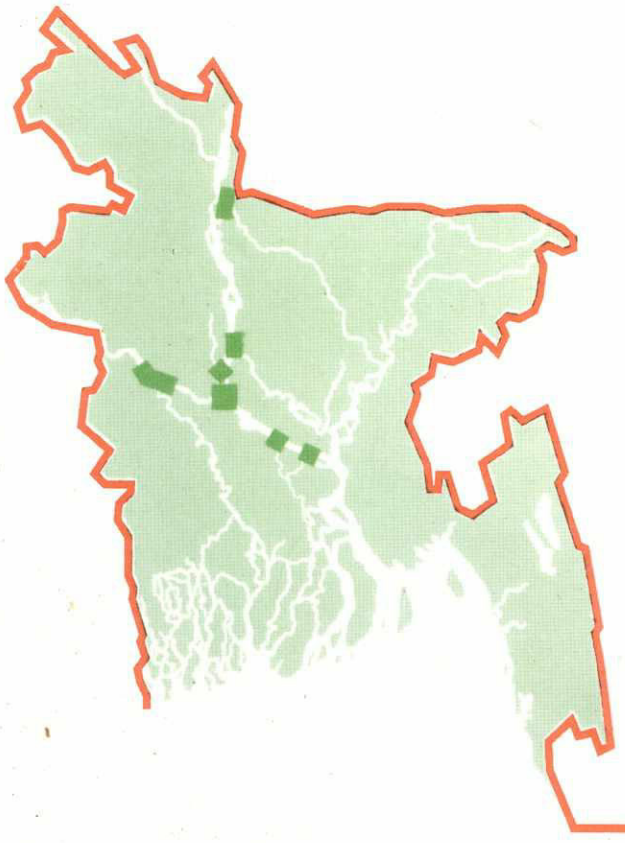
GOVERNMENT OF BANGLADESH
FLOOD PLAN COORDINATION ORGANIZATION

FAP 24 RIVER SURVEY PROJECT

Test Gauging Report

Survey Procedures and Data Presentation



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Test Gauging Report

Survey Procedures and Data Presentation

31 October 1993

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Acronyms and Abbreviations

ADCP	:	Acoustic Doppler Current Profile for measurement of current profiles
AWLR	:	Automatic Water Level Recorder
BTM	:	Bangladesh Transverse Mercator
DGPS	:	Differential Global Positioning System for information on latitude, longitude and altitude
DHA	:	Survey vessel A (mother ship)
DHC	:	Survey vessel C (catamaran type)
EMF	:	Electro Magnetic Flowmeter for measurement of a current vector
FPCO	:	Flood Plan Coordination Organization
GPS	:	Global Positioning System
Hydro	:	A Hydrographic software package
MBM	:	Moving Boat Method for performing various spatial hydrographic measurements while the survey vessel is progressing.
Ott	:	A mechanical current meter
PA	:	Project Adviser
PWD	:	The Bangladeshi Public Works Department vertical geodetic datum
S4	:	An electromagnetic current meter
SOB	:	Survey Of Bangladesh
TS	:	Technical Specifications outlined in the consultancy contract of 22 May 1992 and the attached revisions
UHF	:	Ultra High Frequency
WGS	:	World Geodetic System (1984)

1. Introduction

According to the Consultancy Contract of 22 May 1992, River Survey Project FAP 24, ALA/90/04 a test gauging has to be performed in the Jamuna/Bramaputra River at the Bahadurabad cross-section.

The test gauging has to be performed as early as possible during Phase I. The river flow stage during the test gauging should correspond to a discharge higher than the mean discharge, which is between 25.000 and 40.000 m^3/s and as close as possible to bank-full discharge.

The test gauging was originally planned to take place during the flood season 1992. Owing to a delayed project start in combination with a relatively low flood level it was decided that execution of a test gauging programme at that moment would not have fulfilled the objectives. Consequently it was decided to postpone the test gauging programme until August 1993.

The test gauging programme comprises comparison of three different measurement methodologies for discharge gauging as well as some trials with suspended sediment transport gauging by point- and integrated sampling technique respectively. Bed load sediment transport measurement by Helley-Smith trap sampling and sand-dune tracking is to be investigated also.

The August 1993 test gauging programme, as described in chapter 5, was discussed and agreed with FPCO and the PA prior to initiation of measurements.

In order to properly document the August 1993 test gauging, numerous references are made to the technical specifications (TS) in the consultancy contract and to the test gauging outline of August 1993.

The test gauging has been reported in two separate volumes:

- Test Gauging Report
  Volume I
  Survey Procedures and Data Presentation

- Test Gauging Report
  Volume II
  Selection of Survey Techniques

Volume I, Survey Procedures and Data Presentation, documents past activities and procedures, whereas volume II, Selection of Survey Techniques, considers future River Survey Project activities and planning.

2. Scope of the test gauging

The overall objective of the field programme of the River Survey Project is to collect high quality data and to optimize the efficiency in data collection.

The main scope of the test gauging is to obtain sufficient experience with the proposed equipment and methods with due regard to the prevailing flow and sediment transport conditions in the rivers of Bangladesh. Based on this experience, recommendations for survey vessels and instrumentation as well as final methodologies to be applied during the remaining part of the FAP 24 project, could be established.

Specifically this includes optimization of measurement procedures in terms of;

- o duration of total gauging time
- o number of vertical profiles in each cross-section
- o number of sampling points in each vertical profile
- o sampling time of each point measurement

3. Test gauging programme.

3.1 Intended test gauging programme

Prior to initiation of the test gauging a day by day programme as listed in Appendix 1 was agreed with the FPCO and the PA.

3.2 Completed test gauging programme

All test gaugings were completed though not in full compliance with the intended time schedule, described in Appendix 1. As explained in Chapter 6 the test gauging programme was delayed by difficulties during the execution. The following is a day by day summary of the test gauging programme as it was carried out in the field.

- Monday 16 August

  Site reconnaissance for a suitable test gauging area at Bahadurabad and Fulchari Ghat. Approximately 10 different cross-sections were surveyed in the right as well as in the left main channel during the day.

  The measurements proved the performance of the integrated bathymetric survey system as well as the combined ADCP/EMF set-up.

  The reconnaissance also comprised the central island in Figure 4.2, next chapter. Several channels, of which one was found to carry some discharge, are crossing the island.

- Tuesday 17 August

  Four transect measurements were carried out, two in the morning and two in the evening. One complete inter-calibration profile was carried out. For verification of the performance of the sampling equipment, the measurements were completed by taking five suspended sediment samples, an Andreasen suspended sediment sample and a river bed sediment sample.

  The holding strength and recovery power of the anchoring system as well as the stability of the positioning system was also verified for both the DHA and the DHC survey vessel.

o Wednesday 18 August

Two transect measurements were carried out in the selected cross-section, see Drawing No. 2b. A bathymetric survey covering an area 500 m up- and downstream of the transect lines was also carried out, see Appendix 3.

Sand-dune tracking in another selected area was initiated, see Drawing No. 2a. This first sand-dune tracking was followed by a function test of the side scan sonar.

o Thursday 19 August

The second and the third sand-dune tracking were completed in the same area as the previous day and supplemented with 3 Helley-Smith bed load sediment transport samples from a selected sand-dune formation.

Float tracking was also carried out within the test gauging area, see Appendix 15.

o Friday to Sunday, 20 to 22 August

A test gauging according to the reference method by manual profiling was carried out. All together 19 profiles were measured.

Due to inconsistencies among the various types of current meters an additional inter-calibration was completed.

The current profiling was supplemented with two transect line measurements, one in the morning and one in the evening, during all three days.

The test gauging was completed at 18:00 HRS on Sunday 22 August.

4. Test gauging procedures

4.1 General information

The basic difference between the reference methodology (velocity-area concept) and the recommended methodology (moving boat method) proposed by the River Survey Project concerns the procedures for flow measurement and suspended sediment sampling.

The methodologies used in the FAP 24 River Survey Project comprise the following types of measurements:

- Inter-calibration of current meters
- Discharge measurements by manual current profiling (velocity-area method)
- Discharge measurements with moving boat using EMF
- Discharge measurements with moving boat using EMF and ADCP in combination (moving boat method)
- Suspended sediment transport measurements by manual profiling
- Bed load transport measurements by a trap sampler - Helley-Smith
- Bed load transport measurements by sand-dune tracking
- Bathymetric charting of the river bed configuration for cross-section measurements
- Water-level measurements for relating the bathymetric surveys to a common datum and for establishing discharge rating curves
- Horizontal flow distribution by float tracking

4.2. Classification of river cross-section and measurement intensity

According to the TS for discharge gauging and suspended sediment gauging the individual river cross-sections shall be classified into main channels, smaller channels and shallows.

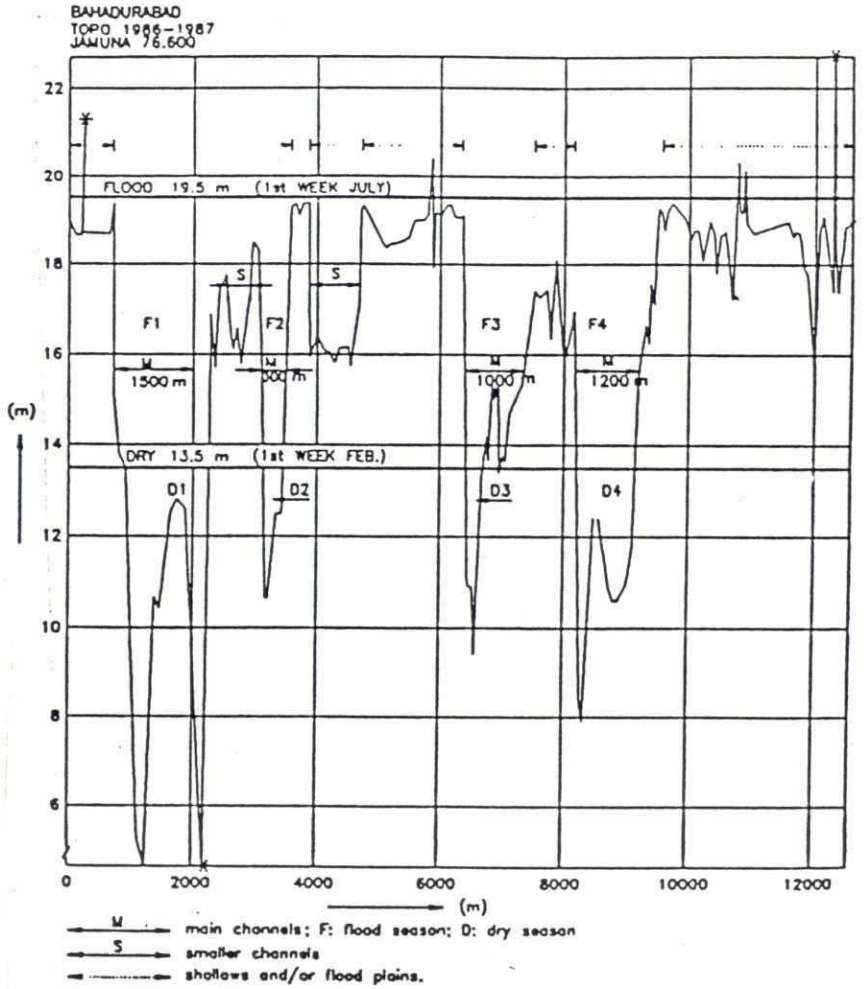
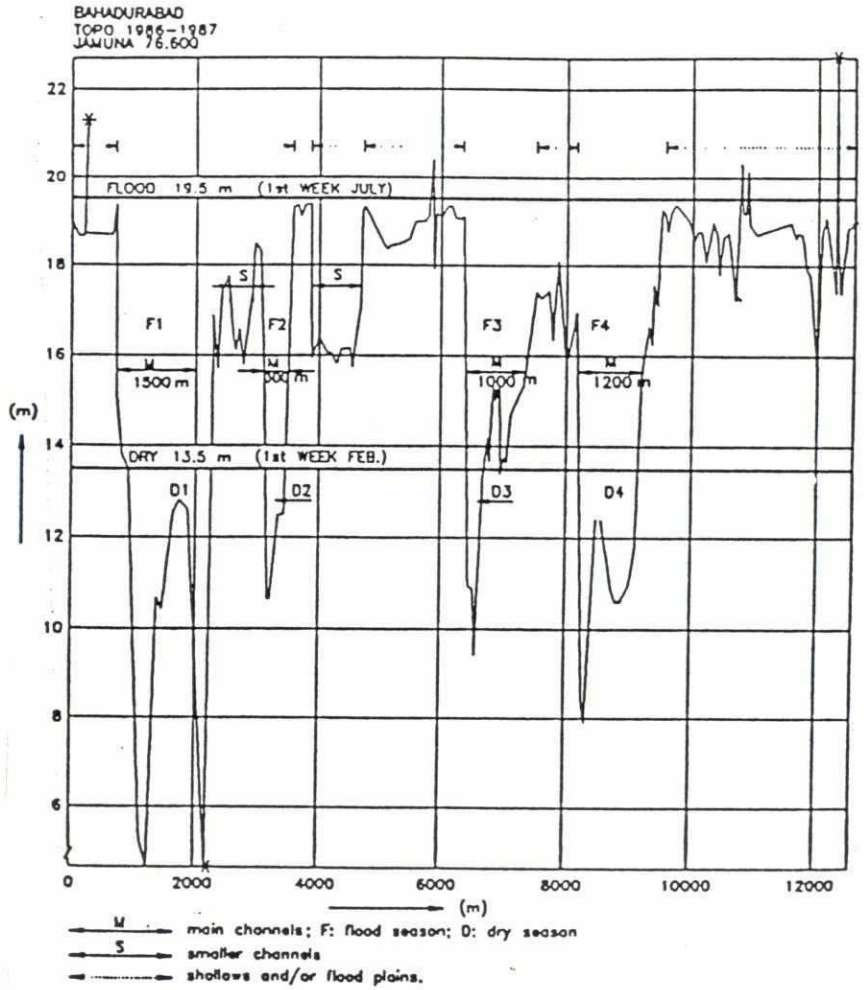


Figure 4.1 Cross-section of the Jamuna river at Bahadurabad with indications of main channels, smaller channels and shallows.

The practical definition of main channels, smaller channels and shallows reads:

- Main channels are defined to be 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 in intensive scouring holes.
- Smaller channels are defined as having widths ranging from 100 m to 500 m and maximum depths ranging from 3 m to 10 m.
- Shallows are those zones without well defined channels as described above, but where depths exceed 3 m at the moment of the gauging

As an illustration, main channels, minor channels and shallows in the



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As an illustration, main channels, minor channels and shallows in the Bahadurabad cross-section are indicated in Figure 4.1. The overall river configuration is illustrated in Figure 4.2 below.

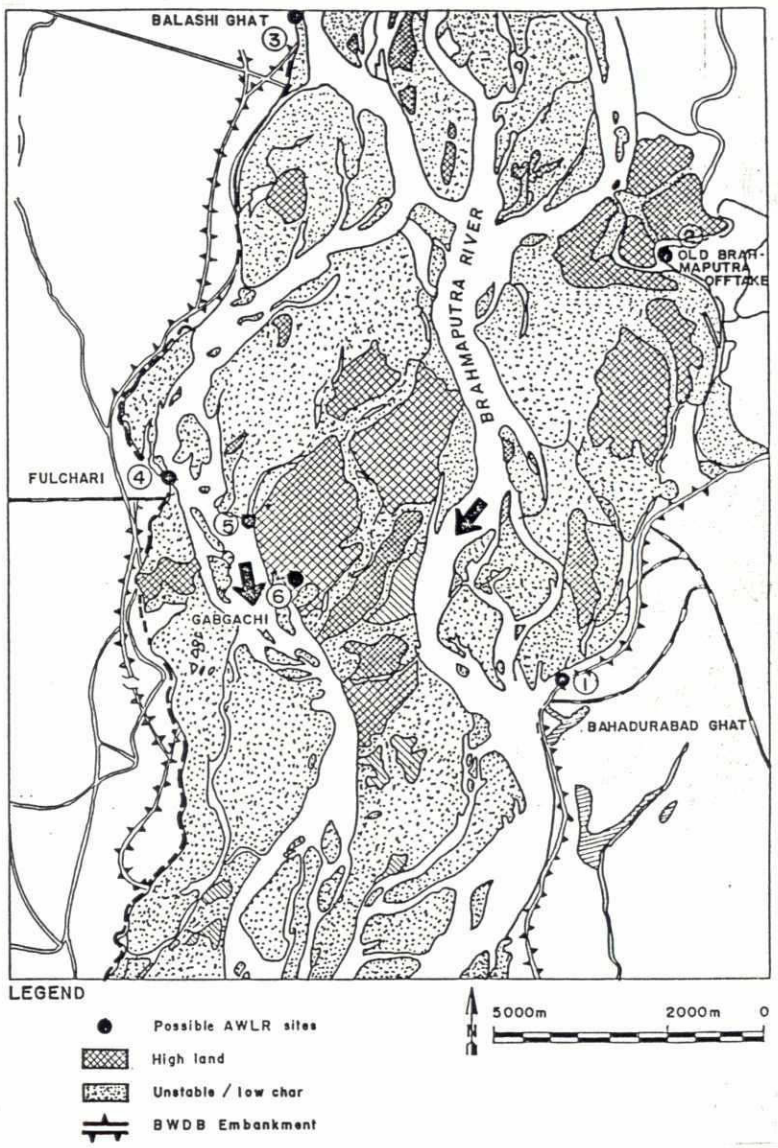


Figure 4.2 Jamuna river in the vicinity of the Bahadurabad cross-section.

Three survey vessels, DHA, DHC and a 12 feet alu craft are available for field measurements, see Chapter 5 or Appendix 1 of 1° Interim Report, Vol. II. During gauging the main channels will be covered by the DHA, smaller channels by the DHC and shallows by the alu craft. When time allows the DHA and the DHC supplement each other with the DHC covering the most shallow parts of the cross-section.

The test gauging procedure and the number of point measurements shall comply with the following requirements (TS).

o Measurement in main channels

- distance between vertical (profiles) maximum 100 m
- six point method for each vertical
- 300 second integration time for each velocity sampling (with record of sampling for each 50 second interval)

o Measurement in smaller channels

- four vertical (profiles)
- three point method for each vertical
- 100 second integration time for each velocity sampling (with record of sampling for each 50 second interval

The Consultants implementation of these requirements in terms of measurement intensities related to an actual cross-section is illustrated in Drawing No. 3.

4.3 Inter-calibration of current meters and instrument verification test

Upon selection of a suitable location for inter-calibration of current meters and verification tests with other equipment the following measurements were carried out from anchored survey vessels.

Current measurements at a single location

Simultaneous measurements were carried out by deployment of EMF, S4, Ott current meters. With the Ott propeller and the S4 current meter six point measurements were carried out in each vertical. With D denoting total depth the six point measurements were obtained in the following depths :

- as close to the surface as possible
- 0.2 D
- 0.4 D
- 0.6 D
- 0.8 D
- as close to the bottom as possible.

Measurements were carried out with 300 second integration time for each velocity sampling and with record of sampling for each 50 second interval.

When measuring, the position of the survey vessel was shown on-line to the pilot and continuously recorded.

Moving boat measurements

o Discharge measurements with a combined EMF and ADCP

o During the site reconnaissance several cross-sections were covered with simultaneous echo-sounding and combined EMF and ADCP measurements (a so-called transect) for verification of performance and to have a view of the distribution of current velocities and relative suspended sediment concentrations.

o Sand-dune monitoring with a side scan sonar

Actual function tests with the side scan sonar were carried out simultaneous with sand-dune tracking using the integrated bathymetric survey system consisting of the Differential Global Positioning System (DGPS) and the dual frequency echo-sounder.

Sediment measurements

Simultaneous suspended sediment point sampling by pumping into 0.5 l bottles and turbidity readings were carried out in the same location as the current profiling described above.

The point sampling was supplemented with a depth integrated sampling. In principle the depth integrated sample is a 2 l bottle, which is lowered to the river bed and then hoisted back aboard the survey vessel. During this cycle, water and suspended sediment is flowing into the bottle, whereby an integrated sediment sample from the entire water column is obtained.

Bed load transport sampling

Bed load transport measurement by using the Helley-Smith sampler was tested also.

Bottom samples

Sediment sampling with the US BM-54 sampler was tested.

The Van Veen grab is only applicable during stagnant current conditions or by deployment from a drifting survey vessel. The Van Veen grab was tested during the October 1992 gauging, and was not included in the August 1993 test gauging.

Anchoring procedures

During the verification tests the anchoring procedure and capability was monitored closely, using the DGPS positioning system. Weighing of anchors was observed in particular.

4.4 Water-level measurements

During the test gauging water-levels were measured by two Automatic Water Level Recorders (AWLR, see Figure 4.3) installed at Gabgachi - an inlet on the western side of the central island in the river, see Drawing No. 2b.

These measurements were backed up by manual staff gauge readings at the same location.

Staff gauge readings were also carried out at the other water-level station just upstream of Bahadurabad Ghat.

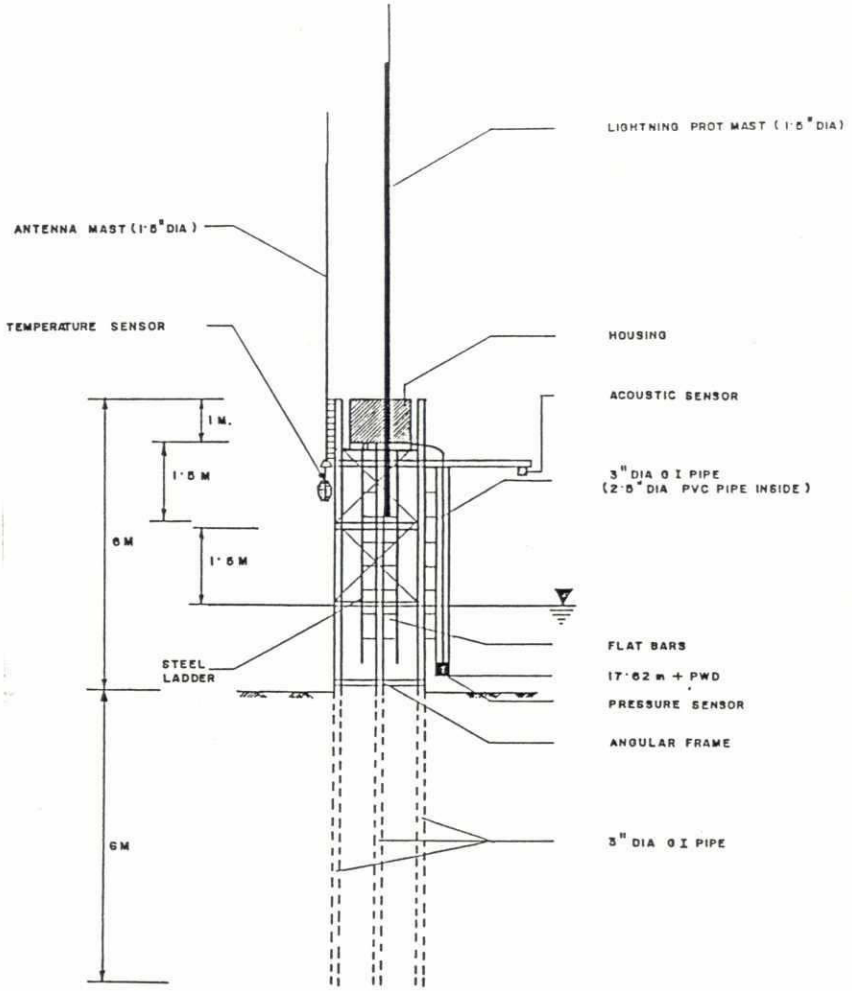


Figure 4.3 The Automatic Water Level Recorder (AWLR) installation with pressure cell and acoustic sensor at Gabgachi.

4.5 Discharge measurements by the recommended Moving Boat Method

Conventional discharge measurements by a series of manual current profiles 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 compromise 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. This is quite often the case in the rivers of Bangladesh, see Figure 4.4 below.

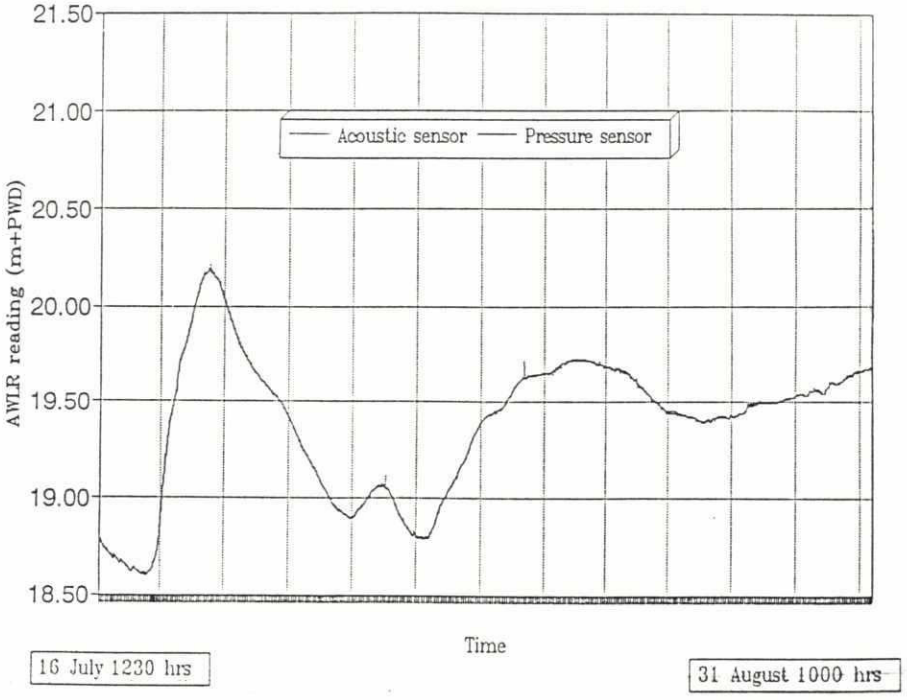


Figure 4.4 Water-level recording at Gabgachi, Jamuna river.

In order to overcome these problems, both the Acoustic Doppler Current Profiler (ADCP) and the electro-magnetic flow meter (EMF) was introduced. This instrument configuration constitutes the consultant's alternative methods for "instantaneous" discharge gauging in the main channels.

"Instantaneous" means that the duration of one discharge measurement equals the travel time of the vessel crossing the river.

The principal instrumentation is illustrated in Figure 4.5. The measurements are carried out by crossing the river from one bank to the other. While sailing the system will record vertical profiles for every 8 - 14 m and continuously present profiles and calculate the discharge by integrating the velocity normal to the path taken by the survey vessel. Data-processing and logging is carried out on-line by PC's installed aboard.

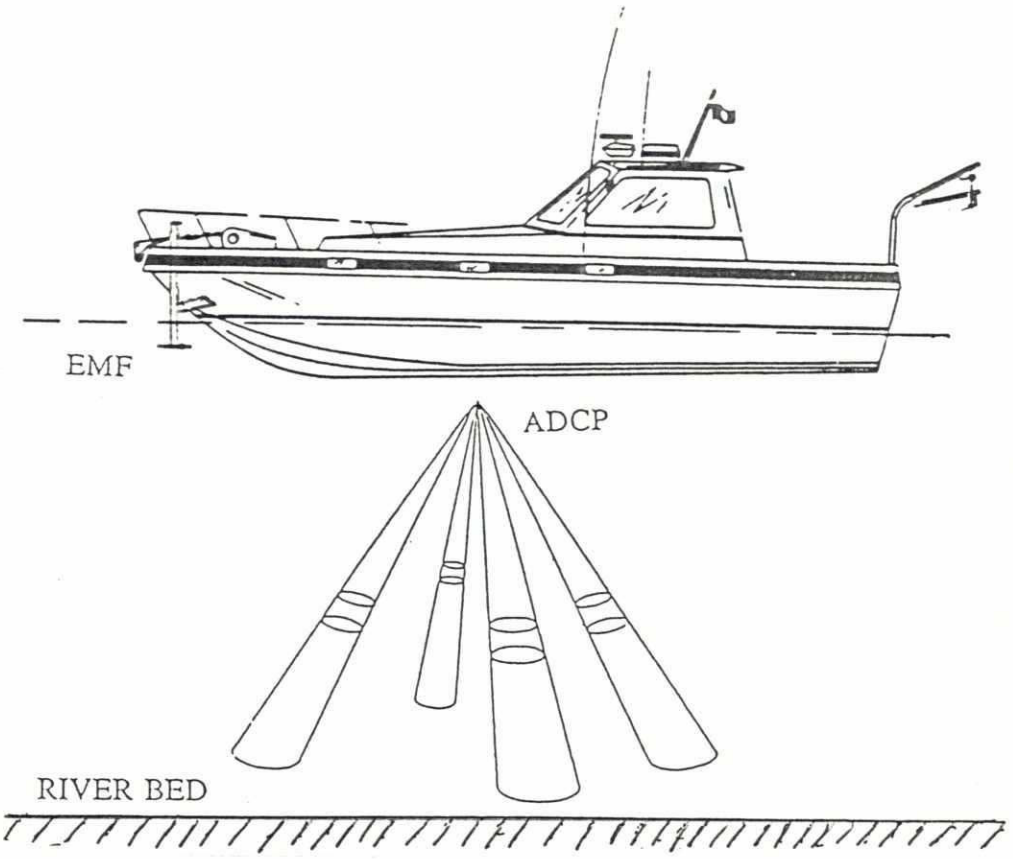


Figure 4.5 Principal sketch of ADCP/EMF instrumentation for the recommended method.

The ADCP can measure, neither 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

The ADCP experience obtained so far, is further elaborated in Appendix 18.

An example of a typical record showing the detailed current distribution in the Bahadurabad Ghat cross-section is shown in Figure 4.6 and 4.7 below. For definition of the presented current vectors, see Subsection 8.1.2.

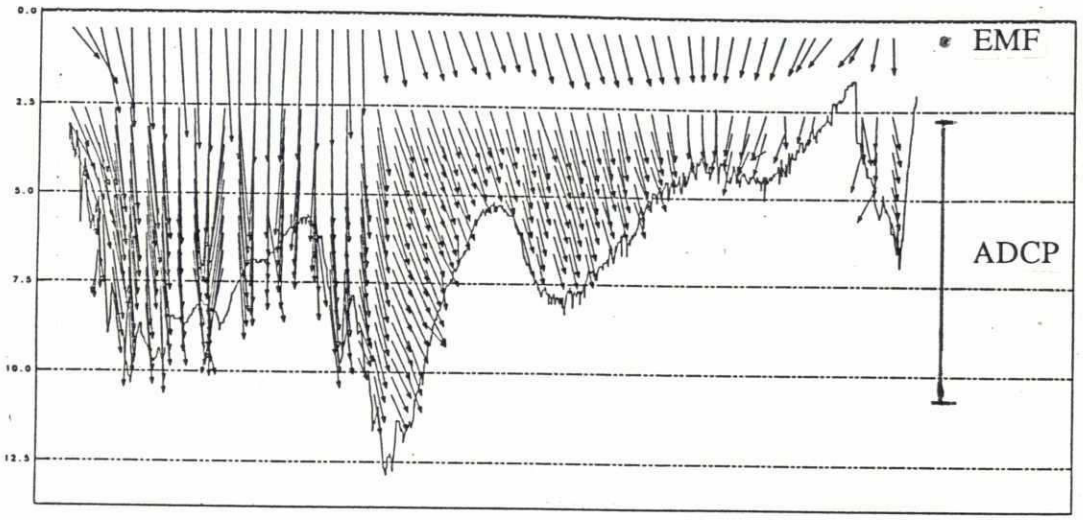


Figure 4.6 Combined EMF and ADCP recordings at Bahadurabad Ghat.

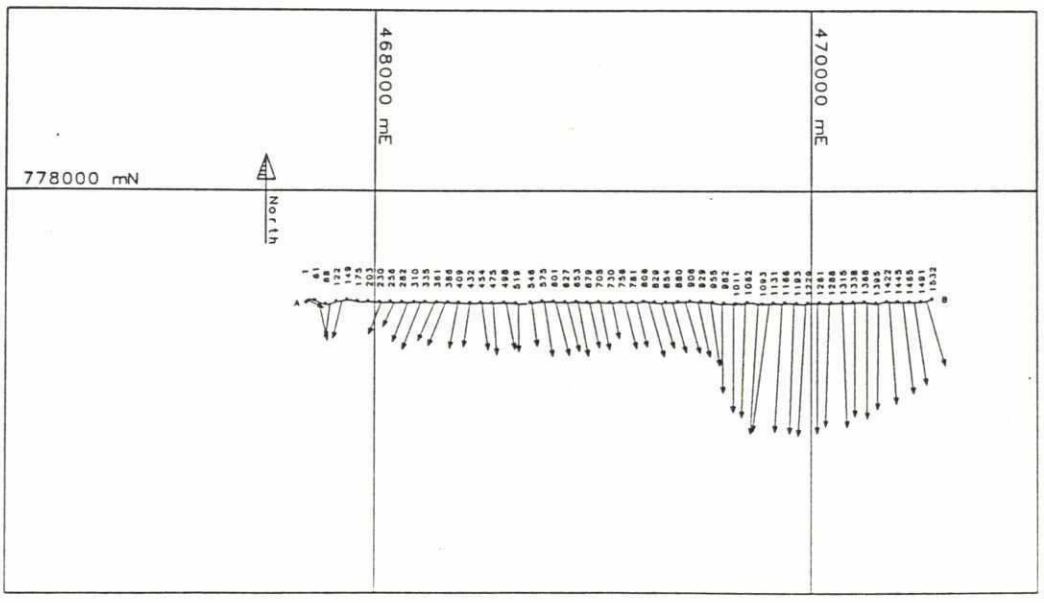


Figure 4.7 Example of horizontal current distribution in the first bin approximately 3 m below the surface at Bahadurabad Ghat.

Owing to the areas not covered by current measurements, see Figure 4.6, the total discharge cannot be calculated by pure interpolations. Three assumptions have been adopted to calculate the total discharge:

- A power function velocity profile in the vicinity of the river bed
- A linear velocity profile, based on the uppermost ADCP current measurement and the EMF measurement 0.5 m below the surface, to describe the upper 2.7 m of the water column
- A linearily decreasing velocity profile from the last velocity measurement in the vicinity of the river bank

4.6 Discharge and suspended sediment transport measurement by the reference Velocity Area Method

Current velocity and suspended sediment sampling are carried out in a simultaneous operation using the combined sediment suction and velocity measurement device shown in Figure 4.8.

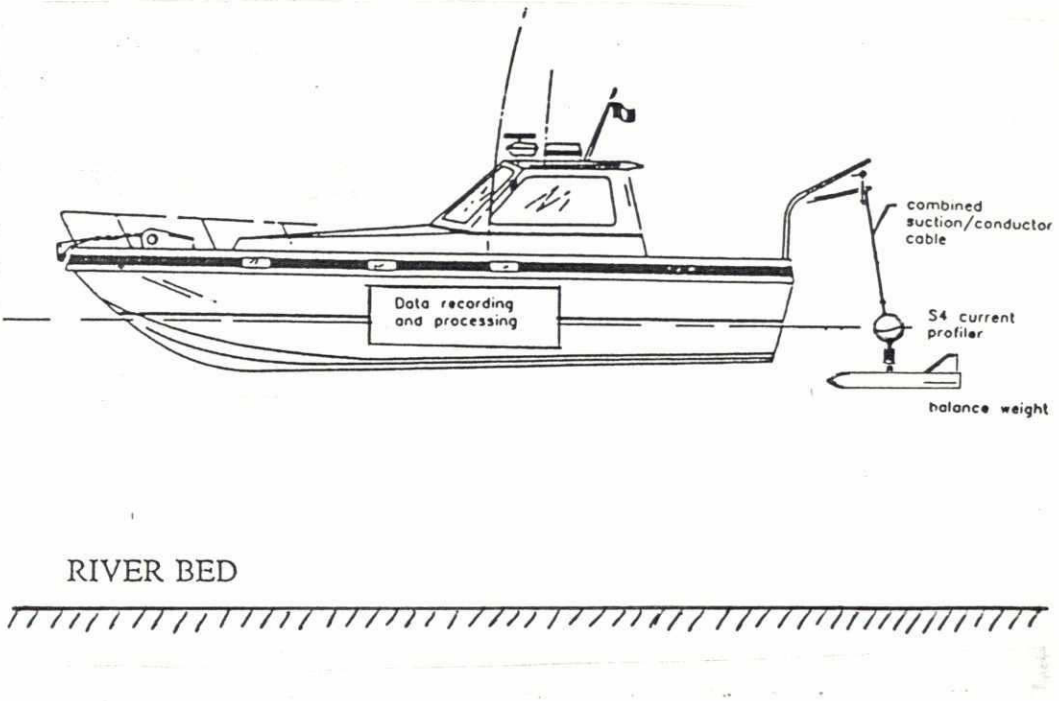


Figure 4.8 Principal sketch of equipment installation for combined current profiling and suspended sediment sampling.

The measuring depth of the drag fish is recorded by a pressure cell mounted inside the current meter and is monitored continuously during operation.

During the test gauging a sediment sampling integration time of 5 minute (e.g. 6 x 50 seconds) has been applied. Samples have been collected in 0.5 l bottles. Supplementary depth integrated 2 l samples were made also. For determination of grain-size distribution of the suspended sediment close to the river bed, 25 l samples were collected.

Also during these measurements data-processing and logging of current velocities and positions is on-line by PC's installed aboard.

During suspended sediment sampling, turbidity measurements are carried out simultaneously and in the same vertical positions by the DHA vessel.

4.7 Mapping of river-bed configuration for detection of sand-dune patterns

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

The sonar makes its registrations by a pair of transducers mounted in a fish being towed behind the survey vessel, see Figure 4.9. The recorder is installed in the wheel-house on the DHA vessel. Side scan sonar surveys are carried out along lines covering the sand-dune tracking interest area. The records show images of the general river-bed configuration including sand-dune formations.

During the test gauging the performance of the instrument was verified in the sand-dune tracking area, see Drawing No. 2a. Due to the high concentrations of suspended sediment the images became quite hazy compared to images obtained during the dry season where concentrations are smaller.

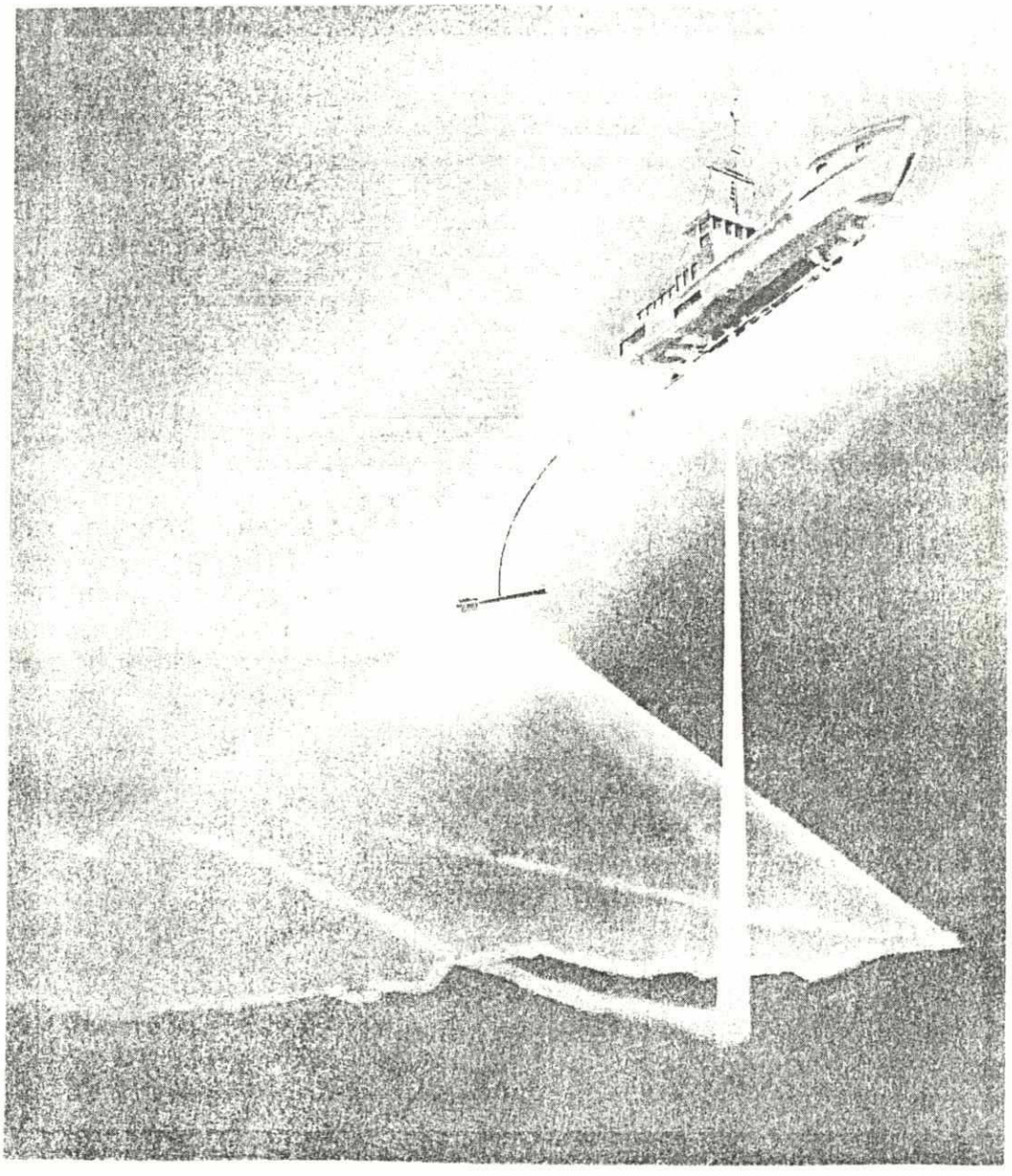


Figure 4.9 Coverage of the side scan sonar and data collection.

4.8 Bed load sediment transport measurement by trap sampling

During the test gauging bed load sediment transport measurements have been carried out in the test gauging cross-section using the Helley-Smith trap sampler. The Helley-Smith trap was removed from the river bed after 1 - 2 minute of sediment collection, depending on the amount of bed load transport. A pair of samples were collected at each location.

The samples were taken in connection with the suspended sediment and current profiling, mentioned above.

4.9 Bed load sediment transport measurement by sand-dune tracking

As an alternative to bed load transport measurement by trap sampling, a sand-dune tracking experiment by echo-sounding was carried out in another area, upstream of Bahadurabad Ghat, see Appendix 14, where well developed sand-dunes were available. The experiment was carried out using a predefined grid of survey lines.

The distance between the survey lines was 100 m. Each line was surveyed 3 times. The sand-dune tracking was supplemented with three Helley-Smith samples, taken in a selected sand-dune.

4.10 Bed material sampling

During the test gauging collection of river bed samples were carried out using the newly installed US BM-54 sampler, see Figure 4.10.

The US BM-54 sampler is operated from separate winches aboard the DHA and the DHC. When lowered to the river bed the sampler bucket will snap-shot automatically when the tension in the deployment wire is relieved. The sampler bucket is powered by a very strong coil spring.

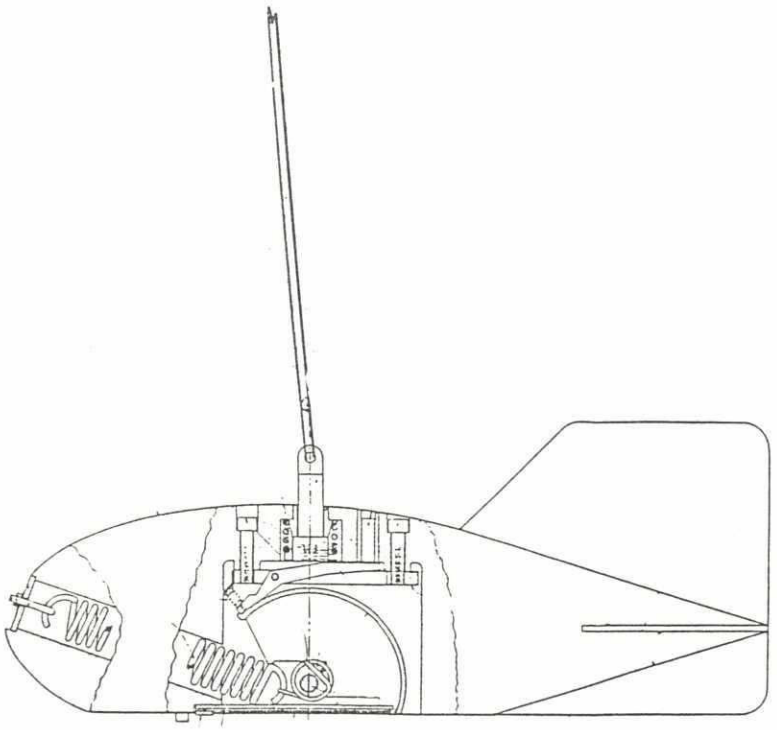


Figure 4.10 Principle sketch of the US BM-54 bed material sampler.

5. Survey equipment and modifications

5.1 Survey vessels and equipment

The River Survey Project FAP 24 operates three survey vessels:

- Ms. DHA, a former police patrol boat, built for shallow waters, see Figure 5.1. The boat has been modified for advanced survey work in Bangladesh. Ms. DHA has the following main dimensions:

- Length over all	20.25 m
- Breadth over all	4.70 m
- Draft	1.15 m

- Ms. DHC, a newly built catamaran survey vessel, see Figure 5.1. The vessel has the following main dimensions:

- Length over all	8.70 m
- Breadth over all	6.30 m
- Draft	0.45 m

- A 12 feet aluminium craft with two 25 hp outboard engines, see Figure 5.1.

Figure 5.1 The fleet of survey vessels on River Survey Project FAP 24 moored at Narayanganj. Ms. DHA is lying behind Ms. DHC and the alu. craft.

Each of the survey vessels are able to perform specialised survey operations comprising bathymetric survey, point current measurement, integrated current measurement, suspended sediment measurement, bed load sediment transport measurement and sediment sampling. Table 5.1 below states the capability and instrumentation aboard each of the survey vessels. A few remarks need to be attached to the equipment listed in Table 5.1 to have a background for understanding problems encountered during operation.

Equipment	DHA	DHC	Alu.cr.
DGPS Positioning system:			
Trimble 4000, 9 channel	X		
Trimble Navtrac, 6 channel		X	X
Bathymetric survey:			
Elac Laz 4420 (echo sounding)	X		
Simrad EA 300 P (echo-sounding)	X	X	X
Point current measurement:			
Ott meter (mechanical)	X		
S4 InterOcean (electromagnetic)	X	X	X
Integrated current measurement:			
ADCP (vertical)	X		
EMF	X		
Float tracking (horizontal)	X	X	X
Suspended sediment measurement:			
Pump bottle sampling	X	X	X
Depth integ. susp. sediment sampler	X		
MEX 3 Turbidity recorder	X		
Bed load sediment transport measurement:			
Helley-Smith trap sampler	X	X	
Sand-dune tracking by echo-sounding	X	X	X
River bed sediment sampling:			
Van Veen grab	X	X	X
US BM-54	X	X	
Side scan sonar:			
EG & G Model 260	X		
Communication:			
VHF radios	X	X	
Walkie talkies	X	X	X

Table 5.1 Capabilities and instrumentation aboard the three FAP 24 survey vessels, August 1993.

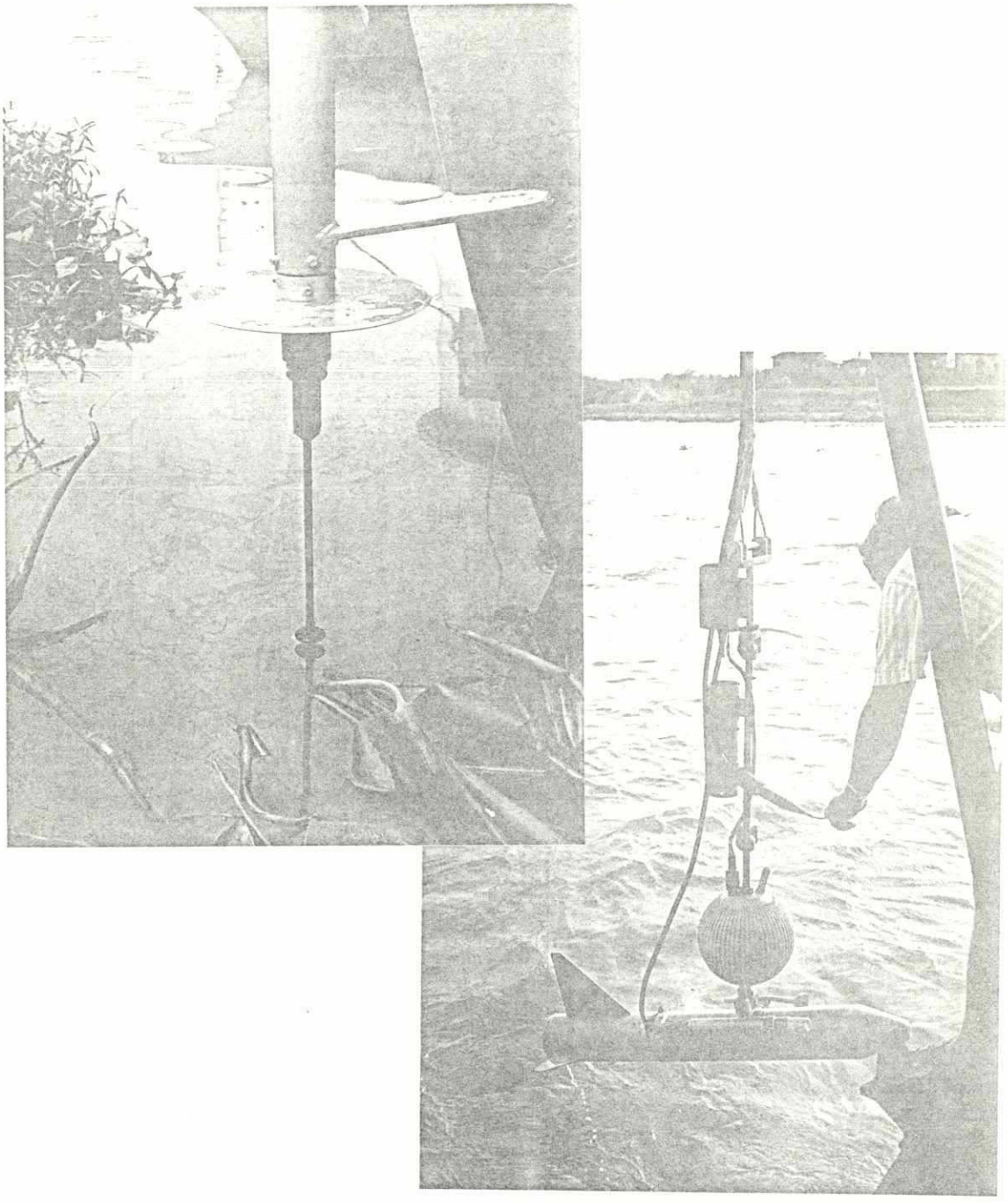


Figure 5.2 The EMF sensor mounted at the bow of Ms. DHA (upper left). Integrated current meter, suspended sediment sampler and turbidity meter (lower right). The turbidity meter is mounted on the side of the fish-type carrier. The suction hose of the suspended sediment pump is seen just above the carrier. The suction hose is succeded by the spherical S4 current meter and the suspended sediment pump.

