and survey marks could be useful for the FAP 24 project. Although nothing was known about the status and availability of data regarding these points when the site visits were made, survey crews were instructed to incorporate these points. This enables to make a check afterwards whenever data might become available.

BWDB
BWDB bench-marks were officially supplied by the FPCO to the project. Distinction is made between BM's and TBM's, the latter being of a lower order. As far as feasible the BWDB bench-marks are used for the levelling of the staff gauges. Site visits have shown that in some cases BM's are in poor condition or not anymore present. In such cases the use of a bench-

mark from another network or the construction of a new bench-mark is proposed. Another problem encountered that often the officially supplied data did not correspond with the data as supplied by the gauge readers or local concerned officials.

FINNMAP
The node of points consists of two parts: Northern part roughly around the Jamuna/Brahmaputra and a coastal part along the Padma and to the south of the Padma. The northern part was officially supplied to the project by the FPCO. For the southern part a request has been sent to the FPCO to supply the required data. All gauges connected to these BM's can be regarded as reliable. Whenever possible connection of BWDB BM's to this network is carried out.

FAP 6
FAP 6 project is also involved in levelling water gauges in particular in the north eastern region of Bangladesh. They were consulted to avoid any duplication of work between FAP 6 and FAP 24.

Checking of water-level stations will not be carried out by FAP 6 before the establishment of a second order levelling network. The works for this network have only just started and would not be finished within one year. Consequently, checking of gauges would certainly not start within one year.

In order not to delay the works on the FAP 24 project it was decided to check the zero level values of the gauges with the nearest available existing BWDB bench-marks or temporary bench-marks. After connection of BM's and TBM's to the second order levelling network by FAP 6, corrections can be applied to the collected data whenever necessary.

Recommendation on the use of networks:

- Where possible the BWDB network is used
- Next to that the FINNMAP network is used. The gauges along the Jamuna/Brahmaputra, Ganges and Padma can be connected to this network with relatively little effort. An exception to this are the gauges of Rampur Boalia and Sardah.
- In the north eastern region along the Meghna and Kushiyara the FAP 6 is executing second order levelling to connect all gauges. Once this network is finished and gauges are connected, also these gauges can be used.

- o Some isolated gauges throughout the country can easily be connected to the SoB/JICA network.
- o Question remains however how these separate networks have been or will be connected to each other (BWDB, FINNMAP north, FINNMAP south, FAP 6 network and SoB/JICA). As long as connection data between the networks are not readily available the use of more than one network should be limited as far as feasible.

2.9.5 Results

At the moment of writing of this report the following progress was made on the levelling works:

Inspection completed	:	47 stations
Levelling	:	26 stations
Proposal for improvement	:	14 stations

The results of the inspection of the stations are summarized in so-called inspection reports, having an agreed format. As an example see the inspection report of Meghna Ferryghat in Figure 2.13 The results of the zero level checking of the gauges will be reported separately. An example of the results of this checking is given in Table 2.12

At a number of stations improvements are proposed, which are summarized in Table 2.13. The location per station is elucidated with sketches, see the examples given in Figure 2.14 and 2.15.

Brahmaputra/Jamuna

45 Noonkhawa
45.5 Chilmari
46 Kamarjani
46.9L Bahadurabad
46.9R Fulcharighat
48 Jagannathganj
49.A Kazipur
49 Serajganj
50.3 Mathura
50.6 Teota
15.5 Mathurpara

Ganges

88 Rampur Boalia
89 Sardah
90 Hardinge Bridge
91 Talbaria
91.1 Sengram
92.1 Mahendrapur

Padma

91.9L Baruria
91.9R Goalundo
93.42 Bhagyakul
93.5L Mawa
94 Tarpasha
95 Sureswar

Dhaleswari

68 Tilly

Old Brahmaputra

225 Jamalpur
228.5 Mymensingh

Arial Khan

9A Off-take of Arial Khan

Gorai

50 Porabari 99 Gorai railway bridge

Upper Meghna including Kushiyara

266 Kanairghat
267 Sylhet
268 Chattak
269 Sunamganj
270 Markuli
271 Ajmiriganj
272 Madna
272.1 Austagram
273 Bhairab Bazar
274 Narsingdi
275 Baidder Bazar
275.5 Meghna Ferryghat

276 Satnal
277 Chandpur
172 Amalshid
173 Sheola
174 Fenchuganj
175.5 Sherpur

Table 2.11 List of BWDB gauges.

TABLE : FAP 24-Checking of zero value of gauges

Gauge Station and number	Reference/Standard BM & their heights in meters PWD		Secondary BM & their heights in meters PWD			Gauge zero value in meter(s) PWD			Remarks
	B M	Height	B M	Height Existing (BWDB)	Height FAP 24	Date & Time	Existing (BWDB)	FAP 24	
Hardinge Bridge (90)	FM BM 8236	23.140	BWDB BM	18.95	18.868	20.2.93 1240	3.24	3.18	Zero value in column FAP 24 is with reference to FMBM located close to BWDB BM.
Bahadurabad (46.9L)	FM GPS-764	20.309	BWDB TBM	21.785	21.768	14.12.92 1620	13.00	12.96	This is test gauging station. As a double check, FM GPS-764 has been used as reference.
			FAP24	-					
			TBM01		22.0075				
			TBM02	-	20.7508				
Fulchari-ghat (46.9R)	FM GPS-7	21.970	FAP24 TBM (T&T)	-	20.5211	13.12.93 1600	13.00	13.63	This is test gauging station. As a double check, FM GPS-7 has been used as reference.
			TBM (Thana)	-	20.6601				
Serajganj (49)	FMBM 7201	13.975	BWDB BM	13.87	13.536	13.2.93 0940	6.53	6.14	FMBM located close to BWDB BM has been used as reference for double check.
Porabari (50)	FMBM 6205	12.934	BWDB BM	12.270	12.265	12.2.93 1045	4.56	4.95	FMBM located close to BWDB BM has been used as reference as BWDB BM has been engulfed by roots of banyan tree.
Bhairab Bazar (273)	BWDB BM	7.371	-	-	-	8.2.93 1555	0.77	0.76	
Narsingdi (274)	BWDB BM	6.814	-	-	-	8.2.93 0920	0.55	0.52	
Baider Bazar (275)	BWDB TBM	6.630	-	-	-	7.2.93 1455	-	1.42	

Table 2.12 Example of gauge checking

A proposal to improve the situation of bench-marks at 14 stations has been sent to FPCO for their approval. A summary of this proposal is presented in Table 2.13.

Nos.	Station	Proposed improvements
45	Noonkhawa	BM 45 be levelled with FMBM 7626
45.5	Chilmari	BM 45.5 be levelled with FMBM 7612
46	Kamarjani	TBM be levelled with FMBM 7602
48	Jagannathganj	TBMs be levelled with FMBM 5114
49A	Kazipur	New TBM be established and connected to FMBM 7209
91	Talbaria	BM 91 be levelled with FMBM 8230
91.1	Sengram	New BM be established and connected with FMBM 8216
93.4L	Bhagyakul	New TBM be established and connected with BM 93.4L
94	Tarapasha	New TBM be established and connected with FMBM 1716
95	Sureshwar	New BM be established and connected with GPS 79
270	Markuli	New BM be established and connected with BM 270
275.5	Meghna Ferryghat	New TBM be established and connected with FM TBM 4103
4 A	Off-take of Arial Khan	New BM be established and connected with nearby FMBM
99	Gorai Railway Bridge	New TBM be established and connected with FMBM 8225

Table 2.13 Proposed improvements

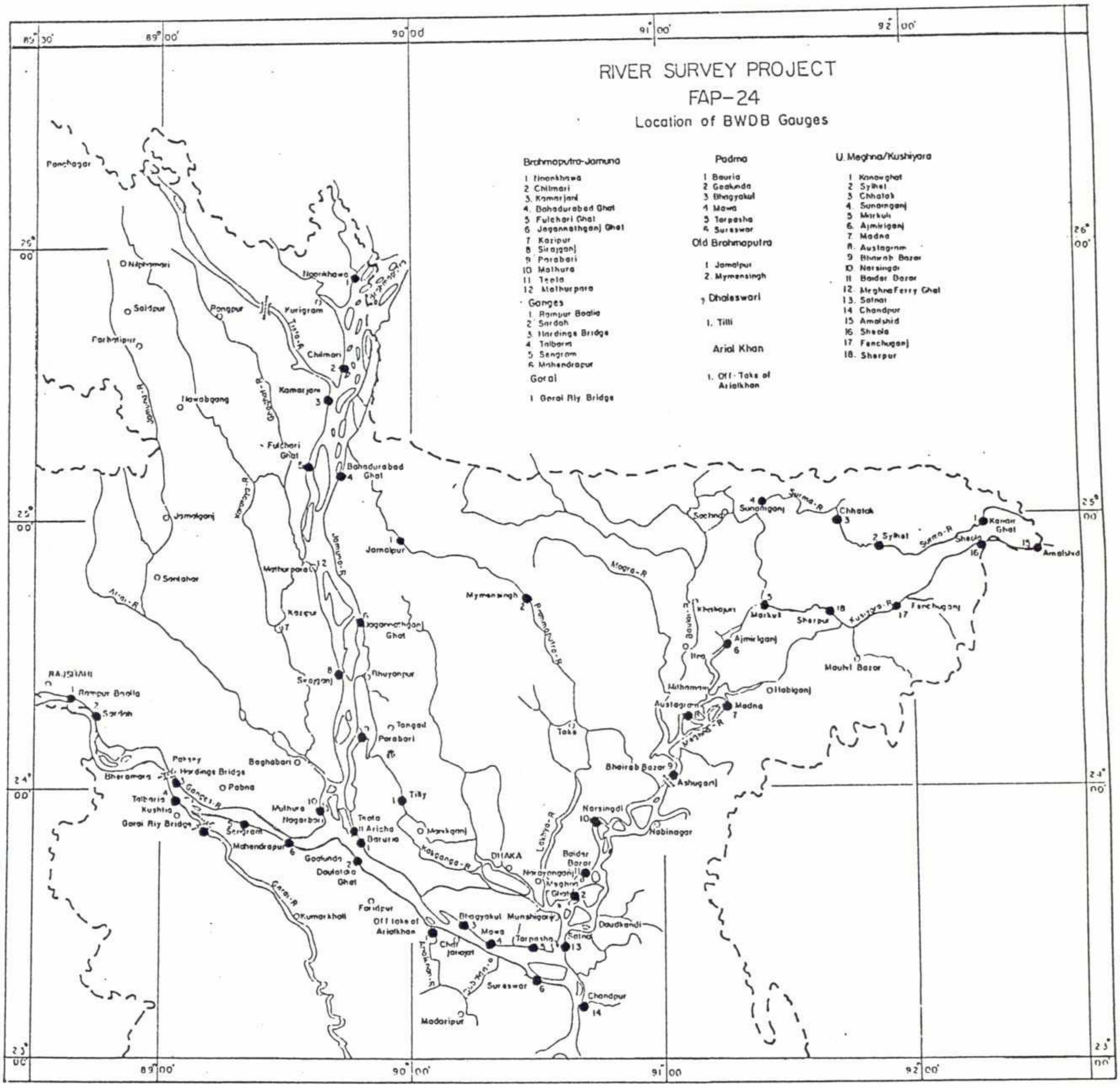


Figure 2.12 Location of BWDB gauges

RIVER SURVEY PROJECT FAP-24
INSPECTION REPORT

1. Gauge.

Name of gauge station	: 275.5 Meghna Ferry ghat
Date of visit	: 04.02.93
Condition of gauge	: Good
Remark	: -

2. Bench mark

Calibration benchmark present	: ~~yes~~/no
Name	: TBM
Location	: Located on the SE corner of Pucca bridge (Culvert) at old Ferryghat Bazar.
Height	: 6.985 meters PWD
Condition	: acceptable/not acceptable

3. If, not acceptable, give reasons: -

4. Distance of gauge to BM : 0.25 Km

5. Conclusion, recommendation : yes/~~no~~
Improvements required, if yes, describe. (Give recommended steps)
One new TBM FAP 24 275.5 be established on the left bank at Meghna Ferry ghat in suitable place and its height be determined by levelling with FM TBM 4103 (length of levelling likely to be approx. 2 Km)

6. Sketch map of the area.
(not to scale)

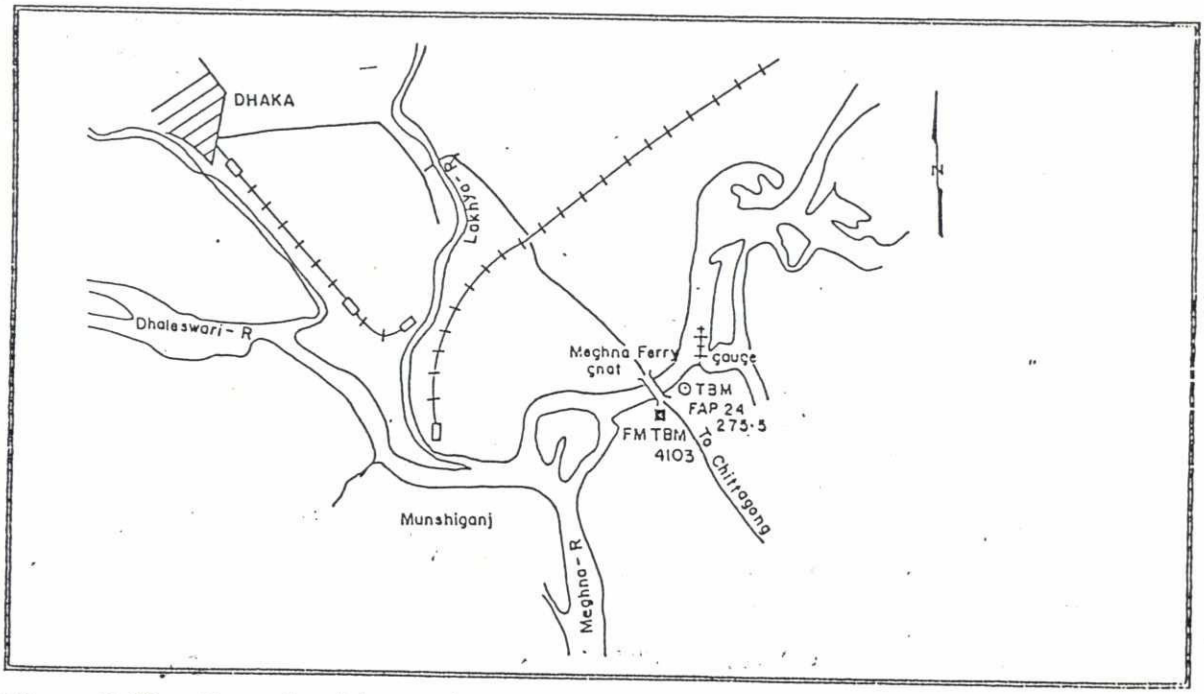


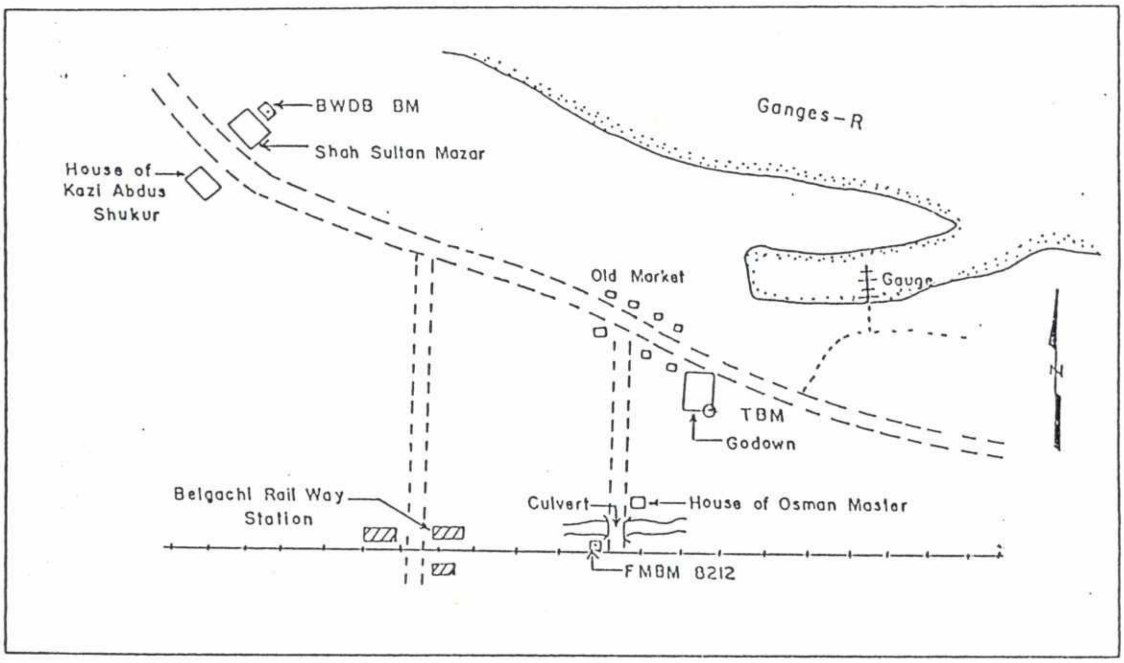
Figure 2.13 Example of inspection report

PROJECT : FAP 24 RIVER SURVEY PROJECT

RIVER : Ganges

GAUGE STATION : 91.2 Mahendrapur

LOCATION SKETCH



LOCATION OF BM & TBM

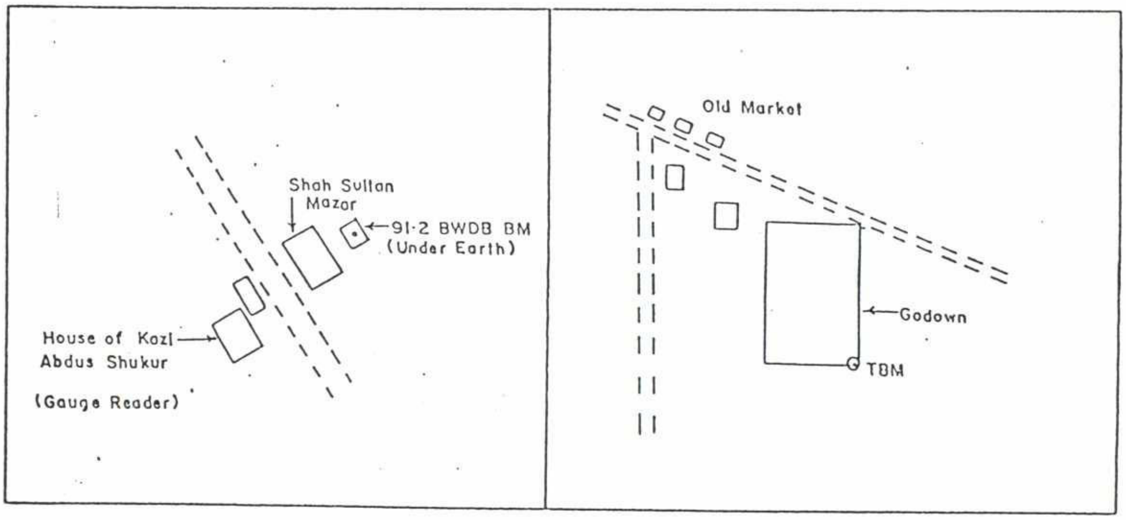


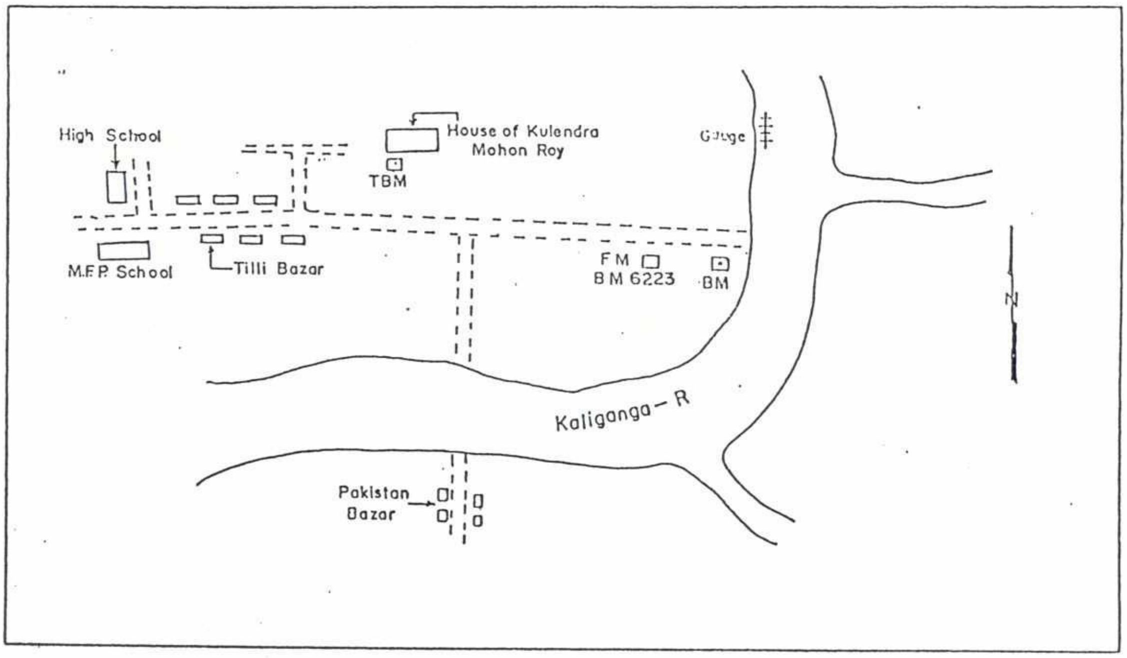
Figure 2.14 Example of location sketch Mahendrapur

PROJECT : FAP 24 RIVER SURVEY PROJECT

RIVER : Dhaleswari

GAUGE STATION : 68 Tilli

LOCATION SKETCH



LOCATION OF BM & TBM

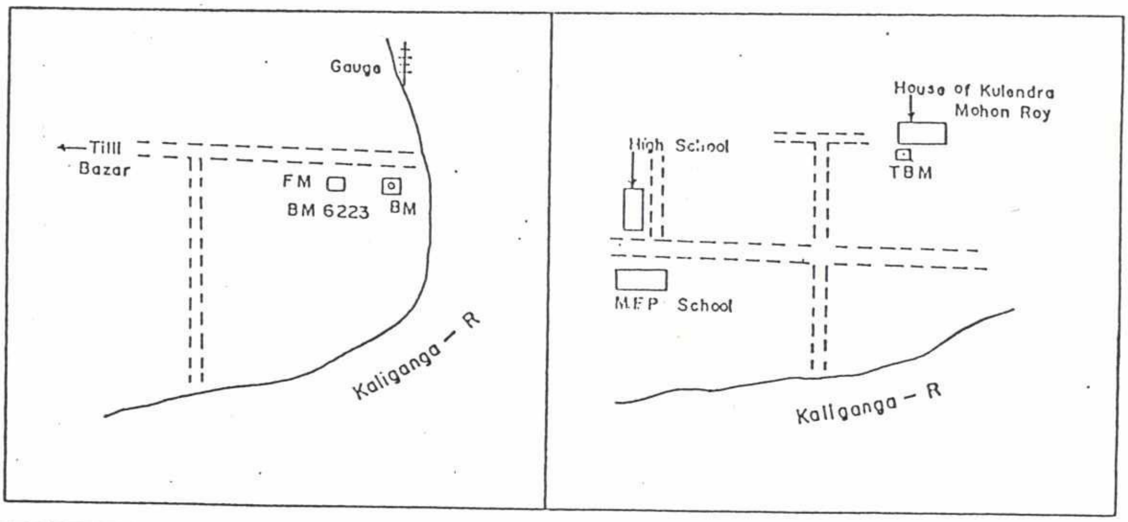


Figure 2.15 Example of location sketch Tilly

Annexure 3

Data-processing

3.1 Data flow description

Considering the size of the total project with its several data sources, including several survey boats, water-level measurements, tidal references etc, the tasks of controlling the flow of data and the administration of these huge amounts of data are crucial to achieving a correct data-processing and reporting of data.

In brief each measurement has to go through the following minimum process:

- o Logging and assurance of the overall correctness of the logging (instrument calibration, usage, error sources etc)
- o Temporary storage with unambiguous positioning and time reference of measurement
- o Transfer to the project office for further processing
- o Storage of raw data as reference backup
- o QA/QC involving editing of errors, tidal correction and instrument post calibration
- o Storage of edited data for later access and further processing
- o Processing of data into derived figures such as discharge, rating figures and river-bed surfaces
- o Storage of derived figures for easy access in the data analysis phase of the project (and for 'third party' users)

In order to ensure a smooth operation and a convenient level of training the following objectives were outlined for the involved software (and hardware) setup:

- o Employment of as few as possible software packages so as to minimize training and setting-up problems
- o Usage of well-proven standard software, where possible, to minimize implementation problems and to concentrate software development efforts to areas where new inventions are needed in connection with new methods and/or new processing methods
- o Hardware should be sturdy and of a type locally serviceable. In reality, this mainly implies using PC-compatible hardware

The following main software packages have been implemented:

HYDROPAC

This system is a field survey software package developed by Trimble Datacom. The package is in general the control identification package managing all vessel-based data collection and storage activities. The system is used for position control, navigation support, data collection and on-line monitoring. It can handle all data collection and data-processing in connection with bathymetrical surveying and is also used for data identification of all other on-line recordings of the survey vessels.

The off-line applications of the system comprise analysis and presentation of bathymetric plans. Analysis of bed load transport by sand-dune tracking is also based on HYDROPAC in combination with a separate bed load transport module that has been developped for the present project.

FIELDMAN

This is a window-based off-line field data management system that has been developed by DHI. The system uses a GIS type interface together with window-based search editors to form a intuitive user interface.

The system is first of all used as the basic library system of the project, keeping track of all data and their main characteristics. The background system can retrieve files as requested by the user. Many of the data files (limited by disk space) can be stored directly in the FIELDMAN database for direct search, retrieval, and presentation.

HYMOS

This package is a general off-line hydrometeorological data management and data-processing package developed by DELFT. It is used to assemble individual measurement series from the FIELDMAN system into correlated measurements for calculation of derived parameters and values, such as for instance a total cross-sectional discharge.

Also, the package will be used for statistical analyses and associated data presentation.

3.2 Data collection and logging

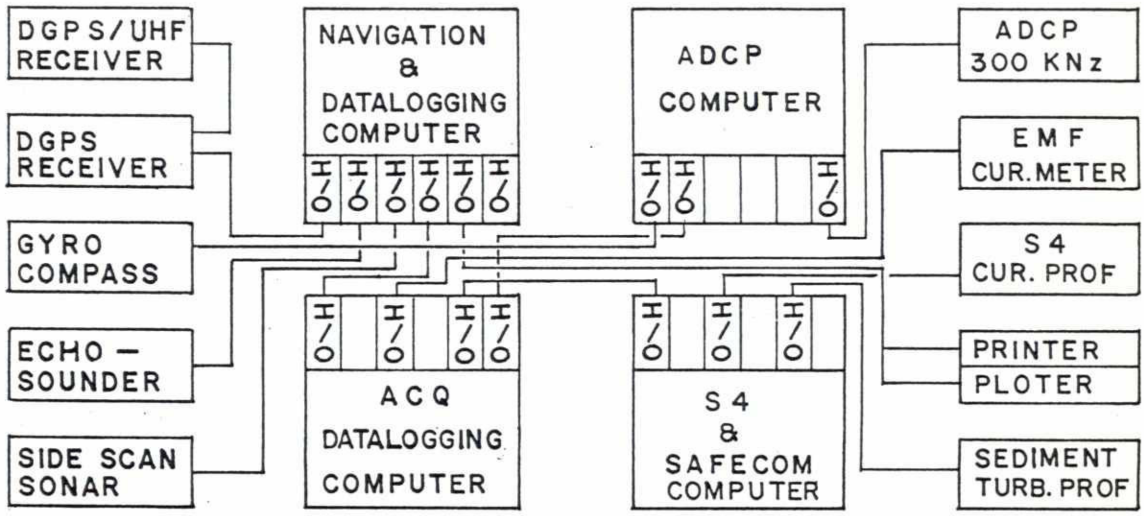


Figure 3.1 Principle hardware set-up survey boat type A and B

For the data sources on the survey boats, both the 'mother ships' and the 'satellite boats' logging of data is performed under the control of the HYDRO package. The HYDRO package carries out all necessary position control functions such as positioning, time reference, navigation output and is also the control centre for the surveyor in charge. The HYDRO package is logging time and position together with relevant sensor inputs such as depth and/or current-profiles, etc. For bathymetric and cross-section measurements, the HYDRO package includes utilities for on-board quality check of the logged data.

The survey set-up on the various types of survey boats, are illustrated above and below.

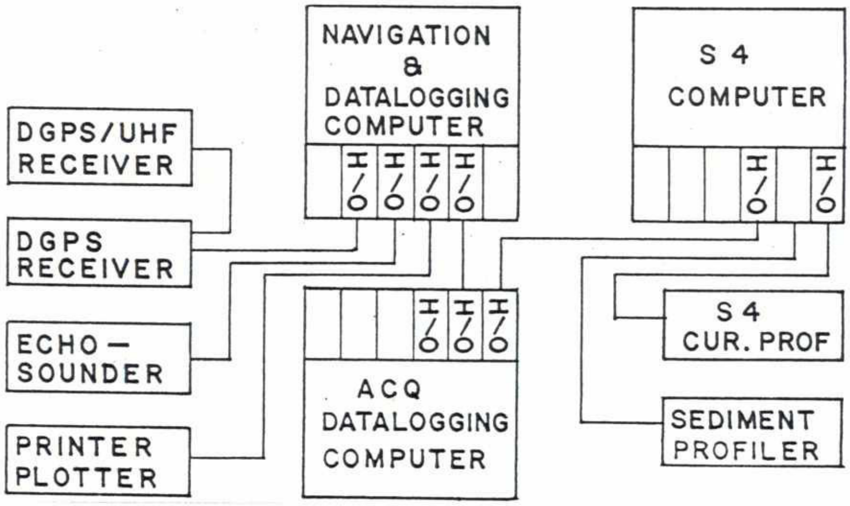


Figure 3.2 Principle hardware set-up survey boat type C

Temporary storage and data transfer

Once data have been collected and pre-checked, they are stored in the file formats of the HYDRO package for later transfer to the project office in Dhaka. The data administration on-board is done on a file-by-file basis with manual tracking of the data contents. In addition, each file contains a header with key information on measurement period and position. As often as practically possible data is transferred to the project office for further processing. The tapes used for this transfer are considered the project's raw data and will remain the ultimate backup and data reference source.

Raw data storage

When tapes are received in the project office the contents are copied immediately to the disk storage for further processing. Library information in the tape contents (data type, area, time period etc.) is entered into the common FIELDMAN library system and registered as external files residing on tape. The tapes are then moved to their final storage. For security reasons the raw-data tapes are stored in a building separate from the project office.

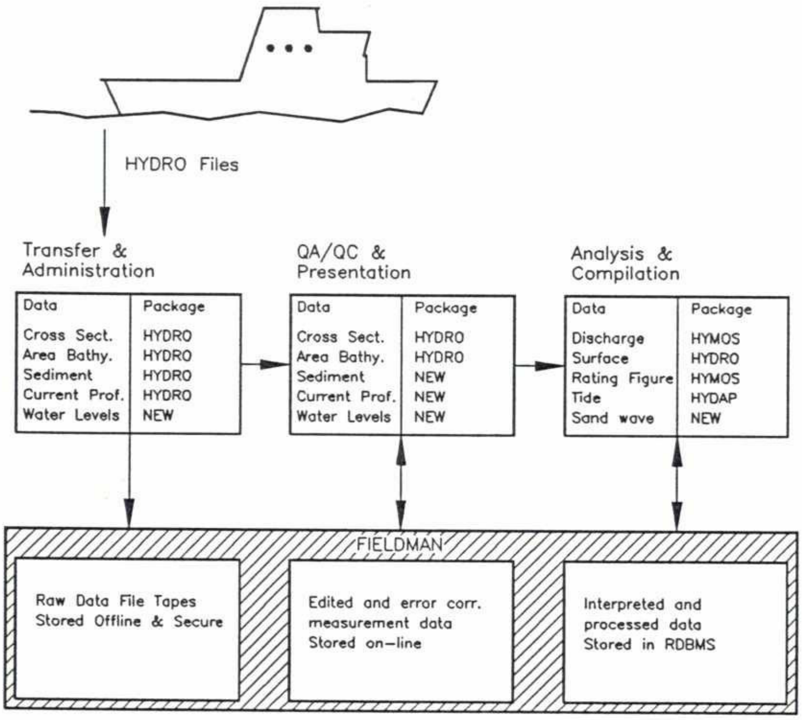


Figure 3.3 Main data flow of on-line survey data on board

3.3 Quality assurance

Although the field data are considered the absolute basis for the data analysis, practical considerations require further processing to be done on accepted data. Because of this, every file is going through the following processing steps:

- o Manual/semi-automatic check for spikes, errors etc.
- o Errors are edited as appropriate by deletion, interpolation and/or filtering
- o Data sets are reduced to include only useful information, so superfluous and insignificant measurements are deleted
- o Possible offset corrections relating to the entire data set, such as instrument calibration or tidal correction

This process results in files with only sound and valid data, allowing for subsequent application of standard processing programs.

96

Storage of edited data

The edited data being the main data source for the further processing and analysis, is stored on-line on optical and/or magnetic disks for immediate acces.

As the number of data files is huge, a storage using ordinary naming conventions and a normal directory structure is considered inadequate. Each file is registered with its characteristics in the FIELDMAN system, meaning that a user who has selected a file has immediate access to its contents if the file format is supported in FIELDMAN. Or, he can immediately transfer the file to his working station for further presentation e.g. in the HYMOS package.

Processing of data

Certain data types (such as water-levels) are considered finalized after the editing stage and all data are stored in their own right after the editing stage.

However, most of the data have some derived results that are important and which most economically are computed and stored as single results. Such results include bathymetric surface models, cross-section ratings and discharge calculations. As several of this category of data will be of interest to access 'by value' (i.e. find all discharges larger than 50000) they are stored directly in the RDBMS tables of FIELDMAN.

3.4 Data-processing office in Dhaka

Hardware setup

All hardware in the data-processing and database environment is based upon standard PC-hardware. To facilitate a multi-user environment, the PC's are connected via an ETHERNET network. One PC is designated as overall server for the connected workstations, which are smaller PC's. The server PC is running the central database applications and controls the overall peripheral equipment. One A0-size plotter (thermal) and one laserprinter (which can also act as a plotter) are attached.

W A R P O LIBRARY DHAKA

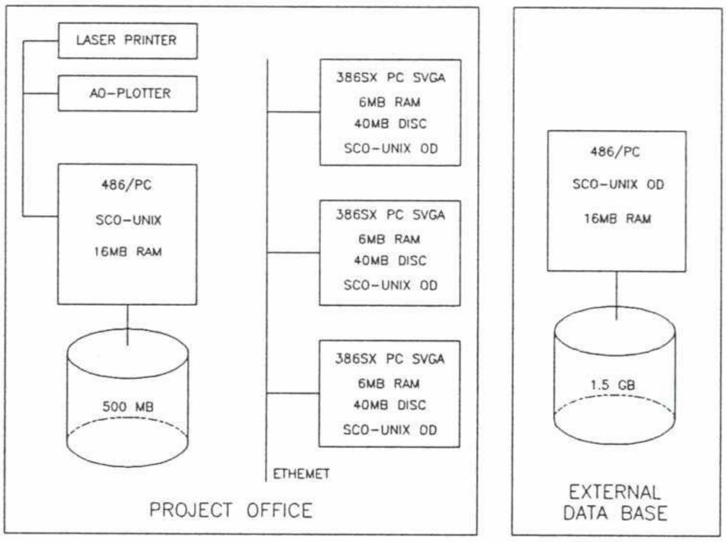


Figure 3.4 A schematic set-up of off-line data-processing centres

Basic software

The operation system software for the project Office and external database is SCO-UNIX (Open Desktop), facilitating a genuine multi-user environment in which more people can work on the same data for presentation, quality control (QC) etc. The network communication is TCP/IP protocol.

3.5 Laboratory analysis of sediments

The collected samples of suspended sediments and river bed sediments are taken to Dhaka for analysis in a laboratory established in the project office.

The following analyses are available at the laboratory:

- o Suspended sediment concentration, by Millipore microfiltering
- o Grain size distribution of suspended sediments, by Andreasen settling tube test
- o Grain size distribution of coarse river bed sediments, by wet sieving
- o Grain size distribution of fine river bed sediments, by hydrometer testing
- o Organic contents of sediment solids, by ignition loss
- o Density of inorganic sediments, by pycnometer tests

Detailed procedures for each type of analysis will be compiled in a Project Sediment Analysis Manual. International Standard procedures will be applied wherever relevant.

Results of the analyses comprise suspended solids concentrations, associated ignition losses, density of inorganic sediments, and grain size tables. Grain size distribution curves are prepared from the tables by a small computer program. All analyses are entered into a protocol, and stored in the database of the project.

Analysis of minerals is done optically. It should be noted here that for medium and finer fractions x-ray diffraction (XRD) techniques are usually applied. These techniques are rather advanced (with respect to required equipment and skill) and costly and were not considered viable for the present project. Angularity is determined either via the particle fall velocity or via the rollability (propagation speed of particles in a sloping cylinder).

Also determination of the organic fraction in the sample is made. Density is determined using a pycnometer or for coarser material the immersion method (volume determination after measuring the dry sediment weight).

3.6 Reporting of survey results and mapping

Deliverable results of the field survey programme comprise:

- o A manual of applicable field survey procedures
- o Processed data stored in the database
- o Topographical and bathymetric charts
- o Survey reports

Survey manual

A manual compiling all survey procedures to be applied in the field for execution of the various types of measurements is under preparation. The manual also includes a detailed description of the entire survey configuration as well as the quality assurance control procedures to be followed when measuring in the field and for the subsequent data-processing

A (rough) list of contents of the first draft version of the manual, called Data Quality Plan, is listed in Table 3.1 & 3.2 below.

List of contents

01.	Introduction	
02.	Phase 1 and Phase 2 surveys	
	2.1	Phase 1
	2.2	Phase 2
03.	Overall approach to data quality assurance	
04.	Set-up on-board survey vessels	
	4.1	Set-up on-board survey vessel DHA
	4.2	Set-up on-board survey vessel DHC
05.	On-line data quality assurance	
06.	File transfer and back-up procedure	
	6.1	File standards
	6.2	Back-up proceudres
07.	Survey log	
08.	Instrument logs	
09.	Survey procedures	
10.	Survey instructions	

Table 3.1 Data quality plan - List of contents

Annexures

01. Start-up of data system
    1 Starting the ACQ computers of the on-line system
        1.1 Starting the ACQ computer
        1.2 Chose the type of survey you want to carry out
        1.3 Starting the HYDRO computer
        1.4 Starting the S4-computer
        1.5 Starting the ADCP-computer
    2 File naming conventions for the on-line system
02. Survey report forms and checklists
    1 Survey instruction
    2 General survey log sheets
    3 Profiling survey checklist
    4 Transect survey checklist
    5 Sand-wave survey checklist
    6 Bathymetric survey checklist
03. On-line checking of data
04. Back-up procedure
05. Instrument log sheet
06. S4 Current meter
    1 Instruction for use
    2 Setting up the S4 logging programme
    3 DHI S4 programme, users manual
07. BB-ADCP, Acoustic Doppler Current Profiler
    1 Instruction for use
08. ELAC Echosounder
    1 Instruction for use
09. MEX-3 turbidity meter
    1 Instruction for use
10. DHI water sampling system
    1 Instruction for use
11. Side scan sonar
    1 Instruction for use
12. EMF current meter
    1 Instructions for use
13. Ott current meter
14. Positioning equipment
    1 Instructions for use

Table 3.2 Data quality plan - List of annexures

9+

Processed data

The processed data may be submitted on diskettes in common standard format still to be agreed between the Client and the Consultant.

Survey charts

Survey charts (of sounding lines, and topographical and bathymetrical contours) are prepared to a scale of 1:20,000 (or whatever is more practical). The charts are based on a common datum, indicated on each sheet, together with a table of characteristic local water-levels. Charts are prepared in A0 format (or less, if more practical).

Survey reports

Reporting of survey results will take place in two stages:

- o First stage is a pure reporting and presentation of measured and quality assured data and as such presents a data catalogue.

  In principle a report will be issued after each field campaign

- o Second stage will be a more interpretive report, where results are compared and scrutinized in details. Conclusions on observed developments will be presented here.

  These reports should be issued on a quarterly basis - say starting by 1 April, covering the measurement period January-March 1993. Another option considered is to issue reports on a seasonal basis.

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Annexure 4

Selection of survey techniques

4. Selection of survey techniques

4.1 Pre-selection in 1991 according to ToR and Technical Specifications

In the ToR (FAP 24, 20 October 1992) the consultant is requested to collect reliable all season hydrological and morphological data at key locations at the country's main river systems with emphasis given to the high water measurements during flood season introducing improved or new technology where appropriate.

Consequently the selection of alternatives in terms of instruments and methods were based on:

- o Overcoming the drawbacks of the presently applied traditional techniques (especially the ones encountered in the monsoon season)
- o Reducing the uncertainties, especially concerning the discharge measurements, by limiting the main sources of error with respect to:
  - unsteady positioning of current meter
  - inaccurate horizontal and vertical positioning
  - inaccurate measurement of flow direction
  - spatial errors (too less measuring points in the cross-section)
  - unsteady flow (flow variations during too long measurements)

The pre-selection of techniques resulted in the recommendation of a series of alternative methods and instruments to be tested in the first phase of the project. For further background information on the previous selection of techniques reference is made to Consultants Technical Proposals of September 1991 (Delft-DHI, 3 October 1991) and February 1992 (Delft-DHI, 22 February 1992) and the Inception Report (FAP 24, 20 October 1992). Results of the pre-selection are further described in the following.

4.2 Reference and recommended method

The following table summarizes the techniques of different measurements and equipment to be used for the "reference method" and the "recommended method".

Methodology	Reference		Recommended	
Measurement	a	b	c	d
Positioning	Sextant + anchoring	DGPS station-air on engine	DGPS	DGPS
Discharge	Area-velocity method	Area-velocity method	Moving boat	Moving boat
- Velocity	Propeller	EMF	EMF	EMF + ADCP
- Direction	Floats			
- Area	Echo-sounder	Echo-sounder	Echo-sounder	Echo-sounder
- Water-level	Water-level gauge	Pressure cell	Pressure cell + wave height	
- Suspended sediment	Water sample	Pumping	Optical + ref. samples (pumping)	Optical + ref. samples (pumping)+ ADCP
Bed load	Dune tracking with dual frequency echo-sounder	Dune tracking with dual frequency echo-sounder	Dune tracking with dual frequency echo-sounder	Dune tracking + side scan + direct sampling
Bathymetry	Echo-sounder	Echo-sounder	Echo-sounder single and dual frequency	Echo-sounder single and dual frequency

Table 4.1 Measuring methods

After the final test measurements, to be done in the monsoon season of 1993, the consultants, along with FPCO, will finalize the selection on the basis of:

- Suitability of application under extreme conditions of Bangladesh
- Rapidity of performance and relative accuracy and reliability of the data obtained

The consultant wants to state that the selected techniques to fulfill the FAP 24 objectives are not necessarily the same as the sustainable techniques envisaged for the Bangladeshi organizations. This may be caused by the different objectives asking for different accuracies.

For the final selection of the sustainable techniques other aspects have to be elaborated such as:

- o The economy of the techniques
- o Repair (spares) availability and maintenance situation
- o Timing of implementation
- o Training requirement

Consequently the FAP 24 techniques and the sustainable techniques are considered to be different issues to be developed separately, also in terms of timing.

A detailed description and technical specifications of the individual instruments are provided in the original Technical Proposal and summarized in Appendix 1.

4.3 Status on technical performance of the survey spread

General

The existing survey spread configuration is summarized in Annexure 2, Table 2.2 and the present status on technical performance of the individual instruments and survey vessels is further described in the following.

It is the consultant's opinion that the survey spread under the prevailing environmental conditions since measurements started at Bahadurabad on 21 October 1992 in general has demonstrated a consistent performance and that in main channels the recommended method for discharge measurements is superior to the reference method in terms of efficiency, data density and data quality.

The sediment transport gauging, involving detailed point sampling, still represents some drawback in the overall operational efficiency. This aspect will be further investigated during the coming field investigations. The aim will be to reduce the spatial density as far as feasible.

Water-level recording

Installation of permanent water-level recorders is awaiting:

- o Final technical clarification of the alternative sensors to be employed
- o Additional site reconnaissance for selection of measurement locations in all 11 sites

Though technical alternatives have not been offered previously, it is proposed that alternative sensors do not affect the unit rates.

Final determination of the locations in the BoQ will be carried out in collaboration with BWDB and FPCO.

Evaluation of technical alternatives in terms of acoustic or pressure sensors is taking place in March 1993. A proposal for the Bahadurabad gauge will also be submitted in March so installation should start sometime in April.

Positioning

Experience from the field has clearly demonstrated that navigating the complex river system in itself requires a very accurate positioning system - like the actually installed DGPS - in particular during the period after the flood season, when water-levels in the rivers are falling drastically and navigation depths change rapidly.

Also from an operational safety point of view, accurate positioning is required. Sometimes the daily field measurements on the river become delayed and navigation back to the berthing site will take place during night hours in complete darkness, in which case navigation can only be based on differential GPS (DGPS).

Applicable co-ordinate systems

During the establishment of the co-ordinates for our reference station (part of our DGPS positioning system), a significant difference between provided and actual measured co-ordinates in the order of 5-600 m were found.

Based on contacts with other FAP projects the consultant understands that the final basis (datum) for determination of horizontal co-ordinates has still not been decided and therefore, the provided co-ordinates are not final either.

Outstanding clarification:

Naturally this subject shall be clarified before initiation of any comprehensive bathymetric survey work now planned to start in May this year.

Discharge measurements by ADCP and EMF (moving boat method)

Based on the experience obtained since the end of October 1992 and until now the following conclusion has been established about the technical performance and employment of the ADCP instrument:

- o The combined ADCP and EMF methodology is considered to provide the highest accuracy in discharge measurements in the main channels by measuring with the highest data density within the shortest time, i.e. by establishing an "instantaneous" current distribution cross-profile with the related flow discharge

- o The critical environmental parameter for the technical performance of the ADCP is the suspended sediment concentration levels close to the river-bed, which may reflect the acoustic signals from the instrument and thereby cause a loss of acoustic contact with the solid river-bed. This phenomena was detected during the test gauging in December in a well developed sand-dune area. The recorded raw data has been analyzed by a specialist (the manufacturer) and it turned out that in the actual case the bottom track had not been lost but was superseded by reflections from the water surface. This phenomena is further investigated

In summary it may be stated that so far the consultant has not been able to find a location causing a continuous loss of bottom track with the ADCP and it is therefore expected that the instrument will function in conditions close to peak flood levels as well.

However, the consultant agrees that this has to be tested at peak flow levels in the coming flood season as planned. Irrespective of the outcome of this exercise it can already now be concluded that the ADCP has proven its performance in flow conditions applicable during the period November-May and thereby increased the overall discharge measurement capacity tremendously. Therefore, application of the system in tidal flows also seems attractive.

In situations where the bottom track is lost a certain percentage of the vertical current profile will yet be measured and the high horizontal measurement density will remain the same. Software has already been developed and tested to determine the vessels speed in such cases from the vessel positions measured with DGPS.

Outstanding clarifications:

This means in more specific terms that the outstanding testing will actually focus on investigating this vertical data coverage in high sediment concentrations. Also the optimum survey speed will get further attention. More precise determination of the boundaries of applicability of the ADCP will be realized by gaining more experience with the system in various flow conditions.

Velocity and suspended sediment measurements by manual profiling (velocity-area method)

The basic principles involved in these measurements in terms of instruments and equipment as well as the combined current string and suction hose (umbilical) employed for the current and suspended sediment profiling has proven its performance during prevailing conditions.

The suction pumps with adjustable capacity allows an adjustment of the in-flow velocity in the suction tube relative to the surrounding flow. The pressure sensor in the S4 current meter allows for a precise monitoring of instrument and suction levels in the water column so by careful handling suspended sediment samples can be collected close to the river-bed (appr. 15 cm).

Outstanding clarifications:

During vertical profiling severe oscillations even disturbing some of the S4 current measurements were detected. It is the consultants intention to solve this problem by adding some kind of fairing to the umbilical eliminating the eddies causing the oscillations. This will first be tested during the coming dry season routine measurements and verified in high flow conditions in the monsoon of 1993.

Mapping of river-bed configuration by side scan sonar for detection of sand-dune patterns

The dual frequency side scan sonar system temporarily installed on board the A vessel has proven its performance under prevailing flow and sediment concentrations. An example of a typical record from the left river channel at Bahadurabad is shown in Annexure 2, Figure 2.8. The record clearly shows the river-bed configuration with sand-dune lengths and heights as well as their relative orientation.

Outstanding clarification:

The final need for the instrument shall be determined. A part of this clarification should be to find a method for measuring the sand-dune movements by frequent surveys in a pre-selected area (as supplement to the sand-dune monitoring by echo-sounding as foreseen in the programme)

Echo-sounding

The echo-sounders have proved their performance. Until now no loss of acoustic contact with the river-bed has been observed.

Until now echo-sounding has been carried out in longitudinal- and cross-profiles - the latter mainly simultaneous with the ADCP discharge measurements. Real sand-dune monitoring for bed load transport measurements has not yet been carried out. The consultant is awaiting conditions with well developed sand-dune formations and the authorities permission to employ DGPS. Some testing in singular lines will be carried out during some of the dry season routine measurements.

Bed load transport measurements

As also mentioned elsewhere only the Helley-Smith trap sampler has been tested until now. It is the consultants conclusion that, by careful handling, the sampler performs very well and gives reliable and consistent results. It is expected that the instrument can be used in current velocities up to 2 m/s.

At each sampling location three samples were taken for a duration of 2 minutes each. The mesh size is 250 μm.

There has been quite some scatter in the quantities actually sampled. To some extent this is expected to reflect the nature of bed load transport. The instrument will be used during the coming dry season measurements and more experience will be obtained.

Positioning of the instrument on the river-bed must be very accurately taking presence of sand waves and general bottom contours into consideration.

Outstanding clarification:

Alternative instruments to be tested for bed load transport measurements must be determined.

Bed load transport measurements by sand-dune monitoring as mentioned above also has to be carried out.

Bed material sampling

Bed material sampling by grab (Van Veen) is a weak point in the operation so far due to prevailing current conditions. A very few samples have been taken.

Outstanding clarifications:

Testing of the USBM 54 sampler is awaiting the importing of the equipment.

Alternative sampling equipment and methods to be tested should be determined. A drag sampler is considered.

Manoeuvering and mooring of survey vessels

The survey vessels crew has been trained in survey navigation on the rivers, i.e. navigating the vessels in pre-selected straight lines (cross profiles or longitudinal lines) in varying flow conditions - in particular when crossing the rivers perpendicular to the current directions. Additional training is still required and will form a natural part of the future dry season measurements.

Apart from the C boat, mooring in the rivers has so far not been any major problem.

Outstanding clarification:

The subject of mooring arrangements versus dynamic positioning will be studied further and alternative arrangements will be prepared for installation and implementation during the coming flood season when required.

A more powerful mooring arrangement will be installed on the C boat.

Possibilities for increasing the cruising speed of the C boat are also investigated by a professional naval architect and possible improvements will likewise be implemented prior to the coming flood season.

Data-processing office in Dhaka

The sediment laboratory and the hardware for the data-processing office in Dhaka has been installed. All the specified software has also been implemented and is functioning.

