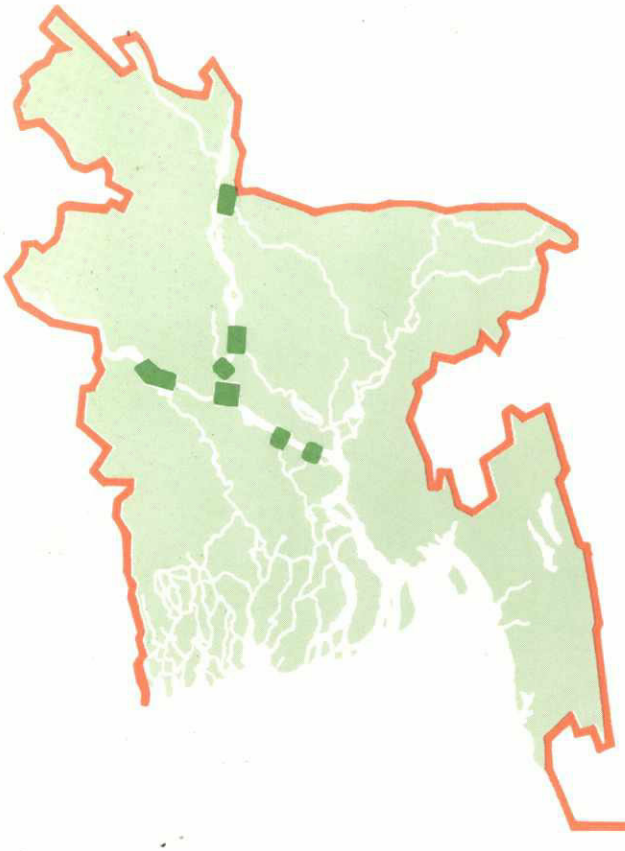
GOVERNMENT OF BANGLADESH
FLOOD PLAN COORDINATION ORGANIZATION

FAP 24 RIVER SURVEY PROJECT

Final Report Phase 1
August 1994



DELFT HYDRAULICS
DANISH HYDRAULIC INSTITUTE
OSIRIS
HYDROLAND
APPROTECH

Project ALA/90/04 — Commission of the European Communities

Final Report Phase 1

August 1994

FAP 24 **RIVER SURVEY PROJECT**

Flood Plan Coordination Organization

DELFT-DHI **Commission of the European Communities**

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August 15, 1994

Chief Engineer
Flood Plan Coordination Organization (FPCO)
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Attention : Mr.Afzalur Rahman.
Superintending Engineer.

Subject : Final Report phase 1

Our ref : RSP/9.1/1051

Dear Sir,

We are taking pleasure in submitting herewith our Final Report phase 1, covering the project activities up to 31/12/93.

Therefore the Final Report phase 1 does not only cover the phase 1 period, being one year from 8th June, 1992 onwards, but also the test measurements of August, 1993 and the discussions during the International Workshop of November, 1993.

Thanking you

Yours sincerely

Claus Iversen
Acting Team Leader

CC : CEC delegation, Dhaka.
Project Management Unit, Dhaka.

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Annexure 1: Sample format of River Data Book

Acronyms and abbreviations

ACQ	:	a data file type used by FAP24
ADCP	:	acoustic Doppler current profiler
AFPM	:	active flood plain management
AIT	:	Asian Institute of Technology (Bangkok)
ASCII	:	a computer data format
AWLR	:	automatic water-level recorder
BIWTA	:	Bangladesh Inland Water Transport Authority
BM	:	bench mark
BoQ	:	Bill of Quantities
BTM	:	Bangladesh Transverse Mercator (a geodetic grid)
BUET	:	Bangladesh University of Engineering and Technology
BWDB	:	Bangladesh Water Development Board
CEC	:	Commission of the European Communities
D	:	grain size diameter
DELFT	:	Delft Hydraulics
DGPS	:	Differential Global Positioning System (a high-accuracy satellite-based poisitioning system)
DHI	:	Danish Hydraulic Institute
DOS	:	a computer operating system
ECU	:	European Currency Unit
EMF	:	electromagnetic flow meter
FAP	:	Flood Action Plan
FAP24	:	FAP project 24 = The River Survey Project
FM	:	Finnmap (a geodetic survey company)
FPCO	:	Flood Plan Coordination Organization
GKS	:	a computer graphical software package
GPS	:	Global Positioning System
h	:	stage (m +PWD)
HOD	:	a data file type used by FAP24
HSD	:	a data file type used by FAP24
HW	:	high water
IHE	:	International Institute for Infrastructural, Hydraulic and Environmental Engineering (Netherlands)
ISO	:	International Standard Organisation
ISVA	:	Institute of Fluid Mechanics, Technical University of Denmark
LW	:	low water
Mb	:	megabyte
MEX	:	a specific turbidity meter
MV	:	motor vessel
NEDECO	:	Netherlands Engineering Consultants
O&M	:	operation and maintenance
PA	:	Project Advisor
PSD24	:	Processed Survey Data from FAP 24 (name of a FAP 24 data base)
PWD	:	Public Works Department datum

Q	:	flow rate (m^3/s)
QPR	:	Quarterly Progress Report
RRI	:	River Research Institute (Faridphur, Bangaldesh)
RSP	:	River Survey Project (= FAP 24)
S	:	sediment transport rate (kg/s or kg/s/m)
SCO UNIX	:	a computer operating system
SLW	:	Standard Low Water (a reference level)
SoB	:	Survey of Bangladesh
SWMC	:	Surface Water Modelling Centre
S4	:	a specific electromagnetic flow meter
TBM	:	temporary bench mark
ToR	:	Terms of Reference
TS	:	Technical Specifications
UNIX	:	a computer operating system
UNDESD	:	United Nations Department for Economic and Social Development
US BM-54	:	a specific bed material sampler
VHF	:	very high frequency
WMO	:	World Meteorological Organisation
WRIS	:	Water Resources Information System (of BWDB)

1. Introduction

The scope and timing of the present Final Report Phase 1 are discussed in Section 1.1 whereas the structure of the report is outlined in Section 1.2

1.1 Rationale

In the ToR of the River Survey Project, both the contents of the Final Report Phase 1 and the timing thereof are described as follows:

Quote:
'A Planning Report i.e. Phase 1 Final Report (Month 12) summarising the results of the hydrological, morphological and hydrographic surveys undertaken in Year 1, giving an assessment of the effectiveness of the equipment and methods used, and proposing a detailed Work Plan for Year 2, with an outline work programme for Years 3 and 4. The report at the end of Phase 1 will also present proposals for a format for annual reporting on the hydrology and morphology of the main rivers. The aim of such report would be to provide each year all data of interest on water levels, discharges, change in morphology, and notable events (scour and filling at critical points). In addition to providing a continuous record, it would serve as a reference for planners and designers.'
Unquote.

A crucial part of this report should deal with the assessment of the effectiveness of the equipment and methods used. However, this assessment should be based on experience during HW test measurements, which took place in August, 1993, that is after phase 1, which ended in early June, 1993. This discrepancy was discussed with FPCO/CEC/PA, and it was decided to proceed as follows:

- A draft planning report to be produced in June as a first version of the Final Report Phase 1 (hence, without results of the test measurements)

- The publication of Final Report Phase 1 to be postponed, thus enabling inclusion of the results of the monsoon measurements of 1993

Consequently, a report, *'Draft notes on planning'*, was published to support the discussions of the survey, study, and training programmes, and to direct the activities in the second half of 1993. These draft notes and the comments received form the basis for the Final Report Phase 1.

As the Final Report Phase 1 does not only cover the phase 1 period, being one year from 8th June, 1992 onwards, but also the test measurements of August, 1993, and the discussions during the International Workshop of November, 1993, it was decided to choose the reporting period as 8/6/92 to 31/12/93.

1.2 Structure of this report

First of all this report is providing a review of the main activities in the River Survey Project (Chapter 2). These main activities are described in some more detail in the subsequent chapters (Chapters 3 to 8).

In these chapters, reference is made to the detailed reports that have submitted underway and, where relevant, a summary is given of the main conclusions and results. These detailed reports and other publications of the River Survey Project are listed in Chapter 9.

In the last chapter, the work plans are given. Both an over-all work plan for phase 2 and a more detailed work plan for the first year of phase 2 are outlined (Chapter 10).

In Annexure 1, a proposal is formulated on the format of hydrological and morphological year books as requested by the TOR (see Section 1.1). The format is based on preliminary communication with the Project Advisor.

2. Review of activities

In the present chapter is given a summary review of the proceedings of the River Survey Project until the end of 1993. An overview of key activities is presented in Figure 2.1.

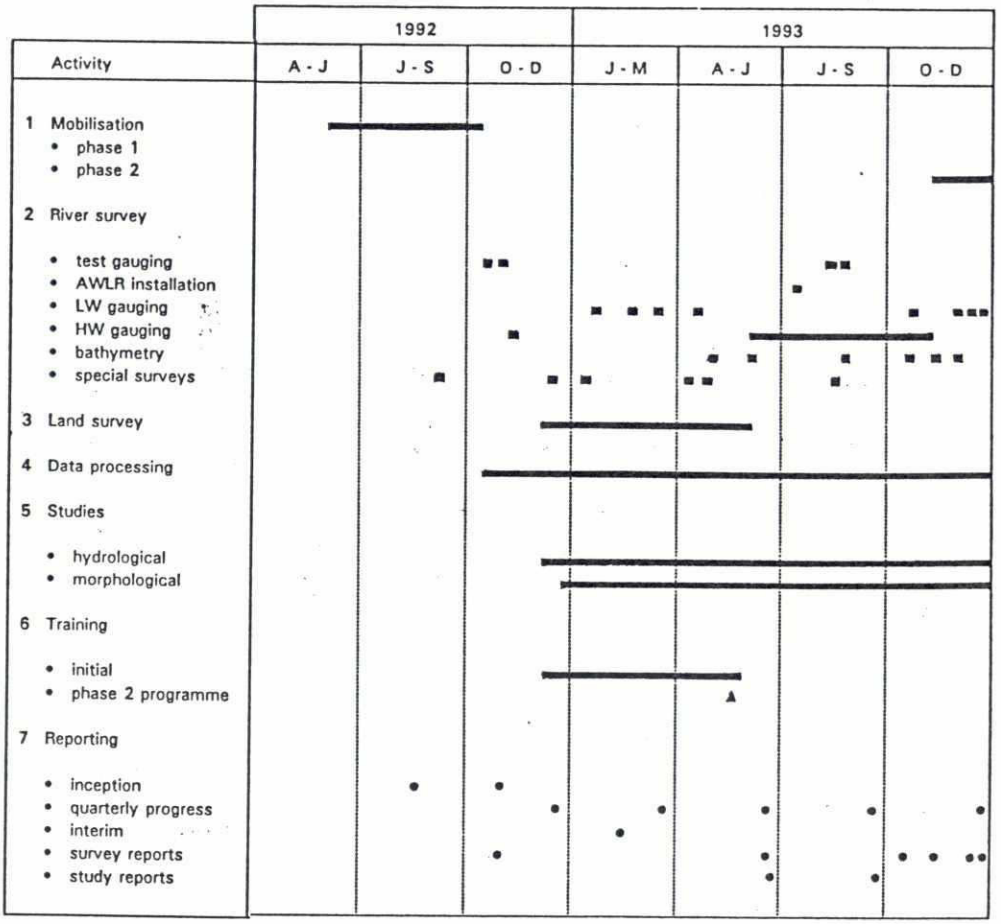


Figure 2.1: Key RSP activities 1992-93

Mobilisation

The mobilisation for phase 1 started immediately when the contract was signed (on May 22, 1992) with vessel identification, procurement of the DHA vessel and construction of the DHC vessel, procurement of instruments, and selection and adaption of on-line processing software. The Team Leader arrived in Dhaka on June 9, 1992, and the first consignment of equipment arrived in Dhaka on August 4, 1992. A project office was rented in Dhaka, and a guest house in Gaibanda. Administrative project staff and service staff were employed, and cars and other provisions were procured. The sediment laboratory and the post-processing office were established. The mobilisation of phase 1 was concluded with a preliminary test gauging programme at Bahadurabad in October, 1992. Mobilisation for phase 2 was initiated by the end of 1993.

River survey

In the meantime, the first river survey was carried out in September, 1992, at Bahadurabad from a rented vessel, BWDB's survey vessel Anwesha. The subsequent, scheduled survey activities comprised test gaugings, routine gaugings, bathymetry, AWLR installation, and special measurements for specific study purposes.

The scope of the test gaugings comprises (i) performance tests of the equipment, (ii) tests of operational procedures, (iii) optimization of measuring methods, and (iv) determination and acceptance of appropriate techniques.

Because of the late project start, the first test gaugings were executed at the end of the monsoon period of 1992. Moreover, the monsoon of 1992 was very moderate. As a result, the tests were executed in mid flow conditions (less than 20.000 m3/s). For the final acceptance test, higher flows were desired, and therefore it was decided to execute the final acceptance tests in the monsoon of 1993.

The main result of the test gauging is the selection of the survey methods and instruments to be used in phase 2 of the River Survey Project. Please refer to Table 4.3 for a summary of the methodology.

In the reporting period, routine gaugings were made all over the main river system of Bangladesh. The first one was executed at the end of the 1992 monsoon in Bahadurabad. The programme has comprised both the so-called reference method, by traditional flow gauging in vertical profiles, and the recommended ADCP-based method. The routine gaugings comprise (i) discharge measurements, (ii) suspended load measurements, (iii) bed-load measurements, and (iv) bed material sampling. Due to the late start of phase 2 of the project, not all the scheduled measurements were accomplished.

Staff gauge readings were initiated at Bahadurabad in October, 1992. One pressure type AWLR was installed near Bahadurabad in June, 1993, and, following a test programme in the Netherlands, another one, of acoustic type, was installed together with an acoustic type in July, 1993. The recorders performed well, the critical issues being to verify the performance of the acoustic transducer and to select a proper place for installation, considering the bank erosion.

Until end of 1993, a total of 6 bathymetric surveys were carried out at Bahadurabad (4 surveys, including one bank-line survey), the Jamuna - Ganges confluence, and Hurasagar.

Special surveys were carried out at Bahadurabad (comparative measurements and surface slope measurements), Lower Meghna, (ADCP performance), Khulna (tidal measurements), and Baruria (demonstration of set-up at the International Workshop). The surface slope measurements were based on readings of 6 staff gauges that were established around Bahadurabad in October, 1992, and June/July, 1993.

Please refer to Chapter 4 for an elaboration of the river survey.

Land survey

The land survey work comprises (i) positioning of the DGPS reference stations, (ii) control of reference levels and construction of new bench-marks, (iii) zero levelling of water-level stations, and (iv) topographical work.

The DGPS positioning of the survey vessels implies that a so-called reference station is set up at a known location near the survey site on the river bank. Usually, when a convenient location is found for the station, the position is not known; therefore, it needs to be measured accurately. For this purpose is used a geodetic DGPS procedure.

Bench-marks are mainly constructed to establish a reference level for a near-by water-level station. Many temporary bench-marks have been made, as well as two permanent ones: One near Fulchari and one near Sengram.

In one case, in december, 1992, a levelling was executed across the Jamuna River near Bahadurabad. The main purpose of this exercise was to establish a small network of temporary bench-marks on the central island between Bahadurabad and Fulchari. This network was required for zero control of temporary staff gauges to be used to study local water level slopes.

One of the tasks of the River Survey Project is to execute a one-time verification of the zero levels of 47 BWDB water-level gauging stations by second order levelling. This work was carried out in early 1993. Also, in the same period, the zero levels of the water-level stations were established relative to nearby BWDB bench-marks.

Topographic information is required for the analysis of the morphological changes in the different river stretches. This implies that topographic survey work is envisaged in the dry part of the river bed. In fact, the configuration of the dry part of the river bed needs to be measured supplementary to the wet part which is measured by the bathymetric survey.

In late 1992/early 1993, test measurements were made near Bahadurabad in order to find the best method for the topographic surveys. Following these tests, the tachymetric method is preferred because of productivity, integration in the existing positioning system and easy interfacing with the existing software. However, the amount of topographical work should be minimized by applying alternative methods such as bank-line surveys and remote sensing techniques. The first bank-line test survey was made in May 1993.

The possibility of using satellite based radar to collect bathymetric information will be studied in 1994/95 by the River Survey Project. If the method is successful and can be used during the highest water-levels there is no need anymore for topographic work.

Data processing

Each ADCP transect produces around 1 Mb of raw data, and each individual vertical profile will produce around 0.1 Mb of raw data. Hence, a typical routine survey will produce somewhere around 10-15 Mb of raw data for each survey at each location, and sometimes more. The off-line data processing comprises file conversion, plotting for

quality check and subsequent data reporting, listing of files in the data catalogue, and subsequent storage.

The different types of samples of river bed sediments and suspended sediments are analyzed in the laboratory for concentration, settling velocity distribution, and grain size distribution, according to the established routines which are based on standard methods.

A brief summary of results of the routine surveys are presented in Survey Bulletins, which are issued as a series, each bulletin describing one survey at one location. Hence, the 27 routine surveys completed by the end of the monsoon season 1993 were reported in Survey Bulletins nos. 1 through 27. In addition to an outlook of the findings, the Survey Bulletins indicate file names for the collected data. The bulletins are intended both as a documentation of the field work that has been carried out and as a reference for the data users.

During Phase 1 of the project, the workload required for post-processing has gradually been reduced to a level of around 4 working days per Survey Bulletin. However, a substantial additional work is required for the subsequent data reporting.

The bathymetry surveys produce as much as up to around 80 Mb of raw data per km^2 of survey. The on-line control comprises position control and area coverage (by plotting and monitoring the survey lines). Also, the depth recordings are monitored on-line, and irregularities, if any, are identified.

In the data processing office, the recorded depths are converted into levels relative to the selected datum. The conversion is a function of time and space, as determined by water-level recordings from the survey area relative to the datum. The bank line is specified, and the data are inspected once again for position and depth irregularities by plots or on the computer screen. Results are presented as bathymetry charts and contour plots. The workload required for post-processing is 8 working days for a large survey, such as a flood season survey at Bahadurabad, and 4 working days for a small survey.

The off-line data quality control normally involves examination of graphic presentation of data from one or more sources. Inter-station comparison is a common tool, for example whether some unusual flow fluctuation occurs at one station only, or whether the pattern appears in several independent records. As another example, a bathymetric survey may display an unusual steep slope between two successive soundings. This may be due to an error, or due to a true, but extreme bed level variation. An evaluation can involve an examination of the specific survey line, whereby for example erroneous spikes can be identified, or adjacent survey lines must be compared in order to find out whether an unusual feature is reflected in independent recordings. Also, observations of unusual bed form developments can be partly verified by comparison of river bed levels from two successive surveys.

The processed data are registered in the Fieldman catalogue system, which is an Oracle-based (UNIX) software system for data management and file retrieval.

Studies

One of the objectives of the River Survey Project is to undertake special studies of the behaviour of the river systems in Bangladesh based on (1) the new data that are collected during the routine surveys of the project, (2) existing data, and (3) through supplementary surveys.

For convenience, the studies may, roughly, be divided into the partly overlapping categories of hydrological and morphological activities.

Please refer to Chapter 7 for a more thorough summary of the proceedings.

Hydrological studies

During phase 1, a substantial part of the resources available has been allocated to establishment of a data base with long time series of historical data for the main stations in the major rivers. A systematic procedure for checking of water-level time series by plotting and comparison with series from adjacent stations has been set up, and the long water-level time series 1966-91/92 from the main discharge stations have been checked and corrected by this procedure.

An improved method for analyzing rating curves has been introduced, based on the ISO-standards. New annual rating curves for the period 1966-91/92 for five discharge stations in the main rivers have been developed by applying the improved and consistent rating curve method.

The long-term trends and magnitudes of shift of the annual rating curves have been analyzed for the major rivers. Apart from providing an outlook of the river dynamics, the analyses have detected and confirmed a number of inconsistencies in the BWDB discharge time series, including the Bahadurabad station, where, since the major flood in 1988, discharges are generally estimated too high for medium to high flow conditions in Jamuna River. Similarly, it was found that the discharge time series for Baruria before 1971 is estimated too low.

Proposed study topics in phase 2 are as follows:

- Water surface slopes
- Water balances
- Changes in rating curves
- Loops in rating curves
- Extrapolation of rating curves
- Overland flow (flow from rivers to catchment during high floods in the river)

Morphological studies

During the morphological study activities, a substantial effort was made to make an inventory, as complete as possible, of morphological data. Furthermore, a selected set of morphological data of the main river system was collected from various sources, and the quality of the data was assessed.

Broadly speaking, a very large amount of data on the main river system is available, such as various types of morphological data, notably (old) maps, satellite images, cross-sections, regular and incidental soundings, bed material samples, bank material samples, sediment transport measurements, etc.

The following characteristics of the main river system have been studied:

a characteristics of the river basin (total length, basin area)
b hydrology: rainfall characteristics, water levels and discharges
c bed material characteristics and sediment transport
d bank material characteristics
e planform and shifting characteristics
f maximum scour depths

From the analysis, a fairly consistent picture emerges. The flow of sediments seems fairly understood, as well as the reduction in particle diameter in the main rivers. Also, more consistent information is available on the sediment entering the distributaries (except for the Arial Khan/Dubaldia distributary system).

The average discharges and water levels in the main rivers are fairly constant during the last decades. It appears that most main rivers are fairly adjusted to their independent variables, with the notable exception of the Upper Meghna River, which still for a long time will have to 'recover' from the avulsion of the Brahmaputra between 1828 and 1830. The discharges in the distributaries have the tendency to reduce (with the exception of the Arial Khan/Dubaldia river). Hence, it may be expected that these rivers are in an adjustment phase.

The planform changes in the Jamuna river are the most pronounced of all the considered rivers. It consists of localized bank erosion, which is difficult to predict over larger time spans. In the reach upstream of Sirajganj, the river appears to widen, and there is a progressive though not continuous shift of the right bank of the river. The planform of the distributaries is relatively stable and the planform changes are predominantly a gradual shifting of meander bends.

Although the available data still have to be studied in more detail, and additional data have to be gathered, the picture that arises from this phase 1 activity is a river system that is not fully in equilibrium, and which is in the process of adjusting to the influence of local tectonic changes that causes avulsions (leaving some rivers 'oversized'), sedimentation due to subsidence (causing sedimentation and unbalance in sediment transport rates), preferred bank erosion on the right side of the braided Brahmaputra River, and deteriorating distributaries possibly by a variety of causes.

A preliminary, qualitative assessment has been made of the hydraulic and the morphological impact of FAP implementation.