The ADCP equipment, listed under integrated current measurement, is able to provide a two dimensional vertical current profile. The current profile consists of velocity vectors from the water column beneath the survey vessel. The ADCP transducers are mounted in a well midships of the DHA vessel, 0.85 m below the surface by normal lading conditions. Hereby the 300 kHz ADCP system is able to measure current profiles in the depth range from 2.7 m below the surface to approximately 1.5 m (the ADCP does not cover the last 6 per cent plus 1 bin size (0.5 m) of the water column) above the river bed.

The EMF equipment, listed under integrated current measurements, provides a point vector current measurement. The EMF equipment is used to supplement the ADCP equipment to span the above mentioned gap of the ADCP surface current measurements. The EMF sensor is mounted 0.5 m below the surface in the bow of the DHA vessel, see Figure 5.2 (upper left).

The S4 current meter, the suction hose of the suspended sediment sampler and the MEX 3 turbidity sensor have all been installed on the same winch operated wire. This combination of instruments is displayed in Figure 5.2 (lower right).

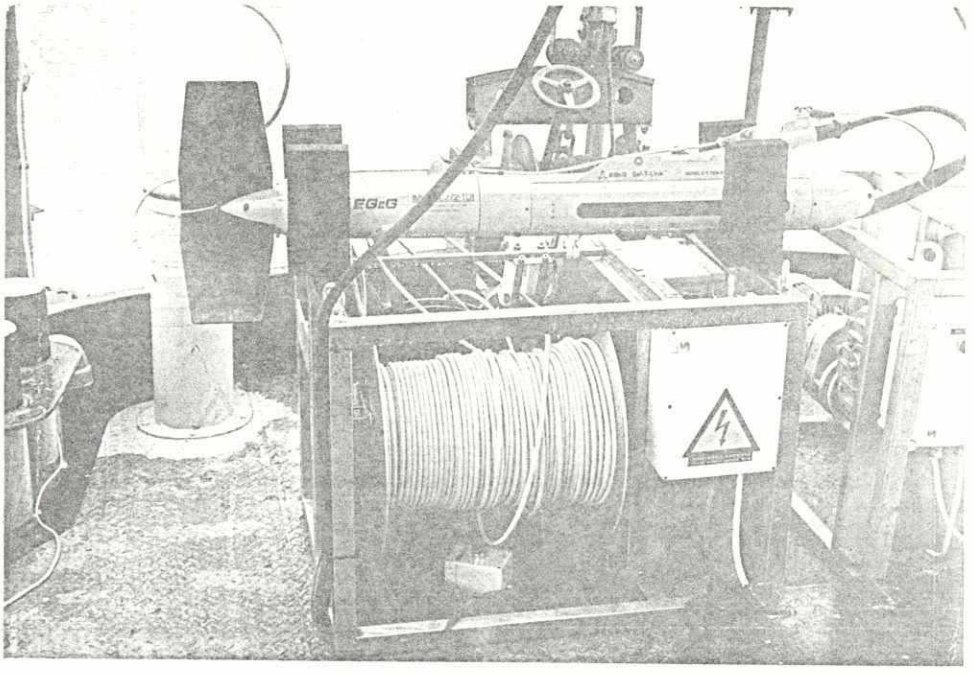


Figure 5.3 Side scan tow fish and winch aboard the DHA survey vessel.

The side scan sonar is able to provide an integrated area image of the river bed. The transducers of the side scan sonar are mounted in a tow fish, which is towed behind the survey vessel. The tow fish and the tow cable winch are depicted in Figure 5.3.

5.2 Modifications of equipment

As foreseen in the Technical Specifications (TS) and as mentioned in Chapter 2 some modifications due to local conditions were to be expected. All extensions and modifications of equipment carried out since February 1993 are summarized below.

o Anchoring System

The anchors on the DHA (one anchor fore and aft) and the DHC have been replaced by original DANFORTH anchors which have proved strong holding power. A stronger anchor winch has also been installed on the DHC.

Up till now the DHA has stayed in position on anchor in current velocities up to 3.5 m/s. Weighing of anchors have not caused any problems either.

o Vertical profiling

The signal conducting cable for the S4 electromagnetic current meter and the suction hose for suspended sediment sampling have been combined in one cable string called an umbilical. The umbilical is deployed from the quarter deck of the DHA.

The initial trials last year, showed that strong vibrations could disturb the measurements and that the vibrations might destroy the deployment winch in the course of time. Since then the vibrations have been eliminated by adding a fairing onto the umbilical.

The turbidity sensor will be better protected in the near future.

o Bed load transport measurements

Helley-Smith trap samplers have been installed on the DHA and the DHC.

o River bed sampling

US BM-54 bed material samplers have been installed on the DHA and the DHC.

o Survey boats and accessory equipment

Extra davits and winches have been installed for improved deployment of instruments.

Power supply to computers has been modified.

6. Selection of test gauging cross-section at Bahadurabad Ghat

The maximum water level in the Jamuna river at Bahadurabad recorded until mid August 1993 was 19.87 m PWD, slightly above the danger or bank-full level of 19.50 m PWD. During the survey in August 1993, the water level at Bahadurabad remained a little below 19.50 m PWD, or almost equal to the bank-full discharge.

Prior to the test gaugings in the Jamuna river several cross-sections were surveyed in the right and in the left main channel at Bahadurabad and Fulchari Ghat for identification of a suitable cross-section for measurements.

Based on the survey it was decided to situate the test gauging site in the left main channel just downstream of Bahadurabad Ghat, where flow conditions were found to be suitable for testing of equipment and procedures. Drawings Nos. 2a, 2b and 4 illustrate how measurements were arranged in the Bahadurabad Ghat cross-section.

Two locations were selected for verification and inter-calibration of instruments.

At the first location varying flow conditions made it impossible to keep the DHA survey vessel in a fixed position despite using two anchors - one forward and one astern. More than 1½ hour was spent on the anchoring operation, which proved futile by the subsequent data analysis.

At the second location the survey vessel was successfully anchored using one anchor forward while running the engine to reduce the current drag. In this location verification and inter-calibration of instruments were completed.

The reconnaissance showed that detection of a so-called ideal cross-section according to international recommendations and standards may be very difficult to fulfil in the Rivers of Bangladesh. In this respect selection of suitable cross-sections allowing for a complete measurement coverage using the moving boat method (by EMF or ADCP) will be a time consuming operation. Further investigations are required to optimize the procedure for selection of a suitable cross-section. It is anticipated that remote sensing will prove very useful.

Reconnaissance was also carried out in inlets and channels on the central island depicted in Drawings Nos. 2a and 2b. One small channel crossing the central island from north to south was detected and should be surveyed to cover the whole of the Jamuna River cross-section from bank to bank. This survey did not form any part of the test gauging, but was included in the subsequent routine discharge measurement.

7. Verification test and inter-calibration

Prior to the test gauging all instruments had to be verified. The verification serves as a functioning check. Good function does not necessarily imply correct measurements, wherefore a comparison with other instruments, a so-called inter-calibration is made.

7.1 Positioning system

Prior to the test gauging, the Differential Global Positioning System (DGPS) was verified by transfer of the DGPS receivers from the vessel to the SOB bench mark GPS 764. GPS 764 is situated in the vicinity of the Bahadurabad Ghat test gauging area, approximately 1 km east of the left river bank.

The DGPS receivers were operated in differential mode, receiving corrections on-line via the UHF radio link to the reference station. The reference station was established at Fulcharighat, on the right river bank. Conversion of WGS 84 data was carried out by the Hydro software package, installed on a PC, which was interfaced to the DGPS receivers.

The positioning system was verified by comparing the BTM coordinates of bench mark GPS 764 to the coordinates obtained from the DGPS positioning system. According to the below positions, the deviation was within the 2 m horizontal accuracy of the DGPS system operated in stationary mode.

GPS 764, coordinates	Measured coordinates	Discrepancy
BTM E 471086.158	BTM E 471084.4	E 1.8 m
BTM N 778478.880	BTM E 778477.4	N 1.5 m

7.2 Echo-sounders

The echo-sounders were operated using a velocity of sound figure of 1500 m/s. Based on temperature and salinity profiles, measured regularly by the S4 instrument, the velocity of sound figure was corrected.

Prior to the test gauging a bar check for verification of the echo-sounder was carried out.

7.3 Current meters

7.3.1 General information

During Phase I of the project, several verification and comparison tests have been carried out using the following types of current meters:

- o Acoustic Doppler Current Meter (ADCP) 300 kHz system
- o Acoustic Doppler Current Meter (ADCP) 1200 kHz system
- o Electro Magnetic Flow Meter (EMF)
- o Electro Magnetic Current Meter (S4)
- o Propeller Current Meter (Ott)

All instruments were calibrated and verified by the manufacturer prior to shipment to Bangladesh.

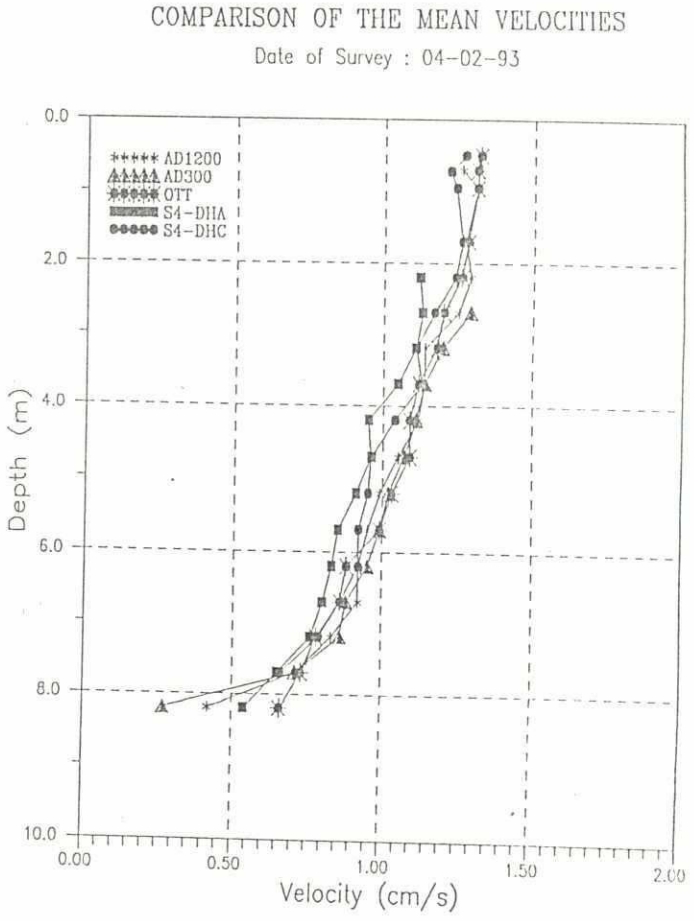


Figure 7.1 Comparison of mean velocities, 4 February 1993.

The verification test carried out in February 1993 indicated good agreement between the ADCP system, the EMF and the Ott current meters by moderate velocities. The S4 current meter were reporting 5 - 8 per cent lower current velocities by the verification test, see Figure 7.1.

Later verification tests still indicated good agreement between the ADCP, the EMF and the Ott current meters. However the Ott current meter systematically seemed to report a few percentage higher velocities than the ADCP and the EMF instruments. The S4 current meter were still reporting 5 - 10 per cent lower current velocities.

The S4 current meter is used for manual profiling because of its ability to measure the local current direction and because of its general applicability. Owing to the incessant underestimation of the velocity by the S4 current meter it was decided to let the US manufacturer recalibrate and verify the calibration. This recalibration was completed in May 1993 prior to the 1993 flood season.

7.3.2 Verification tests of current meters prior to the test gauging

As mentioned in Chapter 3, a complete verification and inter-calibration test was carried out on August 17, at location I1 in the left main channel of the Jamuna river, south of Bahadurabad Ghat, see Drawing 2b.

By the subsequent data analysis a large scatter was observed in the current measurements. This scatter was ascribed to an imbalance of the tow fish and the anchoring problems described in Chapter 6. The tow fish was balanced in the evening. Consequently it was decided to complete a second verification and inter-calibration test under more stable current conditions.

The second inter-calibration test was carried out at location I2 on the 20 August 1993, see Drawing 2b. Not completely certain about the origin of the observed scatter and since previous tests had shown that the revolving Ott propeller had a magnetic impact on the S4 unit, it was decided to do the test in two steps:

- Simultaneous measurements with ADCP, EMF, S4 and Ott current meters
- Simultaneous measurements with ADCP, EMF, S4 and exclusive the Ott current meter.

The results of the second inter-calibration test are presented in Figures 7.2A and 7.2B.

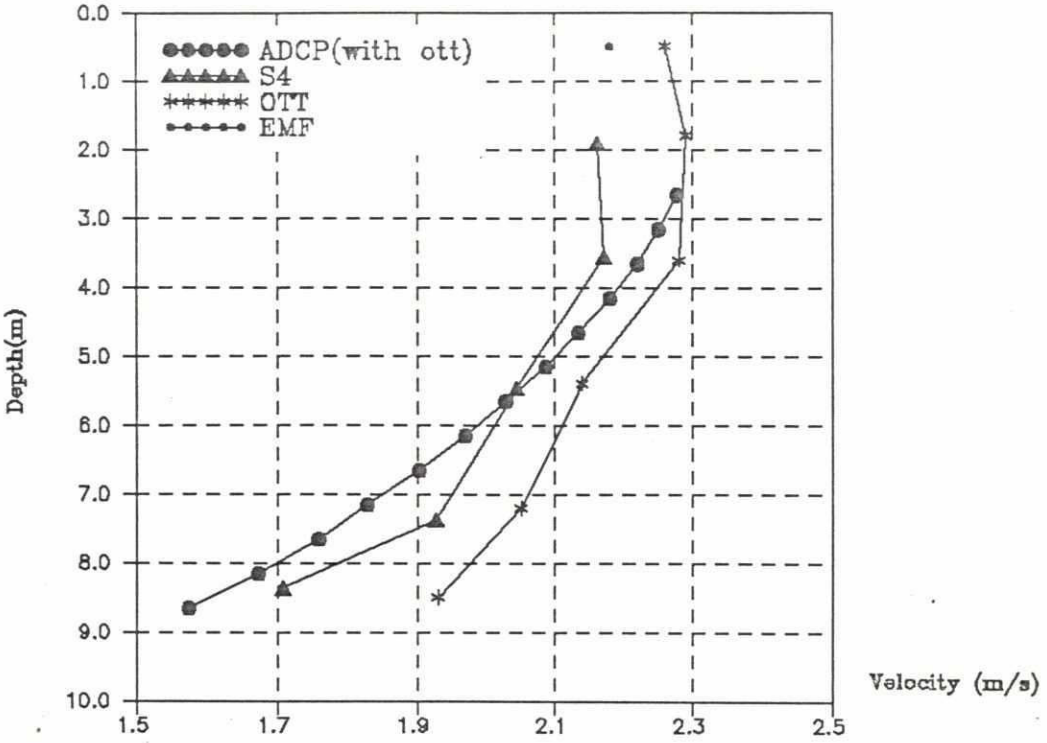


Figure 7.2A Inter-calibration of ADCP, EMF, S4 and Ott current meters at location I2, 20 August 1993.

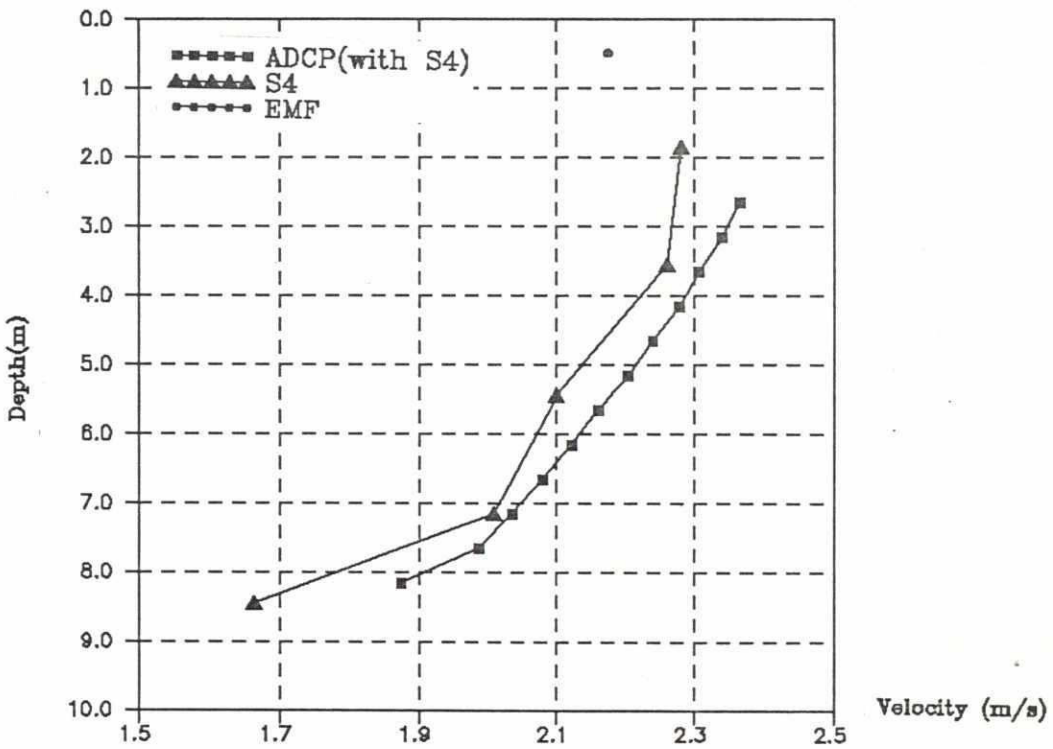


Figure 7.2B Inter-calibration of ADCP, EMF and S4 current meters at location I2, 20 August 1993.

In general the same pattern as observed during the low flood conditions in February 1993 was seen:

- Fair agreement between the ADCP, the EMF and the Ott current meters, with the Ott current meter systematically reporting the highest velocities

- The S4 current meter generally reports lower current velocities than the other current meters

It caused some concern that the S4 current meter was still reporting lower current velocities, but without decissive indications it was impossible to decide any alteration in the test gauging programme. Conclusions had to await the subsequent data-processing in Dhaka.

7.3.3 Evaluation and conclusion of the inter-calibration tests

By the subsequent data processing in the consultants home office it became even more apparant that the S4 current meters were reporting too low current velocities compared to the ADCP, see Appendix 6.

Based on these findings the consultants decided to further investigate the calibration of the S4 current meter. After communication with the S4 manufacturer it became clear that the May 1993 recalibration had been fouled and new calibration settings for the S4 current meter were received, see Appendix 16.

Introduction of the new calibration settings increased the recorded S4 velocities by 12 per cent according to the manufacturer, see Appendix 16. **Consequently all S4 current measurements, obtained before the new settings were implemented (November 1993), have been increased by 12 per cent.** This correction has several implications:

- The agreement between the S4 current profilings, and the ADCP measurements is significantly improved, see the corrected velocity profiles in Appendix 6

- Correction of the inter-calibration at location I2, Figures 7.3A and 7.3B, reveals a large discrepancy between the S4 current measurement and the ADCP and the Ott current meter.

The inter-calibration at location I2 does not have a special status compared to the other profiles in Appendix 6. The correction should be seen and accepted on this context. This of cause, does not free the consultant from digging deeper into the large scatter in the inter-calibration. Obviously there is a problem which needs further clarification, and more inter-calibrations will be made in the future, including other measurement locations, also.

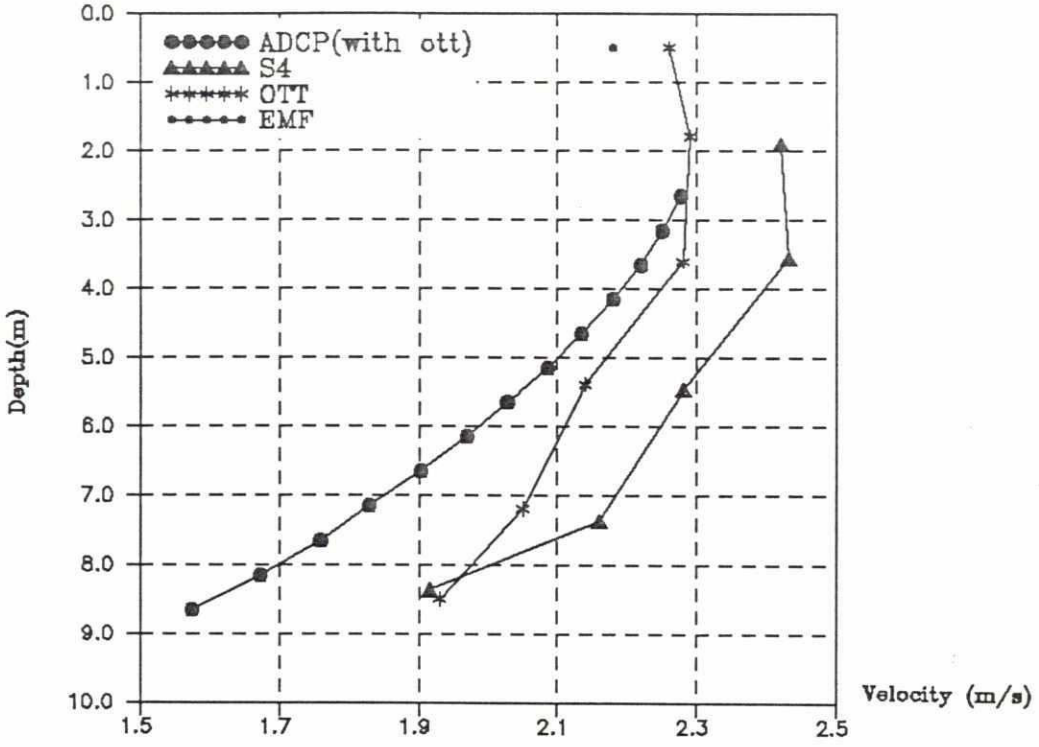


Figure 7.3A Inter-calibration of ADCP, EMF, S4 (corrected) and Ott current meters at location I2, 20 August 1993.

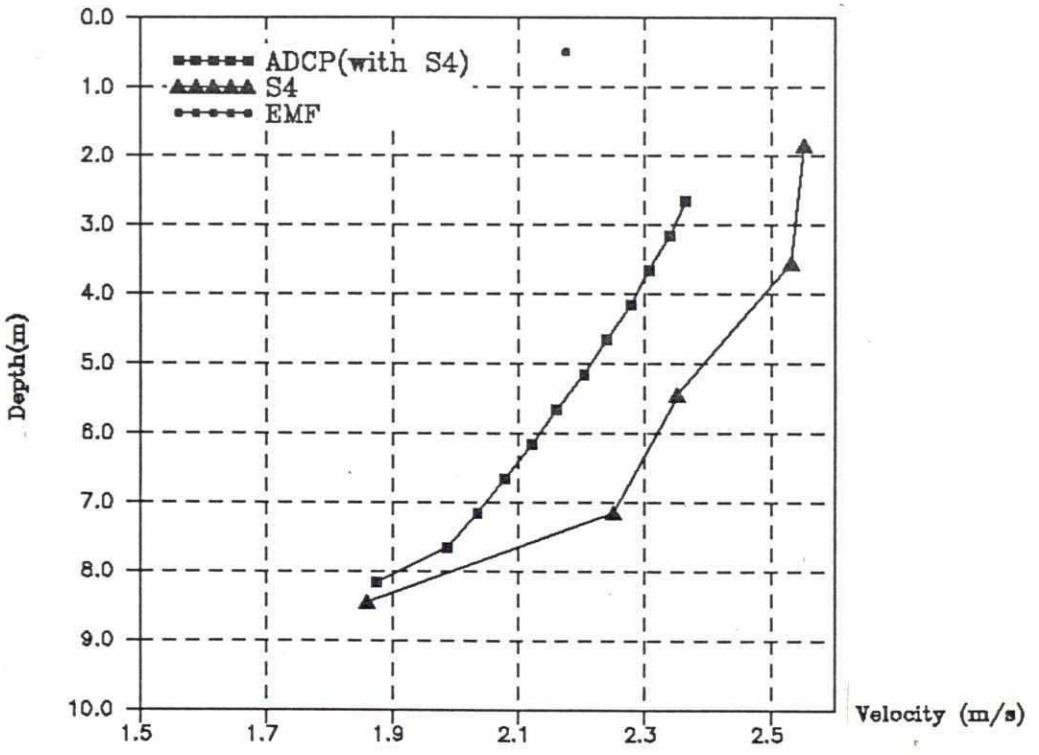


Figure 7.3B Inter-calibration of ADCP, EMF and S4 (corrected) current meters at location I2, 20 August 1993.

8. Measurement results

In our presentation the measurements results are divided into discharge measurements, suspended sediment measurement and bedload sediment measurement. Nevertheless all types of data originate from simultaneous survey activities and are presented along one another in Appendices 3-16 regardless of this practical division.

A further analysis with special regard to selection of survey techniques may be found in Volume II, Selection of Survey Techniques.

8.1 Discharge measurement

8.1.1 Discharge measurement by the reference method

The reference method is also known as the velocity-area method.

The test gauging cross-section for discharge measurement is indicated in Key Plan Drawing No. 2b, Jamuna river at Bahadurabad Ghat. All profilings were carried out using S4 current meters.

Originally during the inter-calibration of the S4 current meter, mentioned in Chapter 7, a serious discrepancy in the current measurements was revealed. This discrepancy has now been recovered. The S4 manufacturer has verified that the original set of calibration settings were erroneous and revised settings has been supplied. After implementation of the revised settings the S4 current measurements are now in fairly good agreement with other measurements.

According to the test gauging procedures outlined in Section 8.2 most of the Bahadurabad Ghat cross-section is classified as a main channel, while a minor part is classified as a smaller channel. The selected test gauging cross-section was covered by current measurements in 18 vertical as indicated in Drawing No. 4. The main channel part of the cross-section was covered by 16 verticals while the smaller channel part of the cross-section was covered by 2 verticals. In summary the cross-section was covered by 102 average point current measurements.

The 16 verticals, with six point manual measurement of 300 second average current velocities in the main channel cross-section are listed in tabular form and plotted as velocity profiles in Appendix 4.

The 2 verticals, with three point manual measurements of 100 second average current velocities in the smaller channel cross-section are listed in tabular form and plotted as velocity profiles in Appendix 4.

Average current velocities from 0.5 m/s to 2.88 m/s were measured.

By using the velocity-area method, the discharge in the test gauging cross-section was in the range 25,774 to 26,429 m^3/s. The discharge calculation is influenced by the various bathymetric surveys of the tests gauging cross-section. The average discharge measured according to the reference method was 26,130 m^3/s.

Appendix 2 contains information on the duration of the individual survey activities. The average field completion time of a six point vertical velocity profile amounted to 61 minute, based on 15 test gauging vertical. The average field completion time of a three point vertical velocity profile amounted to 39 minute, based on 2 test gauging vertical.

The entire test gauging cross-section, comprising 18 vertical, was surveyed in 17 hour and 29 minute of actual operation time during the three days of test gauging.

8.1.2 Discharge measurement by the recommended method

The test gauging cross-section for discharge measurement is indicated in Key Plan Drawing No. 2b, Jamuna river at Bahadurabad Ghat. All current measurements were carried out using the ADCP and EMF equipment.

According to the inter-calibration, Chapter 7 the ADCP and EMF equipment was in fairly good agreement with other current measurements.

The 300 kHz ADCP used during the test gauging, measures a vertical velocity profile every 5 - 6 second. The velocity profile consists of a pair of horizontal current vectors for every 0.5 m. The average survey speed was 1.9 m/s, whereby the entire test gauging cross-section was covered by 279 vertical velocity profiles. With an average depth of 6.9 m, every vertical contains 7 pairs of horizontal current vectors, taking the limitations of the ADCP system into account. Consequently the Bahadurabad Ghat test gauging cross-section would be covered by approximately 2,200 current measurements, according to the recommended ADCP/EMF methodology.

Measurements of the spatial distribution of horizontal current vectors along the entire test gauging cross-section by ADCP are referred to as a transect. The 9 transects, which were surveyed during the test gauging, are depicted in Appendices 5 and 12. The length of the current vectors represent the magnitude of the local horizontal current. The current direction is relative to the orientation of the actual transect survey line. The current vectors are depicted at their vertical positions in the cross-section along with the river bed contour. Consequently two different

projections are depicted along one another in Appendices 5 and 12. As long as it is kept in mind that all velocity vectors in Appendices 5 and 12 represent horizontal velocities this should cause no confusion.

Current velocities from 0.20 m/s to 3.15 m/s were measured during the 9 surveys according to Appendix 12.

Using the calculation method described in 1st Interim Report, Volume II, Appendix 1 the discharge in the test gauging cross-section was in the range 26,444 to 29,430 m^3/s depending on which of the 8 transects was applied. Consequently the average discharge measured according to the recommended method was 28,194 m^3/s.

The entire test gauging cross-section was surveyed in 25 minute and 36 second on the average, with a standard deviation of 1.9 minute.

8.1.3 Comparison of the reference and the recommended method

Owing to the inherent nature of the two types of measurements it makes little sense to make direct comparison between the average current vectors obtained by manual profiling and almost instantaneous transect current vectors. A comparison of the two types of measurements is possible if the ADCP/EMF equipment is kept stationary during the averaging period applied during manual profiling, see Chapter 7. According to Chapter 7 the two types of measurements are in fairly good agreement with one another by this comparison.

The total discharge measurement in the test gauging cross-section provides another comparison of the reference and the recommended method. Table 8.1 contains a lists of total discharge calculations based on the 9 bathymetric surveys completed in the test gauging cross-section. Column 2 of Table 8.1 contains the discharge estimates based on the reference method. Column 3 of Table 8.1 contain discharge estimates based on the recommended method.

Survey	Reference method discharge m^3/s	Recommended method discharge m^3/s
20 Aug 1993, 09:32	26,046	28,412
20 Aug 1993, 10:16	25,774	28,120
20 Aug 1993, 17:07	26,429	28,008
20 Aug 1993, 17:35	26,252	28,656
21 Aug 1993, 09:13	26,186	27,495
21 Aug 1993, 09:42	26,142	29,430
21 Aug 1993, 17:17	25,914	26,444
22 Aug 1993, 09:28	26,133	-
22 Aug 1993, 09:58	26,293	28,986
Statistic: Average St. Dev.	 26,130 198	 28,194 926

Table 8.1 Comparison of discharges calculated by the reference and the recommended method.

The average difference in the discharge estimated by the reference method and the recommended method amounts to 7 per cent. Keeping the almost instantaneous nature of the ADCP/EMF current measurements in mind, it is interesting to observe a standard deviation on the discharge of 3.2 per cent only. This indicates that no averaging over several transacts is needed.

On the average the integrated current measurement by ADCP and EMF was 41 times faster than the point current measurement in terms of actual operation time spend in the test gauging cross-section. If the spatial resolution is included in this comparison the recommended method was approximately 900 times faster than the reference method.

8.1.4 Float tracking

The test gauging cross-section at Bahadurabad Ghat was surveyed by float tracking on the 17th and 19th of August 1993, Appendix 15. The 19 of August 1993 a total of 13 float trackings, covering the entire test gauging cross-section were completed.

Current velocities from 0.07 m/s to 3.15 m/s were measured on the 19 August according to Appendix 15.

All floats had a draft of 1.50 m. Consequently only surface currents were measured and no information on the discharge in the test gauging cross-section is derived.

8.2 Suspended sediment measurement

8.2.1 Suspended sediment transport by point sampling

The cross-section for suspended sediment transport measurement is indicated in the Key Plan Drawing No. 2b, Jamuna river at Bahadurabad Ghat. Based on 0.5 l suspended sediment samples information on suspended sediment concentration was obtained.

According to the test gauging procedures outlined in Sections 4.6 suspended sediment sampling and point current measurements are carried out in a simultaneous operation. The channel cross-section classifications outlined in Section 4.2 pertains to suspended sediment sampling also. Consequently the test gauging cross-section was covered by 102 suspended sediment samples.

The 16 verticals, with six point measurement of suspended sediment concentration in the main channel cross-section are listed in tabular form and plotted as concentration profiles in Appendix 4. Samples from vertical 7 and 18 were not obtained due to mechanical break-down. The same applies to the sediment sample as close to the bed as possible in vertical 4. Otherwise all samples were obtained.

The 2 verticals, with three point measurement of suspended sediment concentration are listed in tabular form and plotted as concentration profiles in Appendix 4.

Suspended sediment concentrations ranging from 37 mg/l to 2076 mg/l were measured according to Appendix 4.

Using the velocity-area method multiplied by the local suspended sediment concentrations, the suspended sediment transport across the test gauging cross-section was in the range 21,675 kg/s to 22,441 kg/s. The suspended sediment transport calculation is influenced by the various bathymetric surveys of the tests gauging cross-section. The average suspended sediment transport according to the reference method was 22,075 kg/s.

According to the test gauging procedures 25 l samples were collected at the lowest suction level for Andreasen settling tube determination of grain-size distribution. Grain size distribution curves and tables of D_{16}, D_{35}, D_{50} and D_{90} are presented in Appendix 9. Data from vertical 7 are missing.

The grain size distribution curves exercise substantial variation.

Using the sediment pump described in Chapter 5 the most time consuming part of the suspended sediment sampling was actually the anchoring operation. No characteristic values on duration can be derived.

8.2.2 Suspended sediment transport by the depth integrated sampler

The cross-section for suspended sediment transport measurement is indicated in Key Plan Drawing No. 2b, Jamuna river at Bahadurabad Ghat. Based on 2 l integrated suspended sediment samples, information on integrated suspended sediment concentration was obtained.

Based on integrated suspended sediment samples from vertical 1, 2, 3, 4, 5, 6 & 7 the calculated integrated suspended sediment concentrations are plotted as straight lines in Appendix 8. The integrated concentrations are plotted on the context of point measurements obtained by the reference method to illustrate their representativeness.

Due to software problems it has not been possible to calculate the suspended sediment transport based on ADCP/EMF transects and integrated suspended sediment concentrations. It is expected that these software problems will be overcome in the near future.

It takes approximately 2 minute to obtain an integrated suspended sediment sample.

8.2.3 Comparison of methods

From the plots of integrated suspended sediment concentrations and point concentrations in Appendix 8 it is seen, that the integrated suspended sediment concentration is always within the bounds defined by the maximum and minimum point concentrations. It is also seen that in most instances the integrated suspended sediment concentration represents a kind of average suspended sediment concentration.

As pointed out in Section 8.2.2 no estimate of the suspended sediment transport based on transects and integrated suspended sediment samples is available. Consequently it is not possible to compare the reference methodology and the recommended methodology.

As an alternative to this comparison the suspended sediment transport based on manual profilings and point and integrated suspended sediment samples in a minor part (46 per cent) of the test gauging cross-section has been calculated by hand. Based on the point samples or the integrated sample, the suspended sediment transport amounted to 16,617 kg/s and 15,216 kg/s respectively. There is thus a difference of 9 per cent in the calculated suspended sediment transport.

The integrated suspended sediment sampling procedure is faster than the point sampling procedure.

8.2.4 Relative sectional distribution of suspended sediment

The ADCP equipment mentioned in Chapter 5 is not only able to measure the spatial current distribution but also the spatial distribution of suspended sediment concentration.

No calibration of the ADCP equipment have been attempted and consequently only relative distributions of suspended sediment are available in the test gauging cross-section at Bahadurabad Ghat, see Appendix 13. The relative distributions shows a great variation throughout the three days of test gaugings.

The entire test gauging cross-section was surveyed in 25 minute and 36 second on the average, which is very fast compared to manual profiling techniques. Due to this very high survey speed the relative suspended sediment concentrations might serve as a valuable tool for positioning of the suspended sediment concentration verticals.

8.2.5 Turbidity

Relative turbidity plots from vertical 1, 2 and 3 in the Bahadurabad Ghat cross-section are presented in Appendix 7 along with plots of suspended sediment point concentrations.

The turbidity is depicted relative to the maximum recording and no transformation to an absolute suspended sediment concentration profile has been attempted. Judging by the point measurements of the suspended sediment concentration, the relative turbidity exercise a similiar variation in each vertical.

8.2.6 Grain size distribution curves

According to the test gauging procedures 25 l suspended sediment samples were collected at the lowest suction level from each vertical within the test gauging cross-section for Andreasen settling tube determination of grain-size distribution. Grain size distribution curves and tables of D_{16}, D_{35}, D_{50} and D_{90} are presented in Appendix 9. Data from vertical 7 are missing.

By comparison the grain size distribution curves exercise substantial variation.

8.3 Bed load sediment measurement

8.3.1 Helly-Smith trap samples

The cross-section for bed load sediment transport measurement is indicated in Key Plan Drawing No. 2b, Jamuna river at Bahadurabad Ghat.

According to the test gauging procedures outlined in Section 4.8 two Helley-Smith trap samples were taken from each of the 18 test gauging vertical. Gradation curves and tables of D_{16}, D_{35}, D_{50} and D_{90} are displayed in Appendix 10.

The average field completion time for a single Helley-Smith trap sample was 11 minutes based on 16 representative cases mentioned in Appendix 10.

8.3.2 Sand-dune tracking

Unfortunately there were no well developed sand-dunes in the test gauging area at Bahadurabad Ghat during the test gauging. Consequently sand-dune tracking by echo-sounding was carried out in an alternative upstream area, see Drawing 2a.

The surveys were completed according to the following schedule:

o	1'st Survey	18 August 1993, 14:00 - 16:35
o	2'nd Survey	19 August 1993, 09:45 - 12:15
o	3'rd Survey	19 August 1993, 15:45 - 16:45

All surveys are found in Appendix 14. During the 3'rd survey the grid was only partially covered.

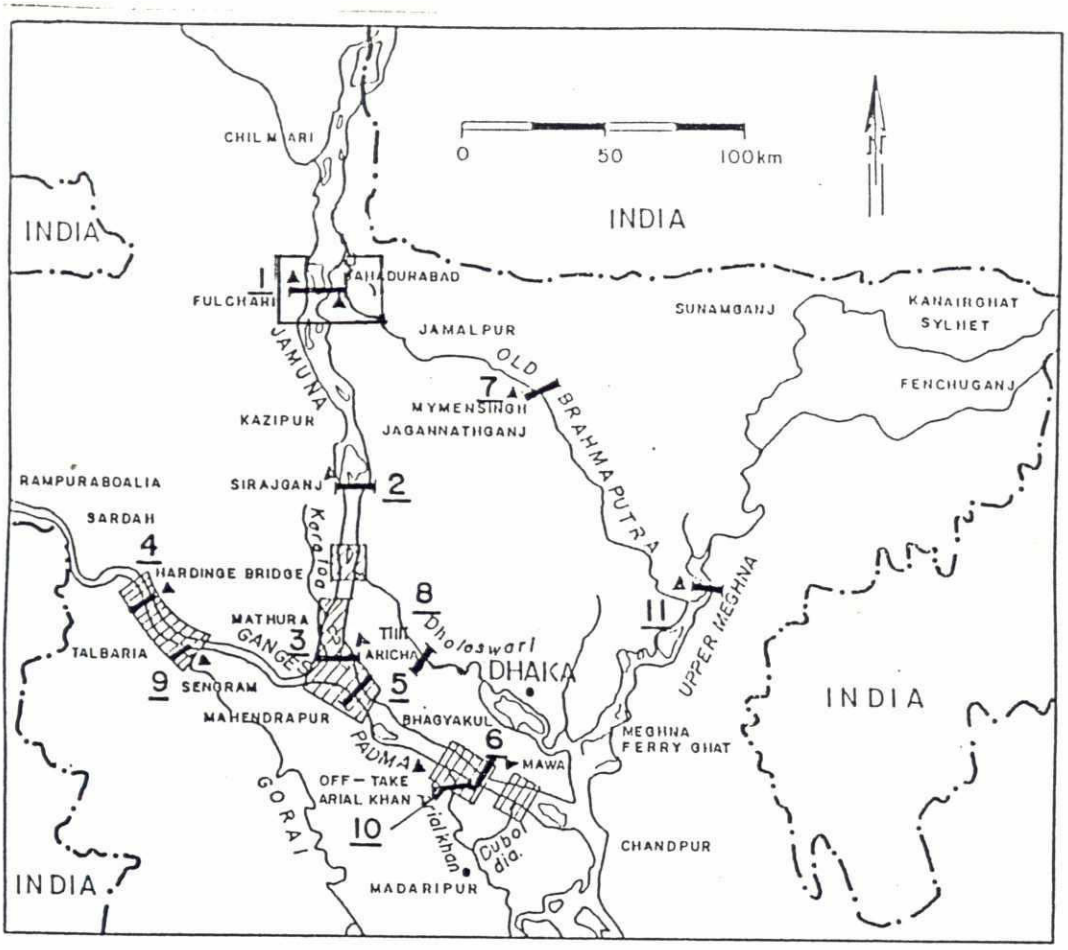
The side scan sonar is able to produce images of the river bed, and is thus a valuable tool for planning of an echo-sounding survey. Examples of river bed images in the alternative area are displayed in Appendix 16. According to Appendix Nos. 16-1 and 16-2 it was very difficult to obtain detailed images during the high flood conditions in August 1993. Despite using different frequency domains all recordings were hazy and difficult to interprete. This is probably mainly due to the high suspended sediment concentrations. As an example of a very detailed side scan sonar image of the same river bed obtained during the low flood conditions in January 1993, Appendix No. 16-3 is enclosed.

List of references

o FAP 24, 1° Interim Report / River Survey Project DELFT HYDRAULICS & Danish Hydraulic Institute, February 1993

o

Drawings



LEGEND :-

- ▲ SITES FOR AWLR.
- CROSS-SECTION, DISCHARGE AND SEDIMENT MEASUREMENT
- INDICATIVE SITES FOR PRE- AND POST MONSOON BATHYMETRIC SURVEYS
- TEST GAUGING SITE

FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		TEST GAUGING REPORT Jamuna River at Bahadurabad	
File:	Date:	LOCATION MAP	Drg.No. 1
Scale:	Init:		

89° 35'

89° 40'

89° 45'

465

468800

469400

468500

469250

470

25° 15'

790

787600

786875

786125

786400

785

25° 10'

JAMUNA RIVER

JAMUNA RIVER

SAND-DUNE TRACKING

Phulchari

FAP 24 RIVER SURVEY PROJECT

DELFT-DHI

Delft Hydraulics Dhaka Hydraulic Institute in association with Univ. Agriculture Wageningen

Test Gauging Report

Jamuna River at Bahadurabad (Left Channel)

File: | Date:

Scale: | Init:

KEY PLAN

Drg.No.2a

89°35'

89°40'

467500

470068
470310
470500

89°45'

460

465

470

GABGACHI

JAMUNA RIVER

JAMUNA RIVER

TEST GAUGING SITE

Harindhara

Bahadurabad
Ghat.

Belgachha

780

778500

77750

775

25°
05'

I1

I2

LEGEND

- WATER-LEVEL GAUGING STATION (AWLR)
- INTER-CALIBRATION POSITION (I1 AND I2)
- TRANSECT LINE

FAP 24 RIVER SURVEY PROJECT

DELFT-OHI

Test Gauging Report

Jamuna River at Bahadurabad (Left Channel)

File:

Date:

Scale:

Init:

KEY PLAN

Drg.No.2b

FAP 24 RIVER SURVEY PROJECT

DELFT-DHI — Delft Hydraulics/Danish Hydraulic Institute in association with Ockrim/Agrotech/Hydroland

TEST GAUGING REPORT

JAMUNA RIVER AT BAHADURABAD GHAT

CLASSIFICATION OF CROSS-SECTION

Drg.No. 3

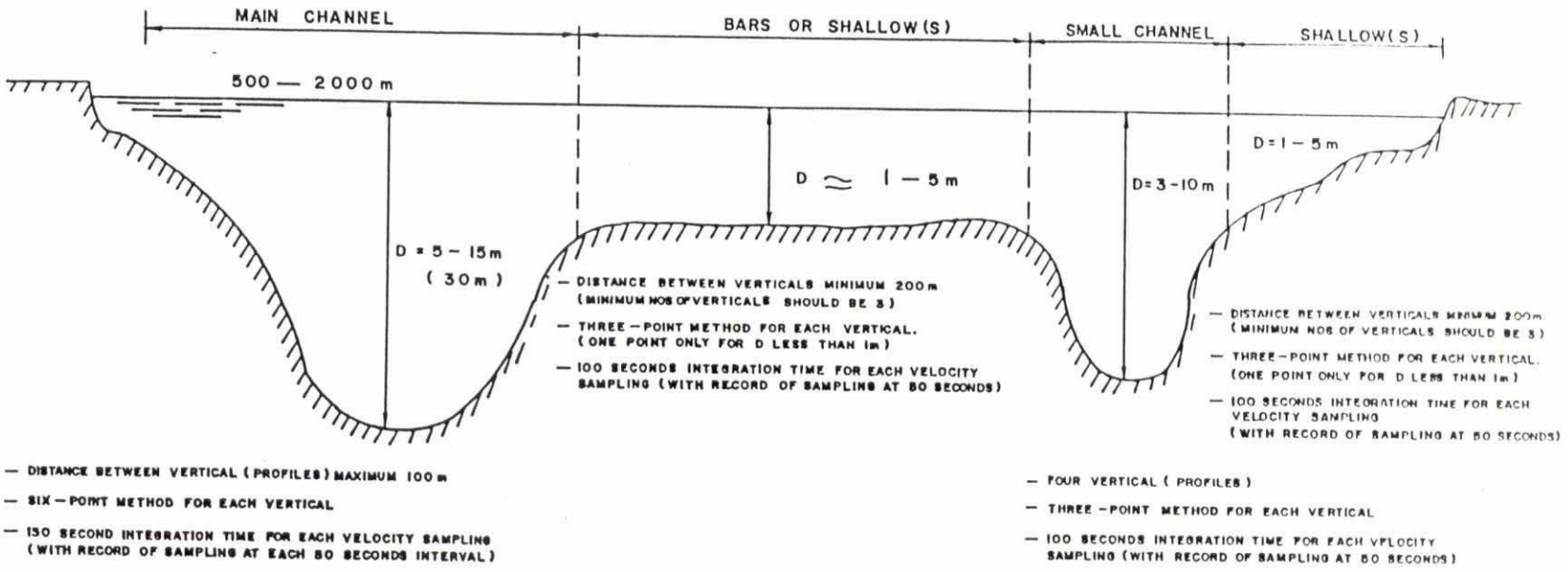
File:

Date:

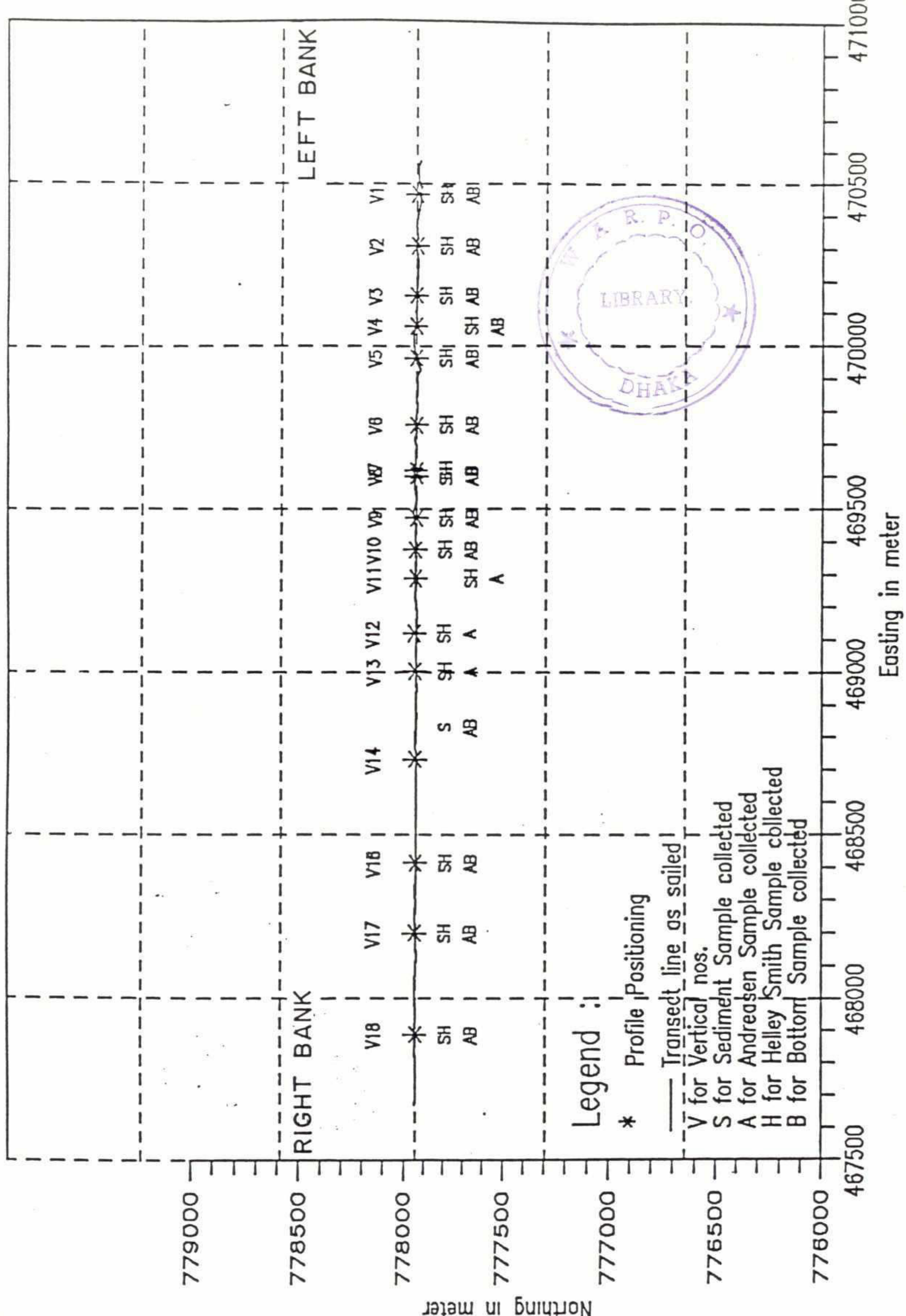
Scale:

Init:

FAP 24 — CLASSIFICATION OF MEASUREMENT CROSS SECTIONS



Principle sketch of measurement cross – section including requirements to no of verticals and point measurements as well as measurement integration time.



FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	TEST GAUGING POSITIONS	Drg.No. 4
Scale:	Init:		

Appendices

Appendix 1

Intended test gauging schedule

Test Gauging Programme

Prior to initiation of the test gauging a day by day programme as listed in the following was agreed with the FPCO and the PA.

Monday 16 August 1993

Selection of suitable cross-sections for verification of instrument performance and inter-calibration as well as for test gauging in a complete cross-section involving:

- o Verification of the integrated bathymetric survey system
- o Longitudinal and transverse bathymetric surveying
- o ADCP cross-sections (transsects)

Tuesday 17 August 1993

- o Float tracking in the area selected for inter-calibration of instruments
- o Inter-calibration of current meters (while lying on two anchors)
- o Trials with suspended sediment sampling as specified with respect to number of samples in a vertical profile
- o Turbidity recording, bottom sediment sampling and bed load sediment sampling using the Helley-Smith trap sampler.

Wednesday 18 August 1993

- o Combined ADCP/EMF and echo-sounding survey (transsect) in the selected cross-section.
- o Function test of the side scan sonar in combination with a reconnaissance survey for a sand dune area. This test will be concluded with the first Sand Dune Tracking in a predefined grid of survey lines.