The final presentation framework will still be subject for discussion for some time between the users including BWDB and FPCO.

4.4 Comparison of measurement results

The results of the measurements have been analyzed. Special attention was given to the comparable measuring results. The objectives of the comparison are:

- o To check the reliability (deviating results ask for further investigations)
- o To assess in how far instruments and methods may replace each other
- o To ultimately achieve an optimal combination of techniques as well as measurement coverage density

The comparison emphasized on:

- o Ott propeller current meter versus S4 and ADCP
- o Ott versus EMF + ADCP
- o Echo-sounder versus ADCP bathymetric cross-profile
- o Discharge by velocity-area method versus ADCP + EMF discharge measurements. Comparison between different measurement densities will be included in this exercise

- o Turbidity measurements versus suspended sediment sampling supplemented with Andreasen settling tube analysis
- o Helley-Smith bed load sampling versus suspended sediment sampling near the river-bed
- o Suspended sediment profile by point sampling versus integrated sampling

4.4.1 Ott propellers versus S4 and ADCP

The Ott propeller current meter measures the current velocity by counting propeller revolutions and in the actual case 300 seconds duration mean current velocities with record of sampling for every 50 seconds interval have been measured.

The S4 electromagnetic current meter records the current velocity and direction continuously by sampling twice per second and thereby provide a detailed record including current fluctuations. 50 seconds mean values are also calculated.

During the measurements with Ott and S4, the velocities were also measured with the ADCP for comparison.

A typical S4 record is shown in Figure 4.1 and a comparison of results from the first inter-calibration exercise in Bahadurabad cross-section is shown in Figure 4.2.

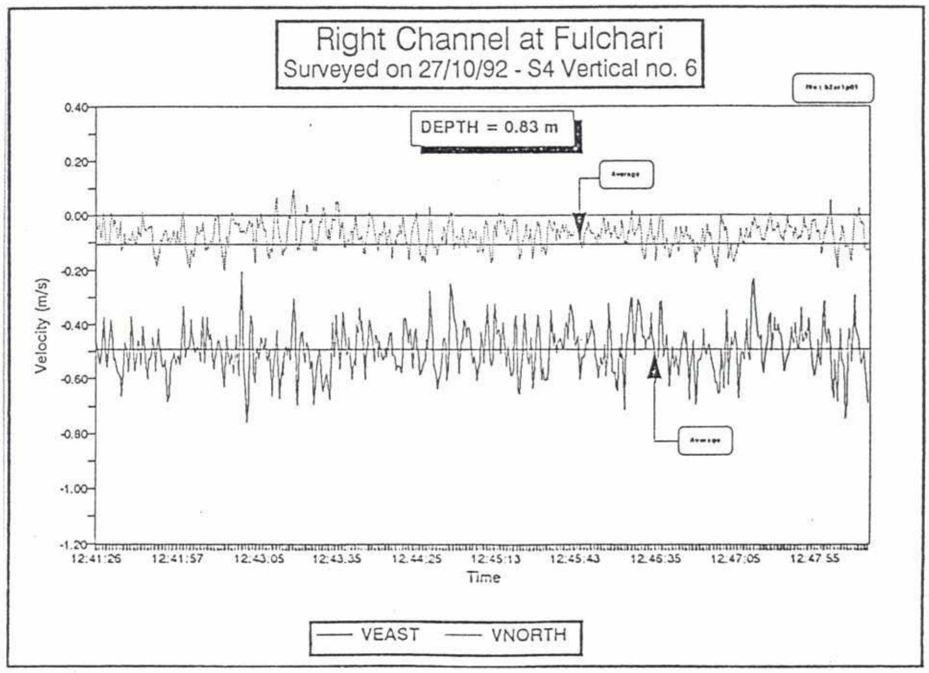

Figure 4.1 Typical S4 current recording

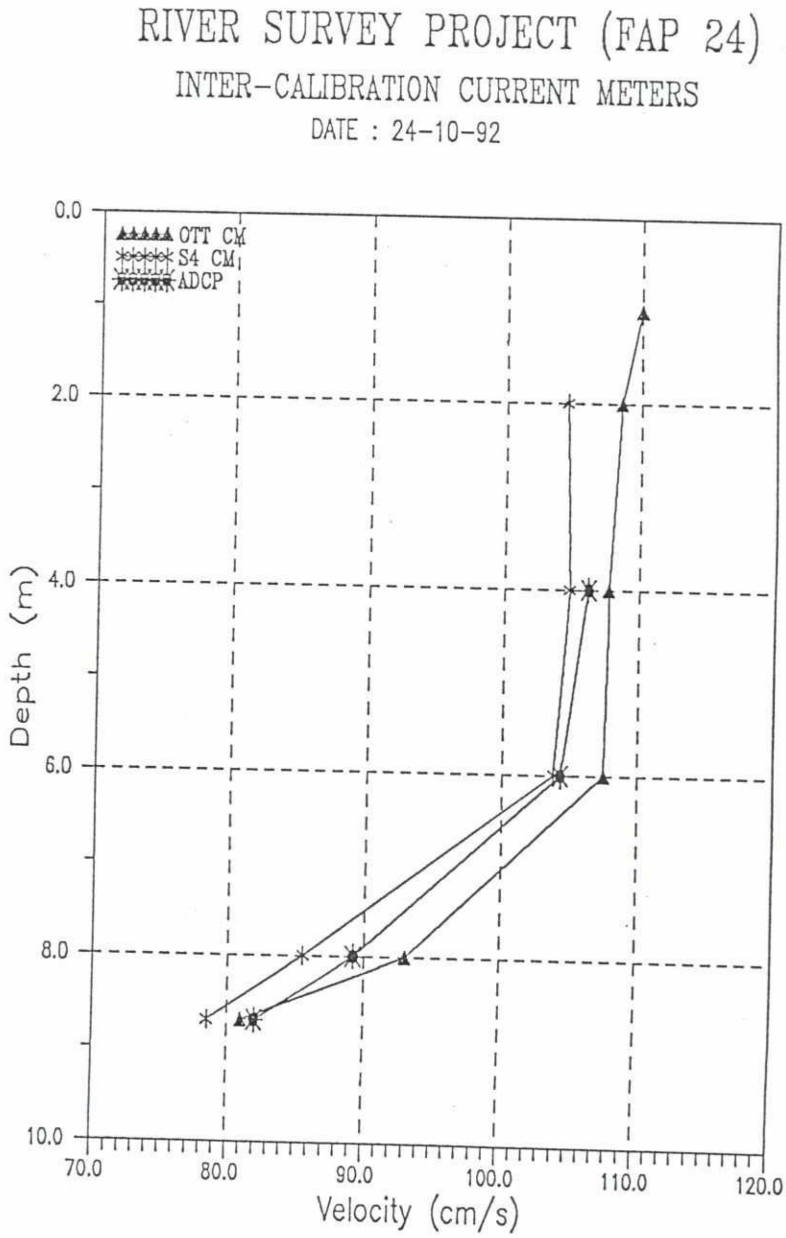

Figure 4.2 Inter-calibration of current meters used during the test gauging on 24 October 1992

The inter-calibration showed consistent results in mid flow conditions and it was concluded to proceed with the S4 meter for current profiling during the lean season.

4.4.2 Ott versus EMF and ADCP combined

Simultaneous profiling with the Ott current meter and the EMF and ADCP recorder has been carried out at several occasions.

A typical comparative profile is shown in Figure 4.3.

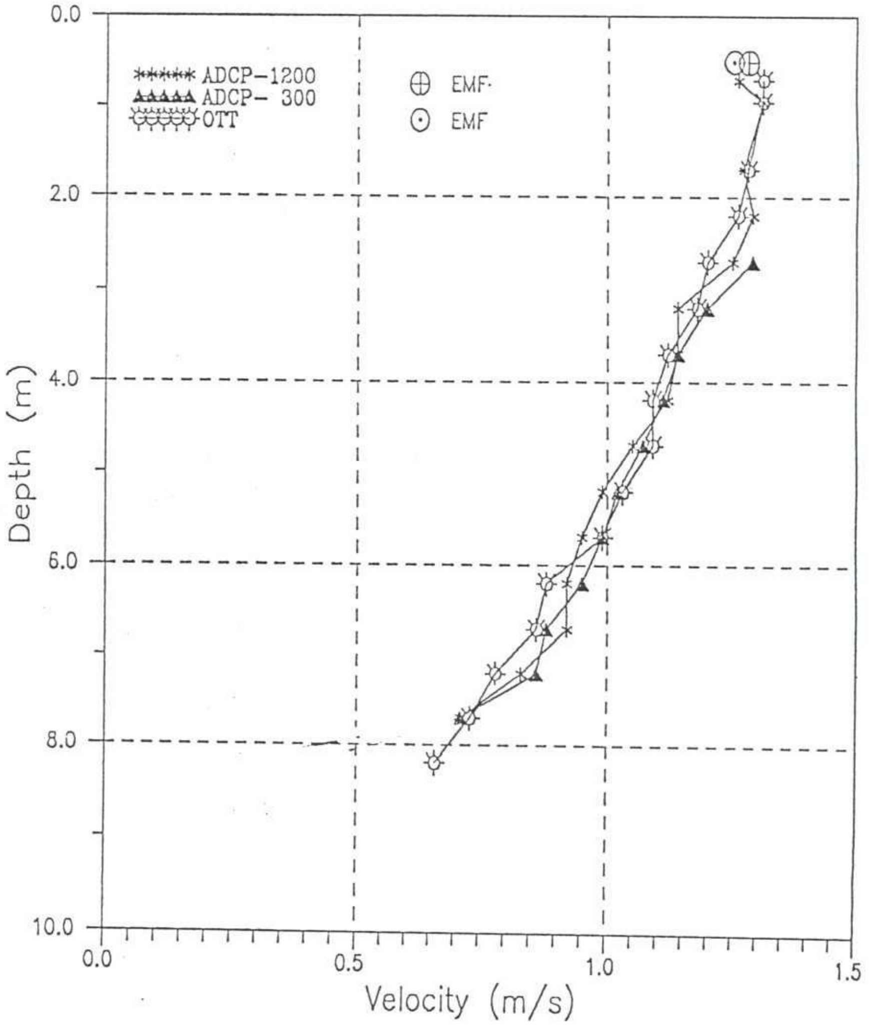

Figure 4.3 Intercalibration of current meters including the EMF

The intercalibration showed consistent results and it was concluded to proceed with the combined instrument configuration of EMF and ADCP for flow discharge measurements. The velocities at the surface (minor differences) will be investigated further. The same applies to the off-line calculation of the ADCP profile close to the river bed.

4.4.3 Echo-sounder versus ADCP bathymetric cross-profile

As a matter of verification simultaneous echo-sounder and ADCP cross-profiles (on-line recording) have been plotted. The results show remarkable good agreement.

The profiles show a horizontal displacement in the order of 10 m, which is caused by the sampling procedure in the ADCP data-processor.

The echo-sounder profile is based on a dense sampling intensity (one sample for every second) and represents the real profile in details.

The ADCP measures a complete current vertical profile and the corresponding depth (singular) for every 5-6 seconds corresponding to 8-10 m sailing distance and therefore shows a displaced profile. It may be observed that when the survey speed becomes low, as in the case of approaching the river banks, the horizontal displacement becomes negligible, as shown at the left river bank on Figure 4.4 below.

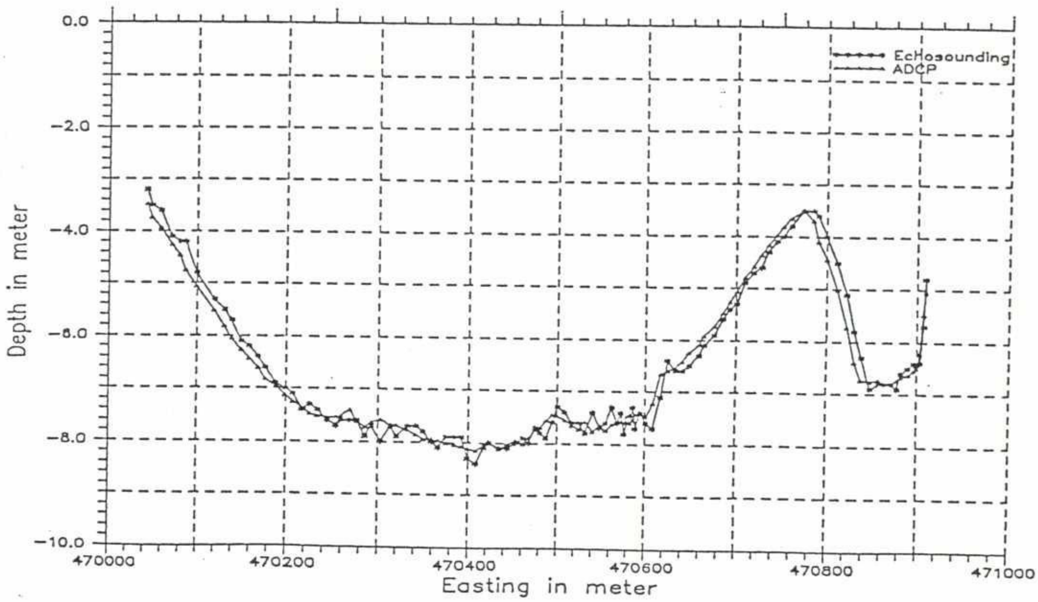

Figure 4.4 Simultaneous echo-sounder and ADCP profile

The ADCP cross-profile is not really used for any calculations. In the actual discharge calculations (off-line) the echo-sounder's real profile is used instead.

The sectional areas of each cross profile are the same.

The vertical differences may partly be caused by general river-bed configurations and partly by the different integration time per depth measurement (ADCP profile is more smoothened).

4.4.4 Discharge calculation by velocity-area method versus ADCP +EMF discharge measurements

The discharge calculation using the velocity area method and the related manual current profiles has been compared with a series of discharge measurements with the combined configuration of ADCP and EMF.

The results are summarized in Table 4.3 below for two series of measurements.

Date	Location	Discharge in m^3/s	
		Velocity area method	ADCP+EMF measurements
26 - 27/10/92	Right Channel	7,700	7,400*
29 - 31/10/92	Left Channel	10,700	11,200*

* Mean value of 3 and 8 discharge measurements respectively.

Table 4.3 Calculated and measured discharge.

The results are still subject to some analysis. The effect of the inaccurate positions of the current profiles used in the calculations for the velocity-area method will be investigated further.

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4.4.5 Turbidity measurements versus suspended sediment sampling.

During the test gauging in Jamuna River a calibration of the turbidity meter installed on the A boat was carried out. The results shown in Figure 4.5 below are very consistent.

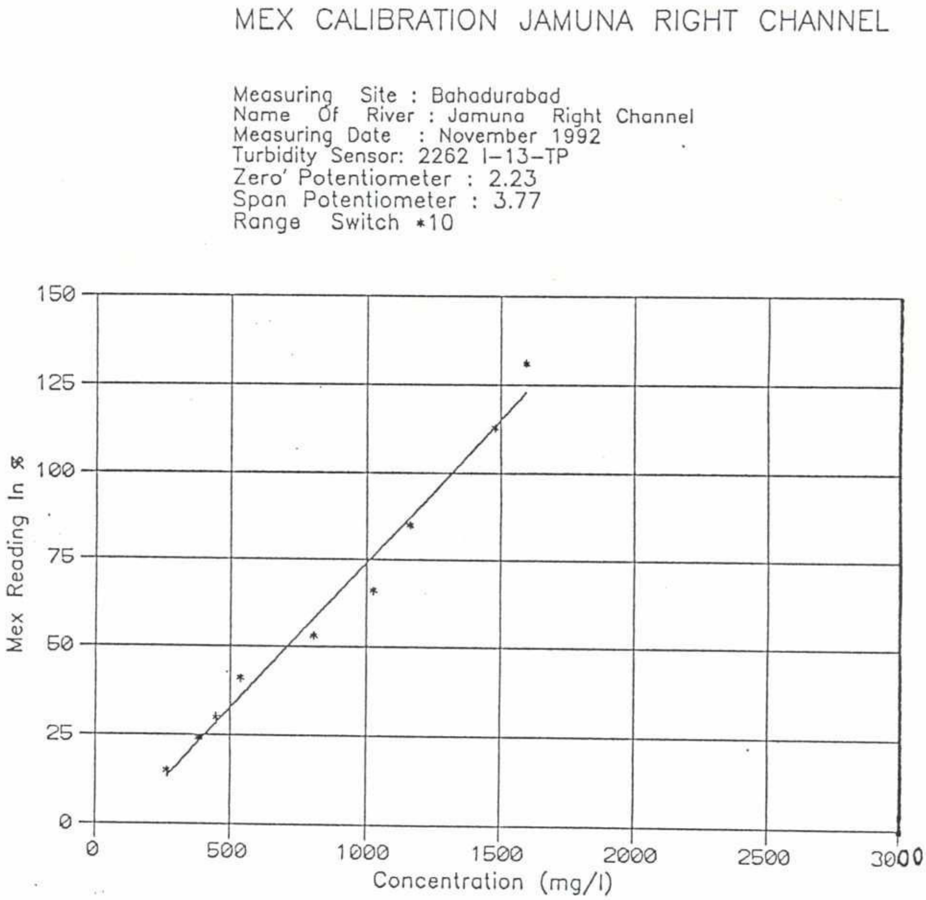

Figure 4.5 Calibration of MEX turbidity meter installed on the DHA.

Since the test gauging, several simultaneous turbidity measurements and suspended sediment sampling have been carried out at various locations. Some results are shown in Appendix 1C. Ultimately the calibrations will be correlated (if possible) to the sediment characteristics.

4.4.6 Helley - Smith bed load sampling versus suspended sediment sampling.

The entrance height of the Helley - Smith sampler is 0.076 m. The considered suspended sediments samples were taken only 0.2 m above the river bed. Yet, the bed load samples (D50) are in the 100 - 350 μm range, whereas the suspended load samples (D50) are in the 20 - 70 μm range, see sub-section 3.1.4. This indicates that there is hardly any bed material found in the suspended load transport. This holds obviously for the observed location in the present lean season conditions. Nevertheless it seems an important issue to be considered in further planning of measurements and analysis.

4.4.7 Suspended sediment profile by point sampling versus integrated sampling

Until now, only a few integrated suspended sediment samples have been collected. Additional sampling will be included in the future sampling programme in order to increase the data basis for comparison. The integrated concentration profile will also be compared with the related turbidity readings.

4.5 Tentative Selection

Based on the experience gained so far a tentative selection of techniques to be applied in phase 2 of the River Survey Project can be made.

A final selection is envisaged at the end of the monsoon of 1993. The tentative selection is summarized as follows:

o Vessels

A third survey vessel is envisaged. In size she should in principle be in between the two vessels available at the moment. Desired characteristics

- type : catamaran
- L : ~ 35 ft
- B : ~ 20 ft
- D : ~ 2 ft
- cruising speed : ~ 16 knots fully laden.

One (may be two) small boats (inflatable or aluminium) provided with outboard engines and measuring frames

- o Positioning
  The positioning systems envisaged for phase 2 are :
  - GPS for reconnaissance work only
  - DGPS for other survey like bathymetry and discharge measurements, etc

  Optimization is directed towards minimizing anchoring

- o Flow measurements
  As far as justified (depending on objective and related accuracy) using EMF with moving boat method in minor channels.

  In main channels supplemented with ADCP (in fact combined ADCP+EMF)

  In minor channels and areas with too less water depth for the ADCP, more detailed data to be measured with an S4 or an Ott propeller current meter.

  Optimization is directed towards maximum use of the EMF+ADCP/ moving boat technique also in tidal areas.

- o Suspended sediment
  To be measured with a combination of optical turbidity profiling and pump bottle sampling.

  Optimization is directed to minimize number of pump-bottle samples.

- o Bed load
  In the lean season direct sampling (Helley - Smith).

  In the flood season dune tracking (side-scan and echo-sounding)

  Optimization is directed towards establishing suspended load / bed load relations to minimize bed load measurements activities.

4.6 Studies for (final) selection

As indicated in Annexure 1.5 further studies are required to:

- o Analyse the reference techniques both for own use and to suggest improvements
- o Analyse the recommended techniques to support the selection of FAP 24 techniques
- o Optimize and develop the selected FAP 24 techniques during Phase 2, towards the final technique to apply also subsequent to FAP 24 completion.

These studies will obviously deal with the various types of measurements:

- o Bathymetric and topographic surveys
- o Hydraulic (flow, water-level) measurements
- o Sediment measurements

4.6.1 Bathymetry and topography

In this context the topographic survey is seen as the dry part of the bathymetric survey when covering the complete river sections. In combination the aim is to measure the river-bed configuration.

The main purpose of these surveys is to monitor the morphological behaviour of the confluences and bifurcations.

Reference

As a reference the bathymetric work suggested by the ToR (FAP 24, 20 October 1992) is taken:

Brahmaputra:	Off-take of Old Brahmaputra	100 km^2
	Off-take of Dhaleswari	100 km^2
	Outlet of Hurasagar	100 km^2
	Confluence Ganges/Jamuna	300 km^2
Ganges:	Off-take of Gorai	100 km^2
	Upper stretch of Gorai	100 km^2
Padma:	Off-take of Arial Khan/Dubaldia	50 km^2
	Totals	850 km^2

Surveyed twice per year (before and after the flood) with a line spacing of 200 m, leads to 8500 km sounding work per year.

However, the ToR also states that the areas are provisional and indicative only.

Moreover, the TS indicate that bathymetric work during the flood needs to be considered.

Techniques

The reference technique for this type of survey comprises:

- Positioning by sextant or Decca-radio-positioning
- Bathymetry by paper-recording echo-sounder
- Reductions with the aid of staff gauge readings
- Manual data-processing and charting

The recommended technique comprises:

- Positioning by DGPS (differential GPS)
- Digital dual frequency echo-sounding
- Reductions with the aid of Automatic Water Level recorder (AWLR)
- Use of track plotter to improve the coverage
- Computerized data-processing and charting

Points of study are:

- Review of objectives
- Review of indicated locations
- Review of indicated timing over the seasons
- Review of areal density (spacing of survey lines)
- Accuracy of the survey (also in view of the bed forms)
  - positioning
  - sounding
  - water-level
- Operation of echo-sounder in high sediment concentrations
- Selection of the appropriate topographical technique
- How to combine the bathymetric and topographic survey work
- How to minimize the topographic part of work (see also Annexure 2.4) by for instance applying remote sensing information and water-line measurement review
- Possibilities of presentation using a GIS

4.6.2 Hydraulic measurements

In this context the following type of measurements are considered:

- o Water-level and -slope
- o Flow velocity and direction patterns
- o Discharge

Obviously the studies supporting the selection and further optimization of hydraulic measurement techniques, will basically compare the prevailing hydraulic conditions in detail and the way these conditions will be measured applying the various techniques considered.

In fact the whole assessment of accuracies is based on the knowledge of the variability (spacial and temporal) of the flow and the schematizations (integration area and/or time) due to the applied techniques.

Some possible points of study are:

- o Review of objectives and acceptable accuracies
- o Review of temporal variability:
  - turbulence versus sampling time
  - possibilities of pulsating flow
  - duration of a measurement (contemporanity)
- o Review of spatial variability:
  - density of verticals
  - points per vertical
- o Water-level slopes, desired applications and accuracies
- o Vertical data coverage in high sediment concentrations and desired ADCP frequencies
- o Effect directions as function of the water-level
- o Additional flow information required for morphological analysis
- o Near river-bed flow profiles
- o Further optimization of flow measurements

This list contains typically a mix of hydraulic river characteristics and related measurement issues. This means that the studies can be done for a certain river (location) and a certain technique plus all kind of combinations.

It is expected that this list will be extended and prioritized in the second half of Phase 1, leading to a hydraulic study programme for Phase 2.

4.6.3 Sediment measurement

In the following the sediment measurements are discussed per survey technique:

- o The reference survey techniques
- o The recommended survey techniques
- o The FAP 24 survey techniques

For the definitions of these techniques see Annexure 1.5.

Reference survey techniques

As an example of the reference survey technique for measuring sediment transport the method used by BWDB is chosen. This method can be summarized as follows:

- o Point sampling in two points in a number of verticals
- o Number of verticals depending on the dimensions of the river and varying between 4 for small rivers to some 70 in the Jamuna River
- o In the Jamuna River the mutual distance between the verticals is 200m, independent of the depth (hence no incremental discharge method is applied
- o Depth of sampling is 0.2 and 0.8 of the depth
- o Instrument used is a so-called Brinkley sampler, essentially taking a water sample
- o Distinction is made between transport of "fine" material (wash load) and transport of "coarse" material (bed material load)
- o Analysis on sediment content and sometimes on particle size distribution by sieving and/or by sedimentation balance
- o Constant correction factors to determine the average sediment concentration in a vertical
- o Sediment transport determined by multiplying with the partial discharge for which the vertical is supposed to be representative
- o Storage of the sediment data in Dhaka at Hydrology-2, both of the detailed forms and of the finally computed sediment load of the river
- o Part of the data entered into a data base

Reviewing these procedures an assessment of potential errors can be made as listed below:

- o Potential errors related to the instruments used:
  - performance and efficiency of sampler

- condition of sampler
- determination of vertical position
- determination of concentration
- determination of size distribution (both final and coarse sediments)

o Potential errors related to the methods used:
  - "duration" of measurement in one point
  - number of verticals
  - number of points in the vertical
  - location relative to dune configuration in longitudinal direction
  - separation between bed material and wash load

o Potential errors related to the data-processing done:
  - adjustment factors (including different assumptions for diffusion coefficient)
  - correction for unsampled zone
  - computation of load from discharge
  - entering into data base

To validate the historical data and, if appropriate, to come up with suggestions for changes in the reference methods, a number of studies. These studies are summarized below:

o Visit to field measurements carried out by BWDB and inspection of processing
o Discussion with local staff (also retired staff)
o Discussion with staff in Hydrology office (BWDB), inclusive inspection of the data procession data entering into data base
o Random checks on data processing and data storage
o Theoretical study on concentration verticals (correction factors, lateral diffusion, unsampled zone) for the specific conditions in the Bangladeshi rivers
o Very detailed measurements allowing to study numbers of point in a vertical and numbers of verticals
o Assessment of accuracy of the measurements (studying all absolute and relative errors and "summing up")
o Comparative measurements by BWDB and FAP 24
o Entering into internal data base, and analysis on outliers, trends, etc.
o Preparation of sediment balances between different stations
o Comparisons of results of balances with changes in average bed levels in the in-between river reaches

The field measurements as part of the above studies are planned for May/June 1993.

Recommended survey techniques

In the proposal optical measurements (supported by pump sampling and ADCP recording) was proposed as the recommended survey technique for the suspended sediment measurement, in combination with dune tracking (supported by side scan and direct sampling) as recommended survey technique for bed load sampling.

First of all it is important to discuss the different modes of transport, notably bed load and suspended load. The bed load is exclusively made up of bed material particles. The suspended load consist of both wash load (finer than say 0.07 mm) and bed material that typically varies in size between 0.1 and 0.4 mm. For this project both bed material transport and wash load are of interest.

The selection of these two techniques is not undisputed. An alternative for both the pump sampling and the direct bed sampling is the Delft Bottle, which can be mounted on a carrier or in a frame hence allowing that measurements can be made at different heights from the river-bed. However, the Delft Bottle catches only part of the suspended bed material and no wash load. Because of this, the use of this instrument seems to be less appropriate on the Jamuna River. However, this needs further investigations. Just like other types of samplers the Delft Bottle gives practical problems when the instrument is lowered on the river-bed during flow velocities up to 3 m/s.

Dune tracking under FAP 1 has been shown to yield too high estimates of the bed load, because part of the suspended bed material load may contribute to the advancement of the dunes. This aspect should be studied in more detail. The problem is that there is hardly any alternative. The BTMA is difficult to handle and it is doubtful whether it will be possible to lower the instrument on the river bed during velocities up to 3 m/s. In addition the mesh size is about 0.25 mm, and hence only a part of the bed load is measured. The same holds for the Helley-Smith which also has a mesh size of 0.25 mm. Smaller mesh sizes are available but they are also prone to clogging. Another problem encountered so far, which means mainly in the lean season, is that either there are no dunes at all or their propagation is questionable. In this case bed load should and can only be measured using the direct samplers.

The above considerations confirm the main part of the recommended techniques but also show that the most uncertain part is the bed load measurement in the high flow ranges. As far as the bed load sampling is concerned we will do some further scanning of the "market" to look for other instruments and at the same time try to get some more insight into the limitations of the use of dune tracking.

FAP 24 survey techniques

Besides the usual pump-bottle system, on board of the FAP 24 survey vessels some instruments are present that may also be selected for the measurements of suspended sediment transport in phase 2 of this project. Notably the MEX-3 optical turbidity meter and the ADCP can be mentioned in this respect. The possible use of both instruments is discussed hereafter, together with the studies which have to be carried out to investigate their potential.

The MEX-3 measures the sediment concentration at one point. It is not able to differentiate between wash load and bed material load, though it is claimed that the MEX-3 measures the fine load better than the coarse load. It may be assumed in addition that the observed "concentration" is an unknown function of both the wash load and the bed material load. The possibilities of the MEX-3 in the rivers in Bangladesh have to be established via special surveys. The MEX-3 is mounted on a fish (but can be mounted on any platform) and can be used analogous to the moving boat method. It is also possible to vary its location in the vertical.

Apart from the frequency shift that can be used to compute the current velocities, the ADCP also provides the intensity of the backscatter. This is a measure of the relative sediment content of the water. Too near to the bottom, the signal gets lost due to the reflection of the river-bed. The range which cannot be sampled depends on the frequency on which the ADCP is working. There is also an unsampled zone in the upper layer of the vertical of 2.7 m for the presently used 300 Khz ADCP. The fact that it is not possible to measure near to the river-bed is a major disadvantage. It should be realized however that also the reference method is not measuring the concentration near the bed. We are in the process of testing an ADCP with a higher frequency (1200 Khz) that allows to measure nearer to the bed and also allows to have more details of the vertical in terms of an average concentration for every 0.25 m instead of every 0.5 m. Also the unmeasured zone near the surface is reduced to 1 m instead of 2.7 m.

Another disadvantage of the ADCP is that also this instrument does not distinguish between the wash load and the bed material load. It is claimed however that the ADCP is especially sensitive for coarse sediments.

There are several possibilities to cope with the problem of the combined measurement of wash load and bed material load. One way is by elaborating the measured concentrations in the following way:

The wash load, consisting of very fine particles, is distributed almost uniformly over the depth and over the cross-sections. This implies that the wash load constant is independent of the depth in the vertical. The transport of bed material, however, is dependent on the local water depth. This implies that if a plot can be made of the sediment content C versus the water depth h, reading at h = 0 would provide that wash load concentration. This is schematically indicated in Figure 4.6.

Experience from another application of this method (Tana River, Kenya) demonstrated that the method is quite sensitive to errors. In that application however, the number of vertical was fairly small. One of the advantages of the ADCP is that many verticals become available. This will probably allow to make much better estimates. In this respect it is of interest to point at some sediment transport measurements done by FAP 1 (ref. FAP 1, First Interim Report, Annex I), which seem to indicate that the above method may provide fair results.

Another way of splitting up between wash load and suspended bed material load is by the combined use of both instruments. As was indicated before, the MEX-3 is more sensitive for the finer sediments, while the ADCP is better suited for the coarse sediments. Because the combined application yields two signal with different "contents", it may be possible to split the total signal into two components.

A final but not unimportant problem is that the reduction in light intensity of the MEX-3 and the backscatter of the ADCP have to be translated into concentration.

It is felt, however, that the combination of the MEX-3 and the ADCP on a long view may provide good opportunities for measuring the sediment content of the water in a fast way and with acceptable accuracy - or at least provide a basis for optimizing the sampling density. More studies and surveys are needed to determine in more detail the possibilities and limitations of these instruments. These studies are listed below:

o Theoretical study on the effect of the unsampled zones near the surface and near the bed for the specific Jamuna conditions on the accuracy

- o Study into the possibility of using MEX and ADCP in a moving boat type of method
- o Experimental study into the relation between the reduction in light intensity of the MEX-3 and the backscatter of the ADCP on the one hand and the sediment concentration on the other hand
- o Experimental study into the possibilities to distinguish between bed material load and wash load
- o If appropriate comparative measurements between the present recommended method and the possible FAP 24 method that could emerge from the above studies

Appendix 1.

Equipment & Measurement Data

Main Contents

Appendix 1A

Equipment

Appendix 1A

Equipment

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1. Introduction

In this appendix a description is given of the equipment used so far in the River Survey Project. Used so far, as this equipment is in fact phase 1 equipment. Substantial additional equipment will be defined and procured after the monsoon of 1993.

After some brief characteristics of the vessels the measuring systems aboard the various boats are summarized in the survey spread matrix, and elaborated in the subsequent sections of Chapter 3. The less known systems like DGPS and ADCP get much more attention than the more standard components.

The last chapter explains how the discharge is calculated from the ADCP measurements. These calculations are done with the aid of special ADCP software called TRANSECT. The information has been copied from the Transect User's Manual, April 1992.

2. Survey vessels

The River Survey Project FAP 24 operates at present the following survey vessels:

- Ms. DHA, a former police patrol boat, built for shallow waters, was modified to carry out advanced survey work in the rivers of Bangladesh. The vessel has the following specifications:

Length oa	20.25 m	Diesel oil cap.	4000 l.
Breadth oa	4.70 m	Drinking water	500 l.
Draft	1.15 m	Max. speed	12 knots
Propulsion power	2 x 220 hp. 1800 rpm.		

- Ms. DHC, new-built catamaran survey vessel with the following specifications:

Length oa	8.70 m	Diesel oil cap.	2500 l.
Breadth oa	6.30 m	Drinking water	400 l.
Draft	0.45 m	Max. speed	14 knots.
Propulsion power	2 x 130 hp. 2900 rpm.		

- 12 feet aluminium craft inclusive 2 x 25 hp outboard engines
- 10 feet Zodiac craft including 40 hp outboard engine

Figure 2.1 Ms. DHA (background), Ms. DHC & Aluminium vessel (foreground)

220

3. Measuring systems

The survey vessels are equipped with the following advanced survey equipment:

- o Differential Global Positioning System (DGPS)
- o Dual/single frequency echo-sounders
- o Dual frequency/channel river-bed mapping side scan sonar system
- o Acoustic Doppler Current Profiler system (ADCP)
- o Electromagnetic Flow meter for moving boat method (EMF)
- o Electromagnetic Current meter for manual current profiling (EMC)
- o Suspended Sediment Profiler inclusive turbidity meter (SSP)
- o River-bed sampling equipment
- o Gyro compass & autopilot
- o On-line datalogging and navigation computer system
- o Advanced survey software packages for datalogging, -processing, navigation and quality assurance

The distribution and extent of survey equipment is shown in Table 3.1 below. The following gives a brief description of the survey equipment.

EQUIPMENT	VESSEL A	VESSEL C	ALU CRAFT
Positioning System:			
* DGPS	x	x	x
Current and discharge measurement:			
* MBM using EMF and ADCP	x		
* Current recording:			
Ott recorder	x		
S4 recorder	x	x	x
* Float tracking	x	x	x
Echo-sounding:			
* Elac Laz 4420	x		
* Simrad EA 300 P		x	x
Side scan sonar:			
* EG & G Model 260	x		
Suspended sediment measurements:			
* Sampling into bottles	x	x	(x)
* Integrated bottom sampler	x		
* Turbidity recordings (MEX 3)	x		
Bed load transport measurements			
* Helley-Smith trap samples	x		
* Sand-dune tracking by echo-sounding	x	x	x
River bed sampling			
* Van Veen grab	x	x	(x)
Communication			
* VHF radios	x	x	
* Walkie talkies	x	x	x

Table 3.1 Survey spread matrix

3.1 GPS/DGPS

General

Global Positioning System is a satellite based positioning and navigating system. The system will provide highly accurate position and velocity information in three dimensions as well as precise time to users around the globe 24 hours a day.

As shown in Figure 3.1, the GPS satellite based radio navigation system consists of of three major subsystems:

- o Space segment
- o Control segment
- o User segment

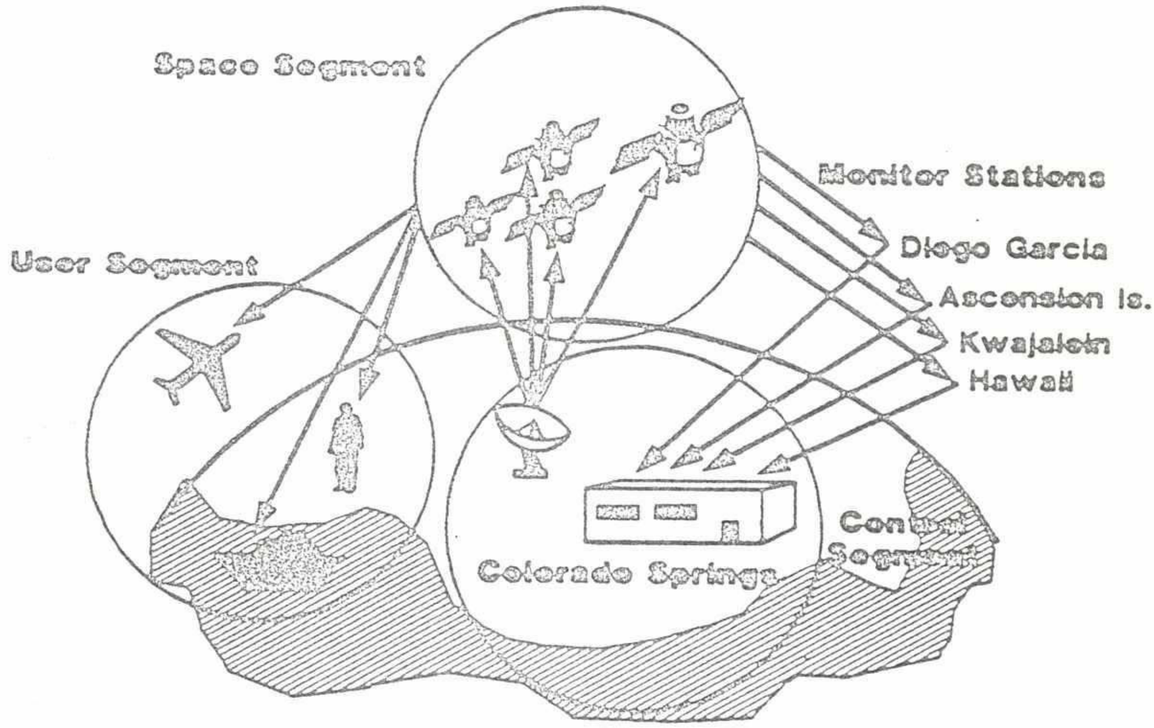

Figure 3.1 NAVSTAR GPS

Space segment

The space segment is a constellation of 24 high-altitude satellites orbiting the earth every twelve hours. Each contains several high-precision frequency standards (cesium and rubidium atomic clocks). Four satellites are located in each of six different orbital planes inclined about 55 degrees to the equator at altitudes of about 20.000 km.

Control segment

The control segment consist of a group of four ground-based monitor stations, three upload stations and a master control station. The monitor stations track the satellites continuously and provide data to the master control station. The master control station calculates satellite ephemeris and clock correction coefficients and forwards them to an upload station. Here, these data are transmitted (uploaded) to each SV (Space Vehicle, i.e. satellite) at least once a day.

User segment

The user segment consists of various civilian and military GPS receivers used on land, sea and in the air.

GPS is based on satellite ranging. That means that the user can calculate his position on the earth by measuring the distance to a group of satellites in space.

GPS satellites transmit two coherent beacon signals. Link one (L1) and link two (L2). The L1 beacon is broadcasted at a frequency of 1575.42 MHz and the L2 at 1227.60 MHz. The L1 signal is modulated with two pseudorandom noise (PRN) ranging codes, a protected (P) code and a clear/acquisition (C/A) code. Civilian receivers use the C/A code to obtain GPS system information. The P code may be encrypted for military use and is the only ranging code broadcast on the L2 beacon.

Each satellite has its own C/A (and P) code to provide satellite identity for acquisition and tracking.The C/A code repeats every millisecond for ease of acquisition.

The user-receiver times the arrival of each satellite signal by synchronizing an internal signal having that satellite's code with the satellite signal (code tracking). Knowledge of the satellite's position is derived from the NAVDATA messages broadcasted by the satellite itself. This knowledge, along with the time-of-arrival measurements from the satellites, enables the user to estimate his position and time (pseudo range). In addition to the code-tracking measurement, it is also possible to phase-lock onto the satellite's carrier signal. This enables a similar estimate of velocity. Advanced processing techniques use the carrier phase measurements to improve position estimates.

A GPS receiver must be tracking signals from at least three satellites to calculate an accurate position. This is called a 2-D (two dimensional) solution. Latitude and longitude are part of a 2-D solution.

For a 3-D (three dimensional) solution, the receiver must be tracking signals from at least four satellites in order to calculate an accurate position including latitude, longitude and altitude.

Accuracy of the GPS working in standard configuration is in the order of 20-30 meter without the SA (Selective Availability) in operation and approximately 100 meter with SA in operation.

In order to improve the accuracy of standard GPS positioning, the GPS can be operated in differential configuration (DGPS).

DGPS relies on error corrections which are transmitted from a receiver that is placed on a known location. The receiver, called reference station, compares the known position with measured position in the reference point, calculates correction values for each satellite and broadcast the corrections on-line to the nearby user receivers, which are corrected in order to eliminate system errors such as SA, clock offset, tropospheric delays etc. (Figure 3.2).

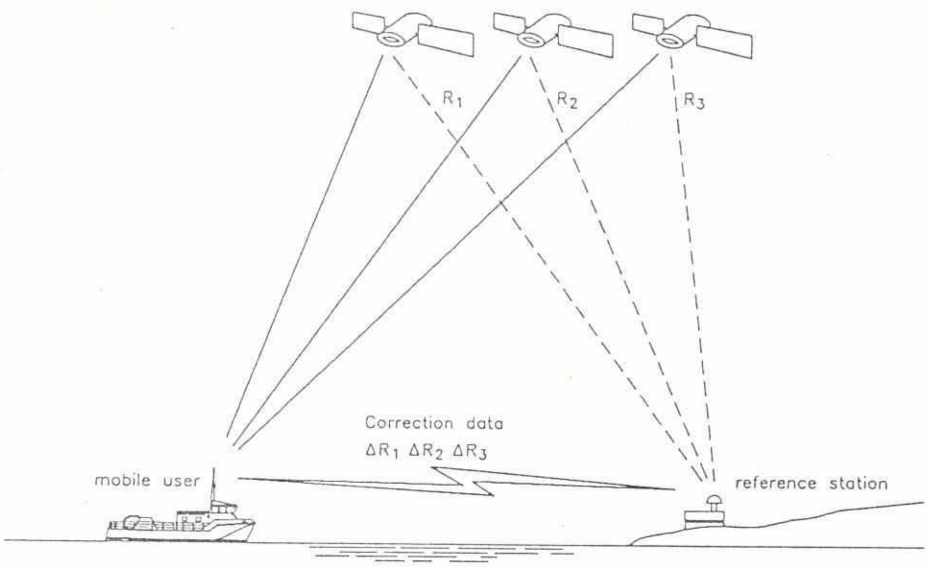

Figure 3.2 Differential GPS based on pseudorange correction

Differential operation of the GPS offers the possibility of accuracies of 2-10 meter for dynamic, navigation applications, and better than 2 meter for stationary applications.

For topographic survey applications, the GPS offers accuracy in the order of centimeters, when used in static mode.

DGPS equipment used by FAP 24

In order to obtain maximum positioning accuracy during field measurements, the survey vessels of FAP 24 are equipped with the following DGPS equipment:

- 3 off Trimble 4000, 9 channel DGPS receivers, configurated for accurate hydrographic & topographic survey work (accuracy equal to 2-5 meter in dynamic mode and down to subcentimeter level in static topographic mode)
- 2 off Trimble NavTrac, 6 channel DGPS receivers, configurated for accurate hydrographic survey work (accuracy equal to 5-8 meter in dynamic mode)
- Advanced DGPS software packages for data-processing and quality control

3.2 Echo-sounder

To carry out discharge measurements and bathymetric survey work the survey vessels are equipped with the following echo-sounders:

- 1 off Elac Laz 4420, dual frequency (30/200 KHz) echo-sounder with analog paper record and dual digital RS232 output for on-line interfacing to the datalogging and navigation computer
- 2 off Simrad EA 300P, single frequency (200 HKz) echo-sounder with analog colour print-out and digital RS232 output for on-line interfacing to the datalogging and navigation computer

3.3 Side scan sonar

In order to monitor the river-bed and carry out accurate sand-dune tracking, the DHA survey vessel is equipped with an advanced side scan sonar system.

General

Traditional monitoring of sea- and river-beds has been carried out for the last 60-70 years by means of echo-sounder equipment. The echo-sounder measures water depths and bed forms by transmitting acoustic energy in form of acoustic pulses and measures the time between the transmission and the reflecting energy (echo) from the sea- or river-bed. With a known sound velocity, the time measurements are converted into travel distances, which, divided by two, gives the water depth. By means of a paper recorder the echo-sounder records the water depth and the bed profile below the transducer.

In the last two or three decades, an excellent tool for bed monitoring has been developed. The system is called side scan sonar system, due to the fact that the system is a side looking sonar system, which is able to provide the user with a wide, acoustic area image of the sea- or river-bed.

Unlike the echo-sounder, which collects only one data point for every sonic transmission, the side scan sonar system collects a whole line of data. Two identical transducers collect data to each side, one to port and one to starboard (see Figure 3.3 below).

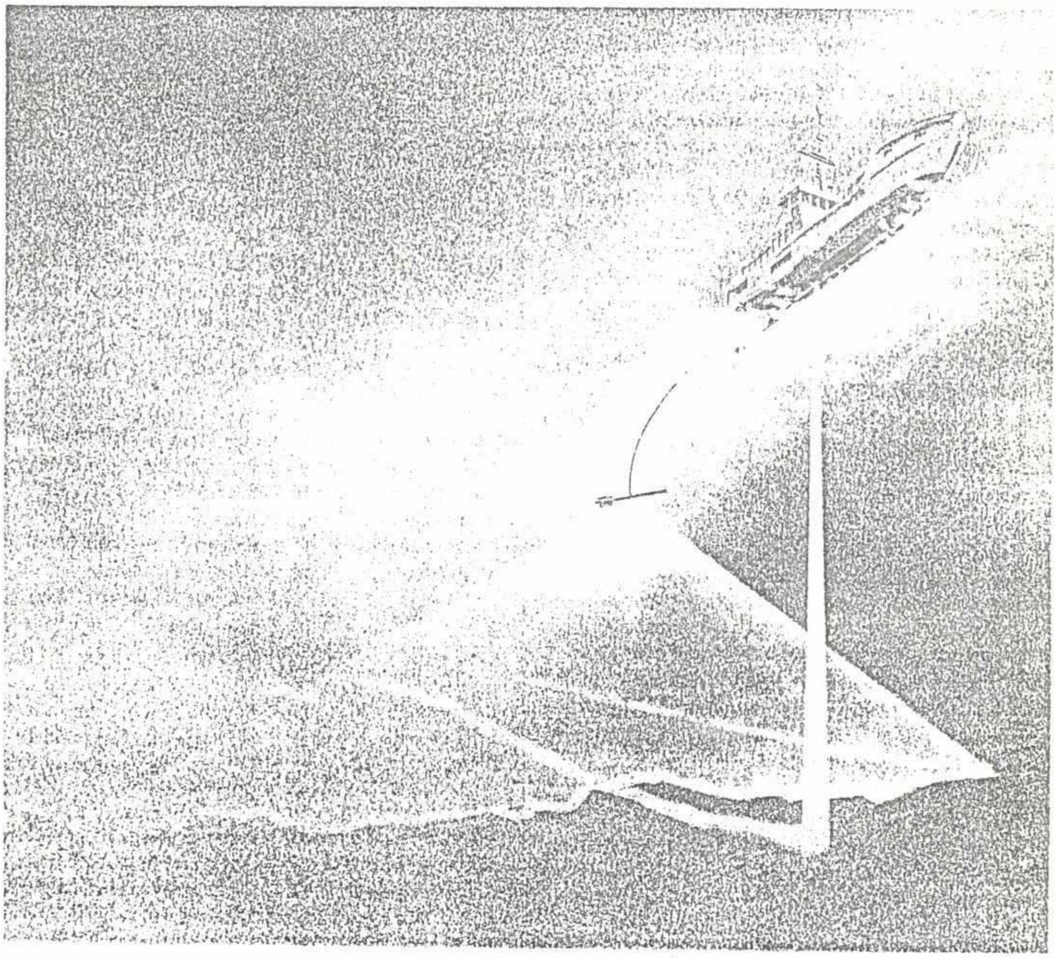

Figure 3.3 Side scan data collection

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Each transducer has a narrow beam in the horizontal plane and a wide beam in the vertical plane. The narrow, horizontal beamwidth concentrates the acoustic energy a swarth perpendicular to the axis of the travel. The wide, vertical beamwidth gives continuous data from directly beneath the transducers to the maximum system range. The instantaneous echo level is a measure of the backscattering strength or roughness of the bed material. As the transducers are moved forward, successive sonic transmissions generate parallel swaths of data, giving continuous bed coverage.

In order to reduce any roll or pitch movement from the survey vessel, the transducers are mechanicaly uncoupled from the vessel, by mounting them in a tow fish , which is towed behind the vessel. This technique also allows for variable tow height over the sea- or river-bed.

The data is transferred via the tow cable to the surface control unit, where advanced data-processing is carried out before data is on-line presented in graphic form by means of a thermo paper recorder (see Figure 3.4).

The latest microprocessor technology has been included in modern side scan sonar systems. Fourth generation systems are able to operate on different frequencies, which allows the operator to optimize the records regarding range and resolution. The new systems are able to carry out on-line slant range and speed correction and present the image of the bed in true scale.

Side scan sonar systems are used in various oceanographic activities such as dredging operations, mine hunting, search & identification of man made objects on the sea floor, environmental studies, bed form studies, planning and installation of offshore oil installations, offshore cable installation, fisheries etc.

FAP 24 side scan sonar system

The EG&G Model 260-TH image correcting side scan sonar system is an advanced fourth generation side scan system with the following main specifications:

- o Dual channel tow fish, model 272-T, with dual frequency 100-500 KHz narrow beam transducers and safety link device
- o 50 meter Kevlar tow cable
- o Dual channel side scan thermo recorder model 260 TH with advanced data-processing including bottom tracking facility, slant range and speed correction for on-line presentation of the bed in true scale. The recorder has digital input for DGPS positioning data in order to annotate records and correct for different vessel speed during survey. Analog output for magnetic data recording is available

The control of the tow fish is carried out by means of a remote controlled winch including 8 brushes slipring for transfer of control signals and sonar signals between the control/recording unit and the tow fish.

Sketches and examples of side scan records as well as a picture of the system are presented in Figure 3.4, 3.5 & 3.6.