The results demonstrate that the initial increase in stages in some rivers (in particular in the Padma, Jamuna and Ganges Rivers), will in due time probably reverse to a reduction in stages. Rough estimates indicate a degradation and lowering of stages of up to 0.6 m

or more for most of the main rivers apart from the Upper and Lower Meghna Rivers. This degradation will only materialize fully after 50 to 100 years or more.

An important finding of the assessment is that the prediction of the future conditions of the distributaries cannot be done in a completely deterministic way. The development of the distributaries is at least partly determined by phenomena which are varying in time. Hence, the period and sequence of implementation of the various projects may be important. The assessment supports the selection of study topics as proposed by FAP 24 and underlines the need to improve the understanding of the behaviour of off-takes.

The tentative selection of study activities during phase 2 concentrates on a limited number of topics, which are:

- over-all hydrology and water balances
- sediment transport and river aggradation and degradation
- offtakes and bifurcations
- bed forms, but only in relationship to hydraulic roughness, measuring techniques
- FAP impact on the river system

During the Workshop in Dhaka in November 1993, it was decided to initiate another FAP project, in which the FAP impact on the river system would be studied in more detail than it is possible within FAP 24. The consequence is that the topic, under FAP 24, can be limited to the phase 1 activities.

Training

In the first phase of the project, the training consisted mainly of in-house on-the-job training and in-house courses on river engineering. The subjects included (i) ship handling and surveying; (ii) data processing and sediment analysis; and (iii) basic hydraulics, hydrology, sediment transport, and river dynamics.

A training programme for phase 2 has been proposed and is described in detail in Chapter 7. This programme comprises external training within the fields of survey techniques, data administration, and river engineering. Participation by staff from BWDB, BIWTA and BUET is anticipated.

The proposed programme includes the following elements: (i) special exercises in the field; (ii) seminars and courses at the BWDB training centre in Bhadyakul and abroad; (iii) workshops; (iv) on-the-job training and long-term participation in the River Survey Project; (v) study tours to some rivers abroad where special measurements are carried out; and (vi) study abroad. Implementation of the programme requires a substantial additional funding.

It is recommended that the programme be coordinated with the UNDESD project 'Water Resources Information System (WRIS)' of BWDB.

Reporting

The reports and notes published by the River Survey Project are divided into the categories as listed below. The numbers in brackets indicate the number of volumes that

cover the period until end of 1993, although some of them, including the present one, were actually submitted in 1994:

- General Project Reports (5)
- Progress Reports (with Survey Bulletins) (6)
- Survey Reports (7)
- Study Reports (3)
- Survey Notes (5)
- Working Papers (1)
- Various (3)
- Workshop contributions (6)
- Lecture Notes (4)

For the future reporting of routine gaugings, a new format has been outlined. The format contains a listing of the survey activities, a short presentation of main results, and a complete catalogue of all primary and edited data files. The format is attached as Annexure 1 to the present report.

A complete list of reports issued by the River Survey Project is included in Chapter 9.

3 Mobilization

Mobilization started just after the award of the contract. In Europe, the main mobilization activities comprised the procurement of equipment including instruments and vessels. In Bangladesh, the former MPO office (House No. 96, Road No. 23, Banani, Dhaka) was rented to be used as Project Main Office and was very well suited for this purpose with space for workshop, data-processing office, general office and staff residence. Also, a field office in Gaibanda was put into operation. Survey equipment was procured from and tested in Denmark prior to shipment by air freight to Bangladesh. In the Netherlands, a coastal patrol vessel was modified for survey purposes and in Singapore, a new catamaran-type of boat was constructed. The vessels were transported on cargo vessels to Chittagong, and sailed on their own keel to Naryanganj, where the survey equipment was installed at a shipyard. The end of the installation marked the end of the mobilization for Phase 1.

Some mobilization milestones are :

1.	Award of Contract	May 22, 1992
2.	Inception of Phase 1	June 9, 1992
3.	Arrival of equipment in Bangladesh	August 4, 1992
4.	Arrival of survey vessel (DHA)	August 22, 1992
5.	Release of equipment	September 7, 1992
6.	Release of vessels	September 22, 1992
7.	End of installation	October 15, 1992
8.	Test Gauging	August 16-22, 1993
9.	Determination of Phase II	December, 1993

The contractual test gaugings were carried out from 16 till 22 August 1993 and the respective reports were issued in October and November 1993.

Following the discussions during the International Workshop and subsequently with the PMU, the final configuration of survey vessels and equipment to be deployed for the remaining phase II period was finally determined and procurement initiated by the end of 1993.

The project mobilization milestones are shown in Figure 3.1 and for more details including a description of the survey vessels and equipment involved in the mobilization activities reference is made to the Revised Inception Report (FAP 24, 20 October 1992); 1° Interim Report and the Test Gauging Reports.

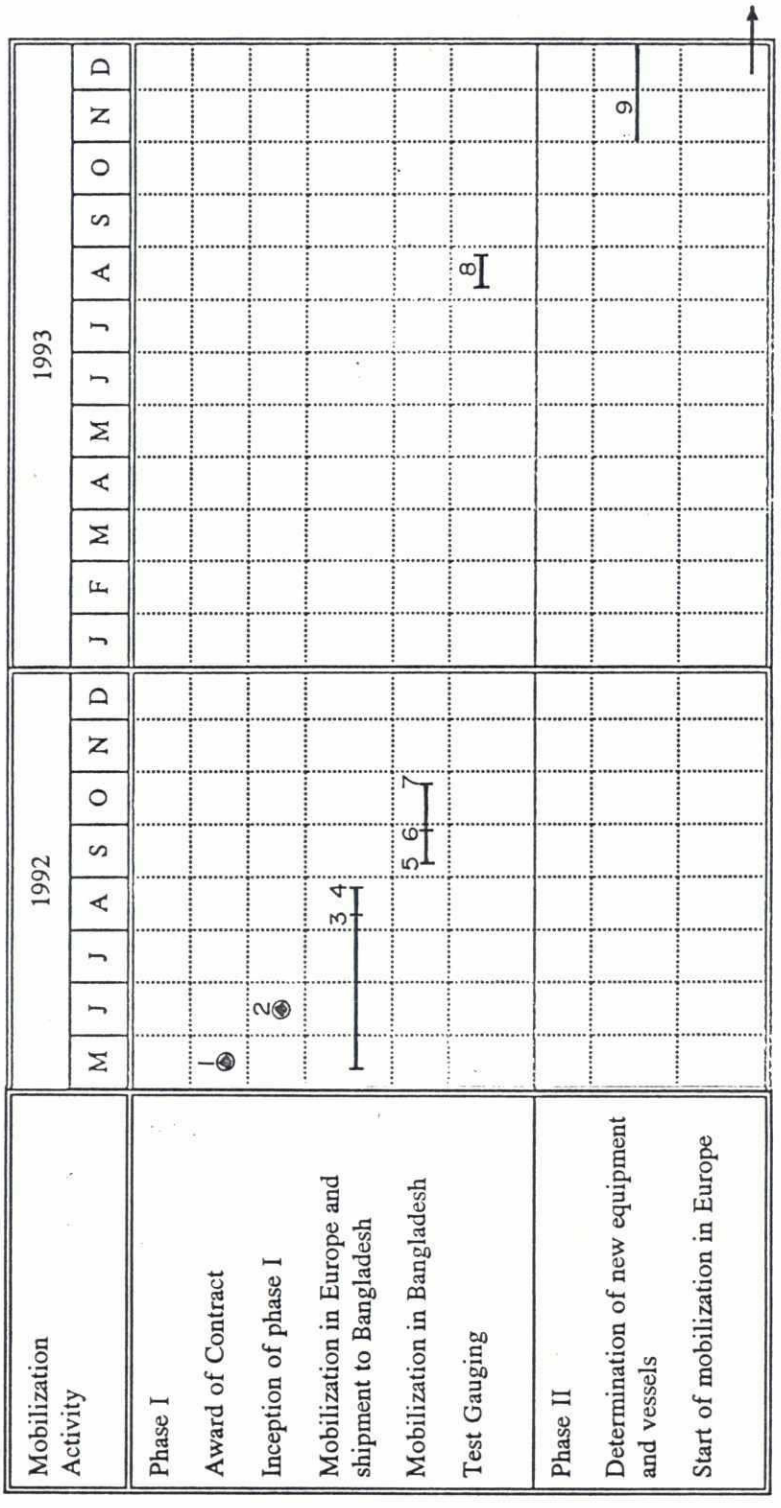


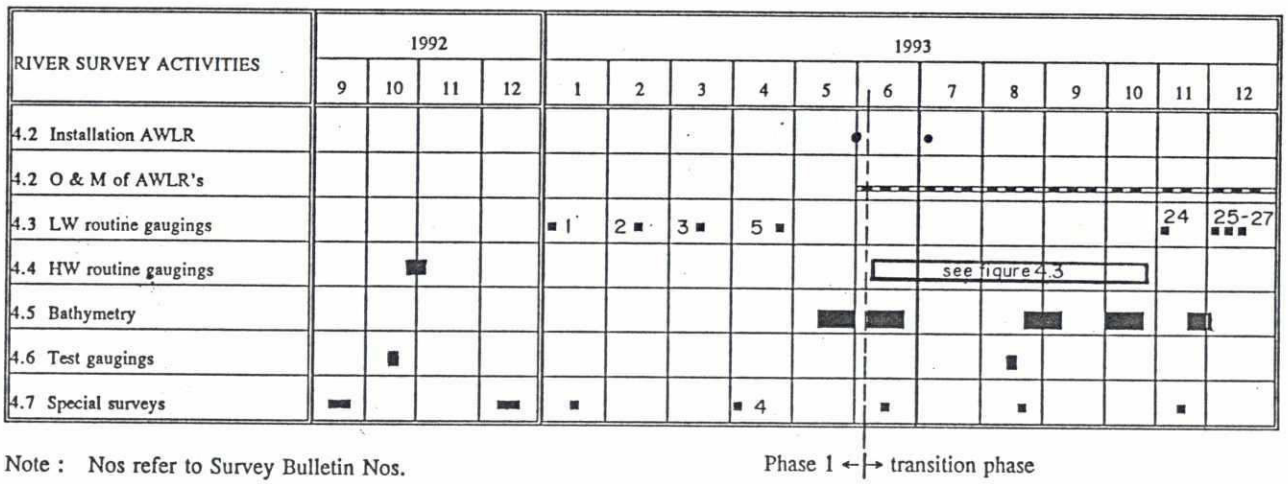
Figure 3.1: Mobilization periods

4. River survey

In this chapter, the 1992/93 survey activities of the River Survey Project on the main rivers of Bangladesh are described. Firstly a summary is given, whereafter the main items: AWLRs, routine gaugings, bathymetry, test gaugings and other special measurements are described in more detail. The last section of the chapter gives a chronology of the activities.

4.1 Summary of activities

The survey activities on the river are summarised in Figure 4.1. The numbers in the left column of this figure refer to the sections hereafter where the various activities have been elaborated.



Note : Nos refer to Survey Bulletin Nos.

Figure 4.1: Main river survey activities

4.2 AWLRs

According to the contract one automatic water-level recorder (AWLR) has to be installed near Bahadurabad in phase 1 of the project. The type of AWLR was chosen to be a pressure cell type.

As the River Survey Project started on June 8, 1992, viz. at the start of the monsoon, it was decided to wait with the installation for the coming lean season (to avoid under water installation).

By the end of 1992, after initial survey work on the rivers, the questions came up what type of platforms and what type of AWLRs were appropriate, especially at certain highly dynamic river sections. It was decided then to test another type of sensor, namely an acoustic one. In early 1993, the testing started in Europe. Also a three month duration test was done aiming at checking the zero-stability of the instrument. Results were so promising that it was decided to install one acoustic recorder in Bangladesh, to be tested during the 1993 monsoon.

In the meantime, a special design of a platform was made to install a pressure type AWLR on deep males near the BWDB gauge at Bahadurabad Ghat. Another type of platform was erected in a shallow and protected inlet near the right bank of the central island, also in the Bahadurabad cross-section, a place called Gabgachi. There, on the (shallow water) platform of Gabgachi, two AWLRs were installed, one pressure type and one acoustic type.

Figure 4.2: AWLR at Mawa (April, 1994)

The results obtained in the reporting period can be summarized as follows:

- o The pressure and the acoustic recorders in Gabgachi were running without problems. This also means that the acoustic type performed well during the monsoon with fluctuating humidity and heavy rain showers.

- o Identical recordings were made from the start on July 15, 1993, when the installation was completed, till the switch-off on November 11, when the water-levels dropped too low (shallow water platform).

- o The deep water AWLR near Bahadurabad Ghat started operation on June 6, but broke down on August 2, 1993, due to heavy morphological action and consequently damaging of cable and burying of the pressure sensor. The structure, however, appeared to be stable.

- o Detailed reporting on the AWLR issue is done in
  - Working paper 1
    Technical recommendations and verification of the acoustic sensor type of AWLR
    October 1993

  - Selection of Survey Techniques
    November 1993
    (this report contains Working paper 1 as an annexure)

  - AWLR stations
    Site selection, installation, operation and maintenance
    In preparation

- o The recordings are also compared with data from staff gauge readings with good results. For water-level data from staff gauges readings, please refer to Section 4.7

Finally, it should be mentioned that a site reconnaissance was made at the 10 other sites where AWLRs will be installed in the lean season of 1993/94. Designs and proposals were prepared in the second half of 1993 and permissions were sought for installation of AWLRs on fixed structures (bridges, etc).

4.3 LW routine gaugings

In the reporting period low water routine gaugings were executed as presented in the following table.

Location	Data	Bulletin no.	QPR
Bahadurabad	12-17 Jan.1993	1	2°
"	12-17 Feb.1993	2	
"	11-17 Mar.1993	3	3°
Bhairab Bazar	26-28 Apr.1993	5	
Bahadurabad	31 Oct.- 3 Nov.1993	24	5°
Baruria	4-5 Dec.1993	25	6°
Sirajganj	7-8 Dec.1993	26	
Bahadurabad	10-13 Dec.1993	27	

Table 4.1: LW routine gaugings

The routine gaugings comprised
- discharge measurements
- suspended load measurements
- bed-load measurements
- bed material sampling

The measuring methods applied in the lean season of 1992/93 have been described in Survey Report 5. The methods applied in the lean season of 1993/94 are outlined in Survey Note 5.

The main results (being the total transports of water and sediments) of these surveys are summarised in Table 4.2. However, a considerable amount of detailed data have been collected, which are presented as follows :

o Part of the survey results are presented in the Survey Bulletins which are appended to the Quarterly Progress Reports (QPR), see also the previous table. The bulletins give the executed survey programmes including the data file names and serve thereby as a hard-copy catalogue of our data base where all the collected data is stored

o The lean season measurements in the first half of 1993 have been reported in Survey Report 5. The LW measurements of the last months of 1993 are reported in *'Survey Data lean season 1993/94'* (in preparation).

4.4 HW routine gaugings

In the reporting period, HW routine gaugings were executed all over the main river system of Bangladesh. The first one was executed at the end of the 1992 monsoon in Bahadurabad. Results hereof are given in the 1° Interim Report.

The main part of the measuring programme was realised during the monsoon of 1993. Please refer to Figure 4.3, which also gives a comparison between the actual programme and the programme outlined in the BoQ. The deficit is due to the late start of phase 2 of the RSP.

STATION	MONSOON 1993								
	June	July	August	September	October	*	Q	S_s	S_b
1. Bahadurabad	6	7	10	11		8	4	3	3
2. Sirajganj		8		12	23	8	3	2	1
3. Aricha				13		2	1	-	-
4. Hardinge Bridge				15		8	1	1	1
5. Baruria			9	14	17 22	8	4	2	2
6. Mawa					18	2	1	1	1
7. Mymensingh						4	-	-	-
8. Tilly					21	4	1	1	-
9. Gorai Rly.Bridge				16		4	1	1	1
10. Arial Khan					19	4	1	1	1
11. Bhairab Bazar					20	3	1	1	-
						55	18	13	10
						Deficit	37	42	45

* Number of measurements according to BoQ
Q, S_s, S_b Number of executed measurements of discharge, suspended sediment and bed load respectively
6 See survey bulletin 6

Survey Methods
- reference and recommended methods Q, S_s, S_b
- recommended method Q
- recommended method Q, S_s

Figure 4.3: HW routine gaugings

During the monsoon of 1993, both the reference method and the recommended method were applied as indicated in Figure 4.3. Not indicated are the bathymetric surveys and the test gaugings done in that period. Please refer to the following sections for a description of those activities.

The survey methods applied, notably the reference and the recommended method, are described in for instance the 1° Interim Report (Volume II, Annexure 4). For a description of the equipment used, please refer to the same report, Volume II, Appendix 1A.

The results of the HW routine gaugings are presented in *Survey Report 8: 'Flood season 1993'*, and are briefly summarized in the following table.

Location		Date	Water-level (mean value) m+PWD	Discharge (average) m^3/s	Suspended sediment transport (average) kg/s
1	Bahadurabad	14-16/1/93	14.17	4,930	597
		13-15/2/93	13.83	4,310	527
		3-9/6/93	14.26	4,395	422
		9-17/7/93	17.30	21,000	11,400
		6-11/9/93	19.75	45,300	49,900
		31/10-3/11/93	18.78	43,500	31,700
			16.28	15,200	5,300
2	Sirajganj	21-30/7/93	13.50	50,159	54,385
		24-27/10/93	11.47	19,424	11,748
4	Hardinge Bridge	26-29/9/93	13.69	44,684	83,323
5	Baruria	3-8/8/93	7.35	59,305	56,392
		19-22/10/93	6.41	34,161	18,738
6	Mawa	3-7/10/93	5.41	64,471	84,510
8	Tilly	16/10/93	7.50	446	222
9	Gorai off-take	29-30/9/93	11.98	2,865	6,008
10	Arial Khan off-take	8/10/93	5.63	1,990	1,910
11	Bhairab Bazar	12/10/93	5.36		160

Table 4.2: Stage-discharge-sediment transport results, routine gaugings

4.5 Bathymetry

Various bathymetric surveys have been executed in the reporting period, as depicted in the following table:

Location	survey periods in 1993	area km^2	inter-distance factor	total area km^2
Bahadurabad	15 - 31 May	-	-	-
do	10 - 26 June	91	2.2	200
do	25 Aug.-5 Sep.	91	2.2	200
do	10-20 November	91	2.2	200
Jamuna - Ganges confluence	15-31 October	300	1.0	300
Hurasagar	23-30 November	50	2.2	110
			Total bathymetric area in 1993	1010

Table 4.3: Bathymetry surveys in 1993

The first survey mentioned in this table was actually a water-line survey.

As specified in the contract, charts for morphological studies are made o. .he following scales:

interdistance 200 m → scale 1 : 20.000
interdistance 100 m → scale 1 : 10.000

Both 'bathy-charts' with digital depth information and contour plots are made. A small-scale example of a contour plot is shown on Figure 4.4. The results of the bathymetric surveys are presented in separate reports:

Survey Report 9: Pilot bathymetric survey in Bahadurabad (in 1993)
Survey Report 11: Bathymetry of the Jamuna - Ganges confluence, Hurasagar and Arial Khan in 1993/94

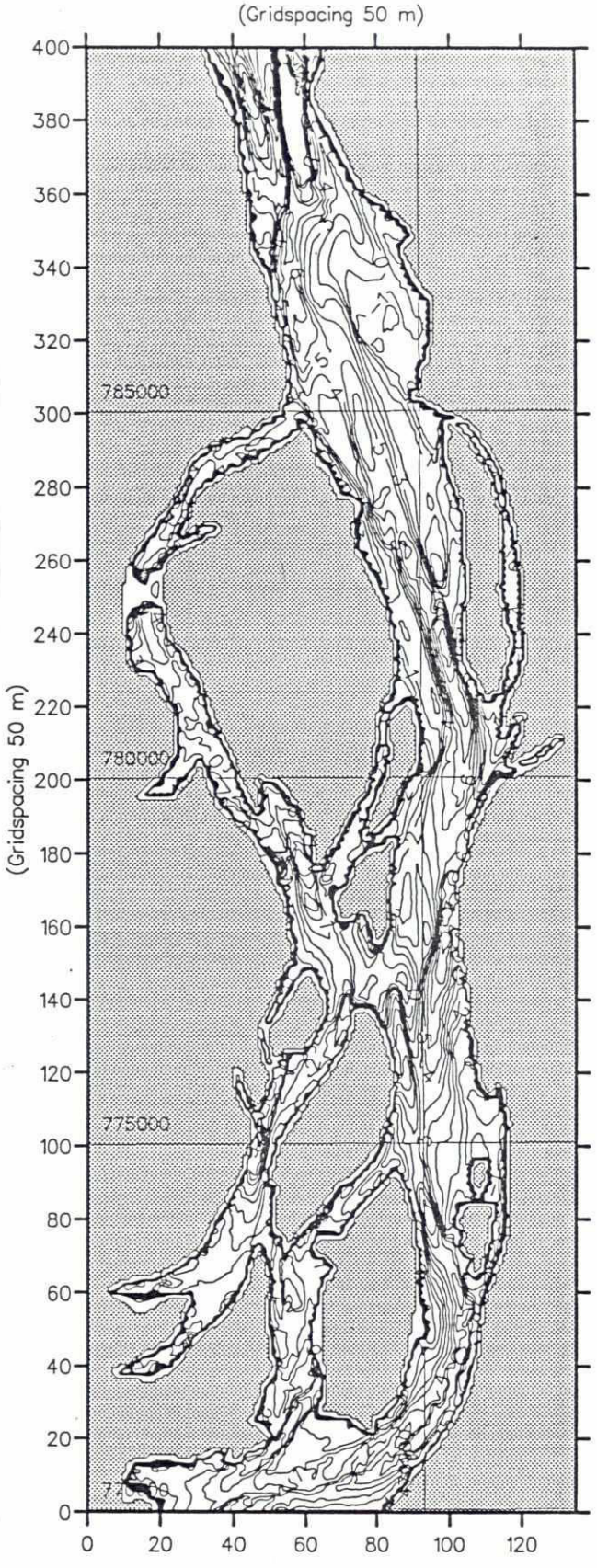


Figure 4.4: Contour plot, Bahadurabad, November 1993, SLW datum, scale appr. 1:95,000

4.6 Test gaugings

Test gaugings were executed in the second half of October 1992 on Jamuna River near Bahadurabad. The gaugings comprise:

- o Performance tests to check the equipment
- o Trials to check operational procedures
- o Optimization tests to optimize measuring methods
- o Overall acceptance tests to determine the appropriate techniques

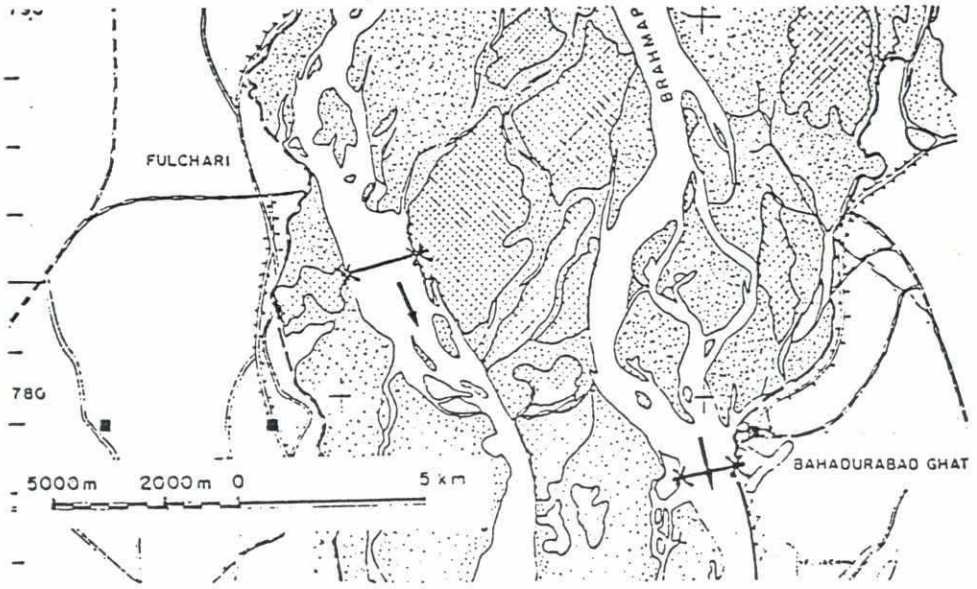


Figure 4.5: Measuring site

Because of the late project start, the test gaugings were executed at the end of the monsoon period of 1992 (second half of October). Moreover, the monsoon of 1992 was very moderate. As a result, the tests were executed in mid flow conditions (less than 20.000 m^3/s). For the final acceptance test, higher flows were desired, and therefore it was decided to execute the acceptance tests in the monsoon of 1993.