Thursday 19 August 1993

- o Test gauging of bed load sediment transport by intensive Sand Dune Tracking supplemented with Helley-Smith sampling. This involves one complete tracking in the morning and in the evening respectively.

Friday and Saturday 20 and 21 August 1993

Discharge and suspended sediment sampling including bed load sediment transport measurements involving:

- Two combined ADCP/EMF crossings in the morning and in the evening
- Based on the first set of records the locations for manual profiling will be decided.
- Manual profiling using:
  - S4 current meter
  - pumping suspended sediments in to bottles
  - integrated water sampler
  - turbidity meter
  - Helley-Smith trap sampler

Appendix 2

Summary of test gauging activities at Bahadurabad Ghat, Jamuna river, 20-22 August 1993

FAP 24 RIVER SURVEY PROJECT

DELFT-DHI — Delft Hydraulics/Danish Hydraulic Institute in association with Ourin/Approach/Hydroland

File:

Date:

Init:

Scale:

Test Gauging Report

Jamuna River at Bahadurabad (Left Channel)

Summary of Manual Profilings

App. No. 2-1

Date of Survey : 20 Aug 93

Type	Time		File	Ver.	Easting	Northing	DISCHARGE GAUGING					SEDIMENT TRANSPORT GAUGING				
	From	To	Name	No.	(meter)	(meter)	ADCP	HYDRO	EMF	S4	MEX	Suspended Sediment Samples	Andreasen Tube Samples	Helley Smith Samples	Integrated Sediment Samples	Bottom Samples
Transect	09:32:15	10:01:14	B38K1T02				T	T	T							
Transect	10:16:17	10:41:45	B38K1T03				T	T	T							
Transect	17:07:06	17:31:12	B38K1T06				T	T	T							
Transect	17:35:10	17:57:56	B38K1T07				T	T	T							
Profile	11:12:28	13:02:31	B38K1P01	2	470309	777497	P	P	P	P	P	6	1	2	1	1
Profile	14:48:49	16:18:30	B38K1P03	1	470468	777497	P	P	P	P	P	6	1	2	1	1

Date of Survey : 21 Aug 93

Type	Time		File	Ver.	Easting	Northing	DISCHARGE GAUGING					SEDIMENT TRANSPORT GAUGING				
	From	To	Name	No.	(meter)	(meter)	ADCP	HYDRO	EMF	S4	MEX	Suspended Sediment Samples	Andreasen Tube Samples	Helley Smith Samples	Integrated Sediment Samples	Bottom Samples
Transect			B38L1T01				T	T	T							
Transect			B38L1T02				T	T	T							
Transect			B38L1T03				T	T	T							
Profile	10:43:52	11:59:01	B38L1P01	3	470157	777500	P	P	P	P	P	6	1	2	1	1
Profile	12:37:34	13:40:34	B38L1P02	4	470062	777501	P	P	P	P	P	6	1	2	2	1
Profile	14:07:19	15:29:20	B38L1P05	5	469965	777500	P	P	P	P		6	1	2	1	1
Profile	16:00:04	16:52:26	B38L1P06	6	469759	777499	P	P	P	P		6	1	2	1	1
Profile	15:27:47	16:15:40	B38L2P05	14	468732	777504		P		P		6	1	2		1
Profile			B38L2P04	15	468566	777502		P		P		6	1	1		1
Profile	13:36:57	14:38:17	B38L2P03	16	468413	777502		P		P		3	1	1		1
Profile	11:47:35	12:04:24	B38L2P02	17	468198	777504		P		P		3	1	2		1
Profile	11:17:16	11:22:16	B38L2P01	18	467887	777501		P		P		1	1	2		1

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FAP 24 RIVER SURVEY PROJECT

Delft Hydraulics/Danish Hydraulic Institute in association with Dhruv/Appropriate Hydrotech

DELFT-DHI

File:

Scale:

Date:

Init:

Test Gauging Report

Jamuna River at Bahadurabad (Left Channel)

Summary of Manual Profilings

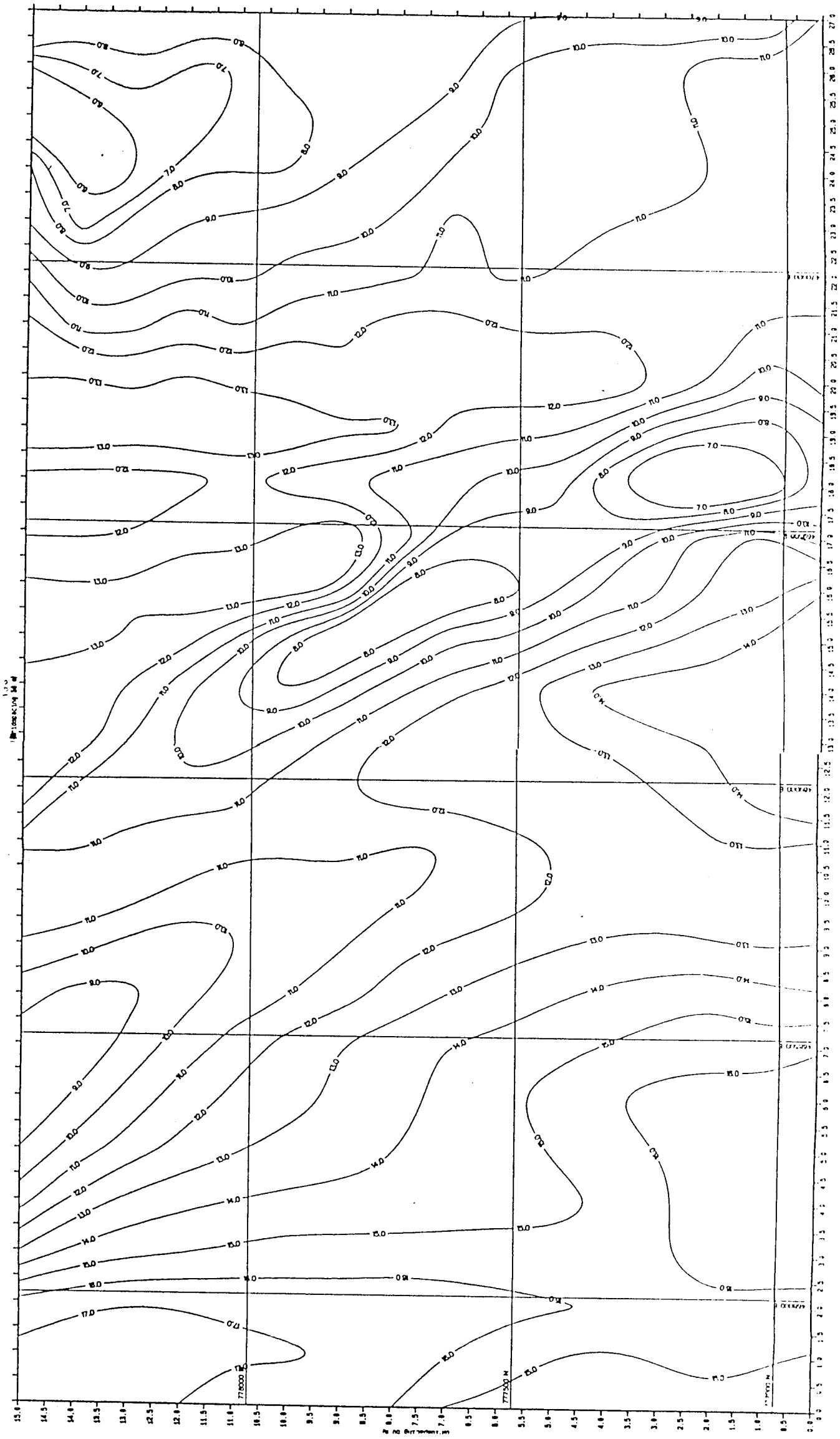
App. No. 2-2

Date of Survey : 22 Aug 93

Type	Time		File Name	Ver. No.	Easting (meter)	Northing (meter)	DISCHARGE GAUGING					SEDIMENT TRANSPORT GAUGING				
	From	To					ADCP	HYDRO	EMF	S4	MEX	Suspended Sediment Samples	Andreasen Tube Samples	Helley Smith Samples	Integrated Sediment Samples	Bottom Samples
Transect			B38M1T01				T	T	T							
Transect			B38M1T02				T	T	T							
Profile	11:43:58	12:33:38	B38M1P01	7	469619	777501	P	P	P	P				2	1	1
profile	14:32:53	15:40:48	B38M1P02	8	469602	777500	P	P	P	P		6	1	2	1	1
Profile	17:02:19	17:28:49	B38M1P04	9	469472	777499	P	P	P	P		6	1	2	1	1
Profile	16:42:59	17:34:17	B38M2P04	10	469375	777503		P		P		6	1	2		
Profile	15:15:00	16:25:58	B38M2P03	11	469287	777502		P		P		6	1	2		
Profile	13:44:52	14:50:13	B38M2P02	12	469119	777506		P		P		6	1	2		
Profile	12:11:11	13:03:15	B38M2P01	13	469003	777503		P		P		6	1	2		

Appendix 3

Bathymetric chart of the test gauging area



FAP 24 DELFT-DHI	RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland	Test Gauging Report	
		Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	BATHYMETRIC SURVEY	App.No.3-1
Scale:	Init:		

Appendix 4

Current velocity and suspended sediment concentration measurements by the reference method

Vertical 1	
Total depth = 6.80	
Depth [m]	Velocity [m/s]
1.29	1.73
2.82	1.70
4.15	1.54
5.67	1.33
6.38	1.13

Vertical 2	
Total depth = 9.80	
Depth [m]	Velocity [m/s]
1.86	2.55
3.56	2.53
5.45	2.35
7.16	2.25
8.46	1.86

Vertical 3	
Total depth = 8.50	
Depth [m]	Velocity [m/s]
1.57	2.65
3.22	2.71
5.12	2.61
6.65	2.43
8.08	1.89

Vertical 5	
Total depth = 7.90	
Depth [m]	Velocity [m/s]
1.55	2.85
3.22	2.80
4.99	2.64
6.36	2.51
7.48	1.92

Vertical 6	
Total depth = 6.00	
Depth [m]	Velocity [m/s]
1.24	2.90
2.35	2.92
3.52	2.81
4.79	2.57
5.50	2.13

Vertical 7	
Total depth = 8.65	
Depth [m]	Velocity [m/s]
1.85	2.44
3.54	2.34
5.43	2.20
7.36	1.92
8.36	1.67

Vertical 8	
Total depth = 9.60	
Depth [m]	Velocity [m/s]
1.75	2.24
3.68	2.16
5.60	1.86
7.52	1.73
8.98	1.38

Vertical 9	
Total depth = 13.20	
Depth [m]	Velocity [m/s]
2.48	1.29
5.08	1.10
7.62	1.02
10.11	0.93
12.37	0.64

Vertical 10	
Total depth = 11.10	
Depth [m]	Velocity [m/s]
0.47	1.29
2.19	1.25
4.44	1.21
6.64	1.07
9.03	0.90
10.53	0.67

Vertical 11	
Total depth = 8.00	
Depth [m]	Velocity [m/s]
0.49	1.09
1.63	1.10
3.22	1.07
4.82	0.94
6.43	0.76
7.10	0.62
0.53	1.09

Vertical 12	
Total depth = 5.40	
Depth [m]	Velocity [m/s]
0.53	1.04
1.11	1.04
2.19	0.97
3.33	0.88
4.38	0.72
4.97	0.62

Vertical 13	
Total depth = 7.00	
Depth [m]	Velocity [m/s]
0.47	1.02
1.44	1.08
2.76	1.08
4.21	0.99
5.62	0.81
6.44	0.70

Vertical 14	
Total depth = 7.20	
Depth [m]	Velocity [m/s]
0.51	1.22
1.41	1.26
2.76	1.11
4.14	0.93
5.51	0.98
6.42	0.74

Vertical 16	
Total depth = 4.20	
Depth [m]	Velocity [m/s]
0.82	1.10
2.49	0.77
3.49	1.07

Vertical 17	
Total depth = 4.70	
Depth [m]	Velocity [m/s]
0.95	1.07
2.81	0.91
3.82	0.77

Vertical 1	
Total depth = 6.80 m	
Depth [m]	Conc. [mg/l]
0.50	964.71
1.29	1128.81
2.82	1185.03
4.15	1717.72
5.67	1094.81
6.38	1889.83

Vertical 2	
Total depth = 9.70 m	
Depth [m]	Conc. [mg/l]
0.50	575.71
1.86	729.34
3.56	858.33
5.45	966.15
7.16	1004.08
8.46	2076.71

Vertical 3	
Total depth = 8.50 m	
Depth [m]	Conc. [mg/l]
0.50	824.82
1.57	851.01
3.22	734.33
5.12	736.84
6.65	1093.23
8.08	1238.17

Vertical 4	
Total depth = 7.80 m	
Depth [m]	Conc. [mg/l]
0.50	1206.78
1.56	723.19
3.02	631.67
4.60	687.84
6.24	751.89
7.37	936.00

Vertical 5	
Total depth = 7.90	
Depth [m]	Conc. [mg/l]
0.50	988.73
1.55	1059.82
3.22	669.27
4.99	759.70
6.36	815.17
7.48	1162.20

Vertical 6	
Total depth = 6.00 m	
Depth [m]	Conc. [mg/l]
0.50	1092.00
1.24	962.69
2.35	1027.14
3.52	675.38
4.79	638.50
5.50	1140.43

Vertical 7	
Suspended sediment not collected in this vertical	

Vertical 8	
Total depth = 9.60 m	
Depth [m]	Conc. [mg/l]
0.50	540.66
1.75	623.17
3.68	713.89
5.60	767.16
7.52	929.08
8.98	882.86

Vertical 9	
Total depth = 13.20 m	
Depth [m]	Conc. [mg/l]
0.50	1591.72
2.48	640.58
5.08	803.75
7.62	861.11
10.11	840.00
12.37	1354.84

Vertical 10	
Total depth = 11.10	
Depth [m]	Conc. [mg/l]
0.47	465.89
2.19	388.89
4.44	571.43
6.64	593.65
9.03	654.44
10.53	736.30

Vertical 11	
Total depth = 8.00 m	
Depth [m]	Conc. [mg/l]
0.49	419.05
1.63	477.05
3.22	506.78
4.82	531.85
6.43	673.53
7.10	752.63

Vertical 12	
Total depth = 5.40 m	
Depth [m]	Conc. [mg/l]
0.53	529.75
1.11	467.95
2.19	533.33
3.33	519.31
4.38	576.12
4.97	602.92

Vertical 13	
Total depth = 7.00 m	
Depth [m]	Conc. [mg/l]
0.47	313.79
1.44	386.51
2.76	485.55
4.21	630.51
5.62	676.80
6.44	698.58

Vertical 14	
Total depth = 7.20 m	
Depth [m]	Conc. [mg/l]
0.51	429.00
1.41	402.72
2.76	478.57
4.14	491.89
5.51	467.53
6.42	557.20

Vertical 15	
Total depth = 5.30	
Depth [m]	Conc. [mg/l]
0.50	572.31
1.00	597.62
2.10	591.61
3.20	623.10
4.20	618.21
4.80	675.38

Vertical 16	
Total depth = 4.20 m	
Depth [m]	Conc. [mg/l]
0.82	719.75
2.49	681.69
3.49	739.20

Vertical 17	
Total depth = 4.70 m	
Depth [m]	Conc. [mg/l]
0.95	538.75
2.81	654.65
3.82	669.01

Vertical 19	
Total depth = 6.90 m	
Depth [m]	Conc. [mg/l]
0.50	347.14
1.38	359.76
2.76	389.97
4.40	392.07
5.50	385.29
6.40	406.06

Date of survey : 20-22 Aug 1993

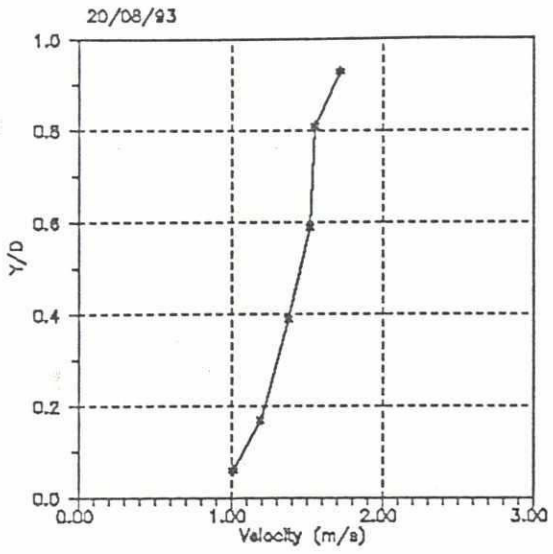
FAP 24 RIVER SURVEY PROJECT
DELFT-DHI
Delft Hydraulics/Danish Hydraulic Institute in association with Osmis/Approtech/Hydroland

Test Gauging Report

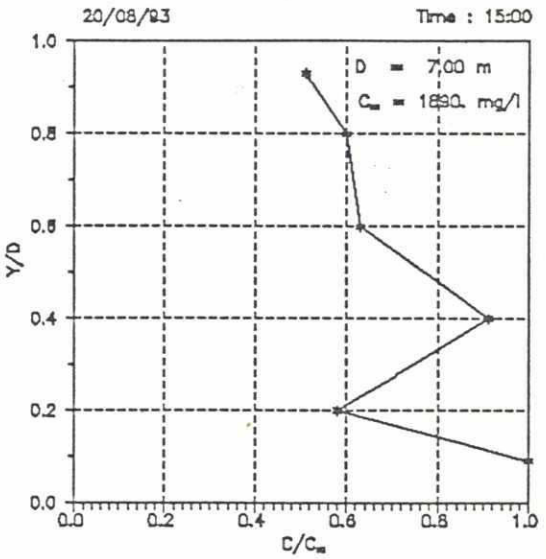
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Suspended Sediment Concentration Profiles	App. No. 4-2
Scale:	Init:		

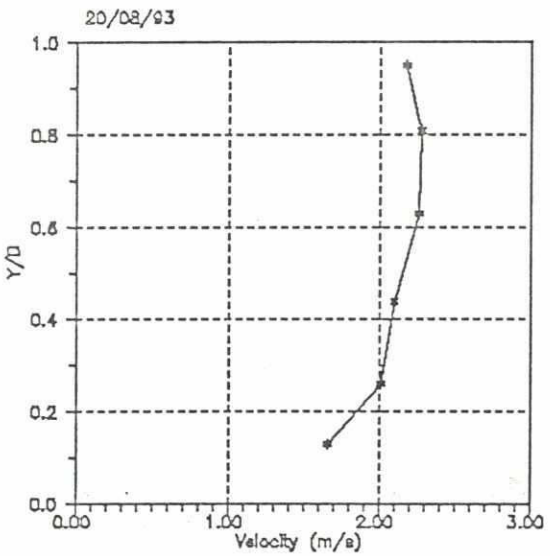
Vertical 1



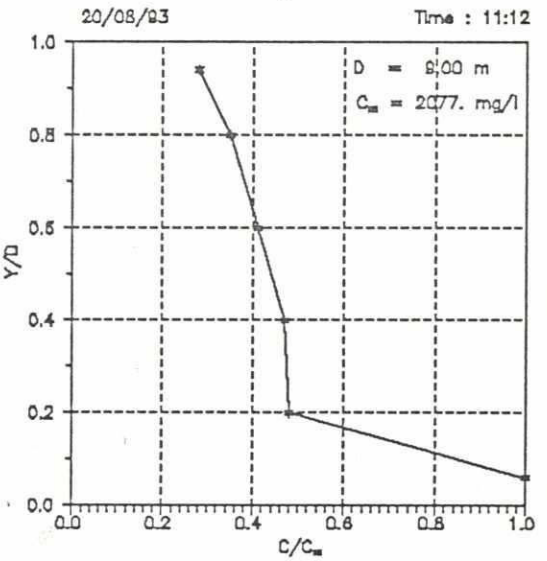
Sample 181



Vertical 2

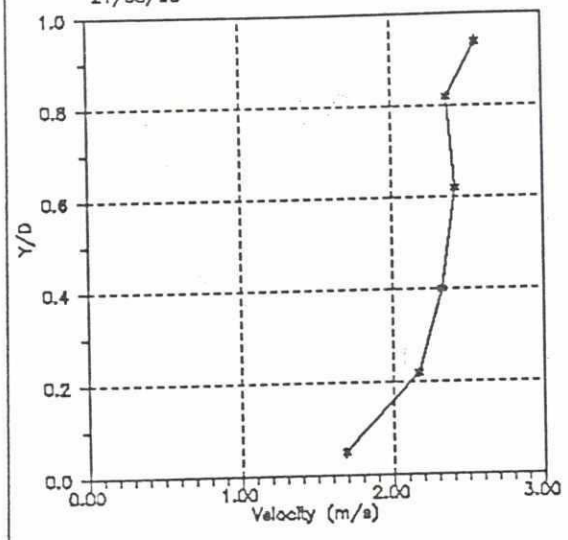


Sample 175

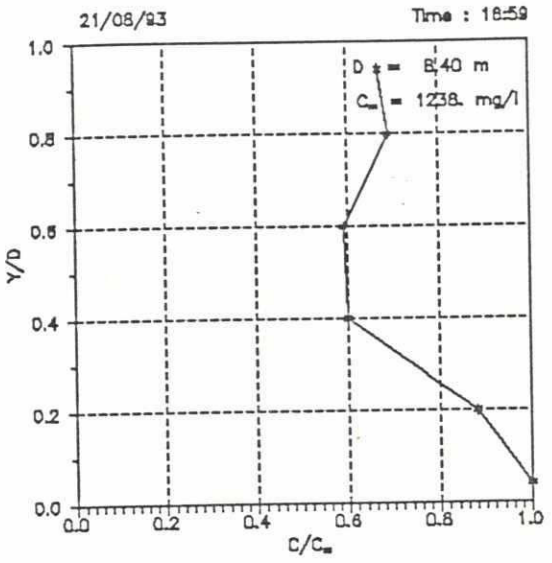


FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report	
		Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity and Suspended Sediment Concentration Profiles	App. No. 4-3
Scale:	Init:		

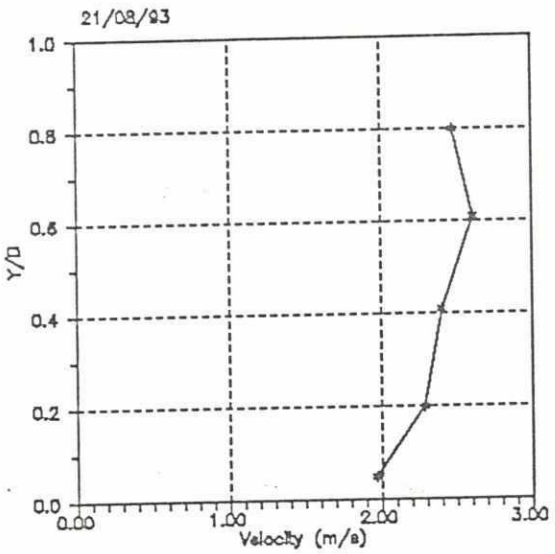
Vertical 3



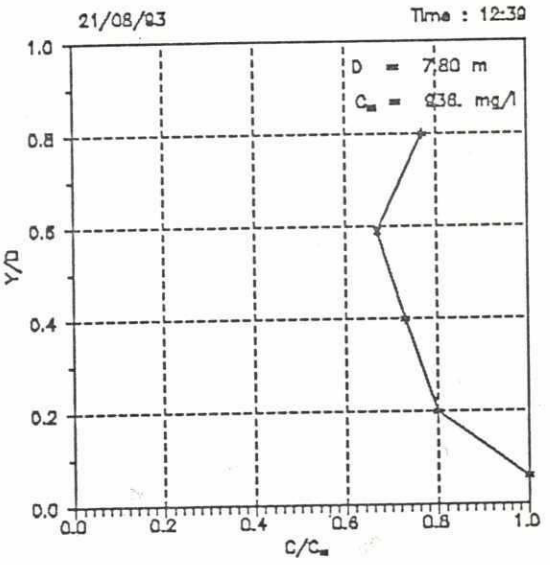
Sample 187



Vertical 4

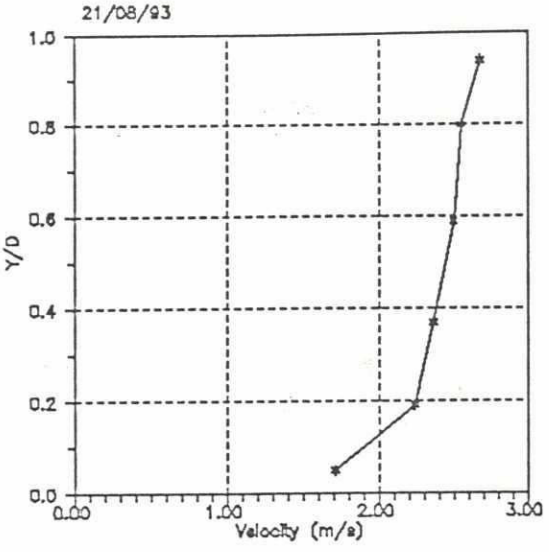


Sample 193

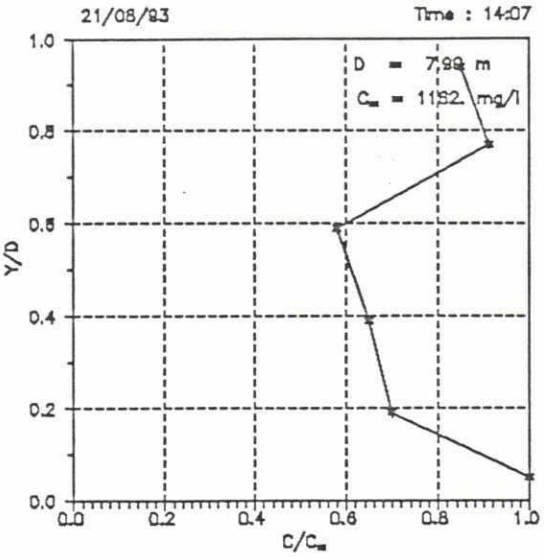


FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity and Suspended Sediment Concentration Profiles	App. No. 4-4
Scale:	Init:		

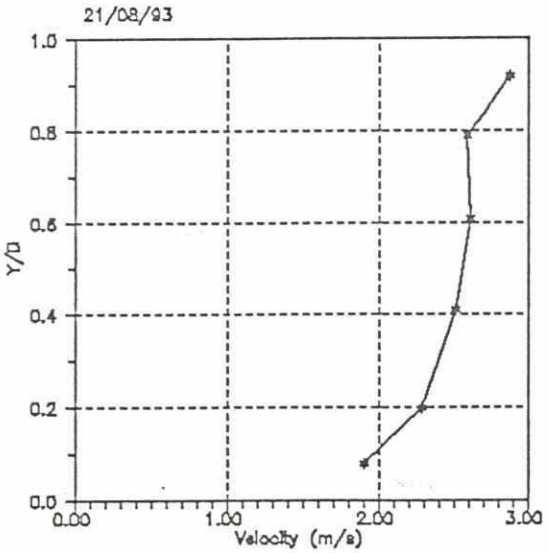
Vertical 5



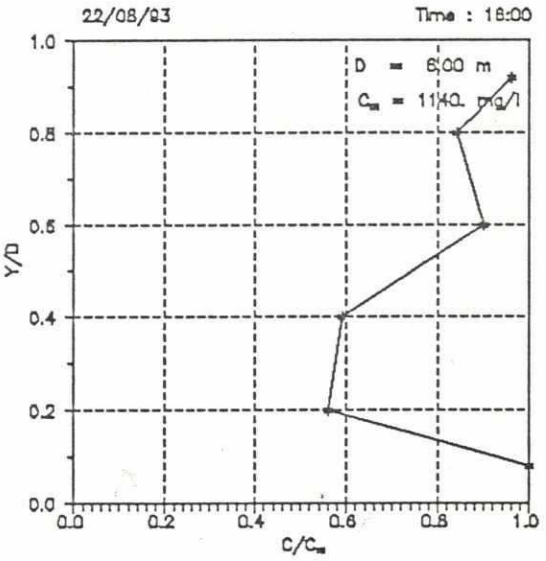
Sample 151



Vertical 6

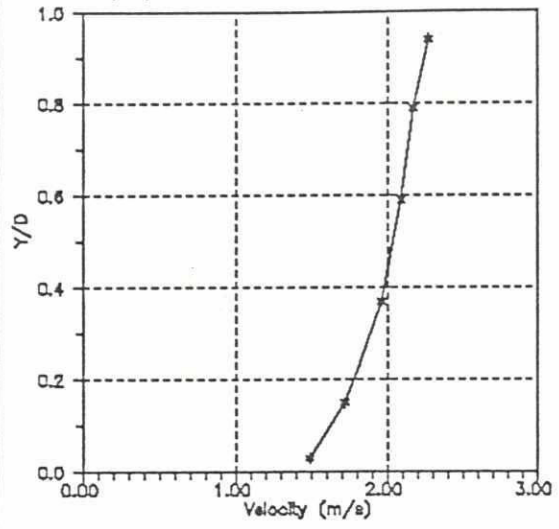


Sample 157

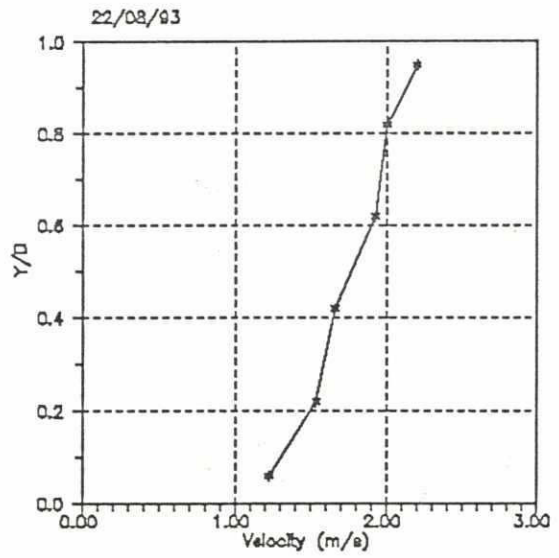


FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity and Suspended Sediment Concentration Profiles	App. No. 4-5
Scale:	Init:		

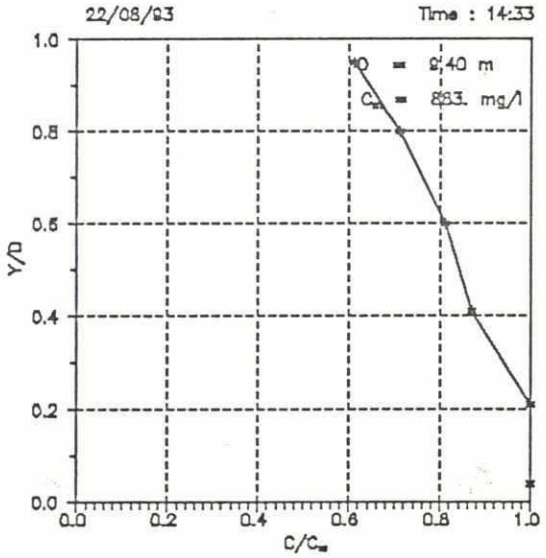
Vertical 7



Vertical 8

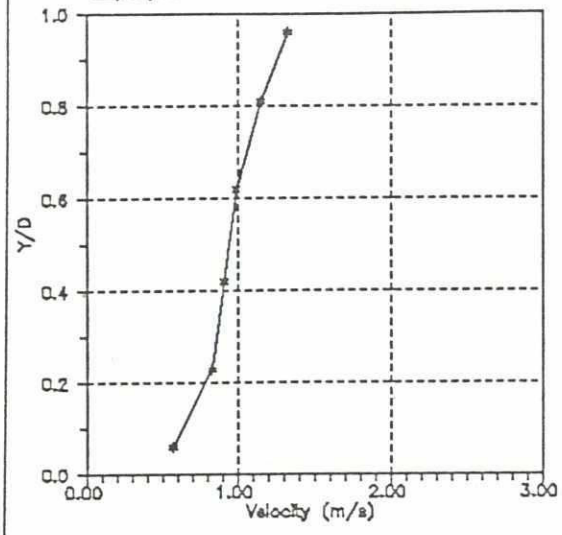


Sample 163

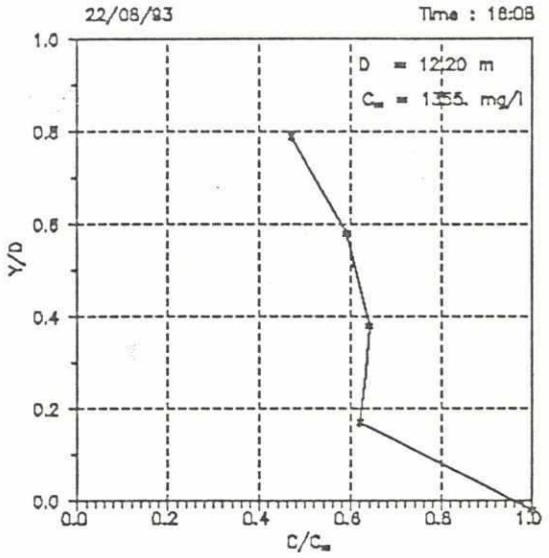


FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osmis/Approtech/Hydroland		Test Gauging Report	
		Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity and Suspended Sediment Concentration Profiles	App. No. 4-6
Scale:	Init:		

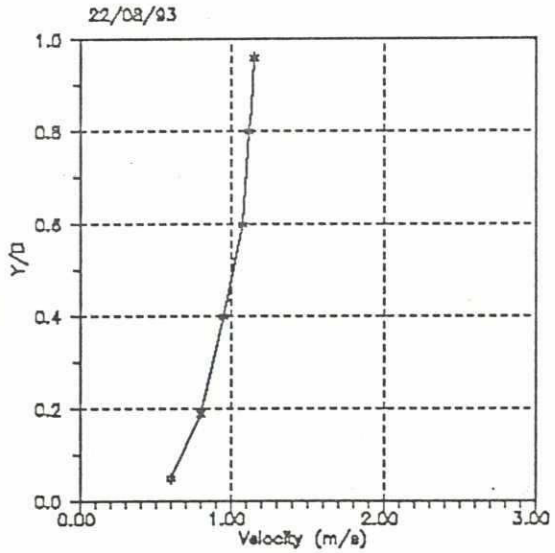
Vertical 9



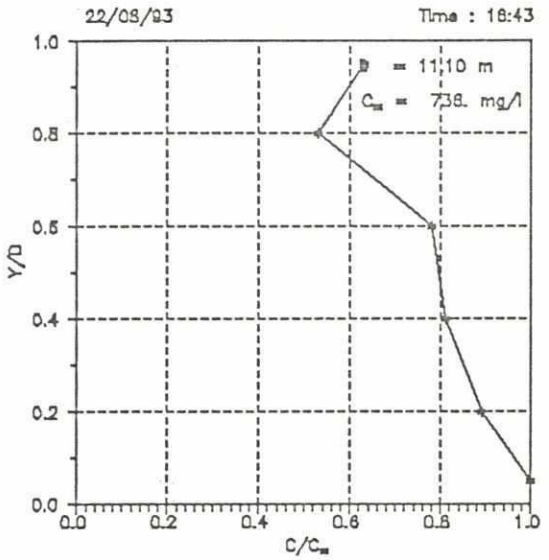
Sample 169



Vertical 10

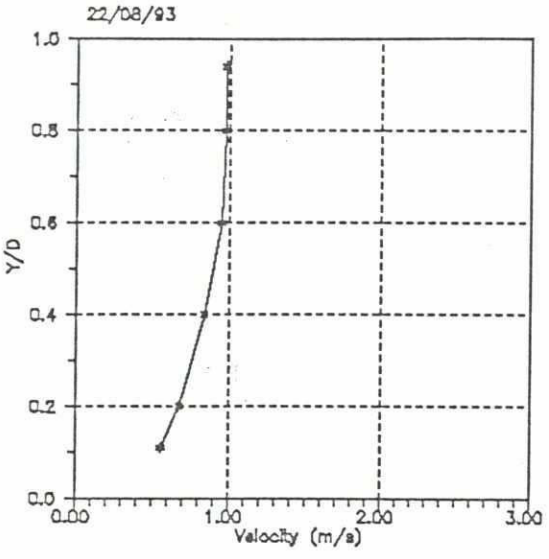


Sample 226

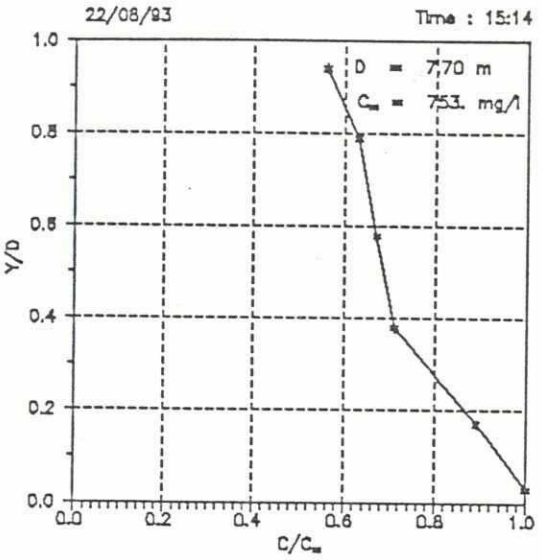


FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osmis/Approtech/Hydroland		Test Gauging Report	
		Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity and Suspended Sediment Concentration Profiles	App. No. 4-7
Scale:	Init:		

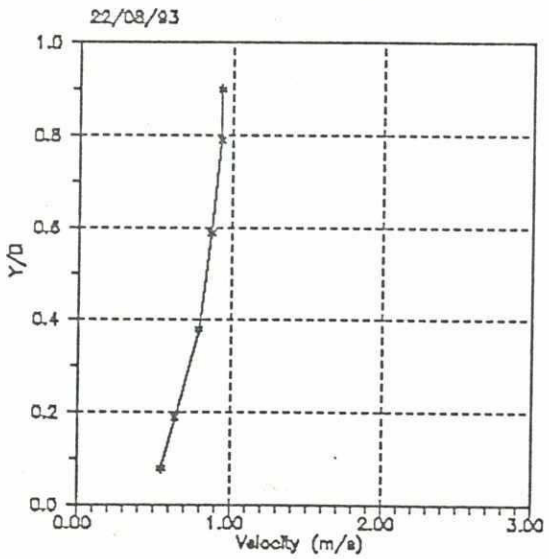
Vertical 11



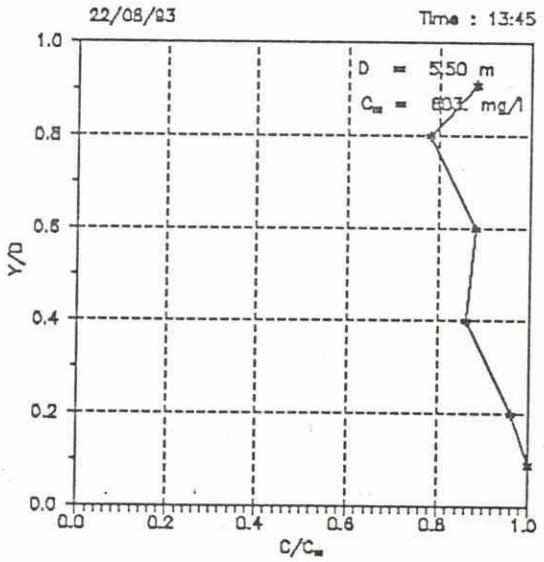
Sample 212



Vertical 12

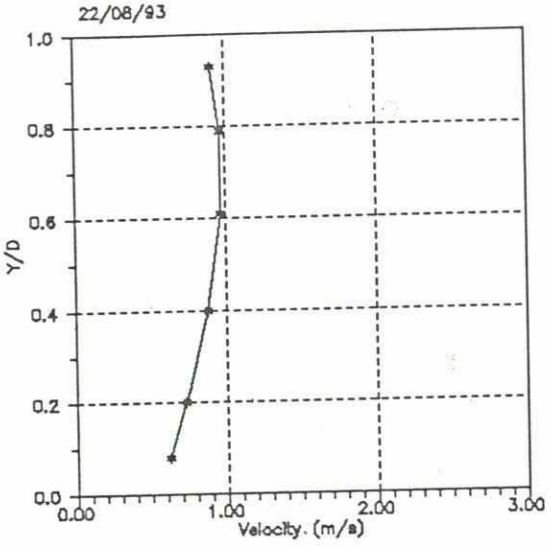


Sample 201

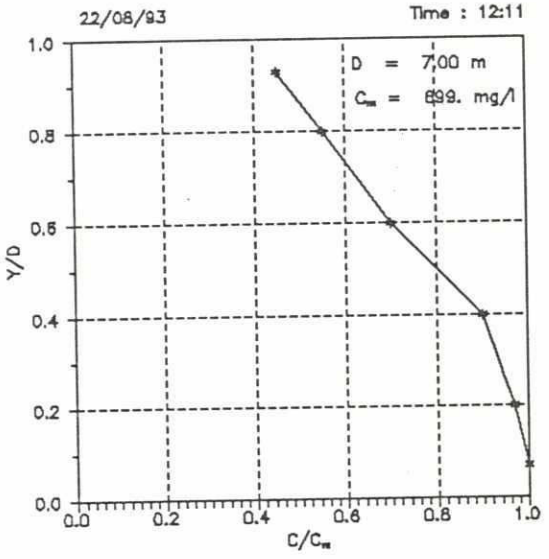


FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity and Suspended Sediment Concentration Profiles	App. No. 4-8
Scale:	Init:		

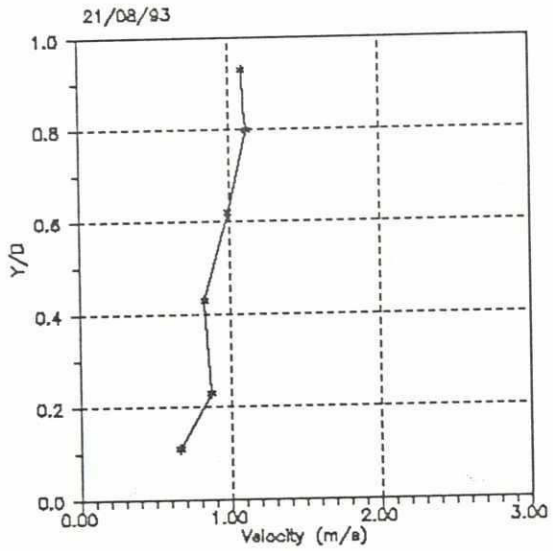
Vertical 13



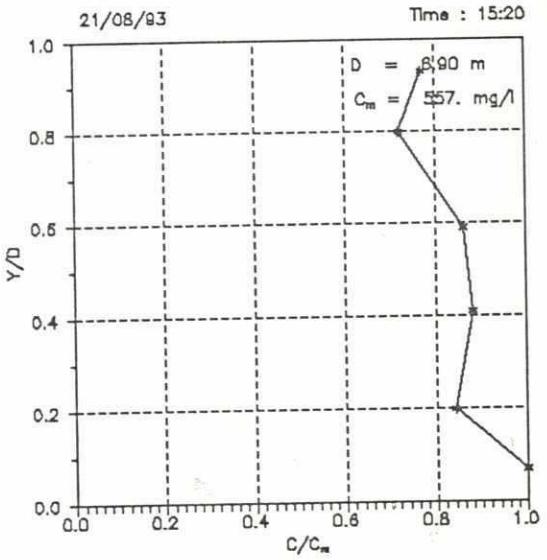
Sample 194



Vertical 14

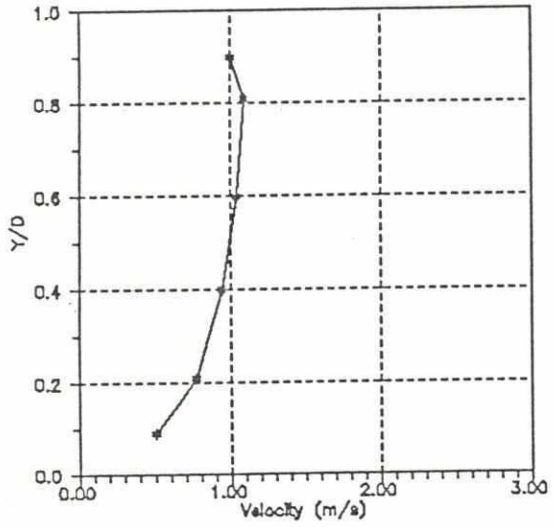


Sample 8005

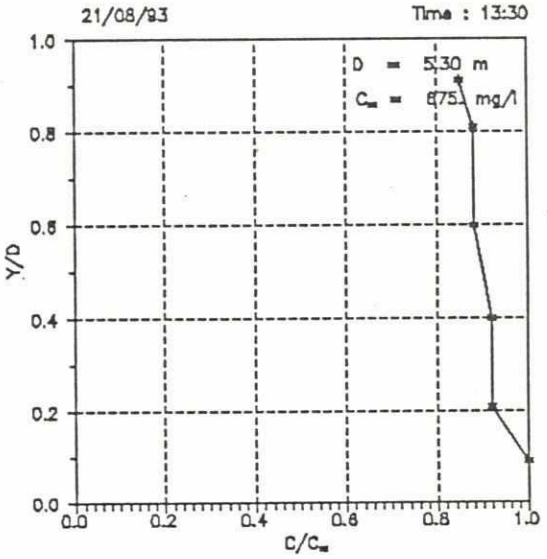


FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report	
		Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity and Suspended Sediment Concentration Profiles	App. No. 4-9
Scale:	Init:		

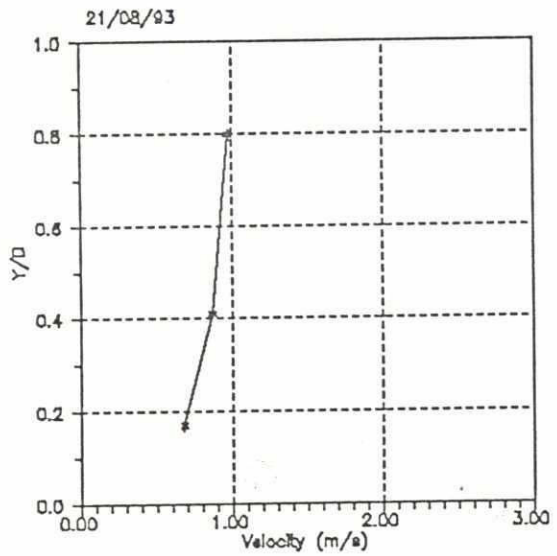
Vertical 15



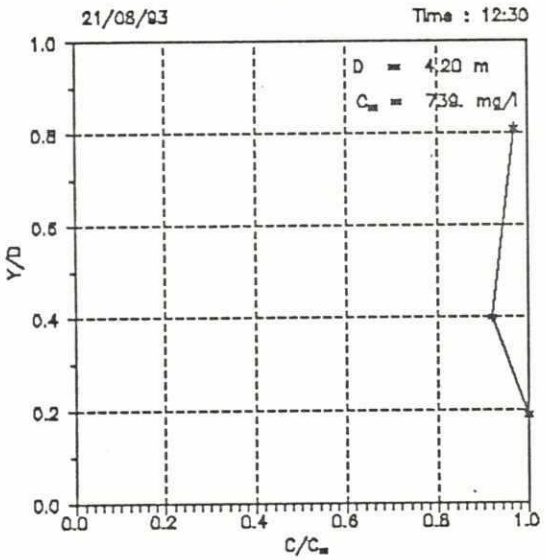
Sample 216



Vertical 16

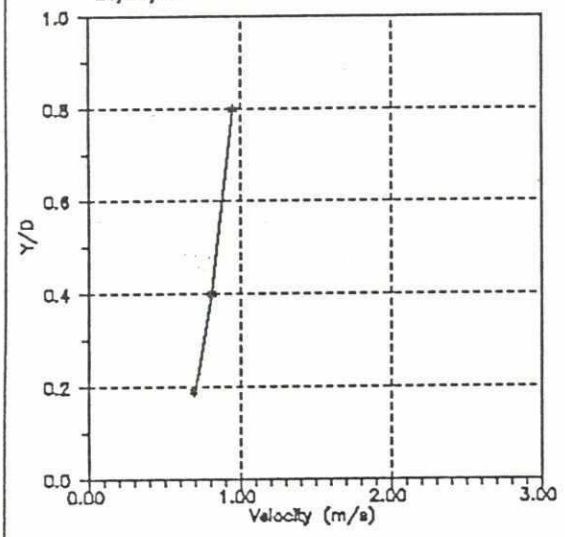


Sample 206

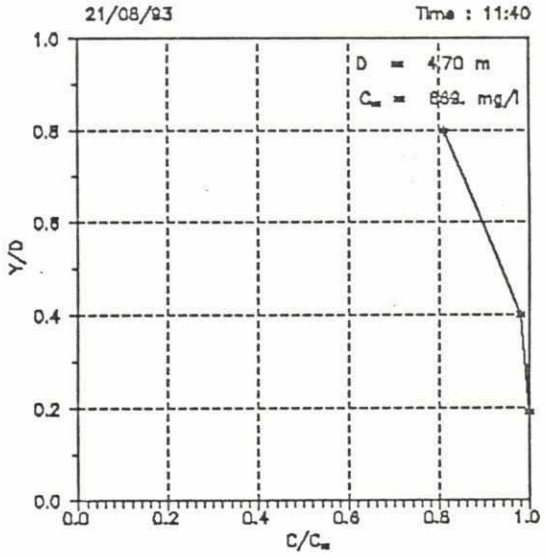


FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Chirtsl/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity and Suspended Sediment Concentration Profiles	App. No. 4-10
Scale:	Init:		