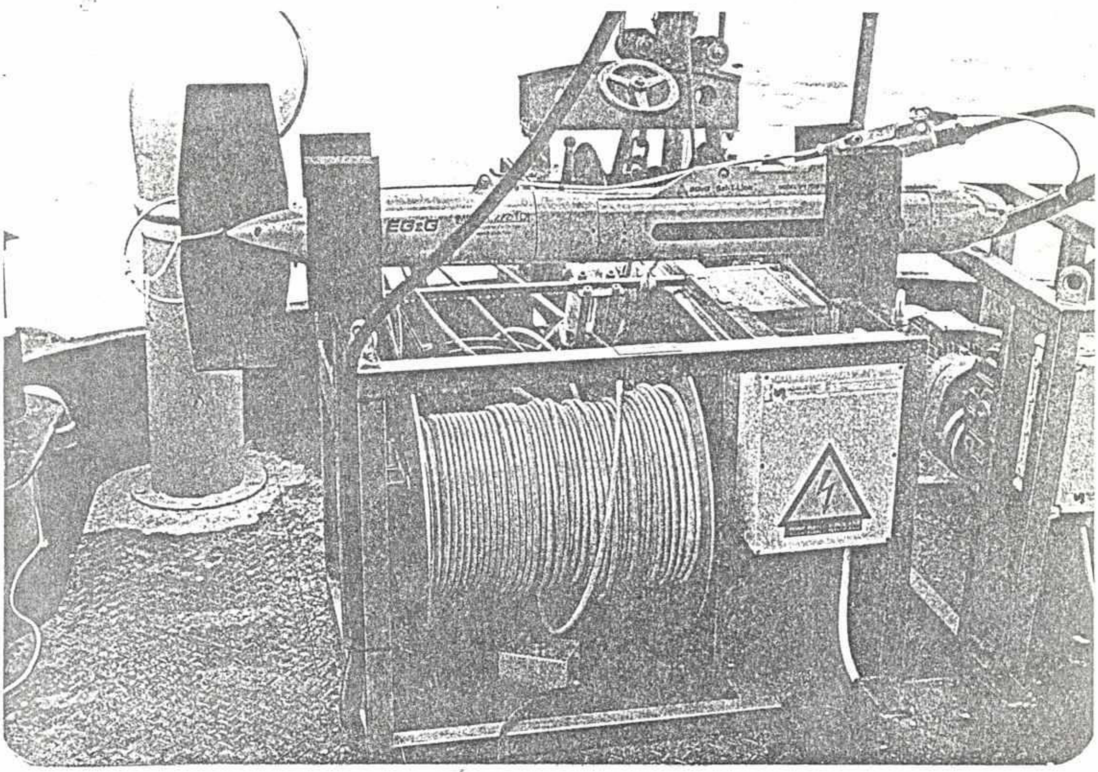

Figure 3.4 Side scan tow fish with winch aboard the DHA

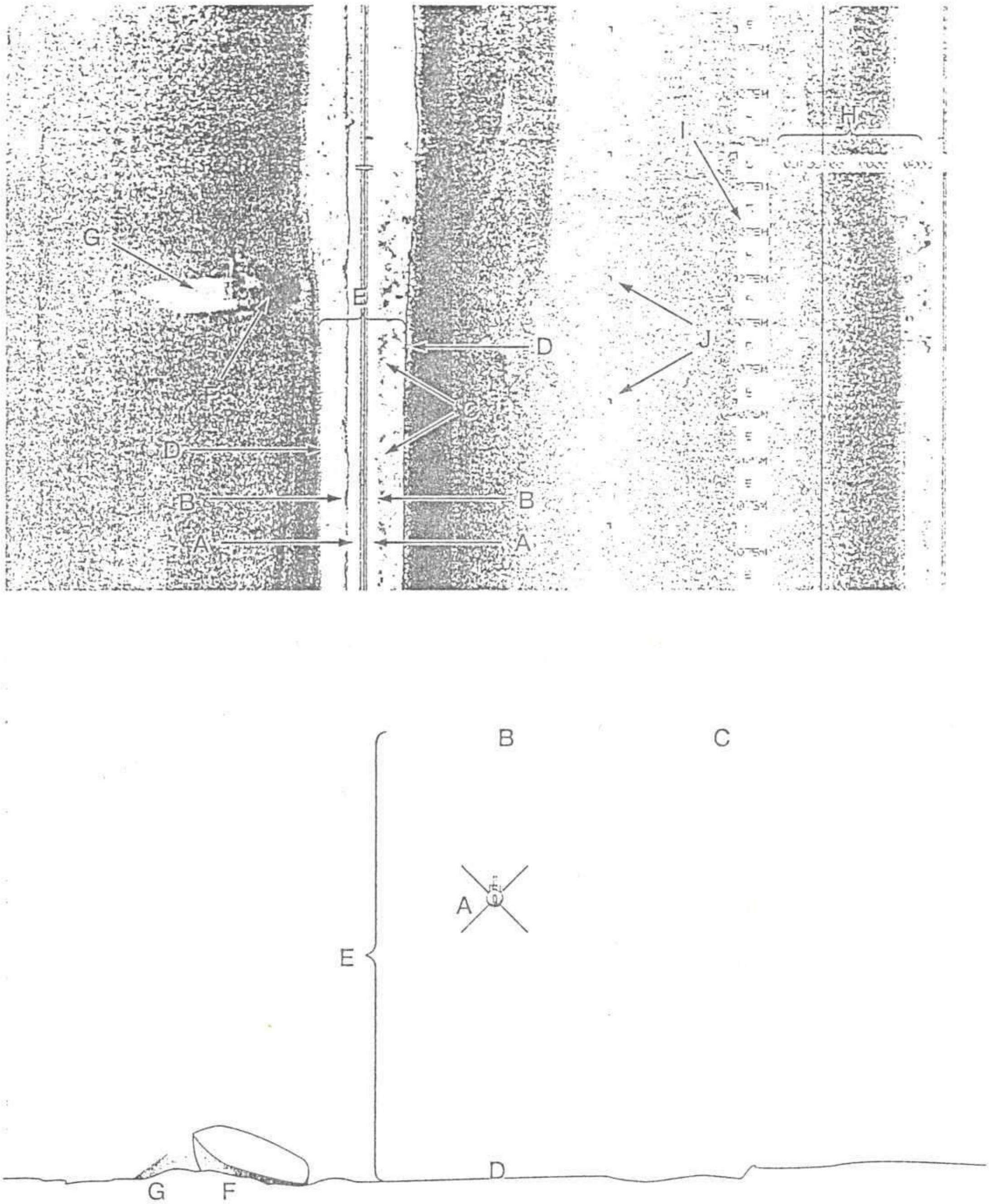

Figure 3.5 This sketch describes the conditions under which record 9 was made. A: trigger pulse, B: first surface return, C: sea clutter, D: first bottom echo return, E: water column, F: sunken fishing vessel, G: shadow

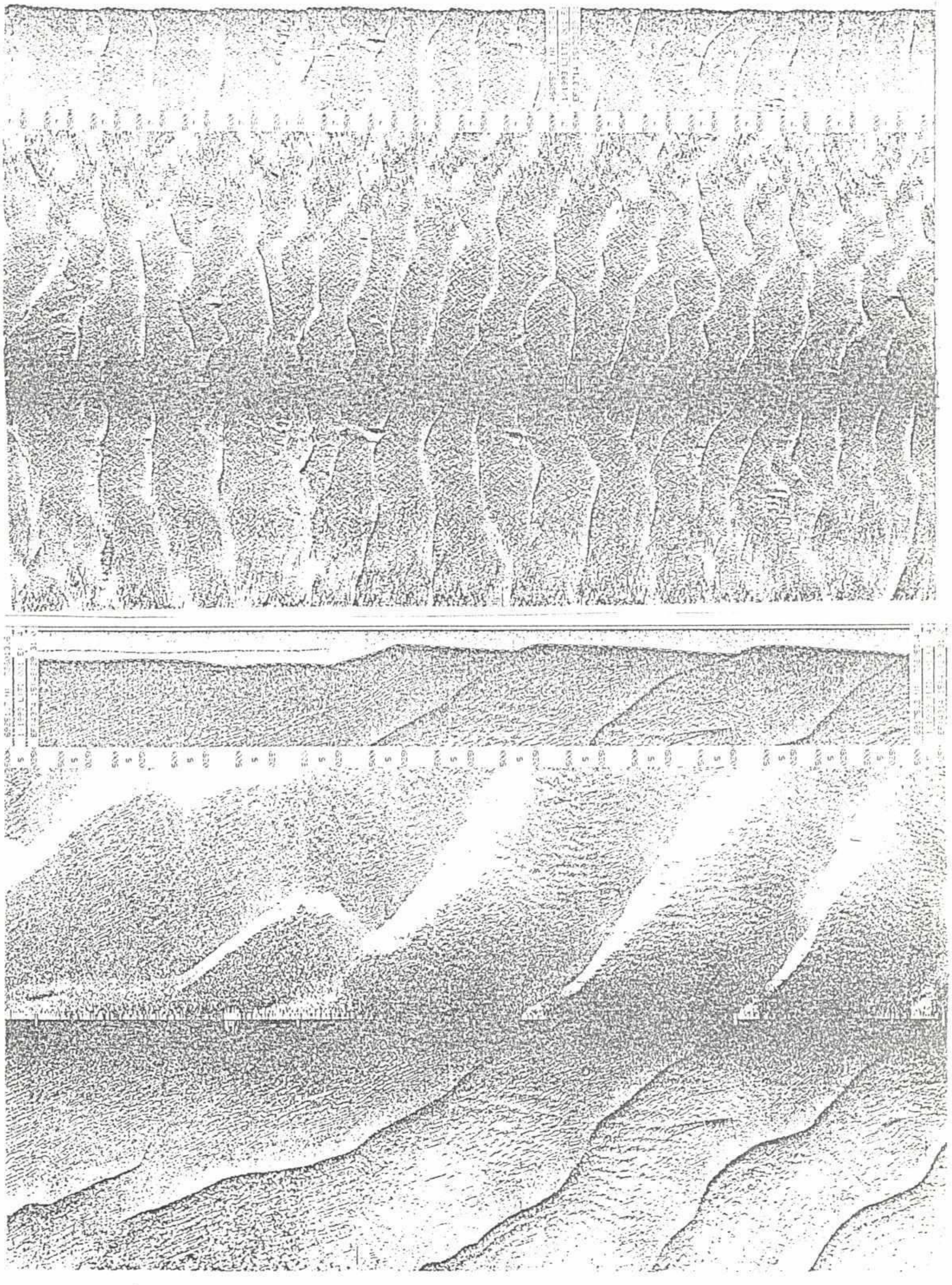

Figure 3.6 FAP 24 side scan records of sand waves in Jamuna River

3.4 ADCP

For monitoring of current and discharge in the rivers of Bangladesh, FAP 24 has introduced a special instrument called Acoustic Doppler Current Profiler. The ADCP is able to measure vertical current profiles and discharge continuously from a moving vessel (ref. Figure 3.7).

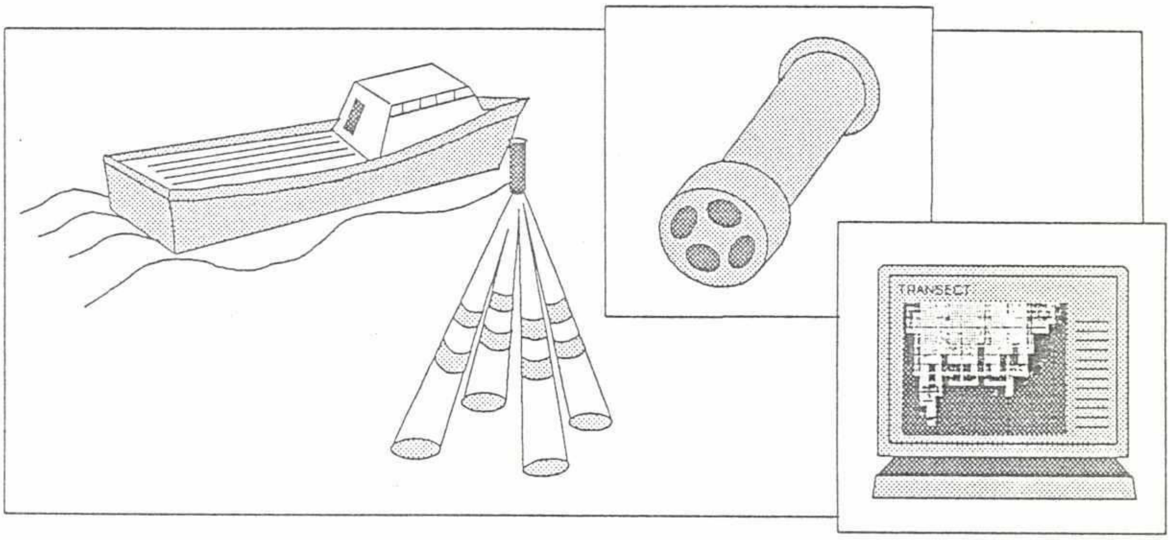

Figure 3.7 Broad Band ADCP system

The following presents a brief description of the ADCP sytem:

General

The ADCP operates by transmitting soundwaves at a fixed frequency and by listening to echoes returning from sound scatters in the water. The sound scatterers are small particles or plankton that reflect the sound back to the ADCP. Scatterers are everywhere in the oceans and rivers. They float in the water and they move with the same horizontal velocity as the water.

The ADCP measures water flow velocity at multiple locations or range cells along the path of acoustic beams. The spatial resolution is achieved by periodically transmitting short bursts of acoustic energy along the direction defined by 4 narrow acoustic beams, then making multiple measurements of the

Doppler shifted frequency of the water mass echoes from each beam in discrete time intervals after sound pulse transmission. In this way a quantized picture (or profile) of the water flow velocity versus range along each beam can be assembled. The effective length of each single beam resolution cell is determined primarily by the duration of the transmitted acoustic pulse. Each resolution cell is located at a distance along the beam corresponding to the product of the two propagation time delay and the sound velocity.

In the above description of the working principle of the ADCP system, the keywords are Doppler shift, time delay and sound velocity.

Doppler principle

The Doppler principle states that the frequency of a backscattered acoustic signal will differ from the transmitted frequency by an amount proportional to the relative velocity between the transmitter/receiver and the backscattering object.

This Doppler shift (frequency shift) between the transmitted acoustic pulse and the returning echoes is measured by the ADCP and converted to velocity for each depth cell along the acoustic beams.

Time delay/range gating

The most important features of ADCP's is their ability to measure current profiles.

ADCP's break up the velocity profile into uniform segments called depth cells or bins.

Profiles are produced by range-gating the echo signal. This method breaks the signal into successive segments and process each segment independently of the others. Echoes from far ranges take longer time to return to the ADCP, than echoes from close ranges (time delay). Thus successive range gates correspond to echoes from increasingly distant depth cells.

Vector measurement

A single acoustic beam produces a one dimensional velocity profile measurement. Normally two or three velocity components are required. By using multiple beams pointing in different directions, the ADCP is able to measure velocity in three dimensions. The key point is that one beam is required for each current component. Therefore, to measure three velocity components (e.g. east, north and vertical), it is necessary to have at least three acoustic beams. The ADCP uses four beams in order to obtain a redundant measurement for data check and instrument reliability. By means of internal or external compass reading the ADCP is able to compute and present the current profile in north, east and vertical velocity components.

Profiling from a moving vessel with bottom tracking

A special feature of ADCP's is their ability to measure current profiles from a moving vessel. By means of the bottom track feature, the ADCP is able to measure the Doppler shift of the returning bottom echo and thereby calculate the vessel's (and the ADCP's) velocity over the ground. This bottom track velocity is subtracted from the combined ADCP/water velocity in order to obtain the nett water velocity.

Discharge measurement with ADCP

With the introduction of the second generation ADCP systems, called BroadBand ADCP, which combines the high resolution required to measure water velocities in shallow rivers and the ability to measure river-bed depth and boat motion relative to the river-bed, the system is an excellent tool for measurement of river discharges.

Discharge is the total volume of water flowing through a cross section of water per unit of time. The ADCP in combination with a personal computer and a dedicated software package is able to compute river discharge directly and accurately while the vessel is crossing the river from bank to bank. The ADCP measures profiles of the current with high resolution both horizontal and vertical. The ADCP also measures the velocity-distance over the river-bed and the depth. Computation of discharge only depends on these data. The transect can be an arbitrary curve as long as it starts near one side of the channel and ends near the other.

Chapter 4 presents the formulas and calculations for discharge computation by the moving boat method using an ADCP.

ADCP system used by FAP 24

At present FAP 24 operates a 300 KHz BroadBand ADCP system produced by RD Instruments.

The system is configurated with 4 narrow beam transducers inclined 20 degrees from the vertical. The system is mounted in a well midship of the DHA vessel. In combination with the software packages the ADCP system is able to measure current profiles in static as well as dynamic mode from 2.7 m below surface to approximately 1.5 m above the river-bed. Tests have been carried out and are still going on, evaluating other ADCP systems which operate with higher frequencies. The choice of frequencies depends on factors such as profile range, resolution needed and sediment concentrations in the rivers. The ADCP system is interfaced on-line to the navigation and datalogging computers for processing and storage of current/discharge data.

3.5 EMF

In order to measure current in the top layer of the river an Electromagnetic Flow meter has been mounted in the bow of the DHA vessel (ref. Figure 3.8).

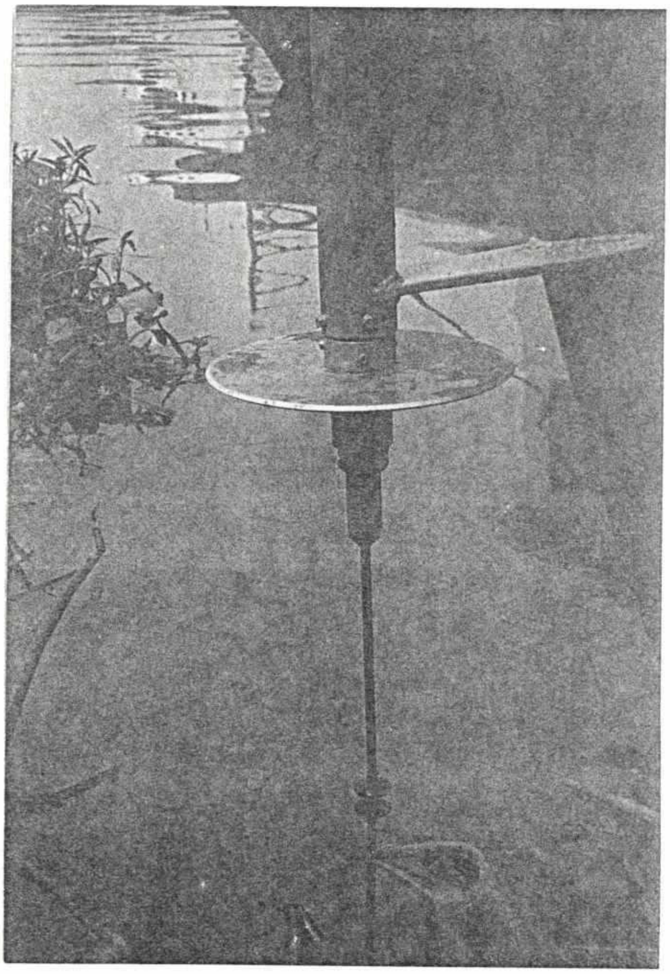

Figure 3.8 Close-up of EMF sensor

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General

The electromagnetic measuring principle is based on Faraday's law of electromagnetic induction.

The sensors of the EMF generates a magnetic field in the water and measure the voltage resulting from the motion of the water in the magnetic field. The voltage is proportional to the flow of the water. By applying 4 sensors without moving parts, the EMF is a reliable high precision vector current meter.

EMF used by FAP 24

The EMF system mounted 0.5 m below the surface in the bow of the DHA vessel is used to measure the current in the top layer of the river as well as in shallow areas of the river, where the ADCP can not measure due to a transducer draft of 0.85 m.

The data from the EMF is combined with Gyro and DGPS data in order to use the system in a moving boat method in combination with the ADCP during discharge measurements.

3.6 EMC

In connection with manual current/suspended sediment profiling the River Survey Project operates several units of the electromagnetic current meter type S4.

The S4 unit operates on the same principle as the EMF described above. The S4 unit includes temperature, conductivity, high resolution pressure cell for depth measurements as well as tilt sensors in order to carry out accurate temperature/salinity and current profiling in connection with suspended sediment sampling. For a picture of an S4 reference is made to Figure 3.9.

3.7 Suspended sediment sampler

FAP 24 has developed an integrated current/suspended sediment sampling system based on an S4 current combined with a turbidity meter and a water pumping system.The system is operated via a single umbilical and a winch with electrical sliprings and water outtake. The system is interfaced to the datalogging computer for processing and storage of manual profile data.

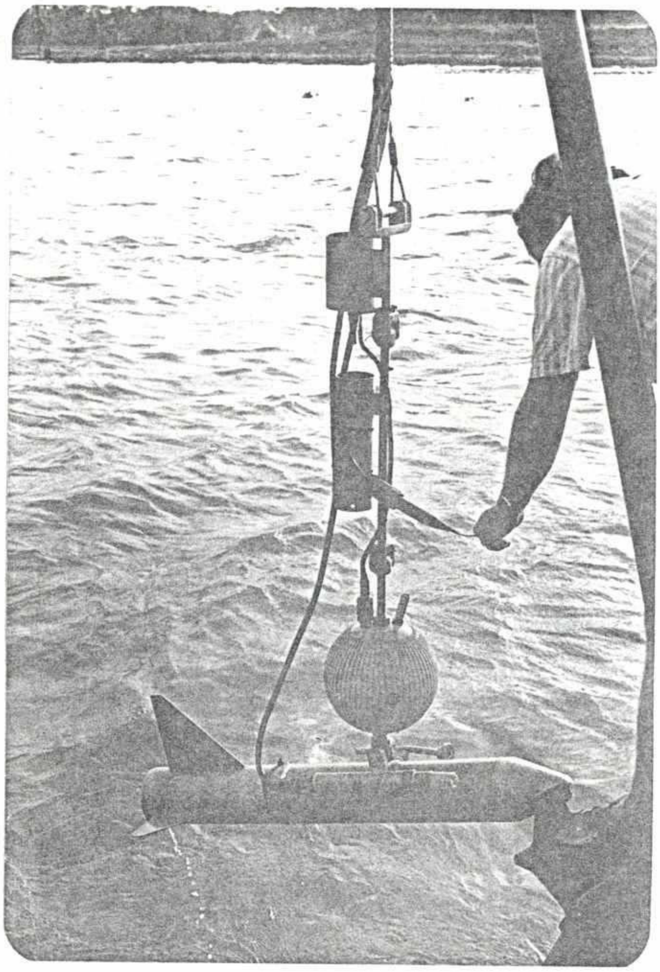

Figure 3.9 Integrated current/suspended sediment sampling system

The picture above shows the fish-type of carrier on which the optical turbidity meter has been installed. Above the carrier the spherical S4 has been mounted. The cylinder above the S4 is the suspended sediment pump.

3.8 Bed load sampler

In order to collect river-bed samples, the vessels are equipped with different types of bed and bed load samplers, including Van Veen grabs and Helley-Smith samplers.

3.9 Gyro compass and autopilot

In order to optimize navigation, the vessels are equipped with gyro compasses of type Robertson RGC 10 and autopilots.

3.10 Navigation and datalogging computer system

The large amount of different sensors calls for an advanced real-time navigation and datalogging system which is able to handle the large amount of data collected during the field surveys. The navigation and datalogging system used by FAP 24 is based on hardware in form of high speed personal computers (486) and special developed software packages, which are able to process, store and display data in a specified format. The system also provides navigation and survey support to the surveyor and the helmsman during survey operations (ref. Figure 3.10).

Figure 3.11 and 3.12 present the survey spread in schematic form for the DHA and DHC survey vessels.

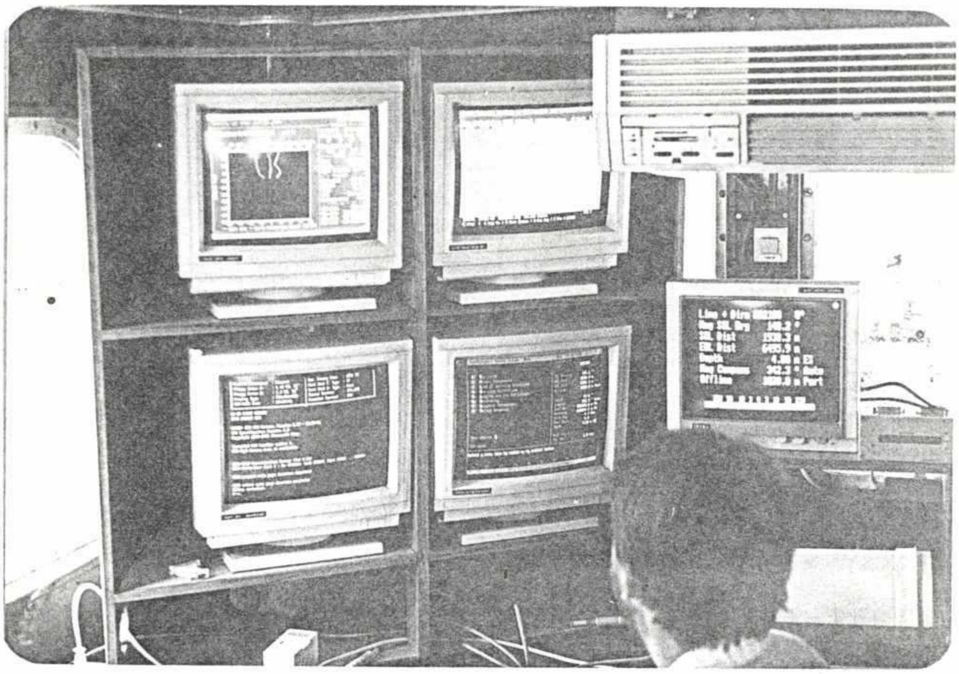

Figure 3.10 Datalogging and navigating centre aboard DHA

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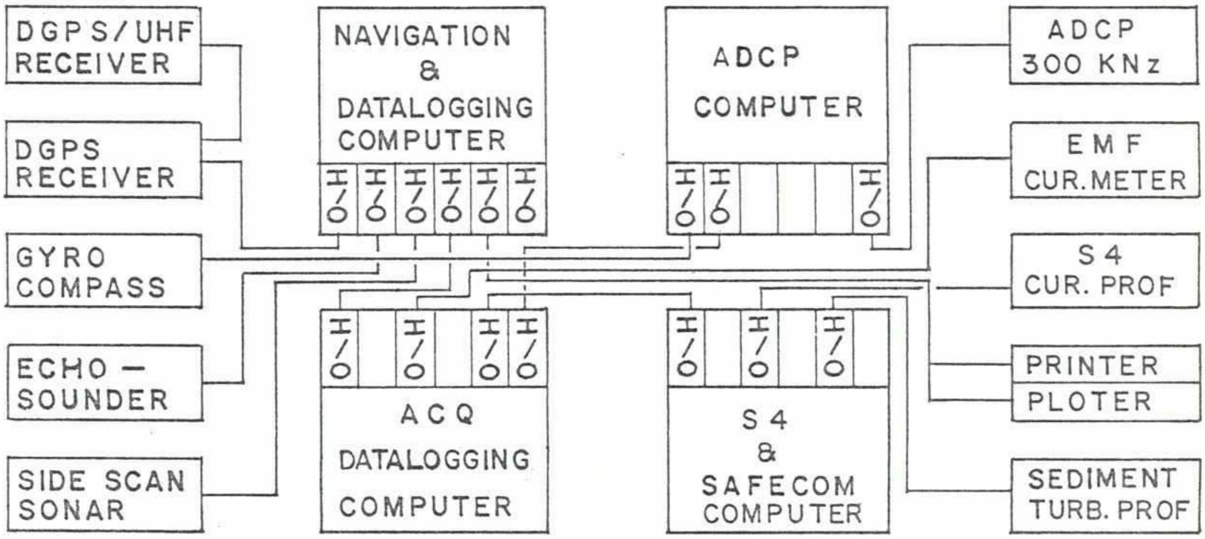


Figure 3.11 Survey spread DHA survey vessel

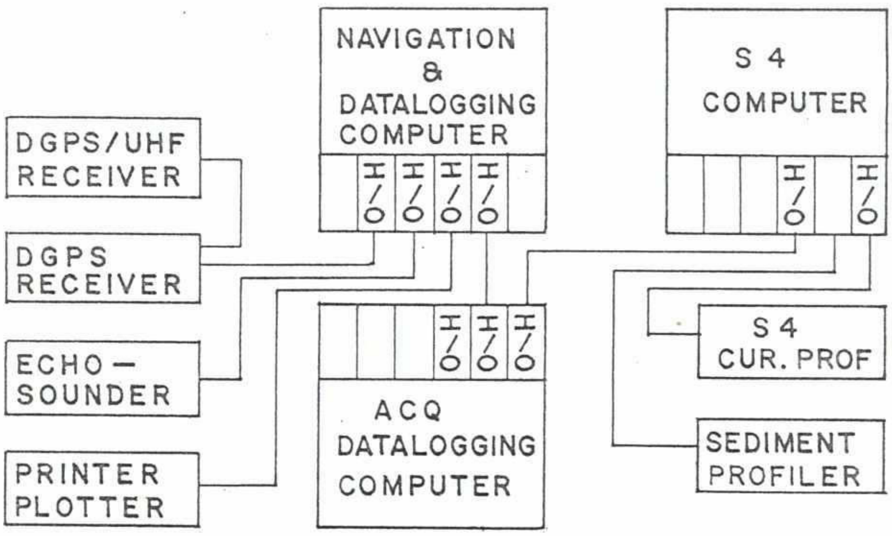


Figure 3.12 Survey spread DHC survey vessel

4. Discharge calculations

The following Chapter F is taken from "TRANSECT USER'S MANUAL - APRIL 1992" and describes applicable formulas and procedures for discharge calculation using ADCP data.

F-1. DISCHARGE CALCULATIONS

This section explains how TRANSECT calculates discharge. For the data measured by the ADCP, TRANSECT calculates discharge (middle water layer - MidQ). For the unmeasured parts of the profile (top water layer - TopQ, bottom water layer - BtmQ) TRANSECT estimates the discharge. TRANSECT accumulates these values over the entire transect (or subsection of a transect if SUBSECTIONING IS NOW = ON in the PLAYBACK menu). When <ALT-U> UNMEASURED is active, TRANSECT displays the accumulated values on the right side of the screen. The total discharge (ΣQ) is the summation of discharge in the top, middle, and bottom layers. TRANSECT also can estimate near-shore discharge and included in the total discharge in the playback menu.

Discharge is the total volume of water flowing through a cross-section of water per unit of time. TRANSECT computes this total volume discharge (ΣQ) for each ADCP ensemble and displays the estimate in the ACQUIRE and PLAYBACK modes. An ADCP measures profiles of water-current velocity relative to the vessel. The ADCP also measures the velocity of the vessel relative to the bottom and depth to the bottom for each ADCP beam. Computation of discharge depends only on these data. We do not need to know compass heading or vessel location. Furthermore, the transect can be an arbitrary curve (see Figure F-1) as long as it starts near one side of a channel and ends near the other.

The uncertainty in the discharge estimate arises from random errors, biases, and missed data (near the surface and bottom, and near the sides of a channel). TRANSECT can extrapolate near-shore discharge (near the channel sides) during playback. The algorithm for estimating discharge is adopted from Simpson and Oltmann (1990), and Gordon (1989).

There are two methods available in TRANSECT for estimating the discharge in the unmeasured parts of the profile. You can use either the CONSTANT method (i.e., "straight up and down") or a POWER law method. If you select a POWER method for either the top or bottom unmeasured part of the profile, you can select the exponent of the power law based on flow conditions and the roughness of the channel bed. For more information on the theory of power laws for flow resistance see Chen (1991).

For this version of TRANSECT, bottom-track velocity data from the ADCP must be valid for the moving-vessel discharge calculation to be correct. The discharge profile plot in the ACQUIRE and PLAYBACK modes displays the depth to which TRANSECT is measuring discharge for the current ADCP ensemble. The TABULAR submenu shows the discharge value and its corresponding depth.

We begin with a discussion of the moving-vessel method of determining discharge using an ADCP. We then discuss how TRANSECT implements this method and determines the size of the top, bottom, and middle water layers. Table F-1 lists several terms used throughout our discussion. The explanations presented here assume the ADCP is looking down, so *first* implies *shallowest* and *last* implies *deepest*.

Table F-1. Discharge Calculation Terms

Term	Definition
Δt	Time difference between successive ensembles.
BtmQ	Estimated discharge for the unmeasured data at the bottom of the profile.
*D_a	Depth cell (bin) size, or the length of the range gate. Each range gate corresponds to a depth cell. The ADCP constructs a profile from a series of range gates or depth cells.
D_{ADCP}	Depth of the ADCP transducer face from the water surface.
*D_b	Blank beyond transmit.
D_{LG}	Depth of the last good bin (i.e., the last bin in middle water layer).
D_{LGmax}	Depth of the last *possible* good bin.
D_{total}	Depth to the bottom (i.e., the channel bed).
D_{avg}	Averaged measured depth from the ADCP beams (not including D_{ADCP}).
*D_o	Lag between transmit pulses or correlation lag.
*D_p	Transmit pulse length. D_p is the length of a single transmit pulse. Broadband systems transmit two or more pulses. If the pulse is coded, this is the total length of one coded pulse, not the length of a single element.
*D_{top}	Depth of the center of the first bin.
MidQ	Discharge computed for the middle of the profile from ADCP velocity and bottom-track data.
*N_p	Number of transmit pulses.
TopQ	Estimated discharge for the unmeasured data at the top of the profile.
X	Cross-product computed from ADCP data (see ¶F-1.2)
X'	Synthetic cross-product computed from the power-curve fit

*NOTE: THESE DATA ARE DIRECTLY OUTPUT BY THE ADCP.

DQ2

F-1.1. DETERMINING MOVING-VESSEL DISCHARGE AND THE CROSS-PRODUCT. The moving-vessel method for measuring total discharge using an ADCP is computed by transecting a channel from bank to bank and accumulating the discharge for each ensemble (see Figure F-1). The general equation for determining total channel discharge (Q_t) through an arbitrary surface (s) is (Simpson and Oltmann, 1990; Gordon, 1989):

$$\iint_s V_f \cdot n \, ds \qquad \text{(Eq.1)}$$

where: ds = Differential area.
V_f = Mean water velocity vector.
n = Unit vector normal to transect path at a general point.

For a vessel moving across a channel, the area of s is determined by the vertical surface beneath the transect path. Because the ADCP measures both vessel motion (ADCP bottom-track velocity) and water velocity, we can re-order the integral above (Eq.1) in the following form.

Let: dz = Differential depth
dt = Differential time
V_b = Mean vessel velocity vector
T = Total transect time
d = Total depth (D_{total})
k = Unit vector in the vertical direction

Then:

$$ds = |V_b| \, dz \, dt \qquad \text{(Eq.2)}$$

$$V_f \cdot n = |V_f| \sin(\phi) \qquad \text{(Eq.3)}$$

$$\Rightarrow \quad \iint_s V_f \cdot n \, ds = \int_0^T \int_0^d |V_f| \, |V_b| \sin(\phi) \, dz \, dt \qquad \text{(Eq.4)}$$

$$= \int_0^T \int_0^d (V_f \times V_b) \cdot k \, dz \, dt \qquad \text{(Eq.5)}$$

Converting the cross-product $(V_f \times V_b) \cdot k$ into rectangular (vessel) coordinates, we get:

$$(V_f \times V_b) \cdot k = F_x B_y - F_y B_x. \qquad \text{(Eq.6)}$$

where: F_x = Cross-component of the mean water velocity vector.
F_y = Fore/aft component of the mean water velocity vector.
B_x = Cross-component of the mean vessel velocity vector.
B_y = Fore/aft component of the mean vessel velocity vector.

The values for F_x, F_y, B_x, B_y are rotated to earth coordinates before computing the cross-product above (which does not affect the value of the cross-product). Note that TRANSECT converts these values to earth coordinates before any processing is done. Throughout the remainder of this appendix, we will assign the symbol X to represent the cross-product.

F-1.2. METHODS FOR ESTIMATING DISCHARGE IN THE UNMEASURED TOP/BOTTOM PARTS OF THE VELOCITY PROFILE. There are two methods available in TRANSECT to estimate discharge in the unmeasured top/bottom parts of the velocity profile based on the TOP/BOTTOM DISCHARGE ESTIMATE settings in the CFG file (set in the CALIBRATION menu). The two methods are CONSTANT and POWER.

Constant Method. This is the simplest method of estimating the discharge in the unmeasured parts of the profile. However, this method does not follow accepted hydraulic descriptions of the vertical distribution of horizontal water velocities in open channels, particularly in the bottom water layer near the bottom boundary where the velocity decreases to zero. Simpson and Oltmann (1990), and Gordon (1989), discuss this method. This "straight up and down" method extrapolates the cross-product from the first good bin in the profile to the top (TopQ) or from the last good bin to the bottom (BtmQ). See ¶F-1.6 and ¶F-1.7 for details on how TRANSECT does this.

Power Method. Chen (1991) discusses the theory of power laws for flow resistance. Simpson and Oltmann (1990) discuss Chen's power law equivalent of Manning's formula for open channels (with b = 1/6).

$$u/u^* = 9.5\ (z/z_0)^b \qquad \text{(Eq.7)}$$

where:
- z = Distance to the channel bed.
- u = Velocity at distance z from bed.
- u^* = Shear velocity.
- z_0 = Bottom roughness height.
- b = Exponent (1/6).

Combining terms not from the ADCP we get:

$$u = (9.5u^*/z_0^b)z^b. \qquad \text{(Eq.8)}$$

If we let $a' = (9.5u^*/z_0^b)$, then:

$$u = a'z^b. \qquad \text{(Eq.9)}$$

For the moving boat discharge calculation, the cross-product (X) is computed from the ADCP velocities (Eq. 6), replacing *u* in the power law of Eq. 9:

$$X = a''z^b. \qquad \text{(Eq.10)}$$

For each depth cell, the distance from the channel bed *z* and the cross-product *X* are computed by TRANSECT. The next step is to solve for the unknown *a″* in the power law of Eq. 10. TRANSECT solves for *a″* by setting the antiderivative of the power law equal to the cross-product values integrated over the valid depth range of the profile.

Let: Z_1 = Distance from the channel bed to last (deepest) good bin
Z_2 = Distance from the channel bed to first (shallowest) good bin

The values for Z_1 and Z_2 define the region of the profile with valid ADCP data (see Figure F-2). This is referred to as the middle layer of the profile. Section F-1.4 discusses how TRANSECT determines Z_1 and Z_2.

First, we integrate the ADCP data over the valid depth range.

Let: $$R_1 = \int_{Z_1}^{Z_2} X(z)\,dz \qquad \text{(Eq.11)}$$

where: dz = depth cell size (D_a).

therefore: $$R_1 = D_a \sum_{i=Z_1}^{Z_2} X_i \qquad \text{(Eq.12)}$$

Second, use the antiderivative of the power law of Eq. 10 to integrate the power law over the middle water layer:

$$f(z) = a'' z^b \Rightarrow F(z) = a'' \frac{z^{b+1}}{b+1} \qquad \text{(Eq.13)}$$

Let: $$R_2 = \int_{Z_1}^{Z_2} f(z)\,dz \qquad \text{(Eq.14)}$$

$$= a'' \frac{z^{b+1}}{b+1} \Bigg|_{Z_1}^{Z_2} \qquad \text{(Eq.15)}$$

$$= \frac{a'' \left(Z_2^{b+1} - Z_1^{b+1}\right)}{b+1} \qquad \text{(Eq.16)}$$

Equating the integrals we solve for *a″*:

$$R_1 = R_2 \qquad \text{(Eq.17)}$$

$$D_a \sum_{i=Z_1}^{Z_2} X_i = a'' \left[\frac{Z_2^{b+1} - Z_1^{b+1}}{b+1} \right] \qquad \text{(Eq.18)}$$

$$a'' = \frac{D_a\,(b+1) \sum_{i=Z_1}^{Z_2} X_i}{Z_2^{b+1} - Z_1^{b+1}} \qquad \text{(Eq.19)}$$

Using *a″*, we can apply the antiderivative of the power law to integrate over the unmeasured regions of the profile at the top and bottom (see ¶F-1.6 and ¶F-1.7).

F-1.3. DETERMINING NEAR-SHORE DISCHARGE. You can use the TRANSECT PLAYBACK menu to estimate the discharge near the shore. TRANSECT uses a ratio-interpolation method for estimating the velocity between the channel bank and the first or last known mean velocity (V_m) in a subsection (ensemble or segment if averaging is ON in PLAYBACK). If we assume a triangular area between the last subsection and the channel bank, an algorithm for estimating the discharge in this near shore area is:

$$Q_{side} = 0.707\ V_m\ L\ d_m\ /\ 2. \qquad \text{(Eq.20)}$$

where: d_m = Depth of the first or last subsection.
L = Distance from the shore to the last subsection.

Again, note that if averaging is ON in PLAYBACK, V_m is the mean velocity for the segment (averaging interval). If averaging is OFF, V_m is the mean velocity for the ensemble. This allows flexibility if there are bad ensembles at the start or end of the transect.

F-1.4. HOW TRANSECT DETERMINES THE SIZE OF THE TOP/BOTTOM/MIDDLE WATER LAYERS. Before computing discharge, TRANSECT must determine the size of the top, bottom, and middle water layers (see Figure F-2). See Table F-1 for term definitions.

TRANSECT uses the center of the first depth cell to find the thickness of the top water layer. To compute the thickness of the top water layer, we start with the depth to the center of the first depth cell, D_{top}.

$$D_{top} = D_{ADCP} + D_b + ((D_p + D_o + D_a)\ /\ 2) \qquad \text{(Eq.21)}$$

For the total water depth, we use the average of the beam depths.

$$D_{avg} = \text{Average of four beam depths} \qquad \text{(Eq.22)}$$

TRANSECT computes the last good bin depth from D_{avg} by determining the depth of noise interference from the acoustic side lobes, adding the depth of the transducer face from the surface, and adding a thickness that depends on the transmit pulse sequence.

$$D_{LGmax} = (D_{avg}\ \cos(\theta) + D_{ADCP}) - ((D_p - D_o)\ /\ 2) \qquad \text{(Eq.23)}$$

D_{LGmax} is the last possible depth of a good bin. D_{LG} is the depth of the lowest bin that is above D_{LGmax}. The position of the last good depth cell (D_{LG}) gives us the starting depth of the bottom water layer. The valid ADCP velocity data in depth cells starting at D_{top} and ending at D_{LG} are used to calculate the middle layer discharge (MidQ). TRANSECT obtains the distance to the bottom (D_{total}) as:

$$D_{total} = D_{avg} + D_{ADCP} \qquad \text{(Eq.24)}$$

From the preceding we can define the boundaries of the water layer (Fig. F-2):

$$Z_1 = D_{total} - D_{LG} - D_a/2 \qquad \text{(Eq.25)}$$
$$Z_2 = D_{total} - D_{top} + D_a/2 \qquad \text{(Eq.26)}$$
$$Z_3 = D_{total} \qquad \text{(Eq.27)}$$

The water layer thickness follows:

$$\text{Top layer} = Z_3 - Z_2 \qquad \text{(Eq.28)}$$
$$\text{Middle layer} = Z_2 - Z_1 \qquad \text{(Eq.29)}$$
$$\text{Bottom layer} = Z_1 \qquad \text{(Eq.30)}$$

F-1.5. HOW TRANSECT CALCULATES MIDDLE LAYER DISCHARGE (MidQ). TRANSECT calculates the middle layer discharge over the range determined by the middle water layer thickness (Eq.29). For each bin, TRANSECT computes the discharge in that bin using the cross-product (Eq.6) and the time difference between successive ensembles.

$$Q_i = X_i \Delta t D_a \qquad \text{(Eq.31)}$$

where: i = Bin number.
Q_i = Discharge in the i^{th} bin.

The value of Q_i is that value displayed in the TABULAR submenu at its corresponding depth. TRANSECT determines the discharge for the middle layer by summing all the discharges from the individual bins.

$$MidQ = \sum_{i=1}^{N} Q_i \qquad \text{(Eq.32)}$$

where: i = The first good bin. If the first bin has bad data, TRANSECT increments i until it finds good data. If TRANSECT does not find good data, it does not calculate discharge for the ensemble.
N = The number of the bin just above the bin that D_{LG} intersects.

F-1.6. HOW TRANSECT ESTIMATES TOP LAYER DISCHARGE. There are two ways to compute the top layer discharge estimate based on the setting of TOP DISCHARGE ESTIMATE in the configuration file. The two options are CONSTANT and POWER. Paragraph ¶F-1.2 outlines these methods.

Constant Method. TRANSECT estimates the discharge for the top water layer by extrapolating the value of the cross-product in the first good bin to the surface. This method extrapolates data in a straight line to the surface.

$$TopQ = X_{FG} \Delta t (Z_3 - Z_2) \qquad \text{(Eq.33)}$$

Power Method. TRANSECT estimates the discharge for the top water layer by integrating the power law of Eq. 10 over the top water layer and multiplying by Δt (see Figure F-2):

$$TopQ = \Delta t \, a'' \int_{Z_2}^{Z_3} z^b \, dz \qquad \text{(Eq.34)}$$

$$= \frac{\Delta t \, D_a \, (Z_3^{b+1} - Z_2^{b+1}) \sum_{i=Z_1}^{Z_2} X_i}{Z_2^{b+1} - Z_1^{b+1}} \qquad \text{(Eq.35)}$$

F-1.7. HOW TRANSECT ESTIMATES BOTTOM LAYER DISCHARGE. There are two ways to compute the bottom layer discharge estimate based on the setting of BOTTOM DISCHARGE ESTIMATE in the configuration file. The two options are CONSTANT and POWER. Paragraph ¶F-1.2 outlines these methods.

Constant Method. TRANSECT estimates the discharge for the bottom water layer by extrapolating the value of the cross-product in the last good bin (X_{LG}) to the bottom. This method extrapolates data in a straight line to the bottom.

$$BtmQ = X_{LG}\ \Delta t\ Z_1 \qquad \text{(Eq.36)}$$

Power Method. TRANSECT estimates the discharge for the bottom water layer by integrating the power law of Eq. 10 over the bottom water layer and multiplying by Δt (see Figure F-2):

$$BtmQ = \Delta t\ a'' \int_0^{Z_1} z^b\ dz \qquad \text{(Eq.37)}$$

$$= \frac{\Delta t\ D_a\ Z_1^{b+1} \sum_{i=Z_1}^{Z_2} X_i}{Z_2^{b+1} - Z_1^{b+1}} \qquad \text{(Eq.38)}$$

F-1.8. REFERENCES. The following references were used in preparing this section.

Chen, Cheng-Lung (1991). "Unified Theory on Power Laws for Flow Resistance." Journal of Hydraulic Engineering, Vol. 117, No. 3, March 1991, 371-389.

Simpson, M. R. and Oltmann, R. N. (1990). "An Acoustic Doppler Discharge Measurement System." Proceedings of the 1990 National Conference on Hydraulic Engineering, Vol. 2, 903-908.

Gordon, R. L. (1989). "Acoustic Measurement of River Discharge." Journal of Hydraulic Engineering, Vol. 115, No. 7, July 1989, 925-936.