The gauging programme of October 1992 is given in the Revised Inception Report (Enclosure G). The results of the tests are described in the 1° Interim Report. For the acceptance tests in 1993, a special programme outline was made (Survey Note 4). The survey data was presented in *Survey Report 3: 'Test Gauging Report'*. The interpretation of the data is given in *Survey Report 4: 'Selection of Survey Techniques'*.

The main results of the test gauging is in fact the selection of the survey methods and instruments to be used in phase 2 of the River Survey Project. This is summarized in the following table:

Type of measurements	Proposed method		
	Routine measurement		Special measurements
	Main channels	Minor channels	
Positioning	DGPS	(same)	(same)
Water-level	- acoustic - pressure -	(same) (same) -	(same) (same) staff gauge
Bathymetry	echo-sounder	(same)	(same)
Discharge	moving boat	(same)	(same) vel-area
Velocity	ADCP + EMF ADCP - - -	- (same) EMF - -	(same) (same) (same) S4, Ott float
Suspended sediments	depth integrating collapsible bag - - - ADCP	(same) depth-integrating bottle sampler - - -	(same) (same) pump bottle optical (same)
Bed load	dune tracking H-S trap sampling - ? ?	(same) (same) - ? ?	(same) (same) side scan Delft Bottle alternative ?
Bed material	US BM-54 -	(same) Van Veen grab	(same) (same)

Table 4.4: Summary of proposed methods (November 1993)

It should be mentioned here that the methods are proposed partly because of the results of the test gaugings, partly because of the experience gained on the rivers and partly as a result of the discussions during the International Workshop.

The above table contains some question marks regarding the method of bed load measurements. The reason is that the acceptance tests in August 1993 revealed that the applied methods viz. dune tracking and Helley-Smith sampling have both their limitations in the high flow range. This means that other methods will be tested in the monsoon of 1994.

It is noted here that part of the testing of instruments is done within the scope of the special surveys, described in the following section. Also further optimization of measuring techniques is done as part of our Study programme (subject 9).

4.7 Special surveys

In the reporting period the following special measurements were executed:

Location	Period	Type of survey
4.7.1 Bahadurabad	6-20 September 1992	Anwesha survey
4.7.2 Lower Meghna	14-24 December 1992	ADCP testing
4.7.3 Bahadurabad	6-11 January 1993	Comparative measurements
4.7.4 Khulna	8-9 April 1993	Tidal measurements
4.7.5 Bahadurabad	June - December 1993	Slope measurements
4.7.6 Bahadurabad	23-24 August 1993	Comparative measurements
4.7.7 Baruria	7 November 1993	Workshop demo

Table 4.5: Special measurements 1992/93

4.7.1 Anwesha survey

Due to the late start of the project (8 June 1992) it was clear that mobilization could not be completed before the high flows of the rivers, say in August. Therefore it was decided to execute a special measuring campaign with rented equipment: vessels and instruments. For that purpose the survey vessel *'Anwesha'* was rented from the BWDB, including survey instruments, crew and survey team. The work to be done was outlined in *Survey Note 1: 'Proposal for additional survey Bahadurabad'*. The measuring methods were given in *Survey Note 2: 'Anwesha Survey,*

Technical Guidelines' and the results are presented in *Survey Report 1: 'Additional Survey, September 1992'.*

Important results from this survey were amongst others the following observations:

- o The staff gauges of Fulchari and Bahadurabad need re-levelling
- o The measured discharge is much lower than recent rating curves indicate
- o One rating curve per channel to be considered during less than bankfull discharge flow conditions
- o Flow directions vary considerably in the cross-section so directional flow meters are desired

4.7.2 ADCP testing

After the test gaugings in October 1992 in mid flow conditions (less than 20.000 m^3/s), several important questions were not answered:

- How is the vessel's behaviour in high flows ?
- Which anchoring procedures and equipment are needed in high flow?
- How will the ADCP behave in high flow, which is characterised by a combination of high turbulence and high sediment concentrations?

In an attempt to get some early answers (and not waiting for the monsoon of 1993), a proposal was made to select, in the tidal part of the river system, a place with high water and sediment flow and execute some measurements there, see *Survey Note 3: 'Proposal Additional Field Tests'.* Such a place was found in the Lower Meghna.

The results of these measurements are given in the *1° Interim Report.* The main result is in fact that the ADCP may indeed give troubles in the high sediment concentrations. When the ADCP 'looses bottom track' this means that the vessel speed over the river bed is not found instantaneously, which implies that the total flow cannot be corrected on-line for the vessel speed in order to obtain the water flow. The problem has been solved by deriving the vessel speed from the DGPS data (positioning data).

4.7.3 First comparative measurements

From 6 to 11 January 1993, discharge measurements were done together with a BWDB survey team. The measurements were done in the Zigabari channel (the left channel of the Jamuna) near Bahadurabad.

The results of this survey are reported in *Survey Report 5: 'Phase 1, Dry Season 1992/93'* (Section 7.1).

4.7.4 Tidal measurements

On 9 April 1993, tidal measurements were done at Hospital Ghat near Khulna, together with a BWDB survey team. The cross-section was only 370 m wide which made it possible to cross the river four times per hour. The results of the measurements of the River Survey Project are given in the following figure.

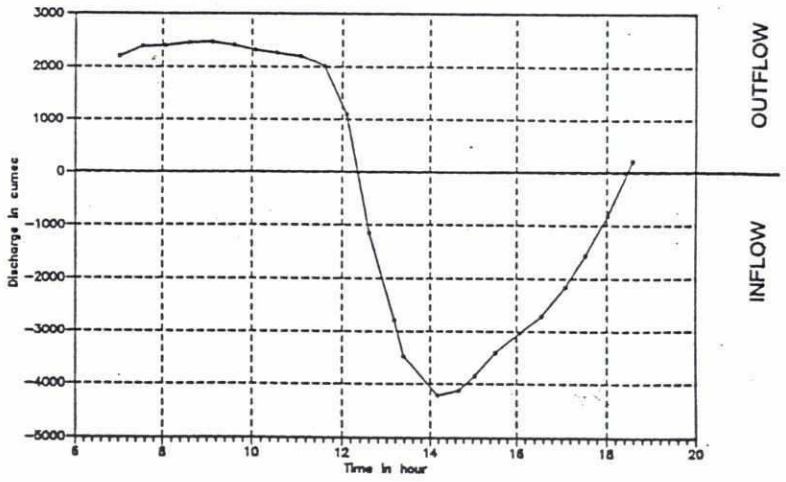


Figure 4.6:Tidal discharge variation at Hospital Ghat, April 9, 1993

The EMF/ADCP configuration applied in the moving boat method appeared to be very attractive in the tidal river conditions.

For further details, please refer to *Survey Report 5: 'Phase 1, Dry Season 1992/93'*, Section 7.2.

4.7.5 Slope measurements

A series of staff gauges were installed by the River Survey Project and operated during quite some period. For the location of the gauges see the following figure.

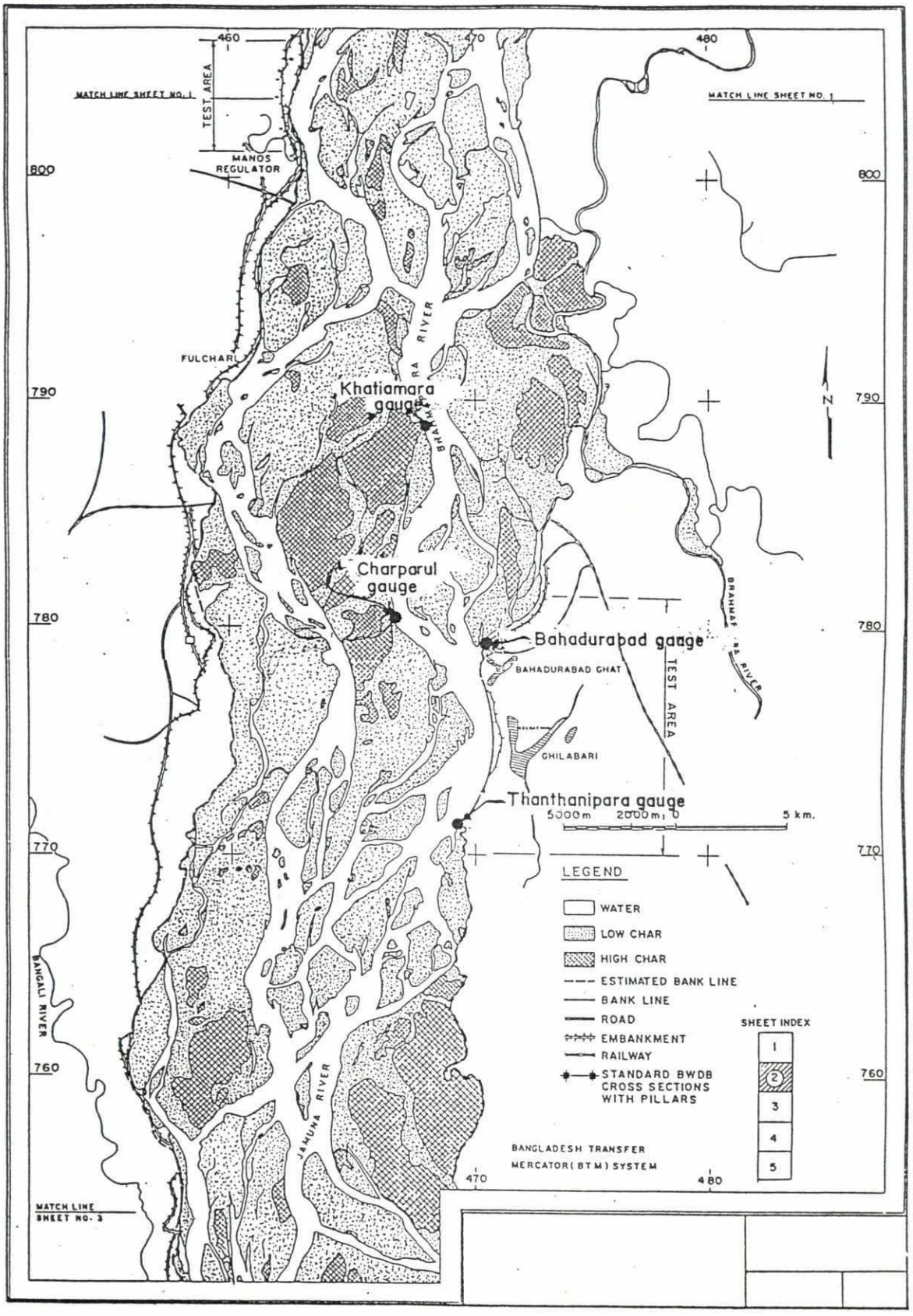


Figure 4.7: Location of RSP staff gauges near Bahadurabad

The periods during which readings are done are indicated in the following table:

Staff gauge	Period till 31/12/93
Bahadurabad	since 28/10 92
Thanthanipara	since 22/6 93
Khatiamara	since 15/6 93
Charparul	since 15/6 93
Gabgachi	since 2/7 93
Fulchari	since 26/10 92

Table 4.6: Staff gauges near Bahadurabad

The data sheets are brought to the office for digitizing and validation. The data will be published in *Working Paper 5: Water-level slopes.*

4.7.6 Second comparative measurements

On 23 and 24 August 1993, comparative measurements were scheduled to take place just after the final acceptance tests at Bahadurabad.

The results of these measurements have been summarized in *Survey Bulletin 10* appended to the *4° Quarterly Progress Report,* and in *Survey Report 8 on the Flood season 1993.*

4.7.7 Workshop demo

During the *International Workshop on the Morphological Behaviour of the Main Rivers in Bangladesh,* one day was used for a field visit to the vessels of the BWDB and the River Survey Project.

Demonstrations were given to show the operational aspects of the various survey techniques.

4.8 Chronology of survey activities

A chronology of survey activities is given in the table hereafter:

Month	Date	Survey activities
September 1992	6-20	First survey by the River Survey Project on the main river system of Bangladesh: Discharge measurements in Bahadurabad using mainly equipment from the BWDB (Anwesha), and together with a BWDB survey team. Mainly the reference method was applied
October 1992	21-25	Verification tests of current meters and other equipment near Bahadurabad
	26-27	Test gaugings right channel
	28	Test gaugings left channel
	29-1	Routine gaugings left channel
November 1992	2-5	Routine gaugings right channel
December 1992	14-24	additional test gauging on Lower Meghna. Special test on the performance of the ADCP in higher sediment concentrations
January 1993	5-17	Surveys in Bahadurabad: o testing of DGPS reference stations o discharge and sediment measurements partly together with BWDB o trials of bed-form measurements and dune tracking
February 1993	12-17	Dry season routine measurements at Bahadurabad. Trials with bed-form monitoring
March 1993	11-17	One LW routine gauging including some sand dune reconnaissance work by bathymetric surveying
	18-31	Return to Naryanganj dockyard for modification work and to prepare for the tidal surveys of April

Table 4.7: Chronology of survey activities -Continued-

Month	Date	Survey activities
April 1993	02-15	Tidal measurement campaign in the Sundarbans for SWMC (outside this Contract)
	08-09	Simultaneous and comparative (tidal) discharge measurements were carried out at Hospital Ghat upstream of Khulna by FAP24 and BWDB field teams
	16-25	Modification work
	26-28	Simultaneous and comparative tidal discharge measurements were carried out at Bhairab Bazar by FAP24 and BWDB field teams
	29 Apr - 27 May	Modification work at the dockyard to prepare the vessels for the coming monsoon Serious delays caused by importation procedures
May 1993	28-31	Survey spread returns to Bahadurabad to assist in completing installation of the first automatic water level recorder at Bahadurabad Ghat and to initiate routine gauging as well as the bathymetric pilot survey
	15-31	Bank line survey of Bahadurabad left channel within the bathymetric pilot survey area
June 1993	1-2	Installation of the AWLR at Bahadurabad Ghat completed
		Installation of a combined acoustic and pressure cell type water level recorder at Gabgachi completed
		Verification of GPS reference points
	3-9	HW routine measurement at Bahadurabad
	10-26	1° bathymetric pilot survey at Bahadurabad

Table 4.7: Chronology of survey activities -Continued-

Month	Date	Survey activities
June 1993 (continued)	27-28 & 30-1	Trials with sand dune tracking in combination with suspended sediment sampling and bed load transport measurements with the Helley-Smith sampler
July 1993	2-6	Modification of the survey spread with equipment just arrived from Europe
	7	Intercalibration of current meters subsequent to the modifications works
	8	Position verification and site reconnaissance for a new cross-section
	9-17	One complete routine measurement in station 1 - Bahadurabad - according to the reference method
	18	Transfer to Sirajganj site
	19-20	Site reconnaissance for location of cross sections suitable for measurements
	21-30	One complete routine measurement in location 2 - Sirajganj - according to the reference method
	31	Sand dune tracking
August 1993	2	Transfer to Baruria site and site reconnaissance for a suitable cross-section for measurements
	3-8	One complete routine measurement in station 5 - Baruria - according to the reference method
	9-10	Transfer to Bahadurabad site for test gauging
	11-15	Preparation for execution of test gauging
	16-22	Execution of test gauging according to the agreed programme
	23-24	Comparative discharge measurements with BWDB in the right and left channel respectively and in the BWDB cross-sections

Table 4.7: Chronology of survey activities -Continued-

Period		Field measurements
August 1993 (continued)	25 - 5 Sep.	Second bathymetric pilot survey at Bahadurabad Ghat within the same specified area involving the entire survey spread
September 1993		Continuation of slope measurement by established water-level staff gauges
		Intercomparison of the pressure and acoustic sensors of AWLRs installed near Gabgachi
		Visit of sites for installation of 10 nos AWLR
	6-11	HW routine gauging in Bahadurabad using the reference method and the recommended method
	17	HW routine flow gauging in Sirajganj using the recommended method
	19	HW routine gauging in Aricha using the recommended method HW routine flow gauging near Baruria using the recommended method
	26-29	HW routine gauging near Hardinge Bridge using the reference method
	29-30	HW routine gauging near Gorai Railway Bridge using the reference method and the recommended method
October 1993		Continuation of slope measurements
		Continuation of intercomparison of the pressure and acoustic sensors of AWLRs installed near Gabgachi
	1	HW routine flow gauging near Baruria using the recommended method
	3-7	HW routine gauging near Mawa using the reference and the recommended method
	8	HW routine gauging near the Arial Khan off take using the reference method and the recommended method

Table 4.7: Chronology of survey activities -Continued-

Period		Field measurements
October 1993 (continued)	12	HW routine flow and suspended sediment gaugings near Bhairab Bazar using the recommended method
	15-31	Bathymetric survey in the Ganges-Jamuna confluence
	16	HW routine flow and suspended sediment gaugings near Tilly using the recommended method
	19-22	HW routine gaugings near Baruria using the reference method and the recommended method
	24-26	HW routine and suspended sediment gaugings near Sirajganj using the recommended method
November 1993	31 Oct-3	LW routine flow and suspended sediment gauging near Bahadurabad using the recommended method
	7	Demo measurements in relation to the International workshop were performed near Baruria
	23-30	Bathymetric survey at Bahadurabad and Hurasagar
December 1993	4-5	LW routine gauging near Baruria using the recommended method
	7-8	LW routine gauging near Sirajganj using the recommended method
	10-13	LW routine gauging near Bahadurabad using the recommended method

Table 4.7: Chronology of survey activities

5 Land survey

The land survey work consists of various activities such as:

- positioning of the DGPS reference stations
- (control) levelling of reference levels including construction of new bench-marks
- zero control levelling of water-level stations (both AWLRs and staff gauges)
- topographical work

5.1 Reference stations

The positioning of the survey vessels is determined with the aid of the Global Positioning System GPS. The system implies that a receiver is installed aboard the vessel which receives signals from orbiting satellites. From the position of various satellites as a function of time, the position of the sailing vessel is calculated. The GPS used in the so-called dynamic mode (which means from a sailing vessel) has an accuracy of 50 to 100 m.

In order to obtain a substantial improvement of that accuracy, Differential GPS (or DGPS) is used. This implies that a so-called reference station is erected at a known location near the survey site on the river bank. The reference station contains a receiver and measures its position by the satellites. The measured position is compared with the known position, and the difference is sent by a VHF radio link to the vessel in order to correct the vessel position. This happens on-line, and an accuracy (in the dynamic mode) is then obtained in the order of 5 m.

The accuracy is obviously also depending on the distance between the reference station and the survey vessel. It is preferred to have this distance as short as possible (also in view of the range of the VHF radio link). With the short range DGPS system applied in the River Survey Project these distances are in the order of 20 to 30 km.

Essential in this process is of course that the reference station is set up in a known position (a bench mark with well established coordinates). Usually, when a convenient location in the field is found for the station, the position is not known and needs to be measured accurately.

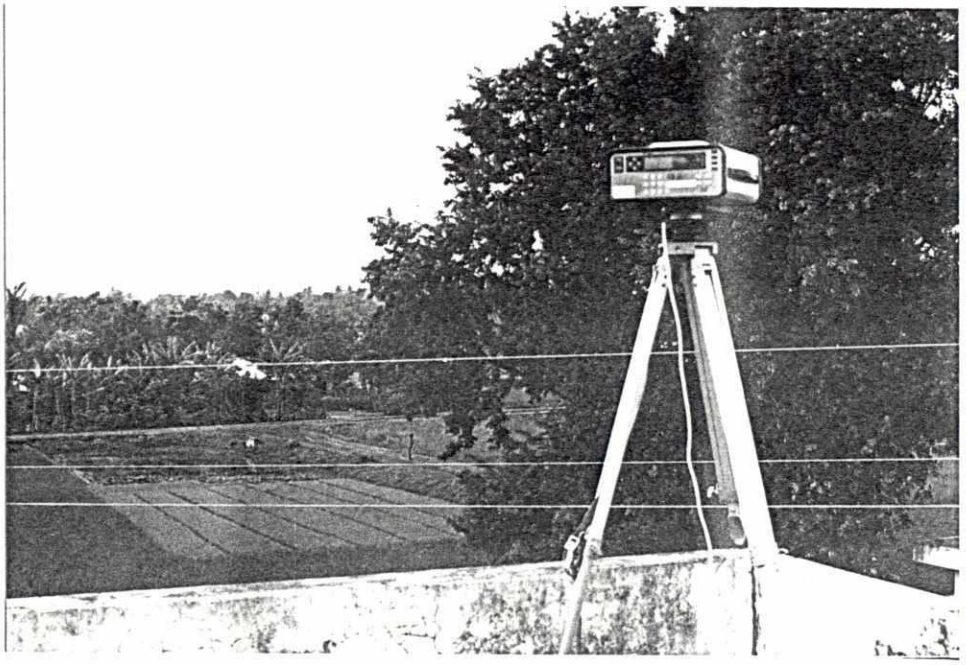


Figure 5.1: Reference station at Talbaria (near Hardinge Bridge)

Determination of the coordinates of the reference station is also done by using DGPS, but now in the static mode. Moreover, the differential corrections are not made on-line but off-line in order to obtain a higher accuracy. In principle, the applied method is as follows:

Receivers (in fact the antennas of the receivers) are placed on top of a bench-mark with known coordinates and at the reference station of which the coordinates are sought.