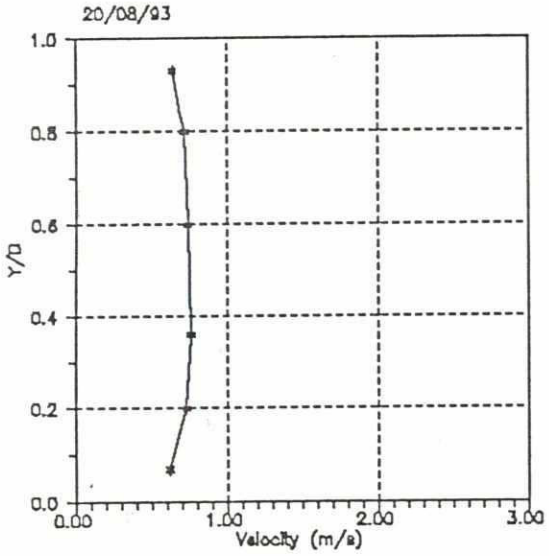
Vertical 17



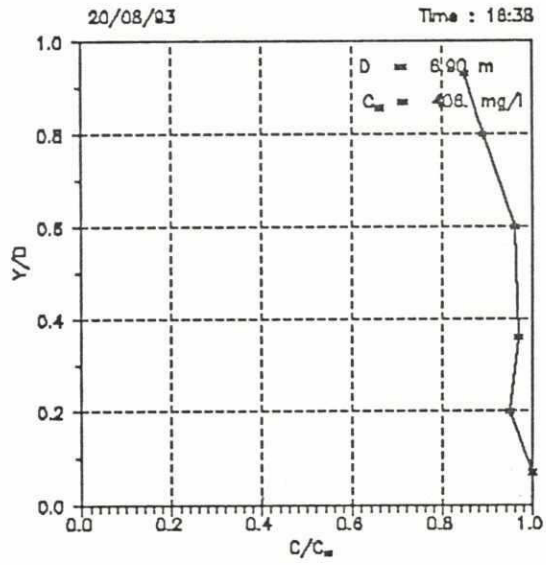
Sample 221



Vertical 19



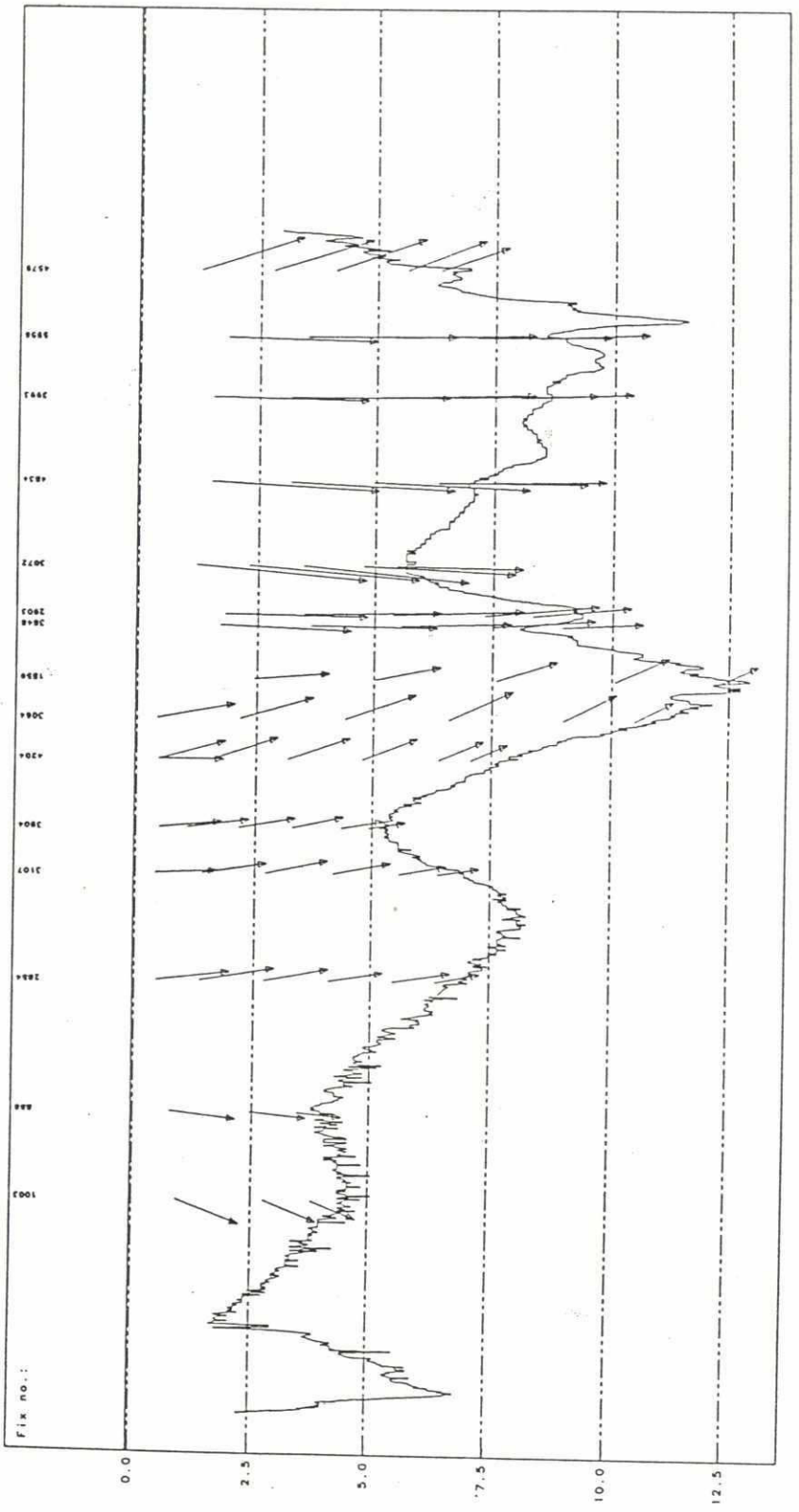
Sample 199



FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity and Suspended Sediment Concentration Profiles	App. No. 4-11
Scale:	Init:		

Appendix 5

Current velocity and suspended sediment concentration measurement by the recommended method



PROFILE CURRENT VELOCITY :

Horizontal Scale : 1 : 15000
Vertical Scale : 1 : 125
Current Arrow Scale : 1.0 cm per m/s
Azimuth of Cross Section : 89.7 Deg North
Current Arrows Relative to North

SURVEY ID. :

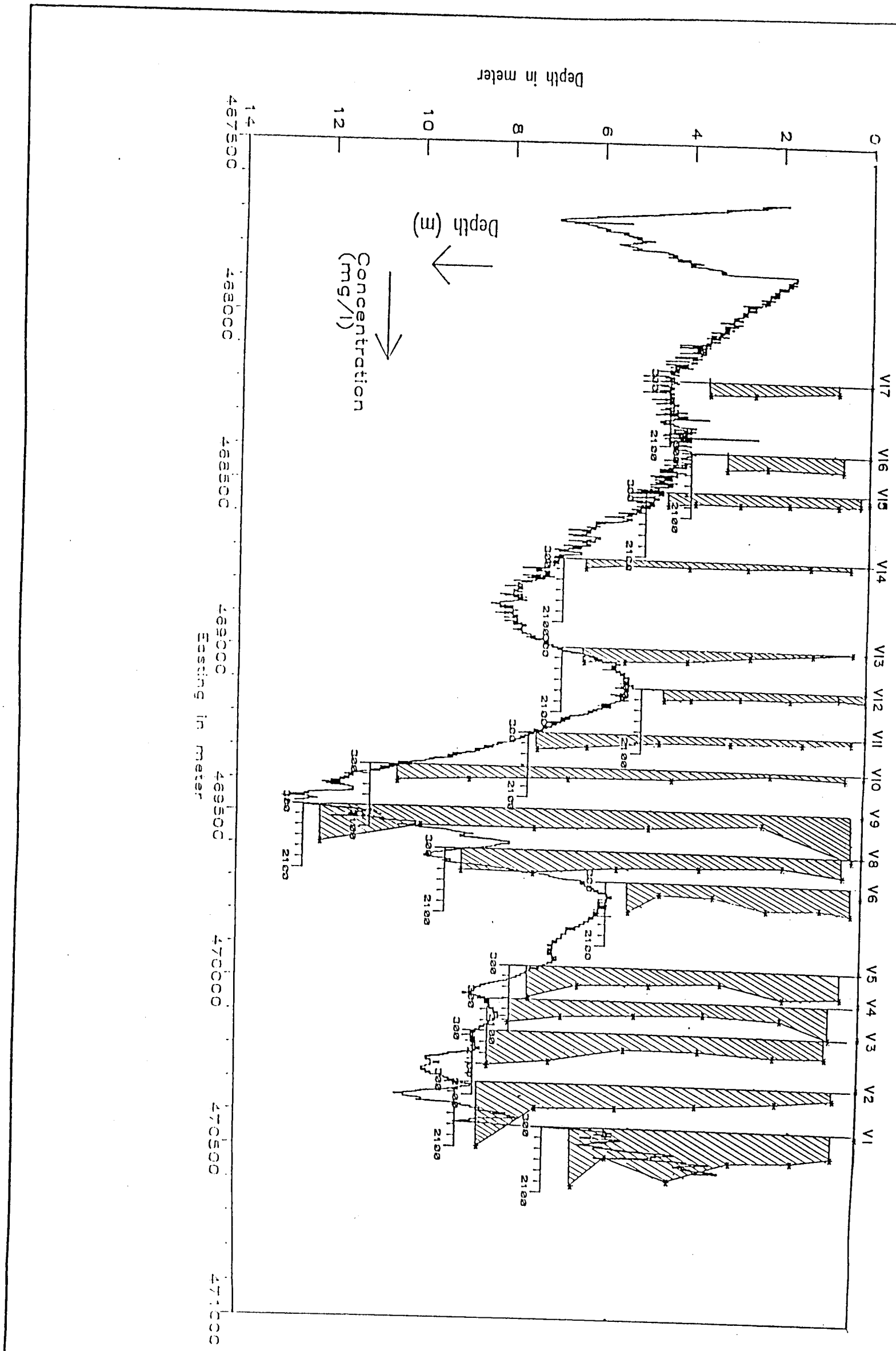
Positions : BTN
Date : 930820
Start Time : 10:16:17
End Time : 10:41:53
Start Position : 467677E 777496N
End Position : 470568E 777513N
Discharge : 24771.34 (m3/s)

PLOT ID. :

Project : River Survey Project FAP 24
File : /u/1240dm/data/93-aug/aug-20/b3b1103
Drawn : Thu Nov 4 14 03 10 1993
Type : Cross Section
Init. : WZH
Rev. : Rev.

Appr. | Id. No.

FAP 24 DELFT-DHI RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sectional distribution of velocity	App. No. 5-1
Scale:	Init:		

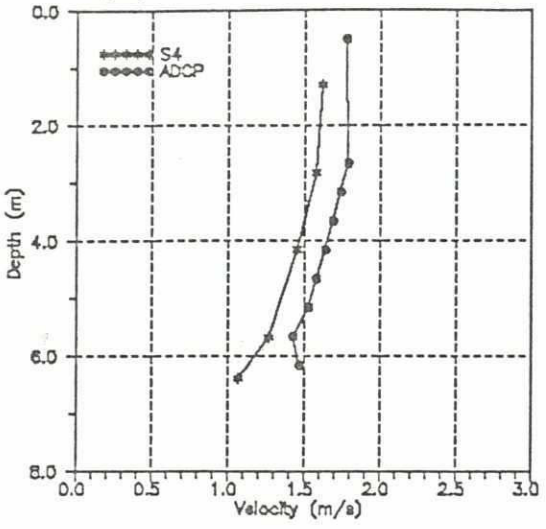


FAP 24 DELFT-DHI RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sectional distribution of Suspended Sediment Concentration	App. No. 5-2
Scale:	Init:		

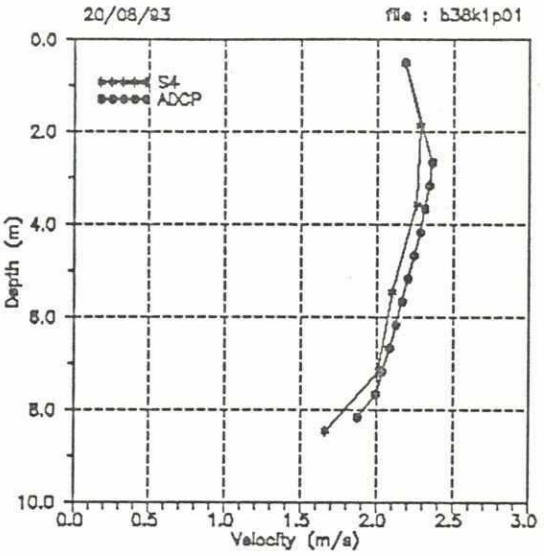
Appendix 6

Comparison of point and integrated current measurements

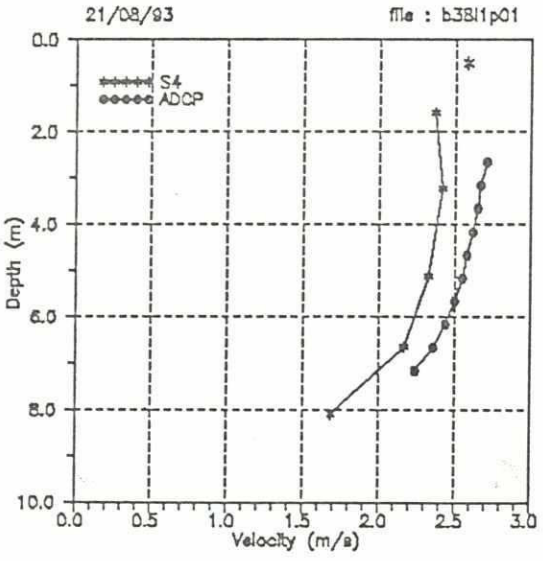
Vertical 1



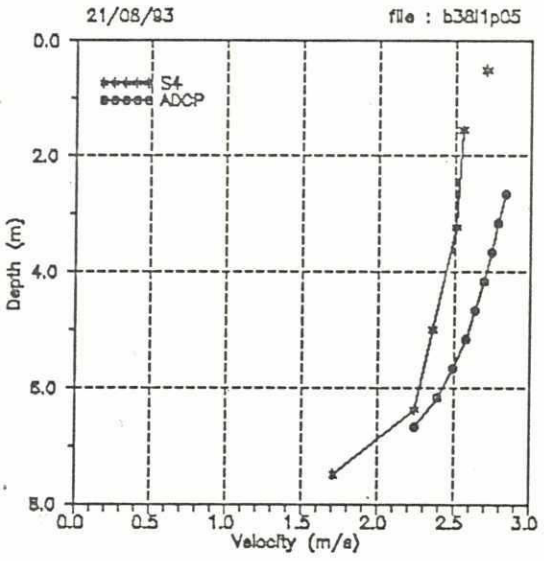
Vertical 2



Vertical 3



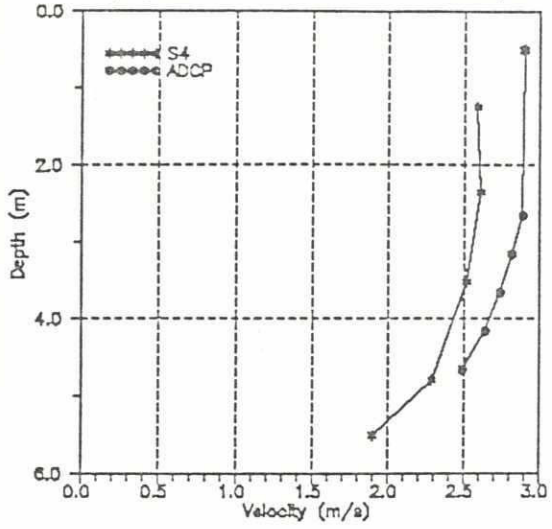
Vertical 5



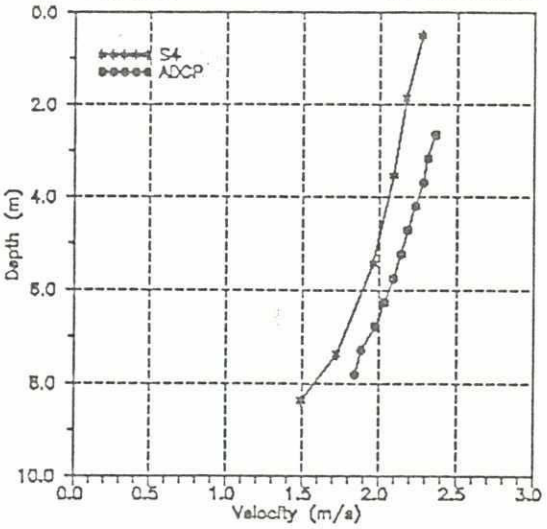
Date of Survey : 20–22 August 1993
Measurements by ADCP and S4 Current Meter

FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report	
		Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity Profiles (as measured)	App. No. 6-1
Scale:	Init:		

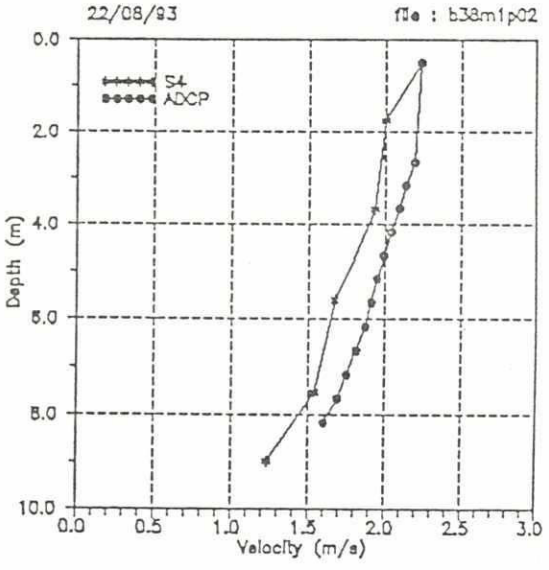
Vertical 6



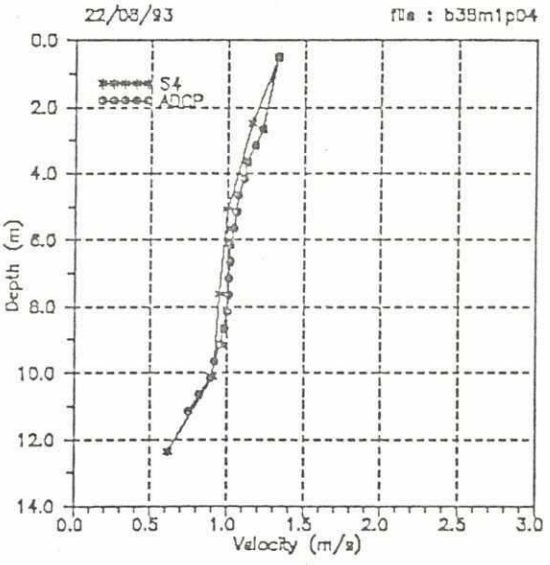
Vertical 7



Vertical 8



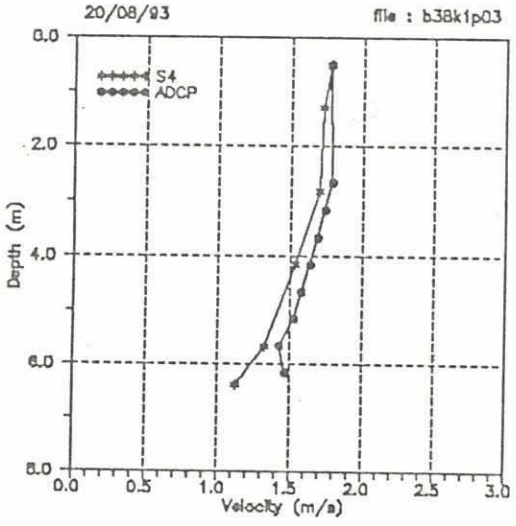
Vertical 9



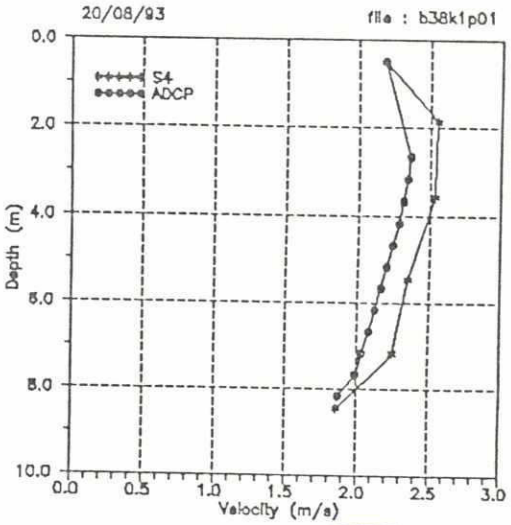
Date of Survey : 20–22 August 1993
Measurements by ADCP and S4 Current Meter

FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report	
		Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity Profiles (as measured)	App. No. 6-2
Scale:	Init:		

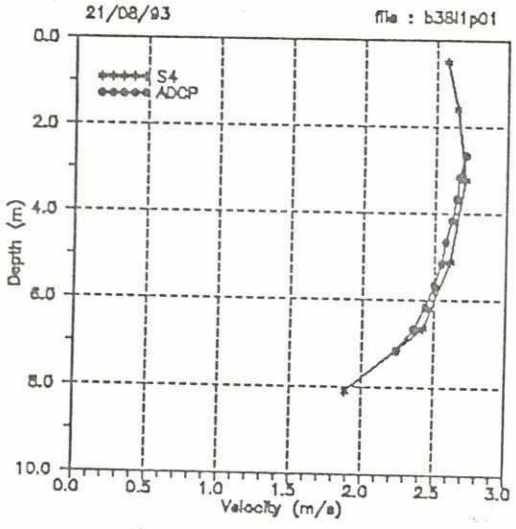
Vertical 1



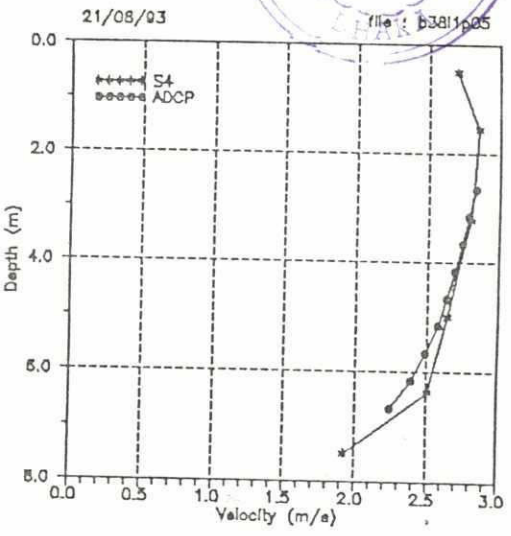
Vertical 2



Vertical 3

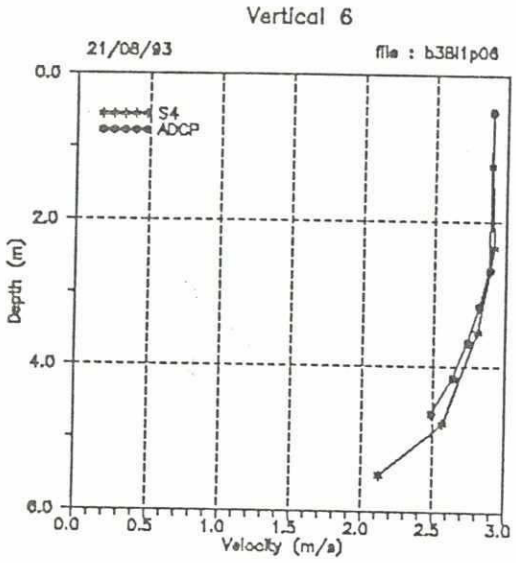


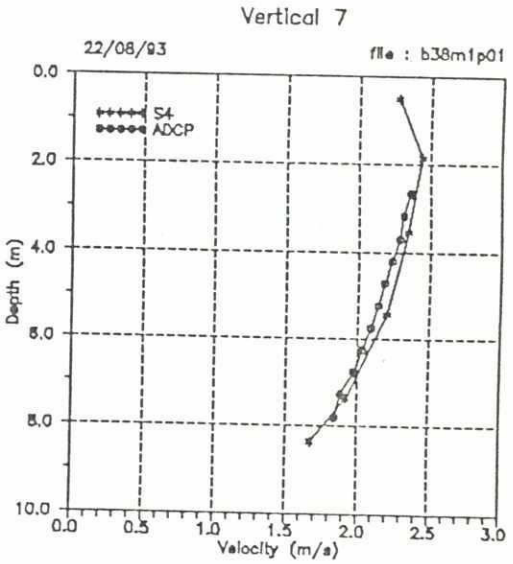
Vertical 5

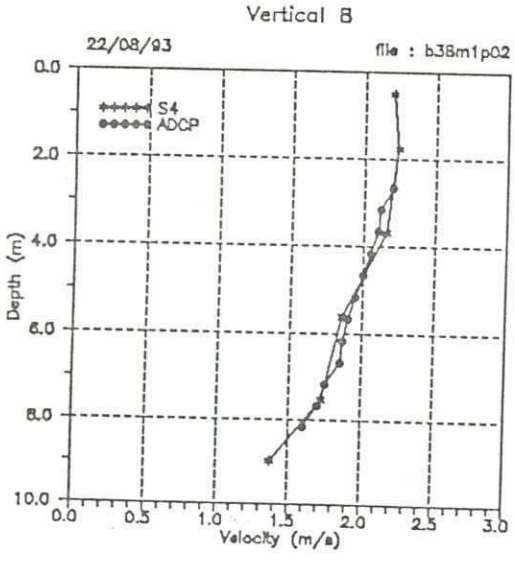


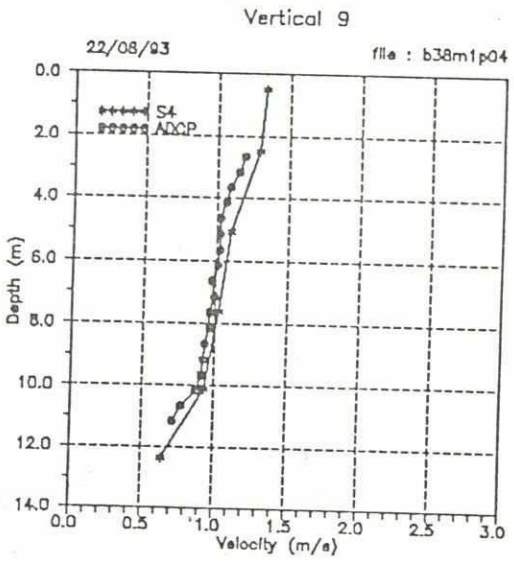
Date of Survey : 20–22 August 1993
Measurements by ADCP and S4 Current Meter

FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osmis/Approtech/Hydroland DELFT-DHI		Test Gauging Report	
		Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity Profiles (corrected)	App. No. 6-3
Scale:	Init:		







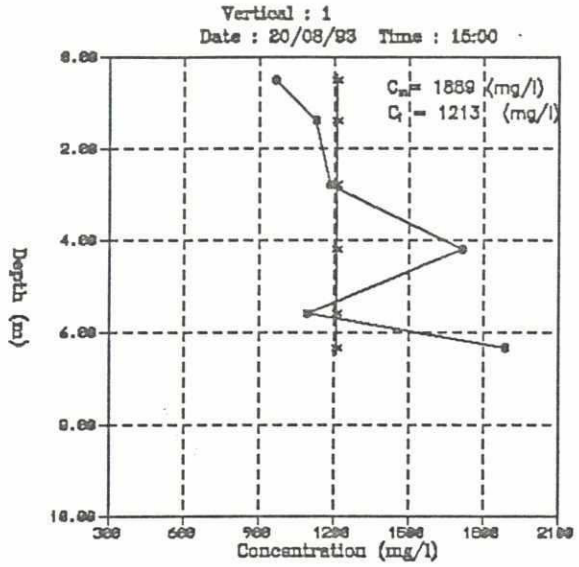


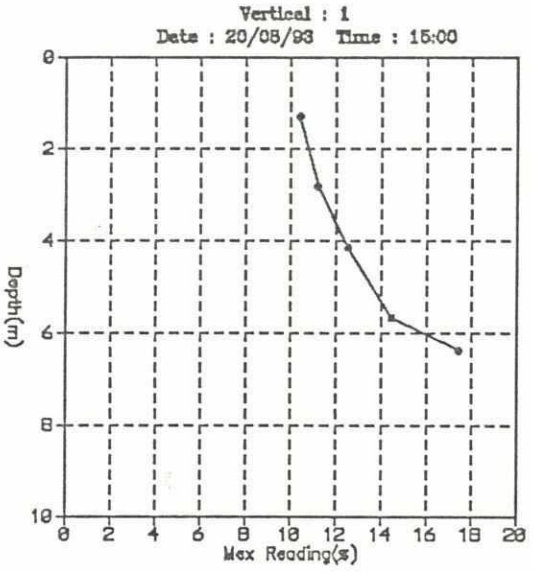
Date of Survey : 20–22 August 1993
Measurements by ADCP and S4 Current Meter

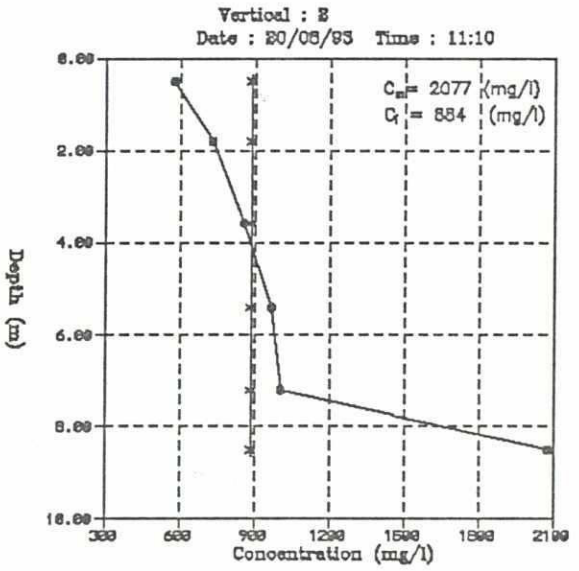
FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report	
		Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Current Velocity Profiles (corrected)	App. No. 6-4
Scale:	Init:		

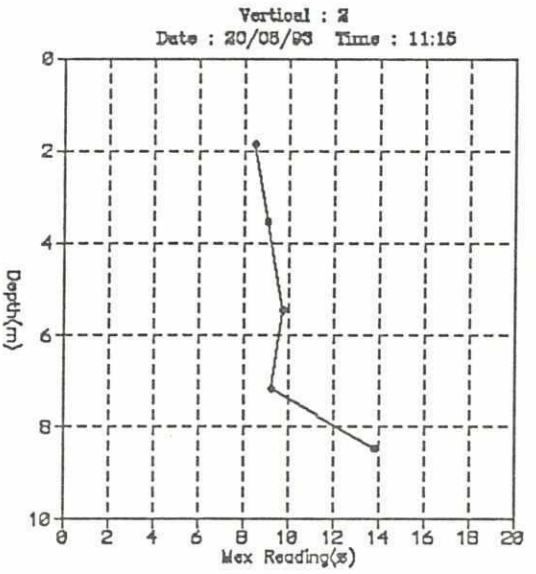
Appendix 7

Suspended sediment concentration and relative turbidity profiles





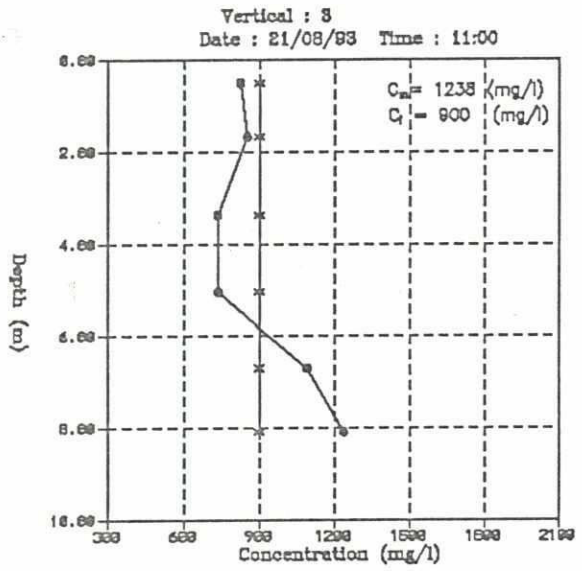


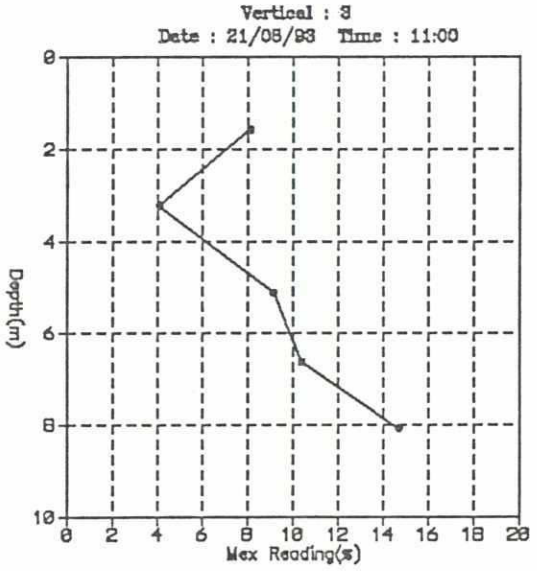


Legend

●●●●● Point Sample
***** Depth Integrated Sample
C_m= Maximum Concentration(Point Sample)
C_i= Concentration(Depth Integrated Sample)

FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Turbidity versus Suspended Sediment Concentrations	App. No. 7-1
Scale:	Init:		





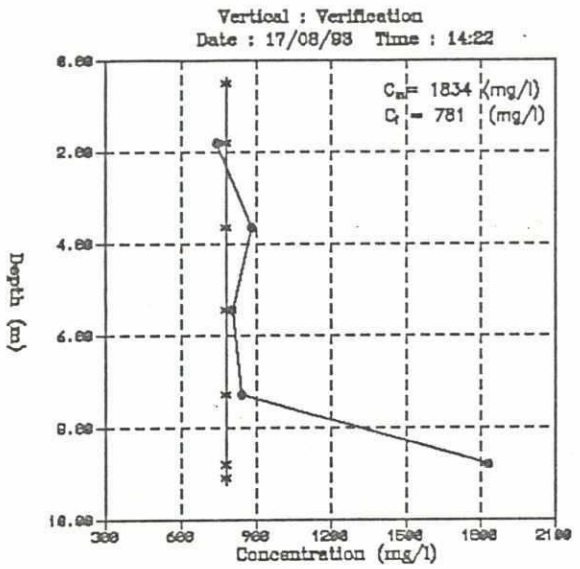
Legend

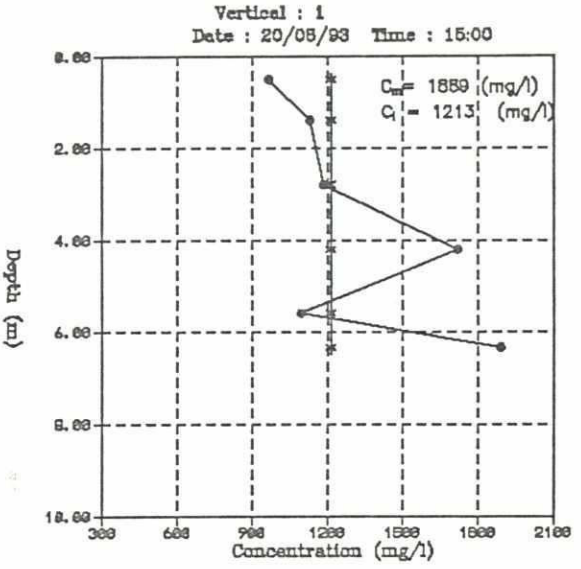
●●●●● Point Sample
***** Depth Integrated Sample
C_m= Maximum Concentration(Point Sample)
C_i= Concentration(Depth Integrated Sample)

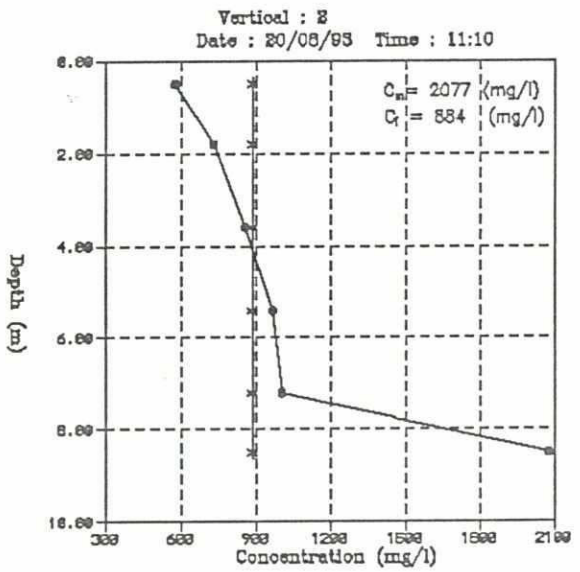
FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Turbidity versus Suspended Sediment Concentrations	App. No. 7-2
Scale:	Init:		

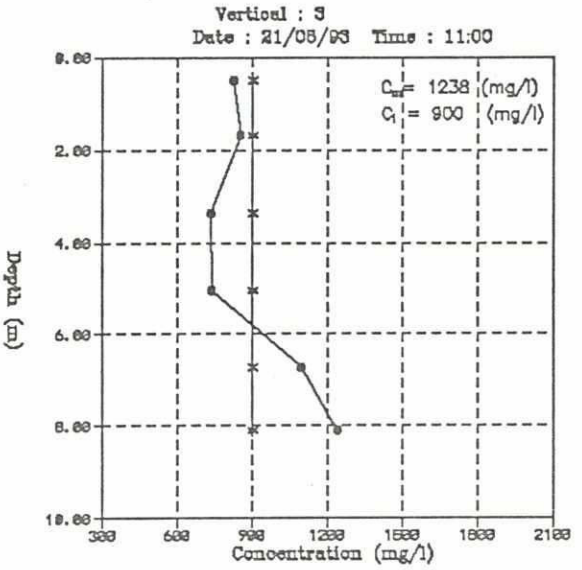
Appendix 8

Integrated suspended sediment sampling





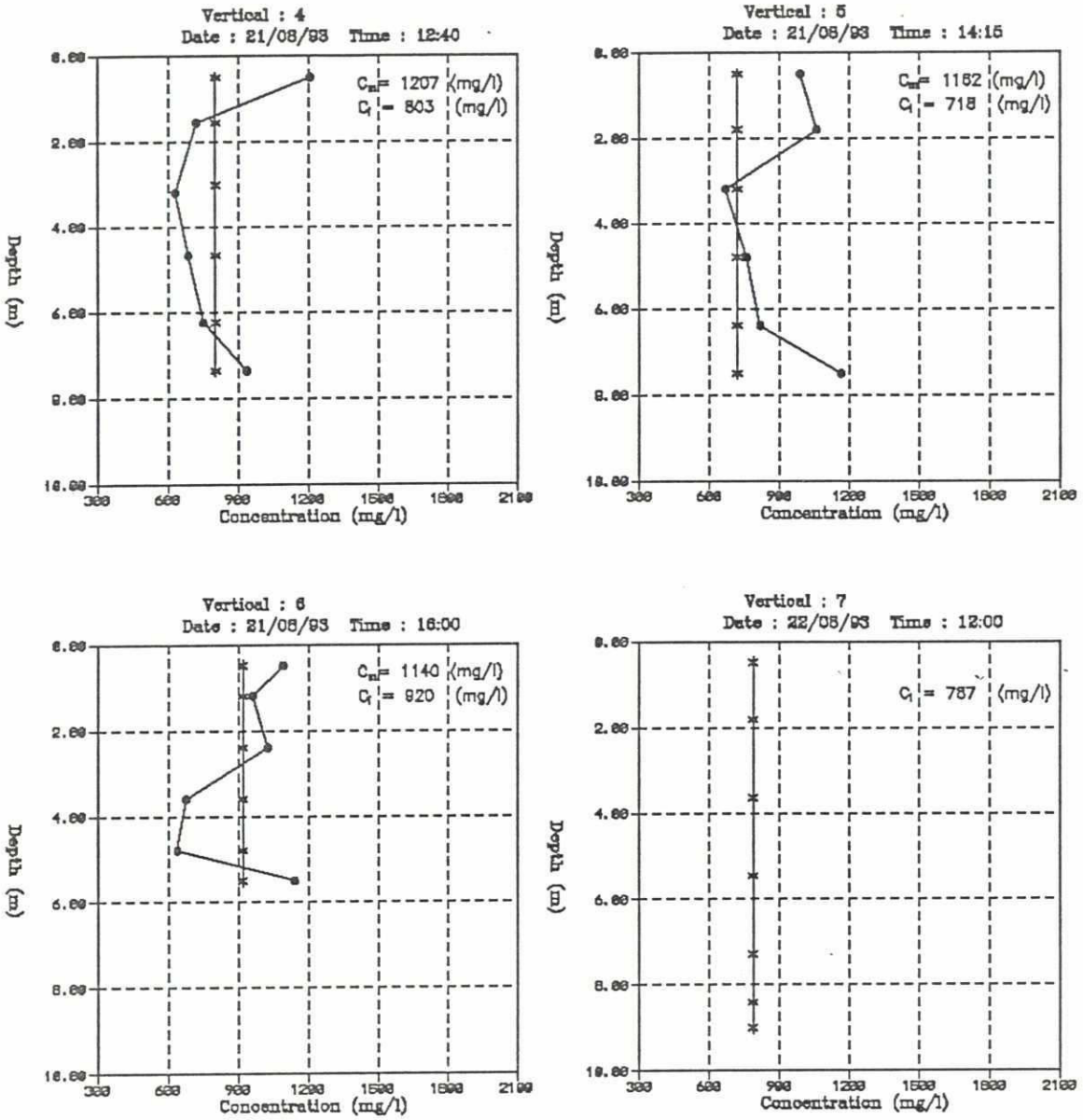




Legend

●●●●● Point Sample
***** Depth Integrated Sample
C_m= Maximum Concentration(Point Sample)
C_i= Concentration(Depth Integrated Sample)

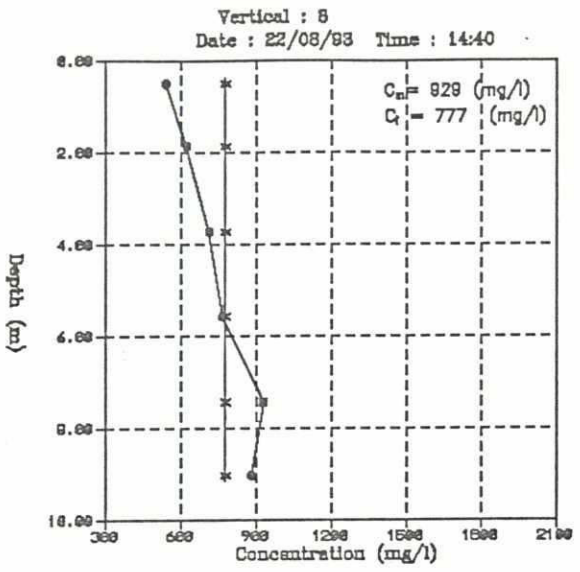
FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Concentration of Integrated Suspended Sediment Sample	App. No. 8-1
Scale:	Init:		

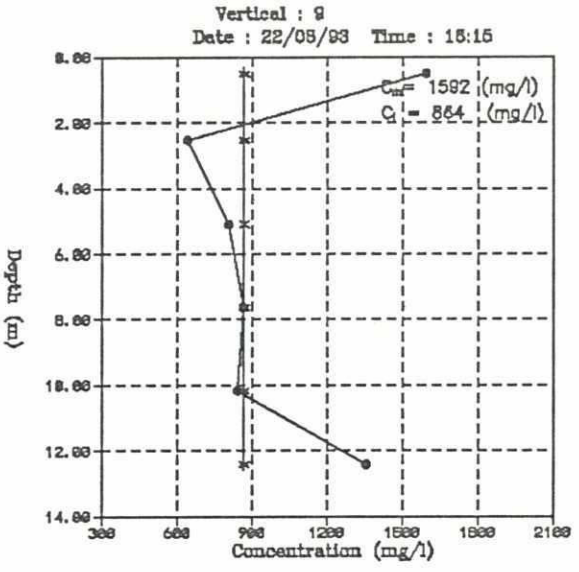


Legend

●●●●● Point Sample
***** Depth Integrated Sample
C_m= Maximum Concentration(Point Sample)
C_i= Concentration(Depth Integrated Sample)

FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Concentration of Integrated Suspended Sediment Sample	App. No. 8-2
Scale:	Init:		





Legend

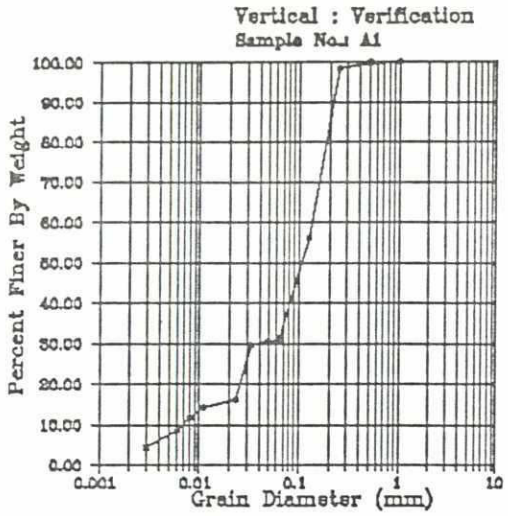
●●●●● Point Sample
***** Depth Integrated Sample
C_m= Maximum Concentration(Point Sample)
C_i= Concentration(Depth Integrated Sample)

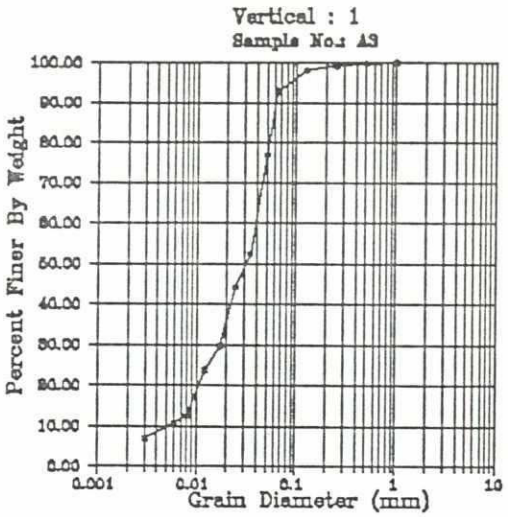
FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Concentration of Integrated Suspended Sediment Sample	App. No. 8-3
Scale:	Init:		

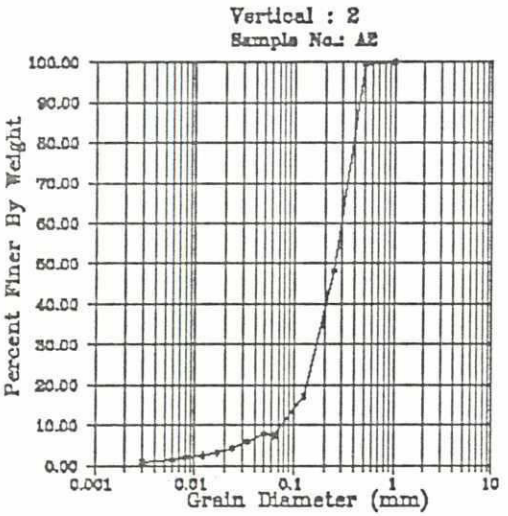
ภ 6

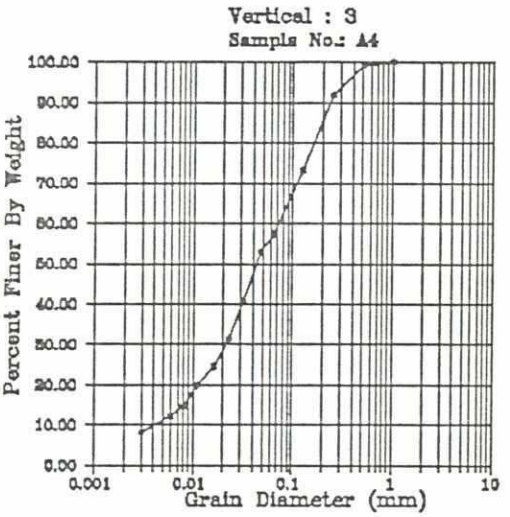
Appendix 9

Grain size distribution of suspended sediment (Andreasen tube analysis)









NO	Time	D_{16} (mm)	D_{35} (mm)	D_{50} (mm)	D_{90} (mm)	Standard Deviation
A1	15:15	0.020	0.070	0.100	0.220	3.500
A3	16:00	0.009	0.020	0.030	0.060	2.583
A2	12:35	0.116	0.190	0.260	0.450	1.889
A4	11:30	0.009	0.025	0.045	0.250	4.722

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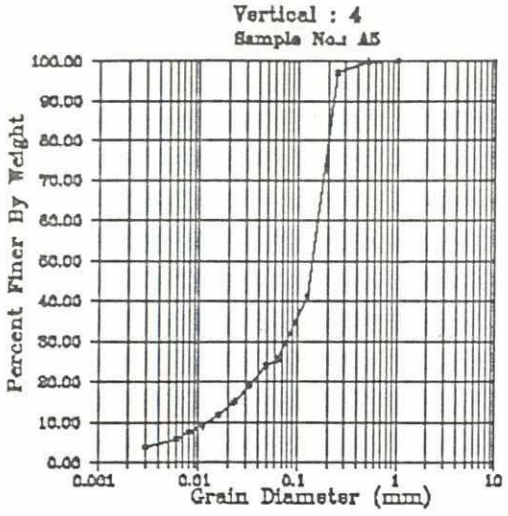
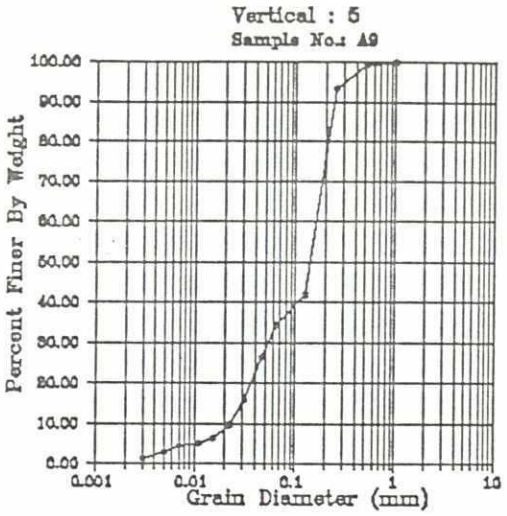
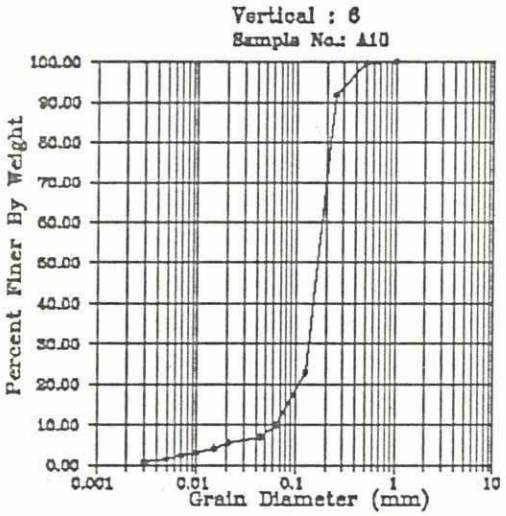
Test Gauging Report

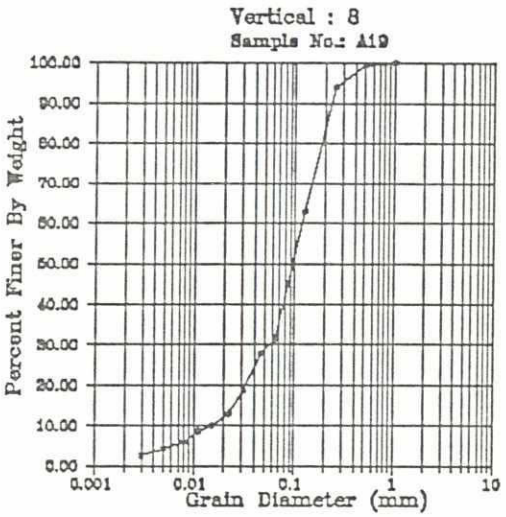
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of Suspended Sediments (Andreasen Tube Analysis)	App. No. 9-1
Scale:	Init:		









NO	Time	D_{16} (mm)	D_{35} (mm)	D_{50} (mm)	D_{90} (mm)	Standard Deviation
A5	13:15	0.025	0.100	0.150	0.250	3.700
A9	15:00	0.030	0.070	0.150	0.250	3.267
A10	16:30	0.085	0.150	0.175	0.260	1.744
A19	15:37	0.027	0.070	0.095	0.200	2.812