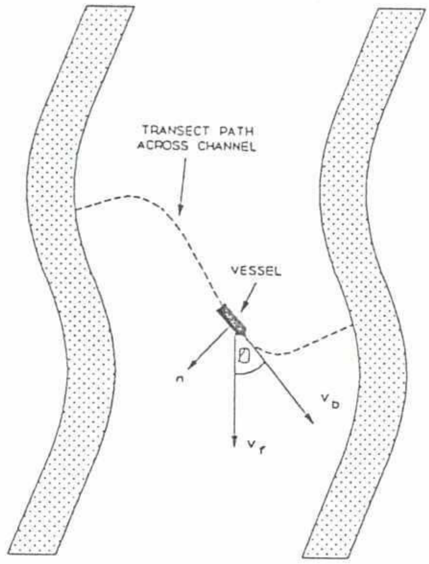


Figure F-1. Sample Transect Across a Channel

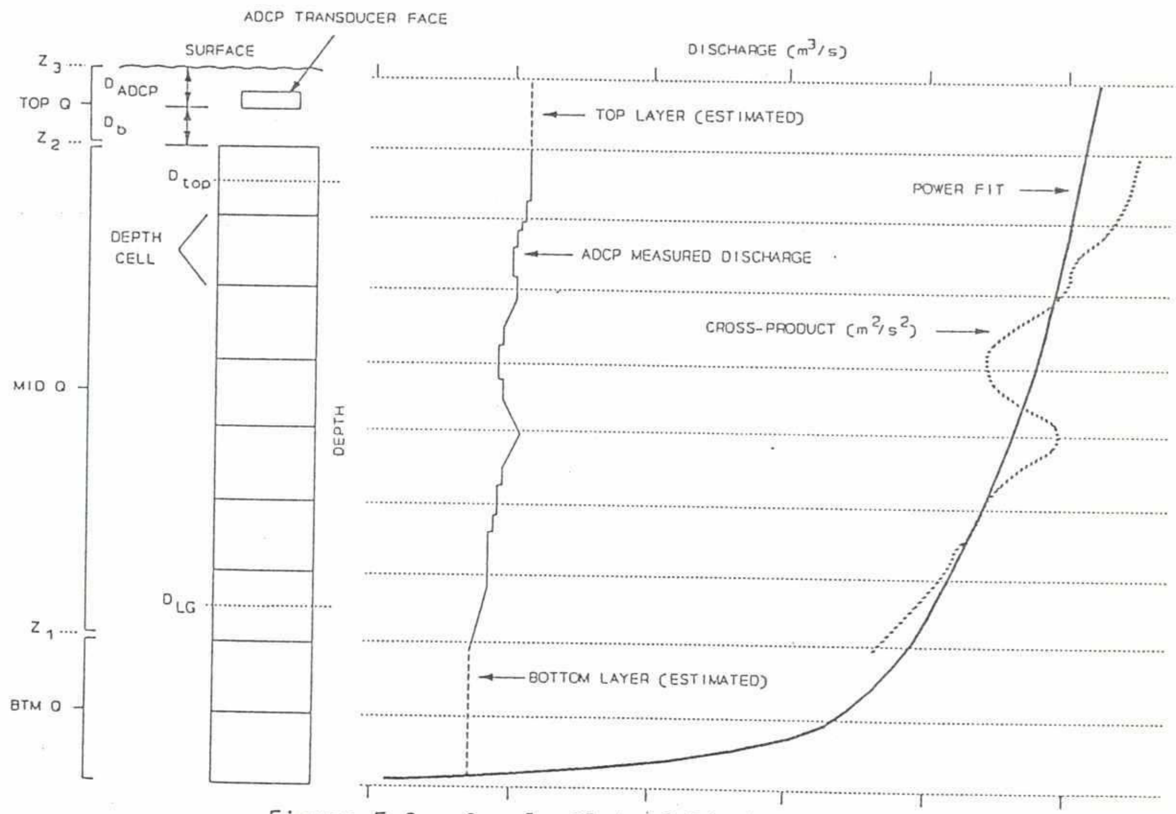


Figure F-2. Sample Plot of Discharge Data

264

Appendix 1B

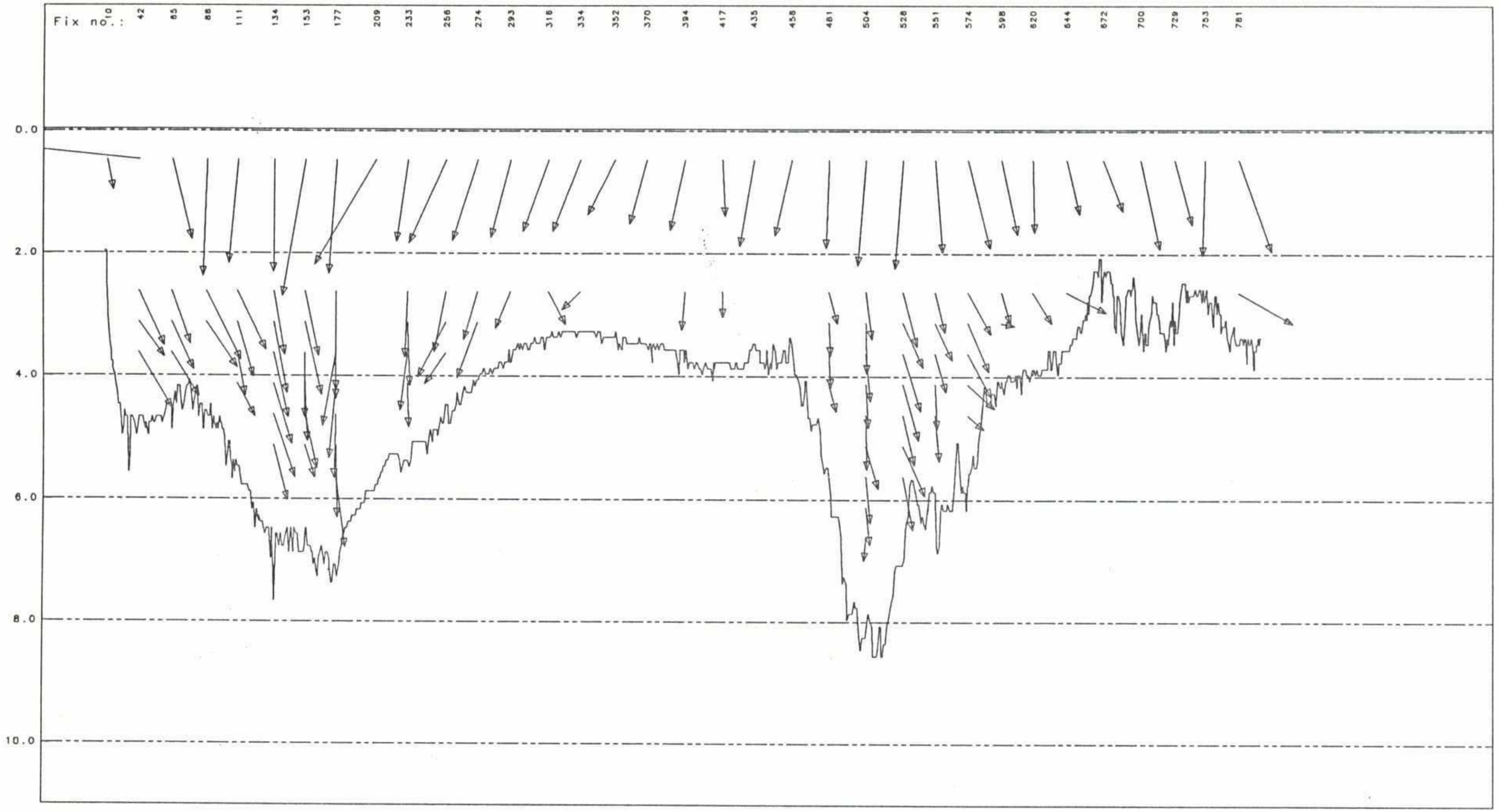
Measurement data from test measurements in October 1992

RIVER SURVEY PROJECT (FAP-24)

Location : Right Channel at Fulchari

Date of Survey : 26/10/92 and 27/10/92

Place of survey / Date/Channel	Type	Time		File Name*	Ver. No.	Easting	Northing	Q(ADCP) (on-line)	Q (off-line)	DISCHARGE GAUGING					SEDIMENT TRANSPORT GAUGING				
		From	To							ADCP +++30	HYDRO +++50	EMF +++60	S4 +++70	MEX +++80	Suspended Sediment Samples	Andreasen Tube Samples	Helley Smith Samples	Integoated Sediment Somples	Bottom Samples
								(m3/s)	(m3/s)										
Fulchari 26/10/92 Right/West Ch.	Transect	09:42:40	09:55:34	B2AQ1T01				3654											
	Transect	10:02:42	10:16:53	B2AQ1T02				4695		T	T								
	Transect	10:21:43	10:37:15	B2AQ1T03				3930											
	Transect	10:40:19	10:53:51	B2AQ1T04				4690	7353	T	T	T							
	Transect	11:05:17	11:06:12	B2AQ1T05															
	Transect	11:10:37	11:25:08	B2AQ1T06				4777		T	T								
	Transect	11:29:38	11:41:23	B2AQ1T07				4637	7741	T	T	T							
	Profile	14:02:49	15:43:00	B2AQ1P01	4	460452.8	783179.0			P	P	P	P		1-6A				
	Profile	15:49:45	15:53:53	B2AQ2P01	5	460510.0	783136.0				P		P		25-28C				
	Profile	16:24:44	16:32:35	B2AQ2P02	7	460649.2	783276.7				P		P		29-31C				
	Profile	00:00:00	00:00:00	B2AQ2P03											32-34C				
Fulchari 27/10/92 Right/West Ch.	Transect	09:28:39	09:43:20	B2AR1T01				4565		T	T	T							
	Transect	10.06.20	10.18.28	B2AR1T02				4623	7426	T	T	T							
	Profile	12.41.04	13.38.15	B2AR1P01	6	460558.7	783262.2			P	P	P	P		7-9A				
	Profile	15.07.51	15.39.44	B2AR1P02	8	460689.0	783284.5			P	P	P	P		10-12A				
	Profile	09.32.43	09.46.21	B2AR2P01	1	469937.7	783012.0				P		P		35-37C				
	Profile	10.00.15	10.13.51	B2AR2P02	2	460185.1	783114.4				P		P		38-40C				
	Profile	10.45.01	11.21.49	B2AR2P03	3	460364.7	783150.7				P		P		41-44C				
	Profile	11.46.47	11.57.22	B2AR2P04	15	461632.9	783618.4				P		P		45-47C				
	Profile	12.08.22	12.21.00	B2AR2P05	14	461567.1	783544.2				P		P		48-50C				
	Profile	12.34.06	12.46.33	B2AR2P06	13	461464.4	783584.5				P		P		51-53C				
	Profile	12.56.01	13.07.57	B2AR2P07	12	761417.0	783497.8				P		P		54-56C				
	Profile	13.35.58	13.49.30	B2AR2P08	11	461158.7	783360.5				P		P		57-59C				
	Profile	14.04.45	14.17.20	B2AR2P09	10	460993.9	783416.2				P		P		60-62C				
	Profile	14.26.13	14.39.22	B2AR2P10	9	460787.7	783346.7				P		P		63-65C				
	Transect	15.59.50	16.15.52	B2AR1T03						T	T	T							
	Transect	16.20.53	16.35.17	B2AR1T04					7000	T	T	T							



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1.00 m/s, East	End Time : 10:53:51	Type : Cross Section
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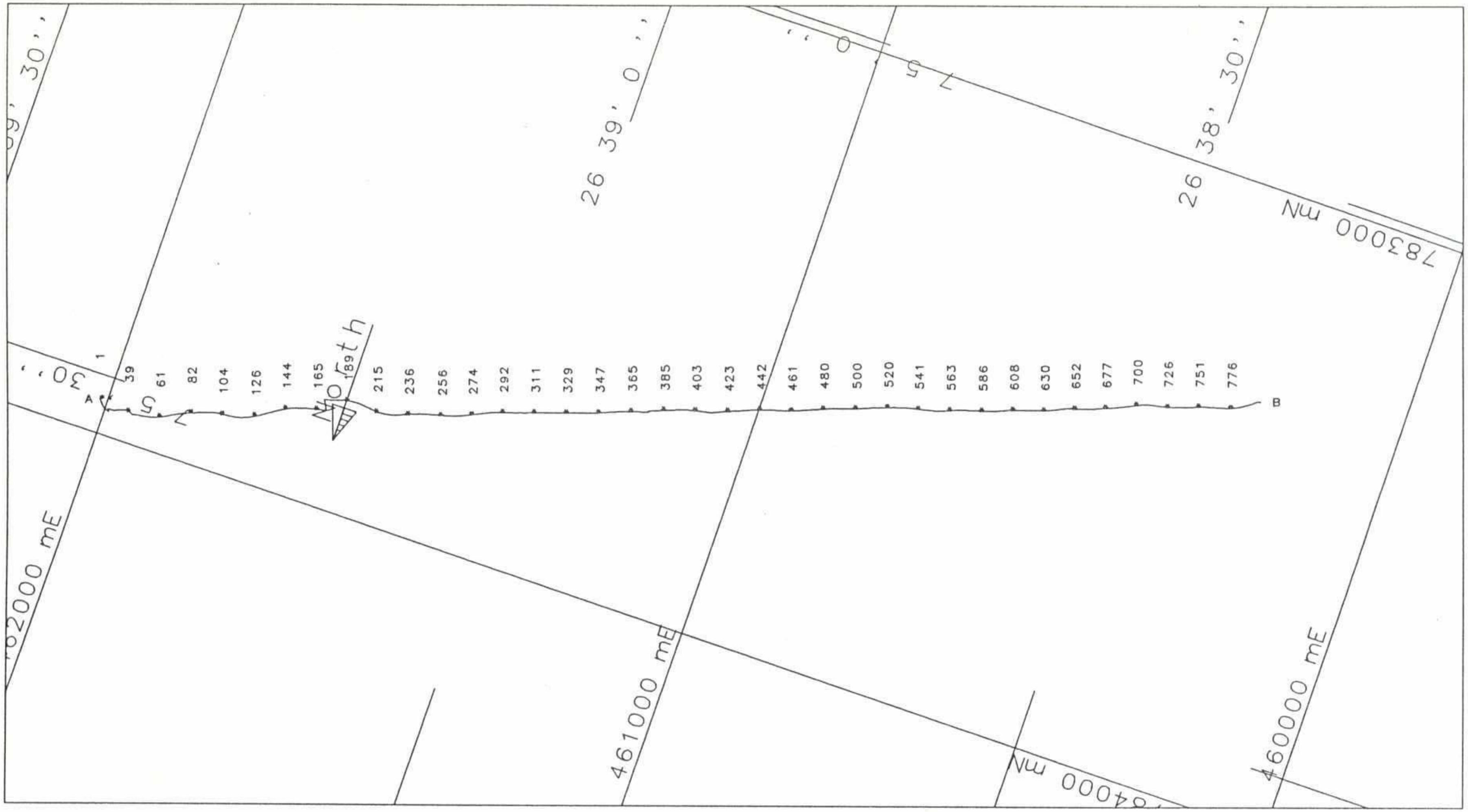

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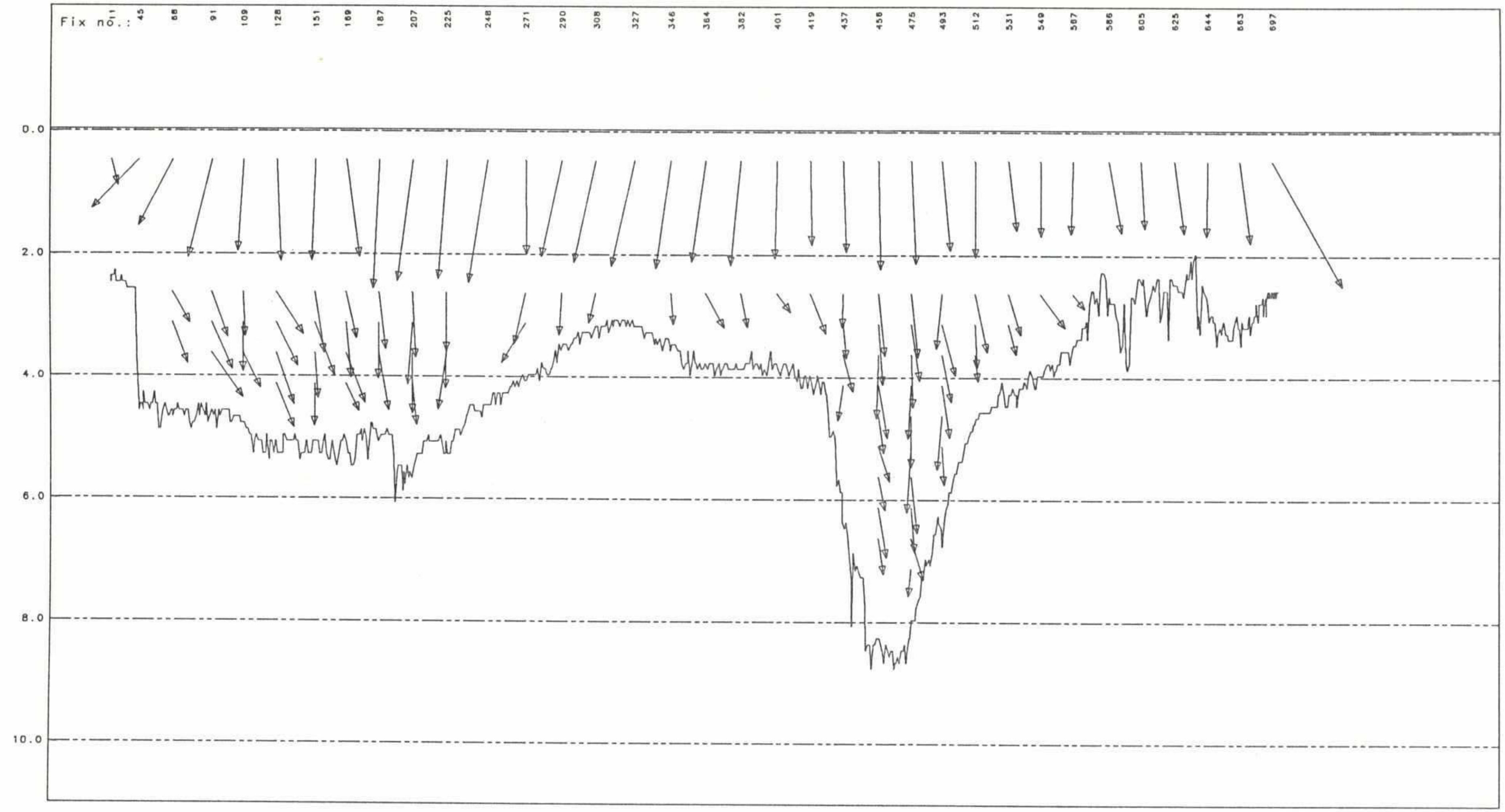
782

282



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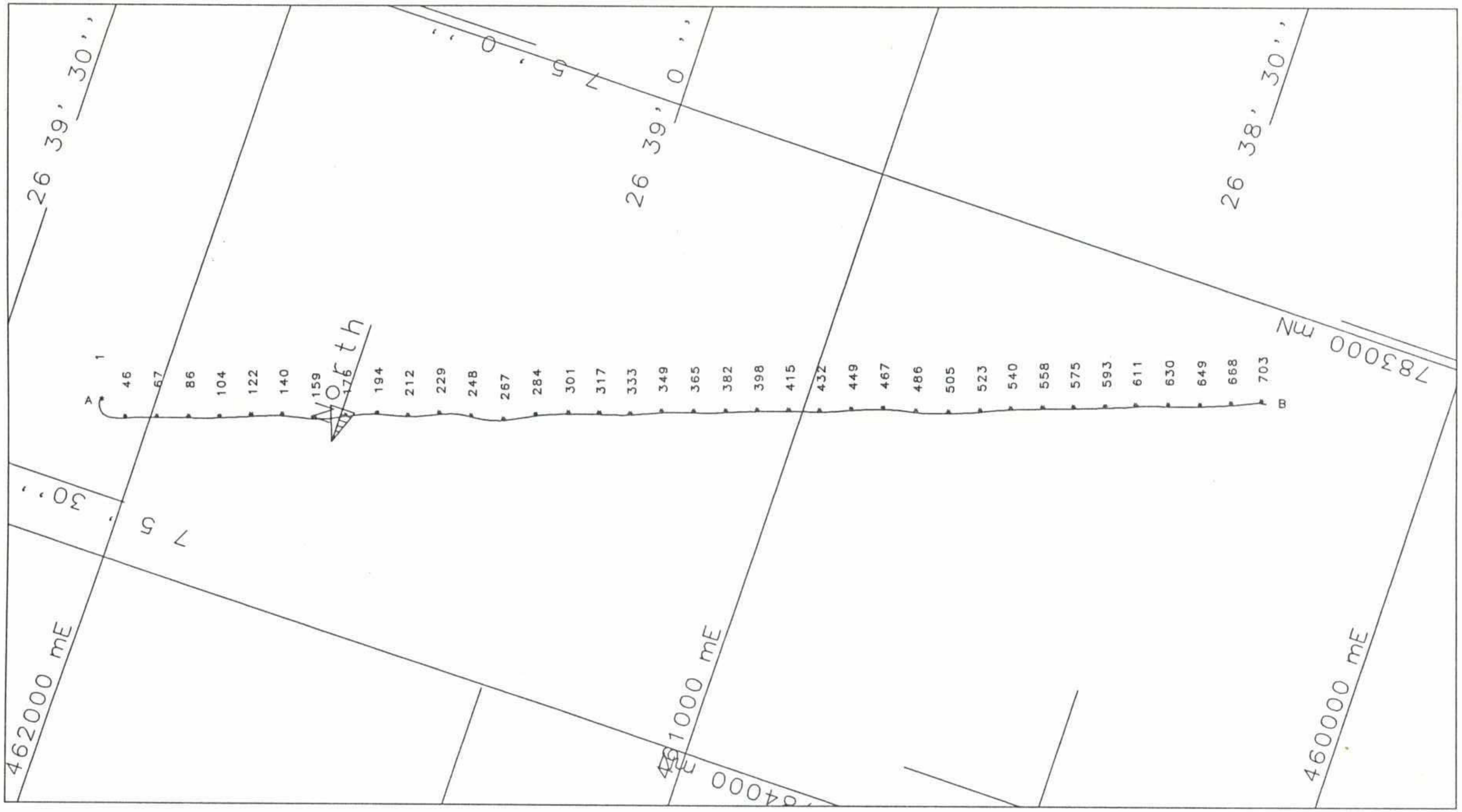

TRACK PLOT :

Scale : 1 : 10000
Track : ———
Fix nos. : •

SURVEY ID. :

Positions : BTM
Date : 921026
Start Time : 11:29:36
End Time : 11:41:23
Start Position : 462086E 783760N
End Posision : 460286E 783152N

PLOT ID. :

Project : FAP 24
File : /u/f24adm/data/92-10-26/b2aq1t7m
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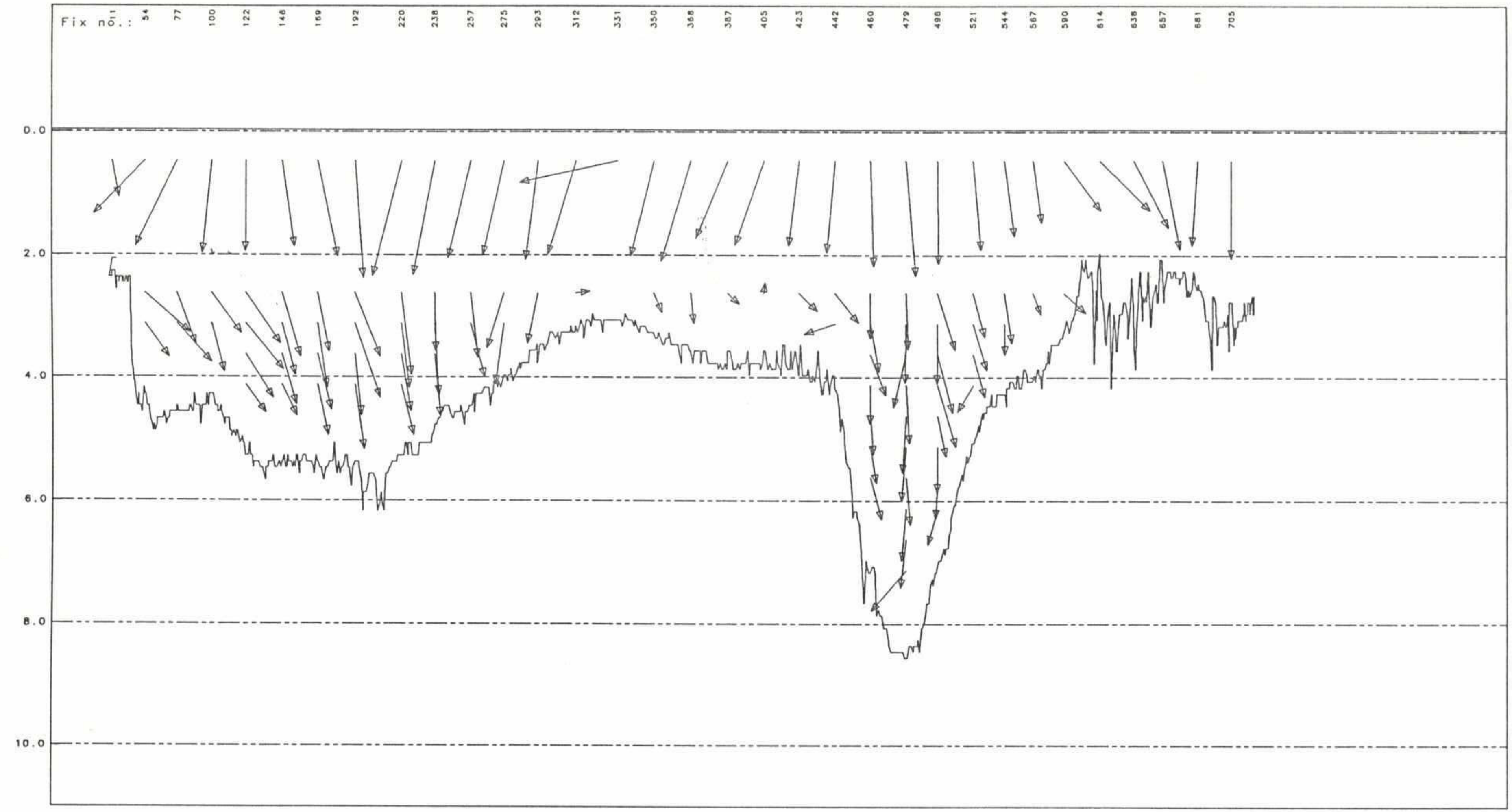
Rev. : A

Appr.

Id. No.

286



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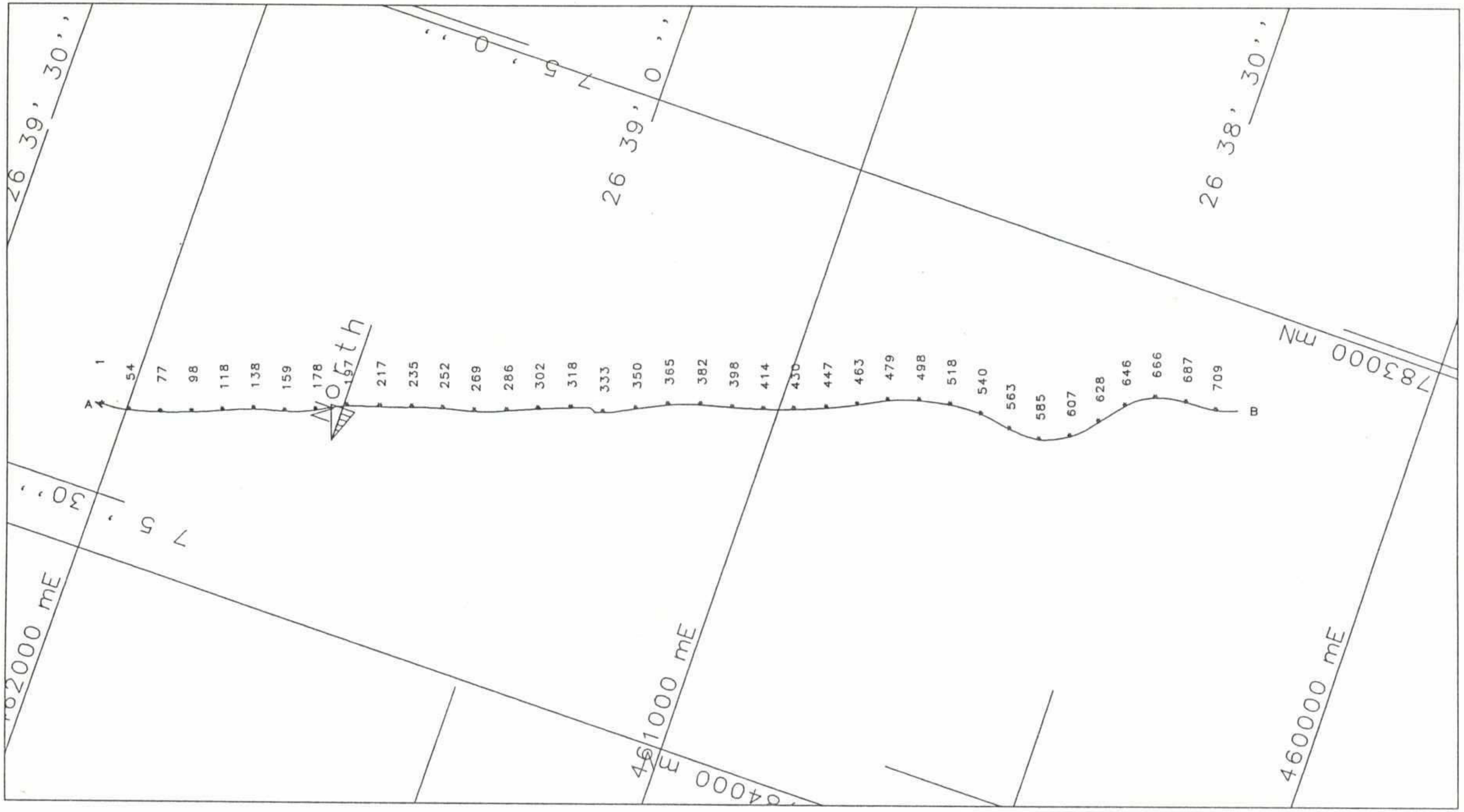

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Fix nos.	: •

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End Time	: 10:18:28
Start Position	: 462043E 783765N
End Posision	: 460292E 783168N

PLOT ID. :	
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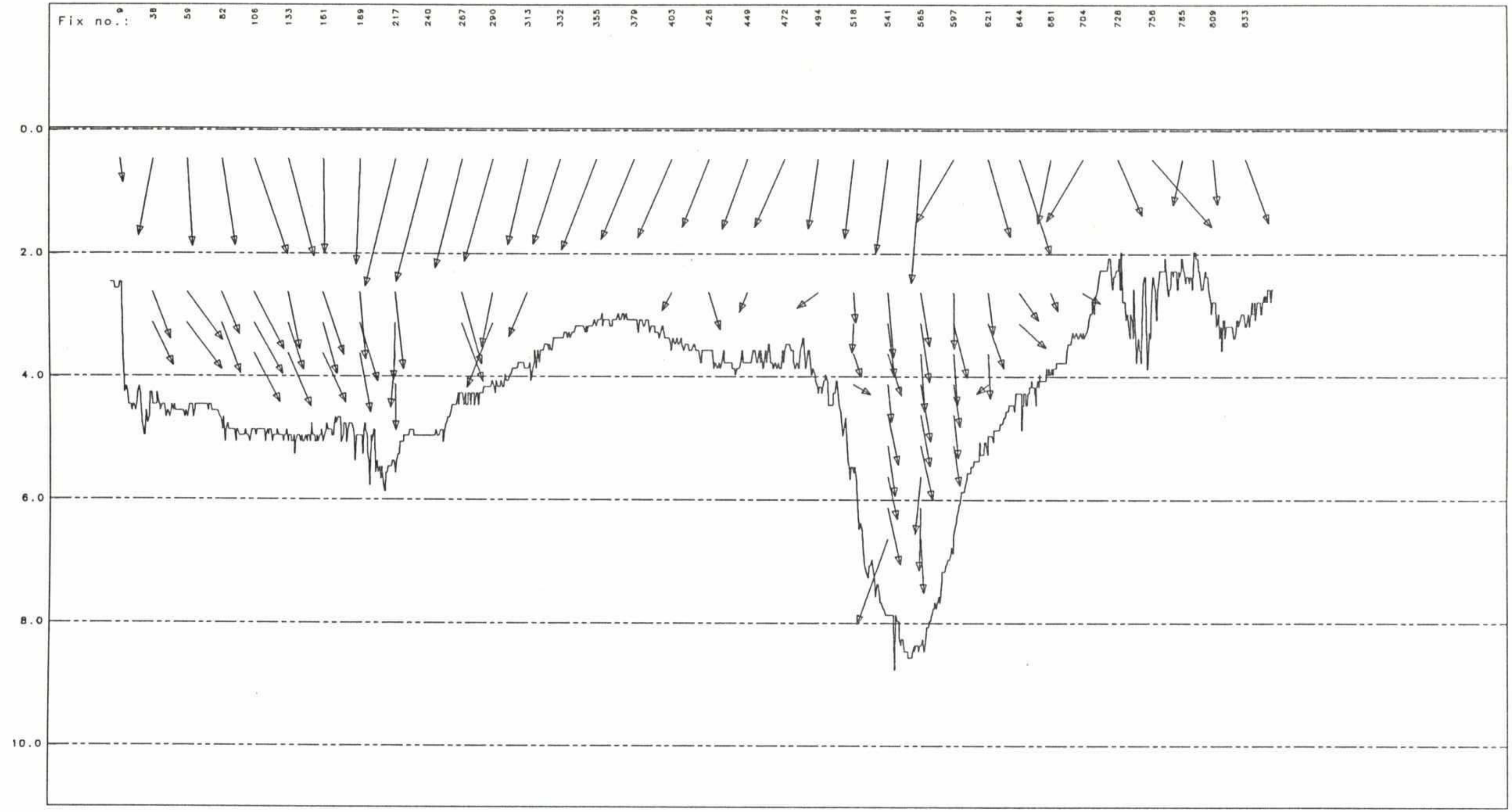

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Horizontal Scale	1 : 100

North

→ 1.00 m/s, East

Seabed : —

SURVEY ID. :	
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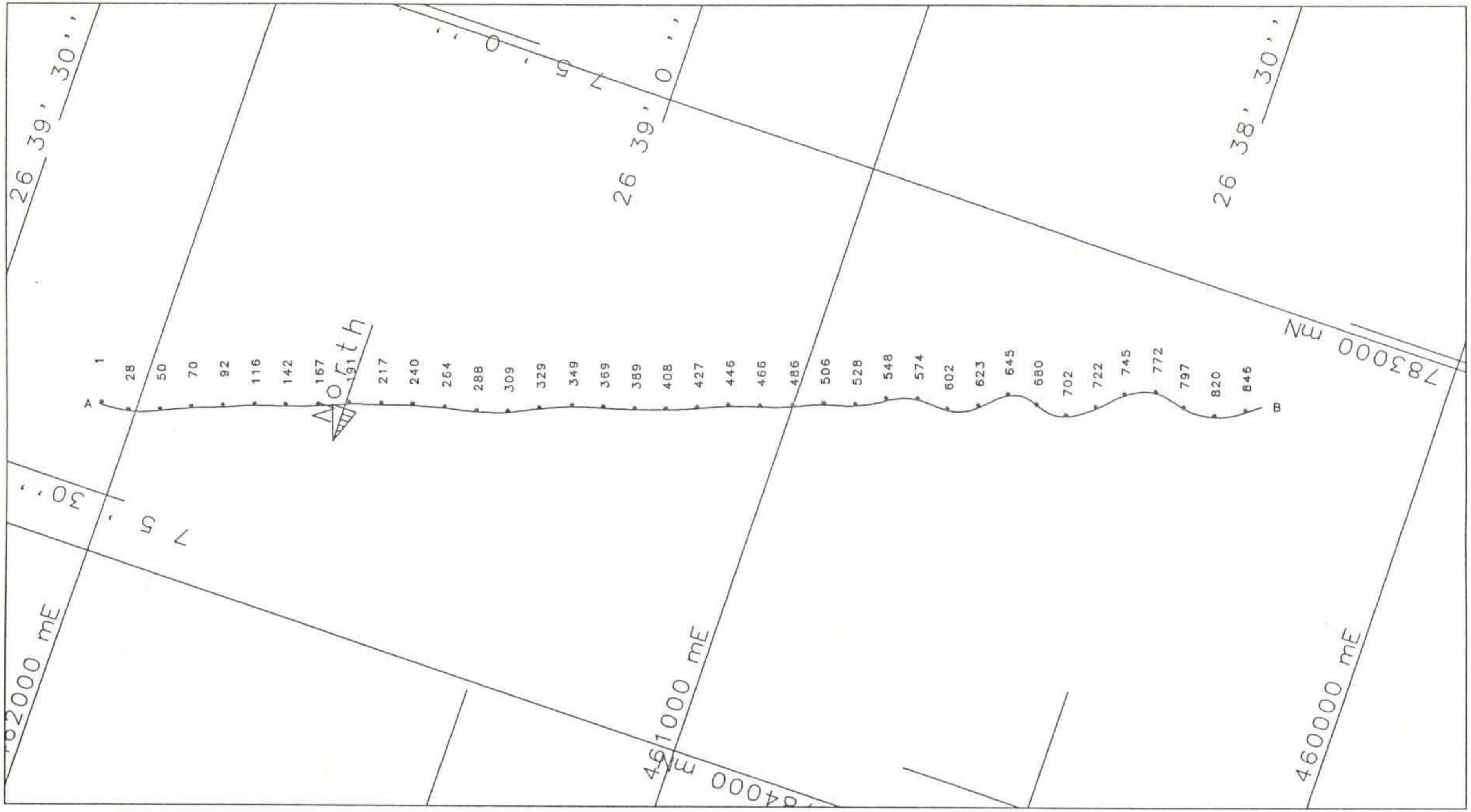

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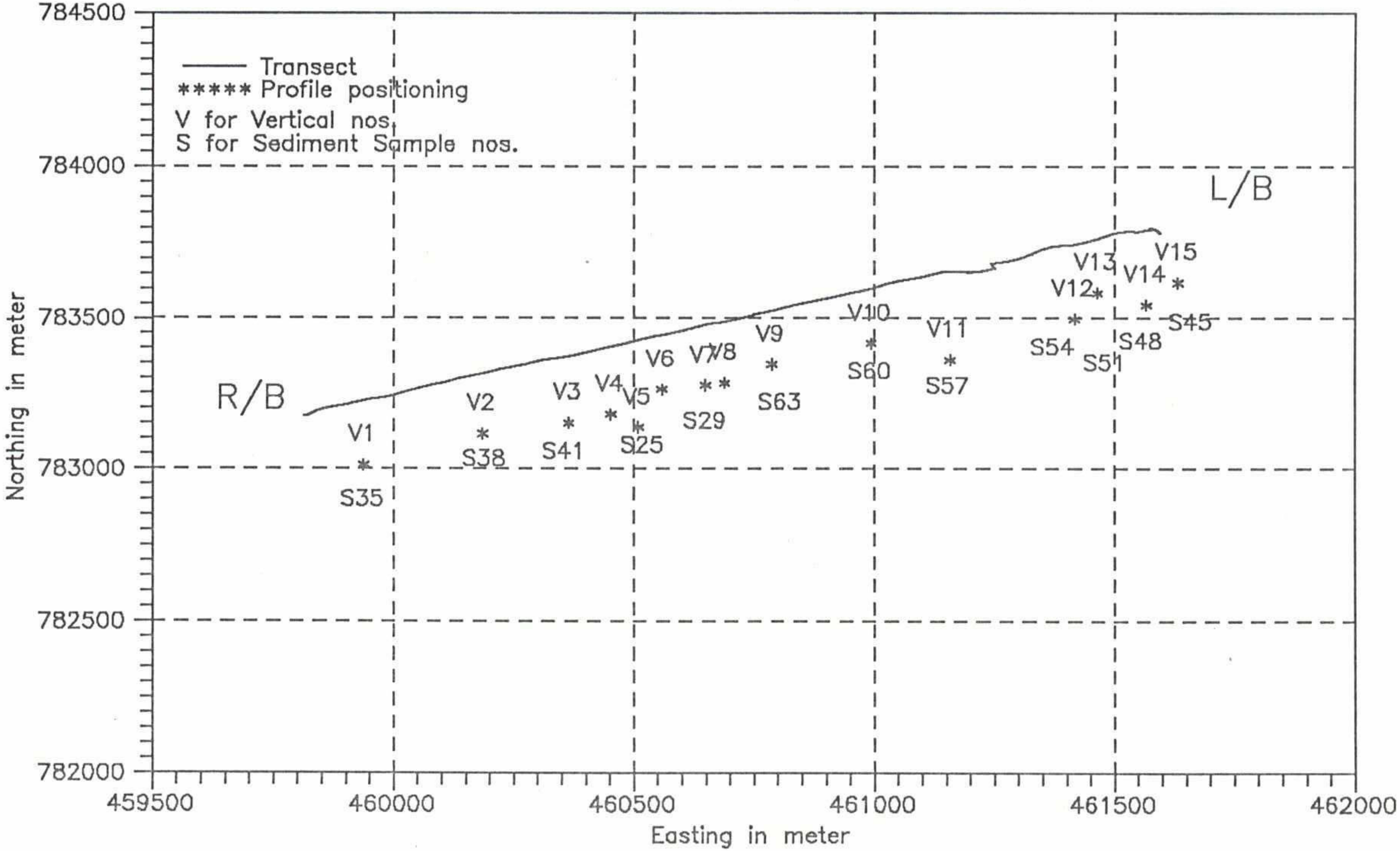
284

River Survey Project (FAP 24)

Location : Jamuna River (Right Channel)

Date of Survey : 26/10/92 and 27/10/92

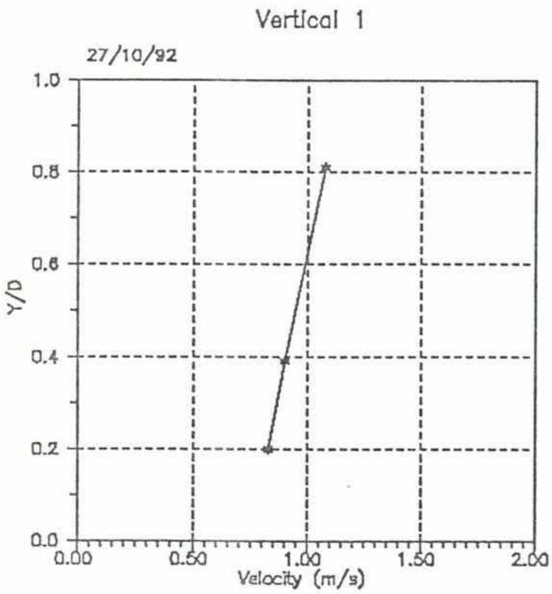


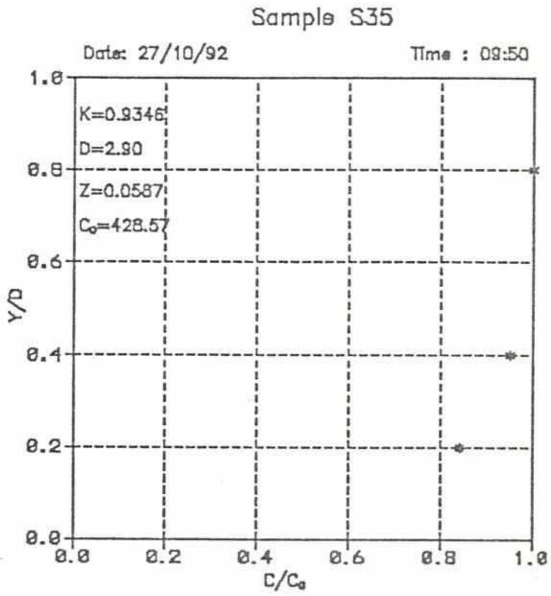
28f

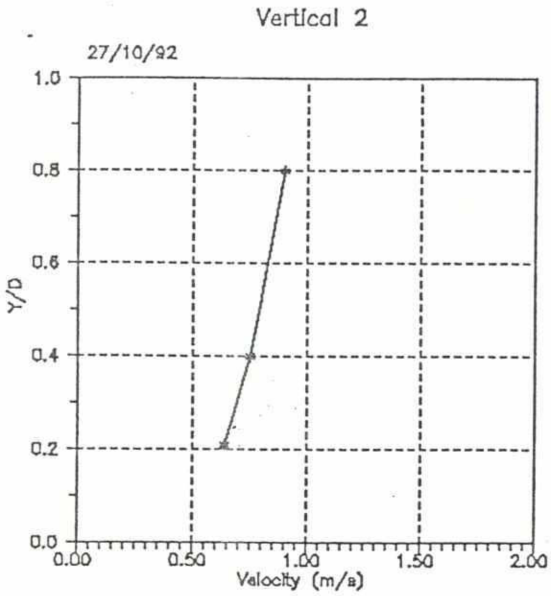
River Survey Project (FAP 24)

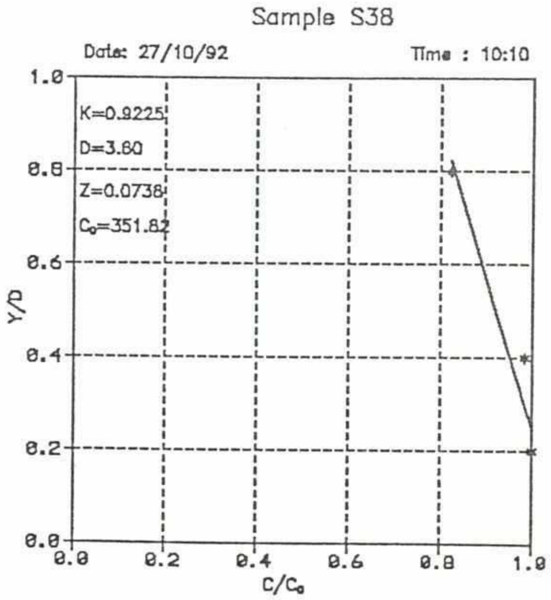
Location : Jamuna River (Right Channel)

Date of Survey : 26/10/92 and 27/10/92





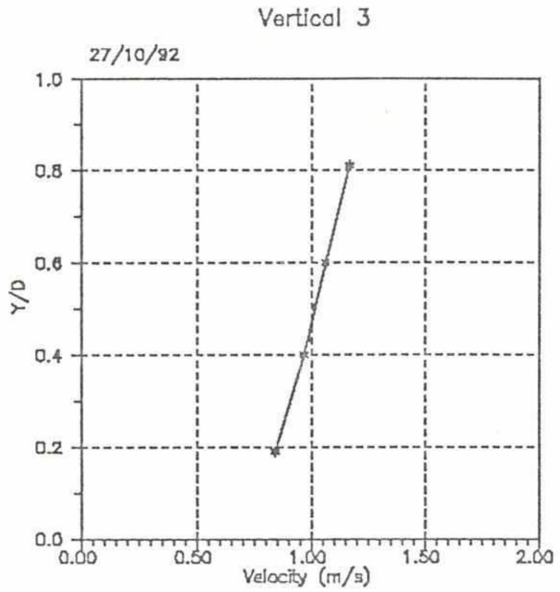


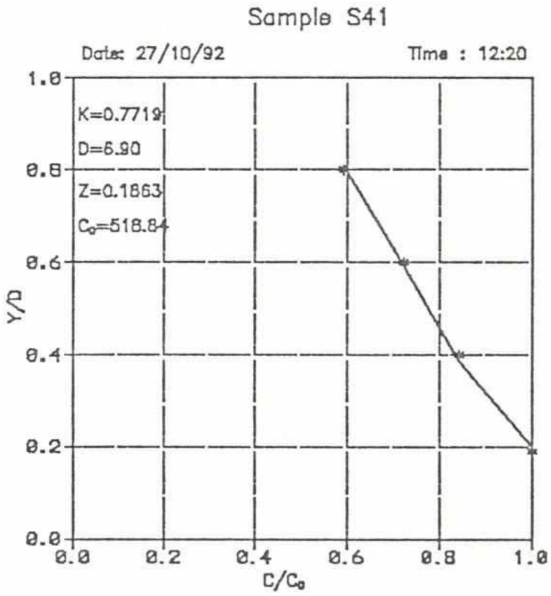


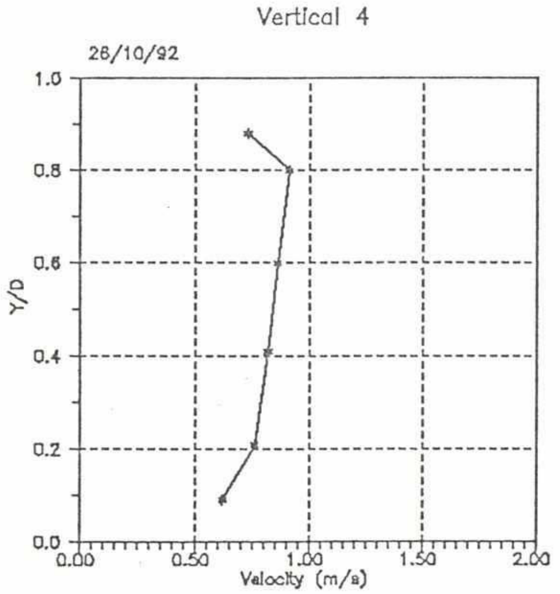
River Survey Project (FAP 24)

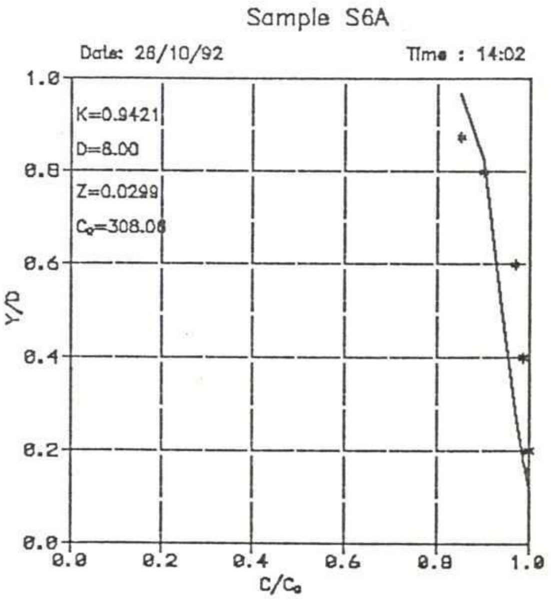
Location : Jamuna River (Right Channel)

Date of Survey : 26/10/92 and 27/10/92





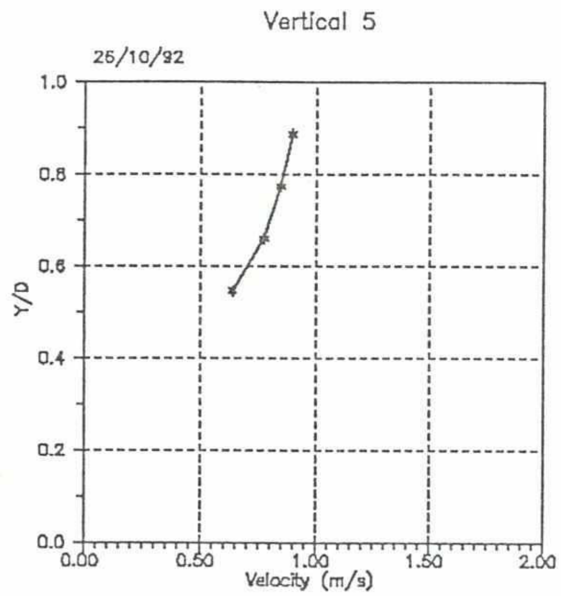


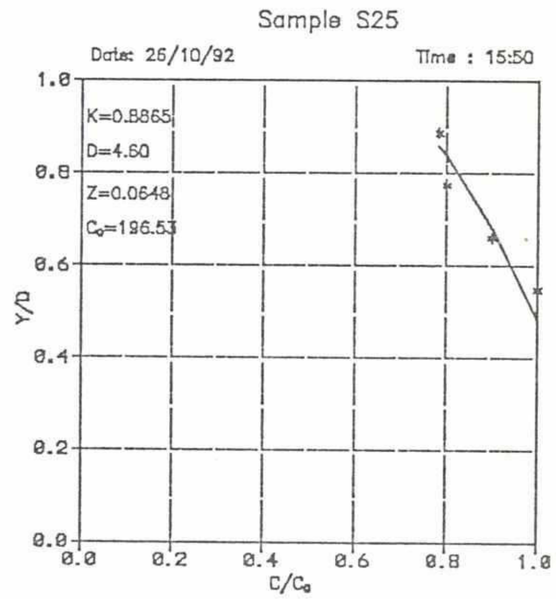


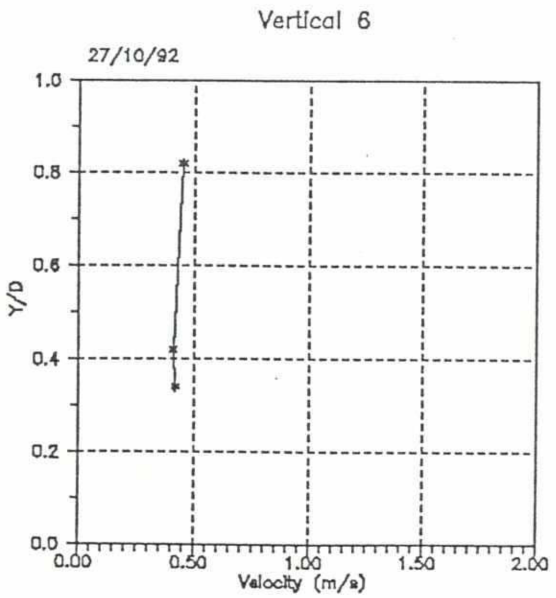
River Survey Project (FAP 24)

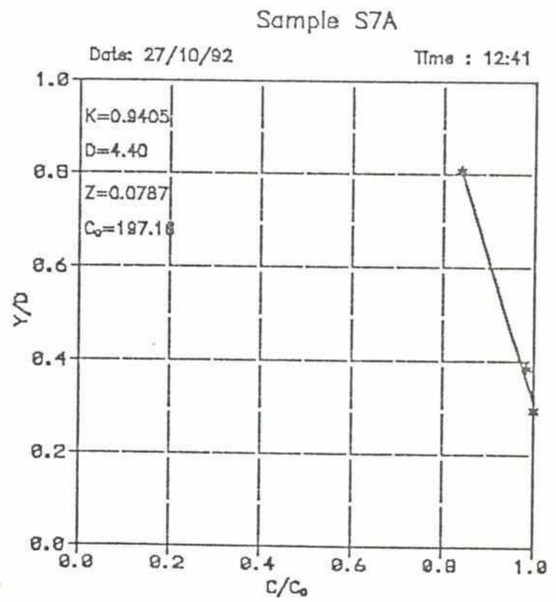
Location : Jamuna River (Right Channel)