During one to two hours, both receivers measure their respective positions from the satellites. These recordings are off-loaded and sent to the office where the three-dimensional vector between the two positions are determined with a special computer programme.

The accuracy claimed is in the order of one part per million of the vector length.

This means in reality, with interdistances in the order of 10 km, that the accuracy is in the order of 1 cm. Consequently, the uncertainty in determination of the coordinates of the reference station (of a few cm) is negligible in comparison with the accuracy of the dynamic vessel positioning (of about 5 m).

The reference stations used in the River Survey Project are portable and are moved to the sites where survey activities are planned. These sites are the areas of the routine gaugings and the bathymetric surveys, see the previous chapter.

5.2 Reference levels and bench-marks

For the vertical control of river survey work extensive bench-mark networks were constructed in the past along the main rivers of Bangladesh. There exists, among others, a BWDB network and a 'Finnmap network'. The latter was just completed in 1993 and is under review/validation of the Survey of Bangladesh (SoB). After acceptance (expected in 1994), the network will become part of the SoB network.

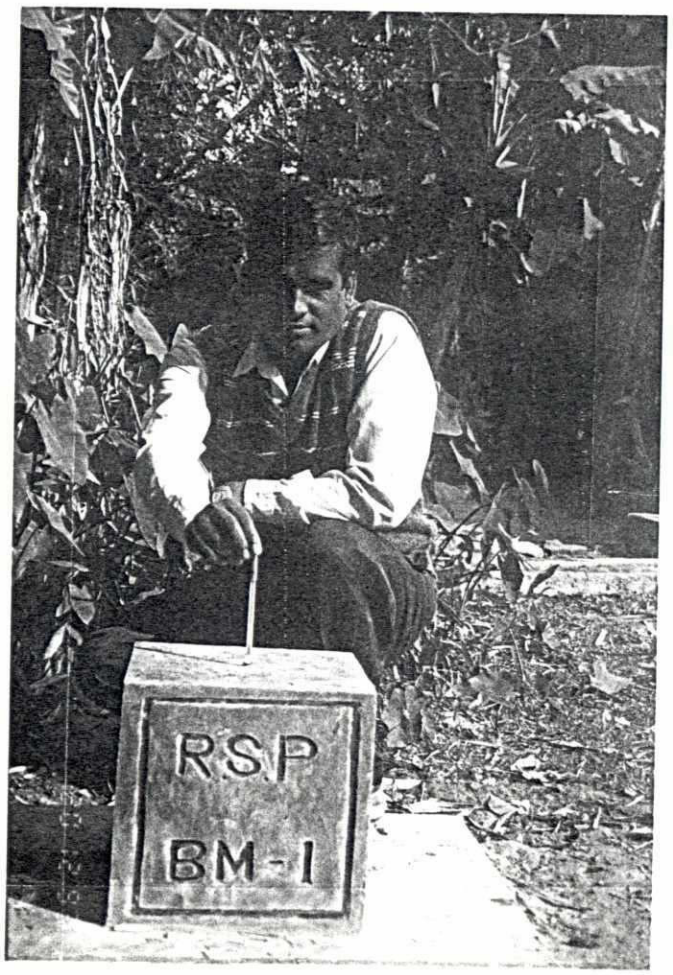


Figure 5.2: Bench-mark near Sengram

The River Survey Project is in principle merely a user of the bench-mark data, as these are made available to the project through FPCO. Nevertheless, some work has been done in the reporting period, especially dealing with:

- o construction of bench-marks
- o establishing the coordinates of these bench-marks
- o checking levels in between existing bench-marks

Bench-marks are mainly constructed to establish a reference level for a near-by water-level station (a staff gauge or an Automatic Water Level Recorder). Many temporary bench-marks are made, often of galvanized iron pipe embedded in concrete, see for instance *Survey Report 7: 'Transfer of bench-mark levels across the Jamuna River near Bahadurabad'*. In two cases, a permanent bench-mark was constructed: One near Fulchari and one near Sengram (see also Section 5.3).

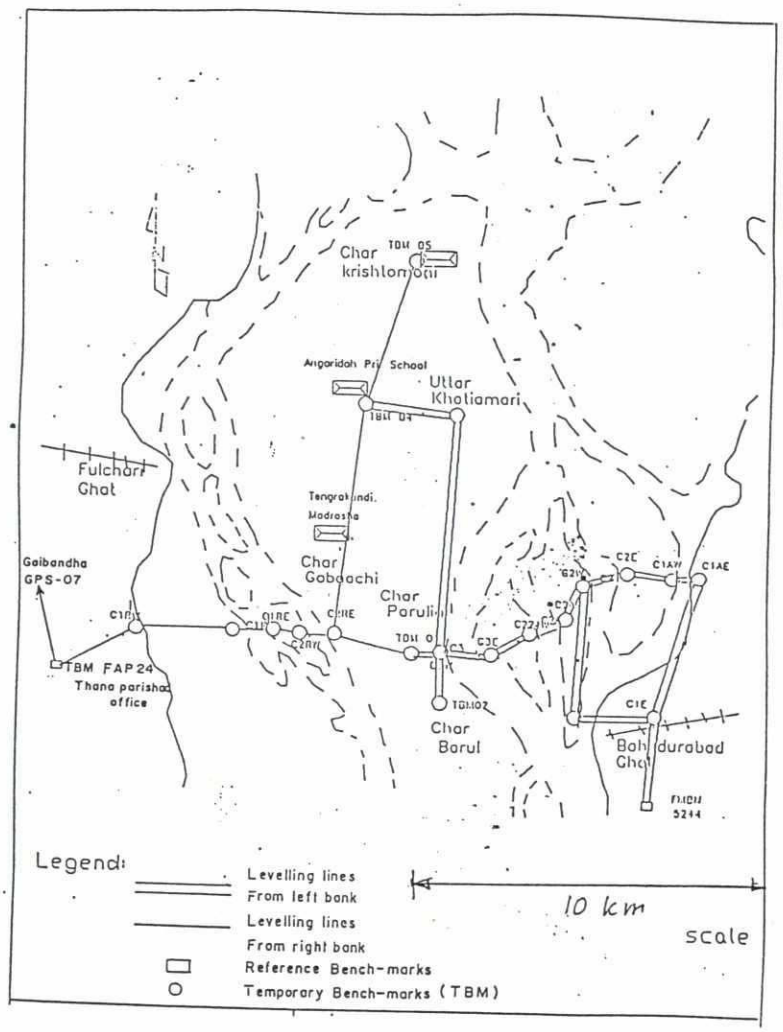


Figure 5.3: TBM's on central island

For the temporary bench-marks, usually only the levels and not the position is determined. This is done by second order levelling. In one case, such a levelling was executed while crossing the Jamuna River near Bahadurabad. The main purpose of this work was in fact to have a small network of temporary bench-marks (TBM's) on the central island between Bahadurabad and Fulchari.

This network was required for zero control of temporary staff gauges to be used to study local water level slopes. In order to determine the TBM levels, the network was connected with existing bench-marks on the left and on the right bank of the river.

1992 was a dry year, and the levelling work was done in December when water-levels were already low and the width of the two main channels to be crossed were limited to about 1000 and 500 m.

It is noted that accurately transferring levels across a river or a channel is a project in itself. Although several methods were tested it was decided to apply trigonometric levelling, being the best available method at that time. Results of this levelling were presented in *Survey Report 7,* mentioned above.

Although checking of levels in between existing bench-marks is not a part of the River Survey Project, it is common practice that, when levelling work is executed (for whatever purpose), nearby existing bench-marks are included. As a kind of secondary result, the levelling provides then a check on the bench-mark network. As bench-mark levels may change for various reasons, such field checks are always useful. On a SoB/FPCO/FAP meeting, survey teams were invited to report the results of these kind of checks. When survey teams of the River Survey Project executed the extensive levelling work for zero-control of BWDB water-level gauges (Section 5.3), both BWDB and Finnmap bench-marks were used and differences were published in *Survey Report 2: 'Land Survey, Water-level Gauging'.*

5.3 Zero control of water-level stations

One of the tasks of the River Survey Project is to execute a one-time verification of the zero levels of 47 BWDB water-level gauging stations by second order levelling.

The stations are listed in Table 5.1, and the locations are given in Figure 5.4.

Brahmaputra/Jamuna

1	45	Noonkhawa
2	45.5	Chilmari
3	46	Kamarjani
4	46.9L	Bahadurabad
5	46.9R	Fulcharighat
6	48	Jagannathganj
7	49.A	Kazipur
8	49	Sirajganj
9	50	Porabari
10	50.3	Mathura
11	50.6	Mathurapara

Ganges

1	88	Rampur Boalia
2	89	Sardah
3	90	Hardinge Bridge
4	91	Talbaria
5	91.1	Sengram
6	92.1	Mahendrapur

Padma

1	1.9L	Baruria
2	91.9R	Goalunda
3	93.42	Bhagyakul
4	93.5L	Mawa
5	94	Tarpasha
6	95	Sureshwar

Dhaleswhari

T	68	Tilly

Old Brahmaputra

1	225	Jamapur
2	228.5	Mymensingh

Arial Khan

A	9A	Arila Khan off-take

Gorai

G	99	Gorai Railway Bridge

Upper Meghna including Kushiyara

1	266	Kanairghat
2	267	Sylhet
3	268	Chattak
4	269	Sunamganj
5	270	Markuli
6	271	Ajmiriganj
7	272	Madna
8	272.1	Austagram
9	273	Bhairab Bazar
10	274	Narsingdi
11	275	Baidder Bazar
12	275.5	Meghna Ferryghat
13	276	Satnal
14	277	Chandpur
15	172	Amalshid
16	173	Sheola
17	174	Fenchuganj
18	175.5	Sherpur

Note: First number or letter is map reference for Figure 5.4
Second number is BWDB reference number

Table 5.1: List of BWDB water-level stations

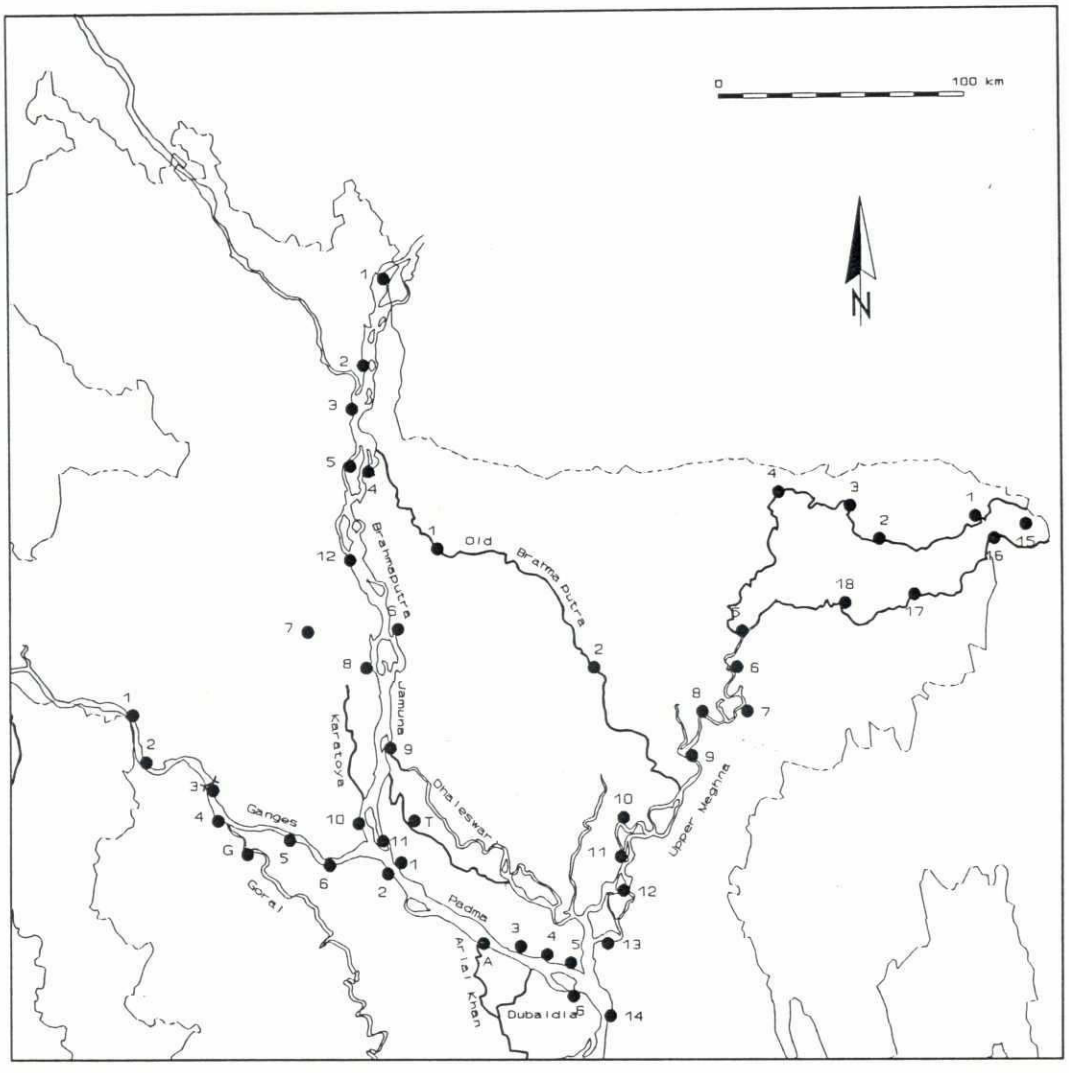


Figure 5.4: Location of BWDB water-level stations

The verification of the zero levels of the water-level stations (staff gauges) was done by levelling between a nearby BWDB bench-mark with a known level and the station. This work, executed in the first half of 1993, was done in four steps:

- First, an inspection visit was paid to the station. Then detailed location sketches were made of the bench-mark and the water-level station (see as an example Figure 5.5) for our own purpose, but also to facilitate inspection activities in the future.

- Then inspection reports were produced with indications of the conditions of bench-marks and gauges, and suggestions for improvement when deemed necessary. See as an example Figure 5.6. A summary of the recommended improvements was submitted to FPCO for further action.

- Thirdly, second order levelling was carried out from the BWDB bench-mark to the staff gauge. When possible, nearby Finnmap bench-marks were included in the levelling.

- Finally, the results were published in *Survey Report 2: 'Land Survey. Water Level Gauging'*.

The main results of this zero-control work can be summarized as follows :

1. Clear description of locations and condition of bench-marks and water-level stations.

2. Table comparing the applied zero levels of the gauges with the levelling results of the River Survey Project.

3. Table with information on measured differences between the BWDB and the Finnmap bench-mark network.

4. Proposal for some improvements of the BWDB bench-mark network.

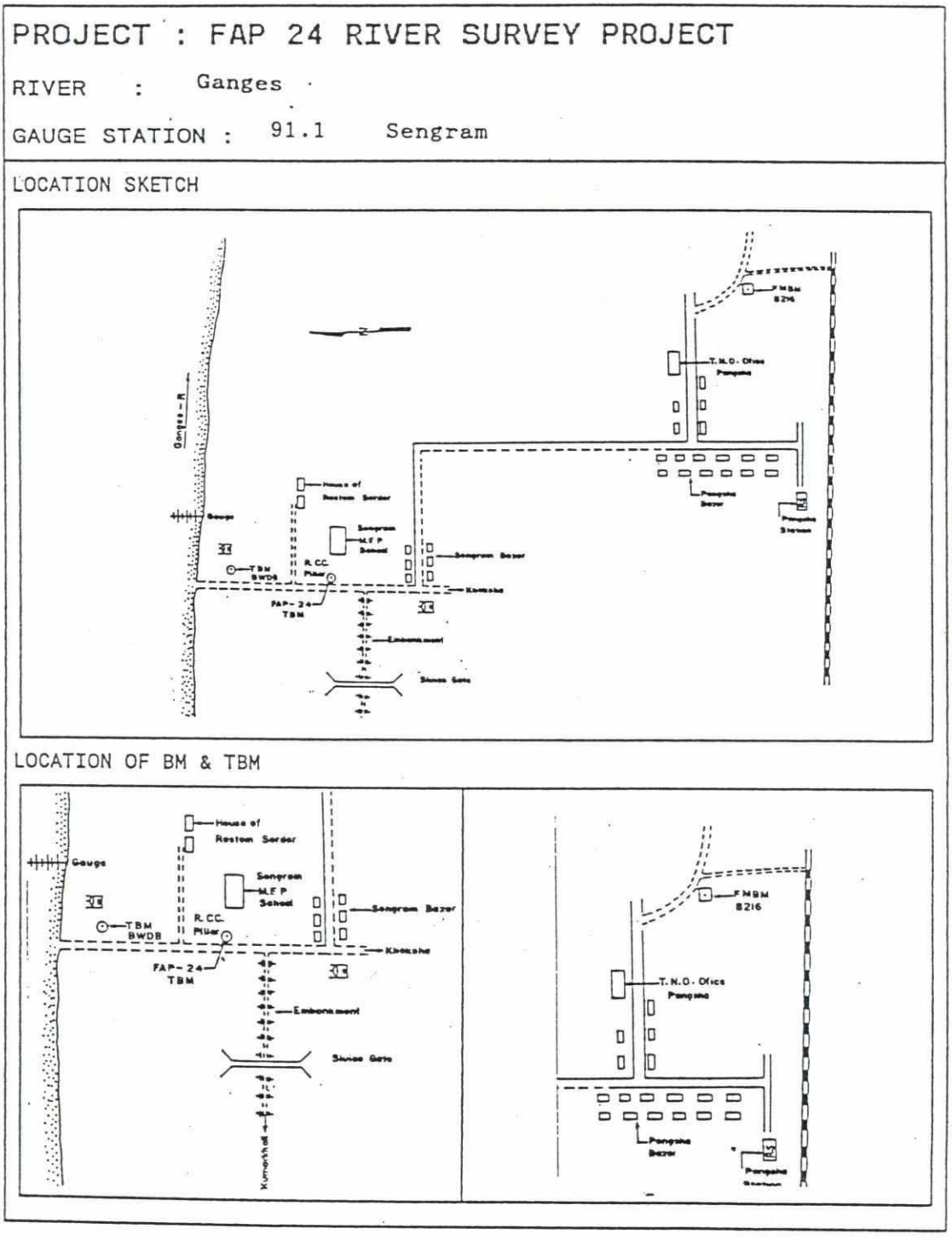


Figure 5.5: Location sketch (example)

RIVER SURVEY PROJECT FAP-24
INSPECTION REPORT

1. Gauge.
   Name of gauge station : 91.1 Sengram
   Date of visit : 31.01.93
   Condition of gauge : Good
   Remark : -

2. Bench mark
   Calibration benchmark present : ~~yes~~/no
   Name : TBM
   Location : Sengram

   Height : -
   Condition : ~~acceptable~~/not acceptable

3. If,not acceptable,give reasons: TBMs at Sengram considered to be not acceptable as their locations and heights are doubtful.

4. Distance of gauge to BM : 0.5 Km

5. Conclusion, recommendation : yes/~~no~~
   Improvements required, if yes, describe. (Give recommended steps) : One B M FAP 24 91.1 be established at Sengram and its height be determined by levelling with nearest FMBM 8216, located at about 15 Km from Sengram.

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

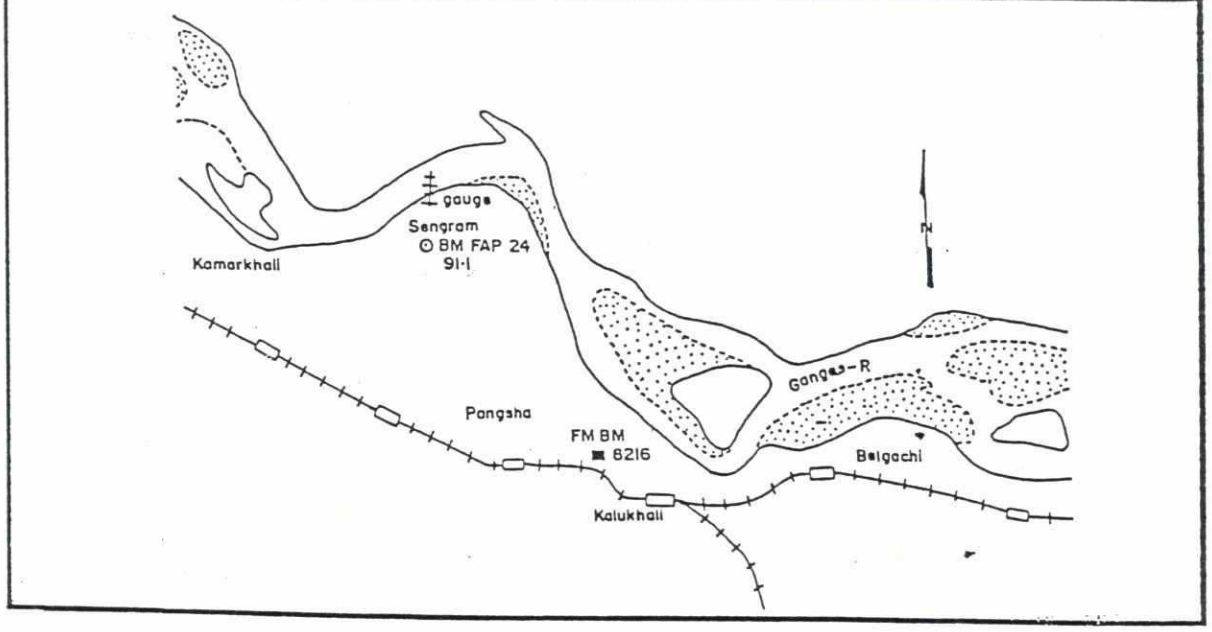


Figure 5.6: Inspection report (example)

5.4 Topographic work

As outlined in the Technical Specifications, topographic information is required for the analysis of the morphological changes in the different river stretches. This implies that topographic survey work is envisaged in the dry part of the river bed. In fact, the configuration of the dry part of the river bed needs to be measured supplementary to the wet part which is measured by the bathymetric survey.