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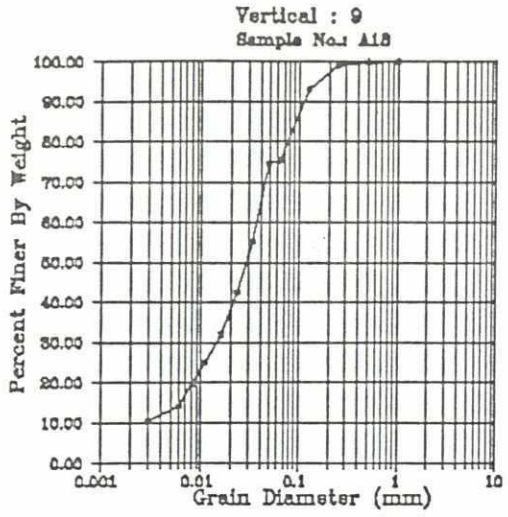
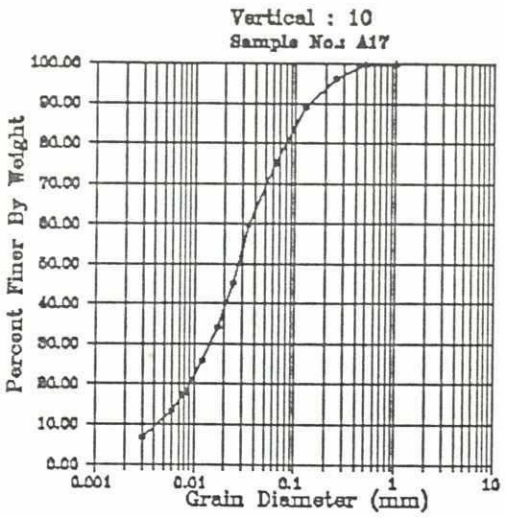
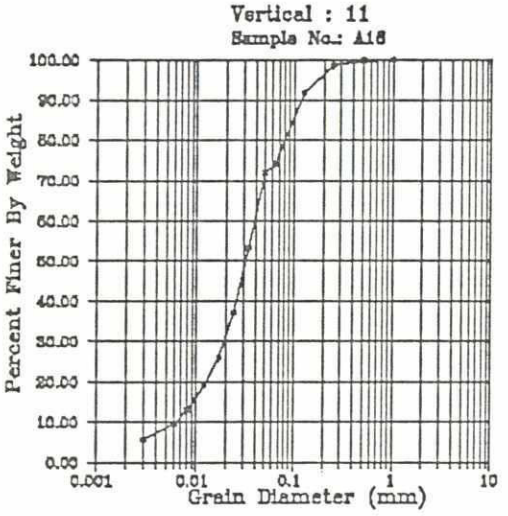
Test Gauging Report

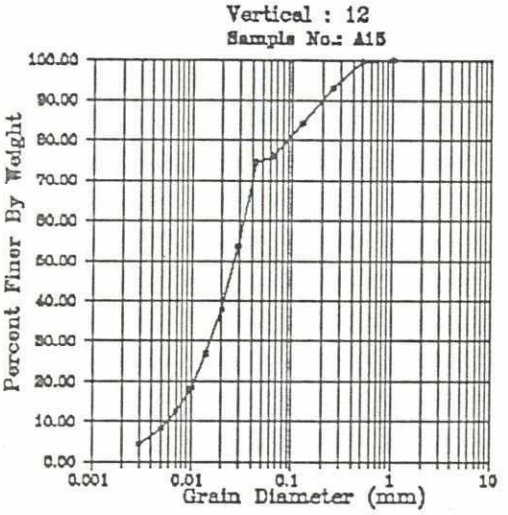
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain-Size Distribution of Suspended Sediments (Andreasen Tube Analysis)	App. No. 9-2
Scale:	Init:		









NO	Time	D_{16} (mm)	D_{35} (mm)	D_{50} (mm)	D_{90} (mm)	Standard Deviation
A18	17:15	0.007	0.018	0.028	0.110	3.607
A17	17:00	0.007	0.018	0.027	0.150	3.780
A16	15:55	0.010	0.024	0.031	0.125	3.002
A15	14:30	0.009	0.019	0.027	0.200	4.277

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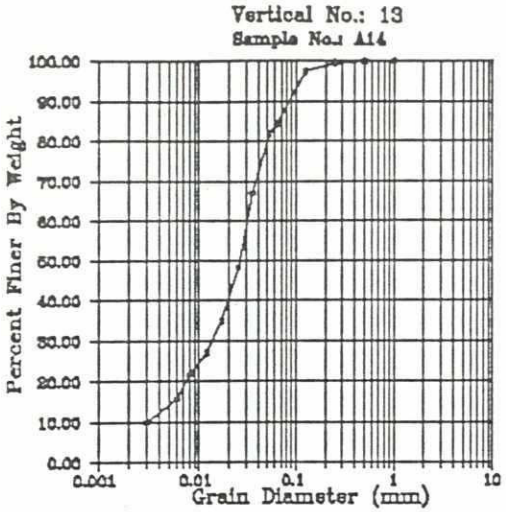
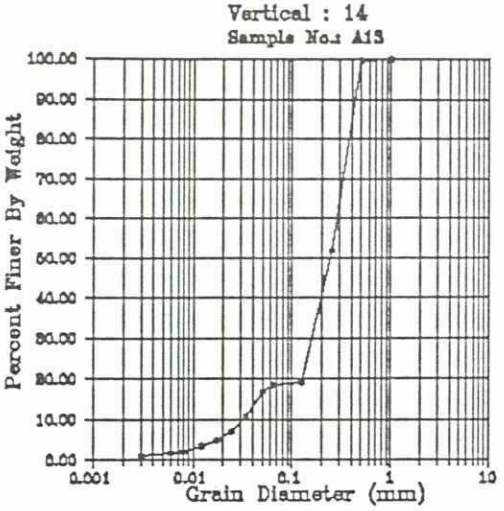
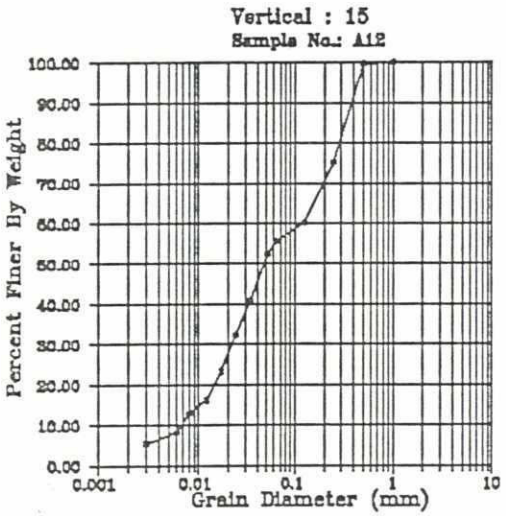
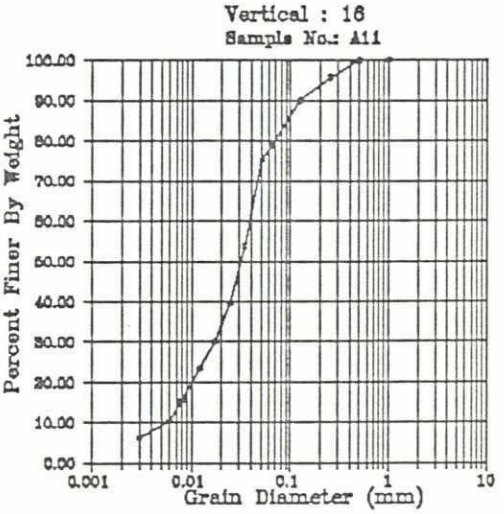
File:	Date:	Grain Size Distribution of Suspended Sediments (Andreasen Tube Analysis)	App. No. 9-3
Scale:	Init:		









NO	Time	D_{16} (mm)	D_{35} (mm)	D_{50} (mm)	D_{90} (mm)	Standard Deviation
A14	12:45	0.006	0.017	0.026	0.080	3.321
A13	15:00	0.045	0.175	0.250	0.450	3.577
A12	14:35	0.015	0.030	0.049	0.400	5.205
A11	12:30	0.008	0.020	0.030	0.140	2.542

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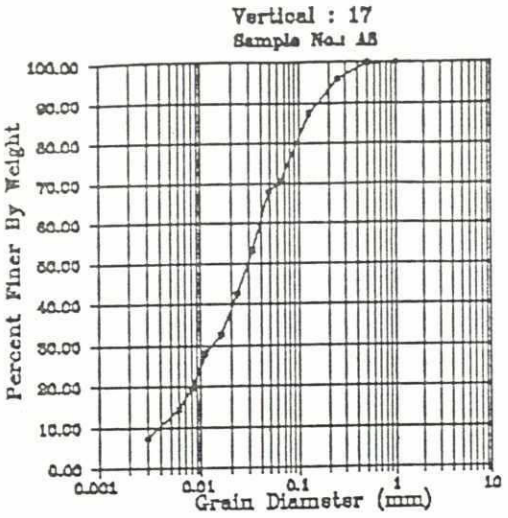
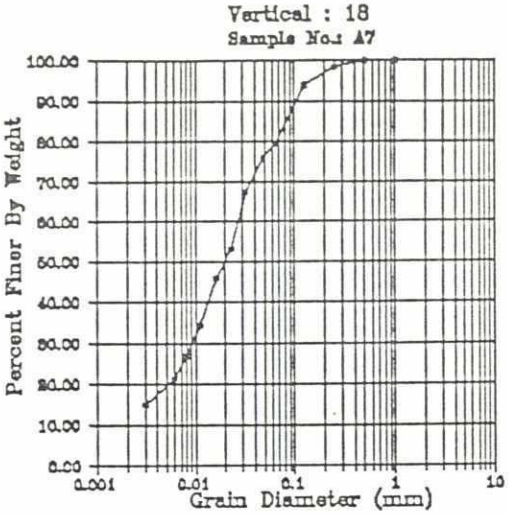
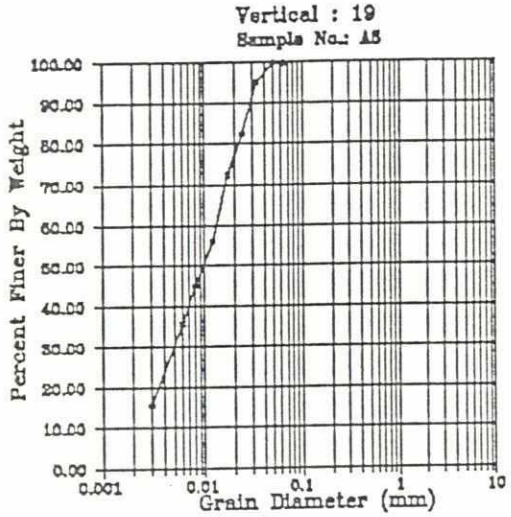
Test Gauging Report

Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of Suspended Sediments (Andreasen Tube Analysis)	App. No. 9-4
Scale:	Init:		





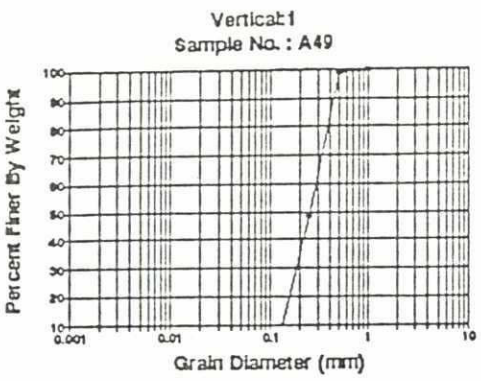


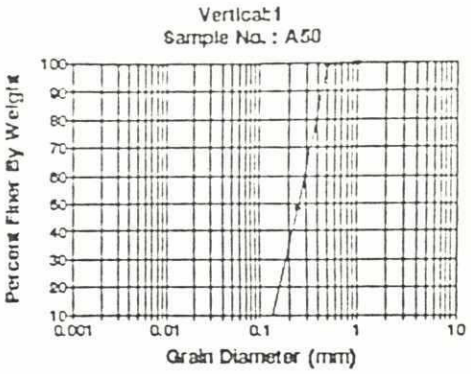
NO	Time	D_{16} (mm)	D_{35} (mm)	D_{50} (mm)	D_{90} (mm)	Standard Deviation
A8	11:40	0.007	0.018	0.030	0.165	4.309
A7	11:15	0.008	0.015	0.021	0.110	3.455
A6	16:45	0.003	0.006	0.010	0.030	2.917

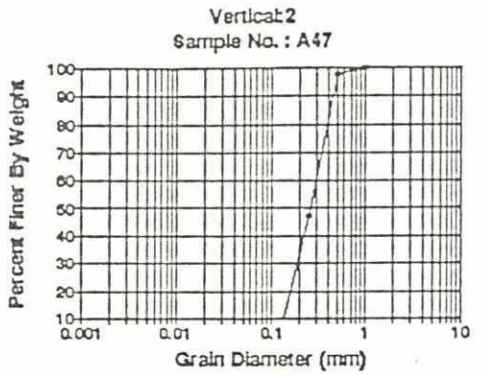
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osmi/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Grain Size Distribution of Suspended Sediments (Andreasen Tube Analysis)	App. No. 9-5
Scale:	Init:		

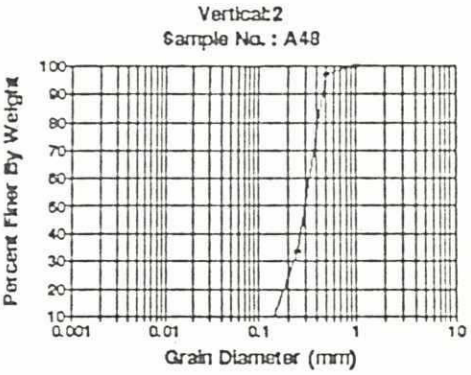
Appendix 10

Grain size distribution of bed load transport (Helley-Smith trap sampler)









Sample No	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation	Transport Rate(Kg M-S)
A49	20/08/93	1500	0.147	0.200	0.255	0.445	1.665	0.3094
A50	20/08/93	1510	0.147	0.202	0.257	0.445	1.654	0.3064
A47	20/08/93	1100	0.148	0.203	0.258	0.465	1.674	0.2825
A48	20/08/93	1115	0.168	0.253	0.299	0.485	1.614	0.4804

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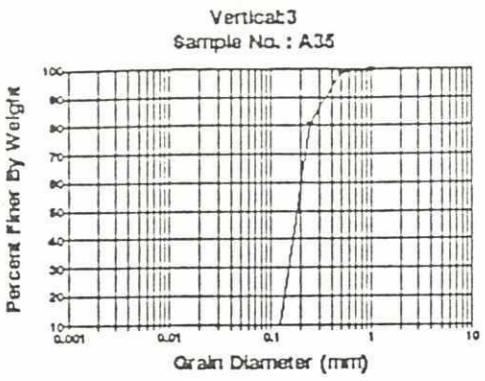
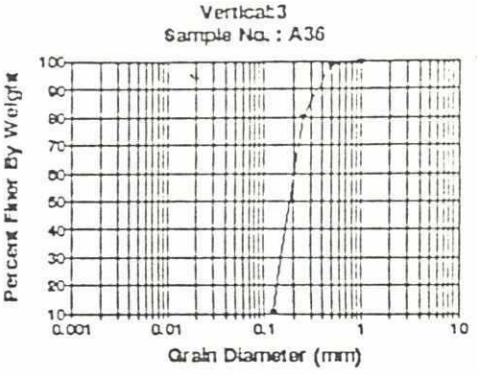
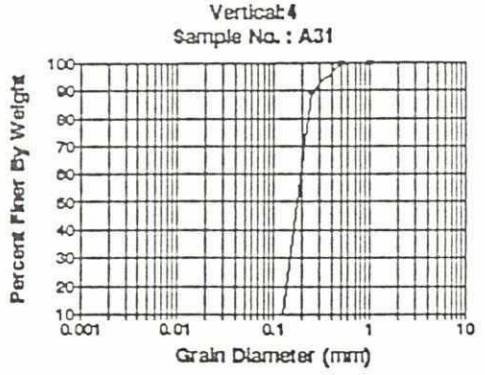
Test Gauging Report

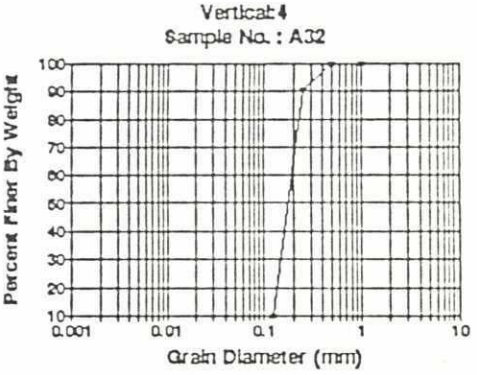
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of Bed Load Transport	App. No. 10-1
Scale:	Init:		









Sample No	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation	Transport Rate(Kg/M-S)
A35	21/08/93	10:45	0.133	0.160	0.185	0.365	1.460	0.1908
A36	21/08/93	10:52	0.131	0.159	0.184	0.365	1.474	0.1599
A31	21/08/93	12:30	0.133	0.157	0.178	0.275	1.338	0.1698
A32	21/08/93	12:39	0.132	0.155	0.176	0.265	1.337	0.1817

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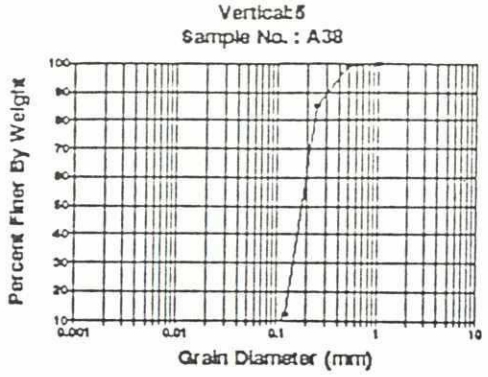
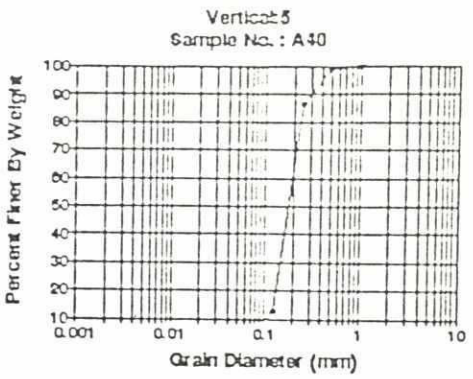
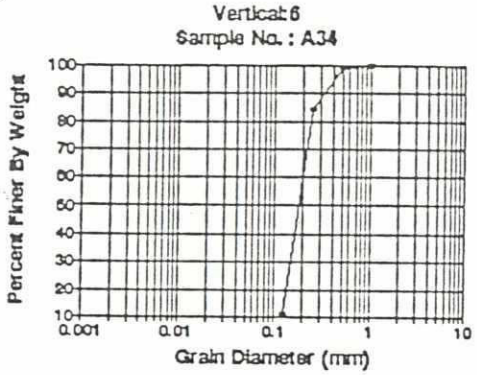
Test Gauging Report

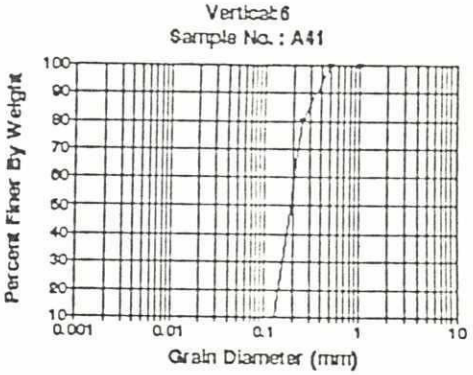
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of Bed Load Transport	App. No. 10-2
Scale:	Init:		









Sample No	Collection Date	Collection Time	D18 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation	Transport Rate(Kg/M·S)
A38	21/08/93	14:00	0.130	0.155	0.179	0.315	1.387	0.2038
A40	21/08/93	14:10	0.129	0.154	0.177	0.300	1.372	0.1806
A34	21/08/93	15:50	0.131	0.156	0.180	0.315	1.379	0.2133
A41	21/08/93	16:00	0.134	0.161	0.186	0.345	1.455	0.3293

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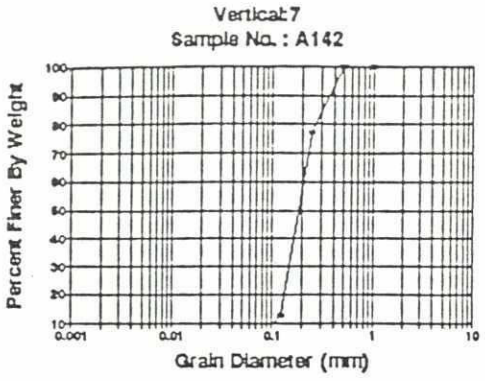
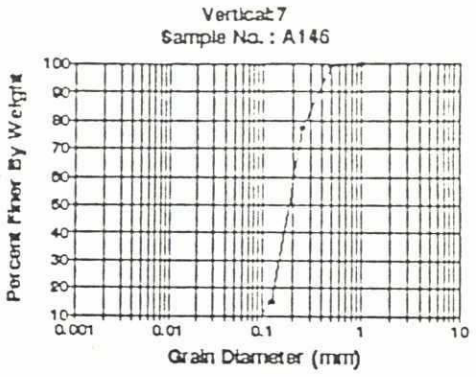
DELFT-DHI

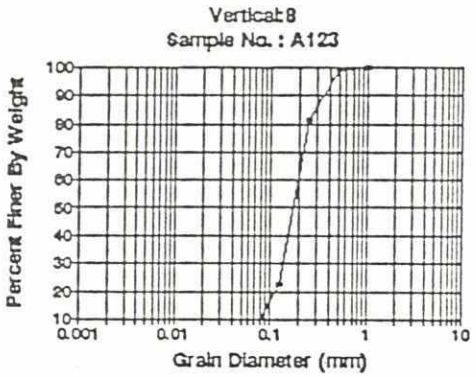
Test Gauging Report

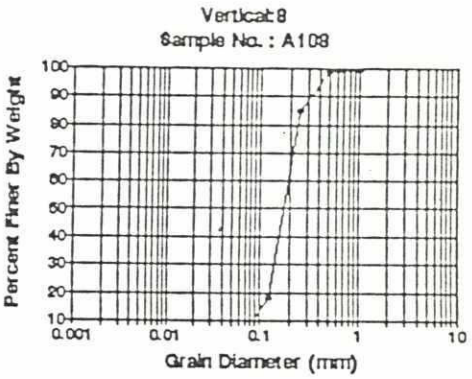
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of Bed Load Transport	App. No. 10-3
Scale:	Init:		









Sample No	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation	Transport Rate(Kg/M-S)
A142	22/08/93	11:35	0.129	0.159	0.188	0.395	1.546	0.1467
A148	22/08/93	11:45	0.127	0.156	0.184	0.390	1.559	0.1075
A123	22/08/93	14:25	0.099	0.145	0.173	0.375	1.669	0.0686
A108	22/08/93	14:35	0.114	0.149	0.174	0.325	1.478	0.1616

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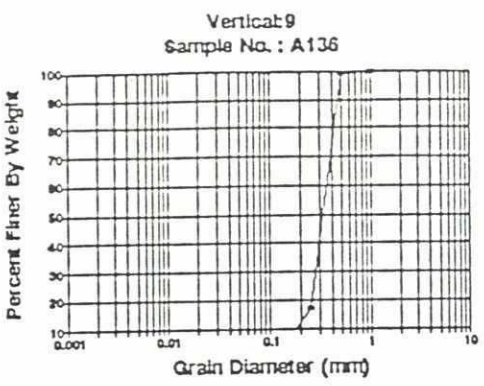
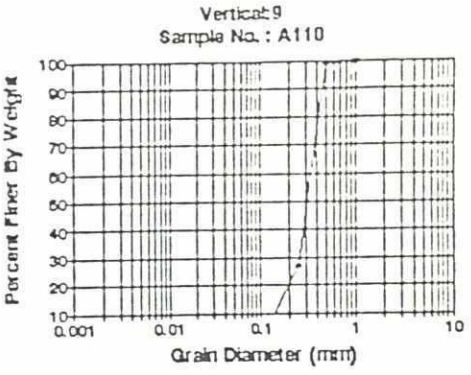
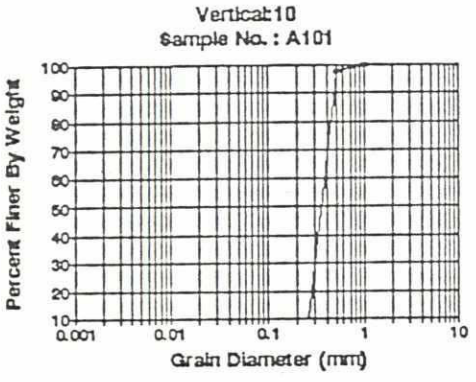
Test Gauging Report

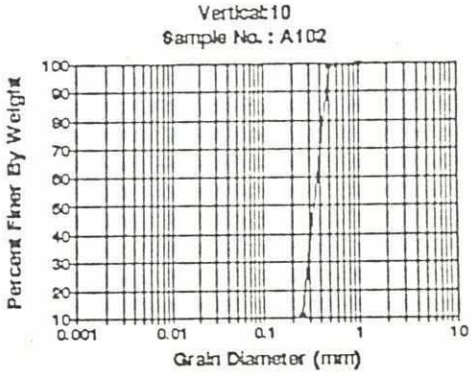
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of Bed Load Transport	App. No. 10-4
Scale:	Init:		









Sample No	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation	Transport Rate(Kg/M-S)
A136	22/08/93	16:00	0.237	0.291	0.330	0.495	1.383	0.01195
A110	22/08/93	16:08	0.174	0.270	0.312	0.450	1.589	0.01118
A101	22/08/93	16:40	0.272	0.314	0.352	0.495	1.288	0.0194
A102	22/08/93	16:50	0.260	0.302	0.340	0.495	1.308	0.0047

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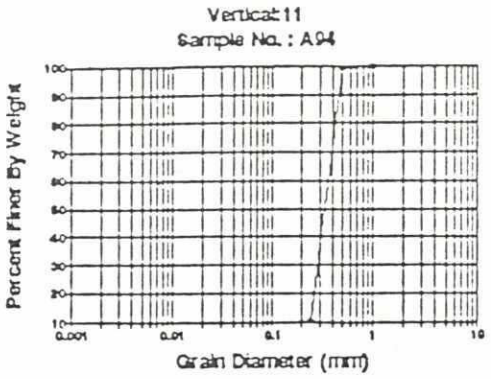
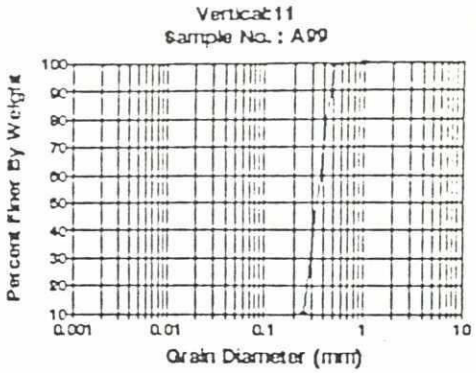
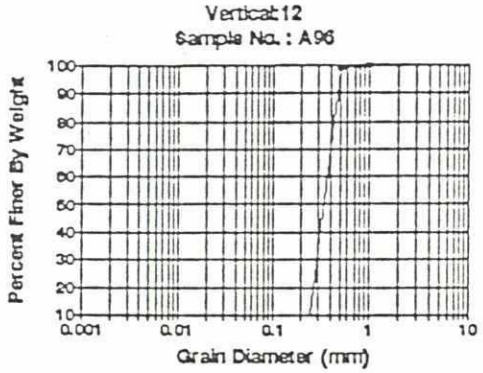
Test Gauging Report

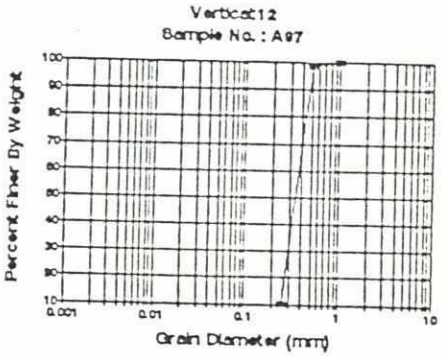
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of Bed Load Transport	App. No. 10-5
Scale:	Init:		









Sample No	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation	Transport Rate (Kg/M/S)
A94	22/08/93	15:00	0.261	0.303	0.304	0.490	1.304	0.02938
A99	22/08/93	15:15	0.261	0.303	0.341	0.495	1.304	0.09298
A96	22/08/93	13:30	0.268	0.307	0.344	0.490	1.295	0.03267
A97	22/08/93	13:45	0.261	0.303	0.341	0.500	1.306	0.00948

FAP 24 RIVER SURVEY PROJECT
Delft Hydraulics/Danish Hydraulic Institute in association with Chris/Approtech/Hydroland
DELFT-DHI

Test Gauging Report

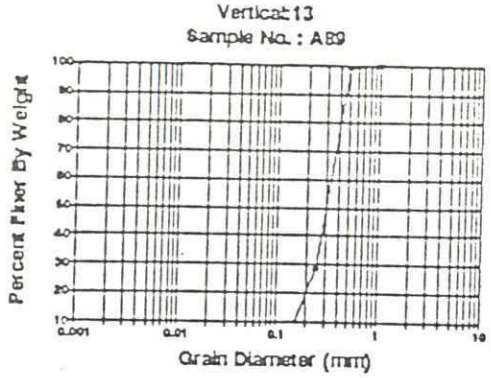
Jamuna River at Bahadurabad (Left Channel)

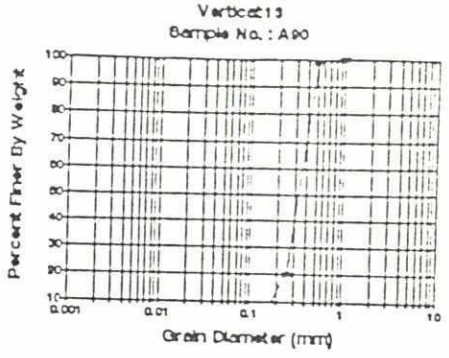
File: | Date:

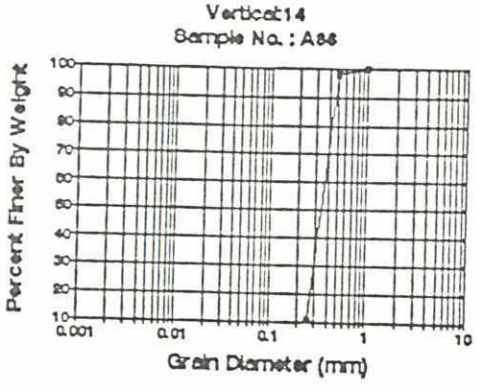
Scale: | Init:

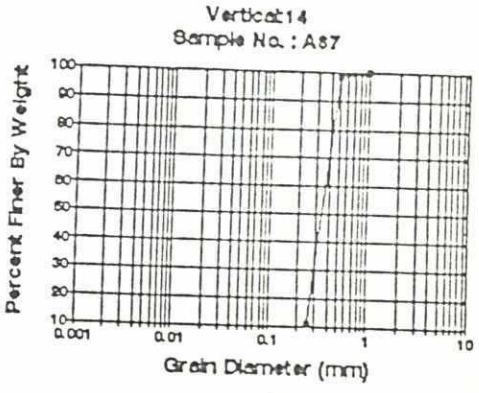
Grain Size Distribution of Bed Load Transport

App. No. 10-6









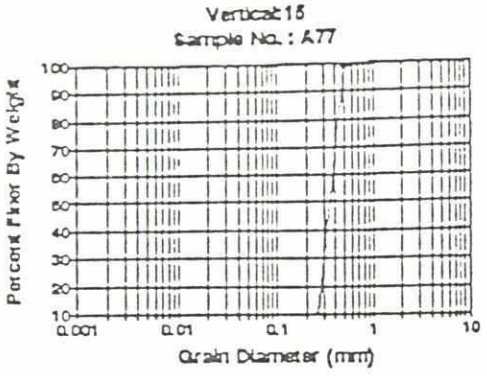
Sample No	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation	Transport Rate(Kg/M-S)
A89	22/08/93	12:10	0.181	0.268	0.308	0.475	1.547	0.3429
A90	22/08/93	12:15	0.214	0.285	0.325	0.445	1.433	0.0014
A86	21/08/93	15:10	0.280	0.303	0.342	0.495	1.314	0.3382
A87	21/08/93	15:20	0.026	0.302	0.341	0.495	1.311	0.3200

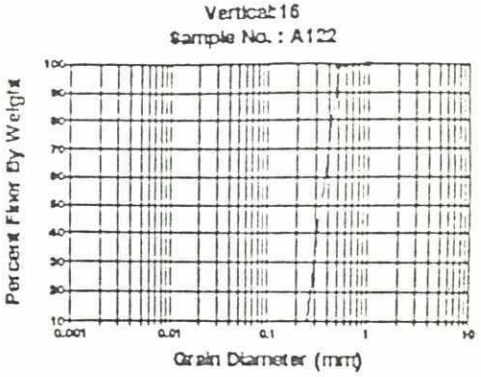
FAP 24 RIVER SURVEY PROJECT
Delft Hydraulics/Danish Hydraulic Institute in association with Osmo/Approtech/Hydroland
DELFT-DHI

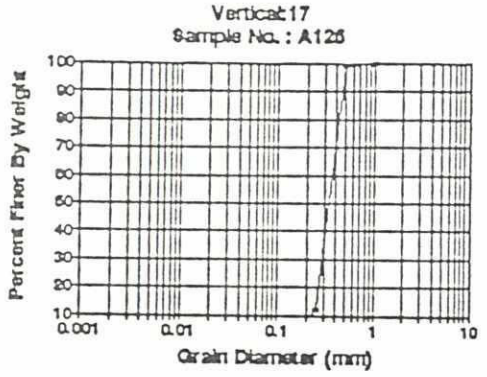
Test Gauging Report

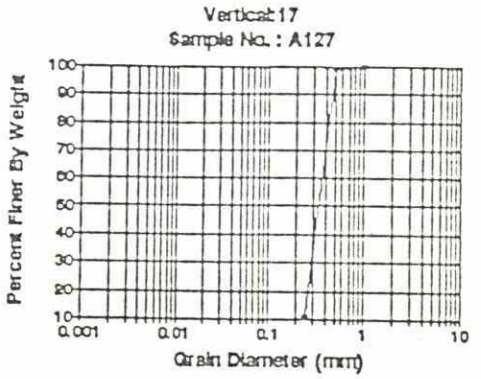
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of Bed Load Transport	App. No. 10-7
Scale:	Init:		









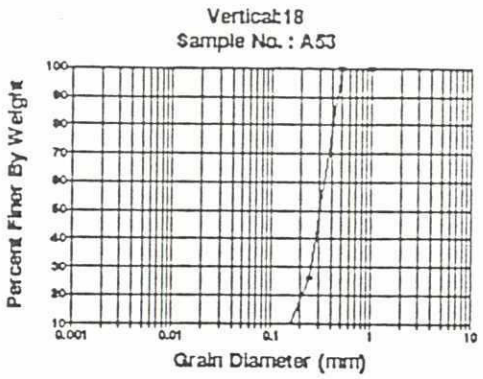
Sample No	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation	Transport Rate(Kg/M-S)
A77	21/06/93	13:30	0.272	0.313	0.349	0.495	1.283	0.0397
A122	21/06/93	12:30	0.269	0.310	0.347	0.485	1.289	0.0578
A126	21/6/93	11:20	0.257	0.299	0.337	0.495	1.311	0.01924
A127	21/06/93	11:40	0.260	0.302	0.340	0.485	1.307	0.09517

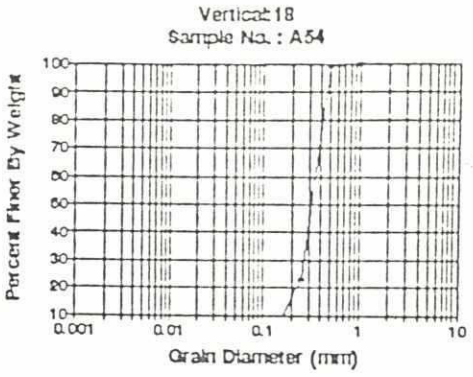
FAP 24 RIVER SURVEY PROJECT
Delft Hydraulics/Danish Hydraulic Institute in association with Chiris/Approtech/Hydroland
DELFT-DHI

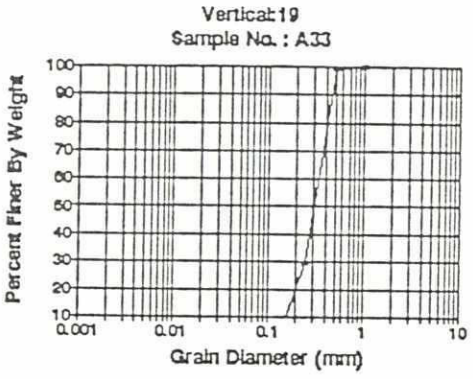
Test Gauging Report

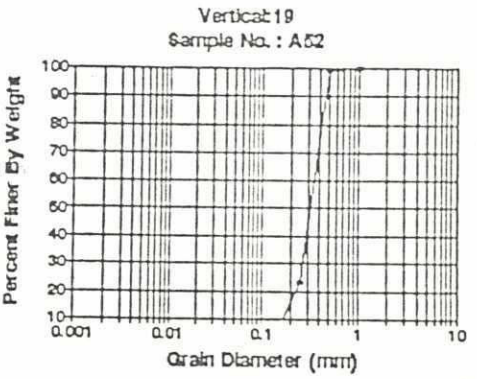
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of Bed Load Transport	App. No. 10-8
Scale:	Init:		









Sample No	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation	Transport Rate(Kg/M-S)
A53	21/08/93	11:00	0.189	0.272	0.313	0.465	1.517	0.09808
A54	21/08/93	11:15	0.199	0.278	0.319	0.470	1.483	0.0268
A33	20/08/93	16:30	0.182	0.265	0.307	0.480	1.544	0.008662
A52	20/08/93	16:40	0.199	0.278	0.319	0.475	1.483	0.00547

FAP 24 RIVER SURVEY PROJECT
DELFT-DHI
Delft Hydraulics/Danish Hydraulic Institute in association with Chiris/Approtech/Hydroland

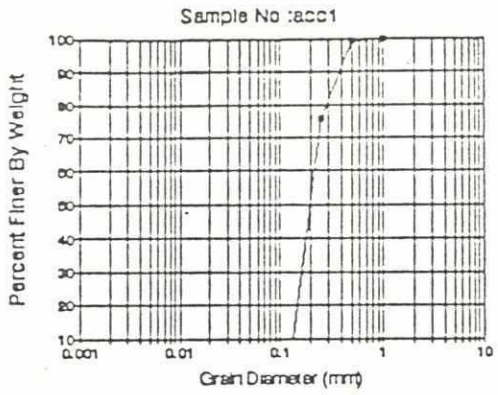
Test Gauging Report

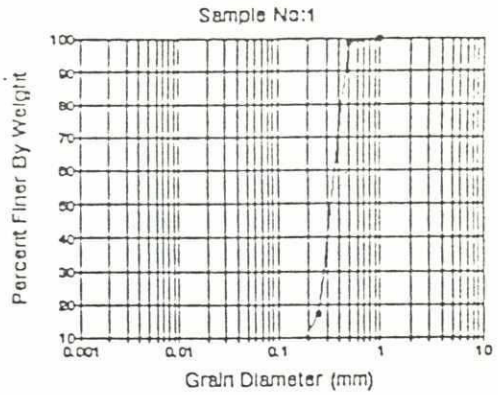
Jamuna River at Bahadurabad (Left Channel)

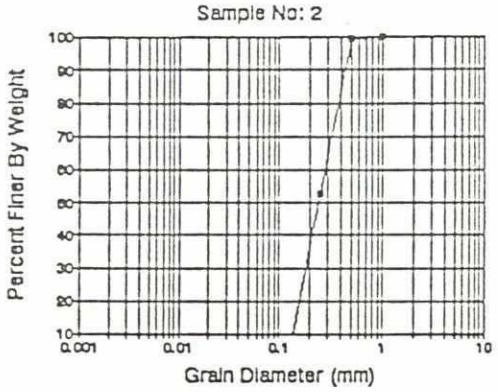
File:	Date:	Grain Size Distribution of Bed Load Transport	App. No. 10-9
Scale:	Init:		

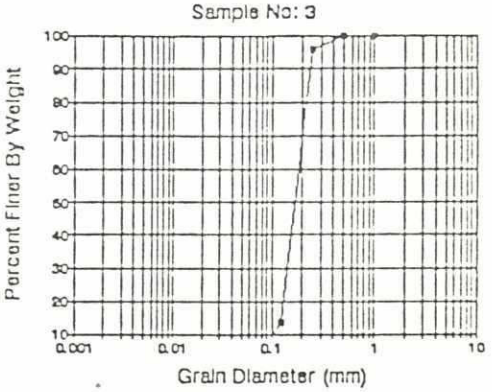
Appendix 11

Grain size distribution of river bed material (US BM-54 sampler)









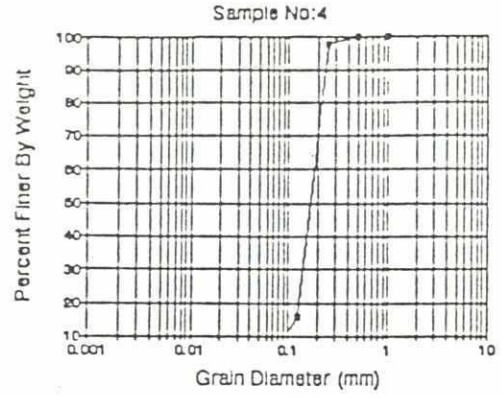
Sample No.	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation
acc1	17/08/93	14:15	0.150	0.168	0.194	0.350	1.507
1	20/08/93	15:00	0.150	0.291	0.330	0.480	1.364
2	20/08/93	12:00	0.150	0.195	0.240	0.425	1.632
3	21/08/93	11:00	0.145	0.150	0.170	0.250	1.632

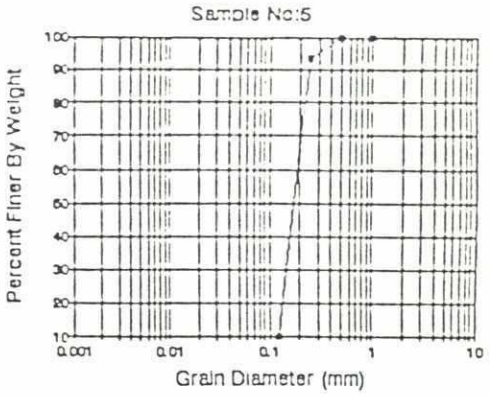
FAP 24 RIVER SURVEY PROJECT
Delft Hydraulics/Danish Hydraulic Institute in association with Osmis/Approtech/Hydroland
DELFT-DHI

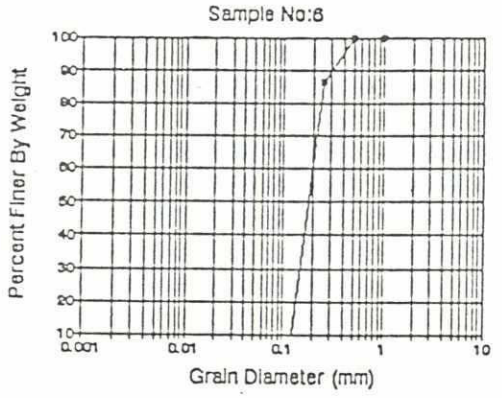
Test Gauging Report

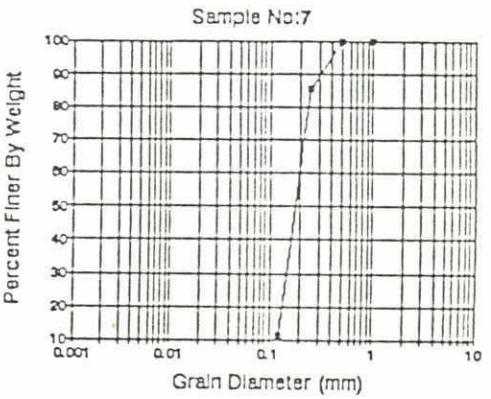
Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of River Bed Material	App. No. 11-1
Scale:	Init:		



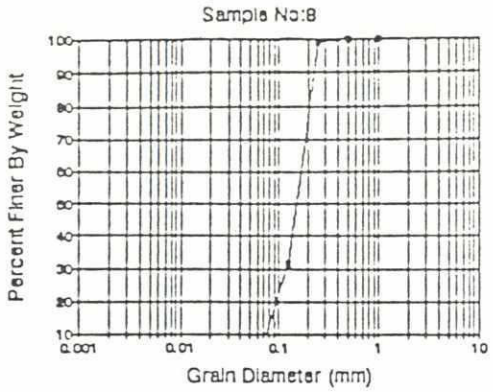


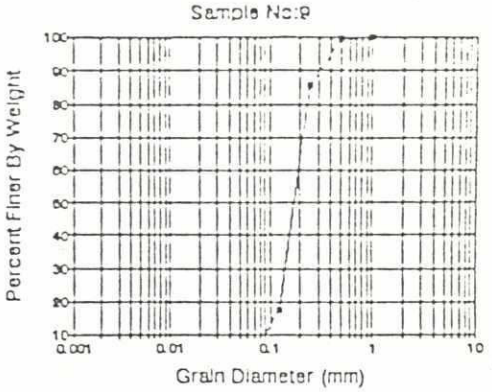


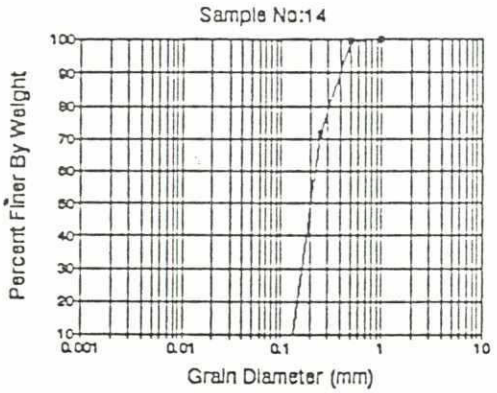


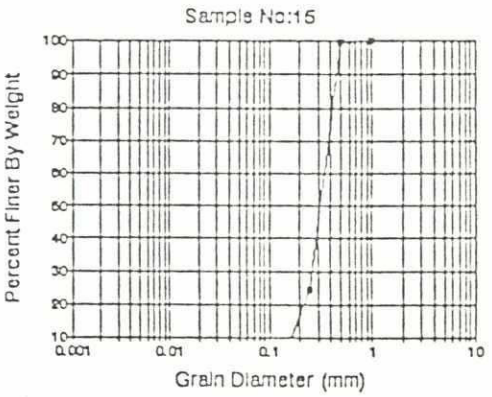
Sample No.	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation
4	21/08/93	12:30	0.150	0.147	0.167	0.250	1.333
5	21/08/93	14:00	0.150	0.154	0.174	0.250	1.230
6	21/08/93	16:00	0.150	0.158	0.181	0.300	1.357
7	22/08/93	11:45	0.150	0.156	0.179	0.300	1.370

FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osmi/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Grain Size Distribution of River Bed Material	App. No. 11-2
Scale:	Init:		









Sample No.	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation
8	22/08/93	14:30	0.085	0.129	0.151	0.200	1.576
9	22/08/93	16:10	0.130	0.149	0.174	0.300	1.450
14	21/08/93	15:15	0.150	0.171	0.200	0.400	1.554
15	21/08/93	13:30	0.200	0.275	0.317	0.450	1.497

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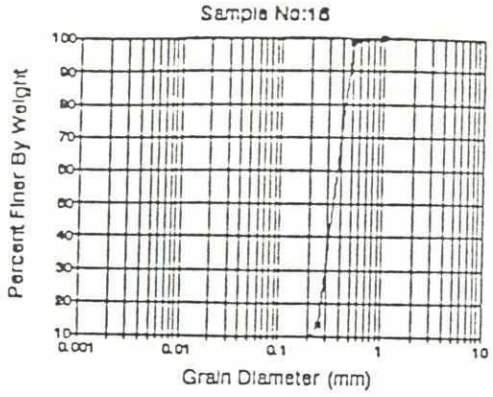
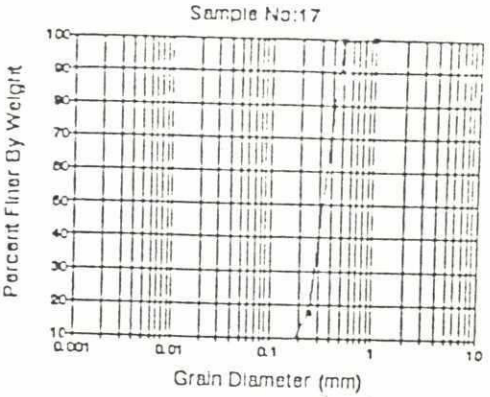
DELFT-DHI

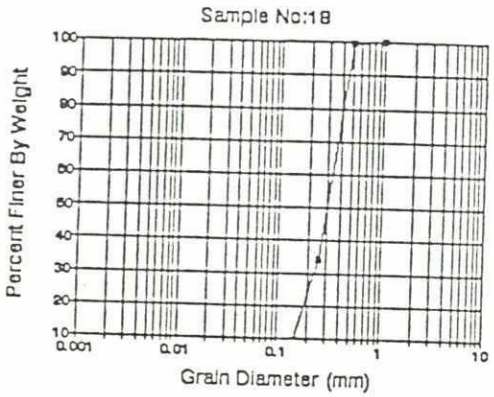
Test Gauging Report

Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Grain Size Distribution of River Bed Material	App. No. 11-3
Scale:	Init:		





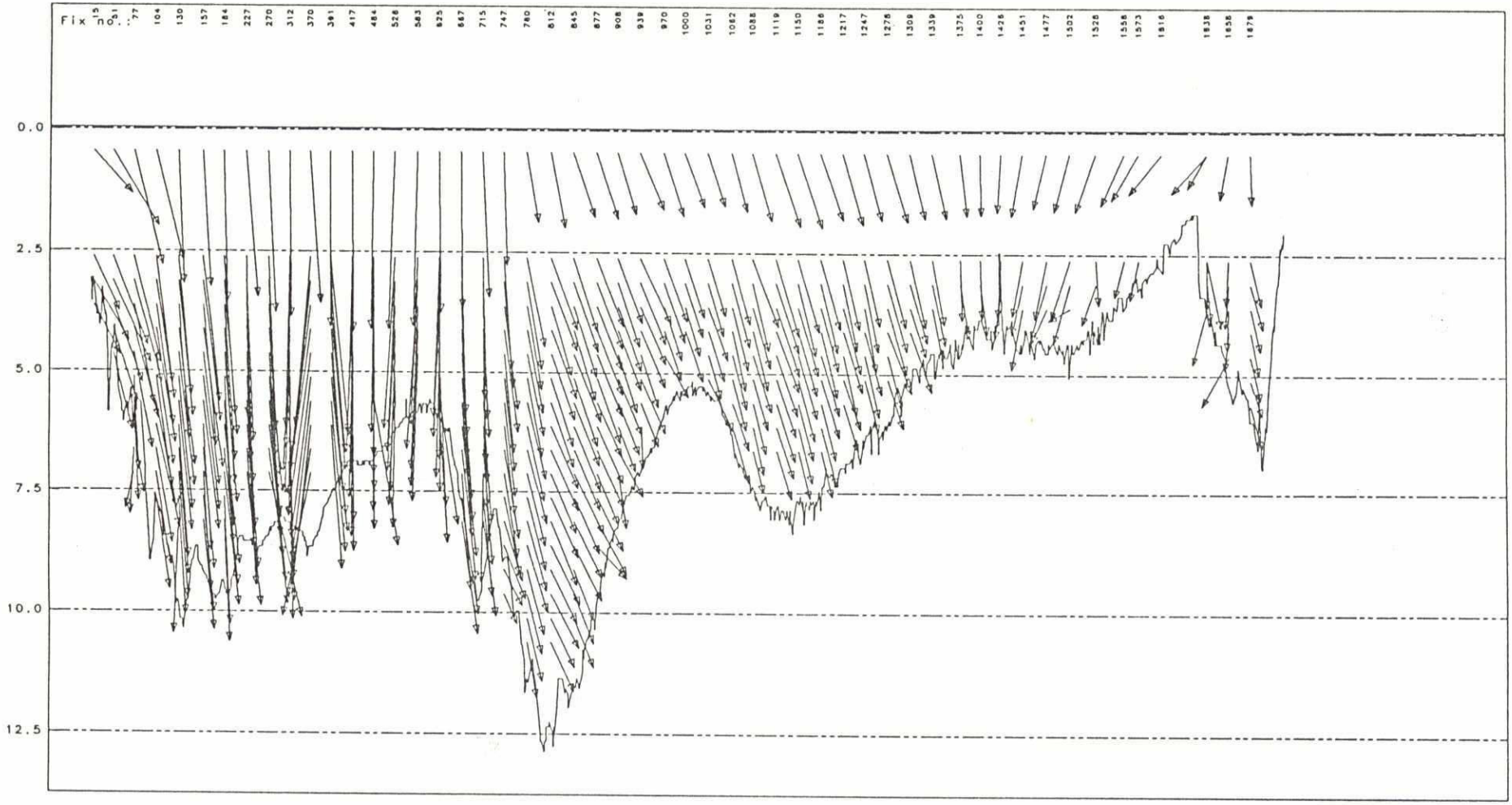


Sample No.	Collection Date	Collection Time	D16 (mm)	D35 (mm)	D50 (mm)	D90 (mm)	Standard Deviation
16	21/08/93	12:30	0.250	0.298	0.337	0.480	1.320
17	21/08/93	11:40	0.150	0.289	0.329	0.460	1.378
18	21/08/93	11:00	0.180	0.252	0.295	0.450	1.590

FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Grain Size Distribution of River Bed Material	App. No. 11-4
Scale:	Init:		

Appendix 12

Sectional distribution of current velocities (ADCP)



PROFILE CURRENT VELOCITY :

Horizontal Scale	: 1 : 15000
Vertical Scale	: 1 : 125
Current Arrow Scale	: 1.0 cm per m/s
Azimuth	: 270.3 Deg. North

SURVEY ID. :

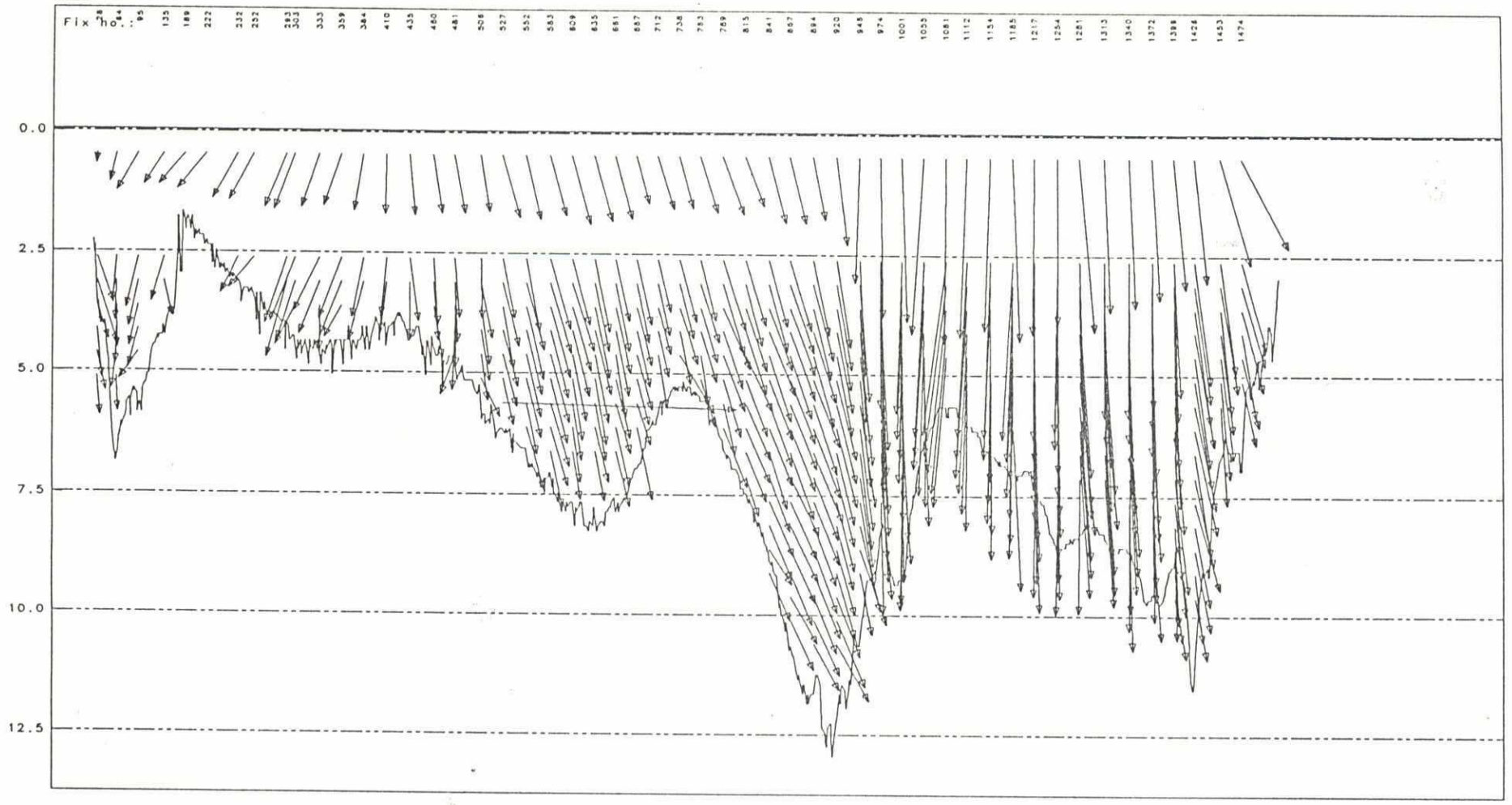
Positions	: BTM
Date	: 930820
Start Time	: 09:32:15
End Time	: 10:01:12
Start Position	: 470571E 777486N
End Posision	: 467671E 777503N
Discharge	: 28369.63 (m^3/s)

PLOT ID. :

Project	: River Survey Project FAP 24
File	: /u/f24adm/data/93-aug/aug-20/b38k1t02
Drawn	: Thu Sep 9 15:10:30 1993
Type	: Cross Section
Init.	: MZH
Rev.	: A

Appr.