Date of Survey : 26/10/92 and 27/10/92





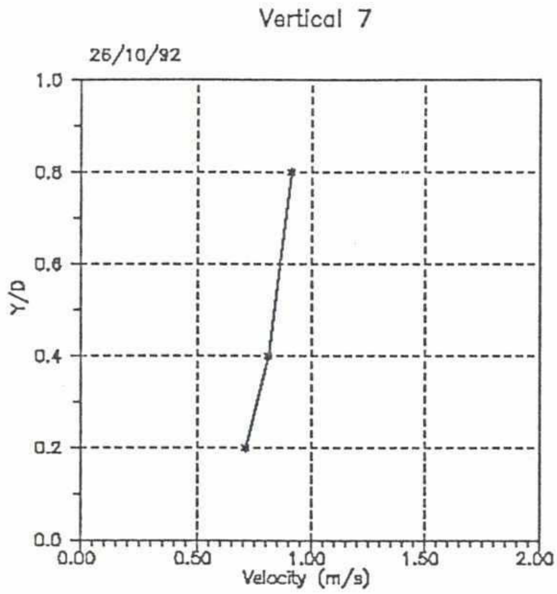


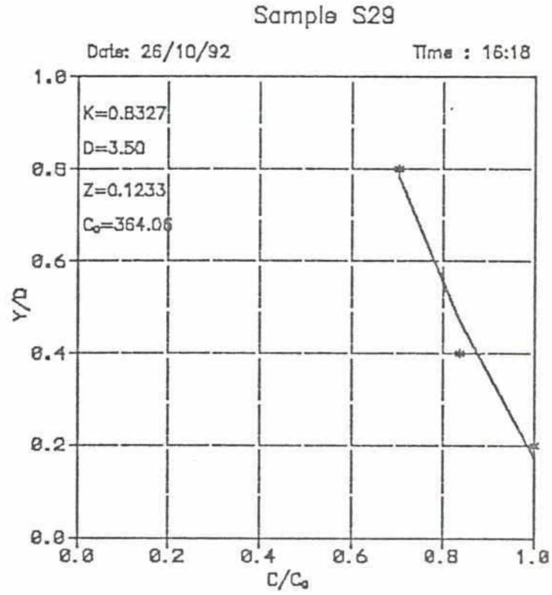


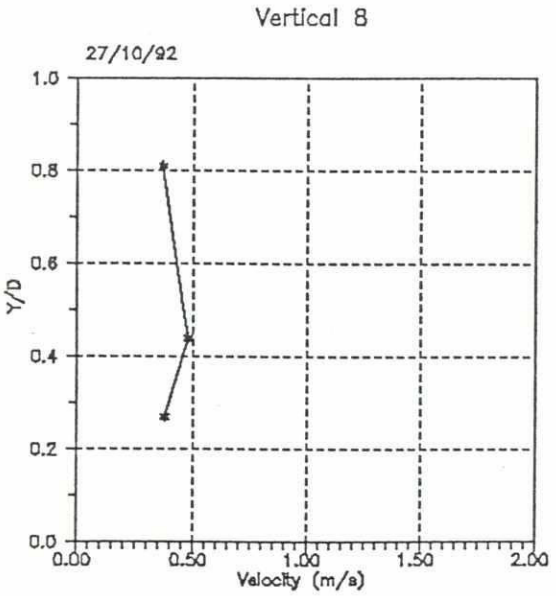
River Survey Project (FAP 24)

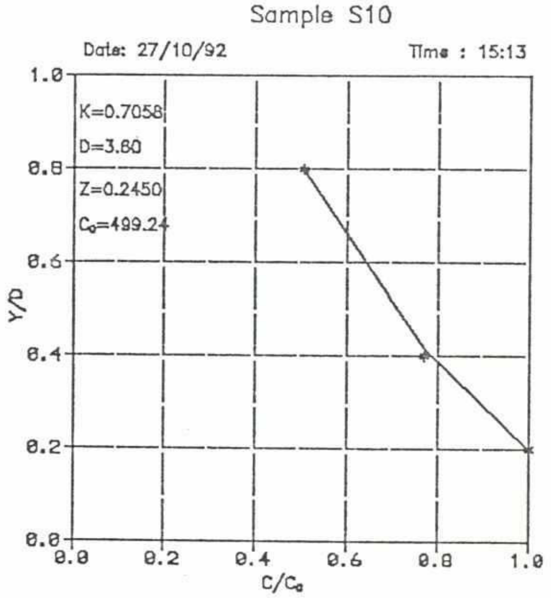
Location : Jamuna River (Right Channel)

Date of Survey : 26/10/92 and 27/10/92







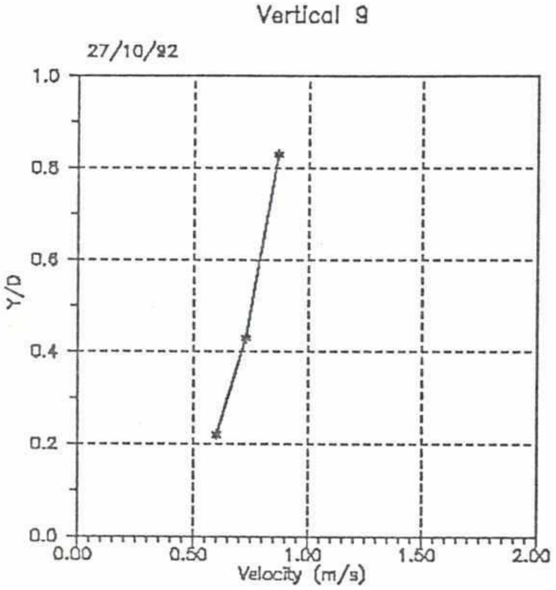


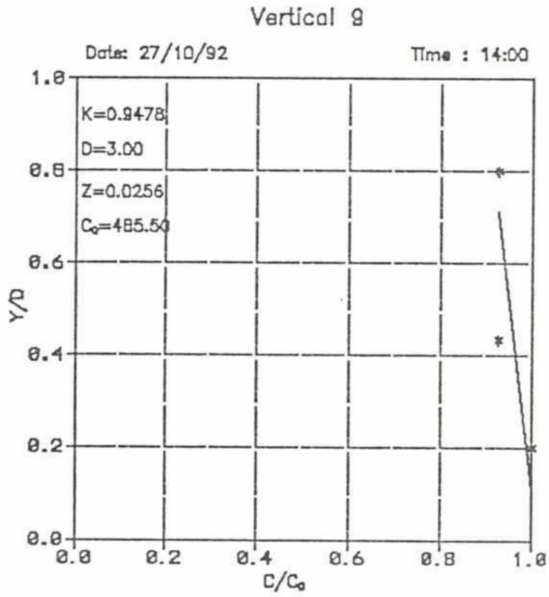
786

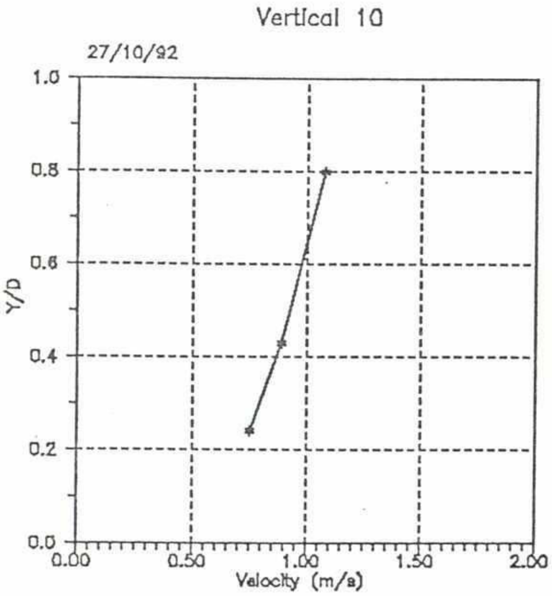
River Survey Project (FAP 24)

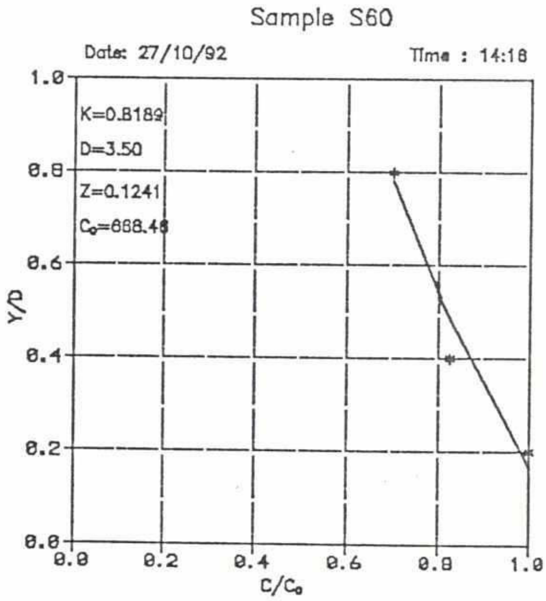
Location : Jamuna River (Right Channel)

Date of Survey : 26/10/92 and 27/10/92





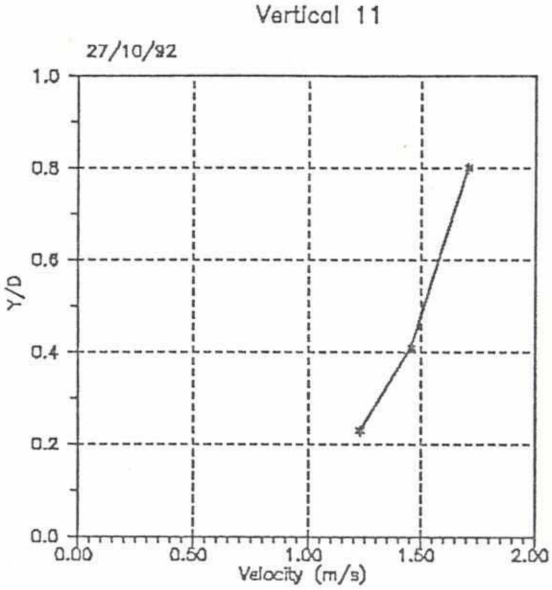


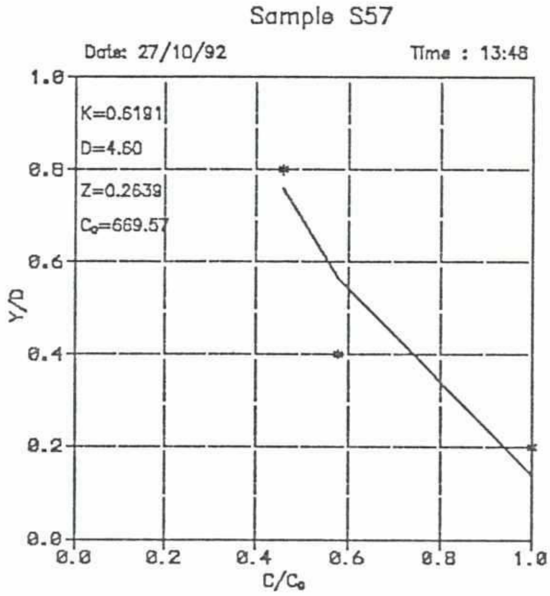


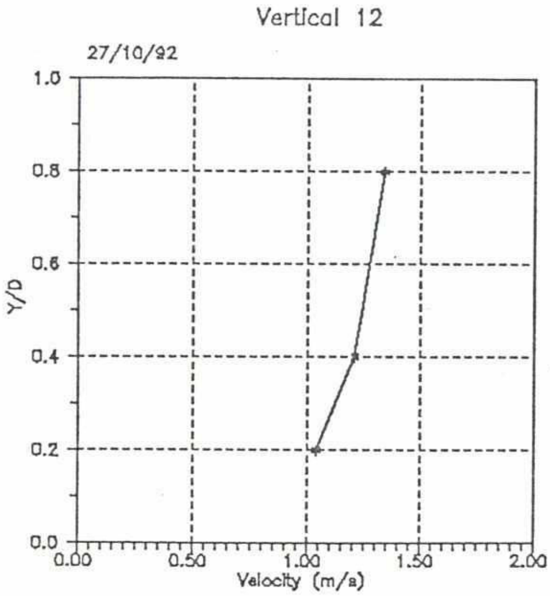
River Survey Project (FAP 24)

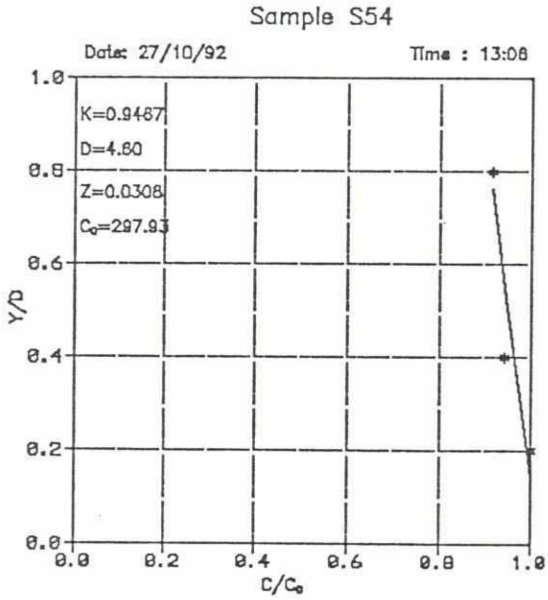
Location : Jamuna River (Right Channel)

Date of Survey : 26/10/92 and 27/10/92









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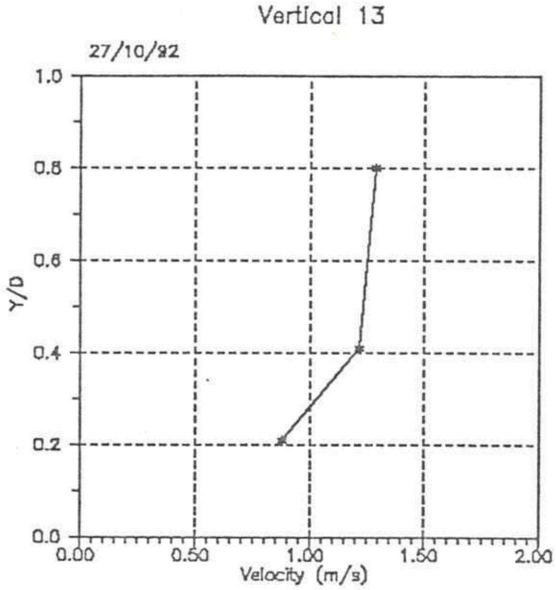
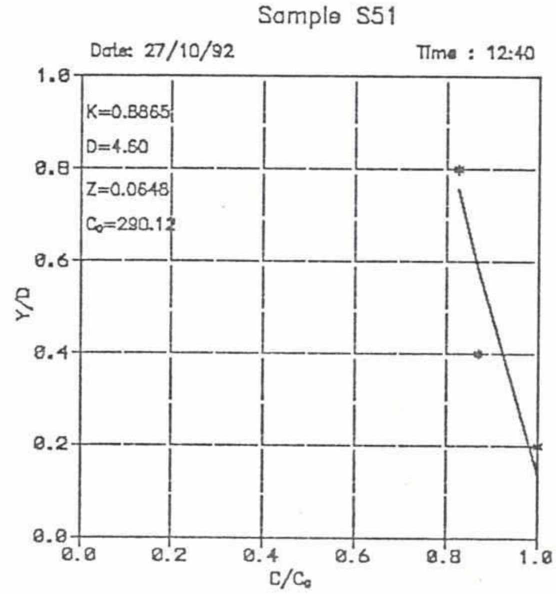
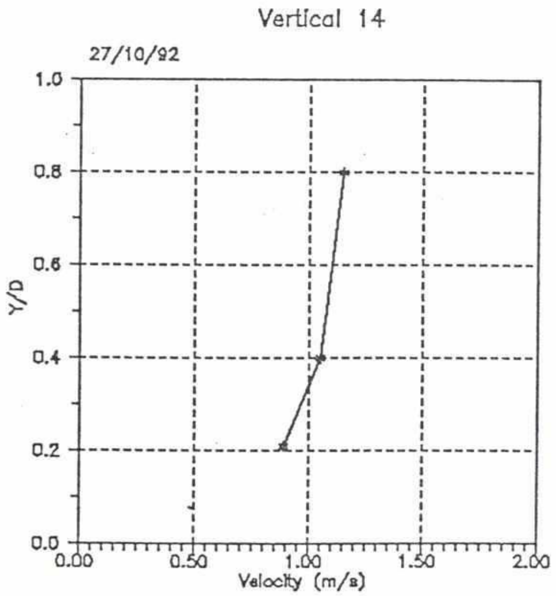
River Survey Project (FAP 24)

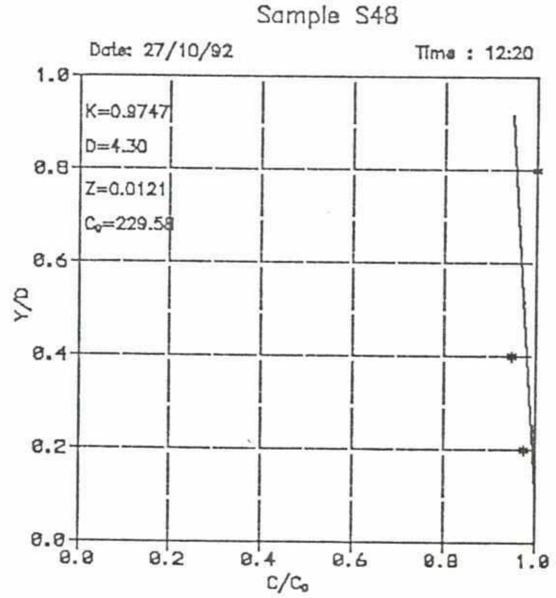
Location : Jamuna River (Right Channel)

Date of Survey : 26/10/92 and 27/10/92







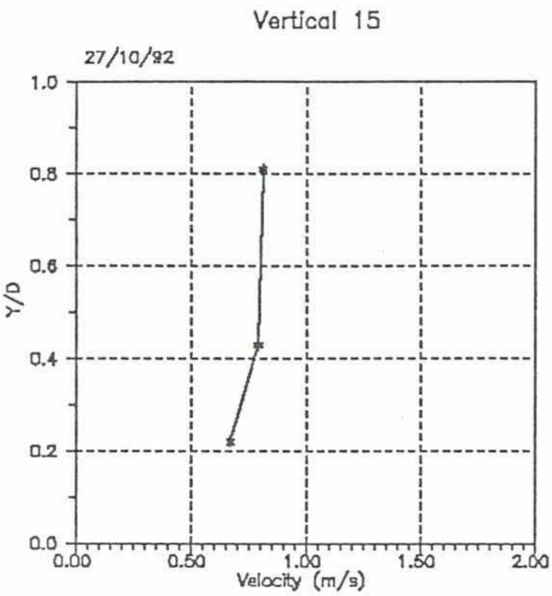


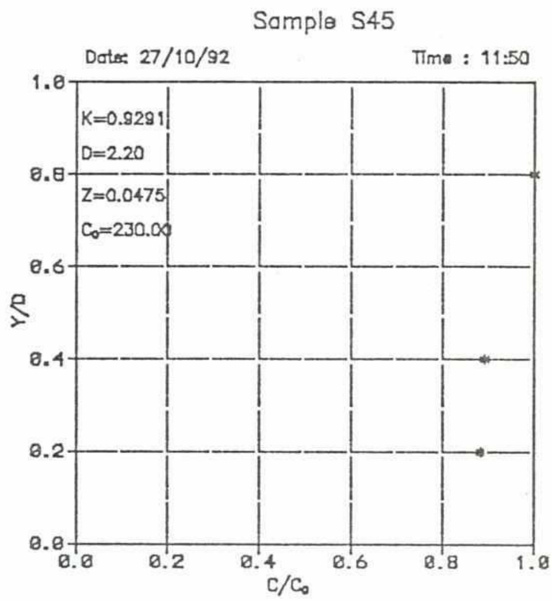
207

River Survey Project (FAP 24)

Location : Jamuna River (Right Channel)

Date of Survey : 26/10/92 and 27/10/92





Appendix 1C

Measurement data from routine survey in November 1992

RIVER SURVEY PROJECT (FAP-24)

Location : Left Channel at Bahadurabad

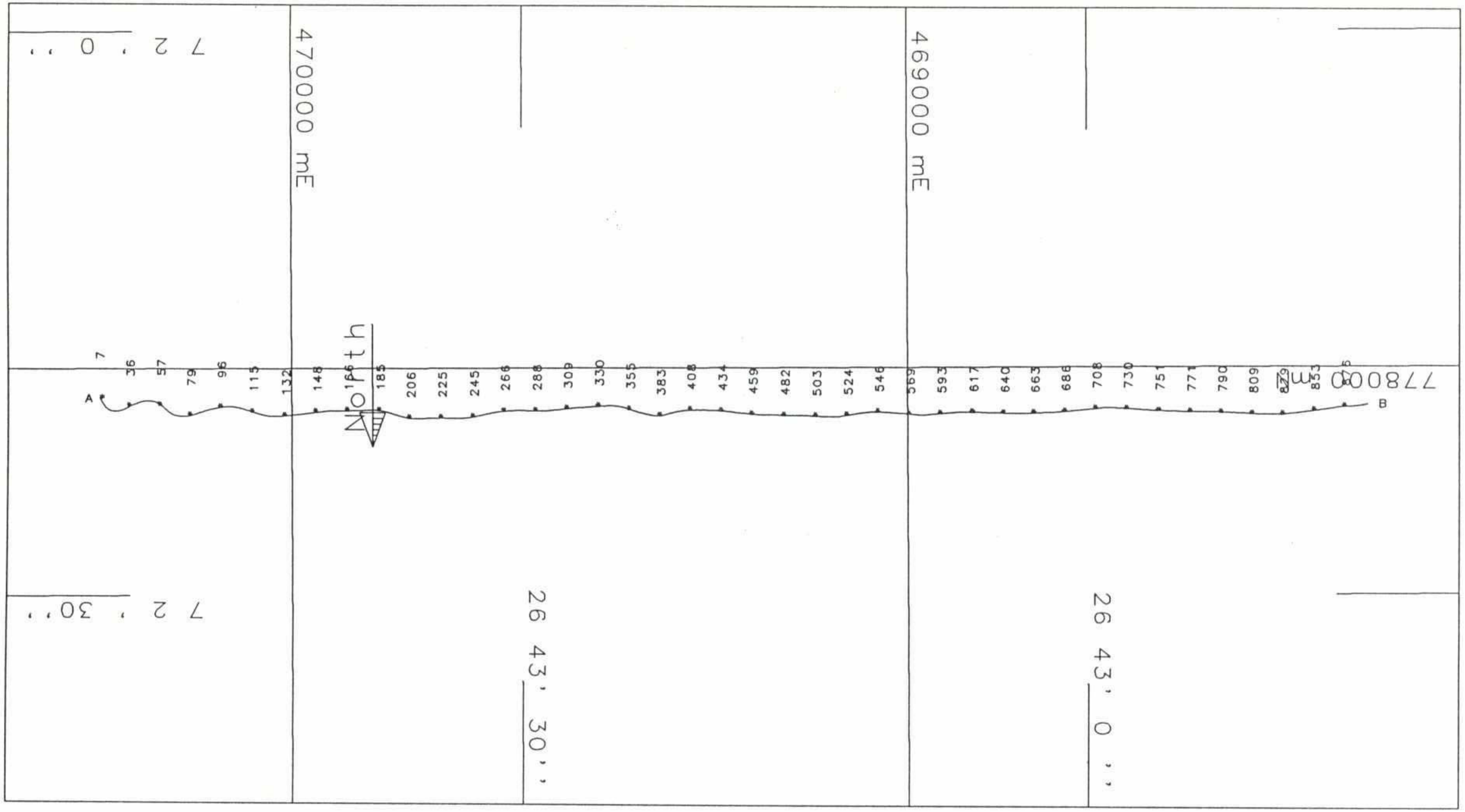
Date of survey: 28/10/92, 29/10/92, 30/10/92, 31/10/92

Place of survey / Date/Channel	Type	Time From	Time To	File Name	Ver. No.	Easting	Northing	Q(ADCP) (on-line) (m3/s)	Q(ADCP) (Off-Line) (m3/s)	DISCHARGE GAUGING ADCP +++30	HYDRO +++50	EMF +++60	54 +++70	MEX +++80	SEDIMENT TRANSPORT GAUGING Suspended Sediment Samples	Andreasen Tube Samples	Helley Smith Samples	Integrated Sediment Samples	Bottom Samples
Bahadurabad	Transect	15:40:20	15:56:05	B2AS1T01				9015		T	T	T							
28/10/92	Transect	16:03:00	16:20:18	B2AS1T03				8632		T	T	T							
Left/East Ch.	Transect	16:27:32	16:45:06	B2AS1T04				8924		T	T	T							
Bahadurabad	Transect	10.45.20	11.02.28	B2AT1T01				8610	11744	T	T	T							
29/10/92	Transect	11.06.03	11.21.11	B2AT1T02				7783		T	T	T							
Left/East Ch.	Transect	11.06.09	11.30.01	B2AT1T03				8461	11778	T	T	T							
	Transect	11.54.57	12.08.13	BAAT1T04				8479		T	T	T							
	Profile	13.49.33	14.22.33	B2AT1P01	15	469792.3	777901.7			P	P	P	P		13-15A				
	Profile	14.52.13	15.55.28	B2AT1P02	14	469561.5	777955.7			P	P	P	P		16-21A				
	Profile	11.06.38	11.19.49	B2AT2P01	1	468034.9	777908.6				P		P		100-102C				
	Profile	11.34.44	11.45.52	B2AT2P02	2	468231.2	777905.8				P		P		103-105C				
	Profile	12.03.49	12.34.23	B2AT2P03	4	468487.7	777896.0				P		P		106-109C				
	Profile	12.52.35	13.03.34	B2AT2P04	3	468468.8	777904.1				P		P		110-112C				
	Profile	13.22.28	14.12.44	B2AT2P05	5	468721.5	777850.2				P		P		113-118C				
	Profile	13.22.28	14.12.44	B2AT2P06	7	468721.5	777850.1				P		P		119-124C				
	Profile	14.25.39	16.19.04	B2AT2P07	6	468744.3	777864.4				P		P		125-129C				
	Transect	16.05.05	16.20.01	B2AT1T05				8440	11859	T	T	T							
	Transect	16.24.37	16.49.31	B2AT1T06				8416		T	T	T							
Bahadurabad	Transect	12.15.56	12.34.18	B2AU1T01				8190	10763	T	T	T							
30/10/92	Transect	12.42.28	12.55.49	B2AU1T02						T	T	T							
Left/East Ch.	Transect	13.05.56	13.22.06	B2AU1T03				8487	11064	T	T	T							
		00.00.00	13.40.27	B2AU1T04				8173											
		17.09.14	17.24.10	B2AU1T05				8455	11413										
		17.30.28	17.44.07	B2AU1T06				8283											
	Profile	14.06.55	15.14.20	B2AU1P01	13	469542.9	777904.5			P	P	P	P		22-27A	27A	H1-H3		
	Profile	12.11.19	13.06.54	B2AU2P01	8	469032.6	777848.8				P	P	P		130-135C	136C			
	Profile	14.20.05	15.05.11	B2AU2P02	11	469389.1	777897.9				P		P		137-142C	143C			
	Profile	16.29.02	17.20.20	B2AU2P03	10	469315.8	777882.7				P		P		144-149C	150C			
	Transect	17.09.14	17.24.10	B2AU1T05						T	T	T							
	Transect	17.30.28	17.44.07	B2AU1T06						T	T	T							
Bahadurabad	Transect	10.49.53	10.55.00	B2AV1T05				7996	10789	T	T	T							
31/10/92	Transect	10:59:04	11:11:14	B2AV1T06				7847		T	T	T							
Left/East Ch.	Profile	00.00.00	00.00.00	B2AV1P01	9	469133.3	777923.2			P	P	P	P		28-33A	28A	H4-H9		
	Profile	11.23.21	11.56.54	B2AV2P01	12	469396.6	777364.8				P		P		151-156C	157C			
	Transect	17:04:04	17.19.17	B2AV1T07				7905	10218	T	T	T							1 No.
	Transect	17:30:21	17.43.49	B2AV1T08				7540		T	T	T							

File : OCT92SUR.WO1

12-Mar-93

W.A.R.P.O. LIBRARY DHAKA



TRACK PLOT :

Scale : 1 : 10000
Track : ——
Fix nos. : •

SURVEY ID. :

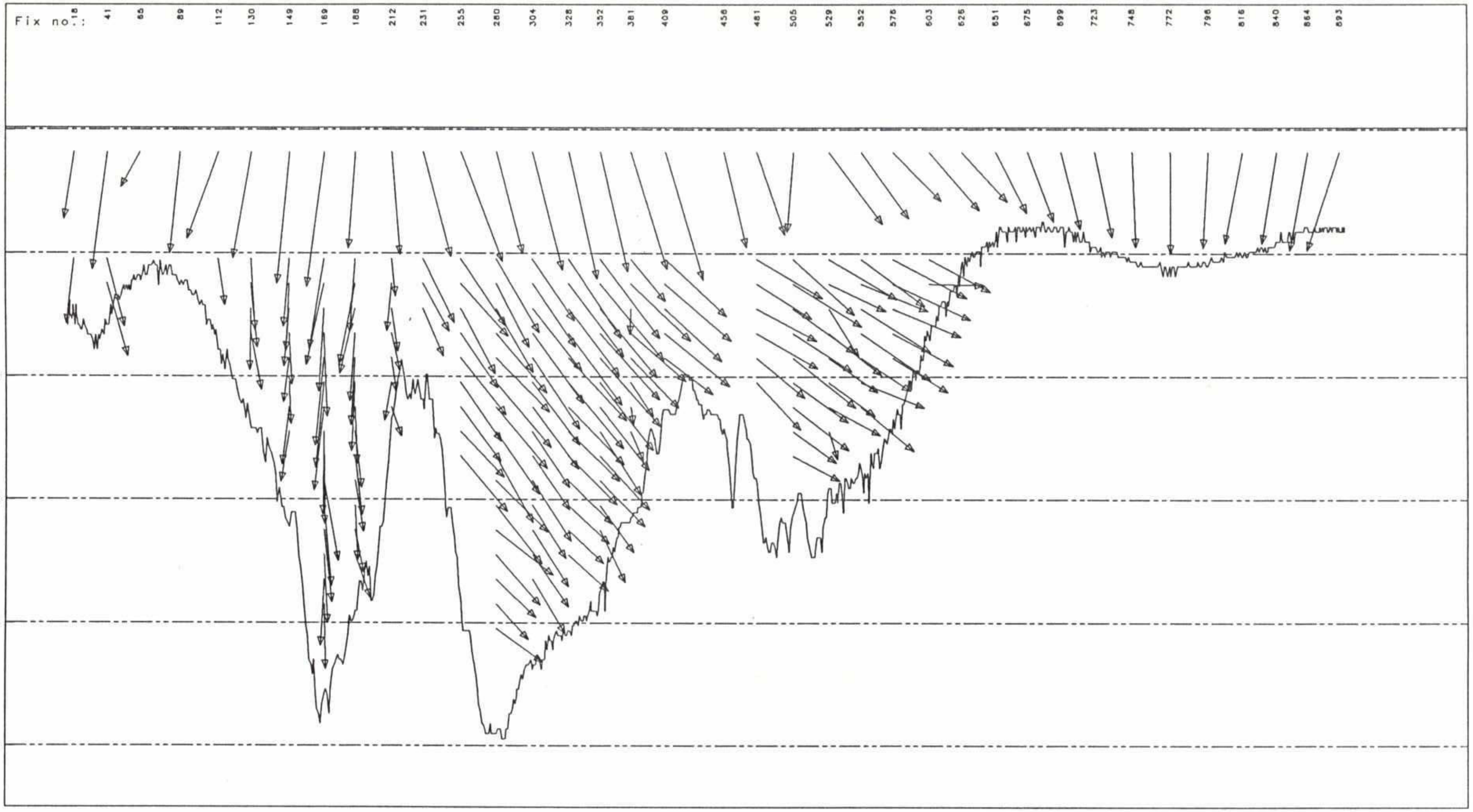
Positions : BTM
Date : 921030
Start Time : 12:19:21
End Time : 12:34:18
Start Position : 470310E 778048N
End Posision : 468249E 778061N

PLOT ID. :

Project : FAP 24
File : /u/f24adm/data/92-10-30/b2au1t1m
Drawn : Sat Mar 20 11:44:42 1993
Type : Track Plot
Init. : MZH
Rev. : A

Appr.

Id. No.



PROFILE CURRENT VELOCITY :	SURVEY ID. :	PLOT ID. :
Vertical Scale 1 : 10000	Positions : BTM	Project : FAP 24
Horizontal Scale 1 : 125	Date : 921030	File : /u/f24adm/data/92-10-30/b2au1t1m
	Start Time : 12:19:21	Drawn : Sat Mar 20 15:25:31 1993
North	End Time : 12:34:18	Type : Cross Section
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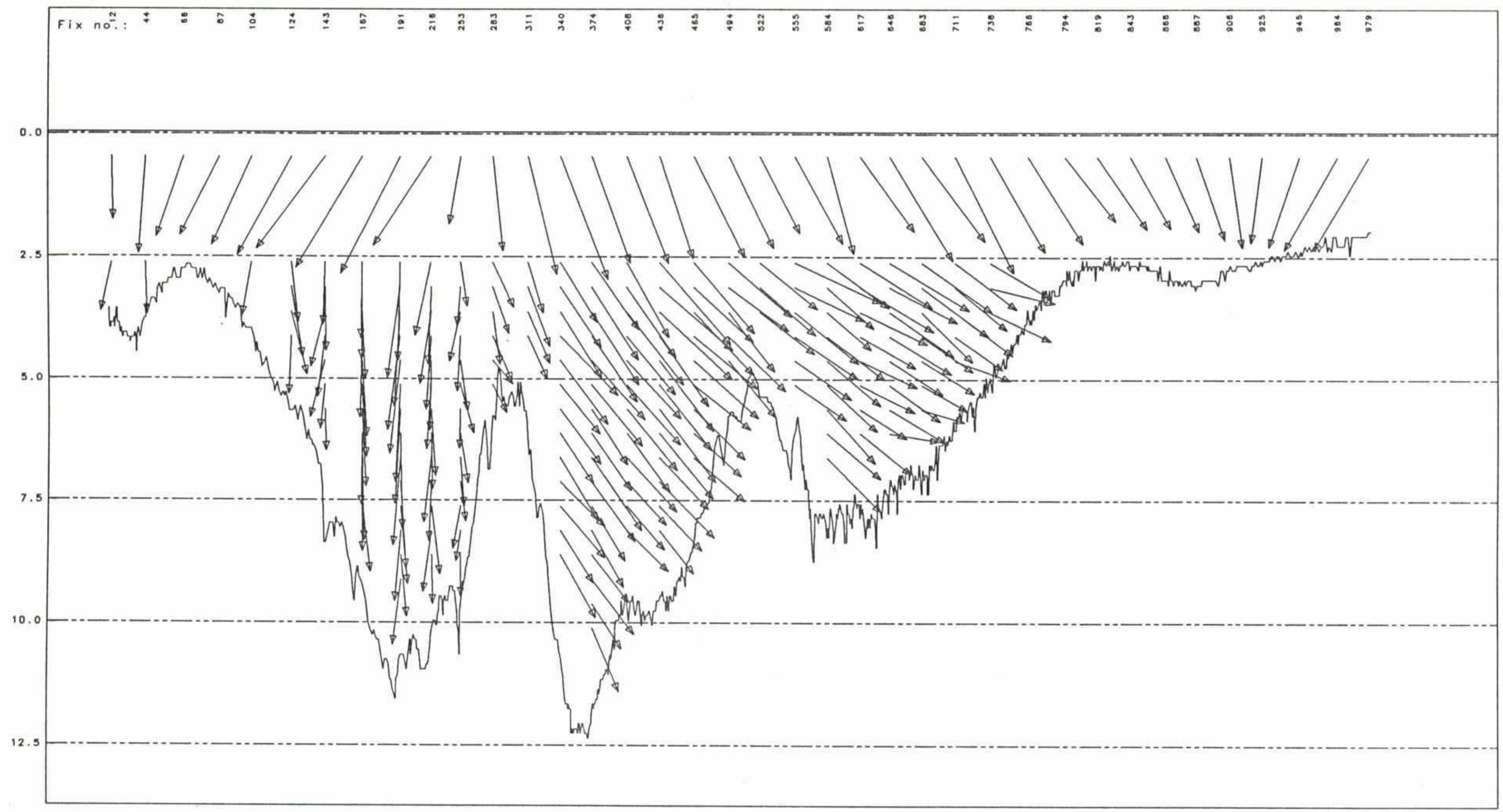
1.00 m/s, East	End Posision : 468249E 778061N	Rev. : A
Seabed : —		Appr. / Id. No.



PROFILE CURRENT VELOCITY :

Vertical Scale 1 : 10000
Horizontal Scale 1 : 125

North
1.00 m/s, East
Seabed : —

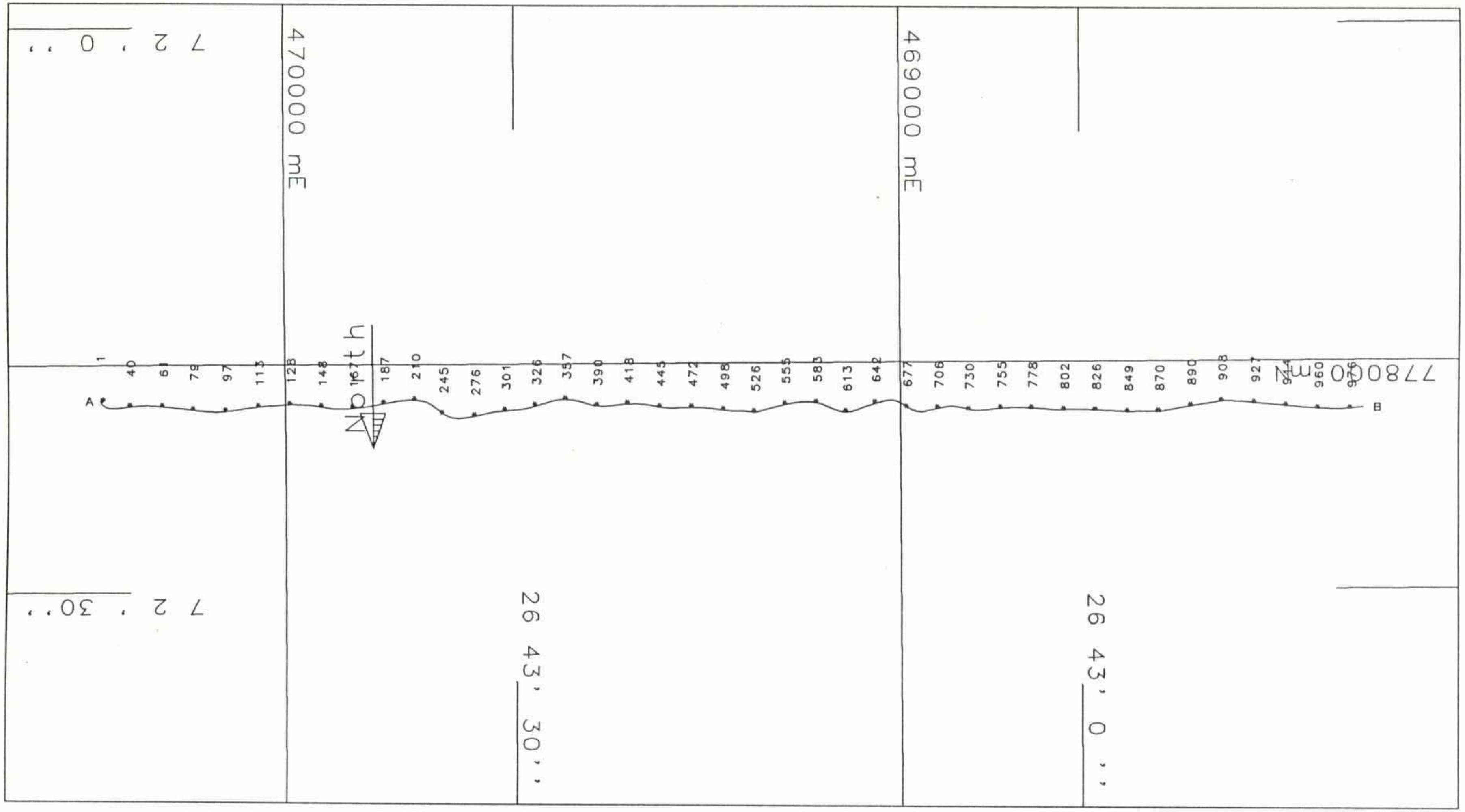
SURVEY ID. :

Positions : BTM
Date : 921030
Start Time : 13:05:46
End Time : 13:22:06
Start Position : 470300E 778058N
End Posision : 468247E 778078N

PLOT ID. :

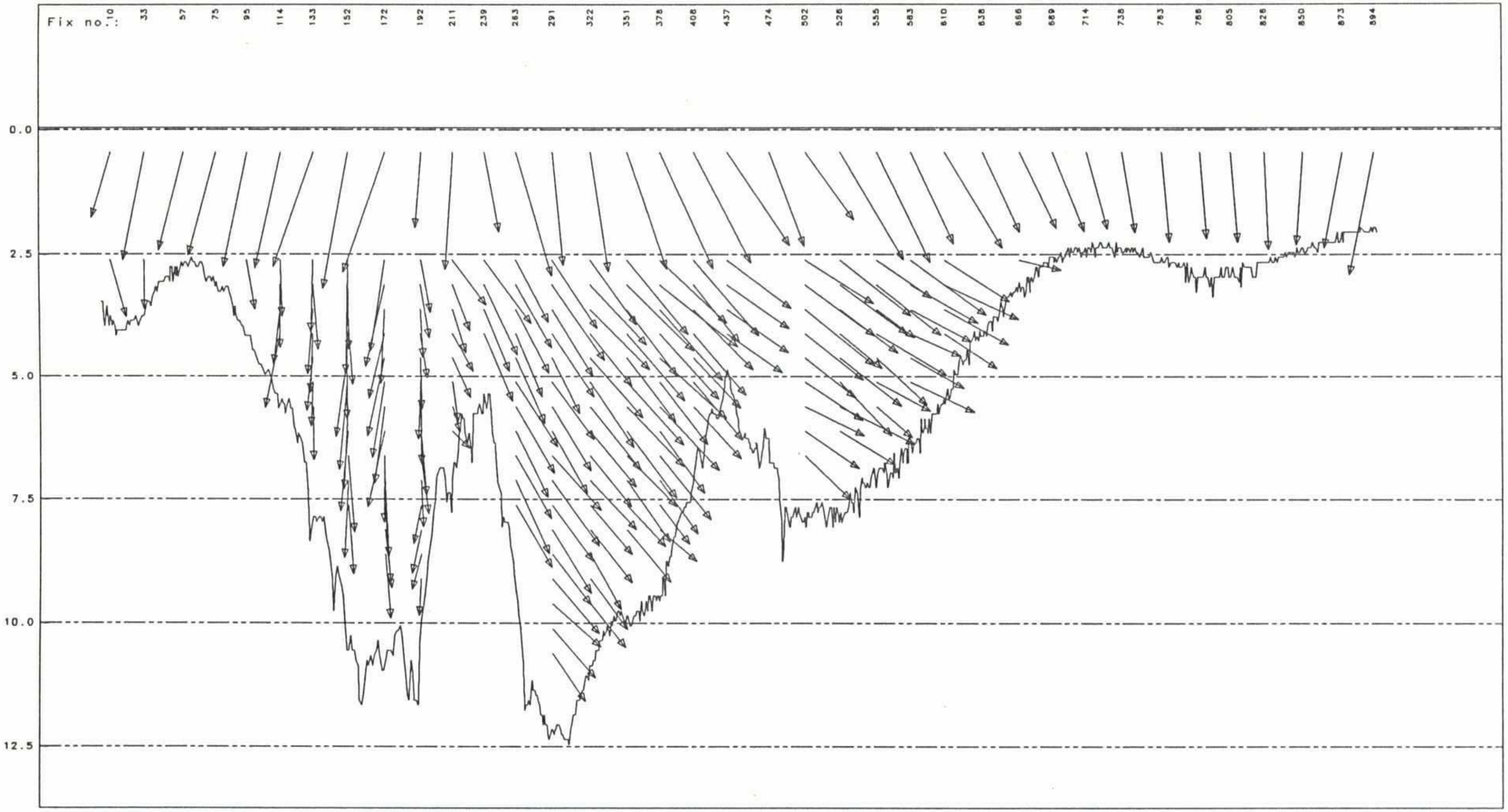
Project : FAP 24
File : /u/f24adm/data/92-10-30/b2au1t3m
Drawn : Sat Mar 20 15:26:06 1993
Type : Cross Section
Init. : MZH
Rev. : A

Appr.
Id. No.



TRACK PLOT :	SURVEY ID. :	PLOT ID. :
Scale : 1 : 10000 Track : ——— Fix nos. : *	Positions : BTM Date : 921030 Start Time : 13:05:46 End Time : 13:22:06 Start Position : 470300E 778058N End Posision : 468247E 778078N	Project : FAP 24 File : /u/f24adm/data/92-10-30/b2au1t3m Drawn : Sat Mar 20 11:45:22 1993 Type : Track Plot Init. : MZH Rev. : A
		Appr. / Id. No.

D2



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Horizontal Scale 1 : 125	Date : 921030	File : /u/f24adm/data/92-10-30/b2au1t5m
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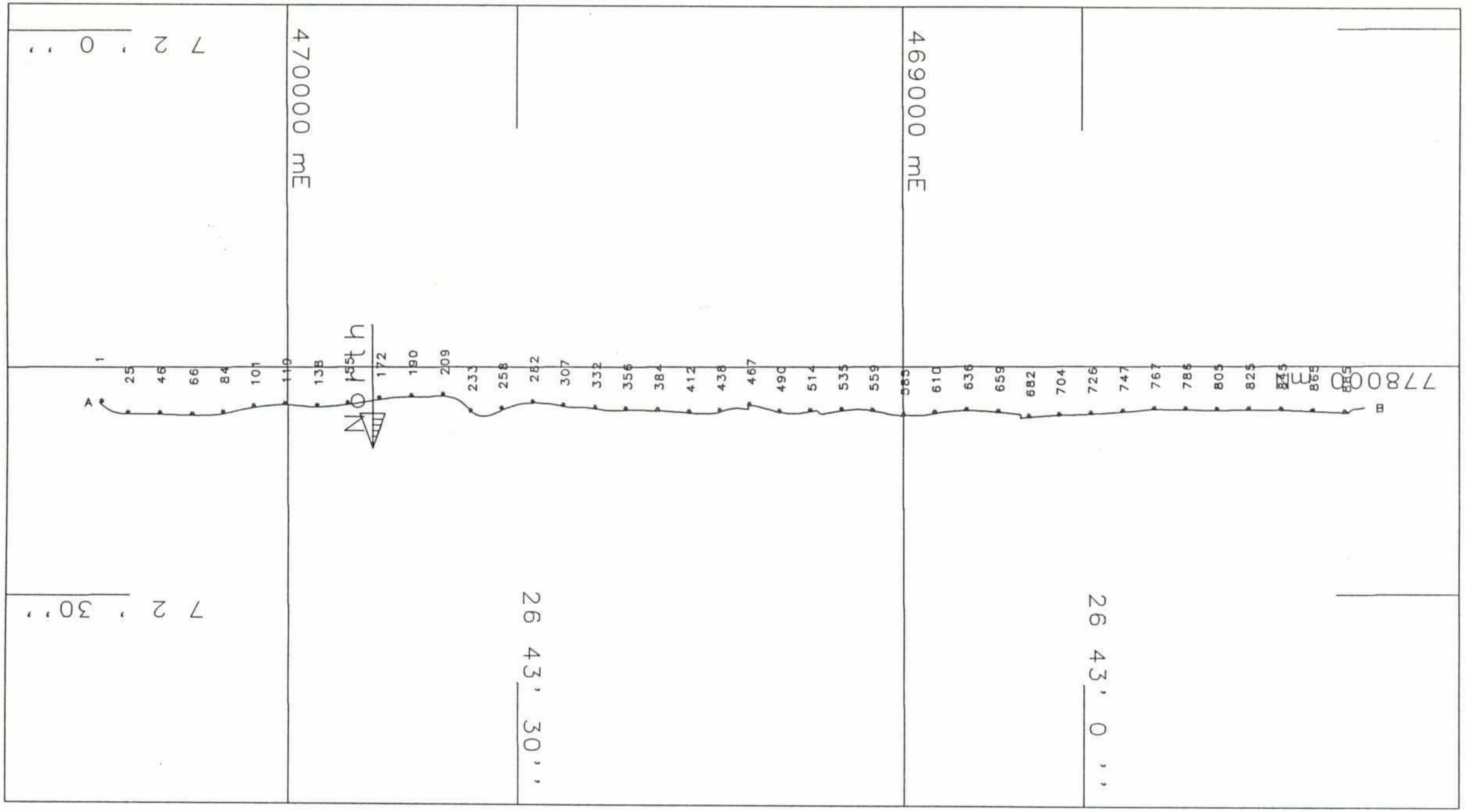

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Scale : 1 : 10000	Positions : BTM	Project : FAP 24
Track : ———	Date : 921030	File : /u/f24adm/data/92-10-30/b2au1t5m
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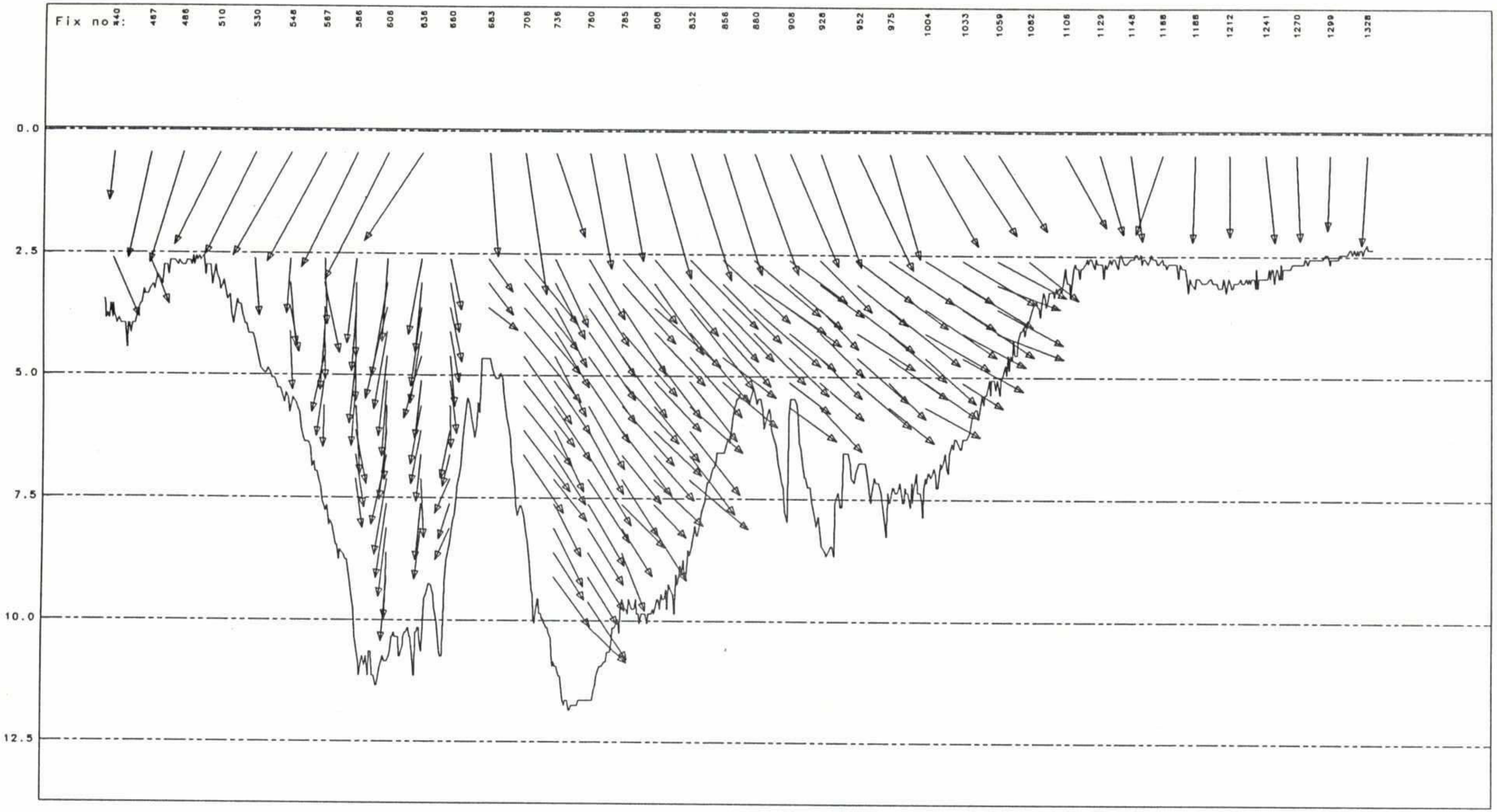

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Horizontal Scale 1 : 125	Date : 921031	File : /u/f24adm/data/92-10-31/b2av1t5m
North	Start Time : 10:39:53	Drawn : Sat Mar 20 15:27:16 1993
1.00 m/s, East	End Time : 10:54:58	Type : Cross Section
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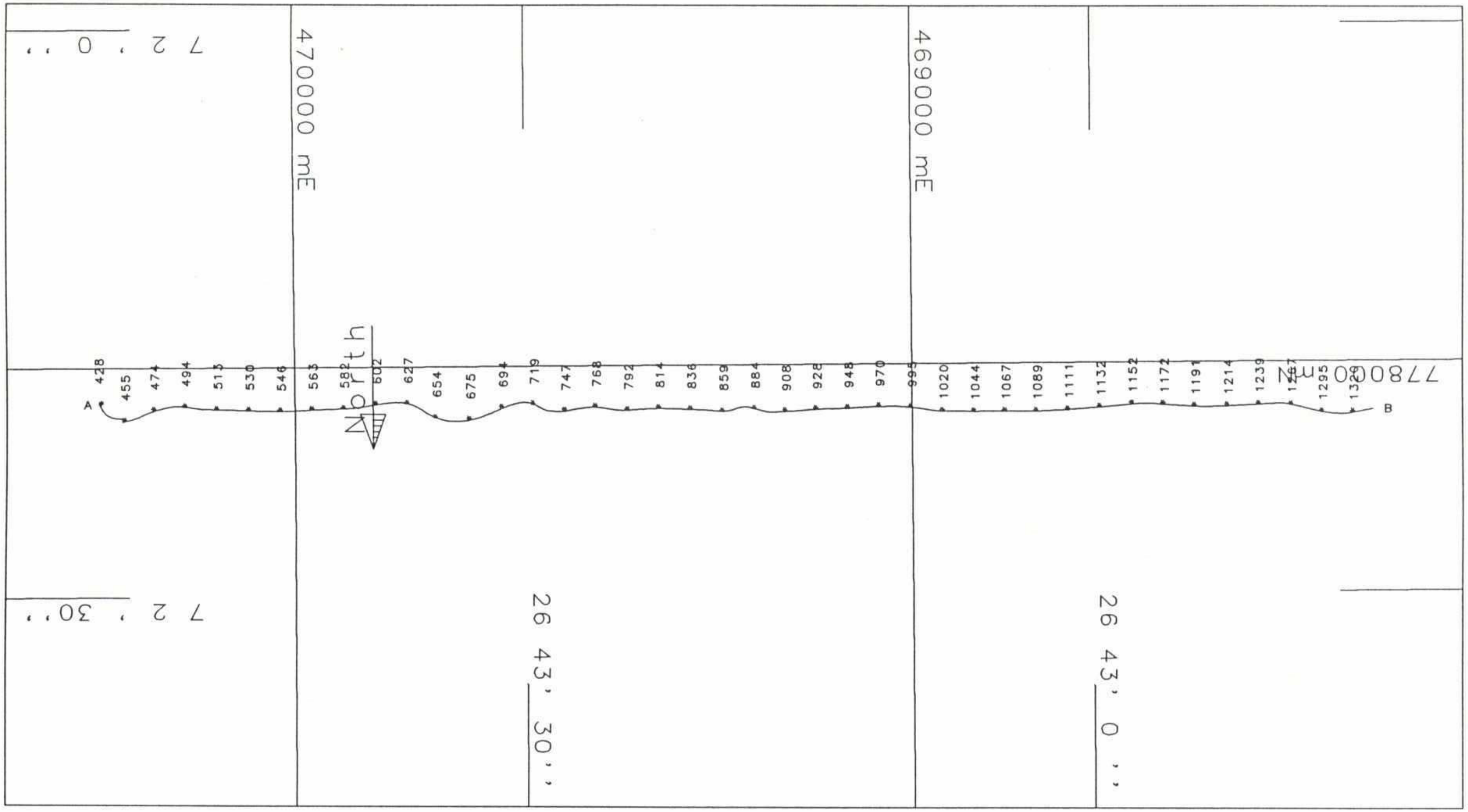
	End Posision : 468251E 778079N	Rev. : A
		Appr. / Id. No.