By the end of 1992, and in early 1993, test measurements were performed near Bahadurabad to find the best method for the topographic surveys. The results of these measurements (partly reported in the *1° Interim Report, Annexure 2),* can be summarized as follow :

- The tachymetric method is preferred because of productivity, integration in the existing positioning system and easy interfacing with the existing software.

- The amount of topographical work should be minimized by applying alternative methods such as water-line surveys and remote sensing techniques.

In May 1993, the first water-line test survey was executed, see Section 4.5.

Although the results were promising, the method appeared to be rather time-consuming and operational improvements were sought. Basically, the idea is to add the water-line on the bathymetric map thus defining the zero line of the corresponding contour plot. By repeating this during different stages of the river, lines of equal depth are collected. To improve the water-line survey capacity, a portable back-pack DGPS system was procured.

Another alternative consists of using radar images during the monsoon to monitor flood extent and thus water-lines. This is studied by FAP 19.

The possibility of using satellite based radar to collect bathymetric information will be studied in 1994/95 by the River Survey Project. If the method is successful and can be used during the highest water-levels there is no need anymore for topographic work.

6. Data processing

6.1 General

The River Survey Project's own production of field data may be divided into four categories:

- routine surveys of flow and sediment transport at 11 locations, by a combination of procedures that include ADCP transect measurements and individual vertical profile measurements
- water-level recordings, at permanent or temporary stations, by staff gauge and/or AWLR
- bathymetry surveys
- special surveys, carried out for (i) specific study purposes (ii) testing, comparison or validation of instruments, or (iii) testing, comparison or validation of working routines. These surveys are carried out by individual procedures selected for the occasion

The data processing for the first three categories is carried out according to standardised procedures, whereas the results of the special surveys are processed according to the specific requirements of the miscellaneous studies that they support.

6.2 Routine surveys

The data from the routine surveys are compiled on-line onboard the survey vessel. The following types of raw data files and additional information are produced onboard the vessel:

- So-called HSB files, which are binary files from the Hydropac software package. They contain series of position (from DGPS), time, and depth (from echo sounder). The corresponding off-line ASCII files are called HOD files
- so-called ACQ files, which contain series of position (from DGPS), time, and current velocity components as distributed over the depth in a grid relative to true north. The current is recorded either by ADCP, by S4, or by EMF. The ACQ file can contain turbidity recordings as well. An HSB file is produced together with each ACQ file
- different types of sediment and water samples, to be analyzed in the project laboratory in Dhaka
- a survey log

The raw data file labels follow a strict convention. The 8-letter file name is coded in a way so that the name identifies the station, year, month and date, vessel, type

of measurement, and a sequence number. The 3-letter raw data file name extension indicates the file type.

> *Consider for example a file named B2AL1T08.ACQ. The name shows that this file origins from Bahadurabad (= B), and was measured on October 21, 1992 (= 2AL) by the DHA vessel (= 1). The data describe a moving boat cross-section transect (= T), and the sequence number of that transect is 8 (= 08). The file is an ACQ type with the defined format of that file type, and it contains raw data as summarised above.*

One common file name is used for the raw data files and the derived files of processed data that origin from the same measurement series. The file name extension shows the extent of processing and transformation. Details about the data file organisation are included in Annexure 1.

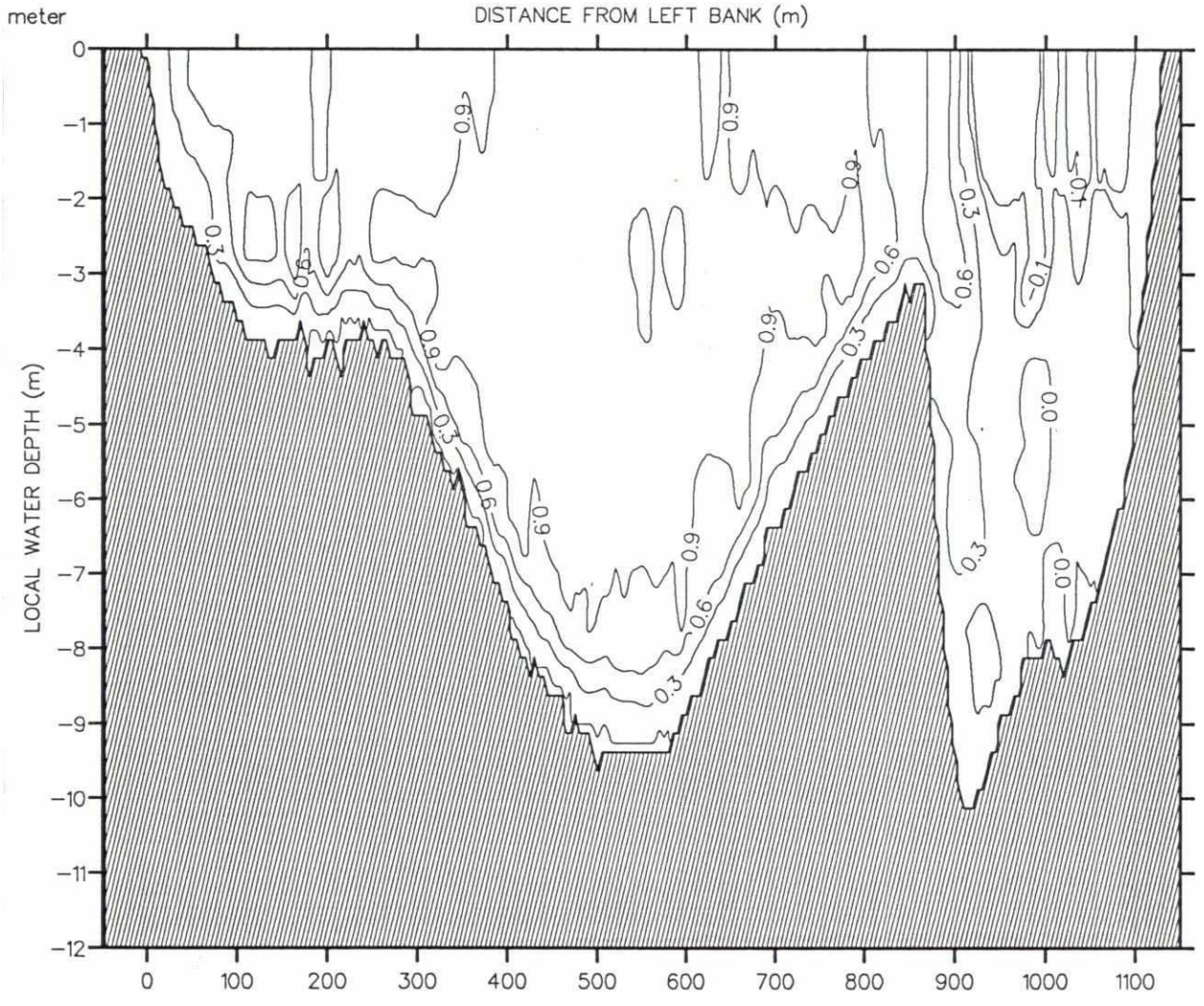


Figure 6.1: Sample presentation of cross-sectional current speed distribution measured by ADCP and EMF moving boat method (example from Bahadurabad, left channel, December 10, 1993)

Each moving boat transect will produce around 1 Mb of raw data, and each individual vertical profile will produce around 0.1 Mb of raw data. Hence, a typical routine survey will produce somewhere around 10-15 Mb of raw data for each survey at each location, and sometimes more.

The off-line data processing comprises conversion of the binary HSB files to corresponding ASCII type HOD files. Selected cross-section transects and all individual profiles are plotted for quality check and subsequent data reporting. All files are entered into the raw data catalogue and are stored.

Software used for the routine post-processing are modules from the Mike 21 Pre- and Postprocessing software package, standard spreadsheets, and utility programmes developed at the River Survey Project.

The different types of samples of river bed sediments and suspended sediments are analyzed in the laboratory for concentration, settling velocity distribution, and grain size distribution, according to the established routines. The results are stored in separate data files at the post-processing office in Dhaka.

A brief summary of results of the routine surveys are presented in *Survey Bulletins,* which are issued as a series, each bulletin describing one survey at one location. Hence, the 23 routine surveys completed by the end of the monsoon season 1993 were reported in Survey Bulletins nos. 1 through 23. In addition to an outlook of the findings, the Survey Bulletins indicate file names for the collected data. The bulletins are intended both as a documentation of the field work that has been carried out and as a reference for the data users.

During Phase 1 of the project, the work load required for post-processing has gradually been reduced to a level of around 4 working days per Survey Bulletin. However, a substantial additional work is required for the subsequent data reporting.

6.3 Water-level recordings

In phase 1 of the River Survey Project, with a few exceptions, all water-level recordings were made by staff gauge readings. Results of the water-level recordings are digitised, converted, plotted, controlled, edited as required, and stored for subsequent analysis. The conversion is a transfer of the reference level from the zero value of each staff gauge to the selected datum, which is normally PWD datum.

The data editing comprises correction of punching errors, removal of occasional spikes from the record, and correction, wherever possible, of casual stage shifts.

The processed data from each record are stored in two files, one containing all readings, and one containing daily mean values.

6.4 Bathymetry surveys

These surveys produce as much as up to around 80 Mb of raw data per km² of survey. Results are stored in the on-line HSB files, which are named according to the general file name standard of the project.

The on-line control comprises position control and area coverage (by plotting and monitoring the survey lines). Occasional DGPS instabilities, which result in an apparent abrupt position shift, are labelled for correction later on. Also, the depth recordings are monitored on-line, and irregularities, if any, are identified.

The raw data HSB files are converted into HOD files at the data processing office. The recorded depths are converted into levels relative to the selected datum. The conversion is a function of time and space, as determined by water-level recordings from the survey area relative to the datum. The bank line is specified, and the data are inspected once again for position and depth irregularities by plots or on the computer screen. Results are presented as follows:

- bathymetry charts, which show survey lines and soundings along the lines to the extent possible at the selected scale
- contour plots, based on interpolated fields of water depths or river bed levels, by application of an arbitrary smoothing of the contours

The originally selected interpolation and smoothing routines from the Hydropac software package were found to be inadequate for the present project. Instead, routines from the Mike 21 Pre- and Post-processing software package have been implemented. The routines have been adapted for the present project, and their performance has been optimised and validated by a comprehensive comparison between raw data, processed data, and final data presentation.

The workload required for post-processing is 8 working days for a large survey, such as a flood season survey at Bahadurabad, and 4 working days for a small survey.

The processed bathymetry data are stored in two types of data files: One file type, the so-called XYZ file, contains sets of position and depths along the survey lines. Another file type contains average depths for the entire survey area in a fixed grid, which is established by bilinear interpolation of the measured values. The former file type is big, and one survey area will normally comprise a large number of files. The latter file type is convenient for certain types of analyses.

For details about the processing of bathymetry data, please refer to *Survey Report 9: 'Bathymetric pilot surveys on Jamuna River at Bahadurabad'.*

6.5 Special surveys

The special surveys serve a variety of specific purposes, such as

- o individual studies of hydrodynamics, sediment transport and river morphology carried out within the River Survey Project. Please refer to Chapter 7 for details
- o testing, comparison or validation of instruments, or of survey procedures

These surveys are carried out by individual survey programmes that are specified for the occasion. To the extent possible, the programmes are composed of elements of procedures of the routine surveys.

Similarly, the data processing follow the routine procedures as far as these procedures can serve the objective of the special survey.

One important purpose of the individual studies and of the special surveys is to generate practical professional experience and to maintain a user feed-back for a continuous improvement of the field survey and the data processing routines.

The reporting of the special surveys is done in separate reports in the survey report series, the study report series, and the working paper series of the River Survey Project.

6.6 Quality control

As usual for this type of work, the data quality control is carried out in three stages:

- o on-line control
- o off-line control
- o user control

In the three stages, different types of errors and deficiencies are monitored, according to the increased aggregation of information.

The on-line control is an integrated part of the survey procedure. It comprises the survey documentation, the basic data coverage, the immediate data consistency, and obvious measurement errors. Errors and deficiencies to be detected can be for example improper performance of instruments or of the on-line data processing system; inconsistent recordings, such as for example instantaneous position shifts; or identification of unusual recordings, where values are outside of an anticipated range. The on-line control results in reporting of actual or potential deviations, and can result in an immediate decision to repeat a suspect measurement.

The off-line control is a more deep examination of the results, which normally involves examination of graphic presentation of data from one or more sources. Inter-station comparison is a common tool, for example whether some unusual flow fluctuation occurs at one station only, or whether the pattern appears in several independent records.

This exercise can be quite time-consuming. For example, a bathymetric survey may display an unusual steep slope between two successive soundings. This may be due to an error, or due to a true, but extreme bed level variation. An evaluation can involve an examination of the specific survey line, whereby for example erroneous spikes can be identified, or adjacent survey lines must be compared in order to find out whether an unusual feature is reflected in independent recordings.

Also, observations of unusual bed form developments can be partly verified by comparison of river bed levels from two successive surveys. If the field of level differences appears to be consistent, it is a strong supporting evidence that both surveys give a valid description of the true conditions. An example is given on Figure 6.2, which shows a plot of the field of differences between river bed levels measured at Bahadurabad in August and November, 1993. The comparison shows an even and smooth distribution of the recorded level differences, without apparent systematic trends, stepwise changes, or other irregularities. It is unlikely that such consistency could have been maintained if one or both of the surveys had been significantly affected by any type of error, such as position, depth or datum errors.

The data quality control is a process that continues for as long as the data are being used, and some errors or deficiencies will inevitably remain after post-processing and data reporting. For example, during a calibration of a hydrodynamic model, small errors within for example stage levels or phase lags can be detected that could not have been identified in any other way.

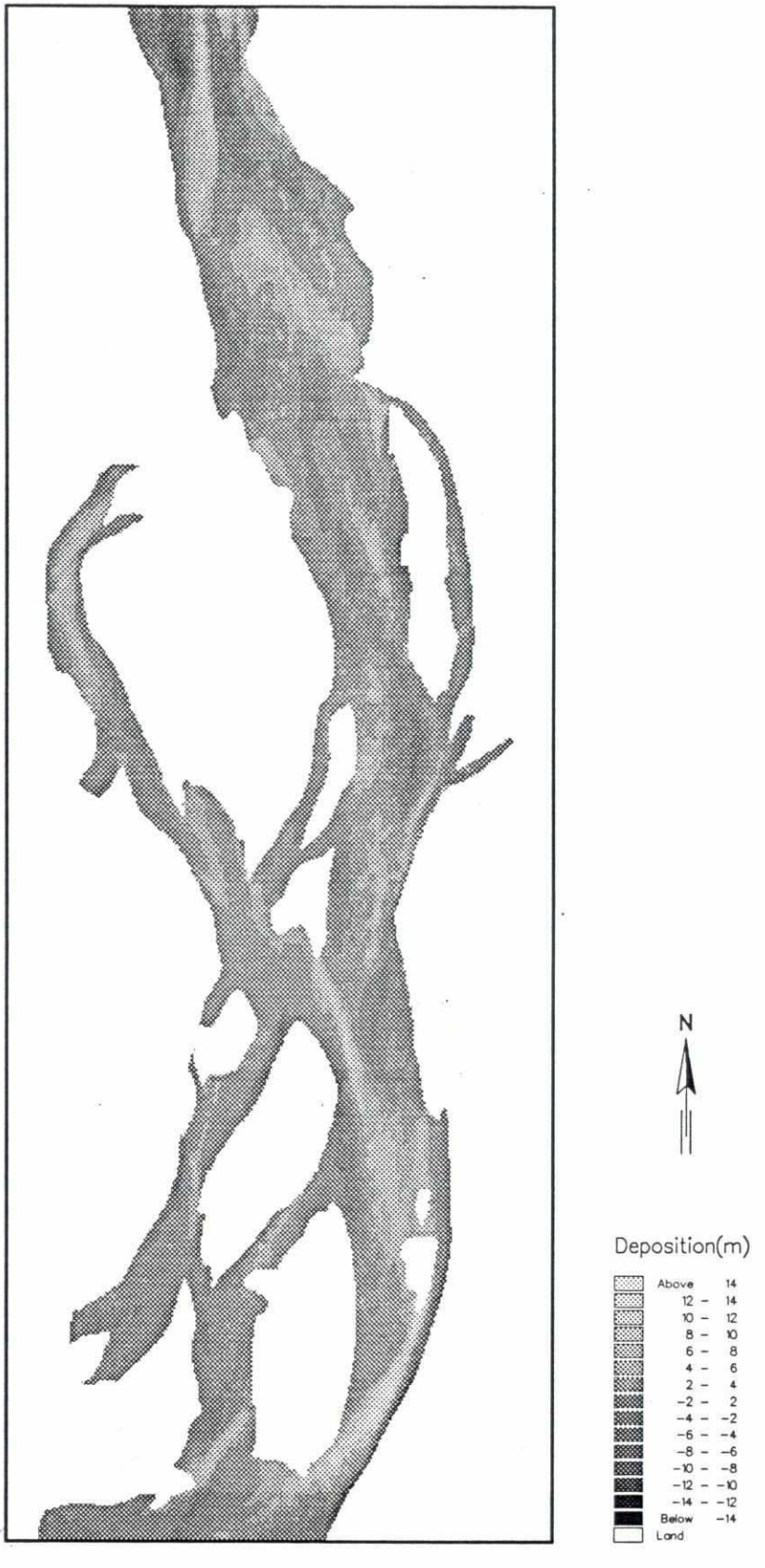


Figure 6.2: Plot of difference between river bed levels at Bahadurabad in August and November, 1993

6.7 Data catalogue and storage

The data are registered in the *Fieldman* catalogue system, which is an Oracle-based (UNIX) software system for data management and file retrieval.

Experience gained in Phase 1 of the project has indicated a user demand of a parallel DOS-based catalogue to be established in Phase 2, together with a data base with edited data files. This will improve the users' access to the data, at the cost of a substantial reduction of the data volume.

All raw data are stored in duplicate on magnetic tapes.

7. Studies

7.1 General

One of the objectives of the River Survey Project is to undertake special studies of the behaviour of the river systems in Bangladesh based on (1) the new data that will be collected during the surveys under the project, (2) existing data, and (3) through supplementary surveys.

As it is written in the ToR: *'This programme of river studies will be undertaken to investigate key characteristics of behaviour of the river systems. The river studies will address aspects of the main river systems which will not be covered under the various regional studies. ... Study topics will be finalised during the phase I and the study programme will have a strong bearing on the details of the hydrological and morphological data collection programme'*, being one of the other two components of the project. Furthermore, it is stated that under phase 1, it is required to *'Review the results of the surveys and studies carried out so far, and prepare a proposal for studies to be carried out during the next phase.'*

In the ToR, a distinction is made between the study topics to be taken up under phase 1 and those for phase 2. The study topics for phase 1 are clearly outlined and the relevant paragraphs of the ToR are quoted hereafter:

'Phase 1 studies:

(...) Collect, analyze and adjust as necessary, in consultation with FPCO and the PA, historical water levels and discharges of selected stations and present them both in tabular form and as frequency curves. Using these records prepare rating curves extended for extreme flood conditions and profiles of the water surface at different discharges for main rivers at different times of the year.

(...) Assess, analyze and report on available data on river morphology (BWDB cross sections, aerial photos, satellite imageries, BIWTA surveys etc) of the Brahmaputra, Ganges, Padma, Old Brahmaputra, Dhaleshwari, and the upper reaches of the Meghna, Gorai and Arial Khan, which is to be used for the definition of the programme under phase 2. This study will make a preliminary assessment of the morphological characteristics of the rivers, their shifting characteristics and expected response in qualitative terms as different components of the FAP are implemented.'

The studies as specified above were finalized during phase 1 of the project. *Study Report no. 2* regarding the hydrological studies was issued in June 1993, and *Study Report no. 3*, dealing with the morphological studies for phase 1 was published recently. The qualitative response of the river system as different

components of the FAP are implemented was assessed in *Working Paper no. 2,* published in March 1994.

For the phase 2 study the following is stated:

'Phase 2 studies

(...) Undertake a programme of studies to investigate key characteristics of the behaviour of the river system. The river studies would address aspects of the main river system that are essential for the planning of projects under the Flood Action Plan. ... The studies will be undertaken in response both to the demands of ongoing FAP studies and to the possible effects of planned Flood Action Plan projects on river regimes.

(...) The following will give an indication of the possible studies that the Consultants may be requested to undertake:

- *further refinement of the rating curves and estimation of peak flood flows at different flooding conditions*
- *further refinement of the profiles of the water surfaces at different discharges for the main river at different times of the year, as well as at different stages of implementation of various components of FAP*
- *quantitative assessment and evaluation of river response with respect to implementation of various FAP projects*
- *behaviour at the confluence of the Ganges and the Brahmaputra and the effect on the outlet of the Hurasagar*
- *the characteristics of overland flow during flood stages*
- *resistance and bed forms at various times of the year'*

In *Study Report no. 1,* the above list was reviewed and updated based on the outcomes of the phase 1 studies and other input. It was intended that the proposed study topics would be reviewed at *'an International Workshop at Dhaka on 'Morphological characteristics of Alluvial river and Their Behaviour with special reference to Bangladesh Rivers' (that) was be organized (...) in order to provide useful input in finalizing the study programme'* (quoted from the ToR). Due to various reasons, this review did not materialize. Nevertheless, a proposal for phase 2 activities to be taken up in the coming years was made.

The present chapter summarizes the different aspects of the phase 1 studies. Sections 7.2 and 7.3 deal with reviews of available hydrological and morphological data. Section 7.4 presents the key characteristics of the main river system as they arise from these reviews. The results of a qualitative impact assessment of FAP implementation are summarized in Section 7.5. Section 7.6 is dealing with the phase 2 study topics.

The contents of this chapter is a summary of the Study report nos. 1, 2 and 3 and Working Paper no. 2. For more detailed information, please refer to these reports.

7.2 Review of available hydrological data

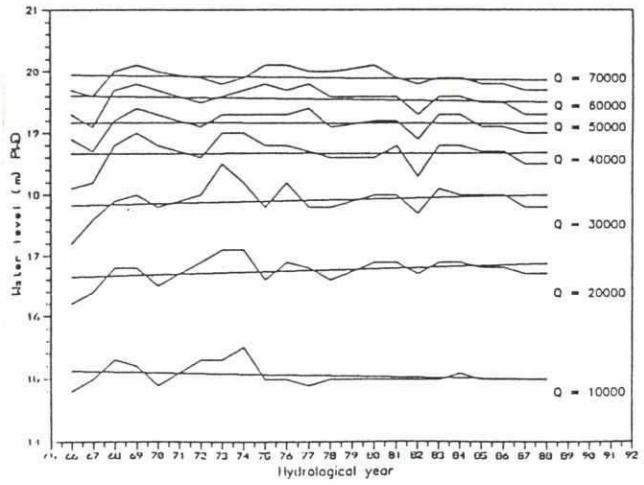
During phase 1, a substantial part of the resources available has been allocated to establishment of a data base with long time series of historical data for the main stations in the major rivers and to rigorous checking and improvement of the quality of these data. A number of agencies were approached to obtain information on past and ongoing studies and projects related to the objectives of the FAP 24 hydrological studies. Reports and available data were reviewed, and information on current procedures for collection, processing, checking and storage of data was obtained.