App. No. 12-1



PROFILE CURRENT VELOCITY :

Horizontal Scale : 1 : 15000
Vertical Scale : 1 : 125
Current Arrow Scale : 1.0 cm per m/s
Azimuth : 89.7 Deg. North

SURVEY ID. :

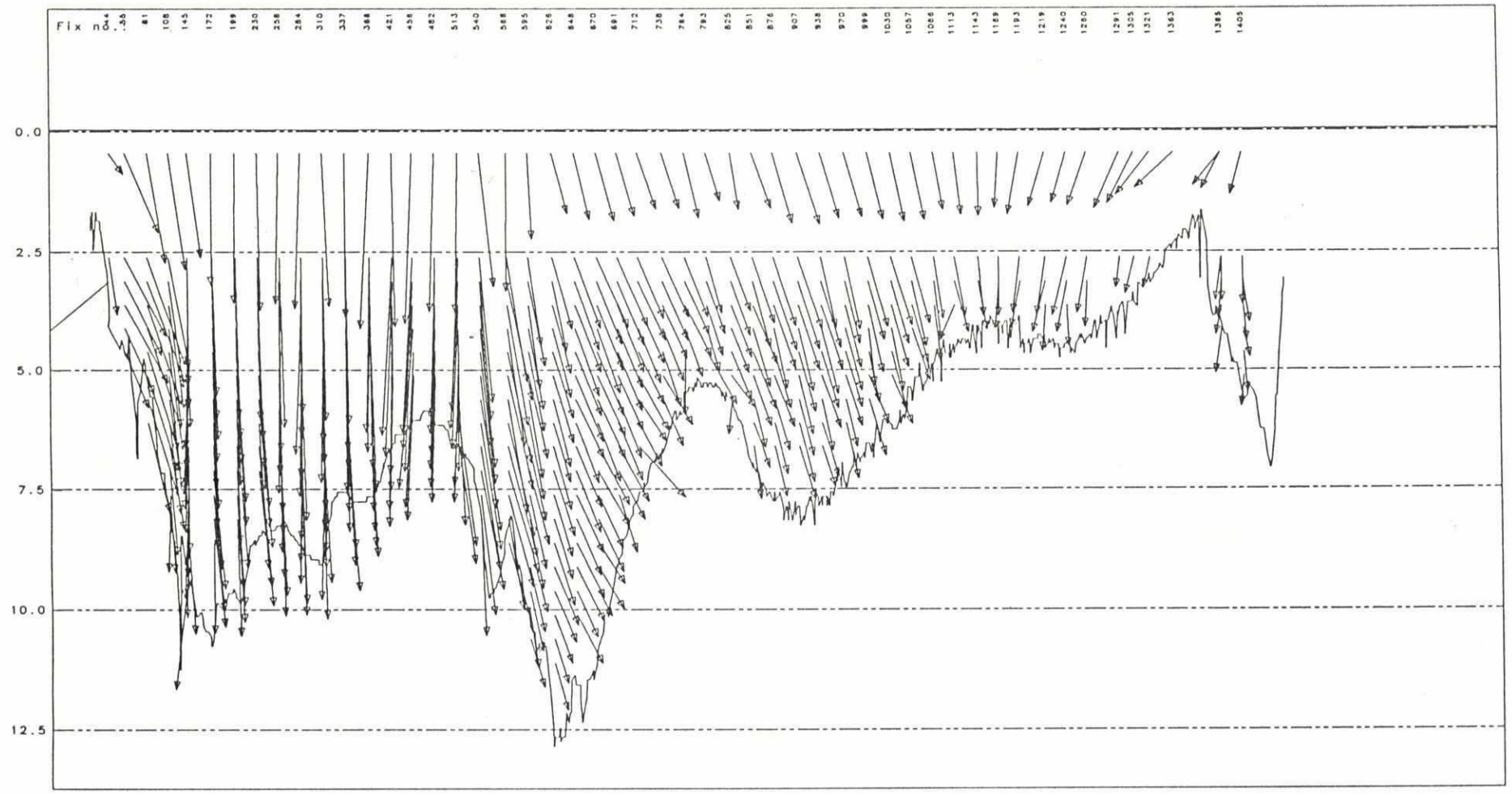
Positions : BTM
Date : 930820
Start Time : 10:16:17
End Time : 10:41:53
Start Position : 467677E 777496N
End Posision : 470568E 777513N
Discharge : 28432.64 (m^3/s)

PLOT ID. :

Project : River Survey Project FAP 24
File : /u/f24adm/data/93-aug/aug-20/b38k1t03
Drawn : Thu Sep 9 15:11:04 1993
Type : Cross Section
Init. : MZH
Rev. : A

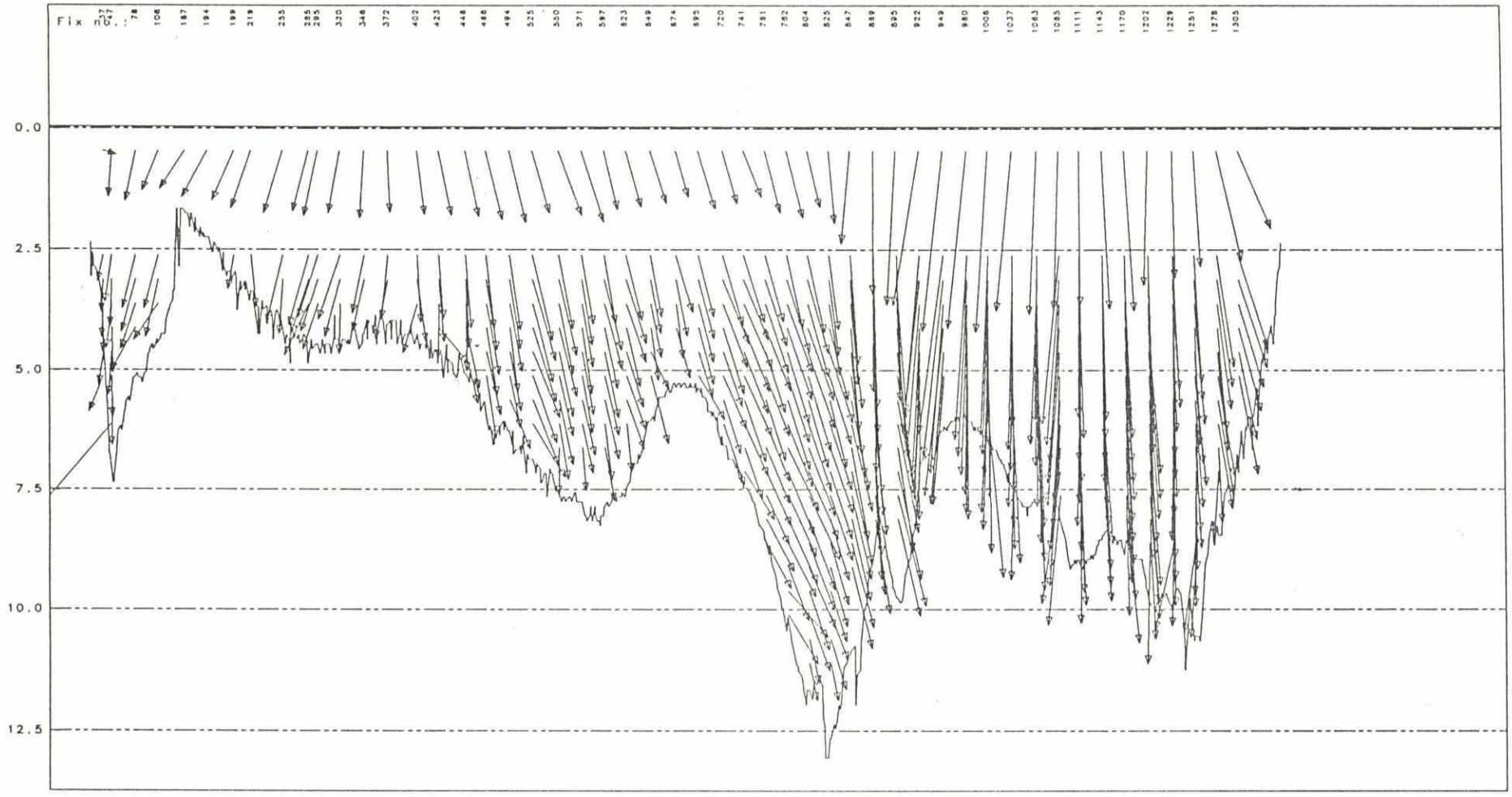
Appr.

App. No. 12-2

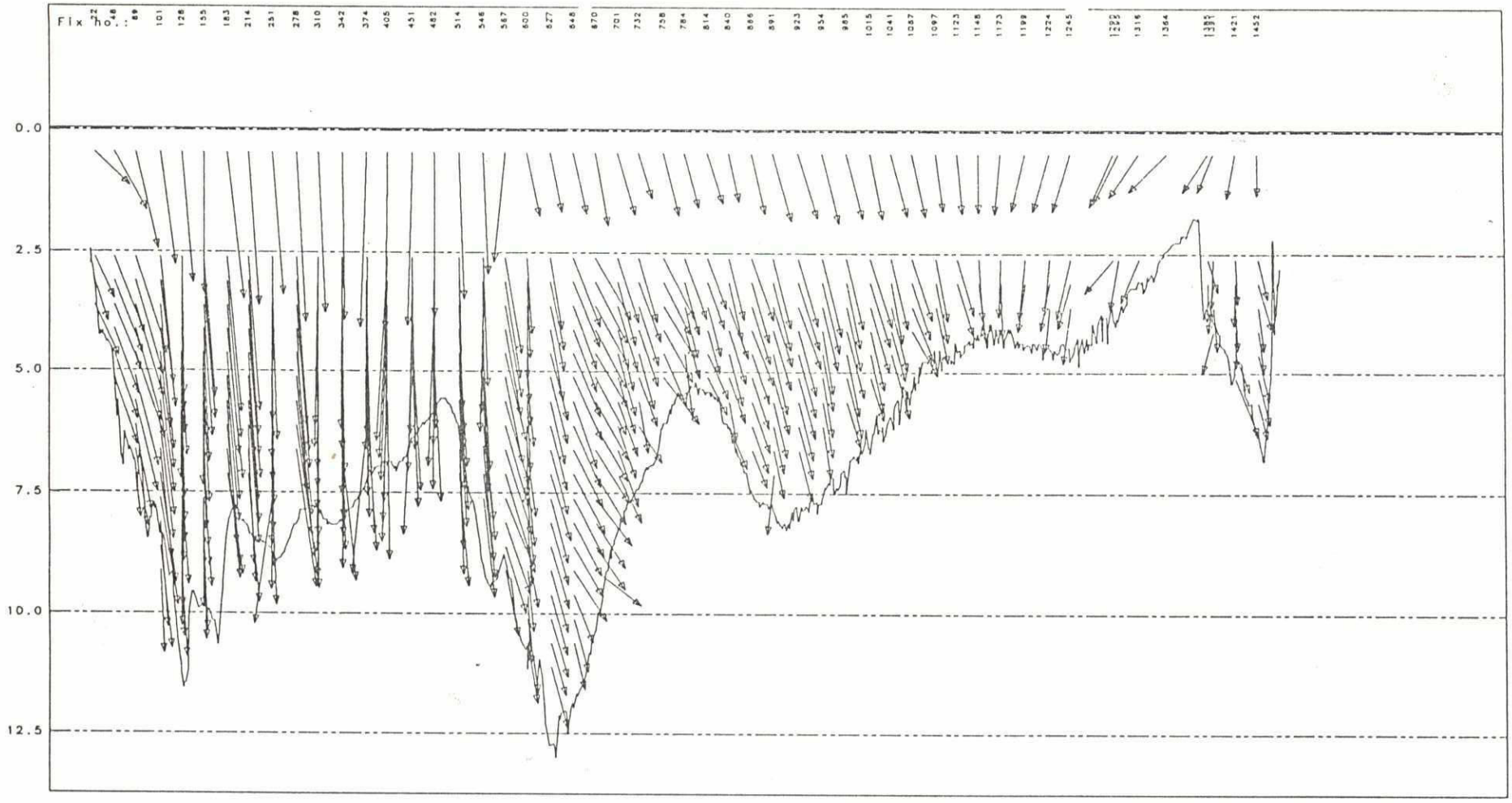


PROFILE CURRENT VELOCITY :	SURVEY ID. :	PLOT ID. :
Horizontal Scale : 1 : 15000	Positions : BTM	Project : River Survey Project FAP 24
Vertical Scale : 1 : 125	Date : 930820	File : /u/f24adm/data/93-aug/aug-20/b38k1108
Current Arrow Scale : 1.0 cm per m/s	Start Time : 17:07:06	Drawn : Thu Sep 9 15:12:09 1993
Azimuth : 269.8 Deg. North	End Time : 17:31:10	Type : Cross Section
	Start Position : 470602E 777506N	Init. : MZH
	End Posision : 467689E 777497N	Rev. : A
	Discharge : 28092.37 (m^3/s)	Appr.

App. No. 12-3

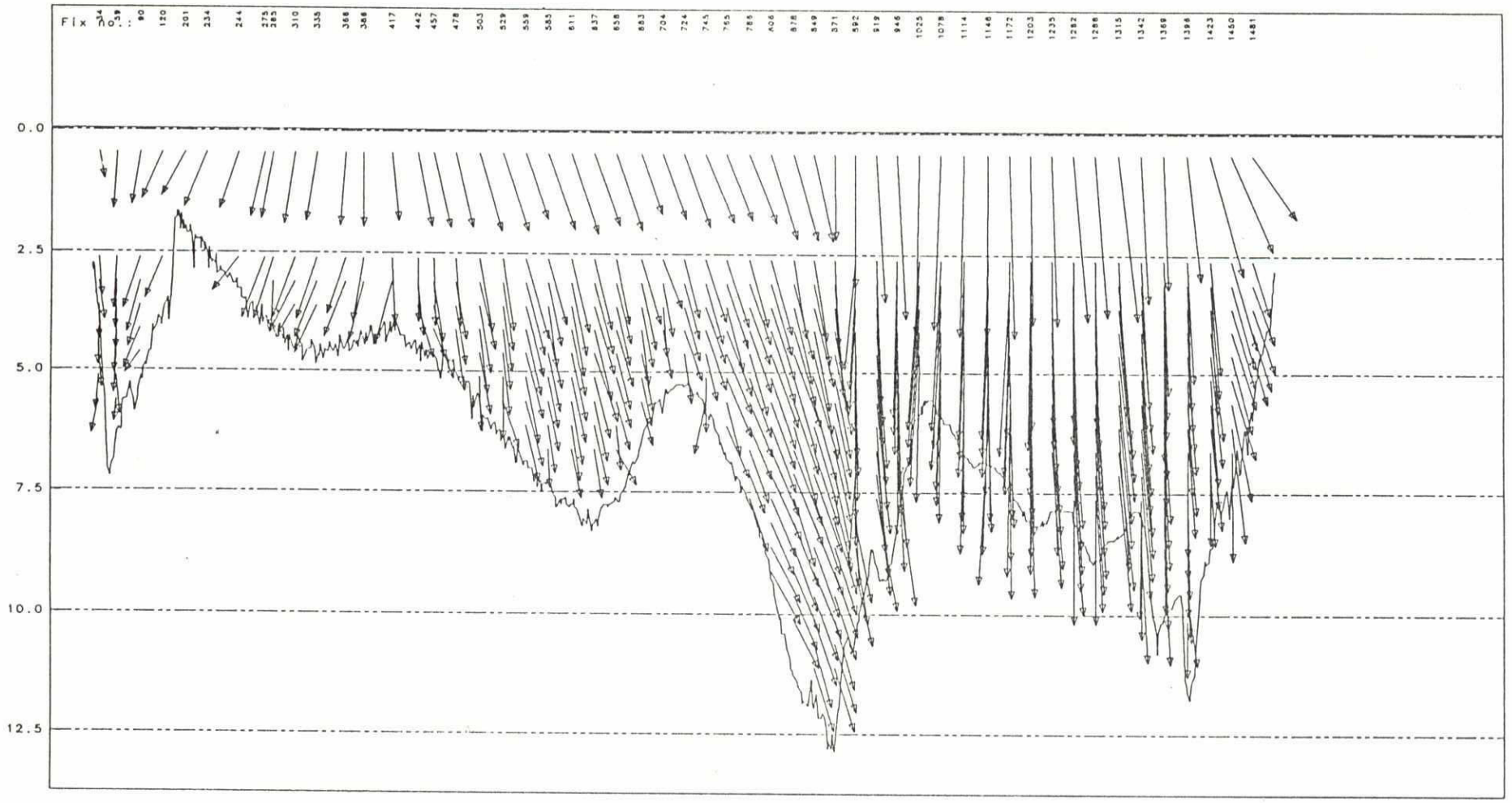


PROFILE CURRENT VELOCITY :		SURVEY ID. :		PLOT ID. :	
Horizontal Scale	: 1 : 15000	Positions	: BTM	Project	: River Survey Project FAP 24
Vertical Scale	: 1 : 125	Date	: 930820	File	: /u/f24adm/data/93-aug/aug-20/b38k1t07
Current Arrow Scale	: 1.0 cm per m/s	Start Time	: 17:35:10	Drawn	: Thu Sep 9 15:12:30 1993
Azimuth	: 88.8 Deg. North	End Time	: 17:57:55	Type	: Cross Section
		Start Position	: 467677E 777460N	Init.	: MZH
		End Position	: 470575E 777521N	Rev.	: A
		Discharge	: 28908.10 (m^3/s)	Appr.	App. No. 12-4



PROFILE CURRENT VELOCITY :	SURVEY ID. :	PLOT ID. :
Horizontal Scale : 1 : 15000	Positions : BTM	Project : River Survey Project FAP 24
Vertical Scale : 1 : 125	Date : 930821	File : /u/f24adm/data/93-aug/aug-21/b3811101
Current Arrow Scale : 1.0 cm per m/s	Start Time : 09:13:24	Drawn : Thu Sep 9 15:20:31 1993
Azimuth : 269.9 Deg. North	End Time : 09:38:30	Type : Cross Section
	Start Position : 470576E 777504N	Init. : MZH
	End Posision : 467683E 777501N	Rev. : A
	Discharge : 27799.02 (m^3/s)	Appr.

App. No. 12-5



PROFILE CURRENT VELOCITY :

Horizontal Scale : 1 : 15000
Vertical Scale : 1 : 125
Current Arrow Scale : 1.0 cm per m/s
Azimuth : 89.4 Deg. North

SURVEY ID. :

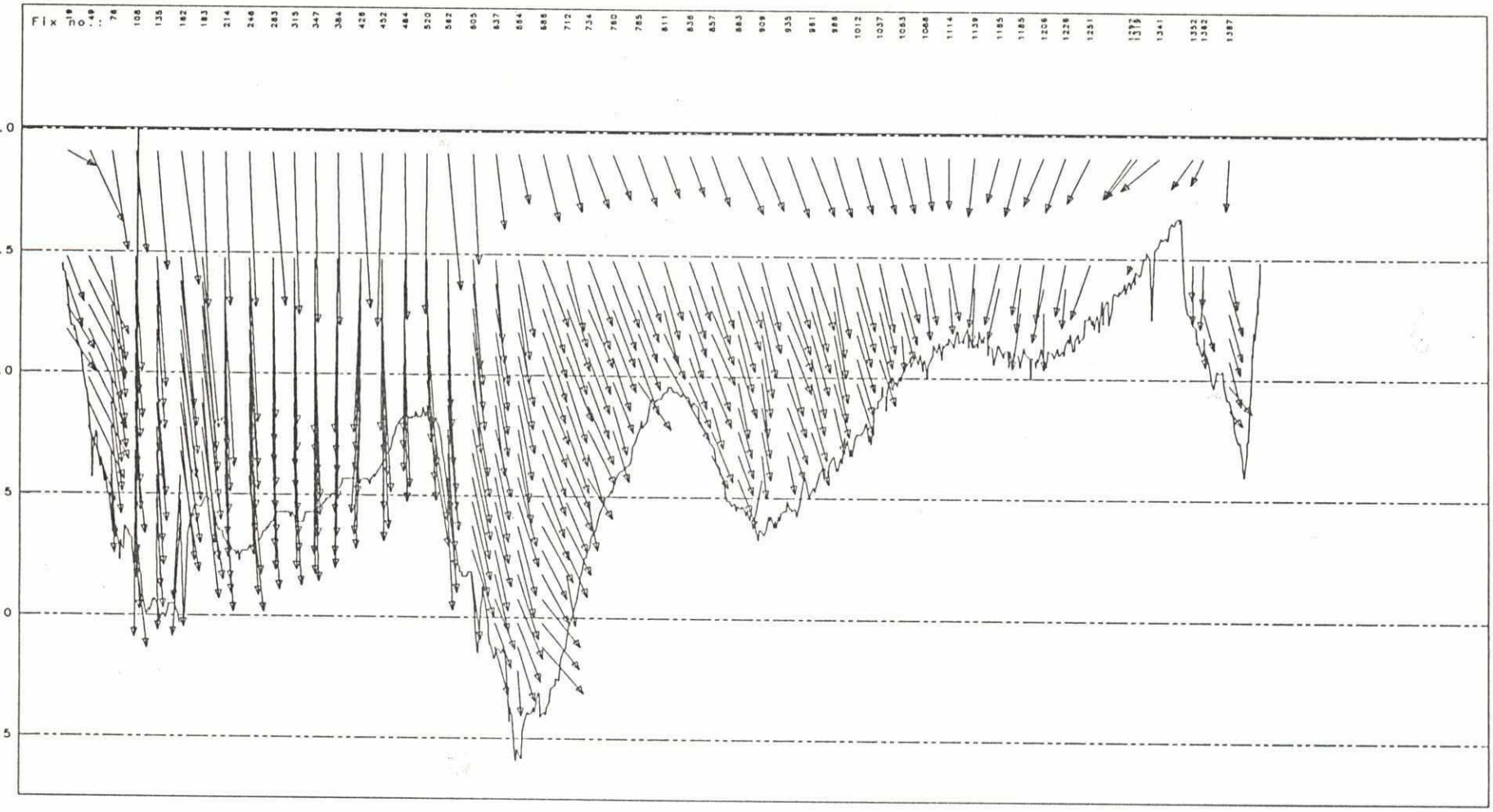
Positions : BTM
Date : 930821
Start Time : 09:42:22
End Time : 10:07:52
Start Position : 467688E 777484N
End Posision : 470569E 777512N
Discharge : 29450.61 (m^3/s)

PLOT ID. :

Project : River Survey Project FAP 24
File : /u/f24adm/data/93-aug/aug-21/b3811t02
Drawn : Thu Sep 9 15:21:14 1993
Type : Cross Section
Init. : MZH
Rev. : A

Appr.

App. No. 12-6



PROFILE CURRENT VELOCITY :

Horizontal Scale : 1 : 15000
Vertical Scale : 1 : 125
Current Arrow Scale : 1.0 cm per m/s
Azimuth : 270.0 Deg. North

SURVEY ID. :

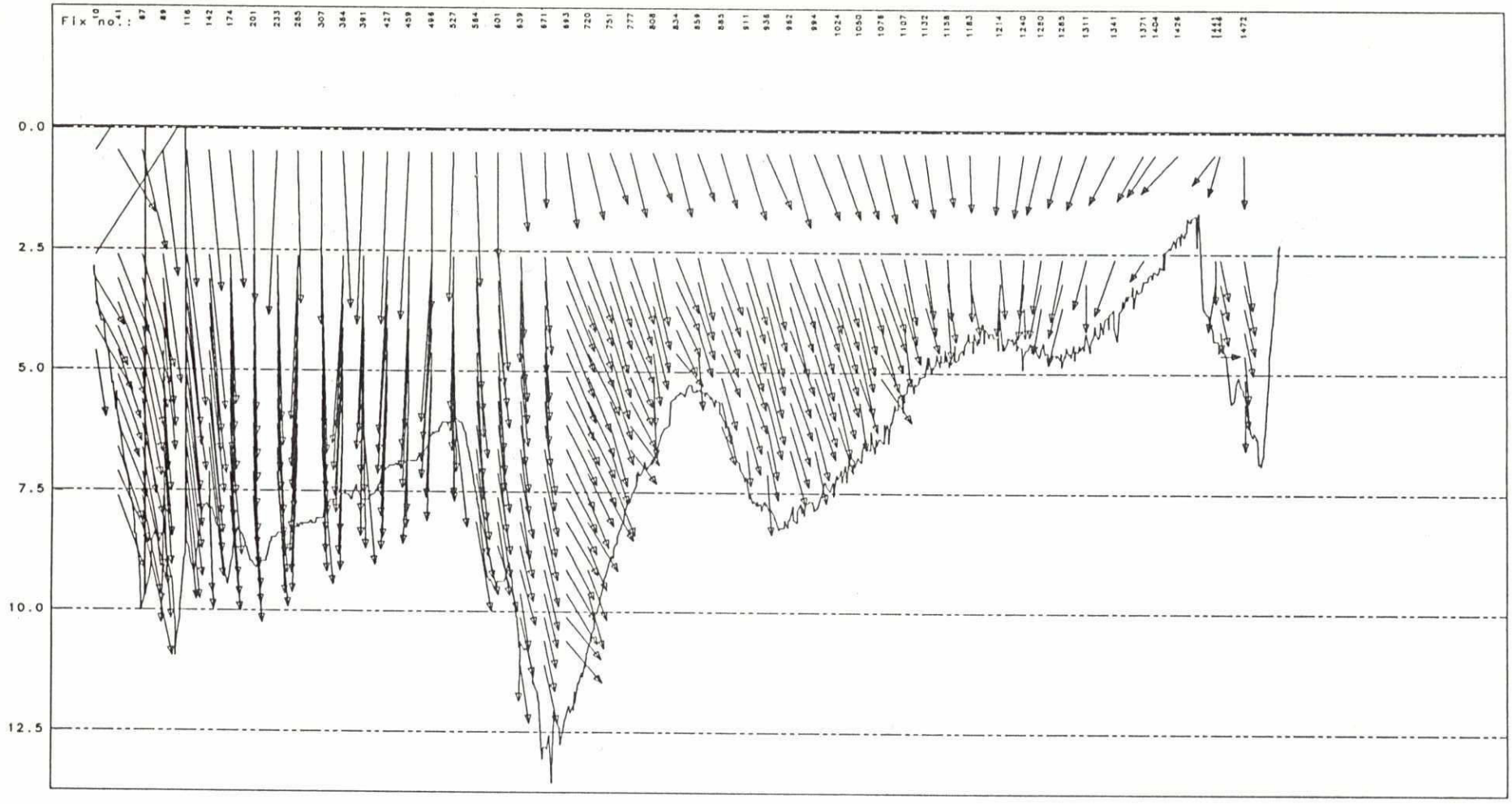
Positions : BTM
Date : 930821
Start Time : 17:17:02
End Time : 17:41:23
Start Position : 470574E 777497N
End Posision : 467682E 777499N
Discharge : 27144.30 (m^3/s)

PLOT ID. :

Project : River Survey Project FAP 24
File : /u/f24adm/data/93-aug/aug-21/b3811t03
Drawn : Thu Sep 9 15:21:44 1993
Type : Cross Section
Init. : MZH
Rev. : A

Appr.

App. No. 12-7



PROFILE CURRENT VELOCITY :

Horizontal Scale : 1 : 15000
Vertical Scale : 1 : 125
Current Arrow Scale : 1.0 cm per m/s
Azimuth : 269.9 Deg. North

SURVEY ID. :

Positions : BTM
Date : 930822
Start Time : 09:28:28
End Time : 09:54:50
Start Position : 470565E 777509N
End Posision : 467678E 777505N
Discharge : 25683.52 (m^3/s)

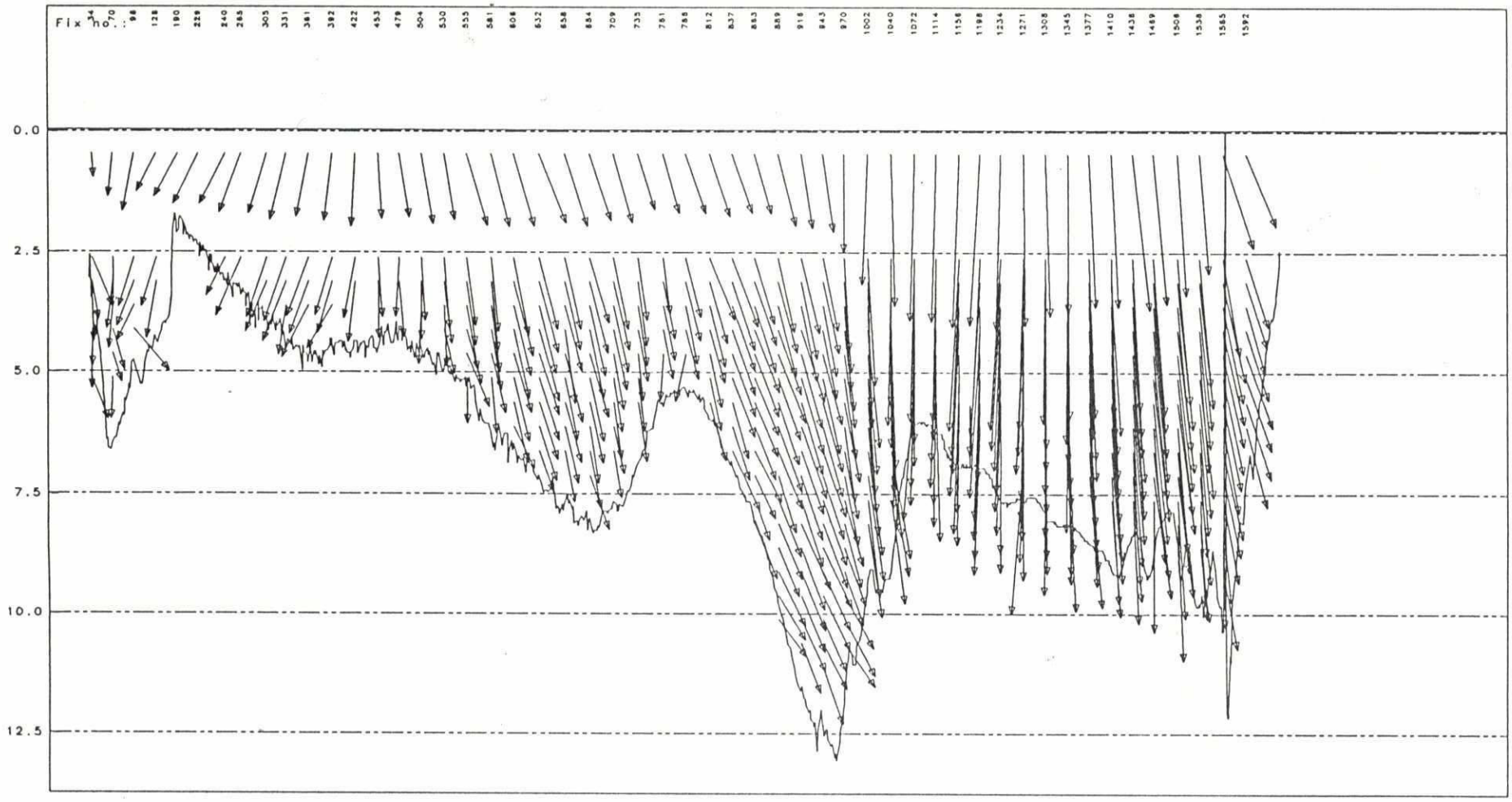
PLOT ID. :

Project : River Survey Project FAP 24
File : /u/f24adm/data/93-aug/aug-22/b3&m1t01
Drawn : Thu Sep 9 15:24:17 1993
Type : Cross Section
Init. : MZH
Rev. : A

Appr.

App. No. 12-8

22



PROFILE CURRENT VELOCITY :

Horizontal Scale : 1 : 15000
Vertical Scale : 1 : 125
Current Arrow Scale : 1.0 cm per m/s
Azimuth : 89.6 Deg. North

SURVEY ID. :

Positions : BTM
Date : 930822
Start Time : 09:58:16
End Time : 10:25:48
Start Position : 467683E 777498N
End Posision : 470569E 777517N
Discharge : 29158.52 (m-3/s)

PLOT ID. :

Project : River Survey Project FAP 24
File : /u/f24adm/data/93-aug/aug-22/b38m1t02
Drawn : Thu Sep 9 15:24:56 1993
Type : Cross Section
Init. : MZH
Rev. : A

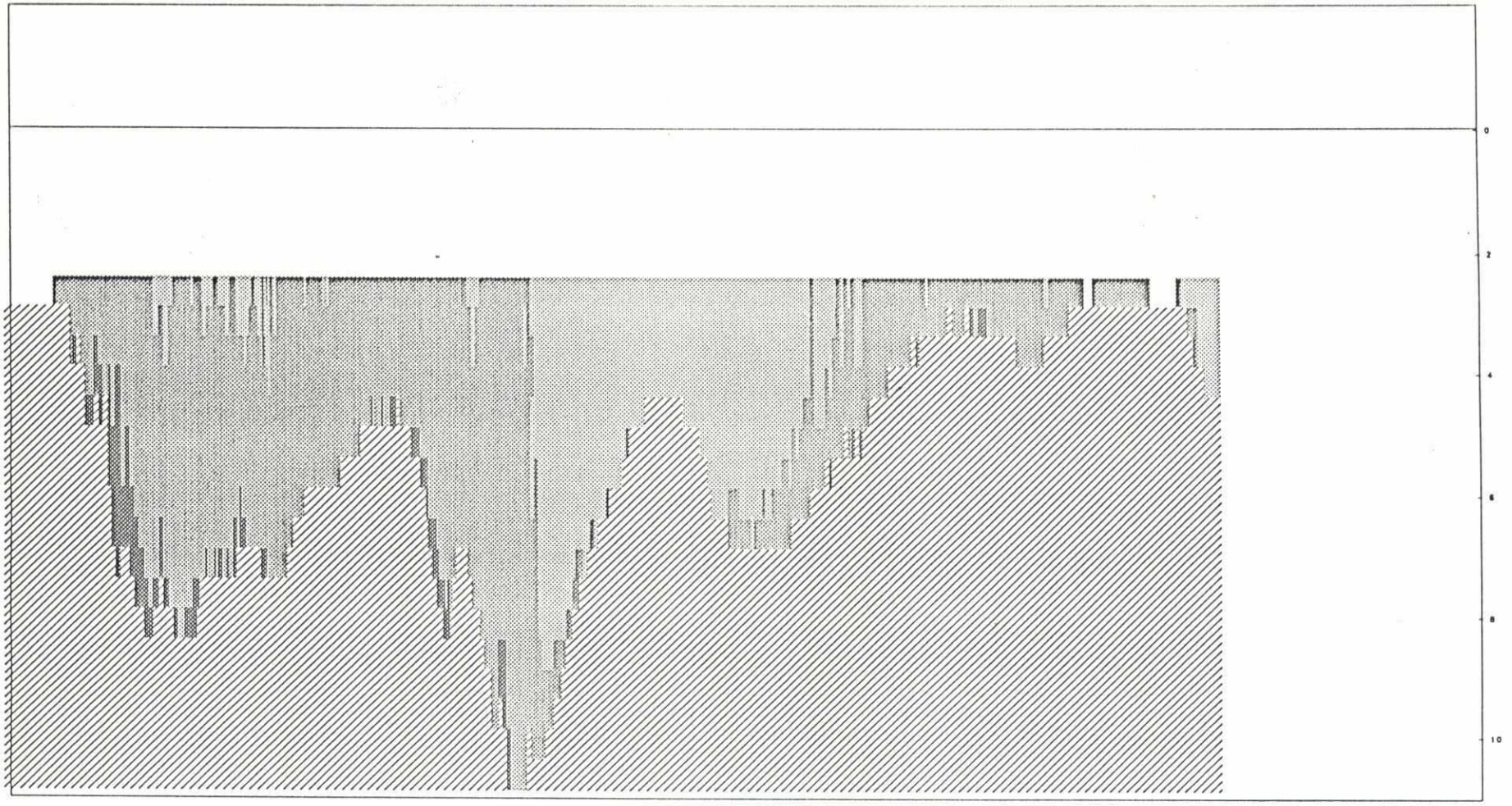
Appr.

App. No. 12-9

Appendix 13

Relative sectional distribution of suspended sediment (ADCP)

DEPTH PROFILE – HORIZONTAL SCALE 1 : 15000 VERTICAL SCALE 1 : 100

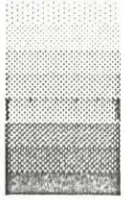


EQUIPMENT :

U/T SENSOR

Positioning system	:	GPS
Echosounder	:	None
Air profiler	:	200 Khz
Caldet profiler	:	no. 1
Adcp profiler	:	1200 Khz

DECIBEL PLOT (dB) :



<=	45
45 –	55
55 –	65
65 –	75
75 –	85
85 –	95
95 –	105
>=	105

MEASURING ID. :

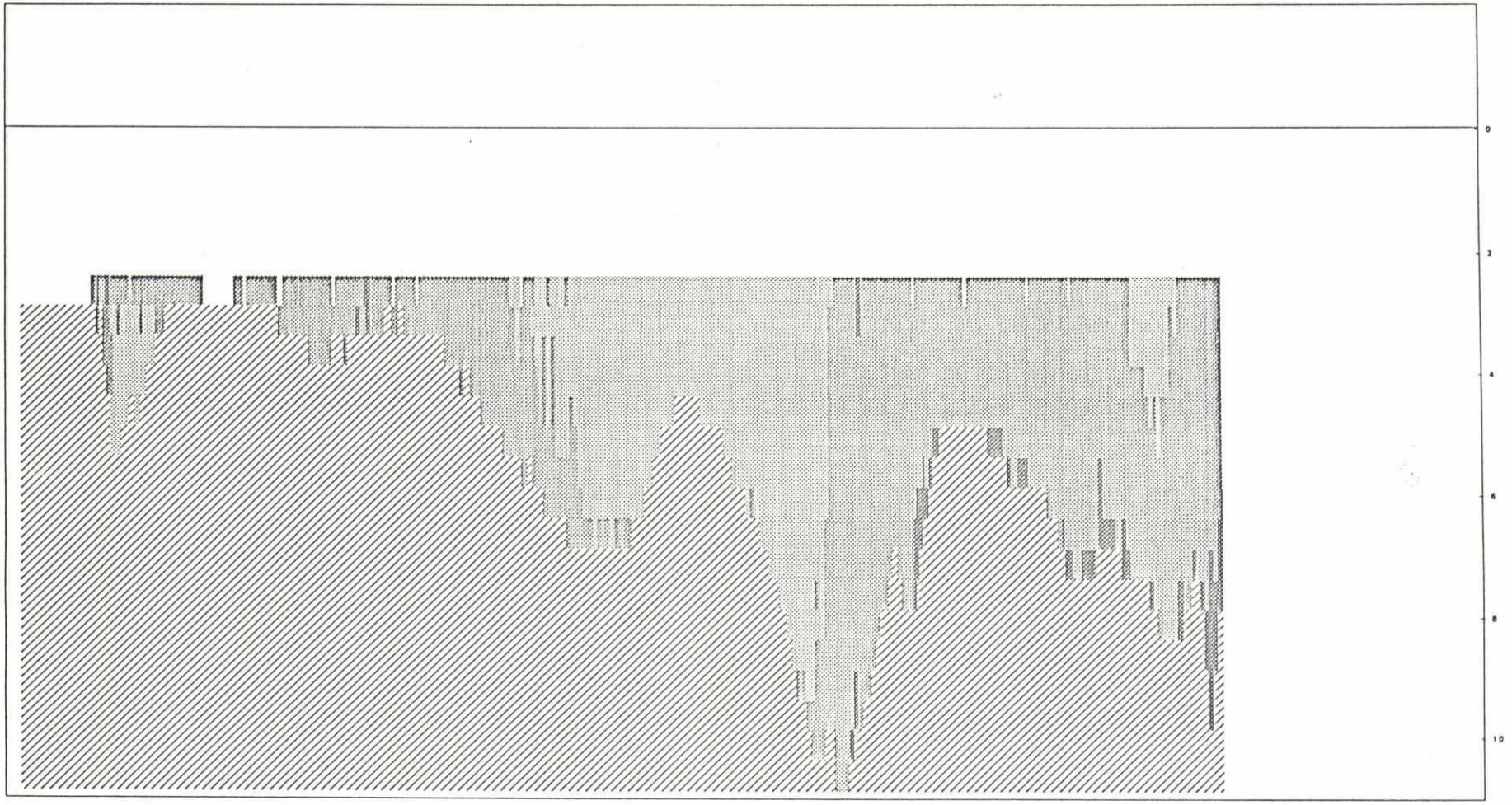
Line	:	
Survey id.	:	(null)
Coordinate system	:	UTM Zone 33
Start position	:	470571E 777486N
End position	:	DE DN
Executed	:	
Time interval	:	D – H:T::

PLOT ID. :

Project	:	River Survey Project FAP 24
File	:	H:T:
Drawn	:	Mon Oct 11 10:30:42 1993
Type	:	P
Rev.	:	
Init.	:	

App. No. 13-1

DEPTH PROFILE – HORIZONTAL SCALE 1 : 15000 VERTICAL SCALE 1 : 100



EQUIPMENT :

U/T SENSOR

Positioning system	:	DPS
Echosounder	:	None
Air profiler	:	200 Khz
Cadet profiler	:	no. 1
Adcp profiler	:	1200 Khz

DECIBEL PLOT (dB) :

<=	45
45 –	55
55 –	65
65 –	75
75 –	85
85 –	95
95 –	105
>=	105

MEASURING ID. :

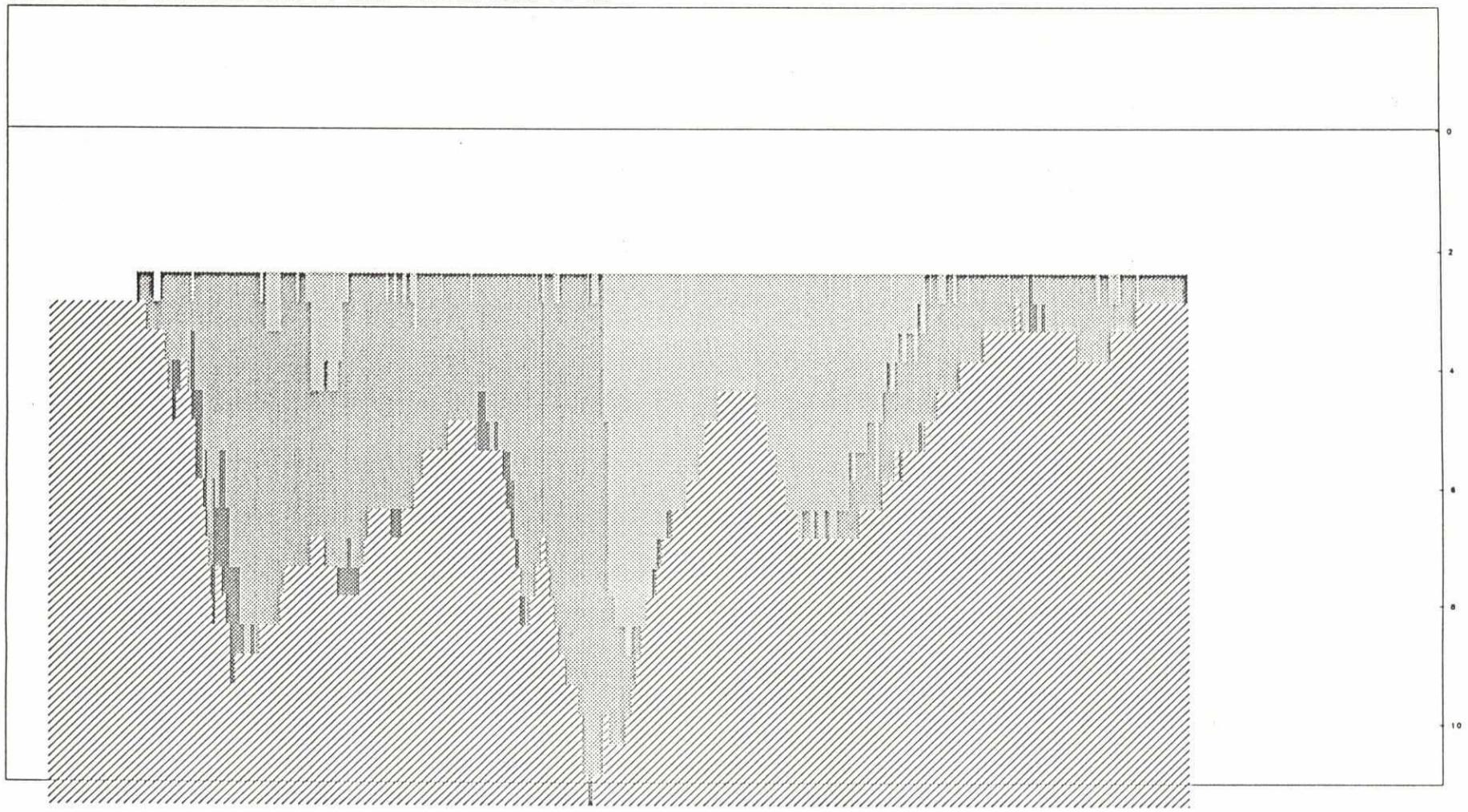
Line	:	
Survey id.	:	(null)
Coordinate system	:	UTM Zone 33
Start position	:	467877E 777498N
End position	:	DE DN
Executed	:	
Time interval	:	0 – H+T++