22 8



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Track : ——	Date : 921031	File : /u/f24adm/data/92-10-31/b2av1t5m
Fix nos. : •	Start Time : 10:39:53	Drawn : Sat Mar 20 11:46:33 1993
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		Appr. / Id. No.

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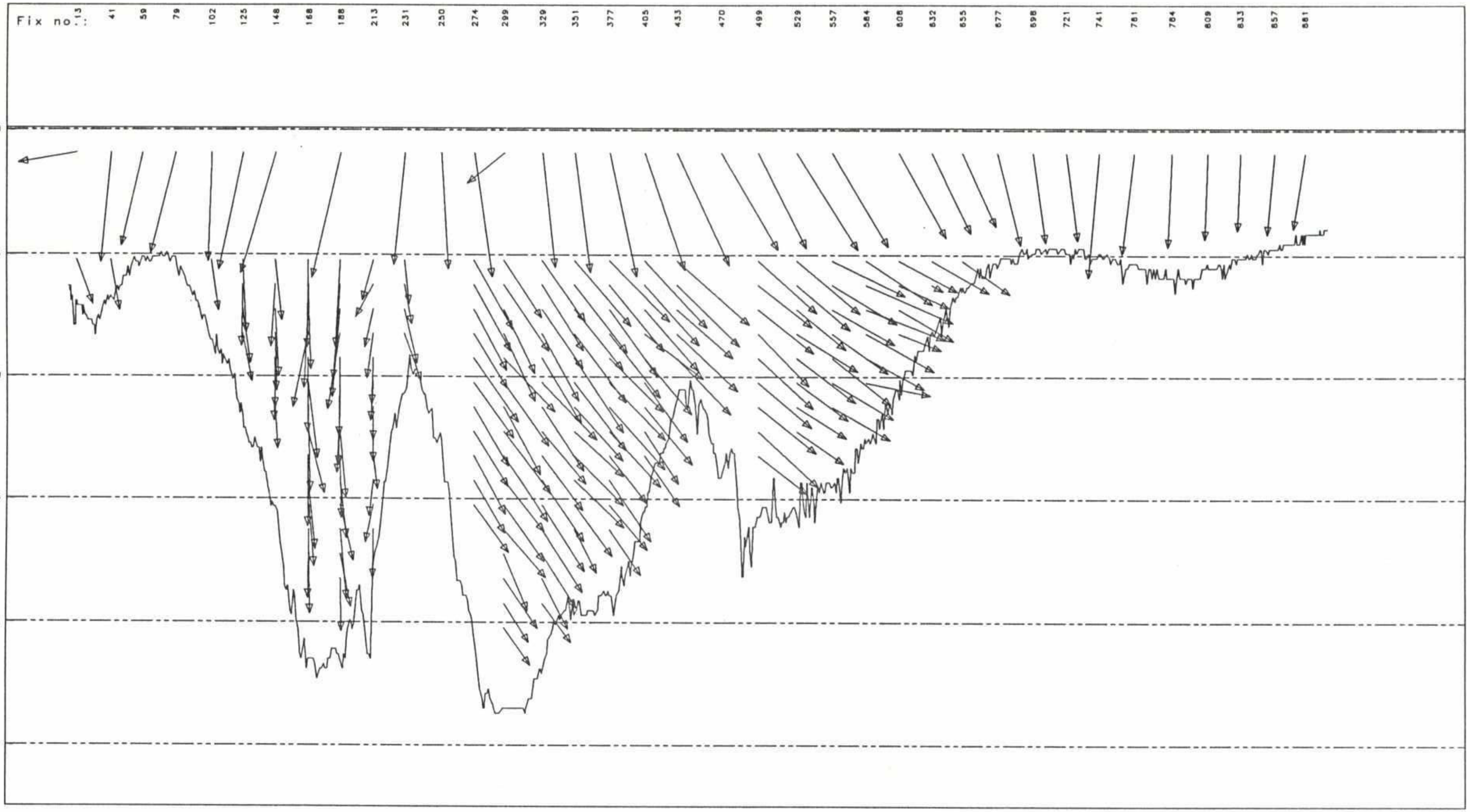

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Vertical Scale 1 : 10000	Positions : BTM	Project : FAP 24
Horizontal Scale 1 : 125	Date : 921031	File : /u/f24adm/data/92-10-31/b2av1t7m
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1.00 m/s, East	End Time : 17:19:16	Type : Cross Section
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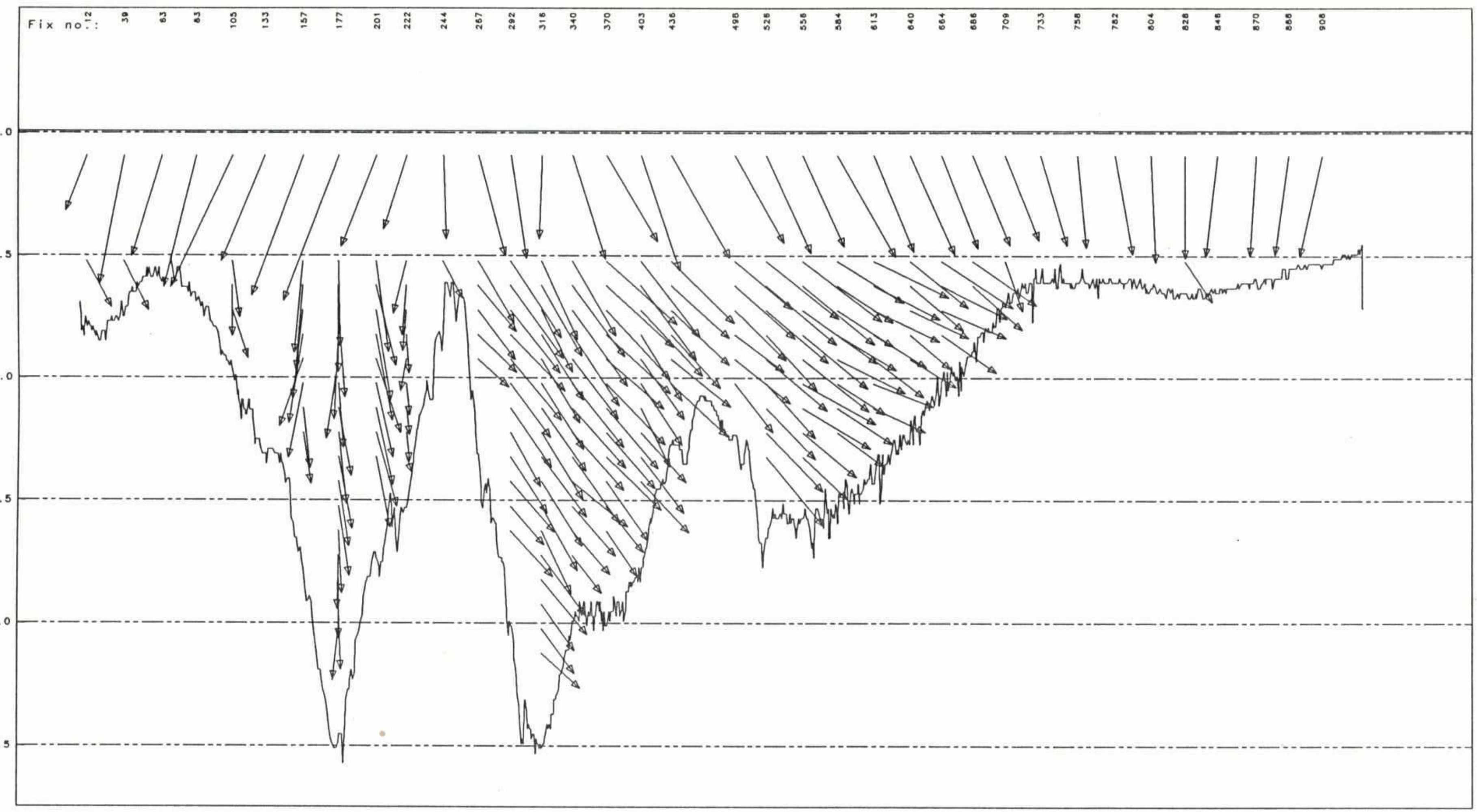
239



PROFILE CURRENT VELOCITY :

Vertical Scale 1 : 10000
Horizontal Scale 1 : 125

North

1.00 m/s, East

Seabed : —

SURVEY ID. :

Positions	: BTM
Date	: 921029
Start Time	: 10:45:20
End Time	: 11:01:06
Start Position	: 470283E 778057N
End Posision	: 468200E 778072N

PLOT ID. :

Project	: FAP 24
File	: /u/f24adm/data/92-10-29/b2at1t1m
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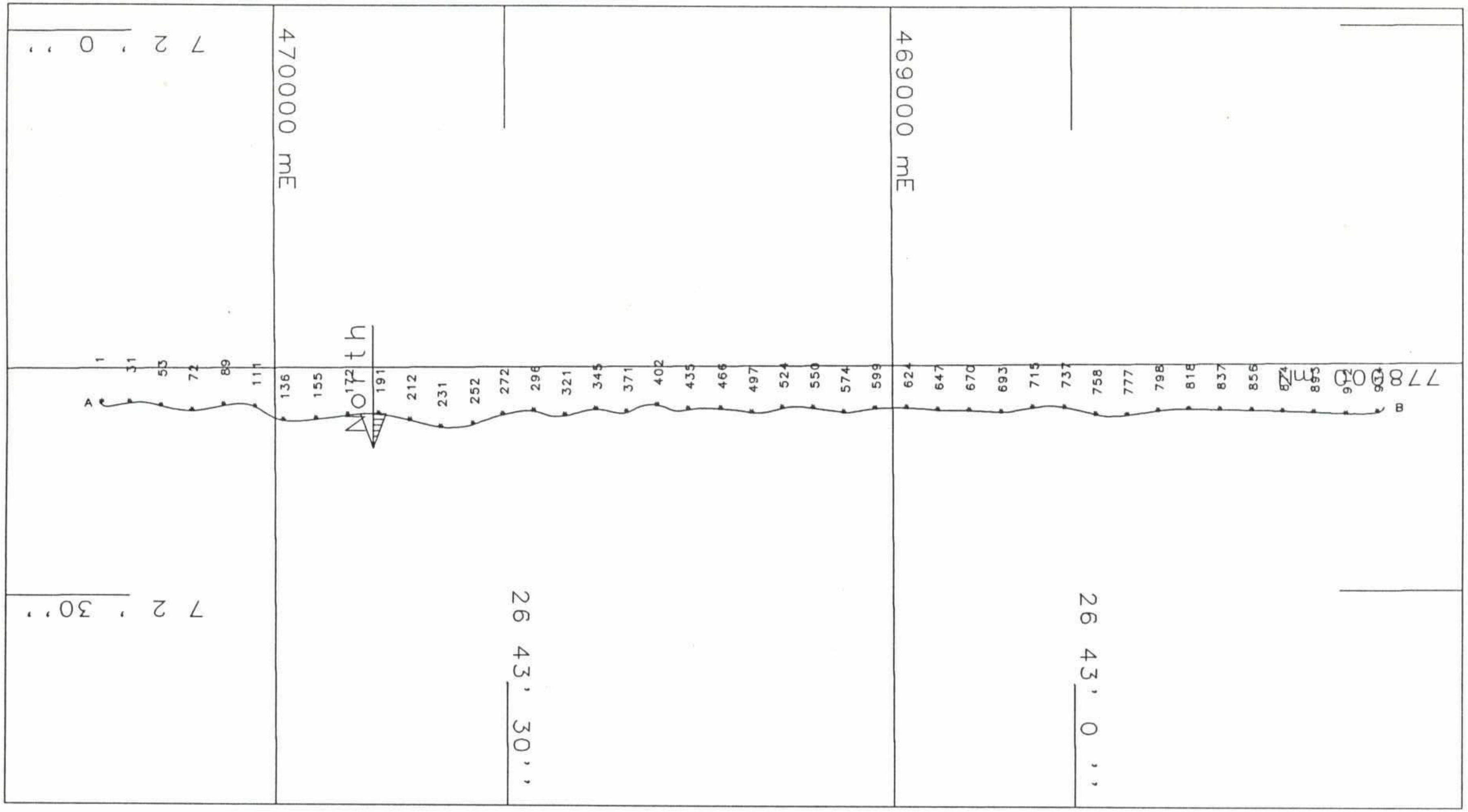
Init.	: MZH
Rev.	: A

Appr.

Id. No.

237



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Track : ——	Date : 921029	File : /u/f24adm/data/92-10-29/b2at1t1m
Fix nos. : *	Start Time : 10:45:20	Drawn : Sat Mar 20 11:38:24 1993
	End Time : 11:01:06	Type : Track Plot
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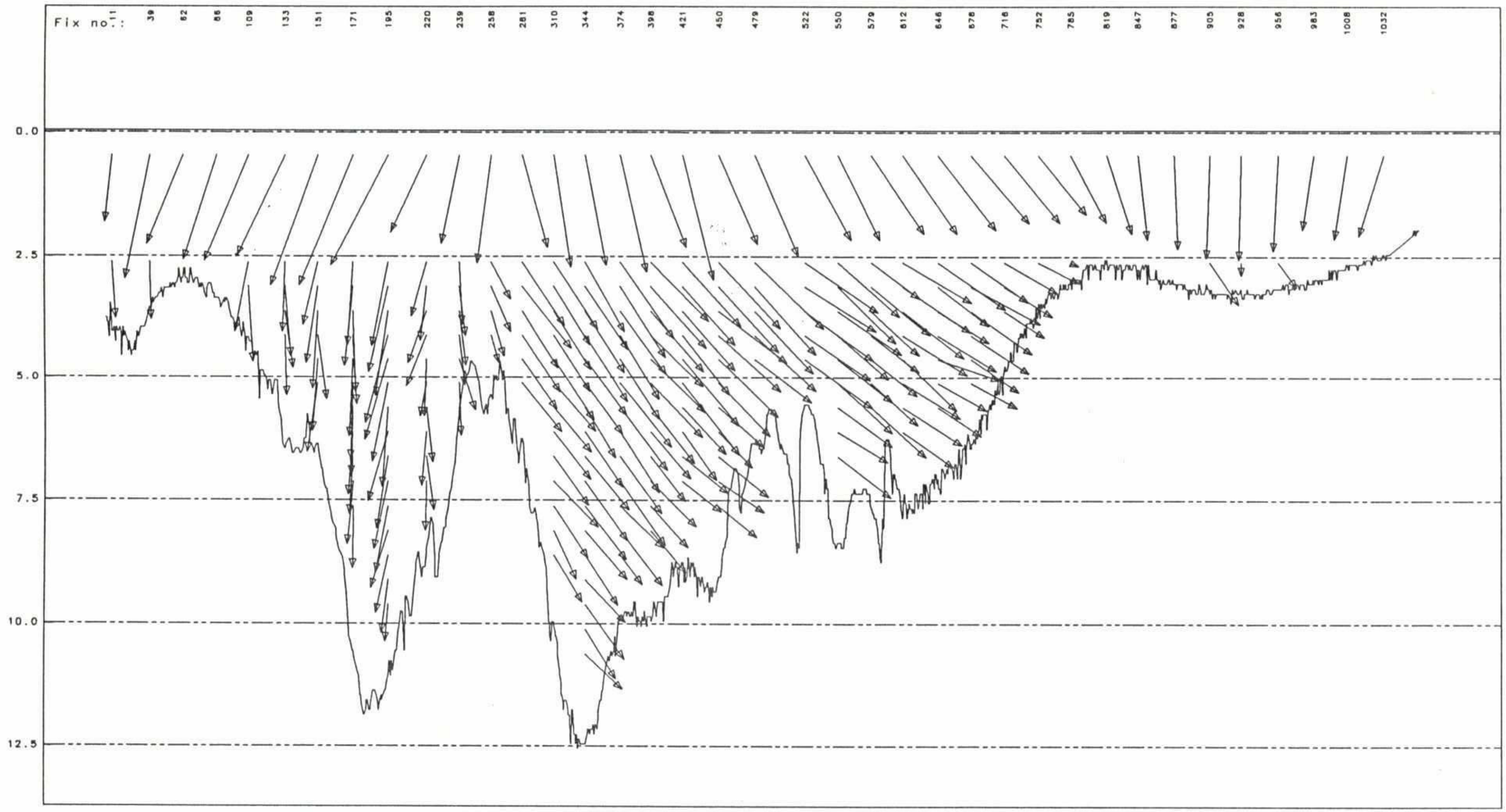
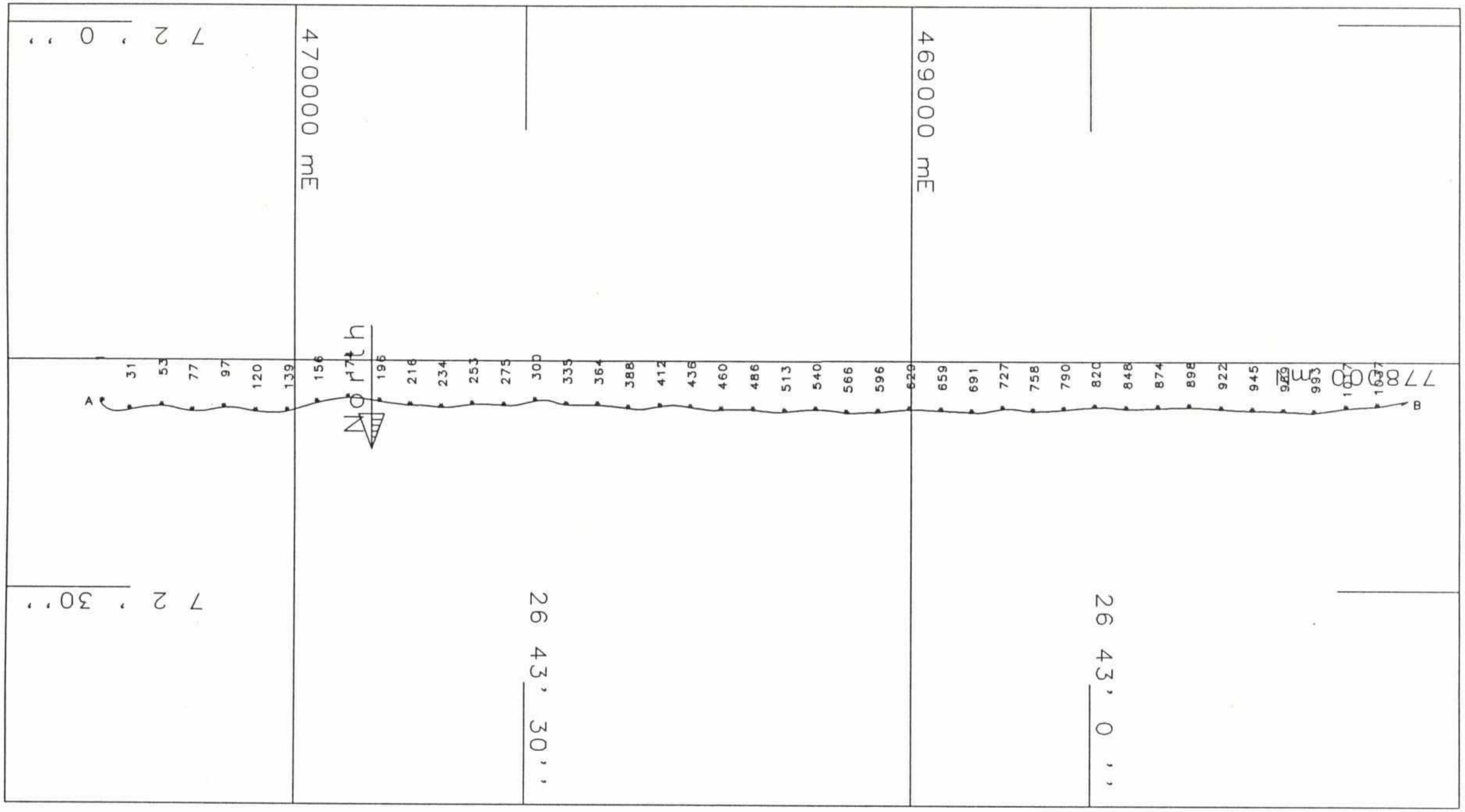
		Appr. / Id. No.



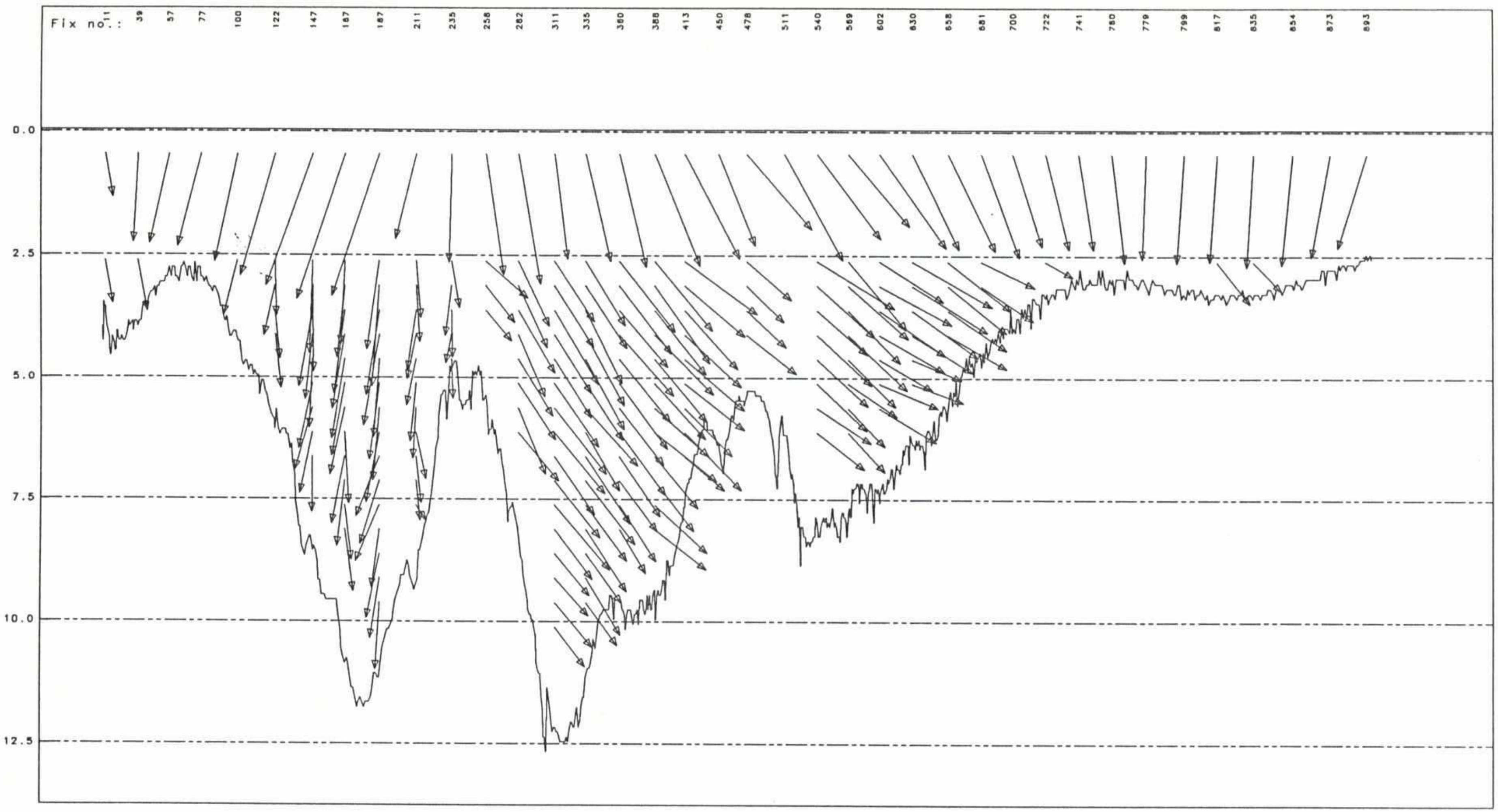
PROFILE CURRENT VELOCITY :	SURVEY ID. :	PLOT ID. :
Vertical Scale 1 : 10000 Horizontal Scale 1 : 125 North 1.00 m/s, East Seabed : —	Positions : BTM Date : 921029 Start Time : 11:30:01 End Time : 11:08:08 Start Position : 470316E 778069N End Posision : 468199E 778068N	Project : FAP 24 File : /u/f24adm/data/92-10-29/b2at1t3m Drawn : Sat Mar 20 15:23:53 1993 Type : Cross Section Init. : MZH Rev. : A Appr. Id. No.

29 D



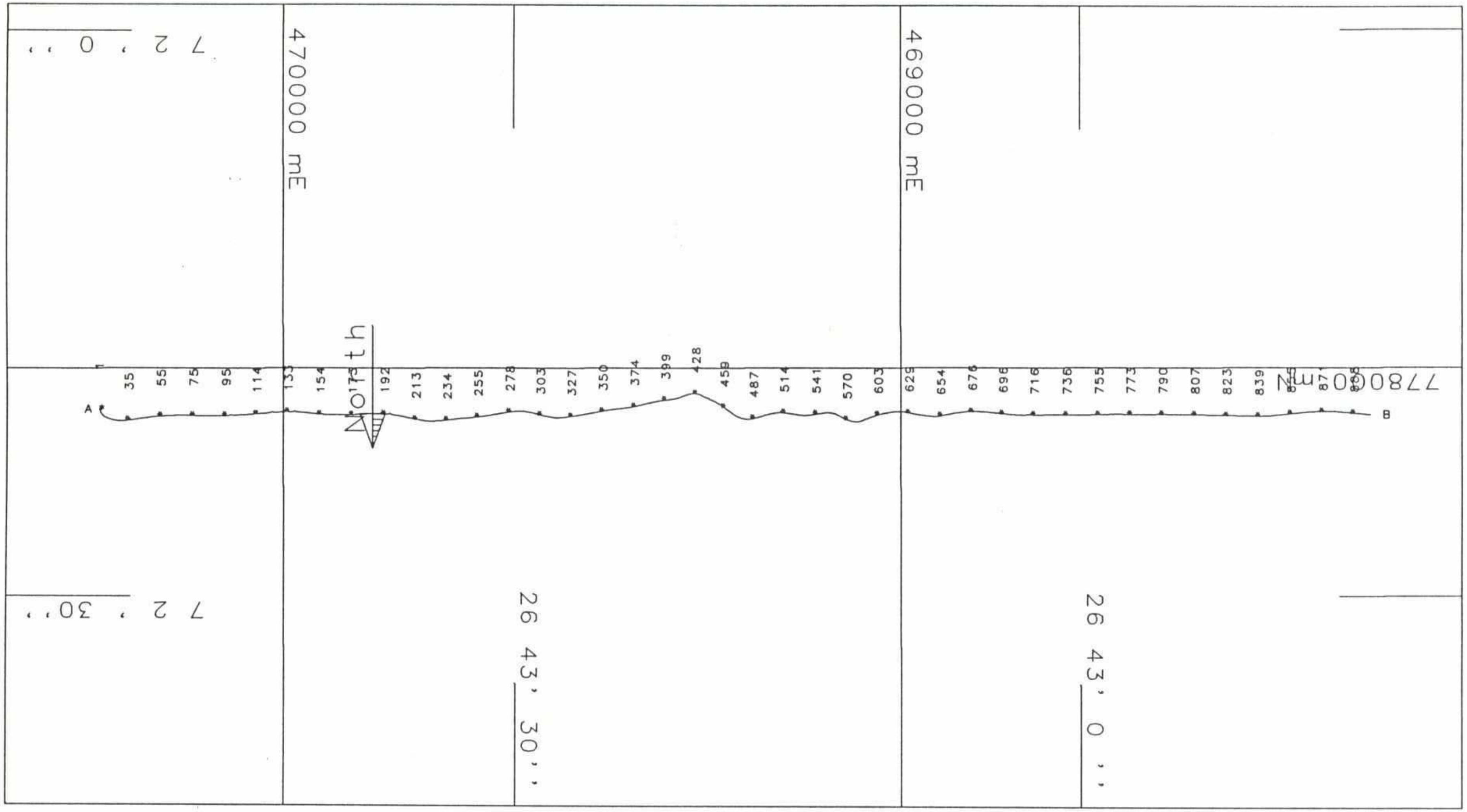
TRACK PLOT :	SURVEY ID. :	PLOT ID. :
Scale : 1 : 10000	Positions : BTM	Project : FAP 24
Track : ——	Date : 921029	File : /u/f24adm/data/92-10-29/b2at1t3m
Fix nos. : •	Start Time : 11:30:01	Drawn : Sat Mar 20 11:39:11 1993
	End Time : 11:08:08	Type : Track Plot
	Start Position : 470316E 778069N	Init. : MZH
	End Posision : 468199E 778068N	Rev. : A
		Appr.
		Id. No.

292



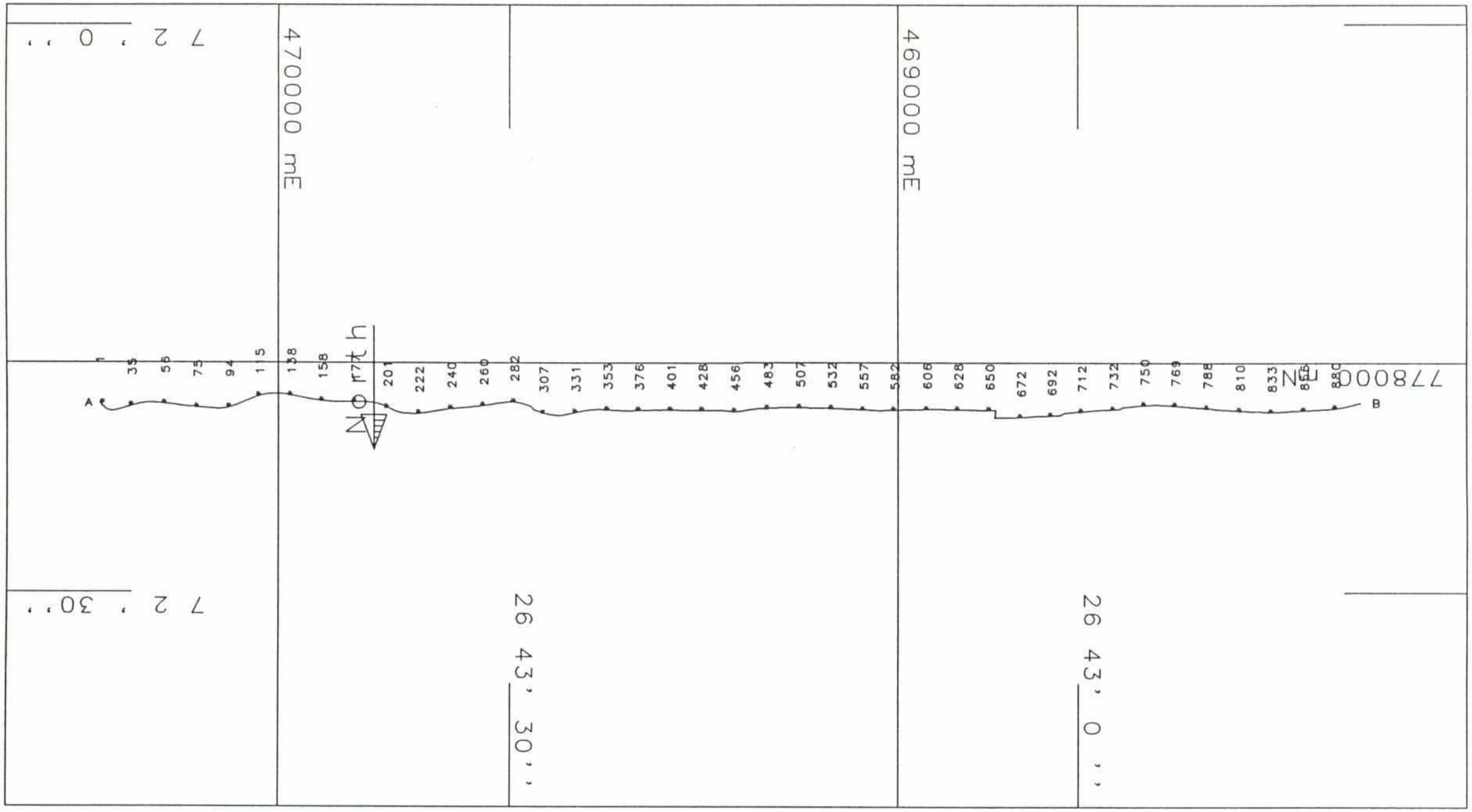
PROFILE CURRENT VELOCITY :	SURVEY ID. :	PLOT ID. :
Vertical Scale 1 : 10000	Positions : BTM	Project : FAP 24
Horizontal Scale 1 : 125	Date : 921029	File : /u/f24adm/data/92-10-29/b2at1t5m
North	Start Time : 16:05:05	Drawn : Sat Mar 20 15:24:26 1993
1.00 m/s, East	End Time : 16:20:01	Type : Cross Section
Seabed : —	Start Position : 470297E 778067N	Init. : MZH
	End Posision : 468234E 778076N	Rev. : A
		Appr.
		Id. No.

292



TRACK PLOT :	SURVEY ID. :	PLOT ID. :
Scale : 1 : 10000	Positions : BTM	Project : FAP 24
Track : ——	Date : 921029	File : /u/f24adm/data/92-10-29/b2at1t5m
Fix nos. : *	Start Time : 16:05:05	Drawn : Sat Mar 20 11:44:08 1993
	End Time : 16:20:01	Type : Track Plot
	Start Position : 470297E 778067N	Init. : MZH
	End Posision : 468234E 778076N	Rev. : A
		Appr. / Id. No.

296



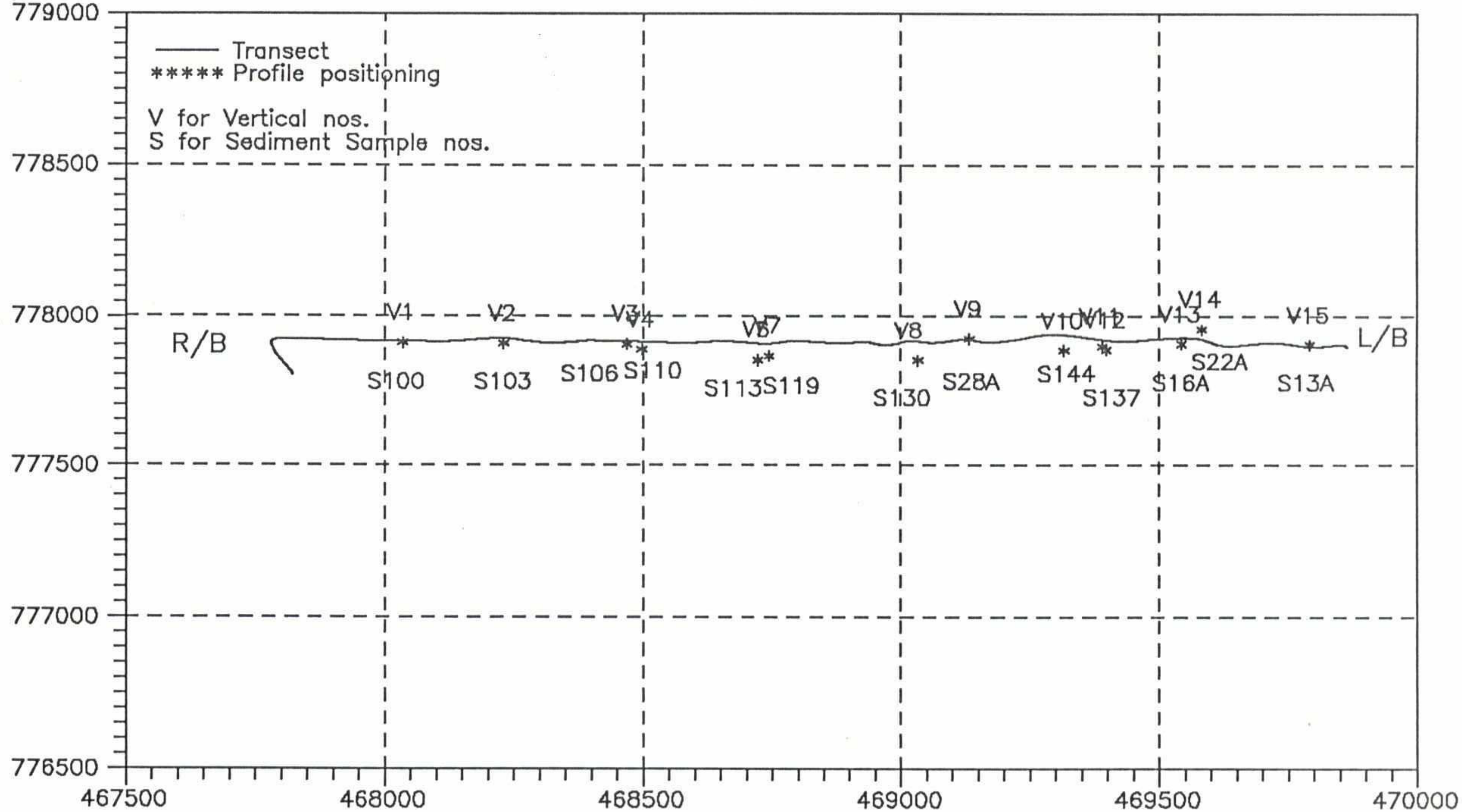
TRACK PLOT :	SURVEY ID. :	PLOT ID. :
Scale : 1 : 10000	Positions : BTM	Project : FAP 24
Track : ——	Date : 921031	File : /u/f24adm/data/92-10-31/b2av1t7m
Fix nos. : *	Start Time : 17:04:04	Drawn : Sat Mar 20 11:47:20 1993
	End Time : 17:19:16	Type : Track Plot
	Start Position : 470287E 778066N	Init. : MZH
	End Posision : 468248E 778065N	Rev. : A
		Appr. / Id. No.

298

River Survey Project (FAP 24)

Location : Jamuna River (Left Channel)

Date of Survey : 29/10/92, 30/10/92 and 31/10/92

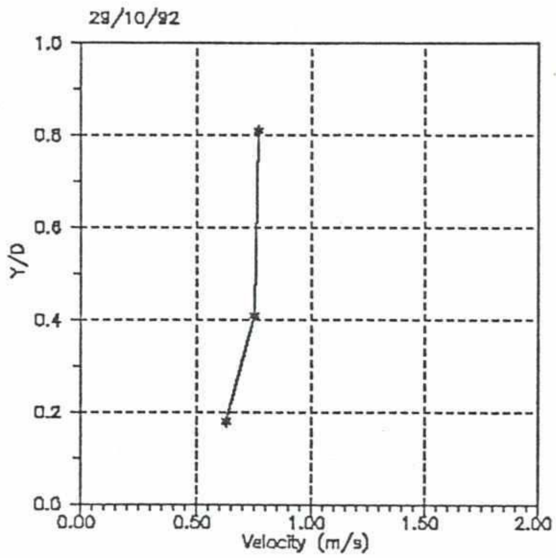


River Survey Project (FAP 24)

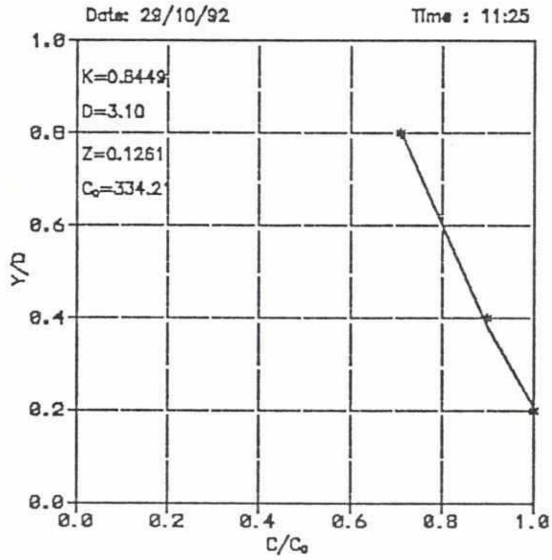
Location : Jamuna River (Left Channel)

Date of Survey : 29,30,31/10/92

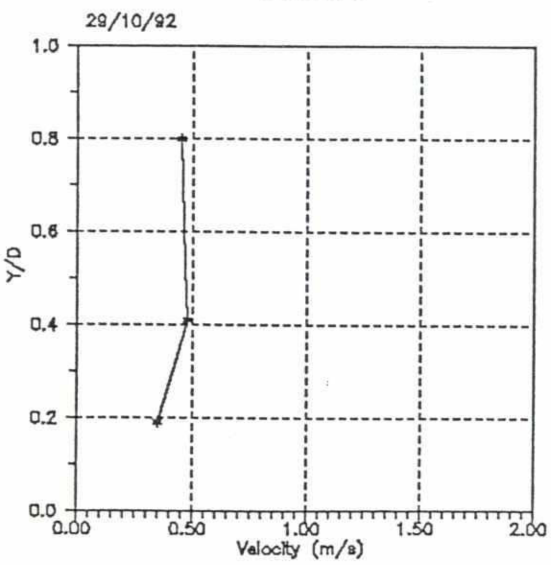
Vertical 1



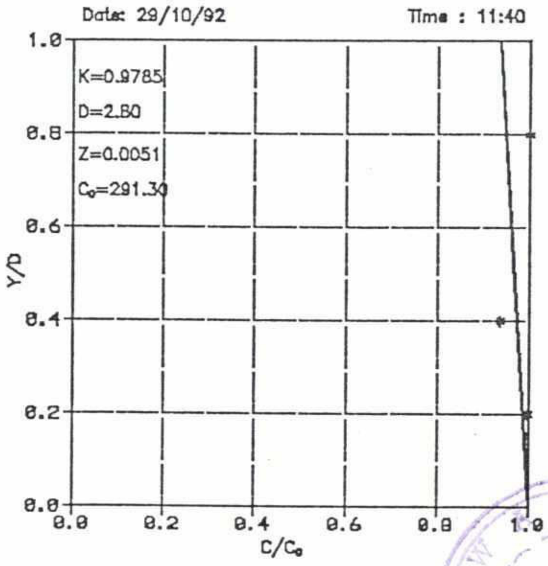
Sample S100



Vertical 2



Sample S103



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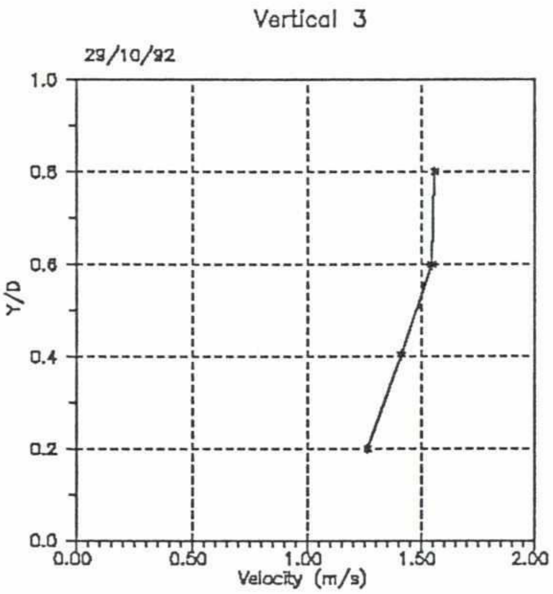
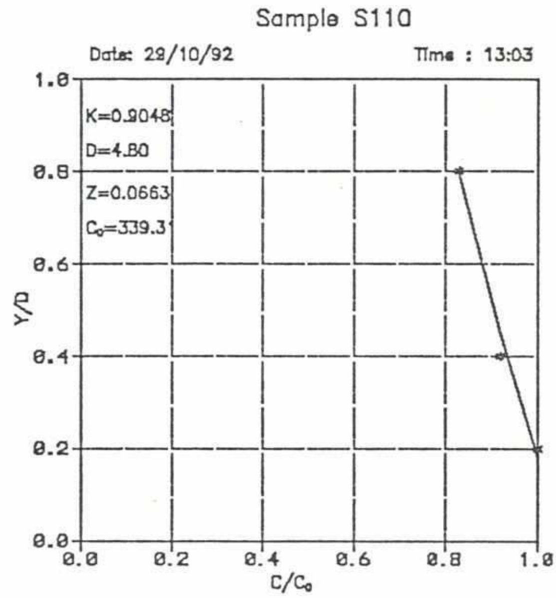
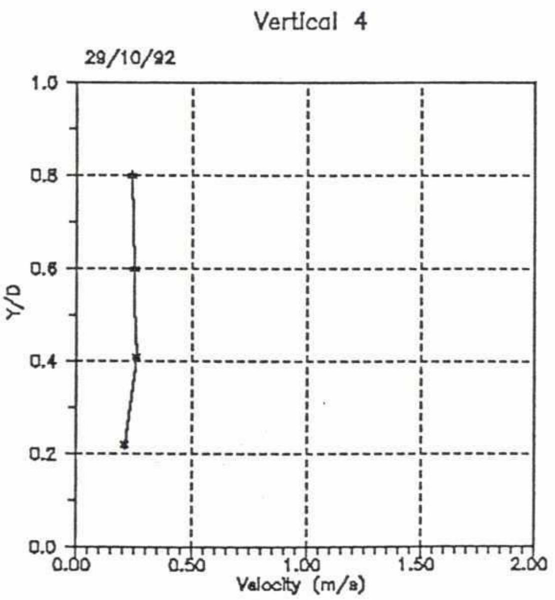
River Survey Project (FAP 24)

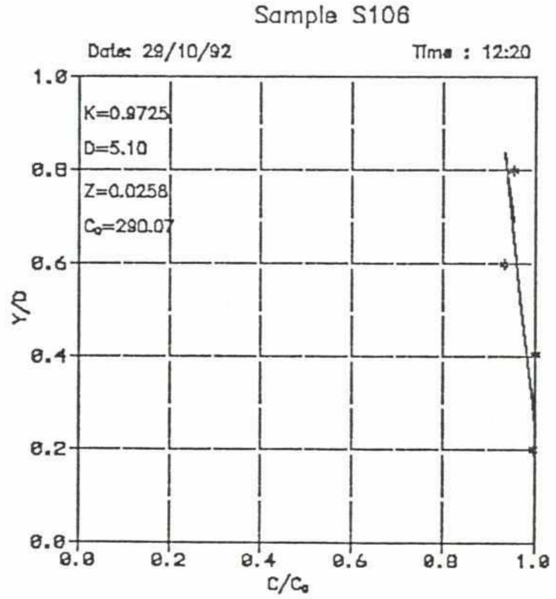
Location : Jamuna River (Left Channel)