The major source of hydrological data is the Directorate of Surface Water Hydrology - II of BWDB. Most of the historical BWDB-data required for the present study was, however, available in computerized form at FAP 25, from where they were procured. The remaining data required, especially for the recent years after 1989 and for some additional stations, were procured directly from BWDB. The collected long historical time series have been stored in a well organized FAP 24 data base for historical data.

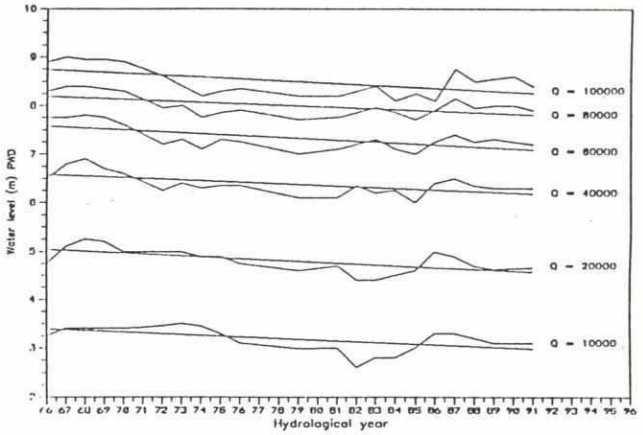
A systematic procedure for checking of water-level time series by plotting and comparison with series from adjacent stations has been set up, and the long water-level time series 1966-91/92 from the main discharge stations have been checked and corrected by this procedure.

An improved method for analyzing rating curves has been introduced, based on the ISO-standards. New annual rating curves for the period 1966-91/92 for five discharge stations in the main rivers have been developed by applying the improved and consistent rating curve method.

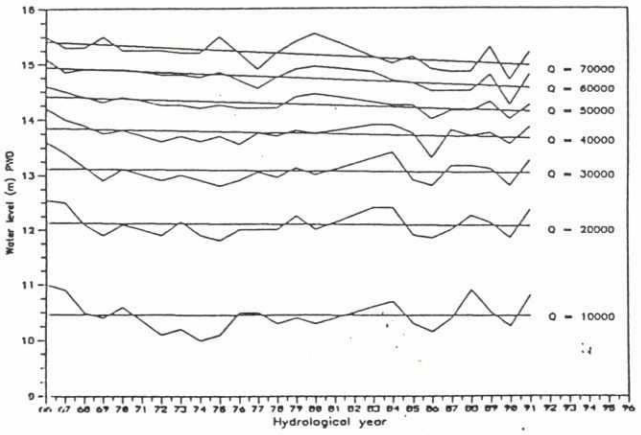
The trends and magnitudes of shift of the annual rating curves have been illustrated by plots of the variation of water-level for selected particular discharges (specific gauge analysis). At the stations in the major rivers there are no consistent long term trends in the water-levels for particular discharges, but variations from year to year up to about 0.5 m. This indicate that the major rivers (Jamuna, Ganges and Padma) are in a dynamic equilibrium. For Gorai River, the analysis, however, clearly shows an increasing trend indicating that this river is aggregating due to deposition of sediments, see Figure 7.1.



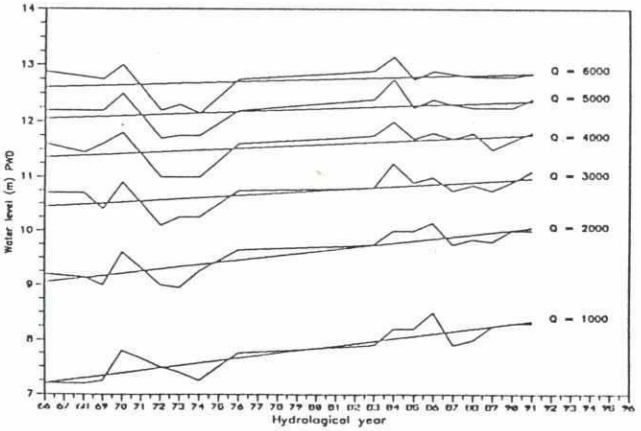
Bahadurabad



Baruria



Hardinge Bridge



Gorai Railway Bridge

Figure 7.1: Specific gauge analyses at Bahadurabad, Baruria, Hardinge Bridge and Gorai Railway Bridge

Simple but powerful trend analyses of the long time series of water-levels and discharges from the five discharge stations have been carried out in order to detect obvious inconsistencies in the time series. The analyses have been based on simple plotting and comparisons of the time series of annual peak discharges and annual monsoon flow volumes. Comparisons between time series from different stations have also been performed.

The analyses have detected and confirmed a number of inconsistencies in the BWDB discharge time series. The most important one is for the most important discharge station in the country, namely Bahadurabad in Jamuna River. The trend analyses and several additional special analyses for this station reveal that the discharge measurements and the resulting discharge time series since the major flood in 1988 are generally estimated too high for medium to high flow conditions in Jamuna River. The analyses for the important station Baruria in Padma River indicate that the discharge time series for Baruria before 1971 is estimated too low.

Apart from the various inconsistencies detected, the basic data quality of the historical data analyzed may be characterized as satisfactory.

Statistical analyses

The corrected and updated long time series for mean daily water-levels and discharges for the five discharge stations analyzed provide an adequate basis for various frequency analysis of the time series. A convenient way to show the variation of the water-levels and discharges through the year for a given station is by means of frequency curves, where each frequency curve indicates the magnitude of the water-level/discharge for a selected specific probability of non-exceedence.

In all cases, the 90%, 50% and 10% probabilities have been selected together with the maximum and minimum values in the years considered.

The corresponding average duration curve gives the average number of days a given value was not exceeded in the years considered.

A comparison of the frequency curves for Bahadurabad and Hardinge Bridge reveals that the maximum flood of the Jamuna River is generally earlier than the one in the Ganges River, and that the flows in these two rivers are not in phase. At Baruria, the flows and the resulting frequency curves are combinations of these non-phased flows in Jamuna and Ganges. At Mawa, the 10%, 50% and 90% - curves are, as expected, very similar to those of Baruria, but the maximum-curves are different, mainly due to unreliable flows at Mawa for some high flow years, e.g. 1988. At Gorai, the timing and distribution of the flows through the years are, as expected, very similar to those of Hardinge Bridge, as the Gorai River is mainly supplied by flow from Ganges, see Figure 7.2.

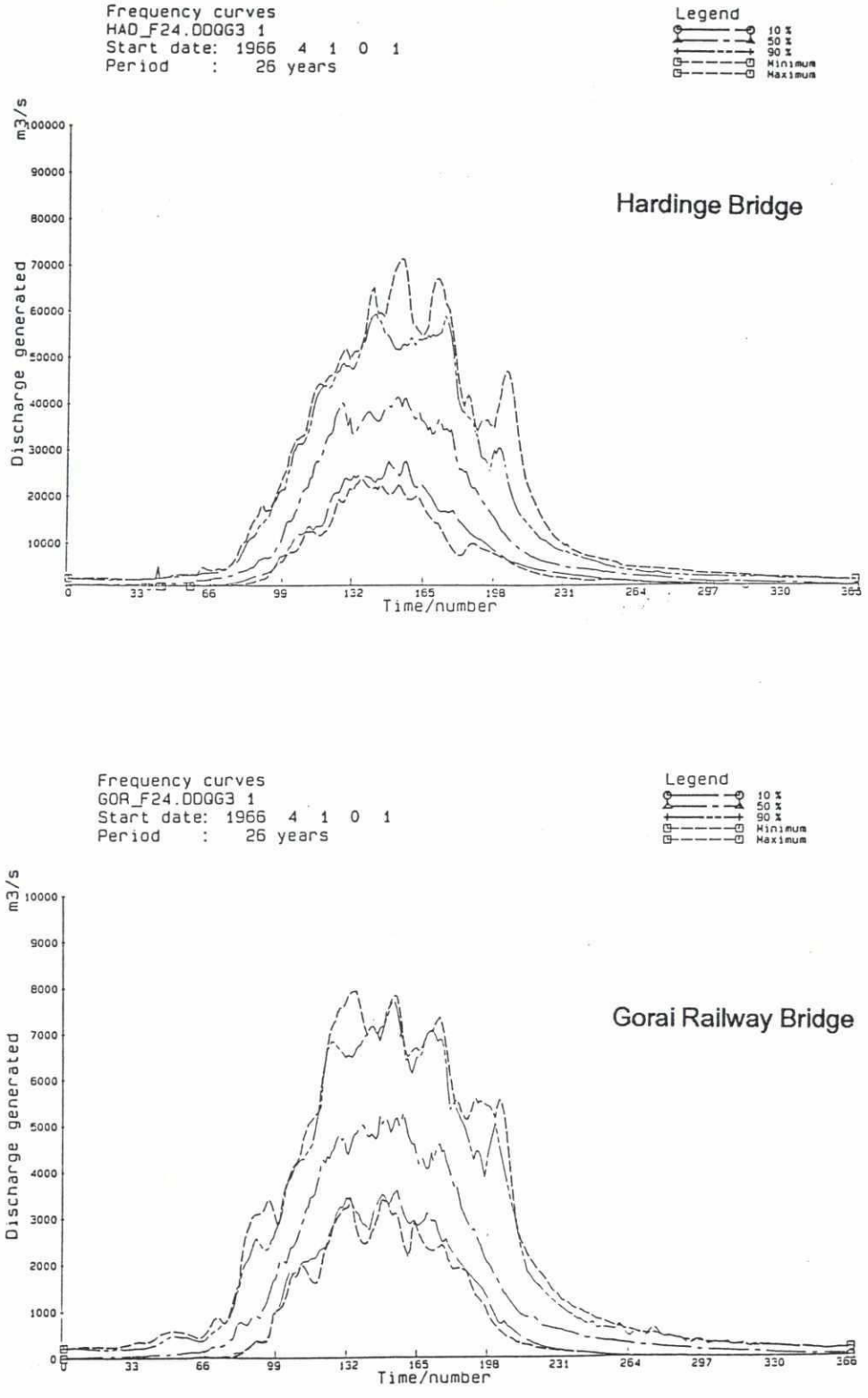


Figure 7.2: Frequency curves for discharges at Hardinge Bridge and Gorai Railway Bridge

Furthermore, frequency analyses of the annual minimum peak water-levels and peak discharges have been carried out in order to assess design water-levels and discharges for various return periods. The 3-parameter log-normal distribution fit well to the peak water-levels at all stations analyzed. For the peak discharges the Gumbel distribution fit well for three stations, whereas the log-normal distribution fit much better for the remaining two stations Hardinge Bridge and Gorai Railway Bridge.

The results of the frequency analyses are summarized in Tables 7.1 and 7.2, where the results are also compared with former estimates.

Station	Source	Return Period (year)					
		2	5	10	25	50	100
Bahadurabad	FAP 24	19.76	20.04	20.20	20.37	20.48	20.59
	FAP 25	19.78	20.04	20.21	20.42	20.57	20.73
Hardinge Bridge	FAP 24	-	-	-	-	-	-
	FAP 25	14.72	14.80	14.85	14.92	14.97	15.02
Baruria	FAP 24	8.19	8.55	8.77	9.06	9.27	9.47
	FAP 25	8.14	8.51	8.76	9.08	9.32	9.57
Mawa	FAP 24	5.91	6.21	6.43	6.73	6.98	7.24
	FAP 25	5.91	6.22	6.44	6.76	7.01	7.27
Gorai Rlw.Bridge	FAP 24	12.91	13.28	13.47	13.68	13.82	13.94
	FAP 25	12.91	13.30	13.51	13.73	13.88	14.01

Table 7.1: FAP 24 and FAP 25 calculated peak water-levels for selected return periods

Station	Source	Return Period (years)					
		2	5	10	25	50	100
Bahadurabad	FAP 24 FAP 25	67000 67000	76000 78000	81500 85000	89000 94000	95000 100500	100500 107000
Hardinge Bridge	FAP 24 FAP 25	51000 49000	59000 59500	63500 66500	68500 76000	71500 82500	74500 89000
Baruria	FAP 24 FAP 25	92000 86000	105500 101000	114500 110500	126000 123000	134500 132500	143000 141500
Mawa	FAP 24 FAP 25	86000 -	99500 -	108500 -	120000 -	128000 -	136500 -
Gorai Rlw.Bridge	FAP 24 FAP 25	6350 -	7200 -	7600 -	8100 -	8400 -	8700 -

Table 7.2: FAP 24 and FAP 25 calculated peak discharges for selected return periods

Water-level profiles/water surface slopes

Overall water-level profiles for the major rivers have been plotted for various flow conditions (high, medium and low), on the basis of observed water-levels at a number of gauging stations along the rivers. For Jamuna River, the overall average slope for high flow conditions is estimated at 7.6 cm per km for the upper reach and 6.5 cm per km for the lower reach, for Ganges 5.5 cm per km, for Padma 4 cm per km and for Meghna 2.25 cm per km.

Further hydrological studies in phase 2

Proposed study topics in phase 2 are as follows:

1.1 Water surface slopes
1.2 Water balances
1.3 Changes in rating curves
1.4 Loops in rating curves
1.5 Extrapolation of rating curves
1.6 Overland flow (flow from rivers to catchment during high floods in the river)

Topics 1.1, 1.3 and 1.5 have been intensively dealt with already in phase 1 and reported in the present report. As new FAP 24 field measurements become

available during phase 2, there will of course be a need for follow-up on these topics to some limited extent. Topic 1.2 has only been dealt with to a very limited extent up to now by comparison of monsoon flow volumes from various discharge stations. This topic should be taken up more intensively in phase 2, and it may also provide some information for the assessment of the last topic, 1.6, overland flow.

On the basis of the studies of rating curves during phase 1, topic 1.4 is not considered to be very significant in the main rivers which are not flashy rivers with rapidly varying unsteady flows. However, loops in rating curves may also be caused by time-lag in bed form development in rivers with high sediment transport. This may result in changing hydraulic roughness and thus water-level for a given discharge, i.e. loops in rating curves. The possible importance and implication of such morphological effects will be studied in connection with the morphological study programme.

In addition to the considerations above, the hydrological analyses carried out during phase 1 has generated ideas for related special topics to be further studied in phase 2, and these topics are described in detail in the *Hydrological Study phase I Report.*

7.3 Review of available morphological data

General
The results of the review of the morphological data available on the main river system in Bangladesh are presented in this Section. This study component concentrated on the collection of available data, a check on the quality of those data, and some analysis of those data, such as in order to determine the key characteristics of the main river system.

Methodology
During the study, a substantial effort was made to make an inventory, as complete as possible, of morphological data. Furthermore, a selected set of morphological data of the main river system was collected from various sources. The quality of the data was assessed, e.g. by comparing data obtained in different ways (e.g. cross-sectional soundings and satellite images), by preparing sediment balances from sediment rating curves, and by checking the consistency of the data of the individual rivers by considering the main river system in its entity.

Morphological studies of the main river system, or parts of it, will benefit from unified databases of checked and complete(d) morphological data series. Up to now, these types of databases are not available. The presented inventories (see the appendices of *Study Report no. 3)* and the assessment of the quality of the available data is a first step towards the development of such data bases for morphological studies.

Data availability

Broadly speaking, a very large amount of data on the main river system is available. This comprises various types of morphological data, notably (old) maps, satellite images, cross-sections, regular and incidental soundings, bed material samples, bank material samples, sediment transport measurements, etc. In the appendices to the previous study reports, fairly complete overviews are given of the availability of the various data.

In *Study Report no. 3,* the availability is discussed extensively. Some salient details are listed hereafter:

- Both (old) maps and satellite images are available and have proven to be extremely useful for studies of the planform (and their changes) of the main rivers. Usually, this information has to be geo-corrected, either because of the use of different projection systems, or because of inaccuracies
- Cross-sections and soundings collected for certain projects may be quite interesting from a scientific point of view, and should be made available, e.g. in data bases
- Although there is a fair understanding of the composition of the bed material in the main rivers and some of their distributaries, there is a need for some more information in this respect. Also, information is lacking on other characteristics, like density, the specific weight, and the shape of the particles, porosity and the angle of repose of the sample, and on the chemical composition of the particles
- Sediment transport data is available for some stations. It took some effort to identify and distinguish the different data, as not all data were correctly stored and registered

Data quality

Generally speaking, the quality of the data is fair, but still there are a number of aspects which need further assessment. The most important ones are listed hereafter:

- The chainages along the rivers are not uniquely defined. This is partly due to the shifting of the river channels. Proposals for a formal chainage and how to fix it were given
- Mutual comparison of cross-sections shows that the characteristic parameters determined from cross-sections are sensitive for errors in the datum for vertical control. There appears to be a scope for a considerable improvement of the vertical control of the bench-marks used by BWDB for the cross-sectional soundings
- Comparisons were made between BWDB cross-sectional soundings and BIWTA soundings on the one hand, and satellite images on the other hand. Differences were discovered that could not be explained fully
- It is proposed to extend the sediment measuring network with a sediment gauging station along the Lower Meghna River and one on the offtake of the Arial Kahn. It was stressed that criteria for the selection of a location

of a sediment measuring station may be different from the criteria for the selection of a station for measuring flow and stages

- There is scope for optimizing the sediment transport measurements by (i) selecting the number of verticals on the basis of two indices, and possibly (ii) by reconsidering the method of taking two samples in each vertical and applying standard weighing factors according to the Straub and WMO (Manual No. 686) method
- The existing BWDB standard method to separate the fine (wash load) and the coarse (suspended bed material load) fraction is satisfactory and is sufficiently accurate
- The coefficients of the sediment rating curve were determined by FAP 24 by analyzing all available sediment transport data. Further studies are needed for the Hardinge Bridge and Baruria stations, because of the high powers obtained
- Mutual comparisons between different years, and using balances prepared under this project, indicate that there is some doubt regarding the sediment transport measurements because of differences in the results of before and after 1971
- Based on these sediment rating curves and the discharge measurements by BWDB, a sediment balance between Bahadurabad, Hardinge Bridge and Baruria/Mawa has been estimated for the fine and the coarse sediment fraction. This sediment balance shows an equilibrium of the coarse sediments and some sedimentation of the fine sediments on the chars and the flood plain between those stations. The existing data series and the accuracy of the data are not sufficient to assess long term tendencies in the sediment transport in the main river system

For morphological studies, the network of standard cross-sections, of water-level, discharge and sediment gauging stations in the main river system are of interest. These networks have been developed gradually in time during which the objectives might have been changed. Therefore, it is recommended to evaluate from time to time whether the regular survey measurements meet the objectives in an optimal way as part of an optimization study. Optimal means that the output just meets the objectives at minimum costs.

7.4 Key characteristics of the main river system

Only the key morphological characteristics of the main river system are discussed here. This main river system consists of the main rivers (Jamuna, Ganges, Padma, and Meghna Rivers), and the distributaries (Old Brahmaputra, Dhaleswari, Gorai and Arial Khan/Dubaldia Rivers). The following characteristics were studied in the various Study Reports:

a characteristics of the river basin (total length, basin area)
b hydrology: rainfall characteristics, water levels and discharges
c bed material characteristics and sediment transport
d bank material characteristics
e planform and shifting characteristics

f maximum scour depths

From these data, a fairly consistent picture emerges (see also Figure 7.3 for a summary of some characteristics of the main river system). The flow of sediments seems fairly understood, and the reduction in particle diameter in the main rivers is e.g. much clearer than in the NEDECO (1968) study. Also, more consistent information is available on the sediment entering the distributaries (except for the Arial Khan/Dubaldia distributary system).

The average discharges and water levels in the main rivers are fairly constant during the last decades. It appears that most main rivers are fairly adjusted to their independent variables, with the notable exception of the Upper Meghna River, which still for a long time will have to 'recover' from the avulsion of the Brahmaputra between 1828 and 1830. The discharges in the distributaries have the tendency to reduce (with the exception of the Arial Khan/Dubaldia river). Hence, it may be expected that these rivers are in an adjustment phase.

The planform changes in the Jamuna river are the most pronounced of all the considered rivers. It consists of localized bank erosion, which is difficult to predict over larger time spans. In the reach upstream of Sirajganj, the river appears to widen, and there is a progressive though not continuous shift of the right bank of the river. The planform of the distributaries is relatively stable and the planform changes are predominantly a gradual shifting of meander bends.

Although the available data still have to be studied in more detail, and additional data have to be gathered, the picture that arises from this phase 1 activity is a river system that is not fully in equilibrium, and which is in the process of adjusting to the influence of local tectonic changes that causes avulsions (leaving some rivers 'oversized'), sedimentation due to subsidence (causing sedimentation and unbalance in sediment transport rates), preferred bank erosion on the right side of the braided Brahmaputra River, and deteriorating distributaries possibly by a variety of causes.