PLOT ID. :

Project	:	River Survey Project FAP 24
File	:	H+T+
Drawn	:	Mon Oct 11 11:30:38 1993
Type	:	P
Rev.	:	
Init.	:	

App. No. 13-2

DEPTH PROFILE – HORIZONTAL SCALE 1 : 15000 VERTICAL SCALE 1 : 100

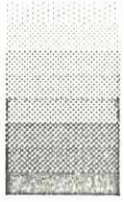


EQUIPMENT :

U/T SENSOR

Positioning system	:	GPS
Echosounder	:	None
Air profiler	:	200 Khz
Cetdel profiler	:	no. 1
Adcp profiler	:	1200 Khz

DECIBEL PLOT (dB) :



<=	45
45 –	55
55 –	65
65 –	75
75 –	85
85 –	95
95 –	105
>=	105

MEASURING ID. :

Line	:	
Survey id.	:	(null)
Coordinate system	:	UTM Zone 33
Start position	:	470802E 777506N
End position	:	0E 0N
Executed	:	
Time interval	:	0 – H+T++

PLOT ID. :

Project	:	River Survey Project FAP 24
File	:	H+T+
Drawn	:	Mon Oct 11 11:35:27 1993
Type	:	P
Rev.	:	
Init.	:	

App. No. 13-3

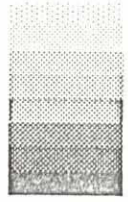
DEPTH PROFILE – HORIZONTAL SCALE 1 : 15000 VERTICAL SCALE 1 : 100

EQUIPMENT :

U/T SENSOR

Positioning system	:	DPS
Echosounder	:	None
Air profiler	:	200 Khz
Cetdel profiler	:	no. 1
Adcp profiler	:	1200 Khz

DECIBEL PLOT (dB) :



<=	45
45 – 55	
55 – 65	
65 – 75	
75 – 85	
85 – 95	
95 – 105	
>=	105

MEASURING ID. :

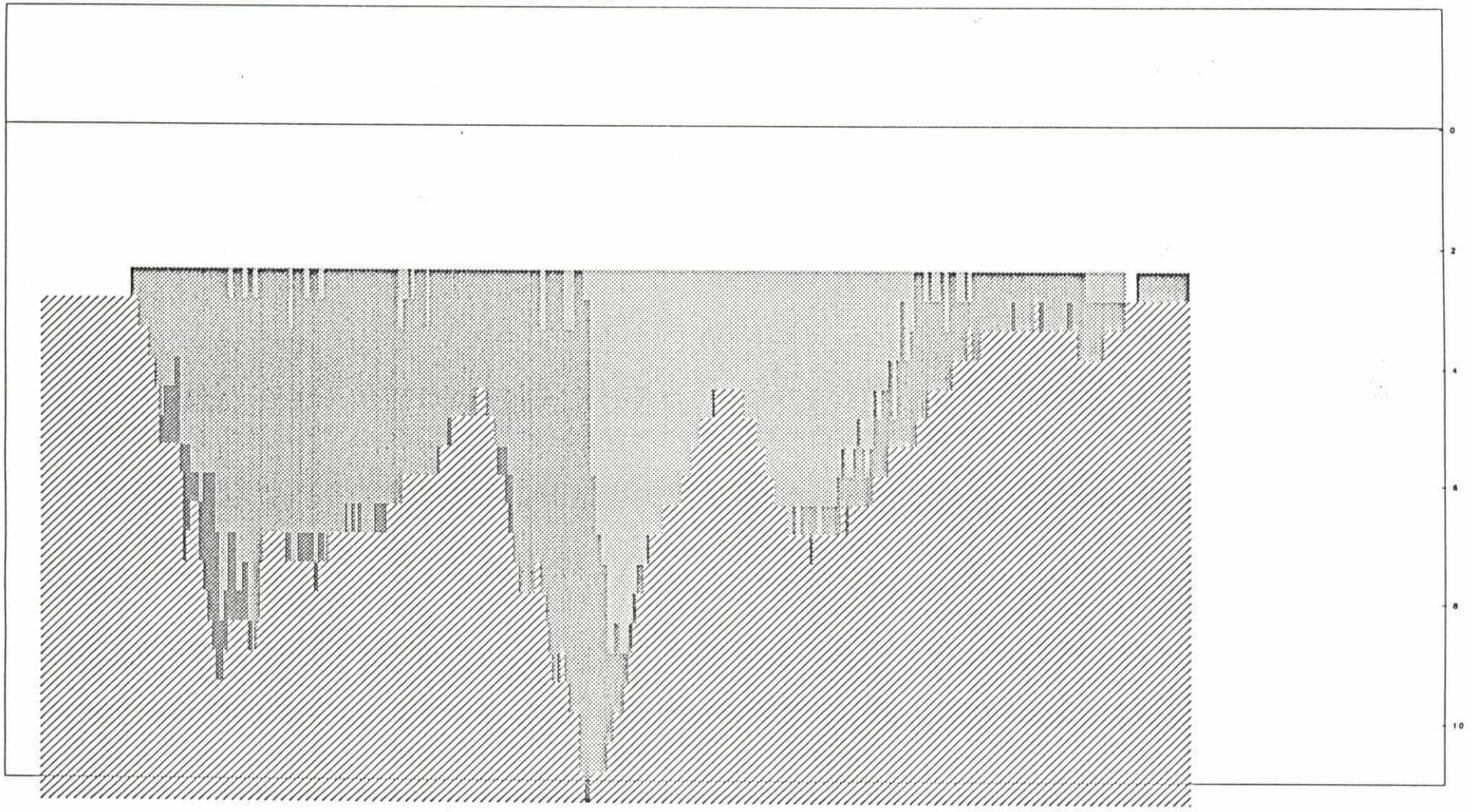
Line	:	
Survey id.	:	(null)
Coordinate system	:	UTM Zone 33
Start position	:	487877E 7774 80N
End position	:	DE DN
Executed	:	
Time interval	:	0 – H:T:*

PLOT ID. :

Project	:	River Survey Project FAP 24
File	:	H:T:
Drawn	:	Mon Oct 11 11:38:43 1993
Type	:	P
Rev.	:	
Init.	:	

App. No. 13-4

DEPTH PROFILE – HORIZONTAL SCALE 1 : 15000 VERTICAL SCALE 1 : 100



EQUIPMENT :

U/T SENSOR

Positioning system	:	GPS
Echosounder	:	None
Air profiler	:	200 Khz
Caidel profiler	:	no. 1
Adcp profiler	:	1200 Khz

DECIBEL PLOT (dB) :

<=	45
45 – 55	
55 – 65	
65 – 75	
75 – 85	
85 – 95	
95 – 105	
>=	105

MEASURING ID. :

Line	:	
Survey id.	:	(null)
Coordinate system	:	UTM Zone 33
Start position	:	470578E 777504N
End position	:	0E 0N
Executed	:	
Time interval	:	0 – H+T++

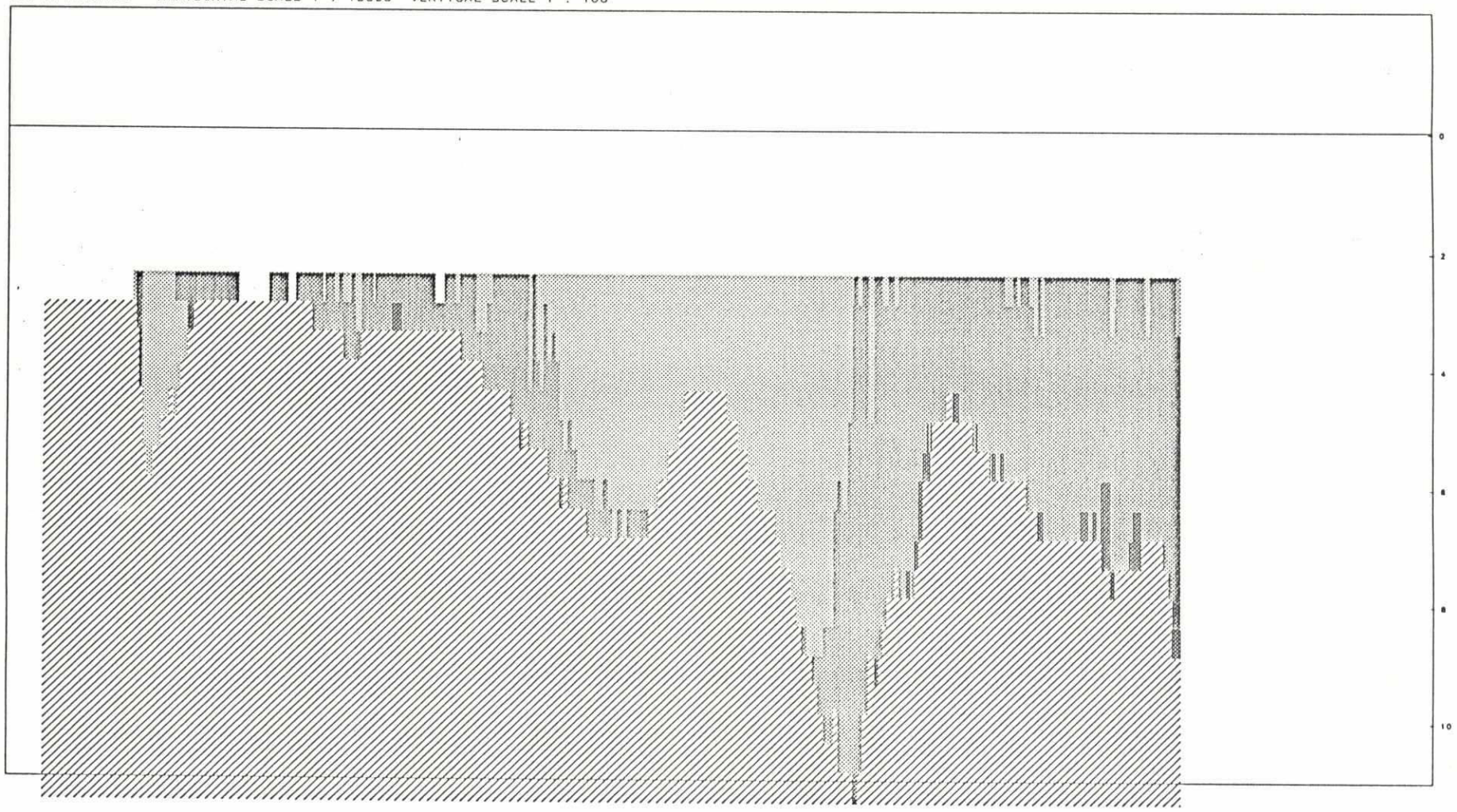
PLOT ID. :

Project	:	River Survey Project FAP 24
File	:	H+T+
Drawn	:	Mon Oct 11 11:43:25 1993
Type	:	P
Rev.	:	
Init.	:	

App. No. 13-5

72

DEPTH PROFILE – HORIZONTAL SCALE 1 : 15000 VERTICAL SCALE 1 : 100

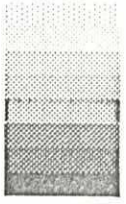


EQUIPMENT :

U/T SENSOR

Positioning system	:	GPS
Echosounder	:	None
Air profiler	:	200 Khz
Caldel profiler	:	no. 1
Adcp profiler	:	1200 Khz

DECIBEL PLOT (dB) :



<=	45
45 – 55	
55 – 65	
65 – 75	
75 – 85	
85 – 95	
95 – 105	
>=	105

MEASURING ID. :

Line	:	
Survey id.	:	(null)
Coordinate system	:	UTM Zone 33
Start position	:	467688E 777484N
End position	:	0E 0N
Executed	:	
Time interval	:	0 – H:T:+

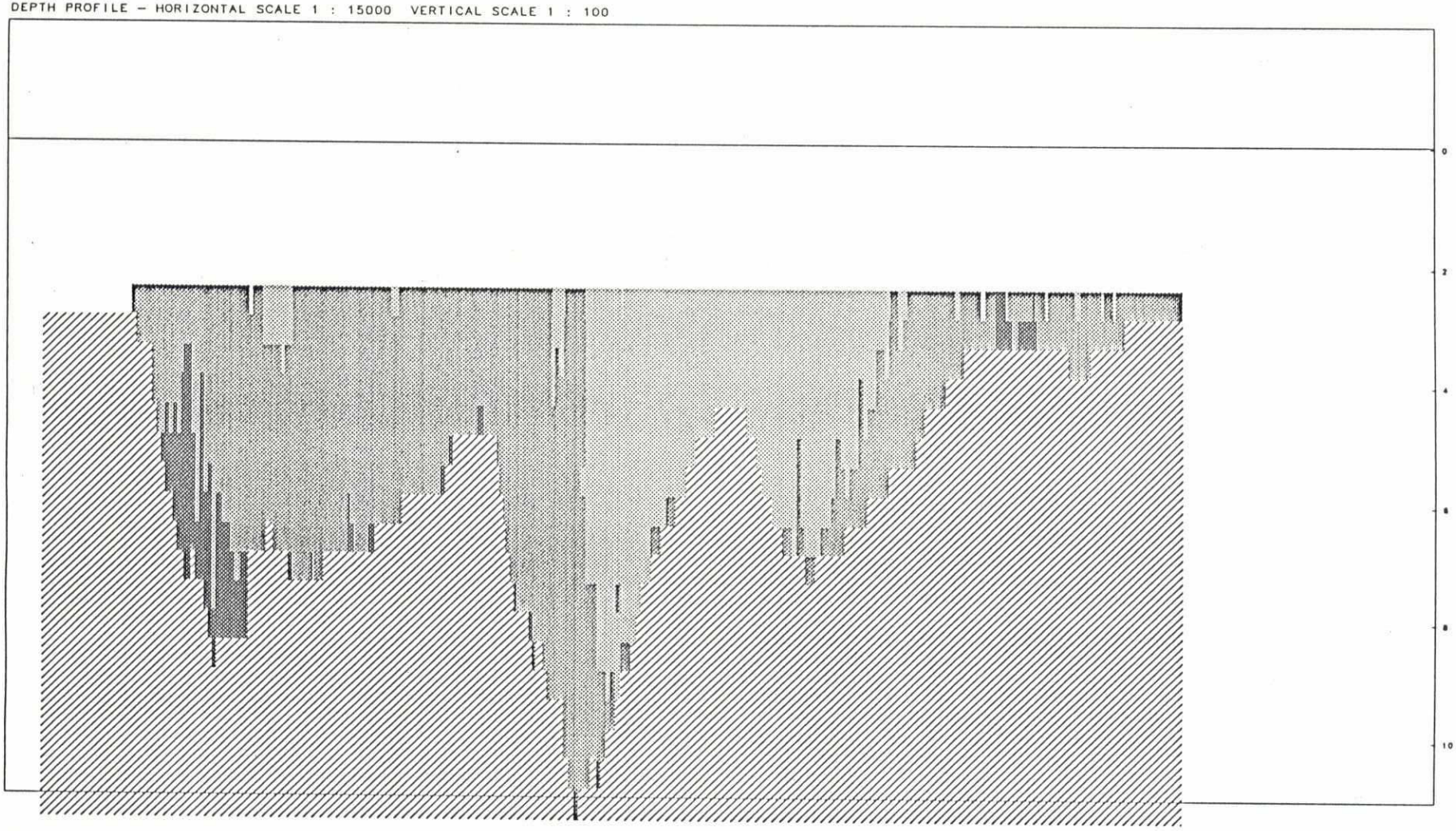
PLOT ID. :

Project	:	River Survey Project FAP 24
File	:	H:T:+
Drawn	:	Mon Oct 11 11:47:01 1993
Type	:	P
Rev.	:	
Init.	:	

App. No. 13-6

262

DEPTH PROFILE – HORIZONTAL SCALE 1 : 15000 VERTICAL SCALE 1 : 100



EQUIPMENT :

U/T SENSOR

Positioning system	:	DPS
Echosounder	:	None
Air profiler	:	200 Khz
Caldet profiler	:	no. 1
Adcp profiler	:	1200 Khz

DECIBEL PLOT (dB) :

<=	45
45 –	55
55 –	65
65 –	75
75 –	85
85 –	95
95 –	105
>=	105

MEASURING ID. :

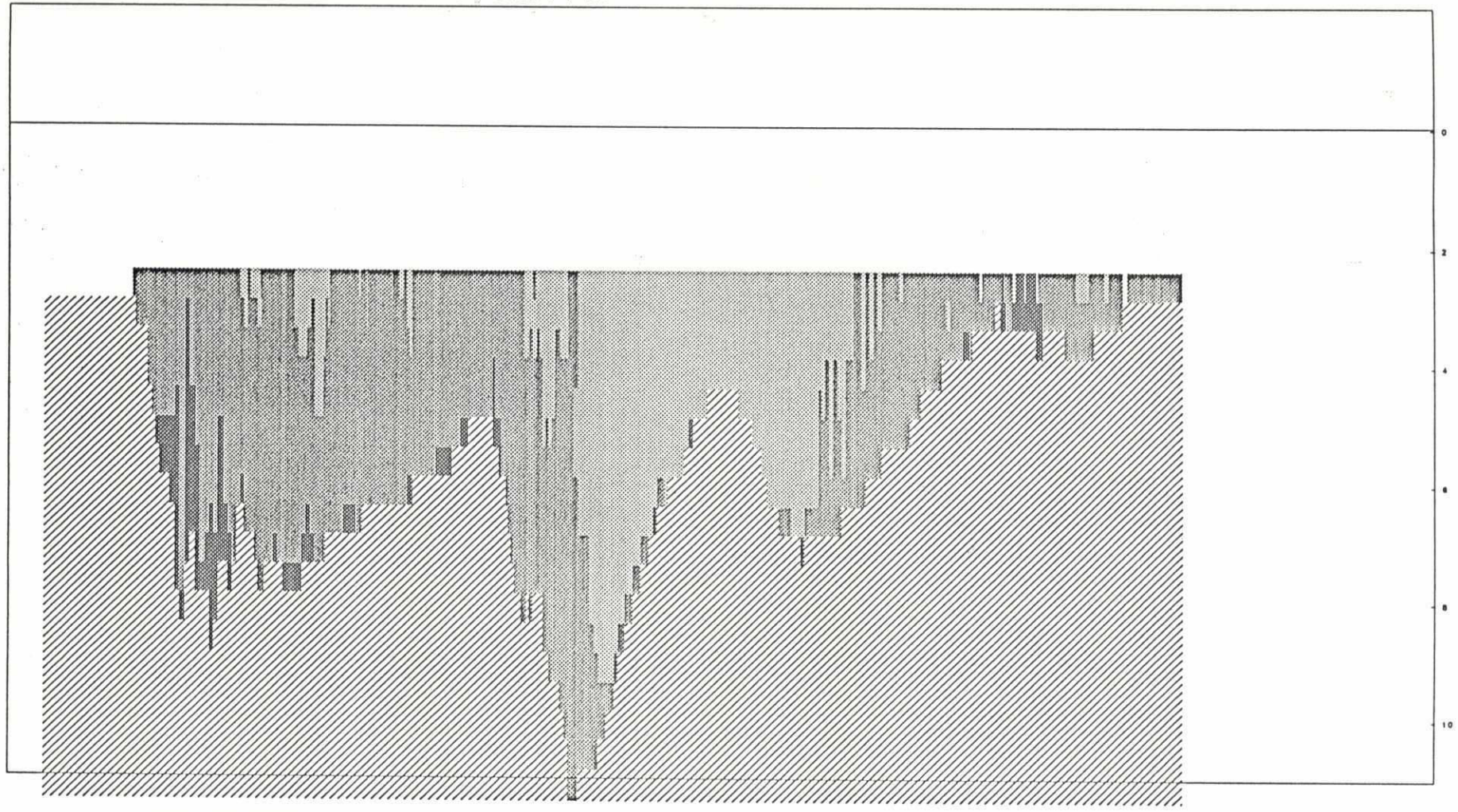
Line	:	
Survey id.	:	(null)
Coordinate system	:	UTM Zone 33
Start position	:	470574E 7774877N
End position	:	0E 0N
Executed	:	
Time interval	:	0 – H+T++

PLOT ID. :

Project	:	River Survey Project FAP 24
File	:	H+T+
Drawn	:	Mon Oct 11 11:57:28 1993
Type	:	P
Rev.	:	
Init.	:	

App. No. 13-7

DEPTH PROFILE – HORIZONTAL SCALE 1 : 15000 VERTICAL SCALE 1 : 100



EQUIPMENT :

U/T SENSOR

Positioning system	:	GPS
Echosounder	:	None
Air profiler	:	200 Khz
Catdet profiler	:	no. 1
Adcp profiler	:	1200 Khz

DECIBEL PLOT (dB) :

<=	45
45 –	55
55 –	65
65 –	75
75 –	85
85 –	95
95 –	105
>=	105

MEASURING ID. :

Line	:	
Survey id.	:	(null)
Coordinate system	:	UTM Zone 33
Start position	:	470365E 777509N
End position	:	0E 0N
Executed	:	
Time interval	:	0 – H+T++

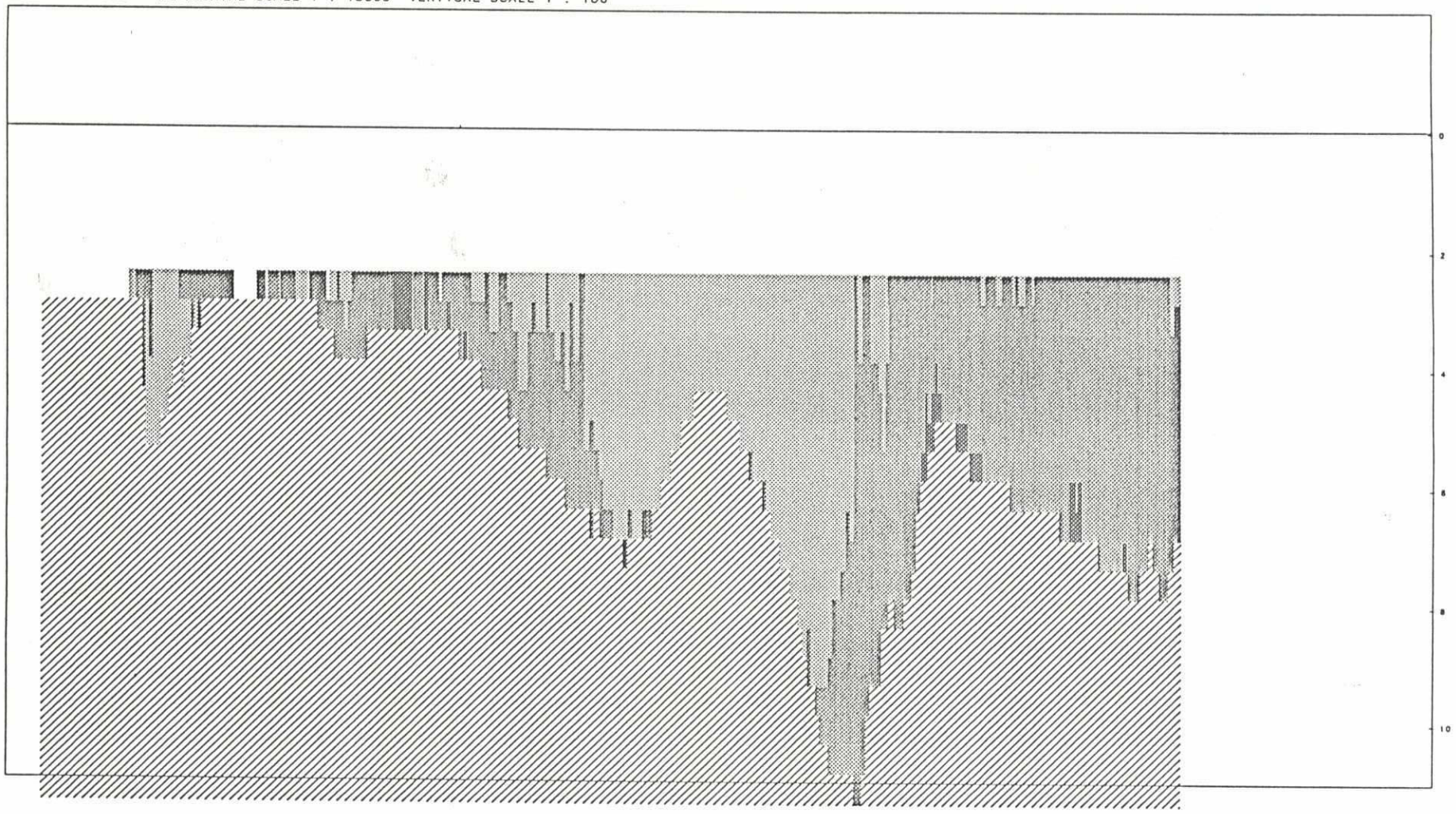
PLOT ID. :

Project	:	River Survey Project FAP 24
File	:	H+T+
Drawn	:	Mon Oct 11 12:07:48 1993
Type	:	P
Rev.	:	
Init.	:	

App. No. 13-8

362

DEPTH PROFILE – HORIZONTAL SCALE 1 : 15000 VERTICAL SCALE 1 : 100



EQUIPMENT :

U/F SENSOR

Positioning system	:	DPS
Echosounder	:	None
Air profiler	:	200 Khz
Caldel profiler	:	no. 1
Adcp profiler	:	1200 Khz

DECIBEL PLOT (dB) :

<=	45
45 –	55
55 –	65
65 –	75
75 –	85
85 –	95
95 –	105
>=	105

MEASURING ID. :

Line	:	
Survey id.	:	(null)
Coordinate system	:	UTM Zone 33
Start position	:	487883E 777498N
End position	:	DE DN
Executed	:	
Time interval	:	D – H:T::

PLOT ID. :

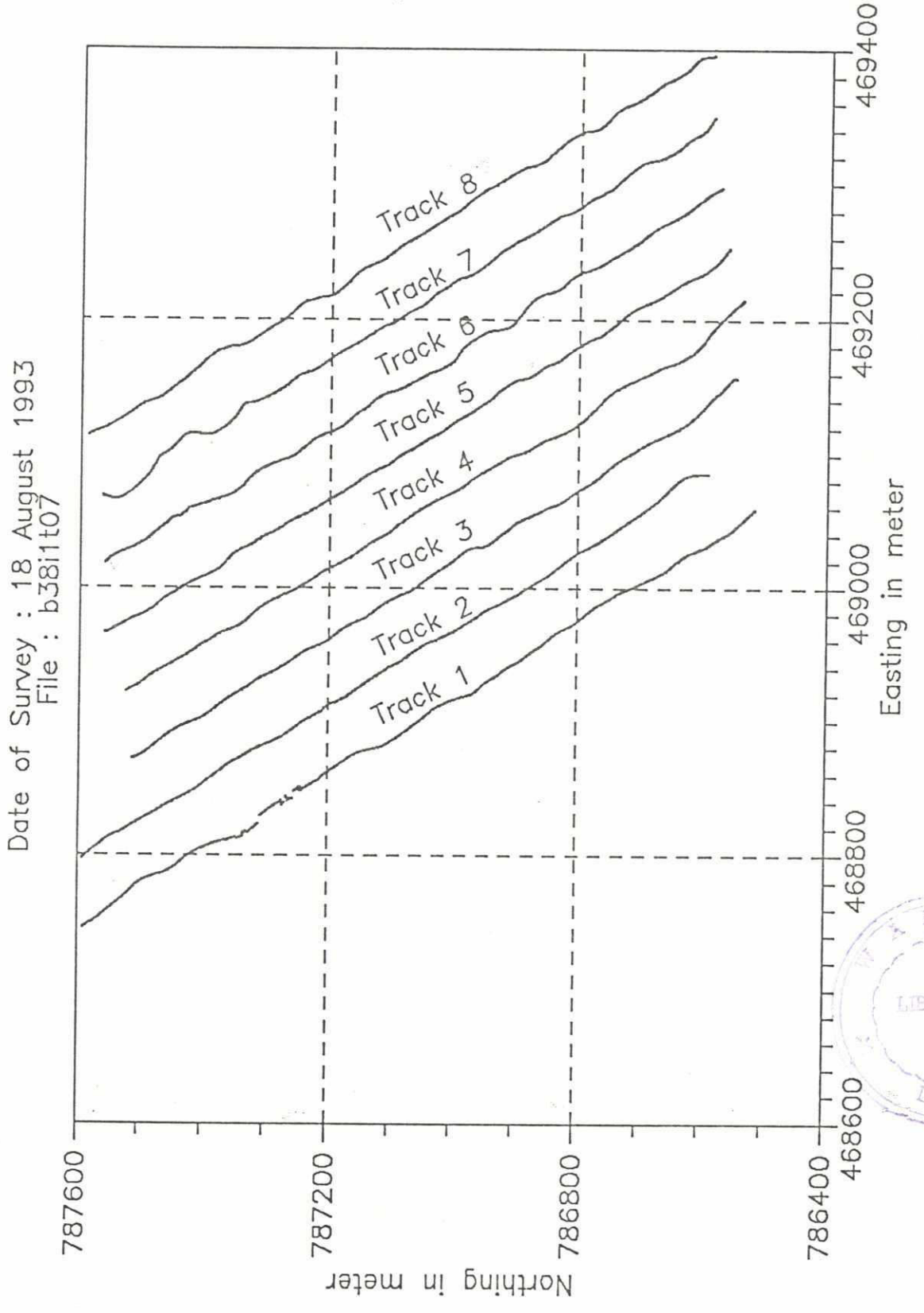
Project	:	River Survey Project FAP 24
File	:	H:T:
Drawn	:	Mon Oct 11 12:11:38 1993
Type	:	P
Rev.	:	
Init.	:	

App. No. 13-9

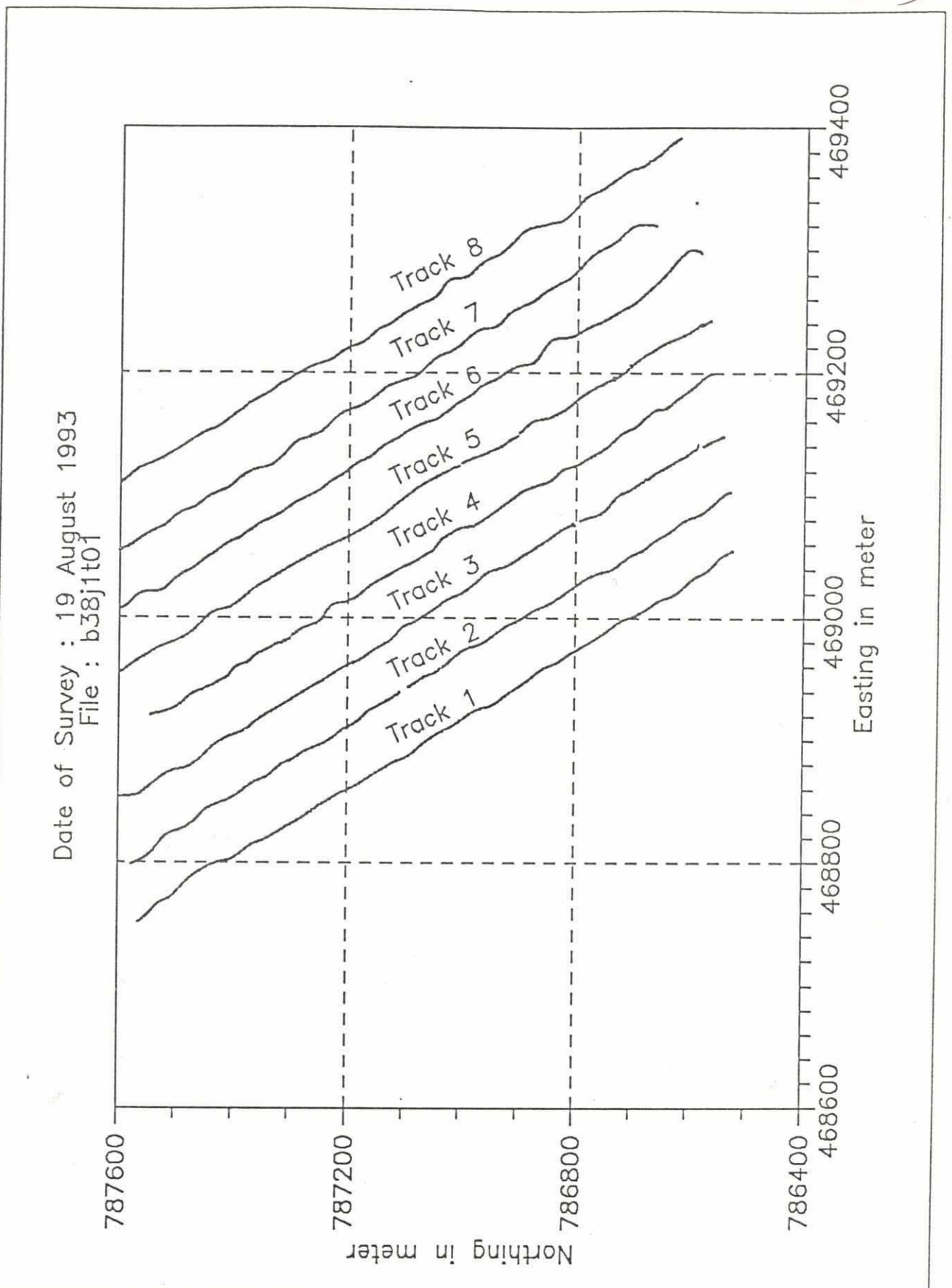
26

Appendix 14

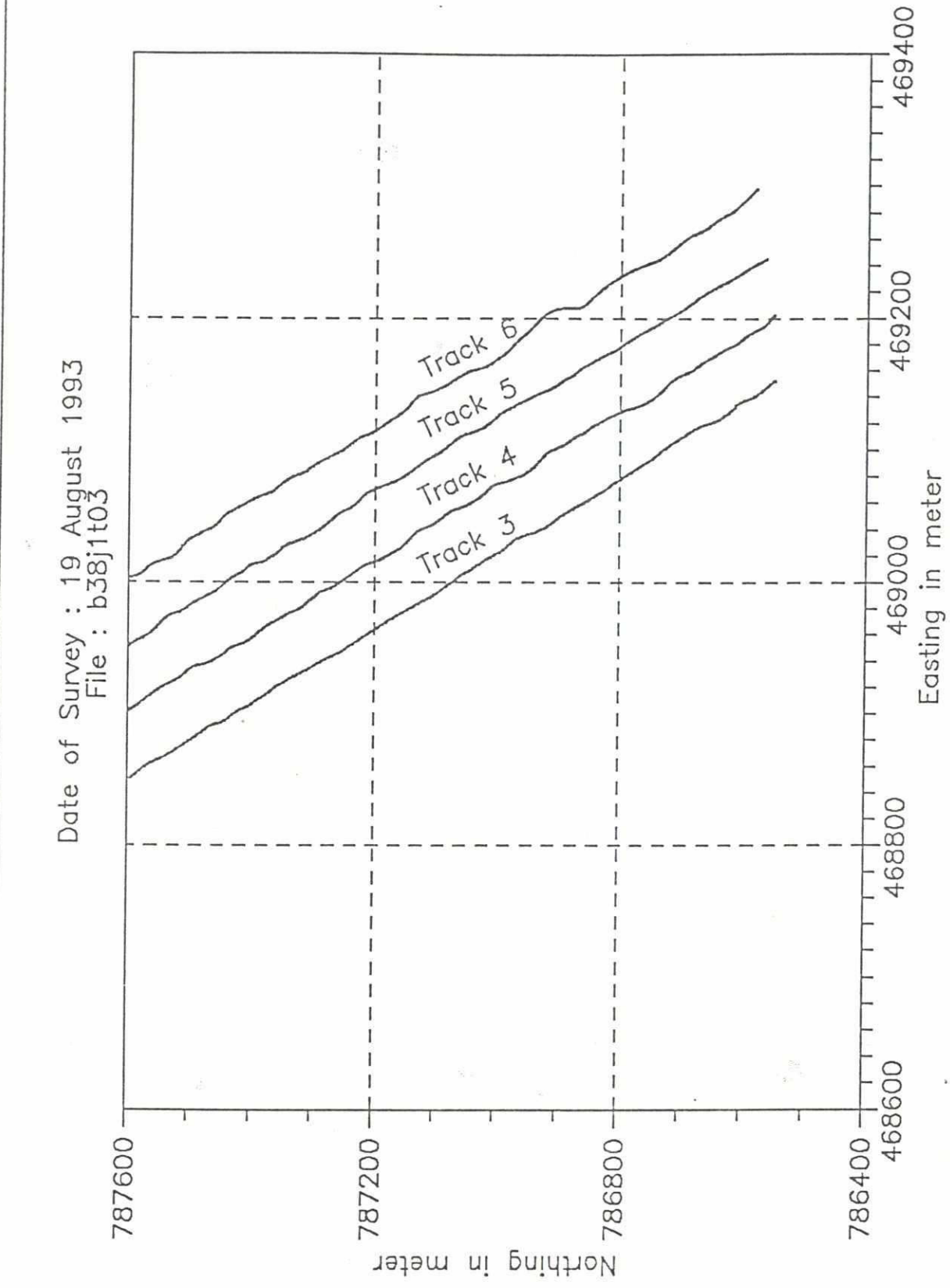
Sand-dune tracking by echo sounding



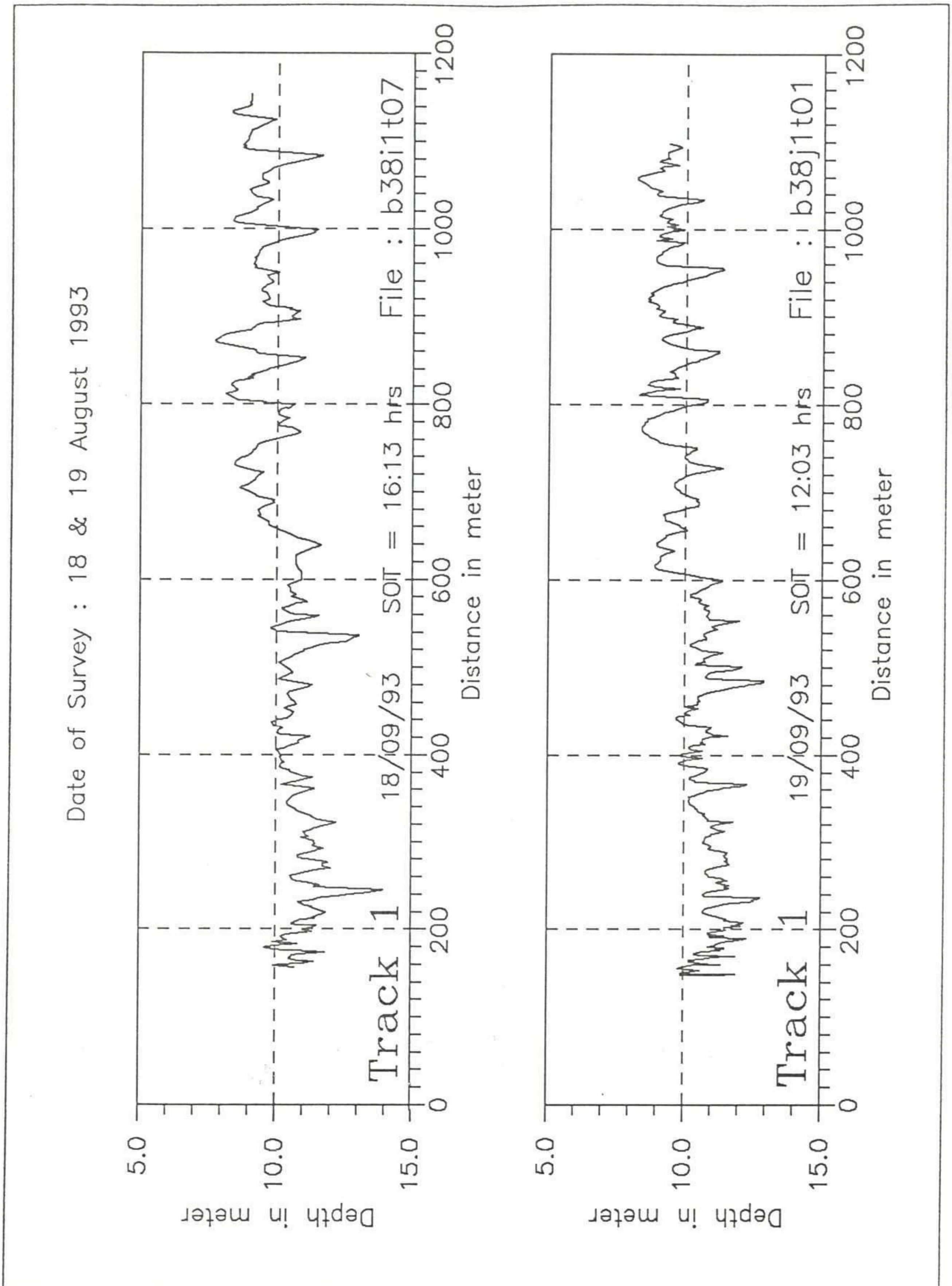
FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sand-Dune Tracking	App. No. 14-1
Scale:	Init:		



FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osmy/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sand Dune Tracking	App. No. 14-2
Scale:	Init:		



FAP 24 DELFT-DHI RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Chanx/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sand Wave Tracking	App. No. 14-3
Scale:	Init:		

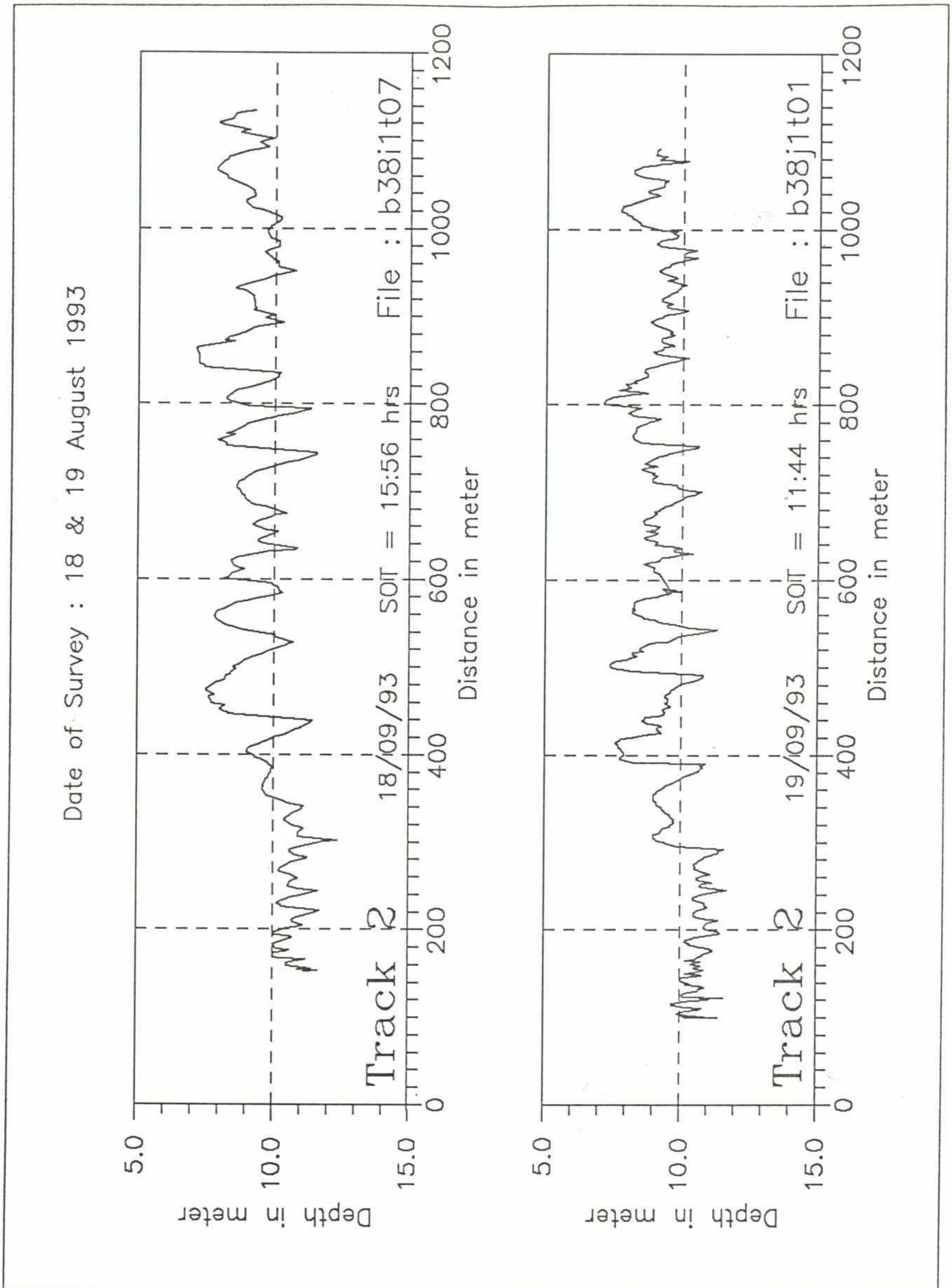


FAP 24 RIVER SURVEY PROJECT
Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland
DELFT-DHI

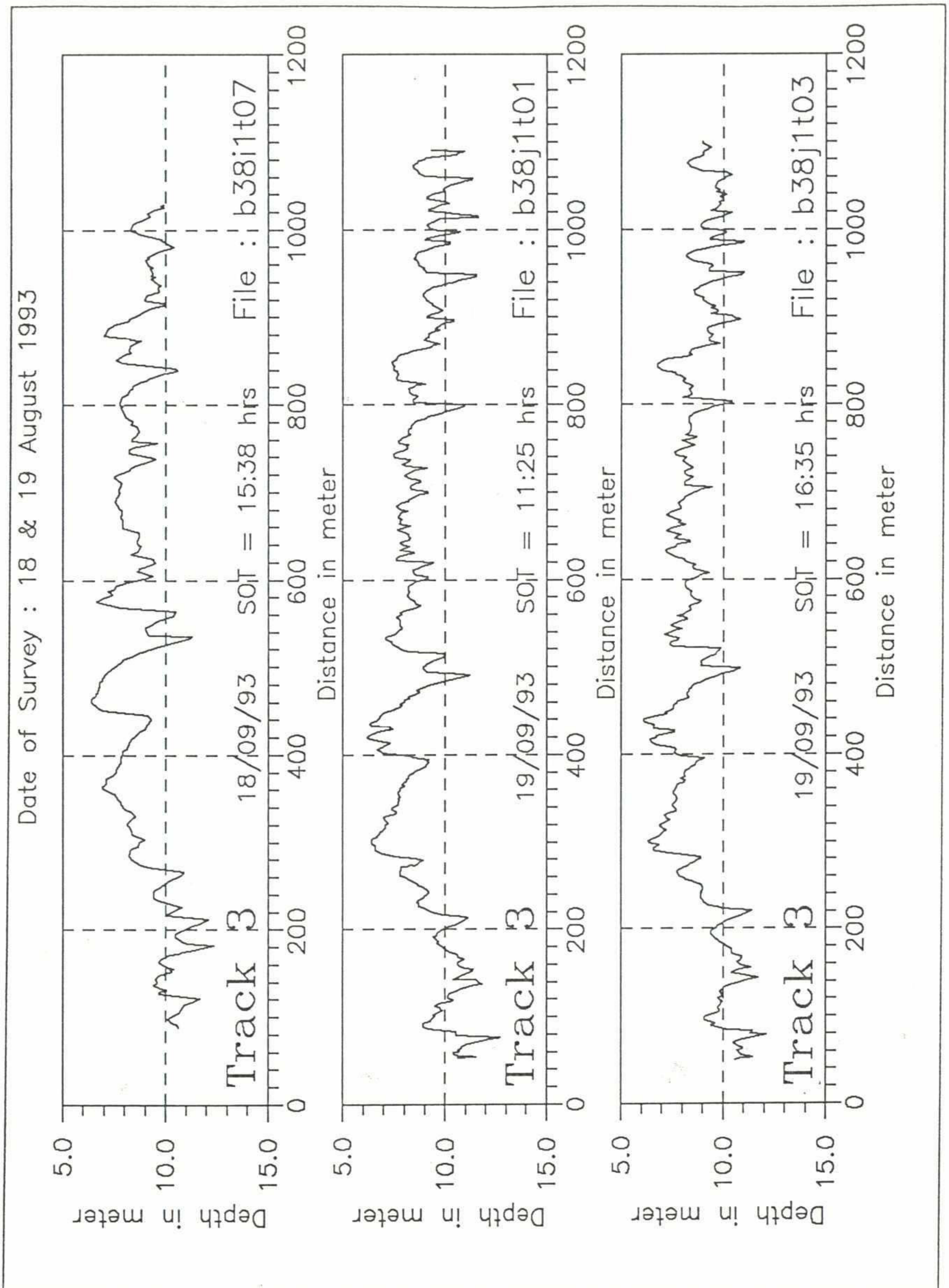
Test Gauging Report

Jamuna River at Bahadurabad (Left Channel)