Date of Survey : 29,30,31/10/92





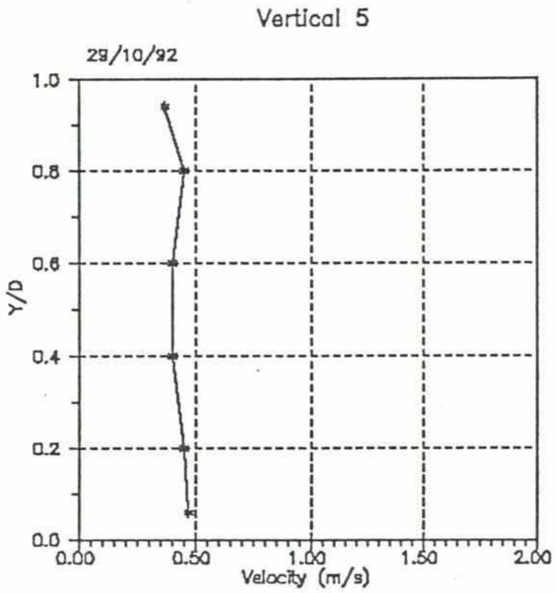


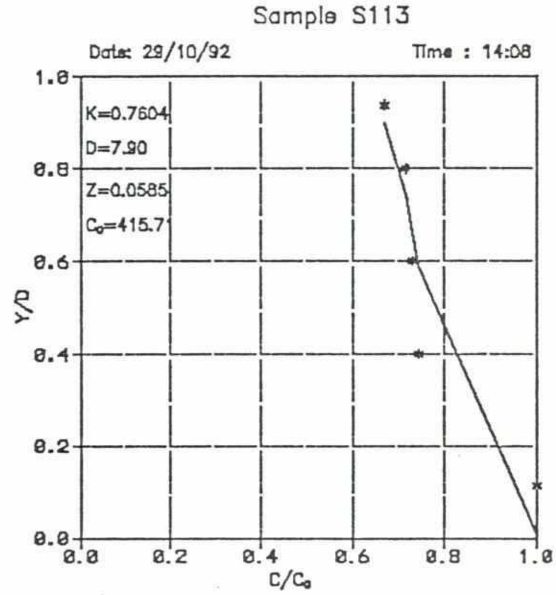


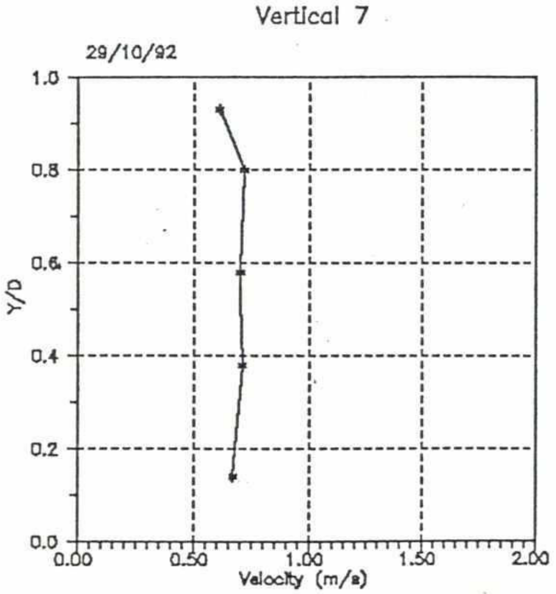
River Survey Project (FAP 24)

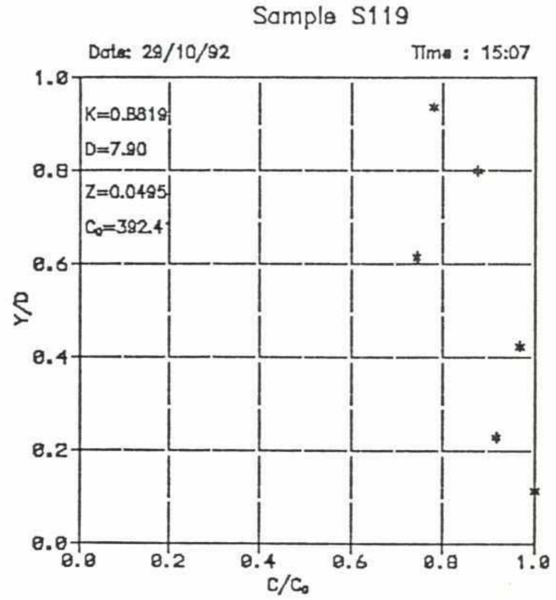
Location : Jamuna River (Left Channel)

Date of Survey : 29,30,31/10/92







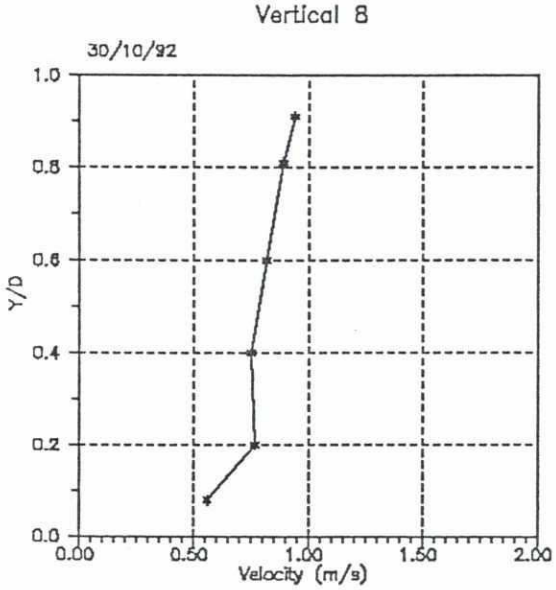


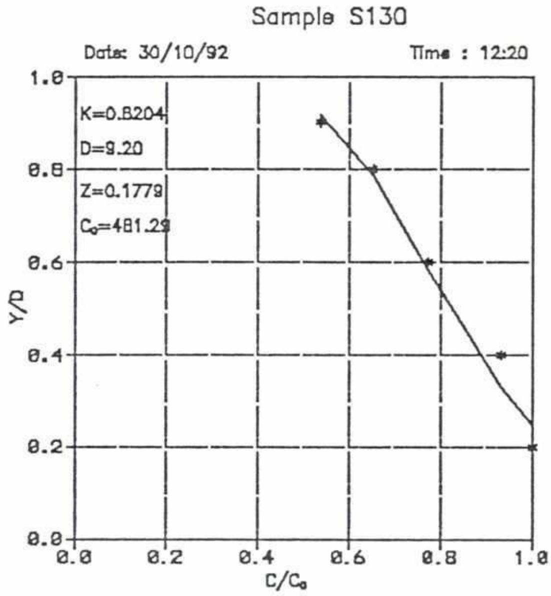
212

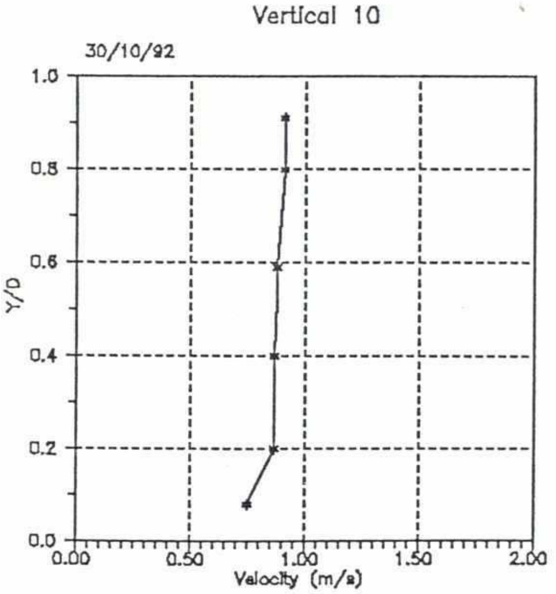
River Survey Project (FAP 24)

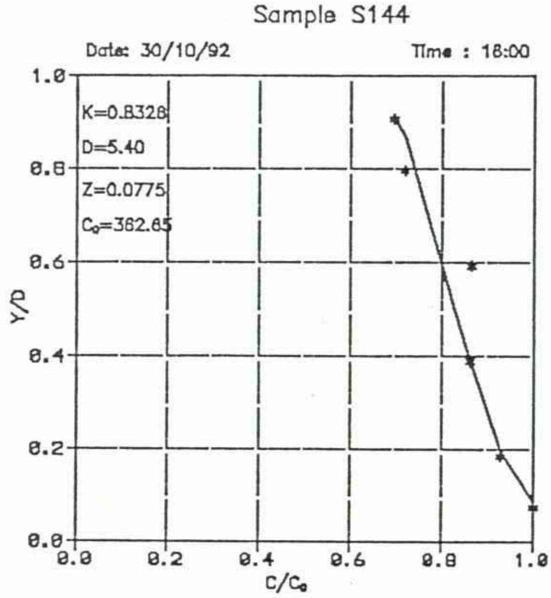
Location : Jamuna River (Left Channel)

Date of Survey : 29,30,31/10/92









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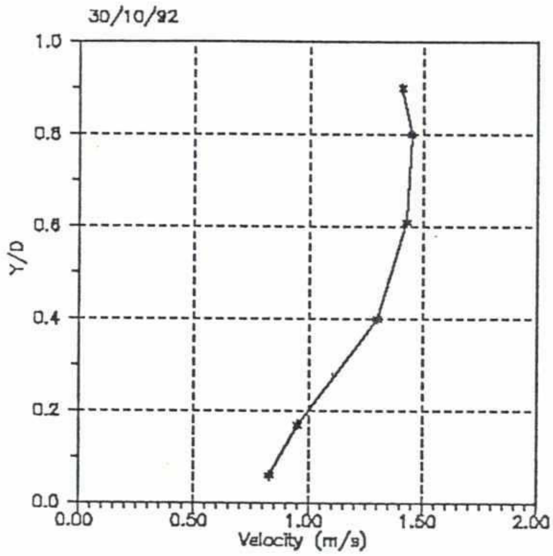
River Survey Project (FAP 24)

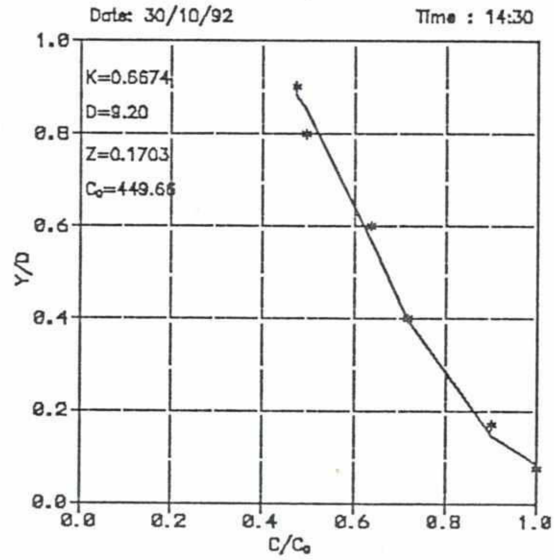
Location : Jamuna River (Left Channel)

Date of Survey : 29,30,31/10/92

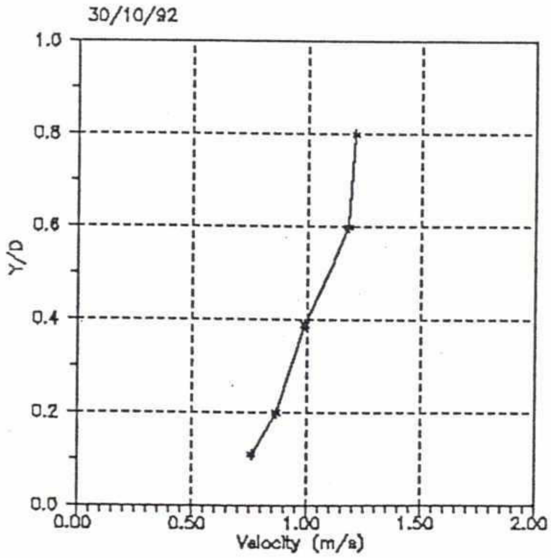
Vertical 11



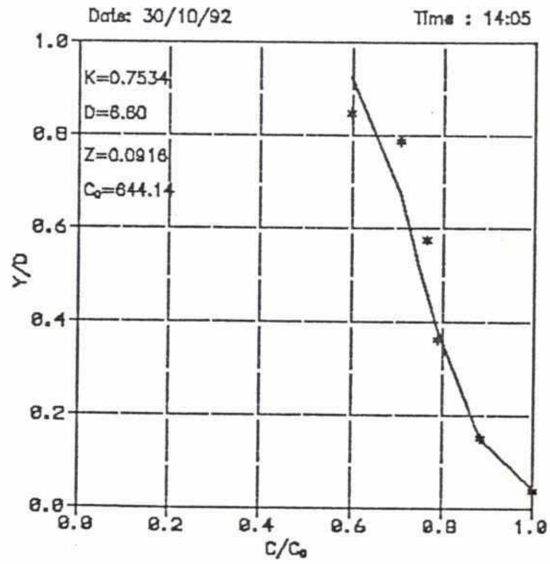
Sample S137



Vertical 13



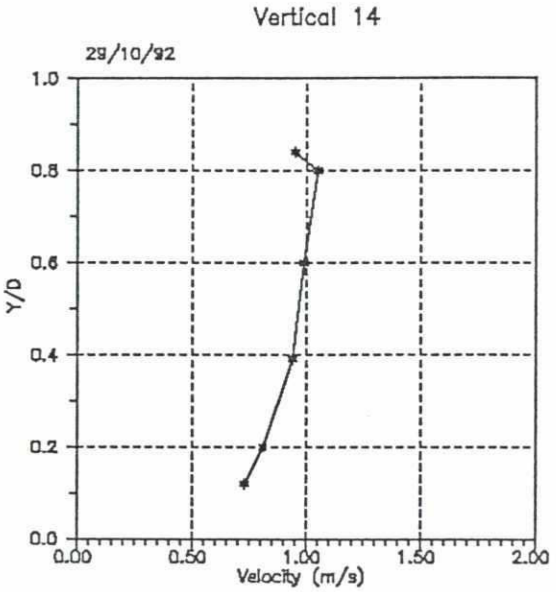
Sample S22A

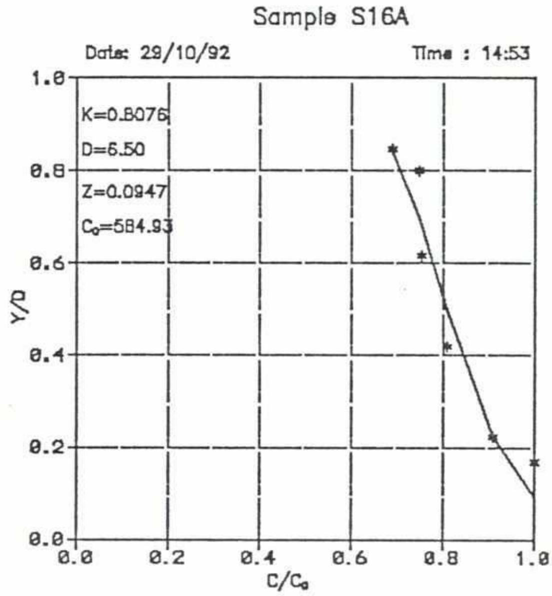


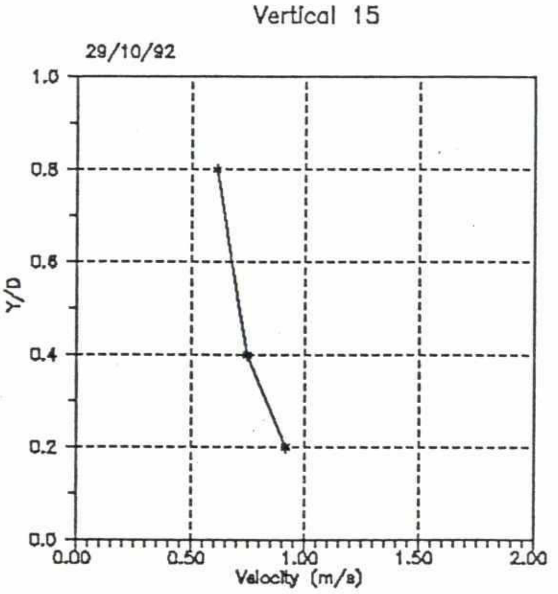
River Survey Project (FAP 24)

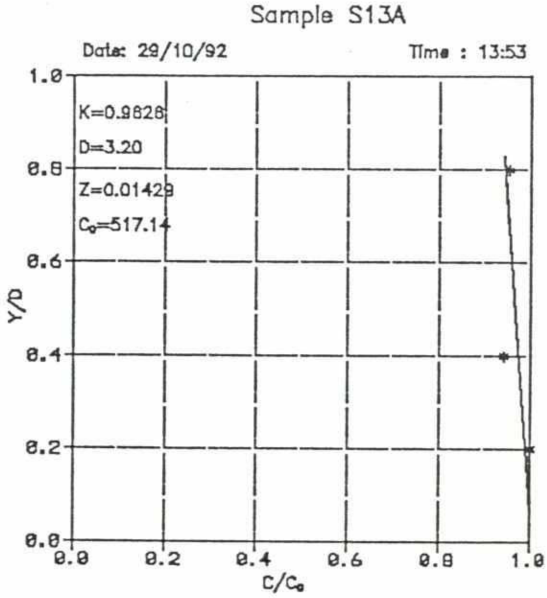
Location : Jamuna River (Left Channel)

Date of Survey : 29,30,31/10/92



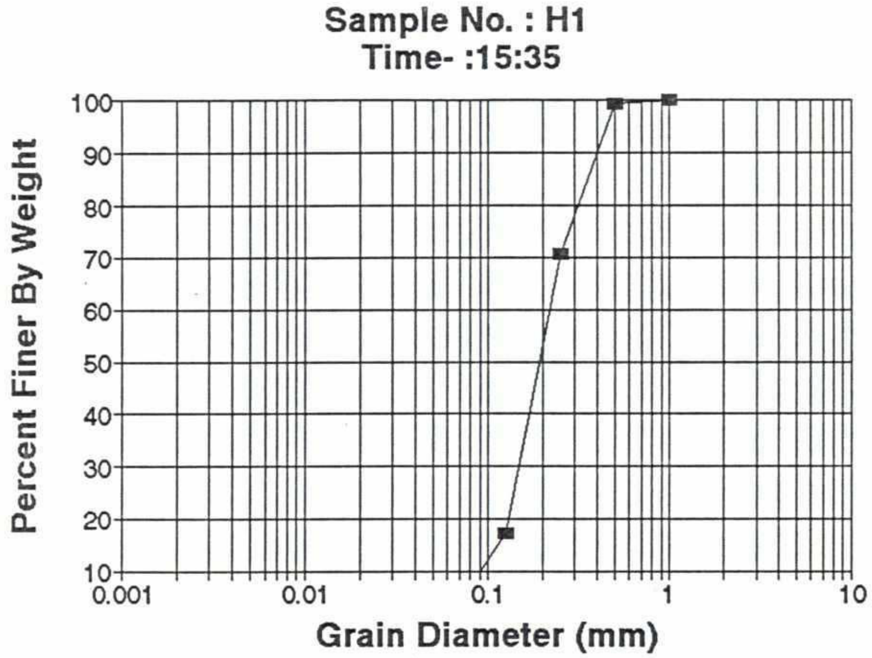






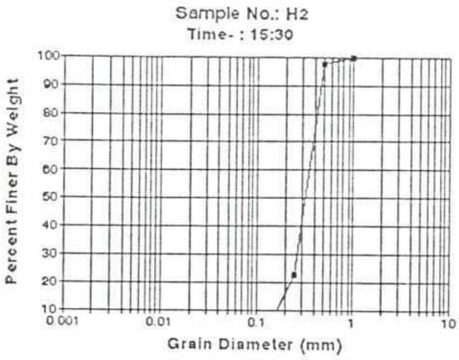
182

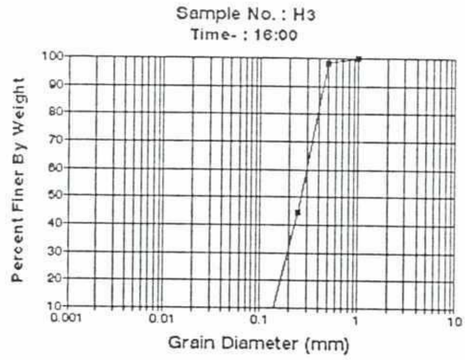
Grain Size Distribution Of Bed Load By Sieve Analysis (Helley-Smith Sampling)

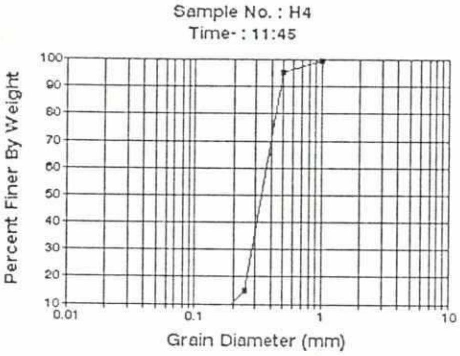


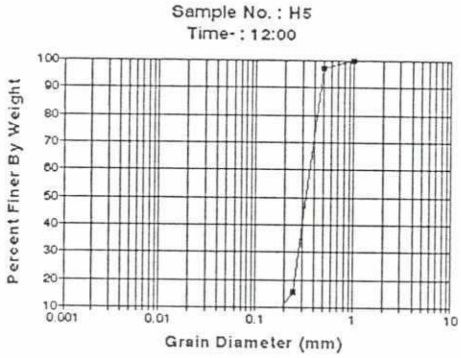
Collection Time	Collection Date	Total Weight(gm)	Transport Rate(Kg/M-S)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
15:35	30/10/92	336.000	0.037	0.158	0.191	0.232	1.598

Grain Size Distribution of Bed Load by Sieve Analysis (Helley-Smith Sampling)



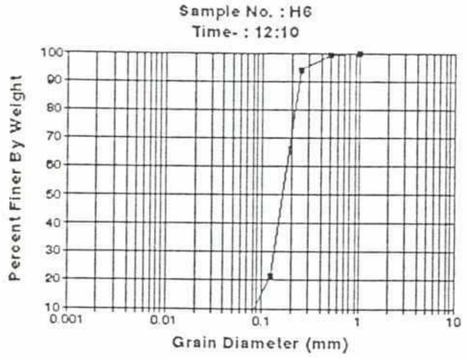


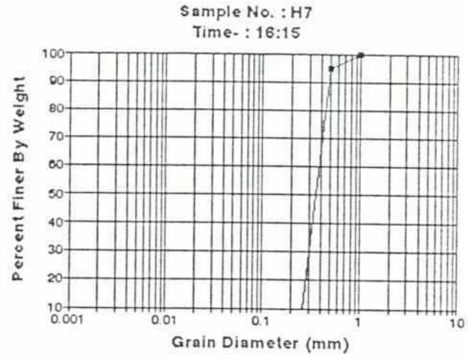


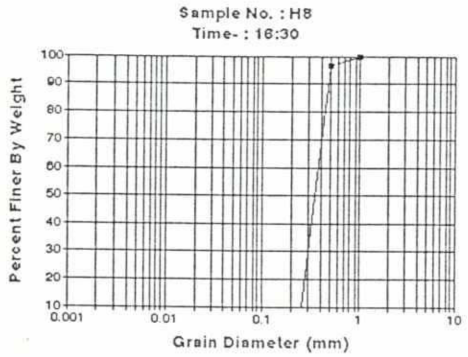


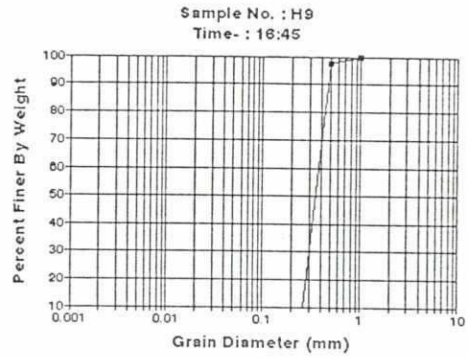
Collection Time	Collection Date	Total Weight(gm)	Transport Rate (Kg/M-S)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
15:30	30/10/92	124.000	0.00678	0.280	0.325	0.350	1.505
16:00	30/10/92	690.000	0.03773	0.213	0.268	0.326	1.511
11:45	31/10/92	41.179	0.00225	0.300	0.350	0.400	1.343
12:00	31/10/92	57.090	0.00312	0.300	0.350	0.400	1.343

Grain Size Distribution of Bed Load by Sieve Analysis (Helley-Smith Sampling)







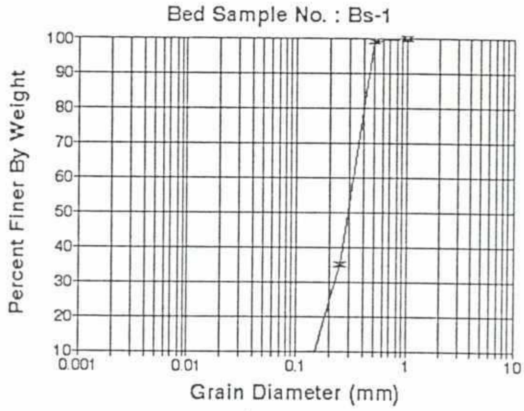


Collection Time	Collection Date	Total Weight(gm)	Transport Rate(Kg/M-S)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
12:10	31/10/92	486.000	0.02657	0.142	0.164	0.190	1.445
16:15	31/10/92	361.590	0.01977	0.319	0.357	0.399	1.267
16:30	31/10/92	436.500	0.02387	0.313	0.351	0.394	1.264
16:45	31/10/92	42.914	0.00235	0.315	0.352	0.393	1.265

Sieve Analysis Of Bed Material

Wet/Dry:	Dry	Position:	BT5X001 SOL DIST:1700
River:	Jamuna	Depth:	11.80m
Station:	Left Channel	Total Weight:	
Collection Date:	31/10/1992	Before Sieving Wt.:	100.503
Collection Time:	17:25	After Sieving Wt:	100.321
Sample Type:	BED MATERIAL	Loss:	0.181

Sieve Size (mm)	Material (gm)	Material (%)	Material <d (%)
1.000	0.028	0.027	99.973
0.500	0.705	0.703	99.270
0.250	64.267	64.061	35.209
0.125	34.515	34.404	0.805
0.063	0.668	0.665	0.139
Pan	0.140	0.139	0.000



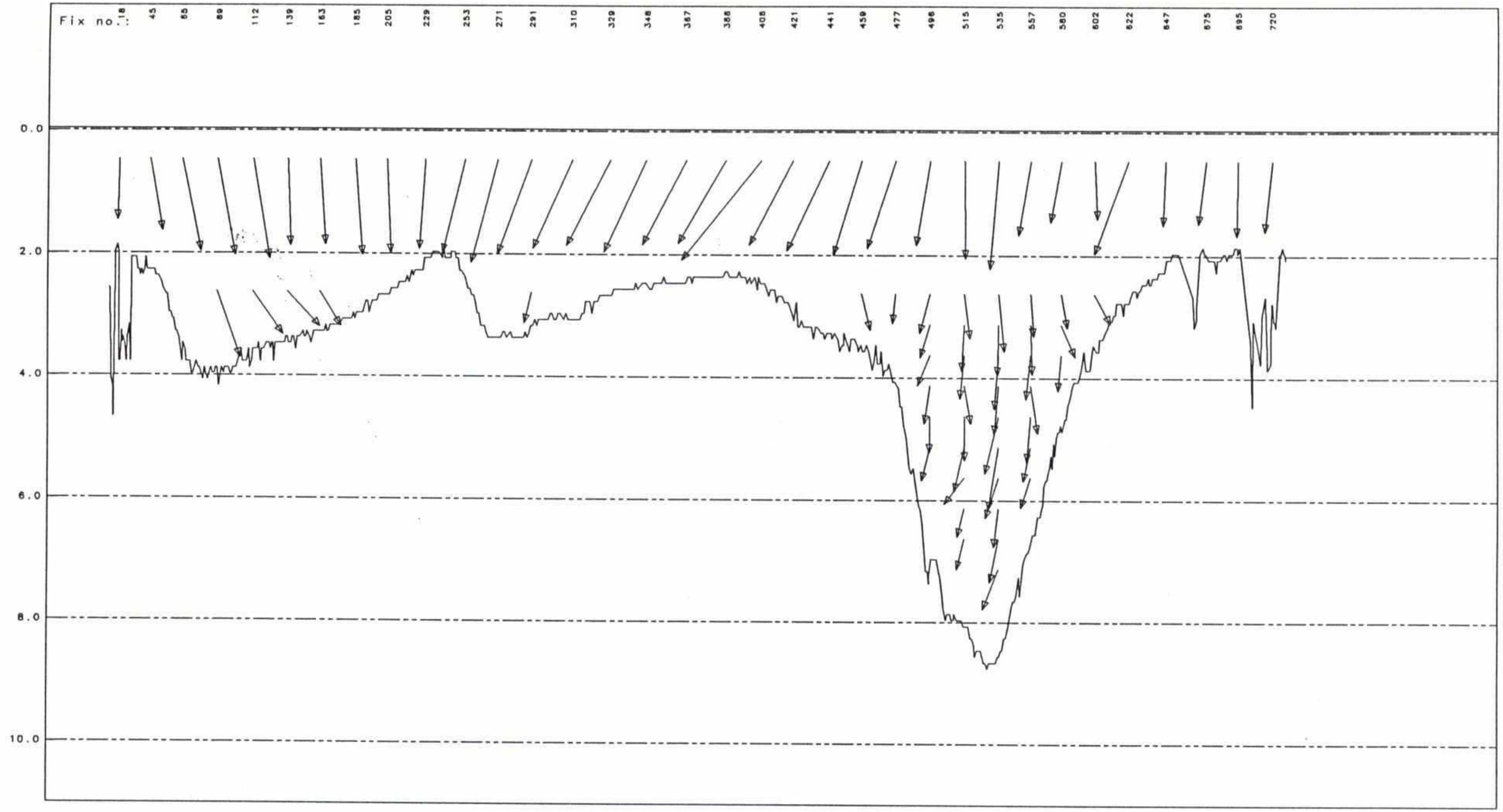
D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
0.249	0.293	0.345	1.578

RIVER SURVEY PROJECT (FAP-24)

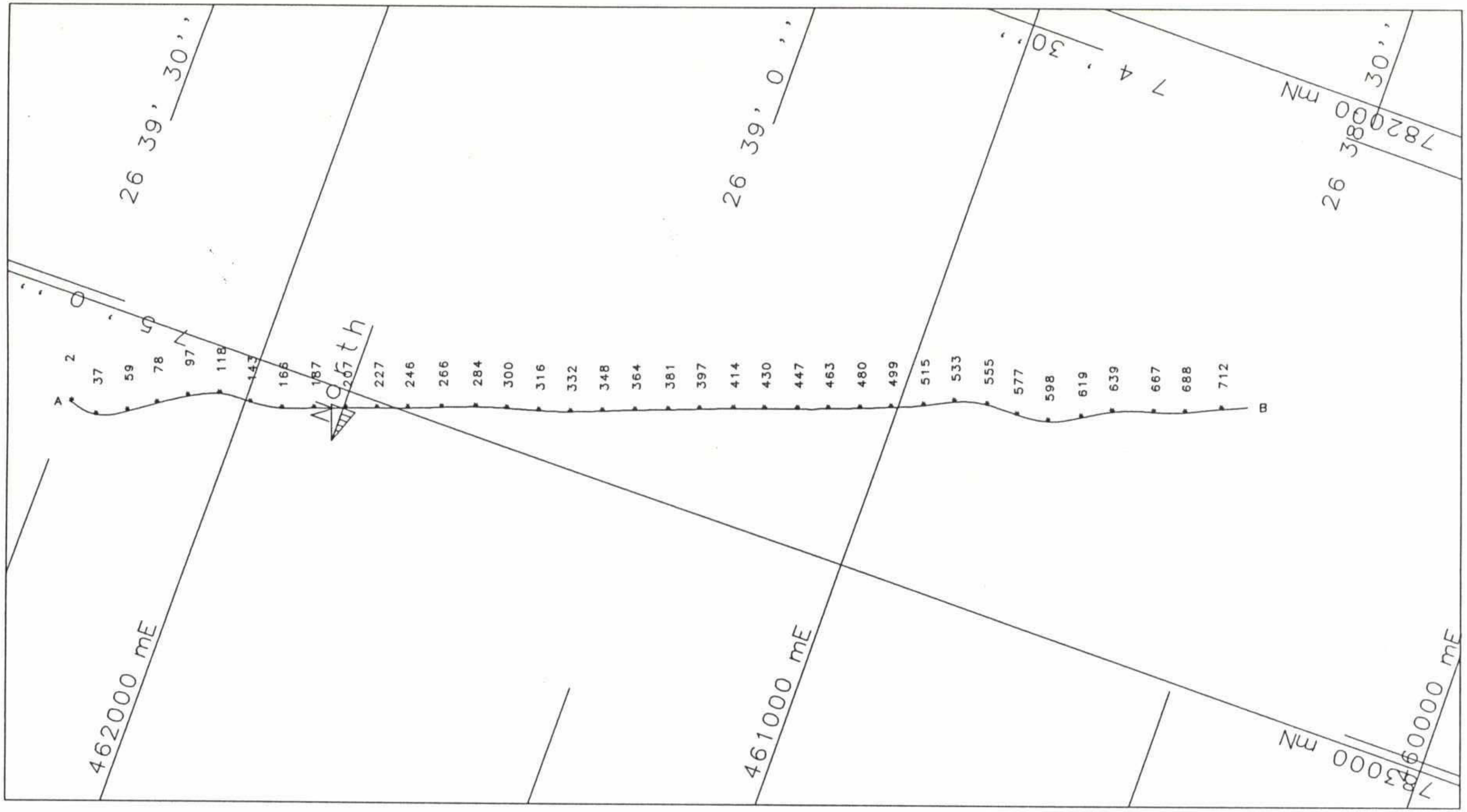
Location : Right Channal at Fulchari

Date of Survey : 03/11/92

Place of survey / Date/Channel	Type	Time From	Time To	File Name	Ver. No.	Easting	Northing	Q(ADCP) (on-line) (m3/s)	Q (off-line) (m3/s)	DISCHARGE GAUAING ADCP +++30	HYDRO +++50	EMF +++60	S4 +++70	MEX +++80	SEDIMENT TRANSPORT GAUGING Suspended Sediment Samples	Andreasen Tube Samples	Helley Smith Samples	Integrated Sediment Samples	Bottom Samples
Fulchari	Transect	09.58.40	10.13.52	B2B31T01				1641		T	T	T							
03/11/92	Transect	00.00.00	10.31.16	B2B31T02				1641		T	T	T							
Right/West Ch.																			
	Profile	12.02.50	13.11.05	B2B31P01	5	460481.5	782526.4			P	P	P	P	P	34-39A	34A	H10-H12		
	Profile	14.07.42	15.18.21	B2B31P02	4	460436.3	782396.3			P	P	P	P	P	46-51A		H13-H15	1 No.	
	Profile	15.21.50	16.36.11	B2B31P03	3	460427.0	782486.9			P	P	P	P	P	52-57A		H16-H17	1 No.	
	Profile			B2B31P04						P	P	P	P	P			H18-H20	1 No.	
	Profile	12.20.47	12.38.39	B2B32P01	14	461723.8	782939.4				P		P		200-202C	203C			
	Profile	12.51.00	13.07.51	B2B32P02	15	461823.7	782751.5				P		P		204-206C	211C			
	Profile	13.26.46	12.44.03	B2B32P03	12	461445.2	782846.9				P		P		208-210C				
	Profile	14.01.24	14.21.06	B2B32P04	13	461476.3	782776.5				P		P		212-214C				
	Profile	14.34.32	14.50.04	B2B32P05	10	461160.9	782768.5				P		P		215-217C	218C			
	Profile	15.01.28	15.17.37	B2B32P06	11	461203.2	782683.3				P		P		219-221C				
	Profile	15.25.56	15.40.17	B2B32P07	8	460912.5	782686.4				P		P		222-224C	225C			
	Profile	15.54.39	16.07.20	B2B32P08	9	460966.8	782560.1				P		P		226-228C				
	Profile	16.19.28	16.33.59	B2B32P09	6	460745.2	782609.0				P		P		229-231C				
	Profile	16.45.16	16.59.14	B2B32P10	7	460781.5	782518.3				P		P		233-235C				
	Profile	17.07.14	17.23.02	B2B32P11	1	460172.1	782429.7				P		P		236-238C	239C			
	Profile	17.34.02	17.49.21	B2B32P12	2	460217.8	782324.0				P		P		240-242C				
	Transect	18.26.12	18.39.32	B2B31T04				1654		T	T	T							



PROFILE CURRENT VELOCITY :	SURVEY ID. :	PLOT ID. :
Vertical Scale 1 : 10000	Positions : BTM	Project : FAP 24
Horizontal Scale 1 : 100	Date : 921103	File : /u/f24adm/data/92-11-03/b2b31t02
North	Start Time : 10:19:02	Drawn : Sat Mar 20 14:59:33 1993
1.00 m/s, East	End Time : 10:31:15	Type : Cross Section
Seabed : —	Start Position : 462268E 783168N	Init. : MZH
	End Posision : 460463E 782531N	Rev. : A
		Appr. / Id. No.



TRACK PLOT :	SURVEY ID. :	PLOT ID. :
Scale : 1 : 10000	Positions : BTM	Project : FAP 24
Track : ——	Date : 921103	File : /u/f24adm/data/92-11-03/b2b31t02
Fix nos. : •	Start Time : 10:19:02	Drawn : Sat Mar 20 10:49:17 1993
	End Time : 10:31:15	Type : Track Plot
	Start Position : 462268E 783168N	Init. : MZH
	End Posision : 460463E 782531N	Rev. : A
		Appr. / Id. No.

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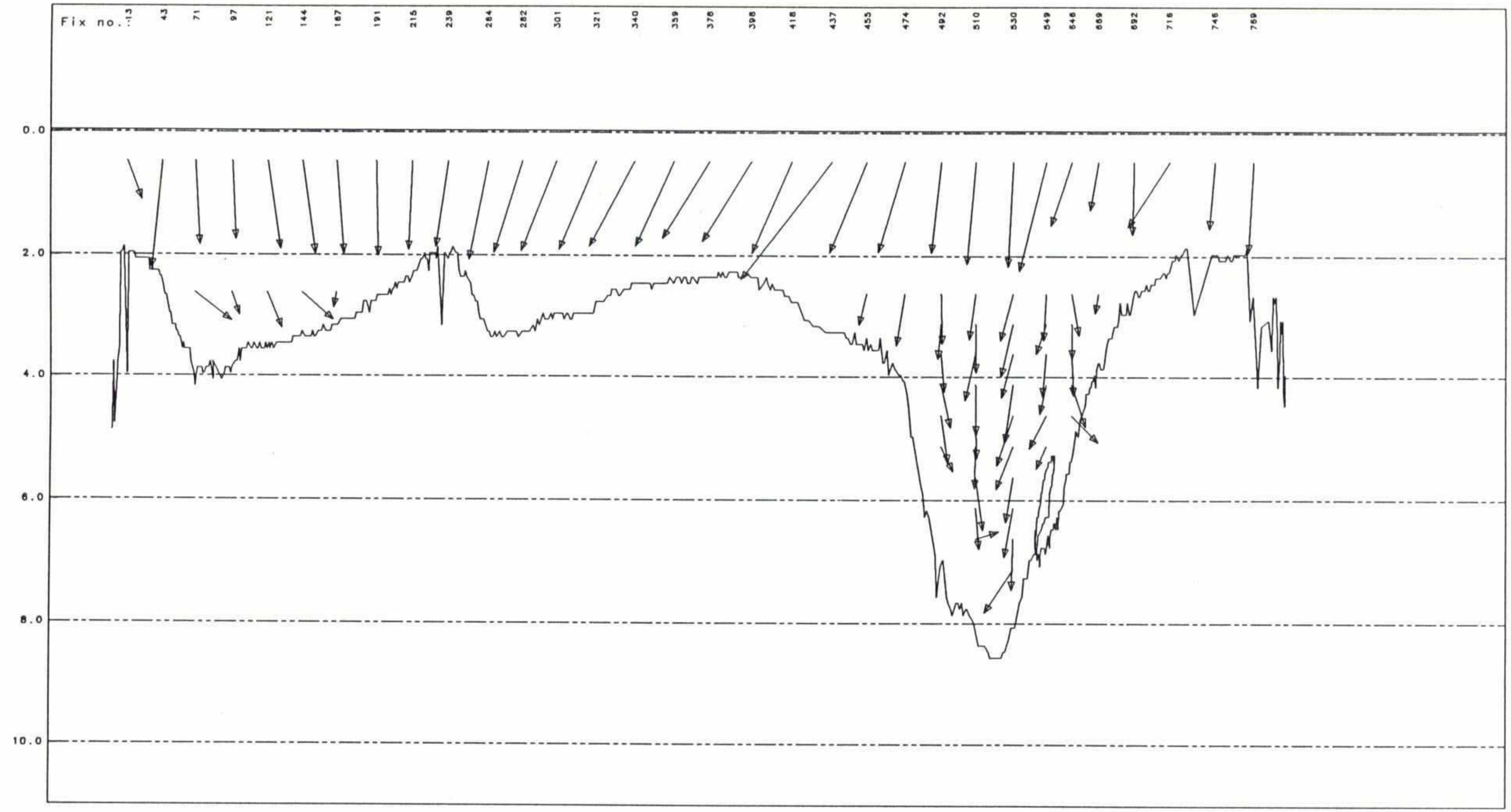
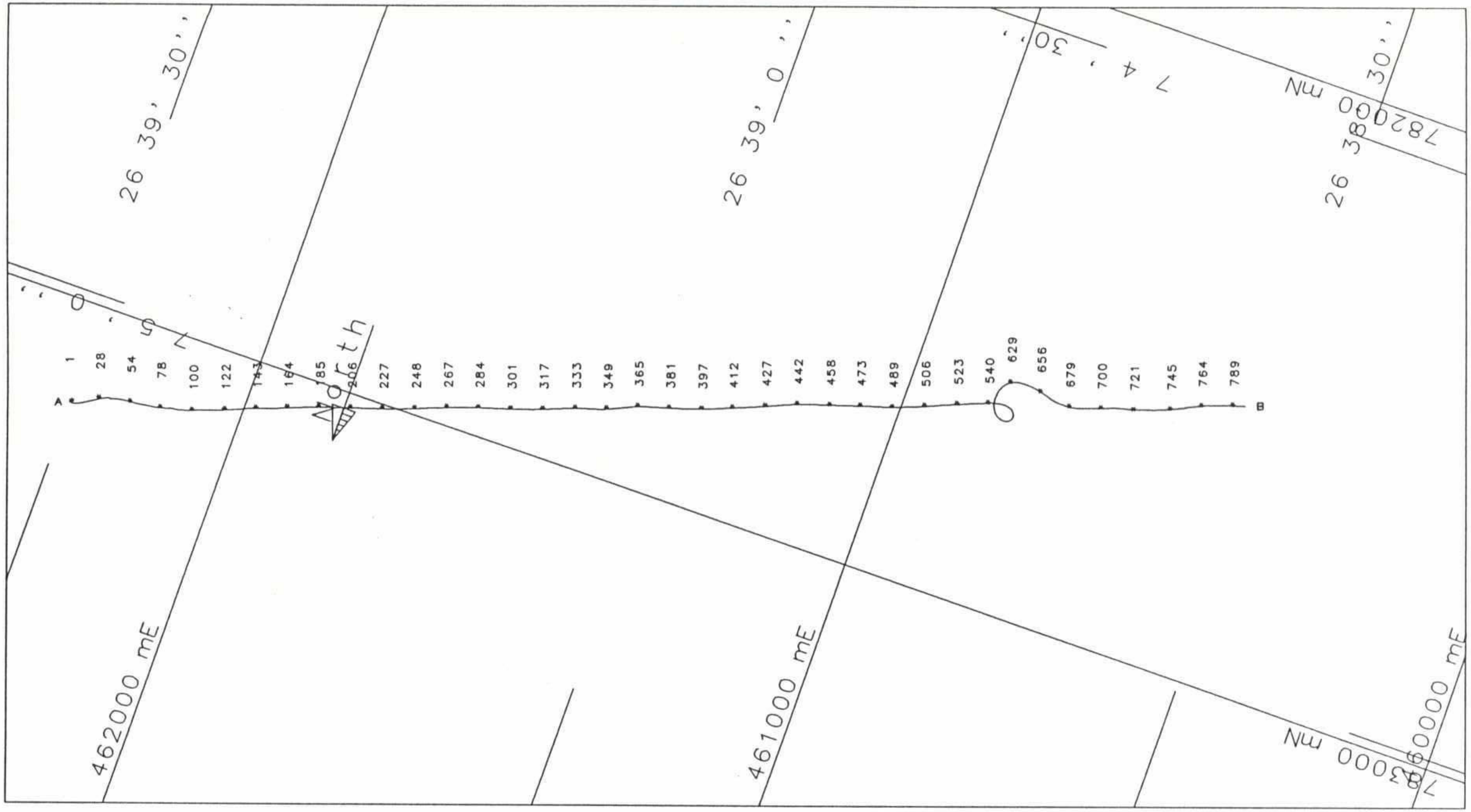


PROFILE CURRENT VELOCITY :	SURVEY ID. :	PLOT ID. :
Vertical Scale 1 : 10000	Positions : BTM	Project : FAP 24
Horizontal Scale 1 : 100	Date : 921103	File : /u/f24adm/data/92-11-03/b2b31t04
North	Start Time : 18:26:12	Drawn : Sat Mar 20 15:00:09 1993
1.00 m/s, East	End Time : 18:39:32	Type : Cross Section
Seabed : —	Start Position : 462269E 783165N	Init. : MZH
	End Posision : 460474E 782539N	Rev. : A
		Appr. / Id. No.



TRACK PLOT :

Scale	:	1 : 10000
Track	:	——
Fix nos.	:	•

SURVEY ID. :

Positions	:	BTM
Date	:	921103
Start Time	:	18:26:12
End Time	:	18:39:32
Start Position	:	462269E 783165N
End Posision	:	460474E 782539N

PLOT ID. :

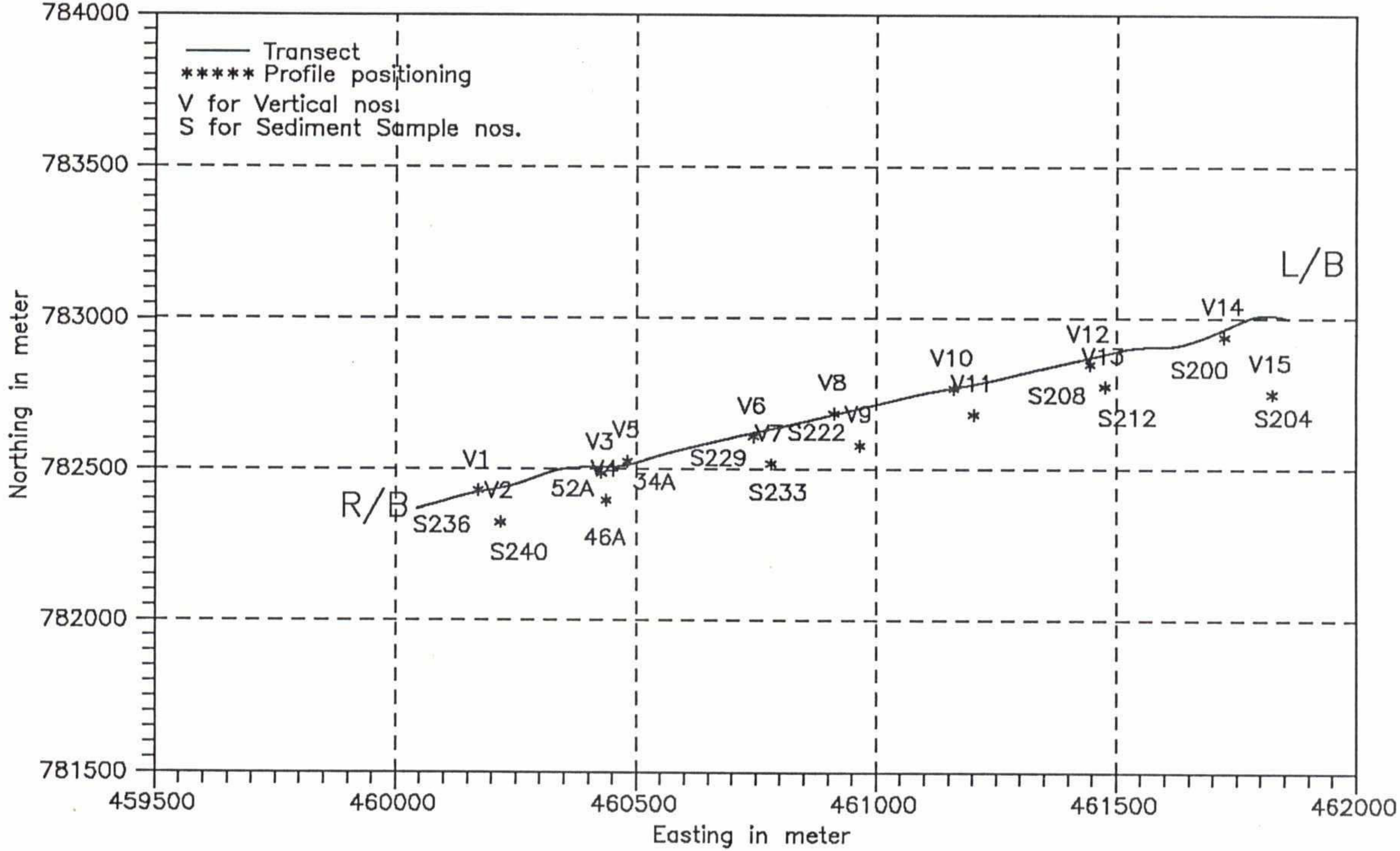
Project	:	FAP 24
File	:	/u/f24adm/data/92-11-03/b2b31t04
Drawn	:	Sat Mar 20 10:46:41 1993
Type	:	Track Plot
Init.	:	MZH
Rev.	:	A

Appr.	Id. No.