For more details on the key characteristics of the main river system, the reader is referred to the three Study Reports:

- *Study Report 1: Selection of Study Topics Phase 2*
- *Study Report 2: Hydrological Studies Phase 1*
- *Study Report 3: Morphological Studies Phase 1*

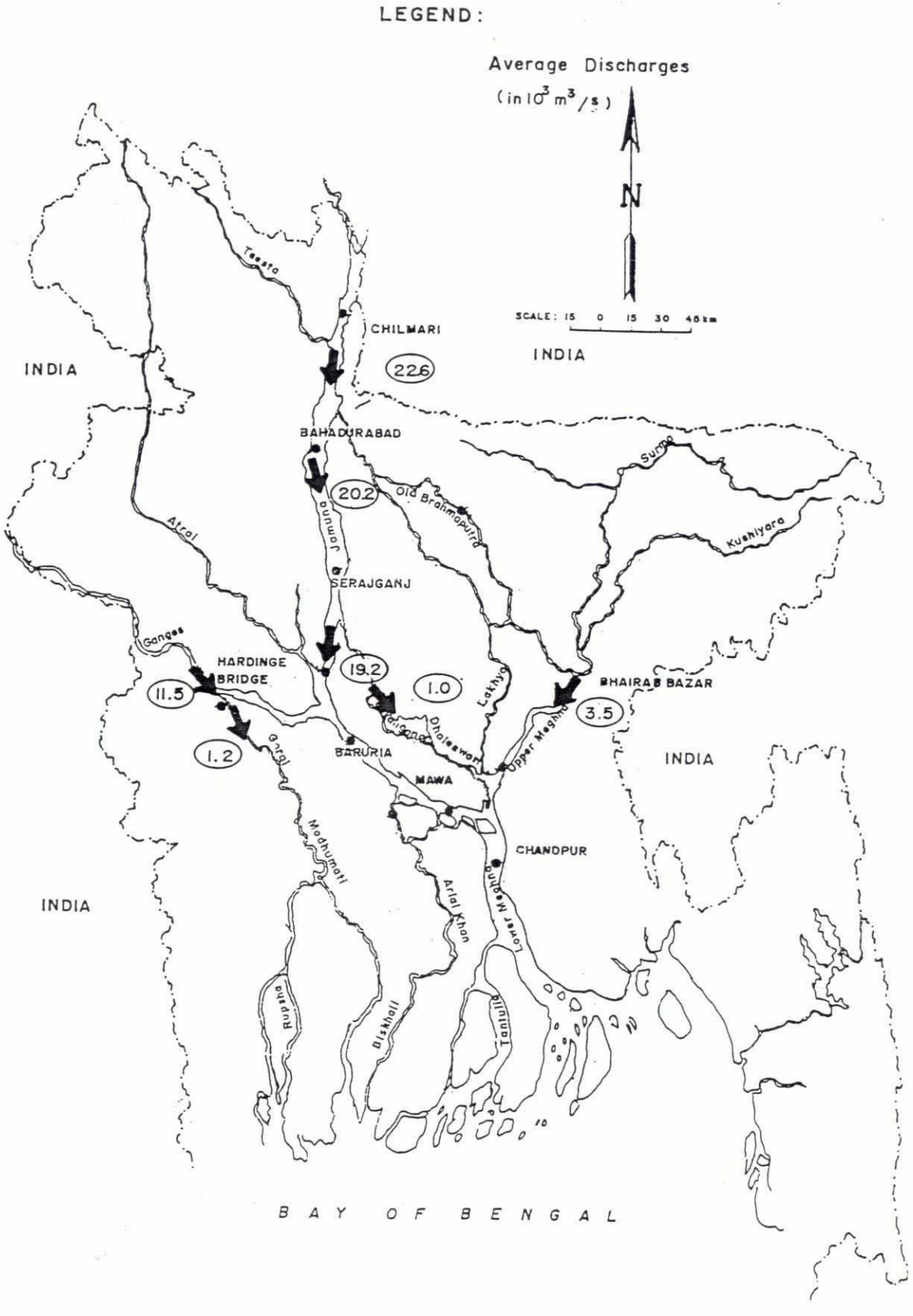


Figure 7.3a: Some characteristics of the main river system (a): Average discharges (10^3 m^3/s)

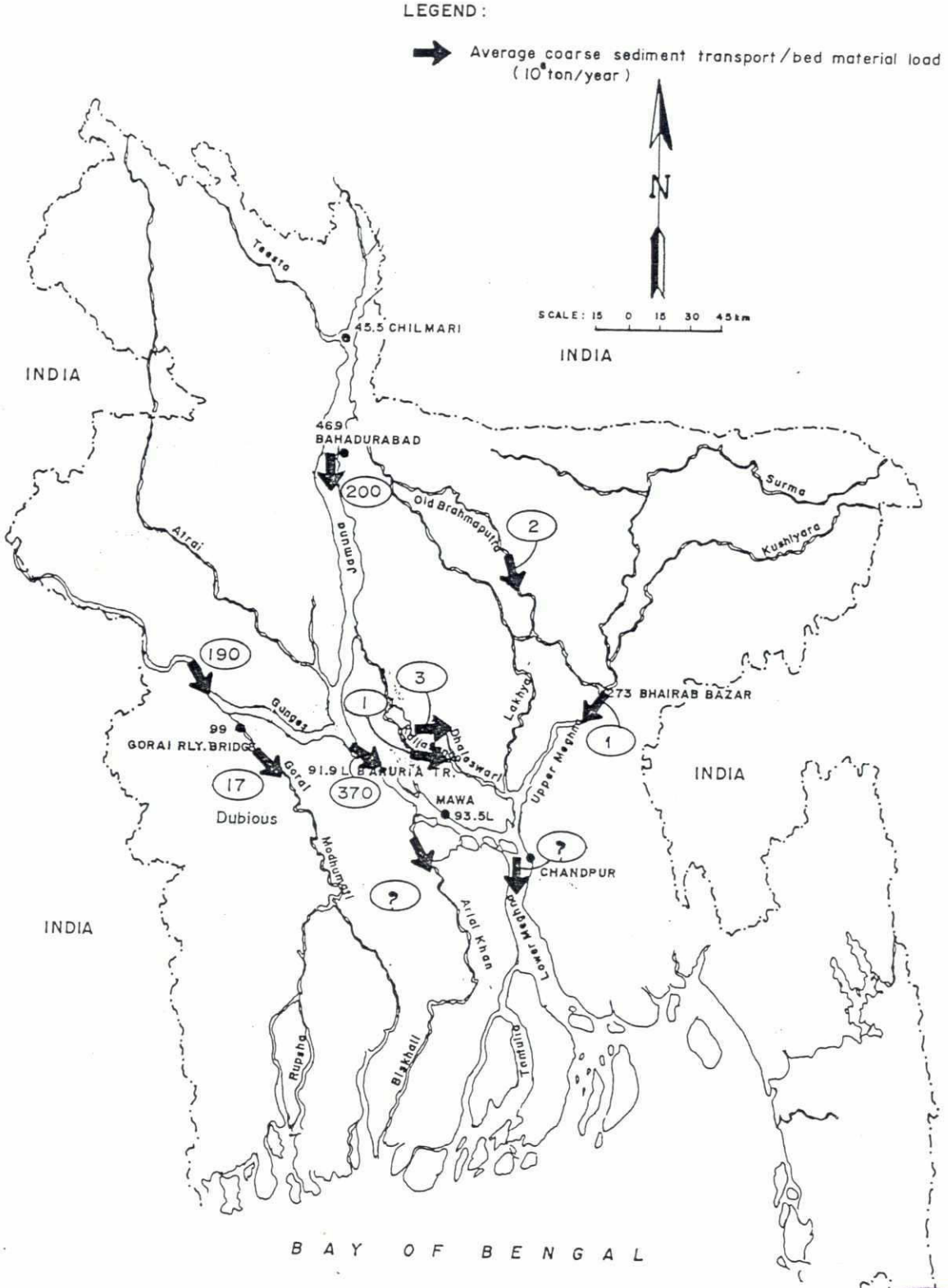


Figure 7.3b: Some characteristics of the main river system (b): Suspended bed material load (10^6 tons)

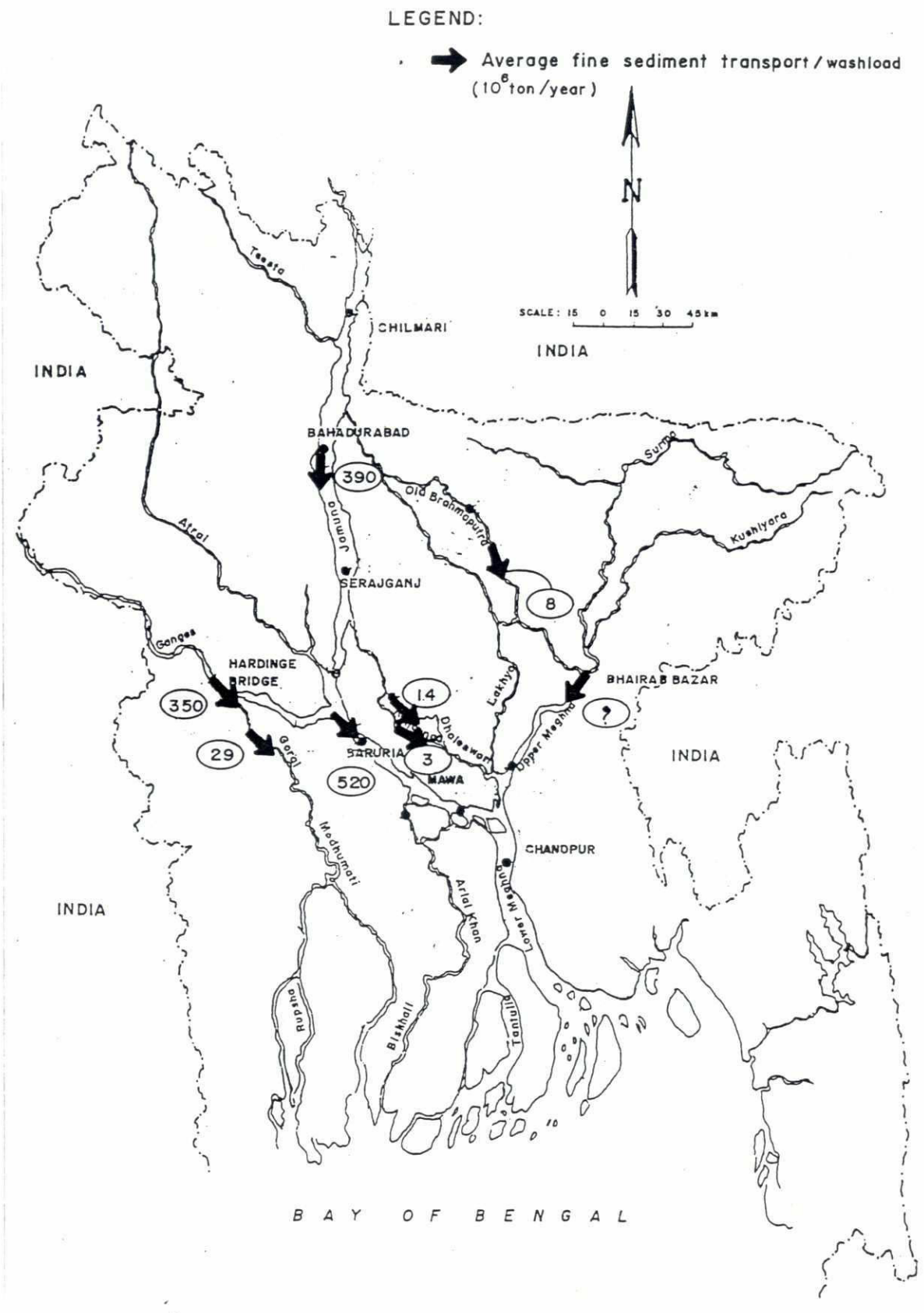


Figure 7.3c: Some characteristics of the main river system (c): Wash load (10^6 tons)

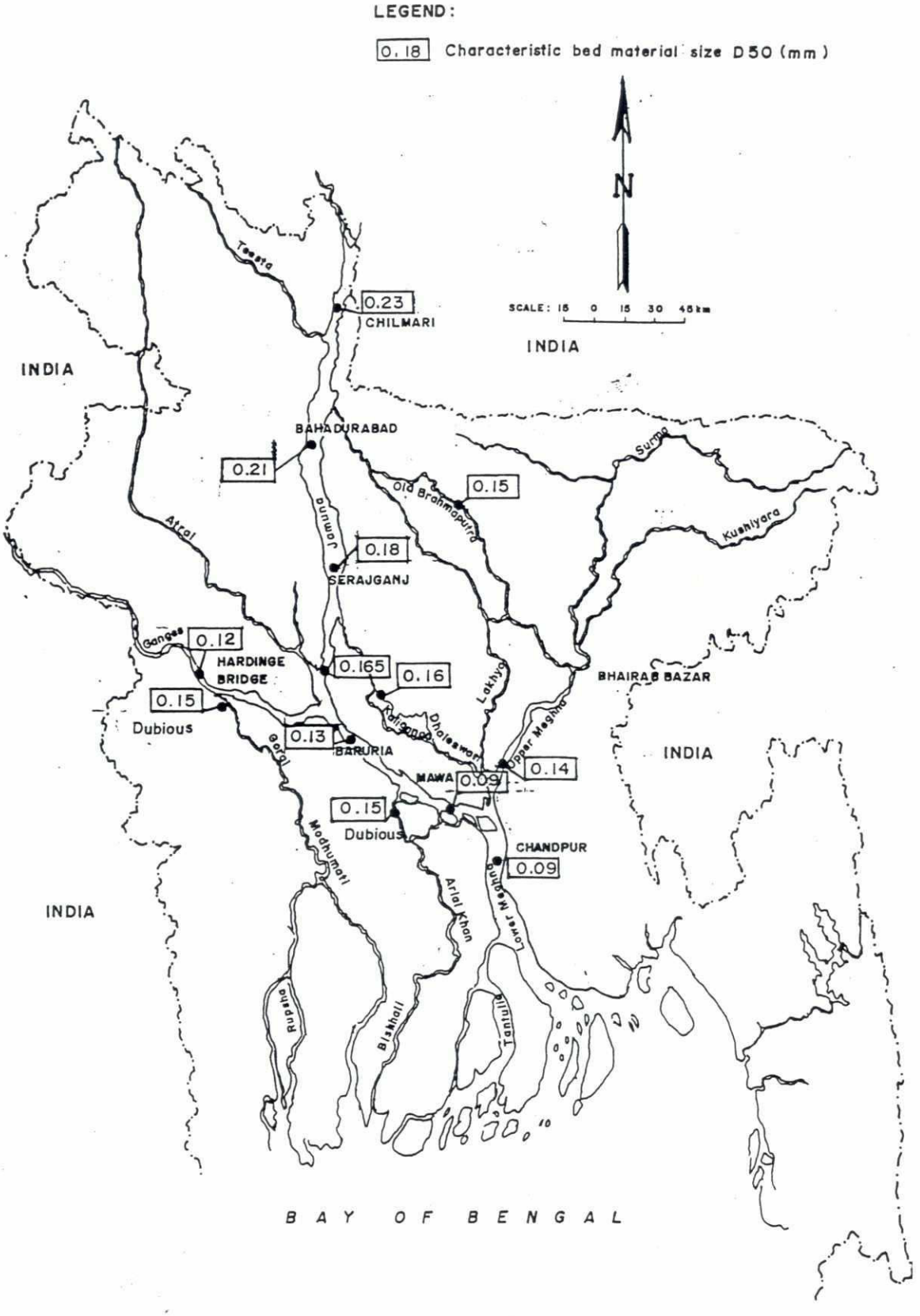


Figure 7.3d: Some characteristics of the main river system (d): Characteristic bed material size D_{50} (mm)

7.5 Qualitative impact assessment of FAP implementation

In *Working Paper no. 2,* a quantitative assessment of the impact of the implementation of FAP on the main river system is made. Here a summary of the main results of this assessment is given. The assessment is limited to the hydraulic and morphological impact. Whether or not a certain development is acceptable or even preferable from an environmental or socio-economic point of view was not studied.

The assessment was done on the basis of the present knowledge of the main river system of Bangladesh as laid down in two FAP 24 reports, notably *Study Report 1: Selection of Study Topics Phase 2,* and *Study Report 3: Morphological Studies Phase 1,* and on the results of the hydraulic simulations carried out by FAP 25, in particular Annexure 2 of the Main Report *(Analysis of country-wide protection schemes).*

The assessment was done in some successive stages. Firstly, the results presented in FAP 25 were analyzed as far as changes in discharges in the main rivers were concerned. Then, the so-called *improved Lane's balance* was applied to assess the ultimate conditions in the main rivers. Next, the intermediate conditions were assessed in a qualitative way. Finally, the impact on the distributaries was estimated, together with the possible feedback on the main rivers.

The results demonstrate that the initial increase in stages in some rivers (in particular in the Padma, Jamuna and Ganges Rivers), will in due time probably reverse to a reduction in stages. Rough estimates indicate a degradation and lowering of stages of up to 0.6 m or more for most of the main rivers apart from the Upper and Lower Meghna Rivers. See also Table 7.3.

Station	River	River(s) downstream	Lowering of water stages		
			Effect of slope change in river (m)	Effect of downstream rivers (m)	Total lowering (m)
Bahadurabad	Jamuna River	Jamuna River-Padma River-Lower Meghna River	0.0	1.0	1.0
Sirajganj	Jamuna River	Jamuna River-Padma River-Lower Meghna River	0.6	0.4	1.0
Hardinge Bridge	Ganges River	Padma River-Lower Meghna River	0.0	0.4	0.4
Baruria	Padma River	Lower Meghna River	0.4	0.0	0.4
Bhairab Bazar	Upper Meghna River	Lower Meghna River	0.0	0.0	0.0
Chandpur	Lower Meghna River	None	0.0	-	0.0

Table 7.3: Preliminary estimates of lowering of stages for ultimate conditions for the most probable scenario of FAP implementation

This degradation will only materialize fully after 50 to 100 years or more. Via a qualitative assessment, an indication was obtained of the changes to be expected in the period from the implementation of the different FAP components until equilibrium has established. The result of this assessment is presented here as Figure 7.4.

An important finding of the present assessment is that the prediction of the future conditions of the distributaries cannot be done in a completely deterministic way. The development of the distributaries is at least partly determined by phenomena which are varying in time. Hence, the period and sequence of implementation of the various projects may be important. The present assessment supports the selection of study topics as proposed by FAP 24 and underlines the need to improve the understanding of the behaviour of off-takes.

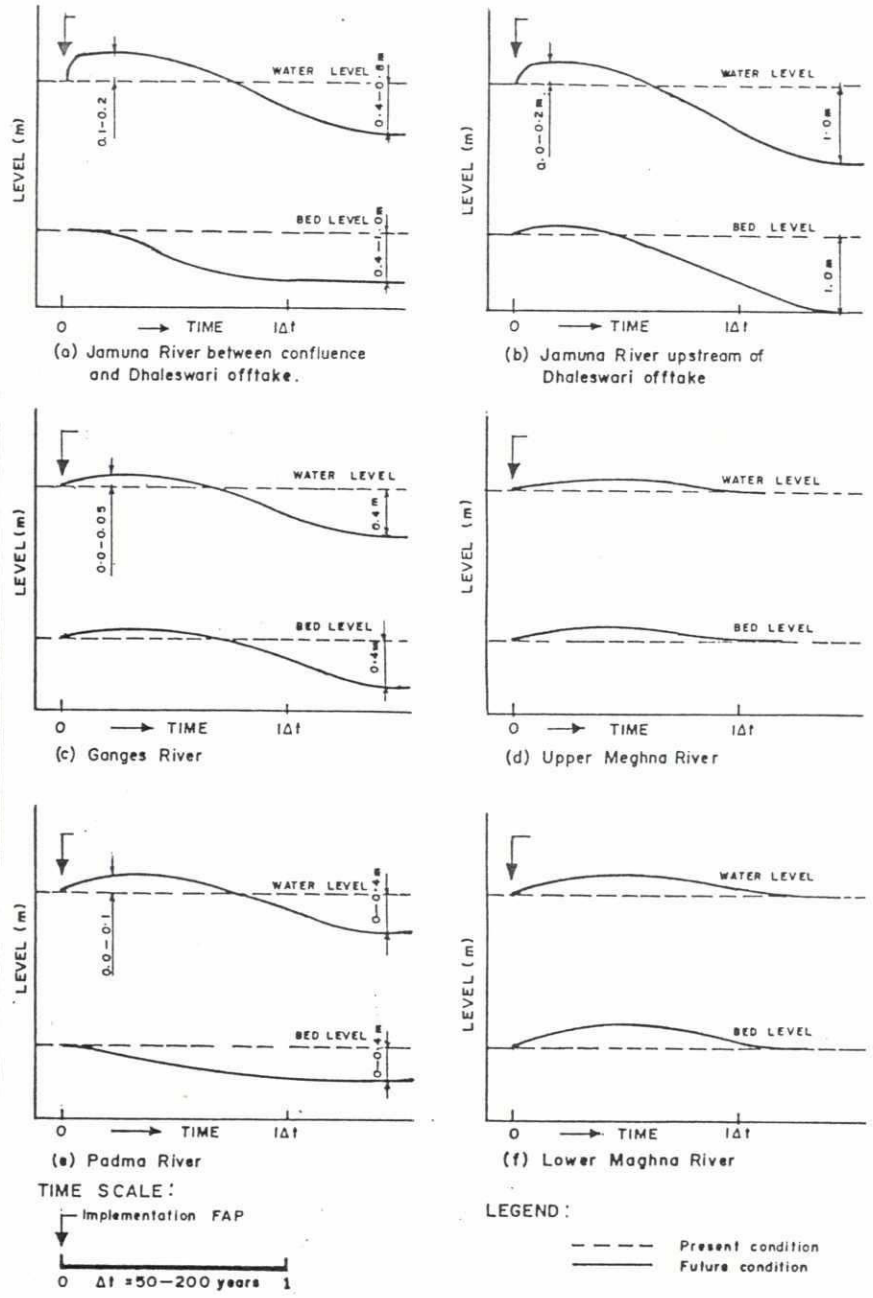


Figure 7.4: Qualitative change of stages and bed levels in the main rivers

The accuracy of the outcome is of course limited by (i) the still limited understanding of the main rivers system, its main rivers, the distributaries and their interaction, (ii) uncertainties as to how the river system will react upon interventions, and (iii) a yet unknown sequence of implementation of the FAP components. Other aspects to consider include:

- there are possibly different ultimate conditions at least as far as the distributaries are concerned
- uncertainties are introduced by the unknown future behaviour of the distributaries
- how changes in planform will affect the results of the present assessment
- the sequence of implementation may have a substantial effect on the response of the distributaries

Nevertheless it is felt that the present assessment provides a fair estimate of how the river system will respond to the implementation of FAP.

Finally, it is noted that the present assessment is a very preliminary one only. It should be followed by more detailed assessments in due time, in which also the sequence of projects and possible adaptations should be studied as part of the development of a well-balanced FAP. For more details, the reader is referred to *Working Paper no. 2: 'Qualitative assessment of FAP implementation'.*

7.6 Phase 2 study topics

General
This Section summarizes the approach followed by the Consultant to identify the study topics for phase 1. Because the aim of the studies should be to help in finding answers to the key problems of the main Bangladeshi river system, it specificly attempts to identify these key problems. In a next step, study topics are identified that should be taken up to provide answers for these key problems.

Methodology
During the preparation of the proposal, the Consultant had already prepared a tentative list of study topics. This tentative list was slightly extended, further to recent studies in which Consultant was involved, and upon screening recent reports prepared by other Consultants.

The list was sent to the different FAP projects who could be interested in additional studies, notably FAP1 through FAP6, FAP16, FAP17, FAP18, FAP20, FAP21/22 and FAP25, with the request to reflect on the proposed topics. Next, most of the team leaders of the FAP projects and also SWMC were interviewed regarding their ideas on the possible study topics and related surveys needed for these topics.