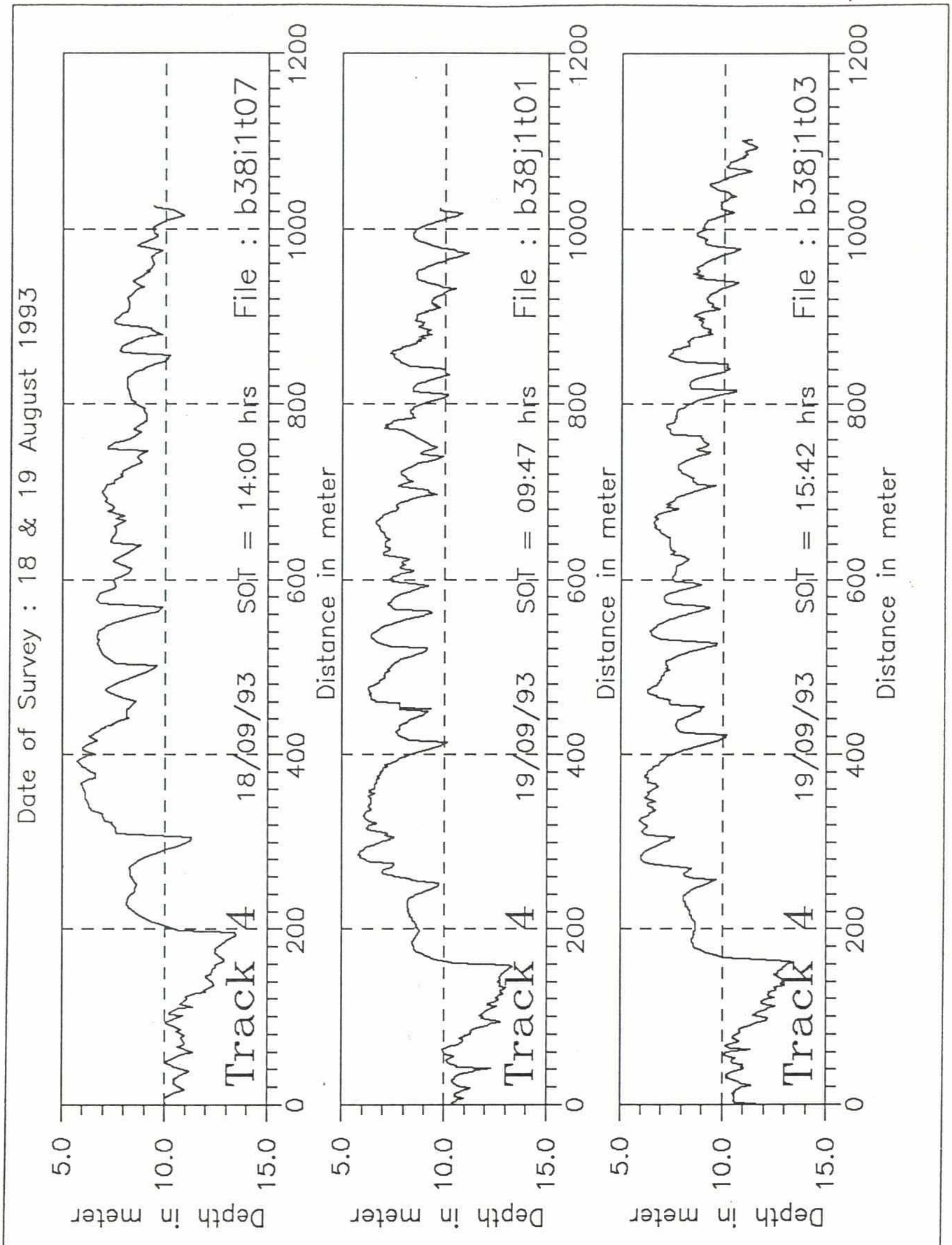
File:	Date:	Sand Dune Tracking	App. No. 14-4
Scale:	Init:		



FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sand Dune Tracking	App. No. 14-5
Scale:	Init:		

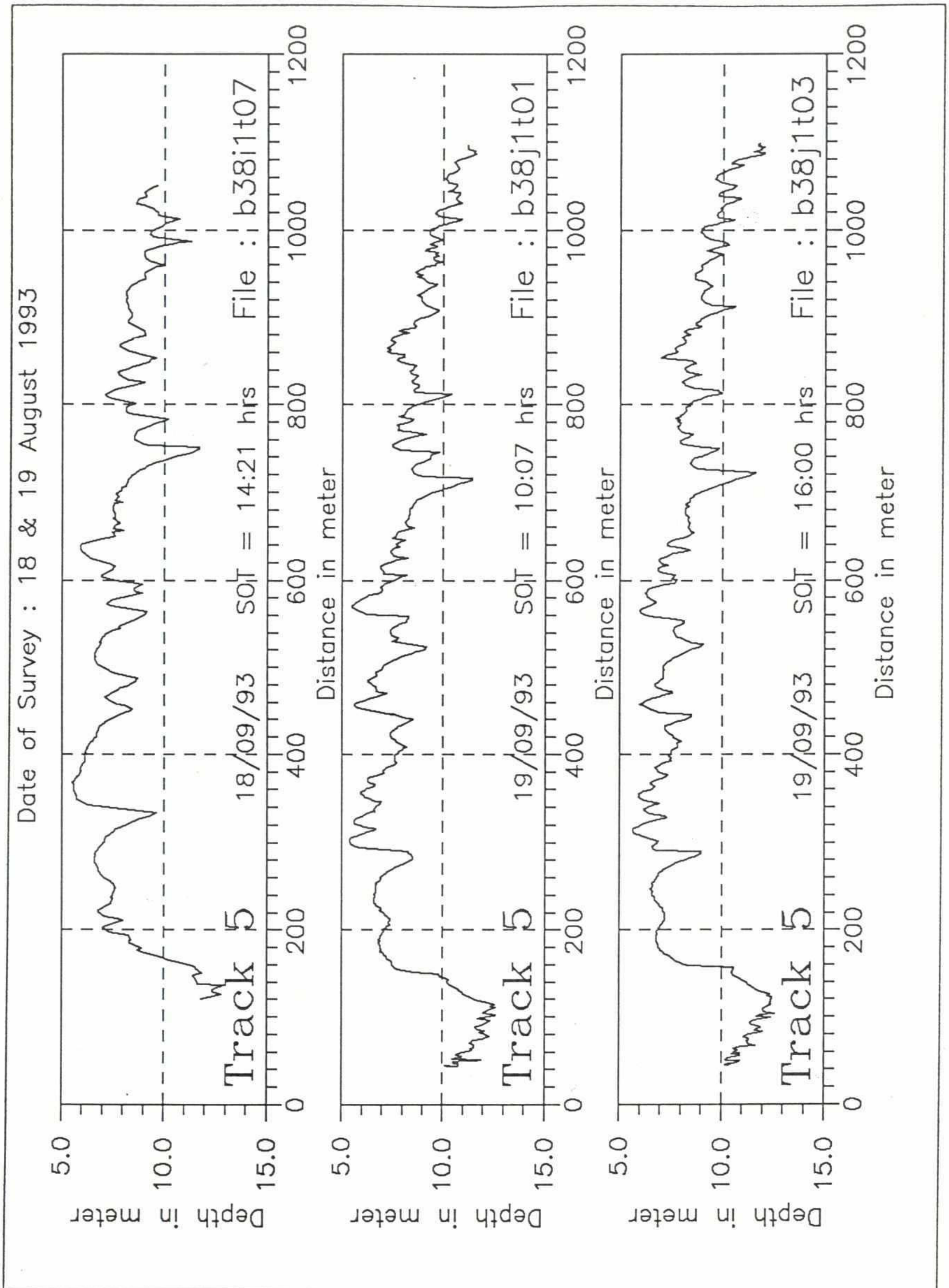


FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sand Dune Tracking	App. No. 14-6
Scale:	Init:		



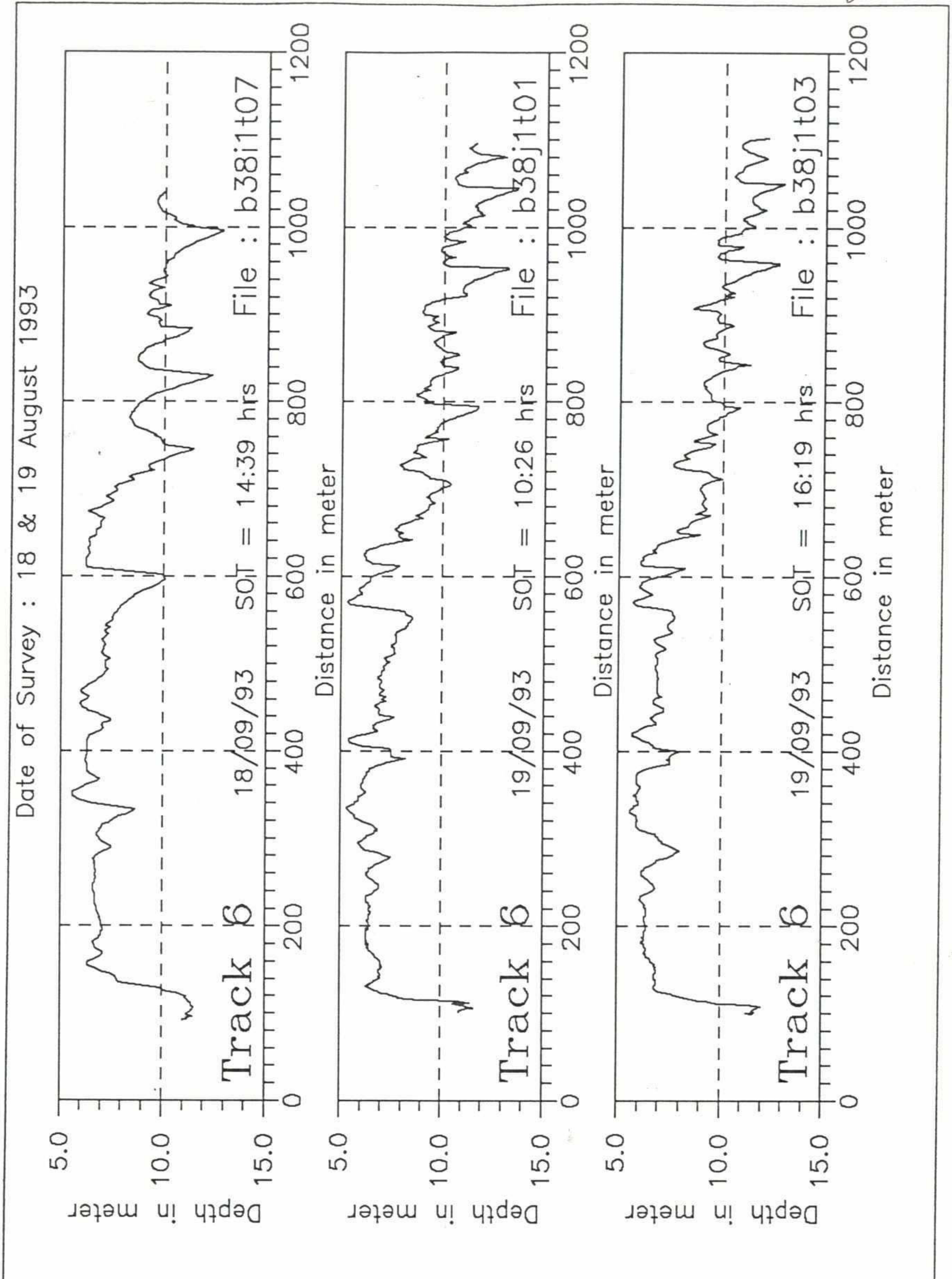
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sand Dune Tracking	App. No. 14-7
Scale:	Init:		

382

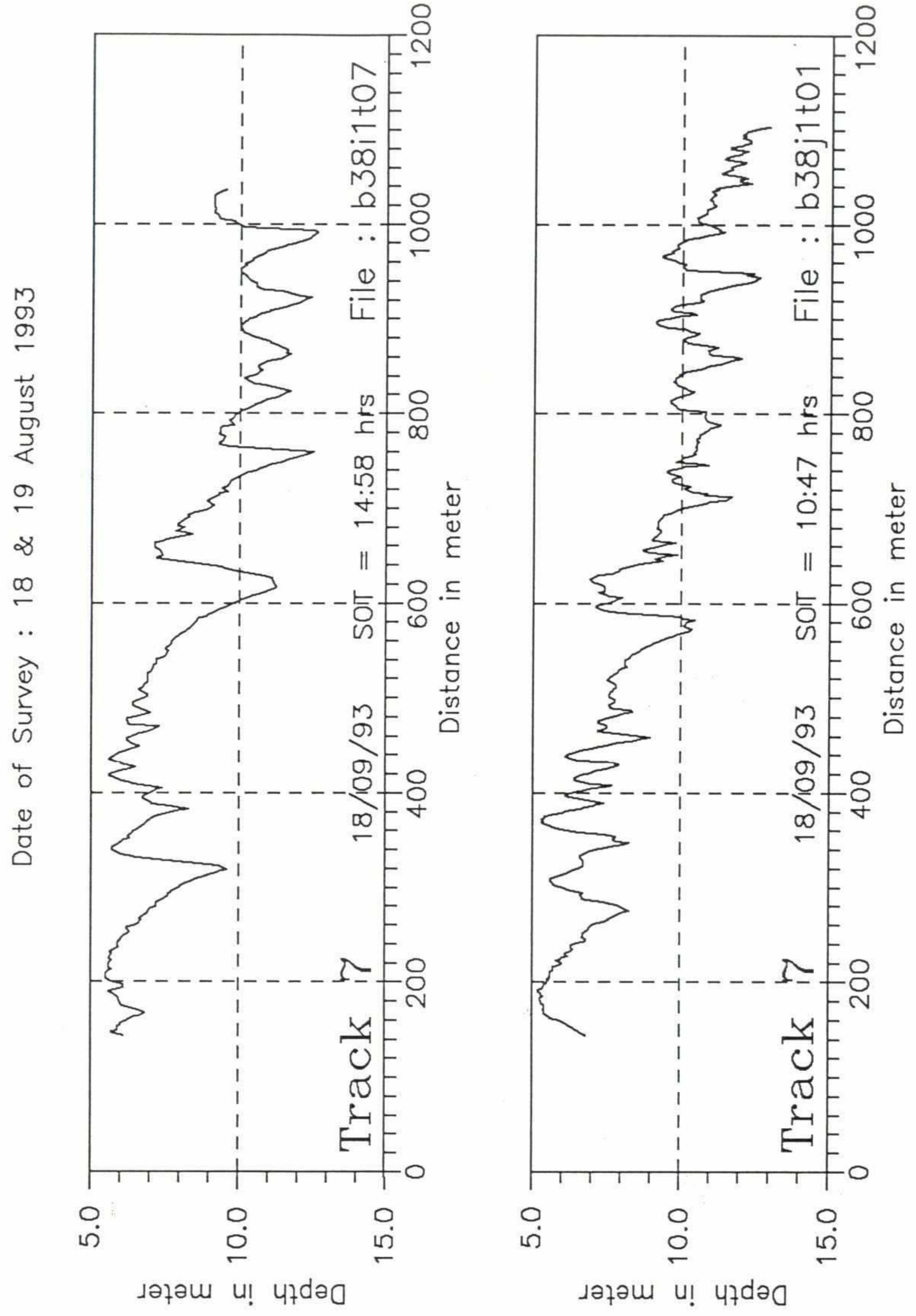


FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sand Dune Tracking	App. No. 14-8
Scale:	Init:		

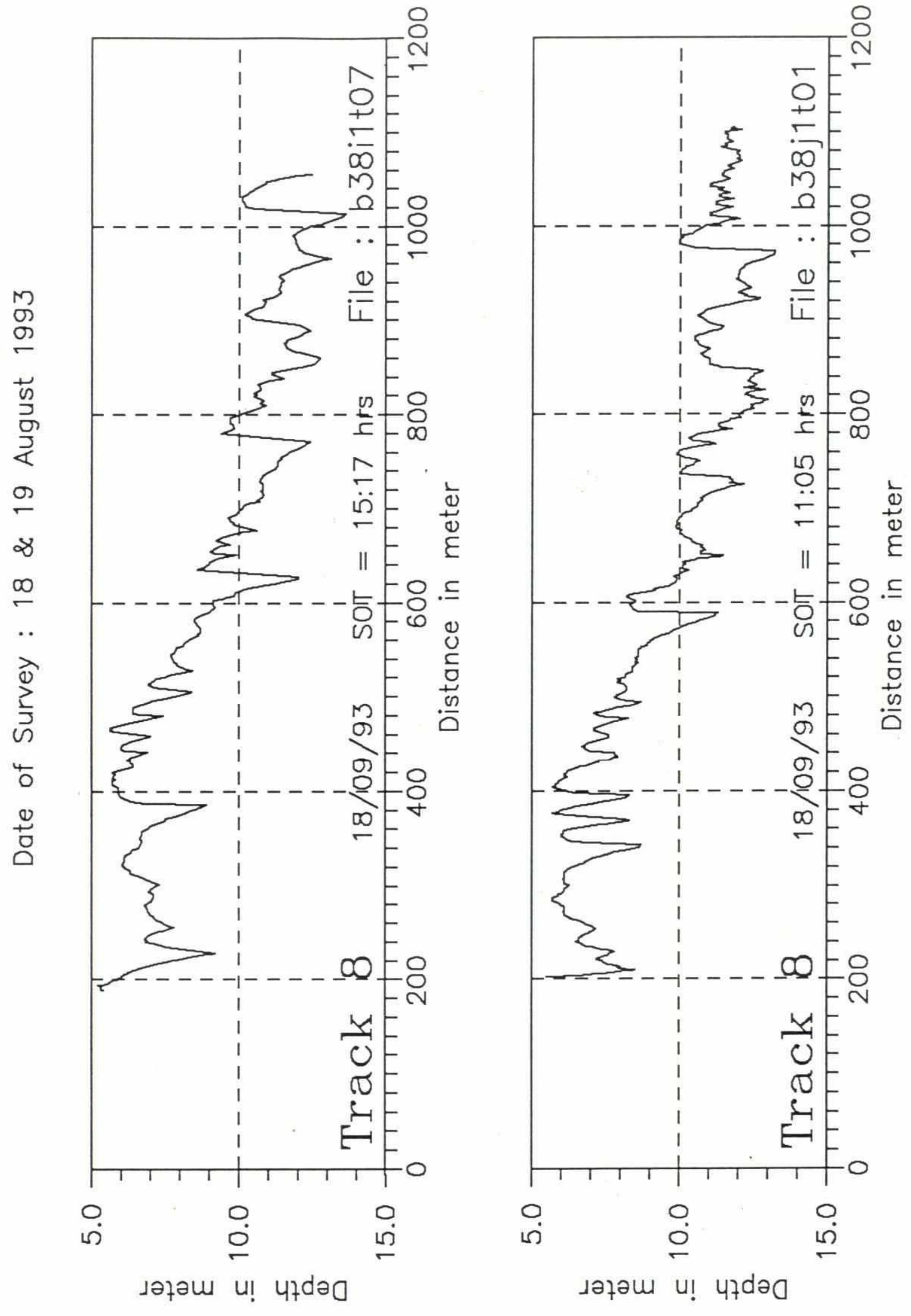
786



FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sand Dune Tracking	App. No. 14-9
Scale:	Init:		



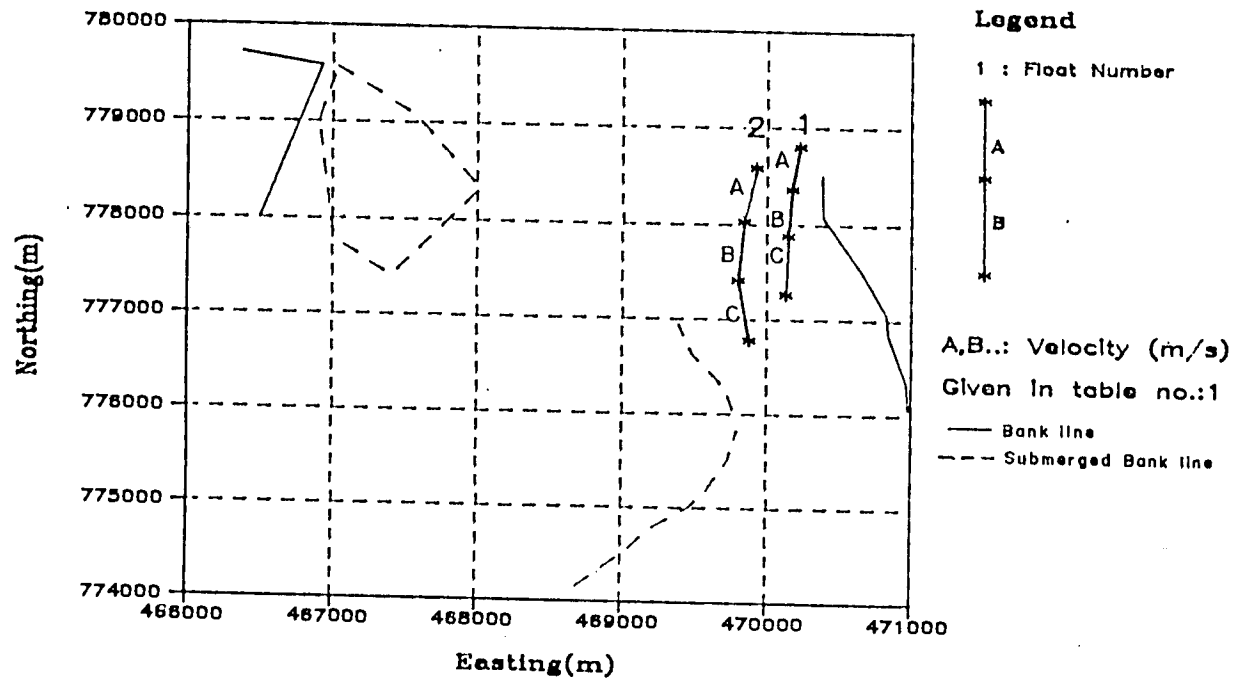
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sand Dune Tracking	App. No. 14-10
Scale:	Init:		



FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Test Gauging Report Jamuna River at Bahadurabad (Left Channel)	
File:	Date:	Sand Dune Tracking	App. No. 14-11
Scale:	Init:		

Appendix 15

Float tracking

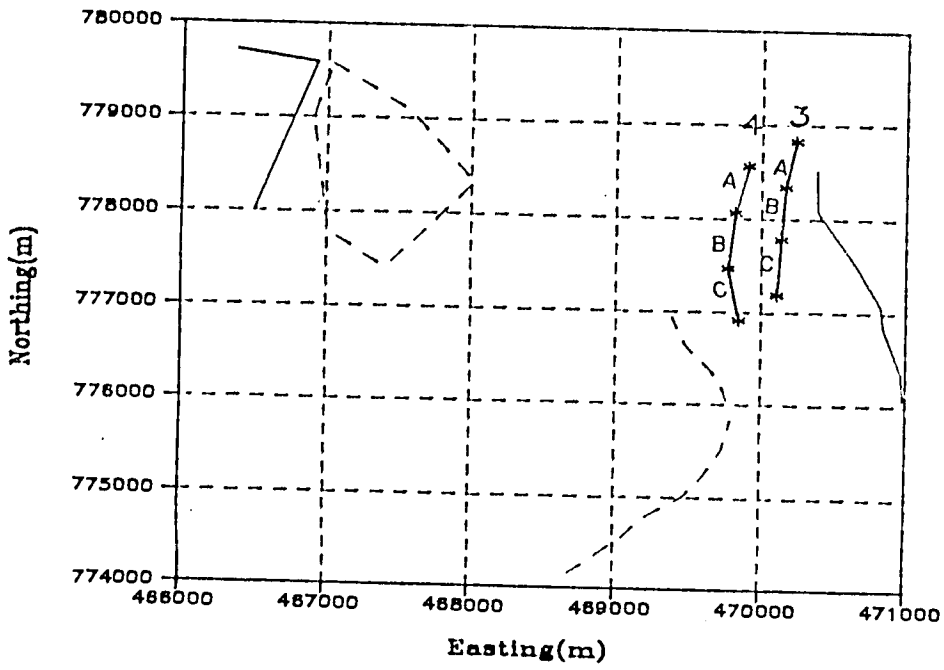


Legend

1 : Float Number

A,B..: Velocity (m/s)
Given in table no.:1

—— Bank line
– – – Submerged Bank line



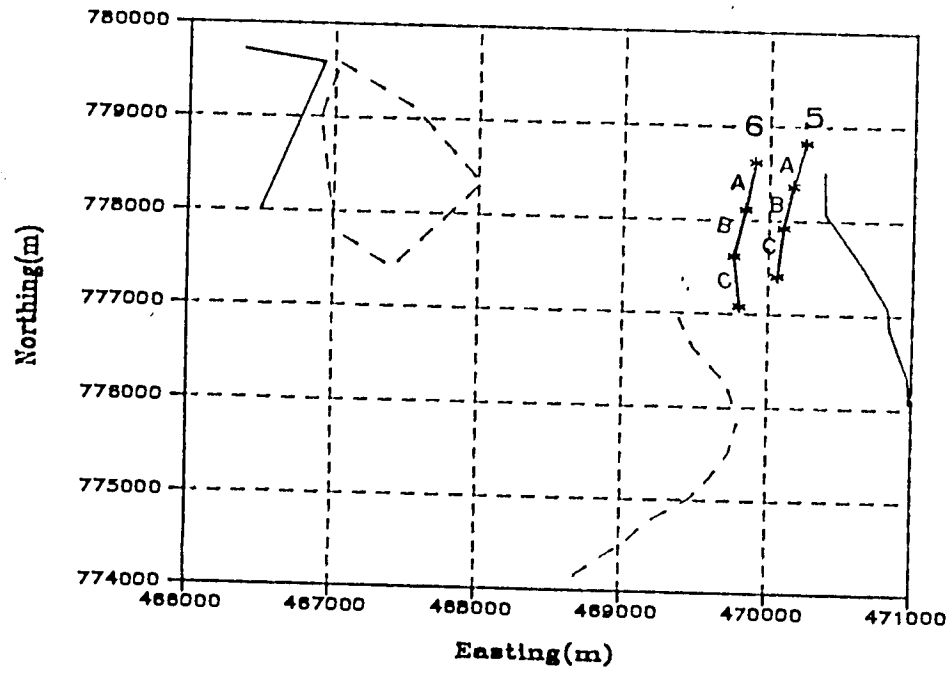


Table No. : 1

Float No→	1	2	3	4	5	6
Velocity A→ Angle→(deg,N)	2.51 187	2.95 189	2.61 189	2.74 190	2.57 191	2.72 187
Velocity B→ Angle→(deg,N)	2.52 183	3.03 184	2.77 183	2.86 185	2.64 188	2.96 189
Velocity C→ Angle→(deg,N)	2.99 181	2.97 173	3.12 182	2.86 172	2.93 174	2.84 175

Float Depth: 1.00m
Survey Date: 17/08/93

FAP 24 DELFT-DHI

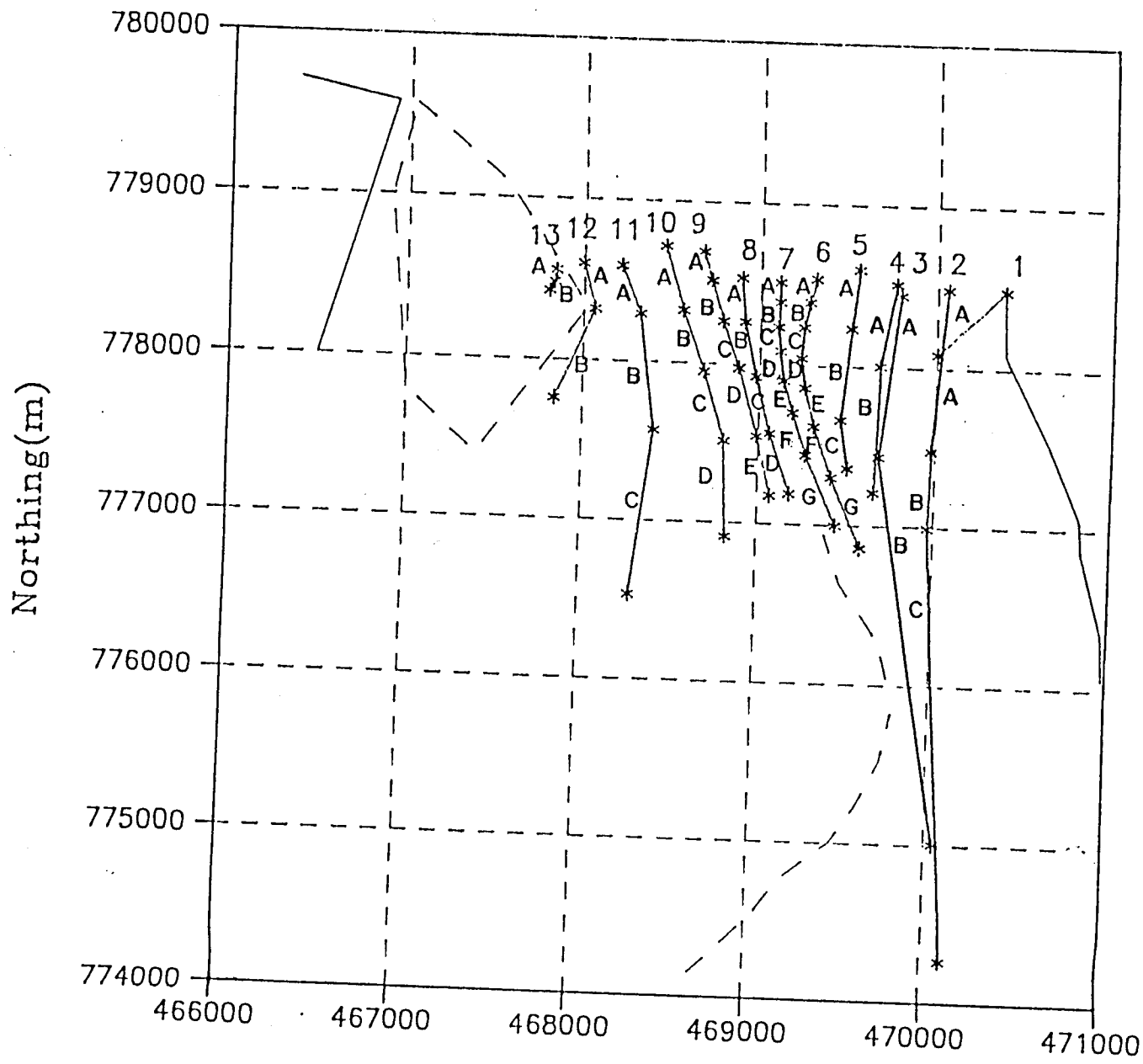
RIVER SURVEY PROJECT

Delft Hydraulics/Danish Hydraulic Institute
in association with Osiris/Approtech/Hydroland

Test Gauging Report

Jamuna River at Bahadurabad (Left Channel)

File:	Date:	Float Tracking	App. No 15-1
Scale:	Init:		



Legend :

1 : Float Number

A

B

A,B..: Velocity (m/s)

Given in table no.:1

—— Bank Line

- - - Submerged Bank Line

Table No. : 1

Float No→	1	2	3	4	5	6	7	8	9	10	11	12	13
Velocity A→ Angle→(deg,N)	2.55 224	2.85 184	2.73 186	2.56 189	1.37 186	1.06 192	0.74 179	0.91 175	0.56 164	1.05 165	1.18 160	0.93 167	0.17 188
Velocity B→ Angle→(deg,N)	out —	3.15 181	3.14 171	2.58 182	1.34 185	1.05 192	0.89 183	1.01 168	0.71 165	1.17 162	1.22 173	out	0.07 206
Velocity C→ Angle→(deg,N)		3.11 177	out —	out —	1.15 171	1.10 184	0.94 174	1.07 167	0.85 162	1.21 164	1.03 186		
Velocity D→ Angle→(deg,N)		out				1.11 173	0.92 173	1.11 162	1.03 165	1.30 178	out		
Velocity E→ Angle→(deg,N)						1.17 167	0.95 165	out	1.23 168	out			
Velocity F→ Angle→(deg,N)						1.37 162	1.08 163						
Velocity G→ Angle→(deg,N)						1.56 158	1.33 158						

Float Depth: 1.50m

Survey Date: 19/08/93

FAP 24 RIVER SURVEY PROJECT

DELFT-DHI

Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland

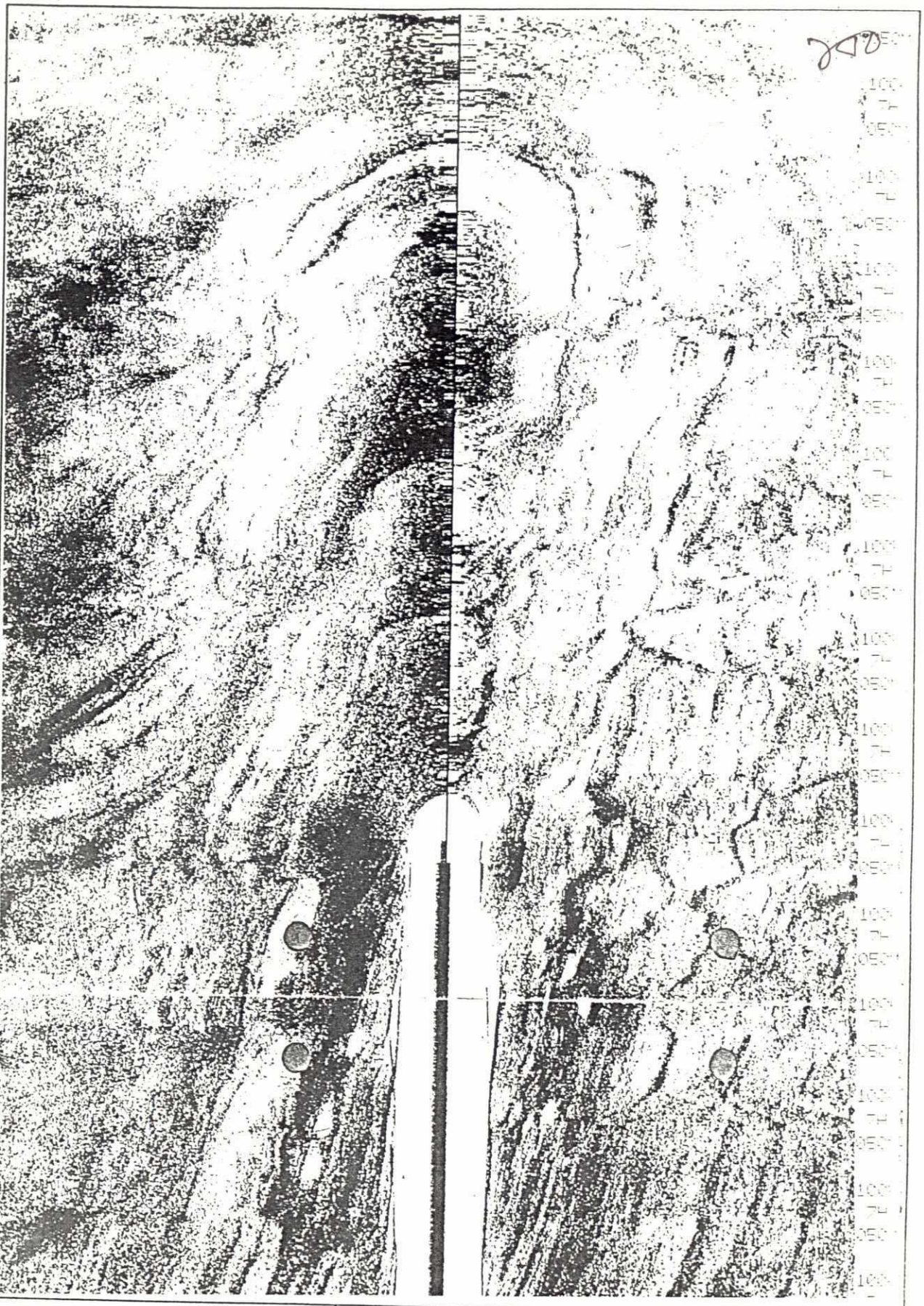
Test Gauging Report

Jamuna River at Bahadurabad (Left Channel)

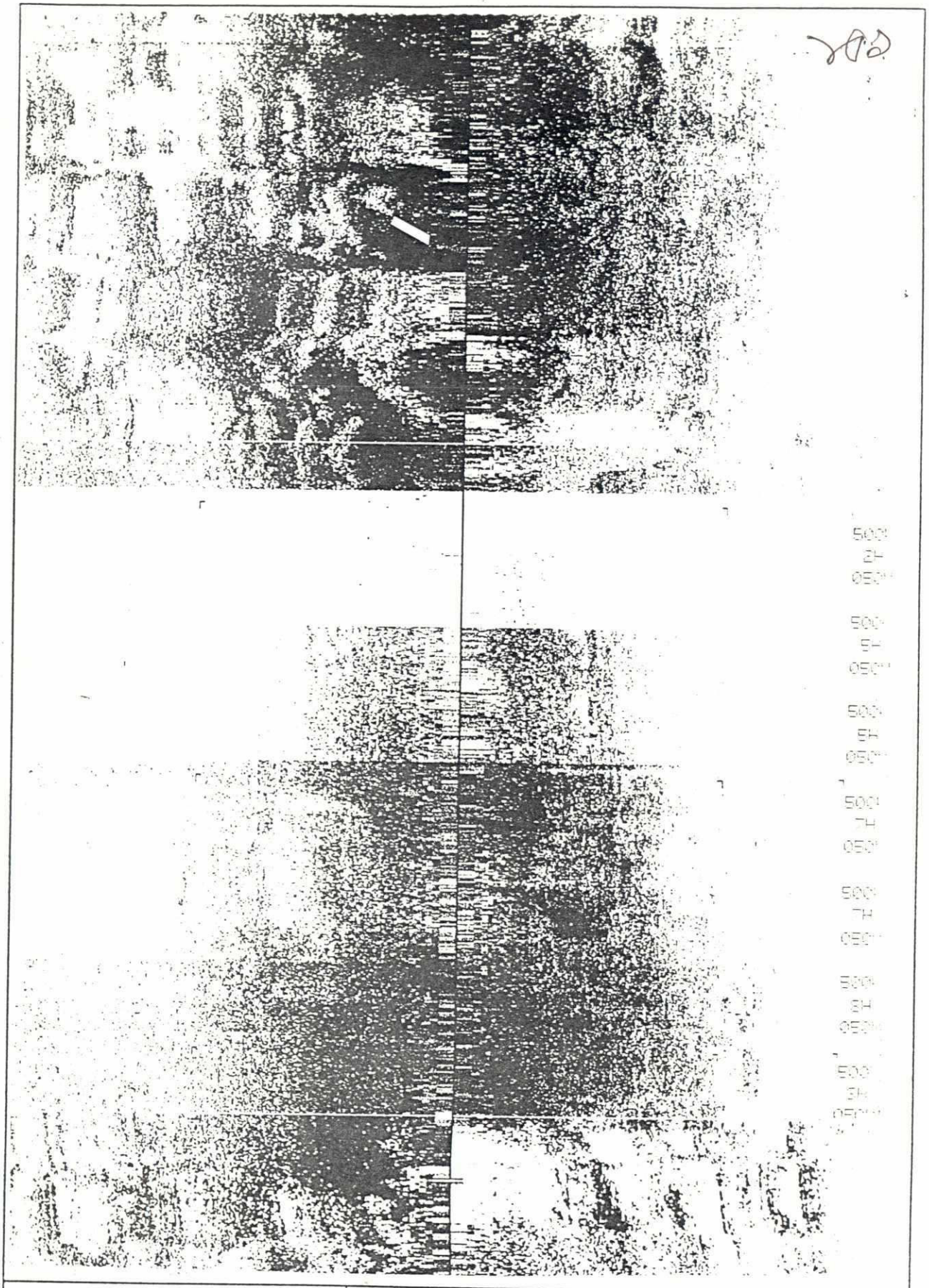
File:	Date:	Float Tracking	App. No. 15-2
Scale:	Init:		

Appendix 16

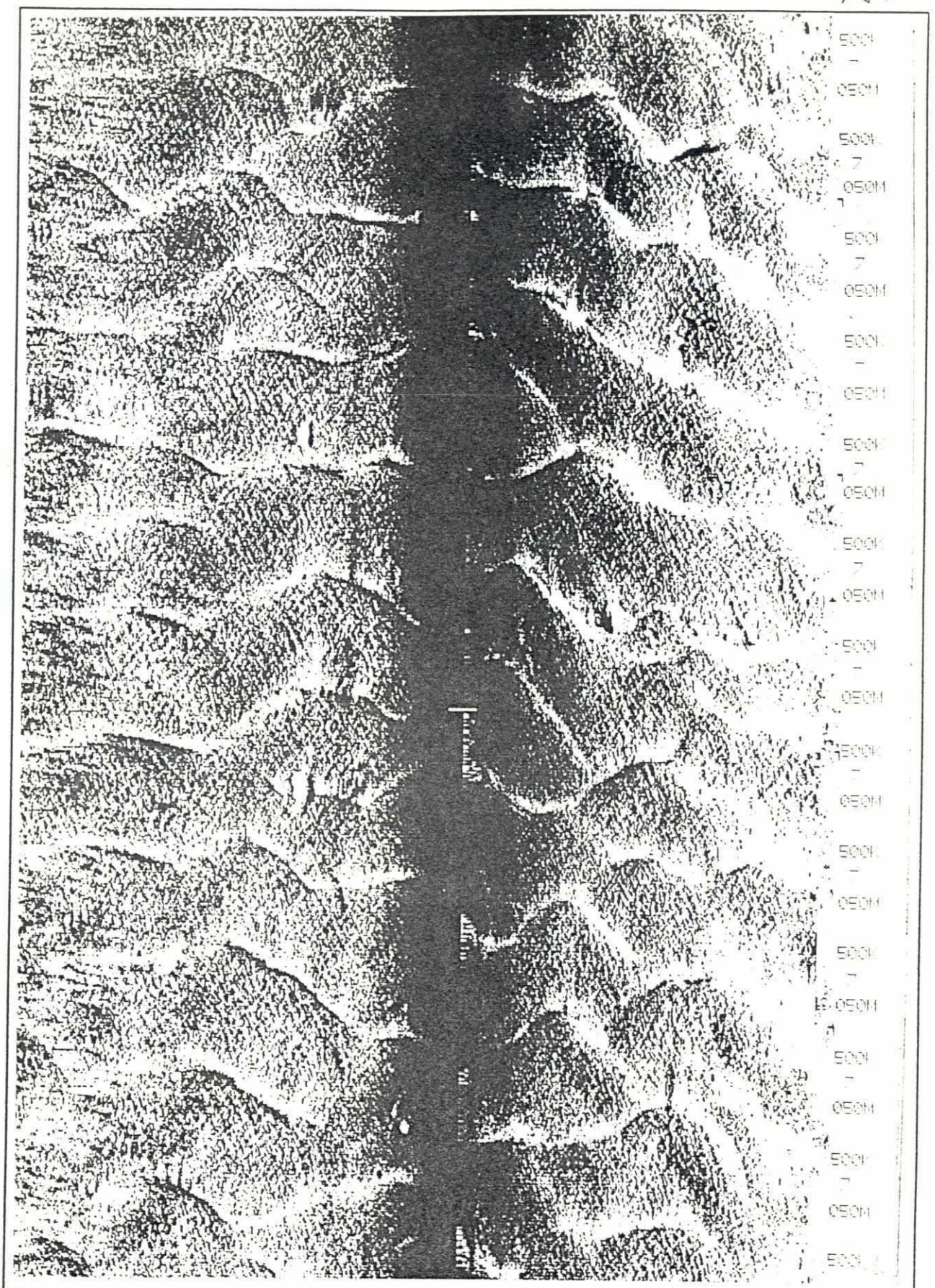
River bed images obtained by the side scan sonar



FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Oberni/Approtech/Hydroland		Test Gauging Report JAMUNA RIVER UPSTREAM OF BAHADURABAD	
File:	Date:	RIVER BED I MAG = BY THE SIDE SCAN SONAR 19 AUG 1993	App.No.16-1
Scale:	Init:		



FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osmis/Approtech/Hydroland DELFT-DHI		Test Gauging Report JAMUNA RIVER UPSTREAM OF BAHADURABAD	
File:	Date:	RIVER BED I MAG = BY THE SIDE SCAN SONAR 19 AUG 1993	App.No. 16-2
Scale:	Init:		



FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osmi/Approach/Hydroland		Test Gauging Report JAMUNA RIVER UPSTREAM OF BAHADURABAD	
File:	Date:	RIVER BED I MAG = BY THE SIDE SCAN SONAR, 31 JAN 1993	App.No. 16-3
Scale:	Init:		

Appendix 17

S4 calibration, fax from InterOcean Systems, Inc.

708

InterOcean Systems, Inc.

Facsimile Transmission

To: Delft - DHI Flood River Project
Atten: Palle Mikkelsen
FAX #: 011-88-02-883-568
Date: October 27, 1993
Ref: Calibrations of S4
From: S. Pearlman

RSP / FAP 24 INCOMING MAIL
DATE : 28.10.93 NUMBER : 01
COPY FOR ACTION : PdM
COPY FOR INFO : CL, PvG
T. H. FILE : S.4 UFO:

No. of Pages sent, including this transmission page: 1

To respond to InterOcean via facsimile, Dial (619) 268-9695

Dear Mr. Mikkelsen,

We have read your fax with concern and have researched into this possible discrepancy you have indicated. I provide our findings:

S4's # 08291838, 08291839, & 08291840 were properly recalibrated for a velocity range of 0-500 cm/sec in May of this year. However during the final step of the verification procedure, the technician erroneously reverted to the standard calibration procedure and readjusted the sensitivity values incorrectly. We now have realized that this caused the sensitivity values to be set too low by approximately 12% for these three instruments. The sensitivity values of the above units should be reset as follows using the *Mxxx,yyy* command from the terminal mode as described in paragraph 9.2.2 on pg 46 of the gold S4 Users Manual.

S4 s/n 08291838 enter M252,257	Xsensitivity = 252	Ysensitivity = 257
S4 s/n 08291839 enter M254,254	254	254
S4 s/n 08291840 enter M261,261	261	261

This should result in increased readings of about 12% which is appropriate and accurate for these three instruments.

Additionally, all standard range (0-350 cm./sec) S4 current meters calibrated by InterOcean since summer 1992 have been verified with correct calibration settings. Instruments calibrated by InterOcean prior to this period, we have later determined, had been under-reporting current speed by about 6%, which was written and circulated to all S4 users in our 1992 report titled *S4 Current Meter Tow Tank Calibrations Around the World.*

Best Regards,

Stephen Pearlman
International Sales
InterOcean SDG.

Appendix 18

Note on ADCP performance in the Jamuna river

30.10.93.PaM

Note on ADCP performance during phase I in Jamuna/Ganges river of Bangladesh.

Background:

During the proposal phase of FAP24 it was decided to investigate alternative methods in form of high technology equipment to carry out discharge measurements in the rivers of Bangladesh.

The moving boat method by means of ADCP and EMF equipment was selected.

The ADCP concept is, by means of acoustic doppler technique, able to measure the water flow with respect to the river bed.
By measuring the doppler shifts between a series of acoustic pulse transmitted by the ADCP transducers and the backscattered sound from the water column as well as the echo from the river bed itself ,the ADCP is able to, by means, of sophisticated signal processing, to separate the velocity vectors in vessel velocity vectors and water velocity vectors with respect to the river bed. This acoustic doppler technique makes the ADCP able to carry out a transect across the river from bank to bank and measures current profiles with a high horizontal and vertical resolution.Due to the bottom track technique the ADCP measures also water depth as well as distance travelled over the river bed ,which in combination with the high resolution vertical current profiles for every 5 - 10 m along the track make the system able to calculate the accumulated discharge by integrating the velocity normal to path taken by the vessel.

The ADCP technique is unique in the way that it does not require any additional data in form of input from positioning system, echosounder, gyro compass etc. in order to calculate the discharge.

Due to the nature of the rivers in Bangladesh a ADCP system which operating on 300 KHz was selected during the mobilization phase of the project.

The main reason for selecting this rather low frequency was the concern of the high suspended sediment concentration, which could be expected during the flood periods and which could create problems for ADCP system to track the river bed.

The drawbacks, of selecting a 300 Khz system with a better penetration than e.g. a 1200 Khz system, are reduced coverage of the water column, less vertical resolution and increased standard deviation.
Although the software package includes algorithms to cover the missing part of the current profiles it was decided to include a EMF sensor to cover the top part (0 - 2.7 m) of the water column , which could not be covered by the ADCP due to immersion of the transducer and the selected frequency of the system.

The selection of the EMF sensor working in the MBM mode makes it possible to cover shallow areas, where immersion of the transducer and the pulse length of a 300 KHz system prevents the ADCP to collect data.

Phase I experience with the 300 KHz ADCP system:

The consultants has achieved considerable experience with the operation of the ADCP system in the rivers of Bangladesh during the first phase and the transition period of the River Survey Project.

Dry season.

Discharge measurements carried out at the Bahadurabad site during the first 7 months covering the dry season have proved the ADCP methodology to be, not only valid in the river of Bangladesh, but also reliable and superior to other system with respect to data coverage within the shortest measuring time. With ADCP system discharge measurements come close to the term "instantaneous discharge gauging". The main channels in Bahadurabad were covered by transect obtained during of 10 -15 minutes.The performance of the 300 KHz did not indicate any problem with respect to penetration and the system's bottom track facility has been operating reliably during the dry season.

Operation with a configuration file designed for the conditions in the Jamuna river make it possible to profile the river bed and measure vertical current profiles every 5 - 6 seconds while the vessel is crossing the river from bank to bank. Missing data in form of lost bottom track or orectic profiles has been observed very seldom during the dry season. Repetation of discharge measurement have been in the order of few present.

The 300 KHz system has its limitations in shallow areas due to the immersion depth of the transducer and the length of the acoustic transmit pulses.

Flood season.

During the transition period, which covered the flood period June to October , the 300 KHz ADCP system has been in operation at various sites in Jamuna, Ganges and Meghna river.

Measurements with the ADCP system has been carried out both in the dynamic transect mode and in stationary mode with the vessel at anchor.

Current velocities have exceeded 4 m at several sites during this period.

The measurements carried out with the 300 KHz ADCP system clearly indicates that the river bed becomes very active when the current exceeds 2 m. The suspension of bed material close to the bed is so dense that the ADCP detects this material as the river bed.
Since the material moves with the current (moving bed) the ADCP bottom track facility detect and interpret this phenomena as a vessel velocity vector 180 degrees to the direction of the current vector. Stationary measurements at anchor under DGPS control across the river section have detected ADCP bottom track velocities ranging from 1 cm/sec -- 90 cm/sec.

This false vessel velocity vector will cause the ADCP system to measure too low current velocities and thereby too low discharge during stationary profiling and dynamic transect measurements.

The phenomena does not prevent the ADCP system from producing high resolution current/ discharge data, but the data must be corrected by applying a correct vessel velocity vector.

The consultants has developed a method to correct the ADCP data,by applying a correct vessel velocity vector obtained by means of the DGPS system. Together with ADCP heading data obtained via the vessel's Gyro compass and water depth data obtained from the echosounder, the ADCP data is corrected. At present this correction is carried out off-line.

Beside the moving bed problem, the high current velocities and the presence of turbulence in the flood season have caused an increase in missing or doubtful profiles.But the percentage of bad profiles in a transect is still very low,in the order of a few percent.

Test of a 1200 KHz ADCP system at Bahadurabad site in the dry season.

See PaM's report of Jan/Feb.93.

Conclusion & recommendation

The ADCP concept and the transect methodology has proved to be a valuable tool for discharge measurements in the rivers of Bangladesh.

Due to the dense data coverage and the short transect time the 300 KHz system is an excellent tool for:

- accurate discharge measurements in main channels
- evaluation of current and suspended sediment gradients over a cross section.
- discharge measurements in areas where flow conditions change rapidly (tidal areas).

The present 300 KHz Broad Band ADCP system provides accurate discharge figures on-line during the dry season.

The presence of high current velocities and suspended sediments during the flood season do not prevent the present 300 KHz ADCP system from producing high quality discharge data. However data has to be corrected due to moving river bed. For the moment being this correction is done off-line, but possibilities for on-line corrections are under investigation.

The 300 KHz system provides interesting data regarding moving river bed.

Tests with a 1200 KHz ADCP system carried out in Feb.93 indicates that, although this system does not have the same penetration as the 300 KHz system, it operates well during the dry season in the rivers of Bangladesh.

The 1200 KHz system with its better resolution, both horizontally and vertically, and ability to measure in shallow areas is an interesting alternative to the 300 KHz system for dry season measurements.

During the flood season the system will be vulnerable due to turbulence and high concentration of suspended sediment and it is doubtful if the system can produce data with the same quality as the 300 KHz system.

It is the consultants opinion that a careful selection and combination of different operation frequencies will proved the ADCP concept to be an excellent tool for river discharge measurements during all conditions .

Regarding acoustic measurements with respect to suspended sediment the ADCP system provides the user with reliable distribution data. Research with respect to establishment of correlation between traditional suspended sediment sampling and ADCP data is executed around the world.