River Survey Project (FAP 24)

Location : Jamuna River (Right Channel)

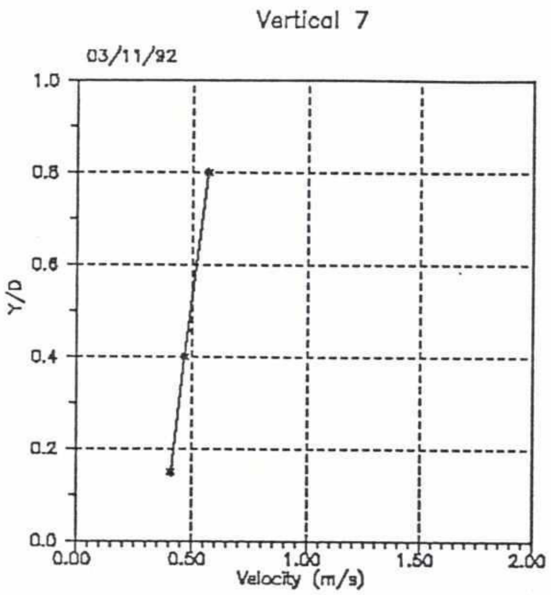
Date of Survey : 03/11/92

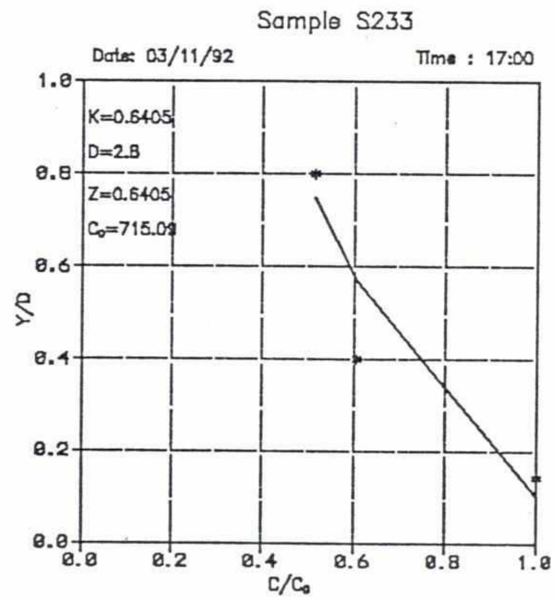


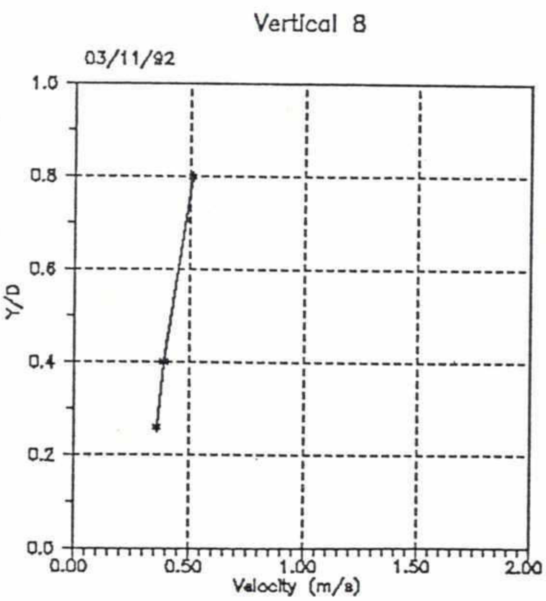
River Survey Project (FAP 24)

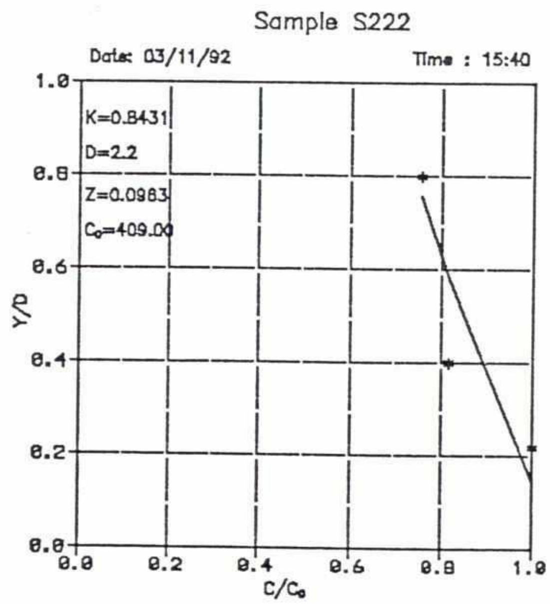
Location : Jamuna River (Right Channel)

Date of Survey : 03/11/92





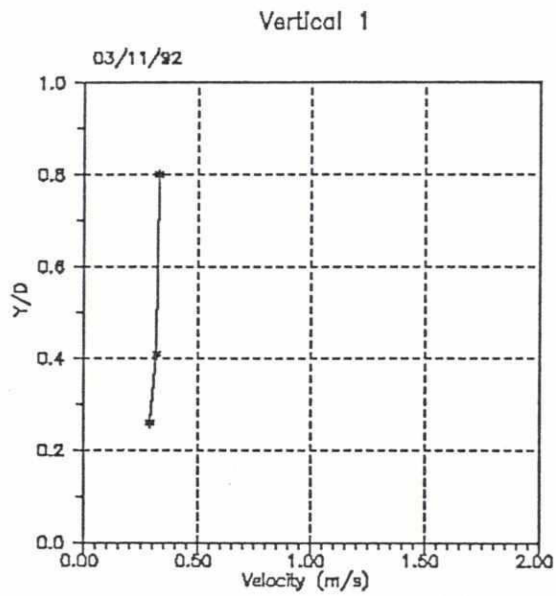


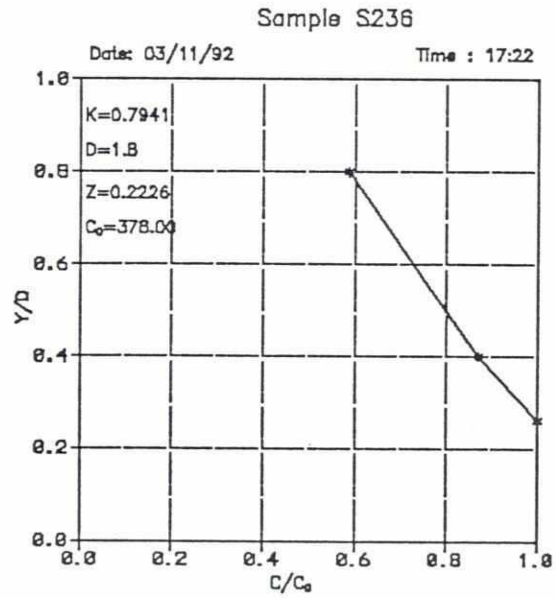


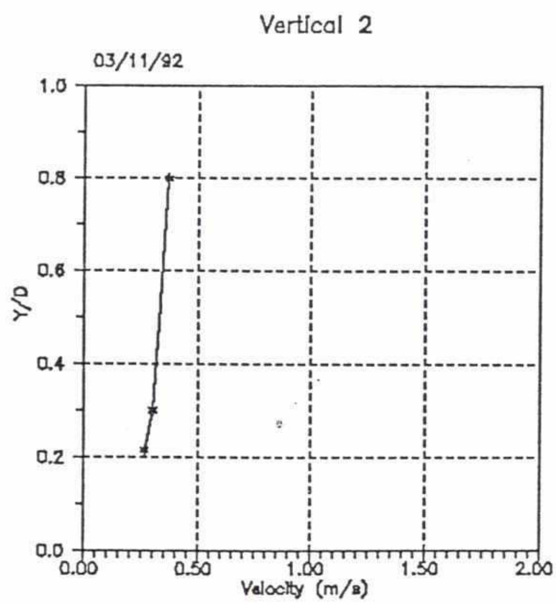
River Survey Project (FAP 24)

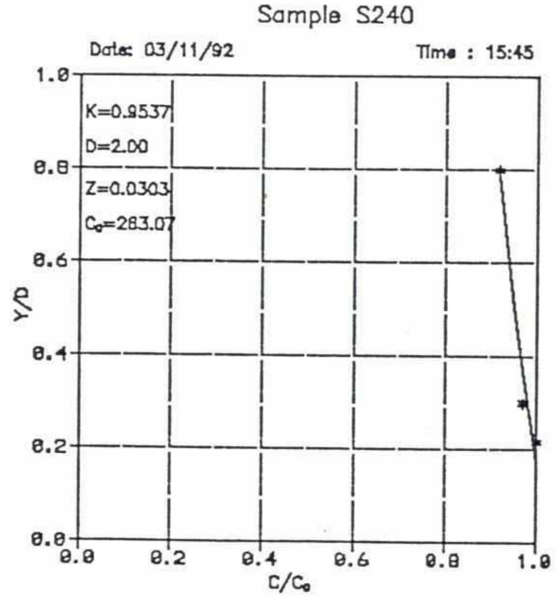
Location : Jamuna River (Right Channel)

Date of Survey : 03/11/92





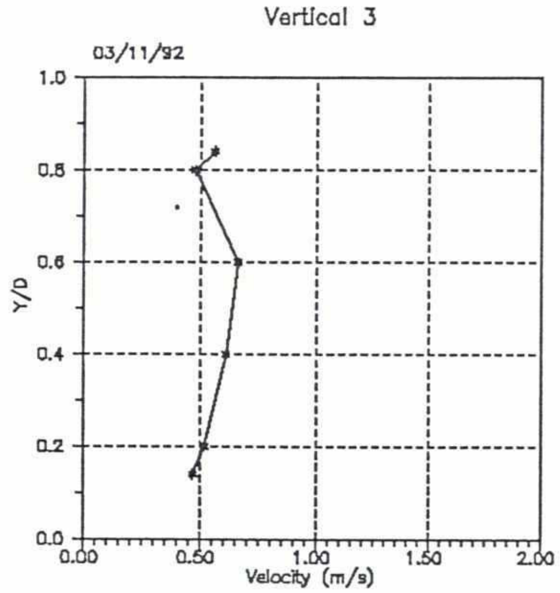


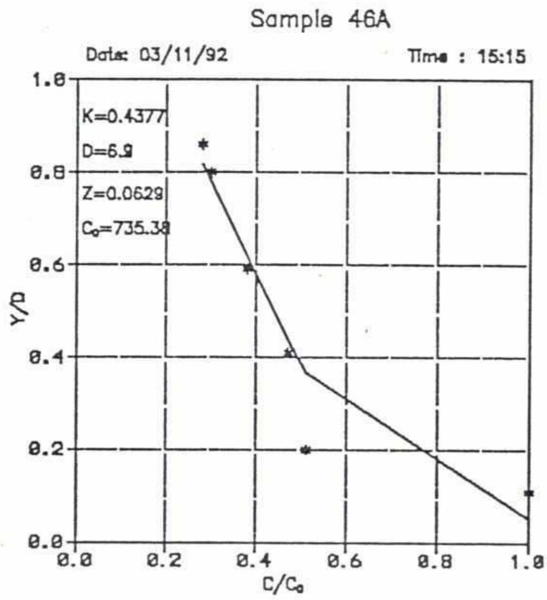


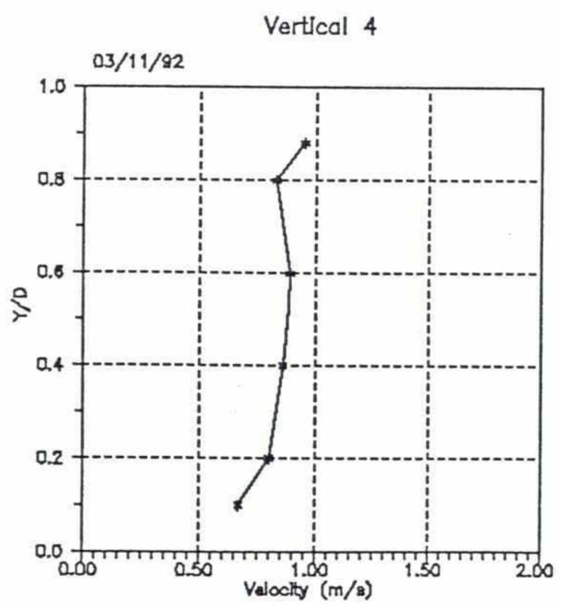
River Survey Project (FAP 24)

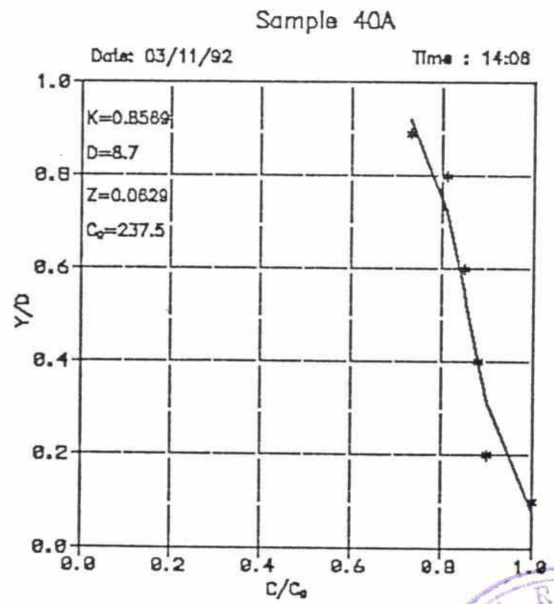
Location : Jamuna River (Right Channel)

Date of Survey : 03/11/92









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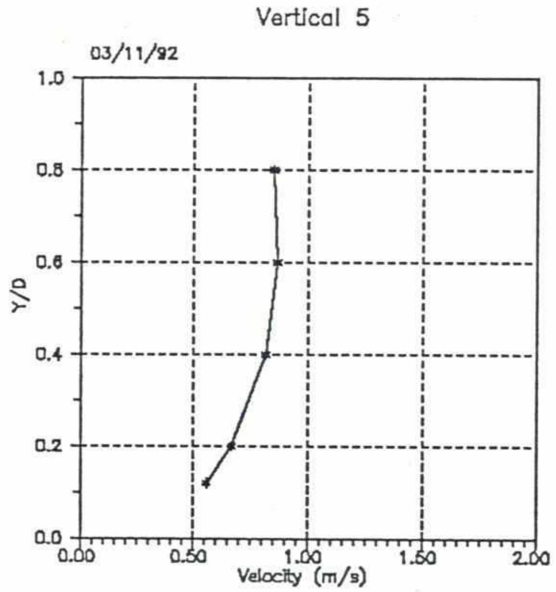
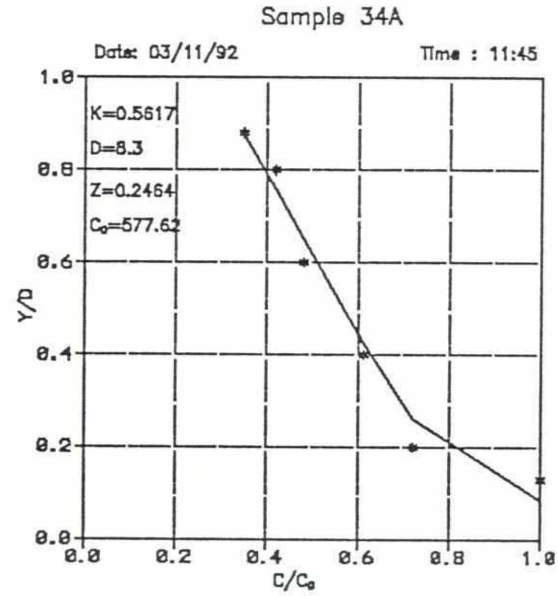
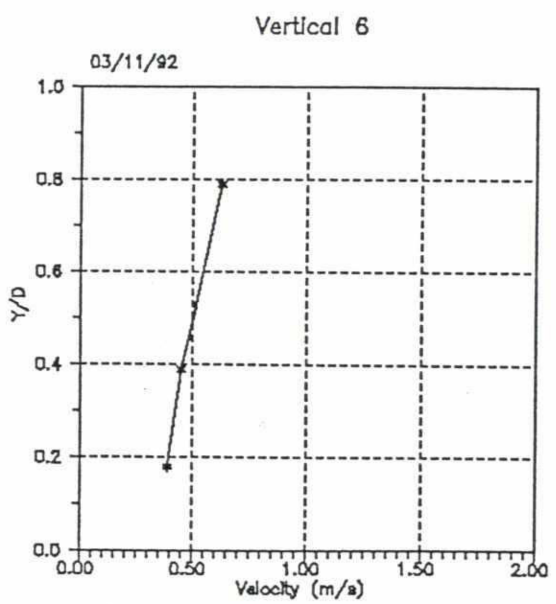
River Survey Project (FAP 24)

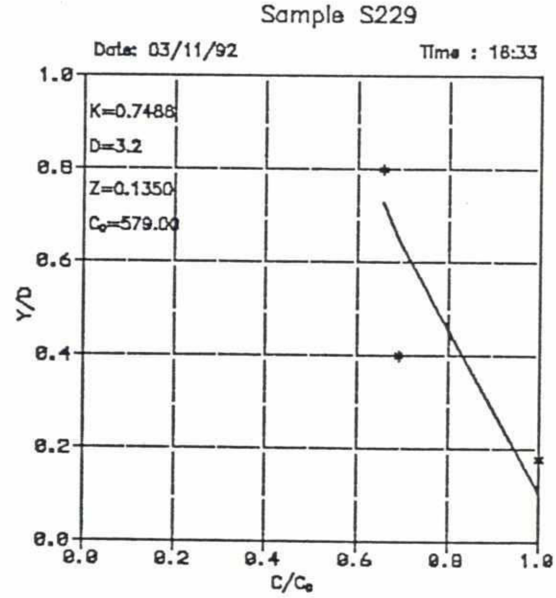
Location : Jamuna River (Right Channel)

Date of Survey : 03/11/92





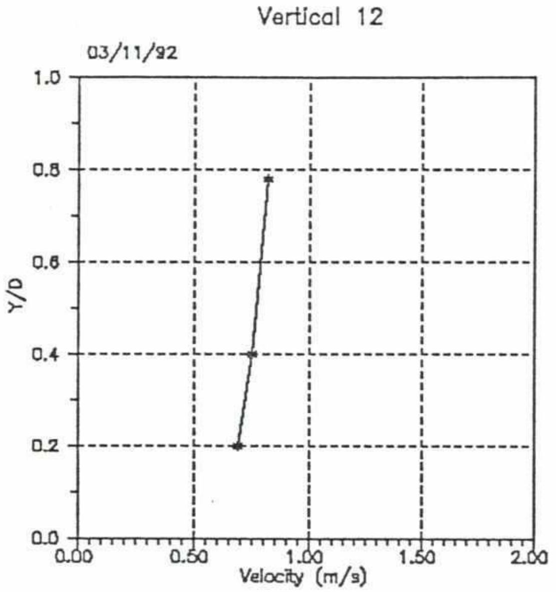


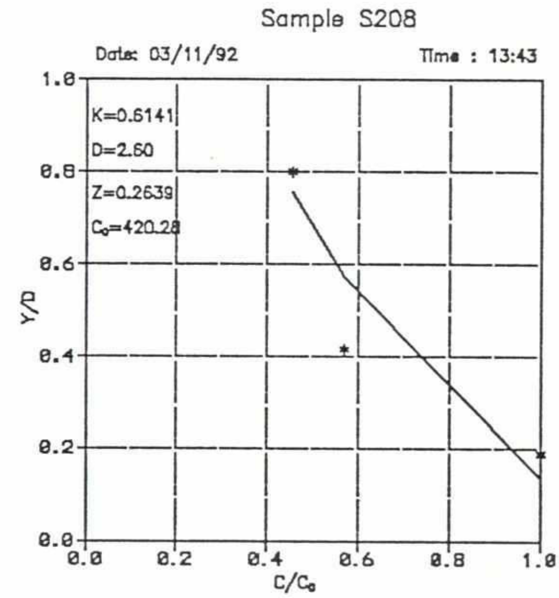


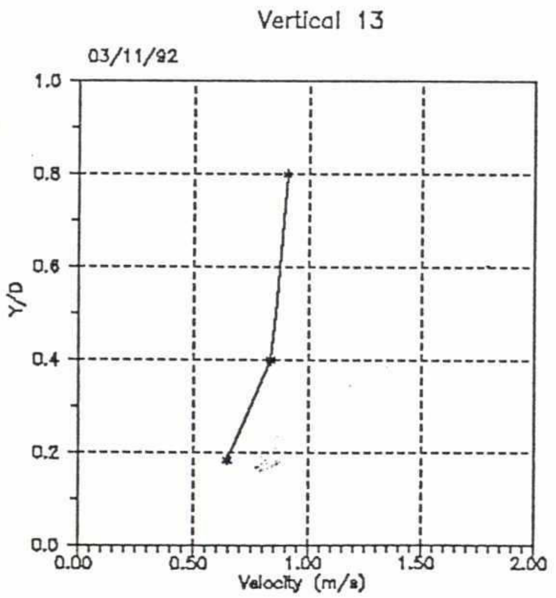
River Survey Project (FAP 24)

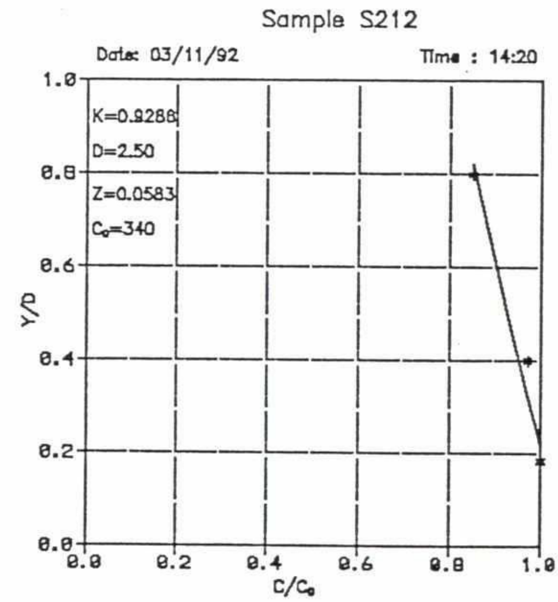
Location : Jamuna River (Right Channel)

Date of Survey : 03/11/92





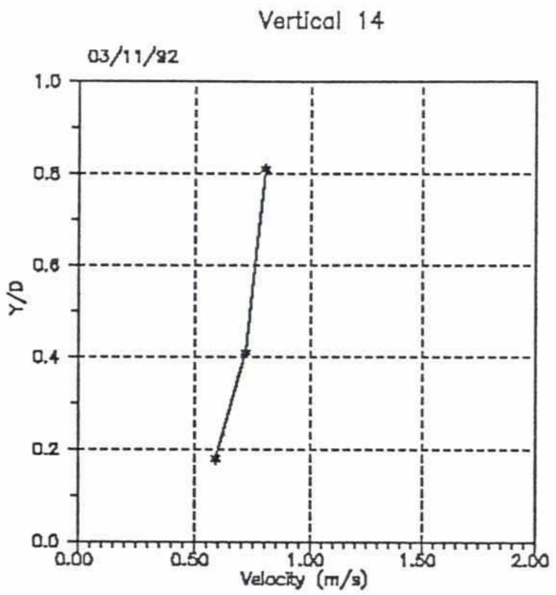


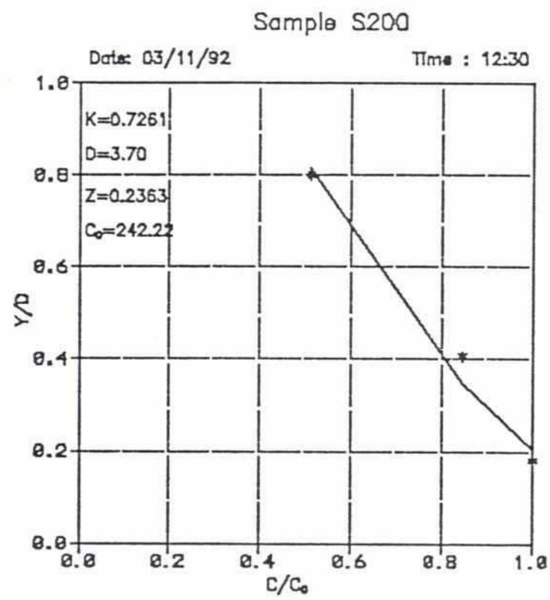


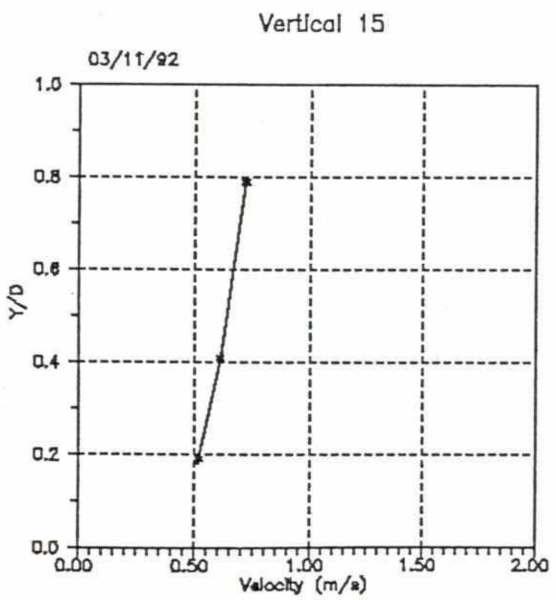
River Survey Project (FAP 24)

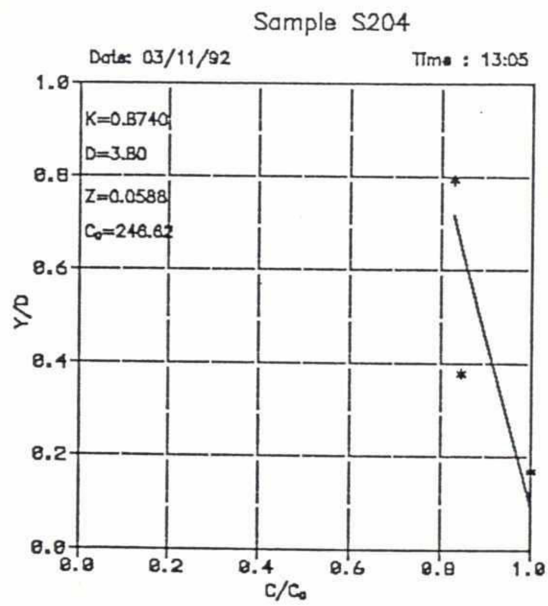
Location : Jamuna River (Right Channel)

Date of Survey : 03/11/92









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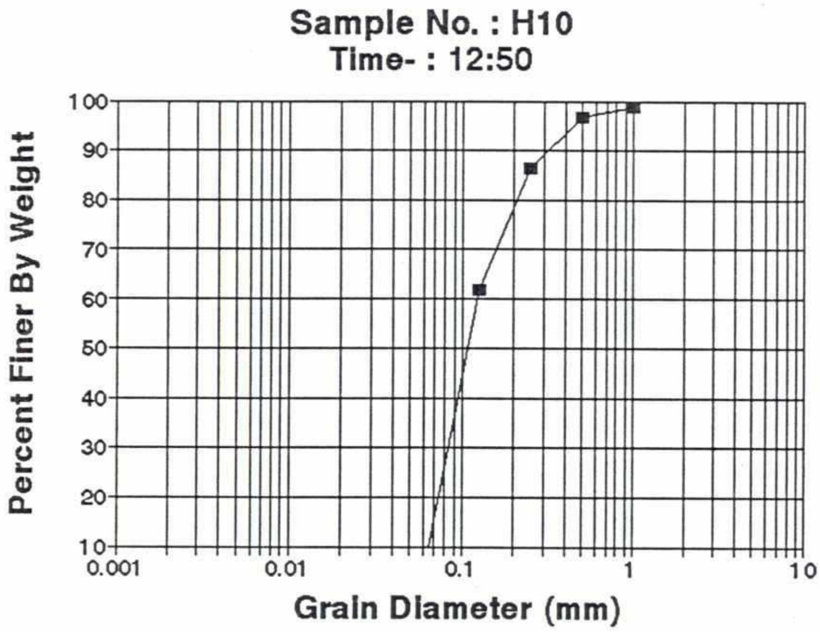
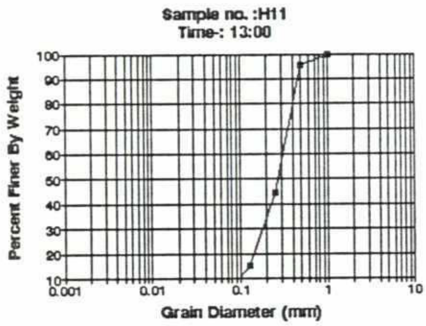
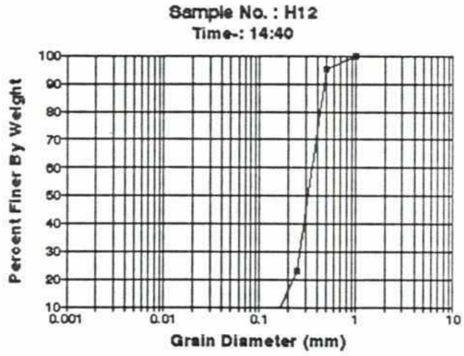
Grain Size Distribution Of Bed Load Dy Sieve Analysis (Helly-Smith Sampling)

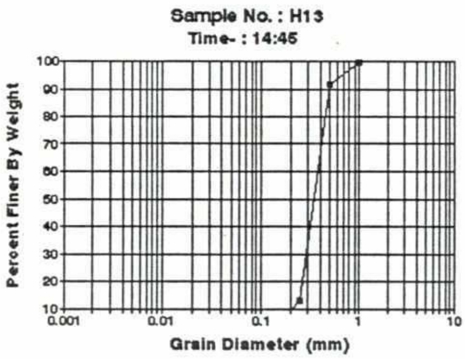


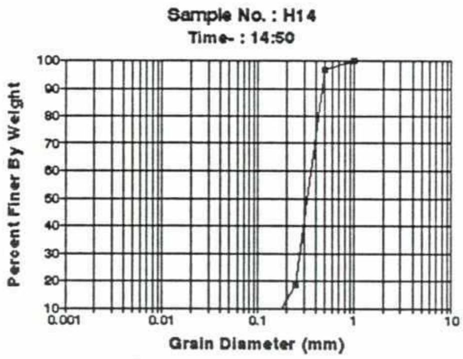
Collection Time	Collection Date	Total Weight(gm)	Transport Rate (Kg/M-S)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
12:50	03/11/92	95.5	0.005	0.089	0.108	0.137	1.928

Grain Size Distribution Of Bed Load Dy Sieve Analysis
(Helly-Smith Sampling)



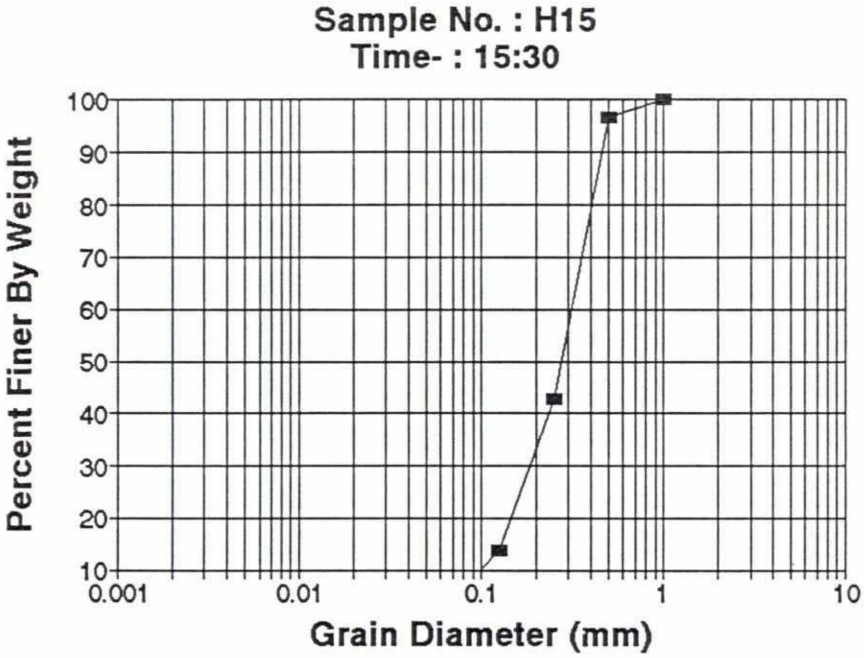






Collection Time	Collection Date	Total Weight(gm)	Transport Rate (Kg/M-S)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
13:00	03/11/92	13.122	0.001	0.199	0.269	0.330	1.722
14:40	03/11/92	875.09	0.048	0.280	0.324	0.374	1.504
14:45	03/11/92	598.5	0.033	0.304	0.346	0.395	1.318
14:50	03/11/92	143	0.008	0.288	0.329	0.376	1.342

Grain Size Distribution Of Bed Load By Sieve Analysis (Helley-Smith Sampling)



Collection Time	Collection Date	Total Weight(gm)	Transport Rate(Kg/M-S)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
15:30	03/11/92	42.000	0.005	0.208	0.275	0.333	1.735

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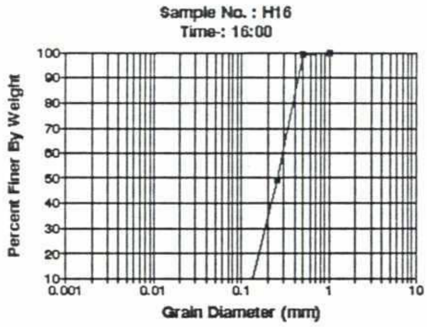
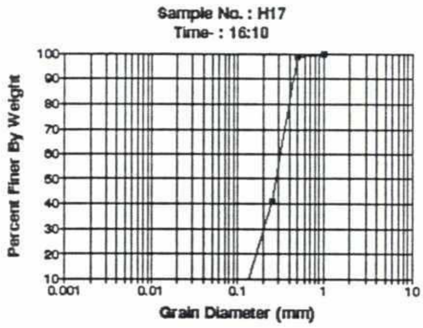
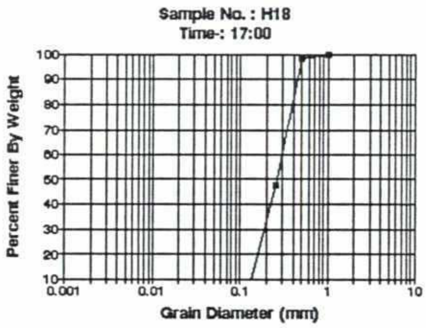
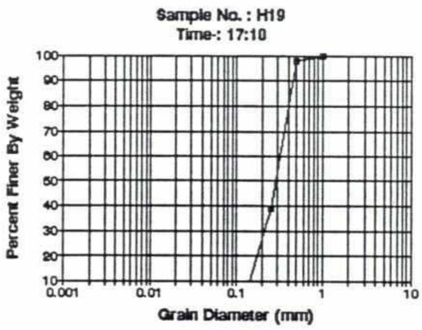
Grain Size Distribution of Bed Load by Sieve Analysis (Helley-Smith Sampling)



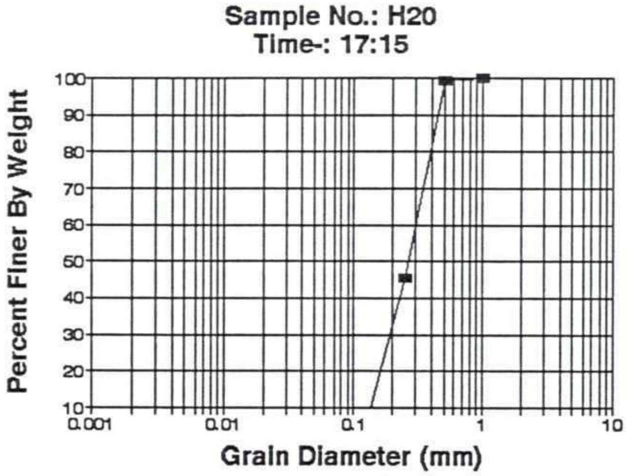






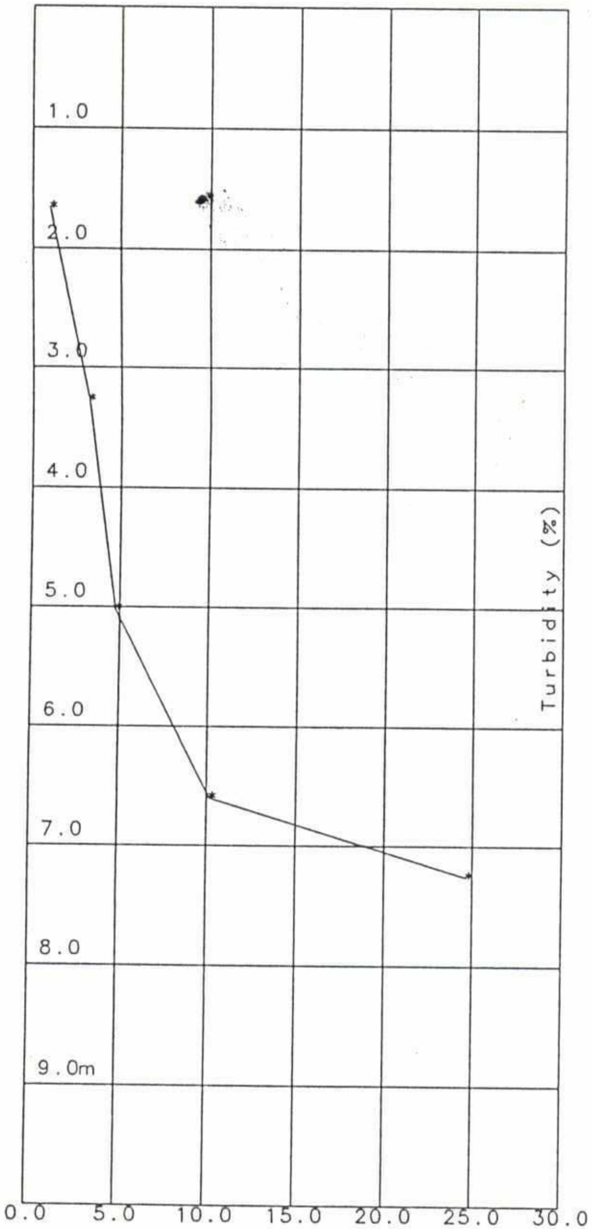
Collection Time	Collection Date	Total Weight(gm)	Transport Rate(Kg/M-S)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
16:00	03/11/92	542.500	0.030	0.200	0.253	0.311	1.651
16:10	03/11/92	186.500	0.010	0.222	0.278	0.333	1.666
17:00	03/11/92	200.500	0.011	0.203	0.258	0.317	1.666
17:10	03/11/92	25.900	0.001	0.232	0.285	0.340	1.629

Grain Size Distribution of Bed Load by Sieve Analysis (Helley-Smith Sampling)



Collection Time	Collection Date	Total Weight(gm)	Transport Rate(Kg/M-S)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
17:15	03/11/92	56.000	0.003	0.209	0.265	0.321	1.643

FAP24 RIVER SURVEY PROJECT:Date of Survey-03/11/92



SURVEY ID :

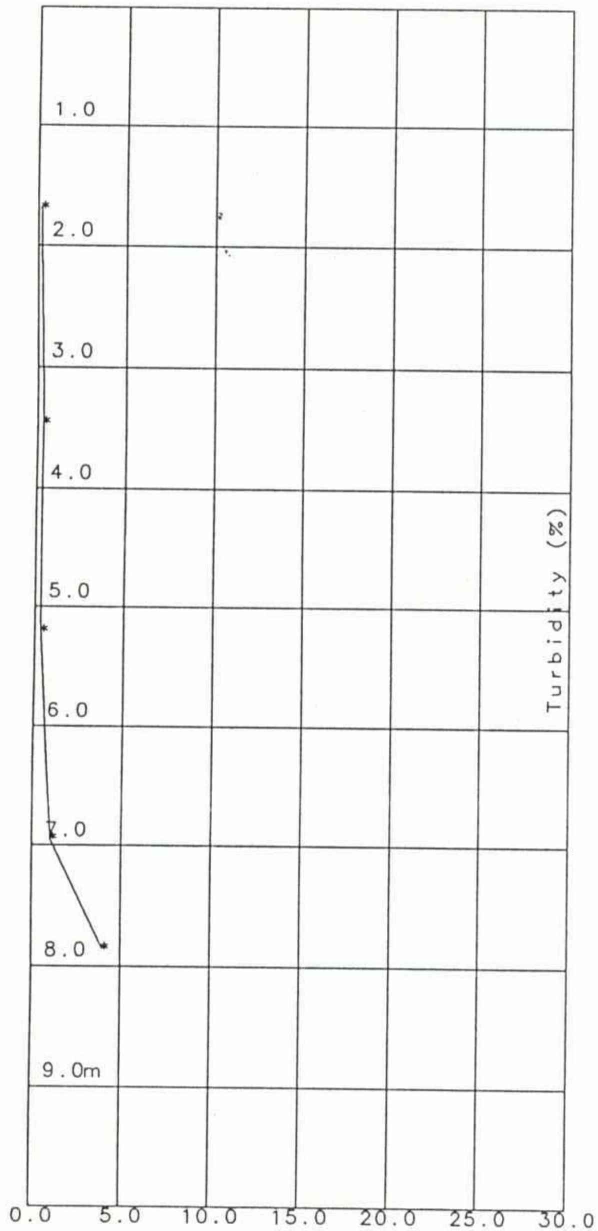
Coord. System : BTM
Easting : 460899.40
Northing : 782689.20
Date : 921103
Time : 13:10:13
Reference Code: 1800001

PLOT ID :
Project : FAP 24
File : b2b31p01
Drawn : Mar 4 10:01:04 1993
Init. : MZH
Revision: A

Appr.	ID. no.

206

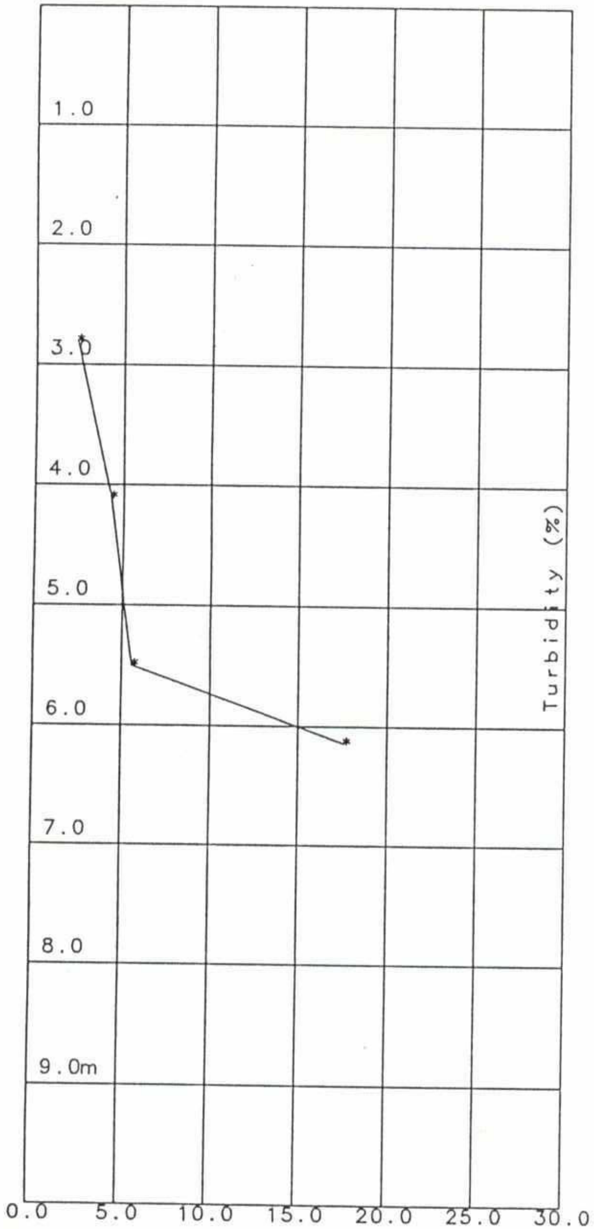
FAP24 RIVER SURVEY PROJECT: Date of Survey-03/11/92



SURVEY ID :	
Coord. System	: BTM
Easting	: 460853.70
Northing	: 782558.40
Date	: 921103
Time	: 15:15:52
Reference Code	: 1800002
PLOT ID :	
Project	: FAP 24
File	: b2b31p02
Drawn	: Mar 4 10:10:42 1993
Init.	: MZH
Revision	: A
Appr.	ID. no.

208

FAP24 RIVER SURVEY PROJECT:Date of Survey-03/11/92



SURVEY ID :

Coord. System : BTM
Easting : 460842.70
Northing : 782649.10
Date : 921103
Time : 16:36:08
Reference Code: 1800003

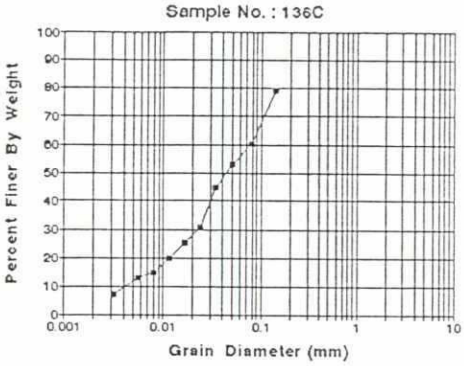
PLOT ID :
Project : FAP 24
File : b2b31p03
Drawn : Mar 4 10:09:19 1993
Init. : MZH
Revision: A

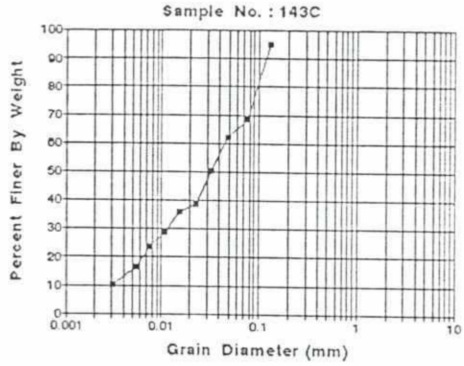
Appr.	ID. no.

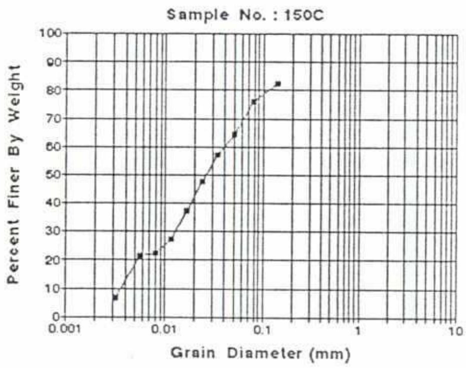
20

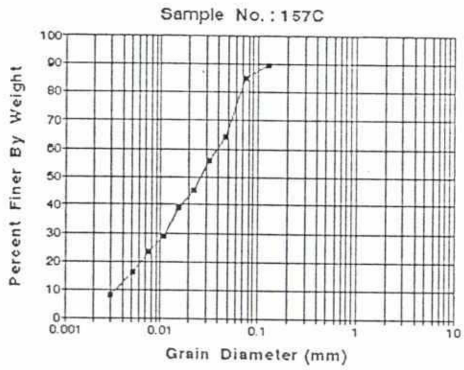
207

Grain Size Distribution In Suspended Sample With Andreasens Tube



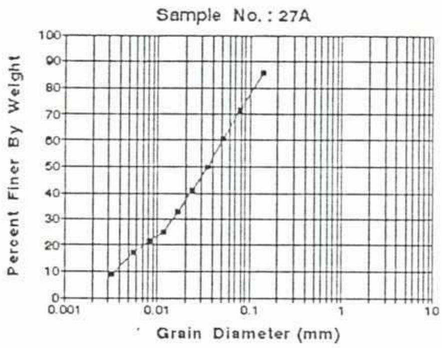


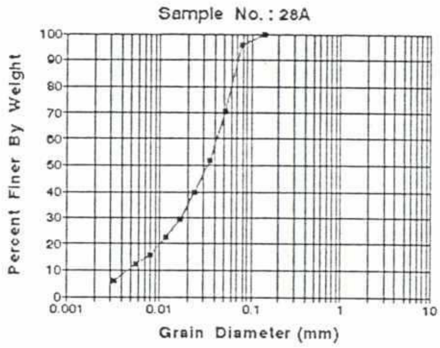


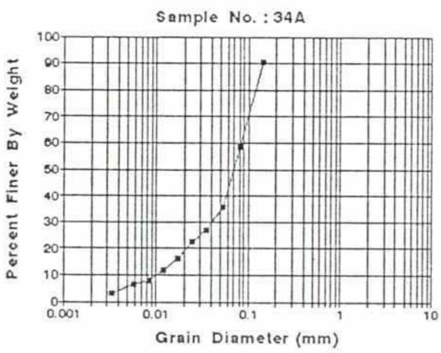


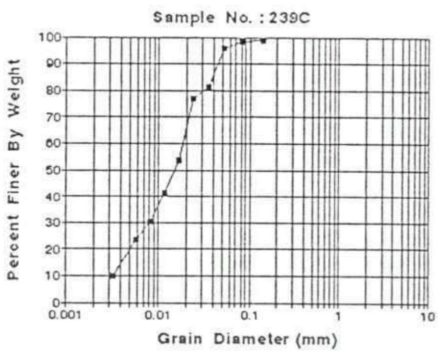
Sample No.	Collection Date	Collection Time	Collection Depth(m)	Total Depth(m)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
136C	30/10/92	13:00	9.000	9.200	0.027	0.044	0.090	4.454
143C	30/10/92	15:05	8.500	9.200	0.015	0.032	0.060	4.471
150C	30/10/92	17:00	5.000	5.400	0.015	0.026	0.052	5.484
157C	31/10/92	11:30	9.000	10.000	0.013	0.026	0.048	3.806

Grain Size Distribution In Suspended Sample With Andreasens Tube



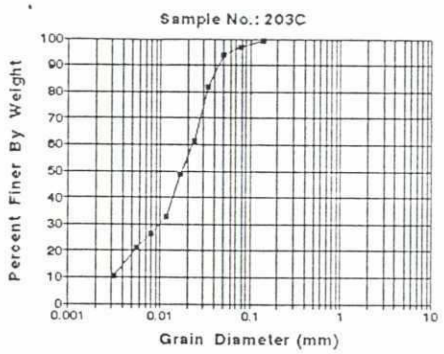


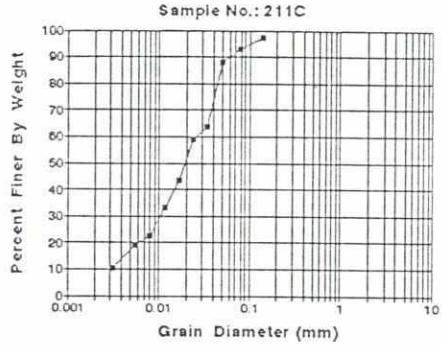


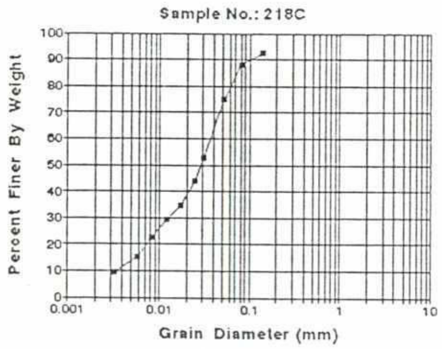


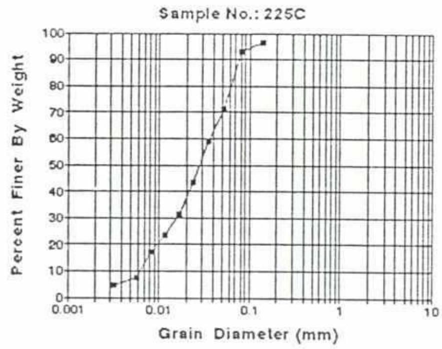
Sample No.	Collection Date	Collection Time	Collection Depth(m)	Total Depth(m)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
27A	31/10/92	12:34	6.350	9.300	0.018	0.035	0.061	5.325
28A	31/10/92	16:07	9.300	11.800	0.021	0.033	0.045	2.820
34A	03/11/92	13:30	8.300	8.300	0.051	0.069	0.090	3.080
239C	03/11/92	17:22	1.330	1.800	0.010	0.015	0.020	5.083

Grain Size Distribution In Suspended Sample With Andreasens Tube







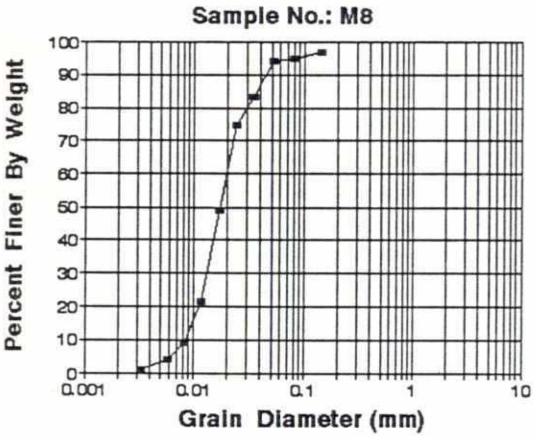


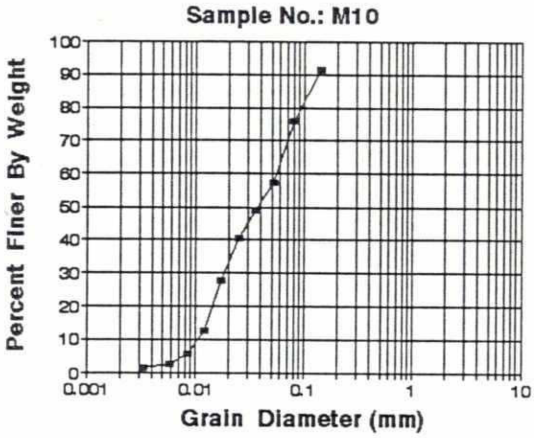
Sample No.	Collection Date	Collection Time	Collection Depth(m)	Total Depth(m)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
203C	03/11/92	12:30	3.030	3.700	0.012	0.017	0.025	3.065
211C	03/11/92	13:43	2.110	2.600	0.012	0.019	0.035	3.427
218C	03/11/92	14:49	2.280	2.900	0.017	0.029	0.041	3.624
225C	03/11/92	15:40	1.720	2.200	0.019	0.028	0.042	2.897

Appendix 1D

Measurement data from test measurements in December 1992

Grain Size Distribution of Suspended Sediment by Andreasens Tube Analysis





Sample No.	Collection Date	Collection Time	Collection Depth (m)	Total Depth (m)	D35 (mm)	D50 (mm)	D65 (mm)	Standard Deviation
M8	11/12/1992	07:45	6.00	7.10	0.014	0.017	0.021	1.909
M10	11/12/1992	18:50	4.50	5.00	0.021	0.037	0.063	2.910