Also FPCO and its Project Adviser were interviewed formally and the same holds for the local and expatriate members of the Panel of Experts of FPCO. Based on

the results of these discussions on the one hand, and the Consultant's own experience in a number of projects in Bangladesh and the experience obtained during the phase 1 studies on the other hand, a tentative ranking of the possible study topics was made. Next, estimates were made of the manpower input needed for the various study topics, and this was compared with the available man-months for studies.

This resulted in the 'top ten' of the study topics, the results of which were felt to be urgently required and that could be tackled with the man-months available. In addition, various universities and other institutions were approached and, where possible, arrangements were made as to their possible input into phase 2 of the studies. Finally, a tentative time schedule was prepared, taking into account the requirements from the study component of the project.

Key problems

As a framework for analysis, rivers are discussed here in terms of input-output systems. The characteristics of a river (like its planform, width, depth, etc.) as an output is dependent on inputs which ultimately are the climate and the geology of the basin, but which, at the level of a particular river reach, come back to the flow hydrograph, the amounts of sediment a river has to carry over a longer time span, the characteristics of the sediment that has to be transported, and, on a geologically speaking short term (but for engineers on the long term), the valley slope. After a very long time, and for constant input parameters, a river is approaching equilibrium conditions, characterised by a dynamic equilibrium (hence fluctuations around a constant average value of a particular characteristic). This approach provides a frame-work for analysis of the main river system in Bangladesh.

A review of the characteristics of the main rivers and their recent history (over the last few centuries) shows that this river system is definitely not in equilibrium. Both the Brahmaputra River in its present Jamuna course and the Upper Meghna River are still in a process of adjusting to their new (only two centuries old) conditions. Furthermore, there is a tendency for at least some of the distributaries to slowly loose their importance. Hence, uncertainties as to the natural development that the rivers are subject to is one type of key problems.

Making predictions of the future conditions in the main river system of Bangladesh is only possible if a good knowledge exists of the present conditions. This condition is definitely not fulfilled. First of all, only scarce data exist from the period before 1965. Secondly, the data available, even those for the later period, are not sufficient for a full understanding. This is of course due to the fact that it is impossible to measure all parameters of a river at all places and at all times, and in the case of Bangladesh this is highly aggravated due to the sheer size of the rivers. The width of the Jamuna River varies between 7 and 17 km, and any major systematic measuring campaign is an enormous undertaking. In this respect it is in itself already amazing how many data have been collected over the last decades. Still, however, the limited knowledge of the main river system definitely belongs to the key problems.

Another aspect is that the independent variables in the river system changes in time. For the main rivers in Bangladesh, this relates in particular to local tectonics. Bangladesh is located in one of the tectonically speaking most active regions in the world, as it lies in the region where the Indian continental plate is sliding under the Eurasian continent. There is some evidence that some of the river courses are affected by this, in particular by faults which delineate units having different rates of subsidence or upheaval. This may be the cause for the gradual shift to the west of the Jamuna river upstream of Sirajganj and for the gradual movement to the east of the upper reach of Lower Meghna River (and the Ganges mouth in the further past). The lack of understanding of these changes and their effect on the main river system in Bangladesh is another type of key problems.

The River Survey Project is part of the Flood Action Plan, and this means that part of the studies have a direct relation with this plan. Key problems in this respect are two-fold. One type of key problems is related to boundary conditions for the different structural elements that have been proposed as part of the Flood Action Plan, in particular for the embankments and the bank protection works. These boundary conditions comprise both hydraulic boundary conditions like design discharges, flood levels and flow velocities, and to boundary conditions related to morphology, sedimentation and erosion, like the safe distance of embankments from present river banks, and scour depths and their probability of occurrence for groynes and other type of bank protection works.

The second type of key problems in direct relation to the Flood Action Plan is the assessment of the impact of the different plans proposed under the various components of the plan. Predictions of this impact require an understanding of the behaviour of alluvial rivers in general and the effect of human interference in particular. Human interference usually leads to a system with a smaller number of freedoms, but still the present understanding is too limited to really predict the effects. Also because the knowledge of the present state of the river, the future adjustment and the changes in the outward controls are only very limited.

The different types of key problems are indicated in Figure 7.5, which schematically indicates which factors influence the transition of the present state of the river system to the future.

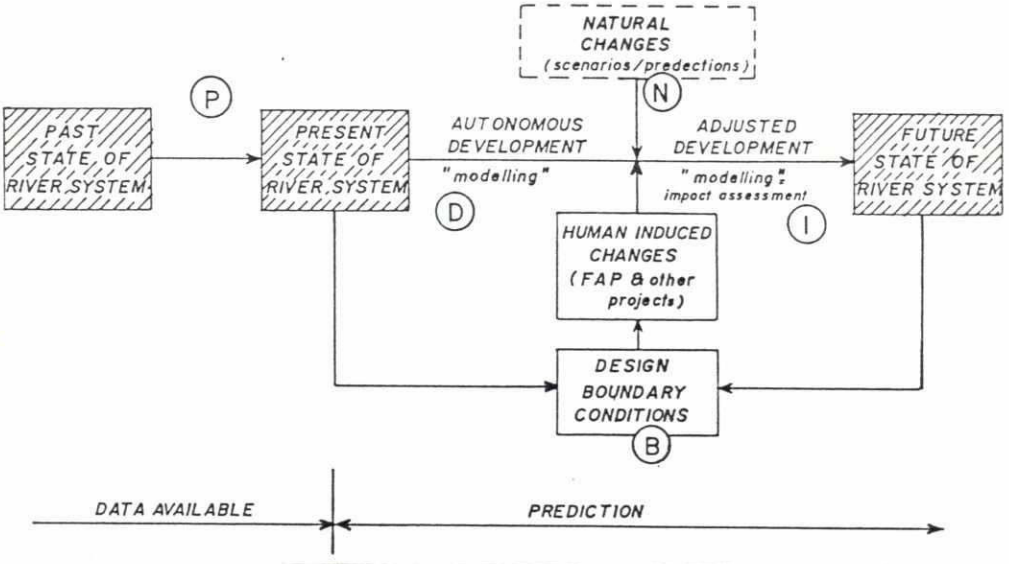


Figure 7.5: Identification and classification of key problems

These considerations have led to the identification of a number of key problems. These are listed hereafter:

(i) Limited understanding of the Present behaviour of the river system:
  (P1) Limited data on present state
  (P2) Dynamic fluctuations around equilibrium
  (P3) Difficulties in measuring in large rivers

(ii) Autonomous development of the river system:
  (A1) Widening of the Jamuna River
  (A2) Adaptation of the Upper Meghna River
  (A3) Fate of distributaries
  (A4) Bank erosion over 2 to 3 years

(iii) Natural changes in independent variables
  (N1) Shifting of river courses
  (N2) Major changes possible?

(iv) Boundary conditions for design
  (B1) Design boundary conditions for embankments (discharges, stages, safe distance)
  (B2) Design conditions for groynes and revetments (stages, magnitude and direction of velocities, bed levels)

(v) Impact assessment
- (I1) Impact of regional plans on river characteristics
- (I2) Effect of narrowing/bank protection works/AFPM measures
- (I3) Effect of embankments on sediment flux towards fields and on siltation in floodplains outside embankments
- (I4) Impact of developments upstream
- (I5) Influence of climatic changes

Possible study topics

In the next step, these key problems were dissected in a number of study topics. In this context, study topics are fairly well described investigations for which the rationale for carrying out the investigation, the approach, the required input in man-months, the required field data, and the expected output can be defined properly. The study topics have been derived by analyzing the different aspects of relevance for each of the key problems. Examples of such dissections are given in the main text of the report.

Subsequently, a list of possible study topics was prepared and this list is given here as Table 7.4, together with the key problems. The study topics are grouped into the following categories:

- Hydrology and water balances (5 topics)
- Sediment transport and river aggradation and degradation (6 topics)
- Planform characteristics and channel dimensions (10 topics)
- Offtakes and bifurcations (4 topics)
- Confluences (3 topics)
- Bars (2 topics)
- Bed forms (4 topics)
- Local scour (4 topics)
- Measuring techniques (6 topics)
- FAP impact on the river system (4 topics)

In Appendix 2 of *Study Report 1,* these topics are described in some detail. Also, the possible approach and the required study tools, a tentative ranking, the expected results, and the required input are listed for each topic.

Table 7.4 was especially prepared in order to illustrate the relation between the key problems and the study topics. As can be observed, different study topics have to be tackled for finding answers to specific key problems. It should be stressed that the study topics as they are visualised here are definitely not meant to solve the tackled problem in a universal way. Rather, the idea is to address the specific topic for Bangladeshi conditions, often combining theoretical frame-works derived from mathematical-physical analyses with specific data from Bangladeshi rivers.

Selection of study topics

As indicated above, for all study topics estimates were made of the required input in both expatriate man-months and local man-months, plus specialized expertise, if any. Furthermore, the requirements as to additional field measurements were evaluated. Adding up the man-months for all study topics and comparing the result with the number of man-months available for studies in phase 2, clearly showed that the available number of man-months was not sufficient. Hence, there is a need for selection of a more limited number of study topics.

This selection was made on the basis of a number of criteria, like (i) the relevance for the impact assessment of the combined FAP's ('impact criterion'), (ii) the relevance for the feasibility but more often the detailed design phase of the regional FAP's ('regional plan criterion'), (iii) whether required for the FAP components that are dealing with bank protection and river training works ('river training criterion'), (iv) whether the topic can be studied in much more detail with the up-to-date surveying possibilities of the FAP 24 survey spread ('availability criterion'), (v) whether it can be done with fairly low investment in man-month ('investment criterion'), (vi) the academic interest ('research criterion'), or (vii) whether the topic is emphasizing the overall behaviour over local phenomena ('aggregation criterion').

In addition, there is of course a criterion related to internal cohesiveness of the study programme: It is of no use to take up one study topic if other study topics needed for finding a solution to a certain key problem are not tackled. To secure this, Table 7.4, the key problem - study topic matrix was used. The proposed selection of study topics is indicated in Table 7.4 by shaded boxes.

The tentative selection of study topics concentrates on a limited number of topics, which are:

- hydrology and water balances
- sediment transport and river aggradation and degradation
- offtakes and bifurcations
- bed forms but only in relationship to hydraulic roughness, measuring techniques
- FAP impact on the river system

During the Workshop in Dhaka in November 1993, it was furthermore decided to initiate another FAP project, in which the FAP impact on the river system would be studied in more detail than is possible within FAP 24. This is in line with previous recommendations from the FAP 25 CAT mission. The consequence is that the topic *FAP impact on the river system* under FAP 24 can be limited to the phase 1 activities (published as *Working Paper no. 2* and here summarized in Section 7.5).

Num ber	Category	Sub num ber	Topic	Key problems															
				Present state			Autonomous de-velopment				Natural changes		Design Conditions		Impact assessment				
				P1	P2	P3	A1	A2	A3	A4	N1	N2	B1	B2	I1	I2	I3	I4	I5
1	Hydrology	1.1	Improved Bahadurabad discharges and rating curves	●	●								●	●	●				
		1.2	Improvement historical Bhairab Bazar discharges	●	●								●	●					
		1.3	Water balances and overland flow	●					●				●	●			●		
		1.4	Water level profiles and water level slopes	●									●	●	/				
		1.5	Phase 2 updat ng	●	●								●	●					
2	Sediment transport and river aggra-dation and degra-dation	2.1	Rating curves and balances	●		●	●		●								●		
		2.2	Sediment transport predictors	●		●			●								●		
		2.3	Integration of existing knowledge via 1-d mophological model	●	●				●						●	●			
		2.4	Long-term development of distribution				●		●			●							
		2.5	Floodplain sedimentation and subsidence	●													●		
		2.6	Phase 2 updating	●	●														
3	Planform charac-teristics and channel dimensions	3.1	Planform classification and meandering and braiding characteristics		●		●	●			●		●	●	●	●			
		3.2	Channel dimensions		●								●	●	●	●			
		3.3	Bank erosion rates							•									
		3.4	Outer bend scour											•					
		3.5	Channel cutoffs		•					•									
		3.6	Effect of tectonics on planform characteristics					●		●	●	●	●						
		3.7	Influence of cohesive material on planform characteristics		•			•		•			•						
		3.8	Local slope changes and their importance for planform changes							•		•							
		3.9	Prediction of medium-term planform changes		•					•			•						
		3.10	Long-term changes of the location of the rivers								●		●						
4	Offtakes and bifur-cations	4.1	Discharge and sediment transport distribution				●		●										
		4.2	Seasonal variation of erosion and deposition						•										
		4.3	Influence of bars				●		●										
		4.4	Influence of bed-forms						•										
5	Conflu-ences	5.1	Erosion and deposition of out-of-phase floods		•								•	•					
		5.2	Influence of bars and bed-forms		•									•					
		5.3	Confluence scour											•					
6	Sand bars	6.1	Occurrence, dimensions and dynamics of bars							●									
		6.2	Time-dependence of bars		●					●									
7	Bed-forms	7.1	Occurrence, dimensions and dynamics											•					
		7.2	Time-dependence of bed-forms		•									•					
		7.3	Three-dimensionality of bed-forms											•					
		7.4	Roughness and bed-forms		●								•						
8	Local scour	8.1	Dimensions of local scour around structures											•					
		8.2	Time-dependence of local scour		•									•					
		8.3	Influence of bed-forms											•					
		8.4	Combination with other types of scour											•					
9	Measuring techniques	9.1	Selection of measurement sites			●													
		9.2	Optimization of hydraulic measurements			●													
		9.3	Optimization of sediment measurements			●													
		9.4	Bed load transport via dune-tracking			●													
		9.5	Bathymetry and remote sensing			●													
		9.6	Sustainable survey techniques			●													
10	FAP impact on river system	10.1	Formulation of scenario's												●	●	●	●	●
		10.2	Simulation of ultimate river response via analytical modelling												●	●		●	●
		10.3	Quantitative assessment of FAP impact with 1-d morphological model												●	●		●	●
		10.4	Morphological model river system including changes in braiding and meandering characteristics												•	•		•	•

Table 7.4: Key problem - study topic matrix

As only a limited number of study topics can be tackled by the FAP 24 team, already in an early stage attempts were made to attract the interest of Universities and other institutions to taking part in some elements of the FAP 24 studies. It was considered that the unique measuring opportunities would be of interest to the scientific community, and that this would be an asset in relation to doing some studies in relation to key problems in Bangladesh. This was confirmed several times. It has resulted in research proposals from a number of universities and other institutions, notably:

(1) IHE DELFT (International Institute for Infrastructural, Hydraulic and Environmental Engineering), The Netherlands, for a study into the fate of distributaries
(2) University of South Carolina, USA, for a study into subsidence and floodplain sedimentation
(3) University of Amsterdam, The Netherlands, for a study into the effect of local tectonics on planforms and planform changes
(4) University of Leeds, England, for two studies, one into sand bars and another one into bed forms and their hydraulic roughness
(5) ISVA (Technical University of Denmark), Denmark, for a study into the influence of suspended sediments on the dune tracking method
(6) Rijkswaterstaat, The Netherlands, for cooperation into automated identification and characterization of bed forms from longitudinal soundings

Timing and staffing schedule

Based on the tentative selection of the study topics, a division of the different activities (as far as the studies are concerned) over the different staff members, both expatriate and local, was made. On this basis, a time schedule was made for the different study topics. The time schedule was presented in *Study Report 1: Selection of Study Topics for Phase 2.* In the meantime, some adjustments of the programme have been made, as briefly explained in Chapter 10 of the present report.

Integrated study and survey programme

For a number of study topics, additional surveys will be needed. An initial proposal by the Consultant to add a measuring section for special studies in bar formation and the movement of bars was not accepted. To still do additional surveys for the study topics, the Consultant prepares, on a yearly basis, a revised survey schedule taking into account these additional measurement requirements, investigating at the same time to what extent this can be combined with the programme of standard measurements.

Concluding remarks

Unfortunately, only a part of the required study topics can be taken up by the River Survey Project. However, it is felt that the package of study topics proposed here by consultants, supported by the unique possibilities for collecting field data on a scale and with a combination of instruments unprecedented anywhere in the world, and together with the investigations proposed by the different universities,

will result in a step forward in the understanding of the morphological behaviour of alluvial rivers in Bangladesh. This will allow to better address the key problems in Bangladesh as far as they are related to the morphological behaviour of the rivers.

As has been stressed also in the ToR *('The first of these (studies) will be identified during the preliminary phase of the project; others will be identified during the surveys and studies phase')*, there is a need for regular updating the list of study topics.

Updating may also be needed during phase 2 of the project. During this phase, results of both surveys and studies will become available. These results may indicate that it is preferable to change some of the study topics, or to adjust the manpower estimates required. In appropriate cases, adjustments will be proposed by the Consultant.

8. Training

8.1 Rationale

8.1.1 Introduction

One of the components of the River Survey Project FAP 24 consists of training. In the first phase of the project, the training consisted mainly of on-the-job training and in-house courses on river engineering. At the end of phase 1, a training programme for phase 2 has to be elaborated.

In this section, the scope of the training is given. Thereafter the realized training programme of phase 1 is presented (Section 8.2), and in the last section, the programme for phase 2 is described (Section 8.3).

8.1.2 Objectives and scope

In the ToR of the River Survey Project, the objectives and scope of the training are described as follows:

Quote:

- *Objectives of training (Section 3.1)*
  'To strengthen BWDB by providing on-the-job training to professional staff from BWDB, and where applicable BIWTA and staff of associated, local consultants in the fields of river surveys and studies, so that they can continue the data collection programme in the long term and to upgrade the institutional capability in Bangladesh for river hydrological and morphological data collection and study programme'
- *Training phase 1 (Section 4.2 c)*
  'In conjunction with FPCO and BWDB prepare and outline a programme for training BWDB and, where applicable, BIWTA staff and staff of associated local consultants. Initial training of all local and counterpart staff will be carried out in phase 1. Initial recommendations for upgrading of technology and equipment will be made'
- *Training phase 2 (Section 4.3 c)*
  'Prepare and carry out programmes for training BWDB and, where applicable, staff of other Bangladeshi organizations, including the staff of associated local consultants and contractors in the use of modern equipment, instruments, techniques and technology so that they are able (a) to carry on with the surveys after completion of the project and (b) to upgrade the routine survey programmes being undertaken by those organizations. This would mostly take the form of on-the-job training, but would be supplemented by some training seminars and workshops.'

Unquote.

In the Technical Specifications (TS), the training activities are described in a slightly different way.

Quote:
No formal training is included in phase 1. It is however expected that the Consultant, when assessing the data acquisition and processing performed by the local organizations, will give useful guidance and will consider the participation of local hydrographers in its field experiments.

The on-the-job training to be achieved during phase 2 must lead to a transfer of technology to make possible the continuation of part of the routine activities at the end of phase 2.

The training programme will be agreed on in consultation between FPCO, BWDB, the involved local authorities, the Consultant and the Project Adviser.

As the Consultant has the final responsibility of the results, the training programme has to be set up in such a way not to hamper his activities. The Consultant must therefore propose in his tender document the minimum training activities, their frequency, duration and content.
Unquote.

8.1.3 Constraints

There are in fact two problems limiting the training activities:

- There is no budget for training
- The equipment is only temporarily imported in Bangladesh and must be taken out of the country at the end of the project

The present absence of a budget is initiated by the ToR where the following is stated under staffing for training:

Quote:
'The Consultant would have to show his experience in this field and the staff he intends to employ, but he is not required at this stage to give an estimate of the number of manmonths involved.'
Unquote.

On the other hand, the ToR and the Special Conditions of the Contract suggest that at a later stage, a quantification of training work is required. Moreover, in the Financing Memorandum, an amount of 0.1 mio ECU is mentioned for training.

At the moment, only limited on-the-job training is possible. Limited, as the training activities may not harm project results (Subsection 8.1.2, last para).

During the pre-bid meeting of August, 1991, it was decided that the project equipment is only temporarily imported. As discussed earlier (Interim Report, Annexure 5, page 5.23), this may affect the training programme. For the type of instruments, only used by the River Survey Project in Bangladesh, training at the operational level does not make sense.

8.1.4 Outline

Target disciplines

The following disciplines may be considered for training:

- Survey vessel crew
- Surveyors, hydrographers
- System analysts, data handling specialists
- Sediment analysts
- River engineers, hydrologists, morphologists

The main subjects of training, obviously closely related with these disciplines, are respectively as follows.

Main subjects

- Ship handling, maintenance, manoeuvring
- Surveying; water-levels, bathymetry, discharge, and sediments
- System operation and management, data storage, data processing
- Laboratory analysis of sediments
- Hydrological and morphological study topics

Target organizations

- BWDB, Hydrology
- BIWTA
- RRI
- BUET
- Approtech, Hydroland (associated local consultants)
- Other local staff of the River Survey Project

Subject/organization matrix:
In the following matrix it is indicated which subjects of training will be given to which organization:

Main subject / Organization	Ship	Survey	Data	Lab	Study
BWDB	-	+	+	-	+
BIWTA	-	+	-	-	-
RRI	-	-	-	-	+
BUET	-	-	-	-	+
Approtech	-	-	+	-	+
Hydroland	-	+	-	-	-
RSP	+	-	+	+	-

Table 8.1:Subject/organization matrix

The training for the last three groups is considered to be in-house training.

Methods of training:
The methods to be considered for external training depend strongly on the subjects:

- Survey :
  -short term on-the-job (days)
  -special exercises in the field
  -seminars, courses, lectures
  -study tour

- Data :
  -mid term on-the-job (weeks)
  -courses, workshops on packages

- Study :
  -long term on-the-job (months, years)
  -short field visits, participation in surveys
  -conferences
  -long term abroad (AIT, IHE)

Obviously, the methods chosen are strongly depending on the available resources, see Subsection 8.1.3

Target level
The degree of detail in which certain subjects will be handled depends on the level of the target group. See for example the levels of personnel involved in the hydrological service.

Officers/Employees		Level
1.	Chief Engineer, Hydrology	Decision Level
2.	Superintending Engineer/ Director	
3.	Executive Engineer/ Deputy Director	Implementation Level
4.	Sub-divisional Engineer	Field Level
5.	Assistant Engineers	Operational Level
6.	Sectional Officers/ Assistant Director	
7.	Surveyors	
8.	Gauge Readers	
9.	Vessel crews	
10.	Survey crews	

Table 8.2:Levels of personnel

The decision level needs general information about survey techniques, possibilities, pros and cons. The objective of the training for this level is to provide the background data required for an appropriate selection of survey techniques.

The implementation level and the field level need to have more details. Especially the physical background should also be known. It is assumed that the field level will train the operational level. Therefore the field level will be the prime target level for training by the River Survey Project.

8.2 Training activities phase 1

The training programme implemented in phase 1 is summarized in the following schedule:

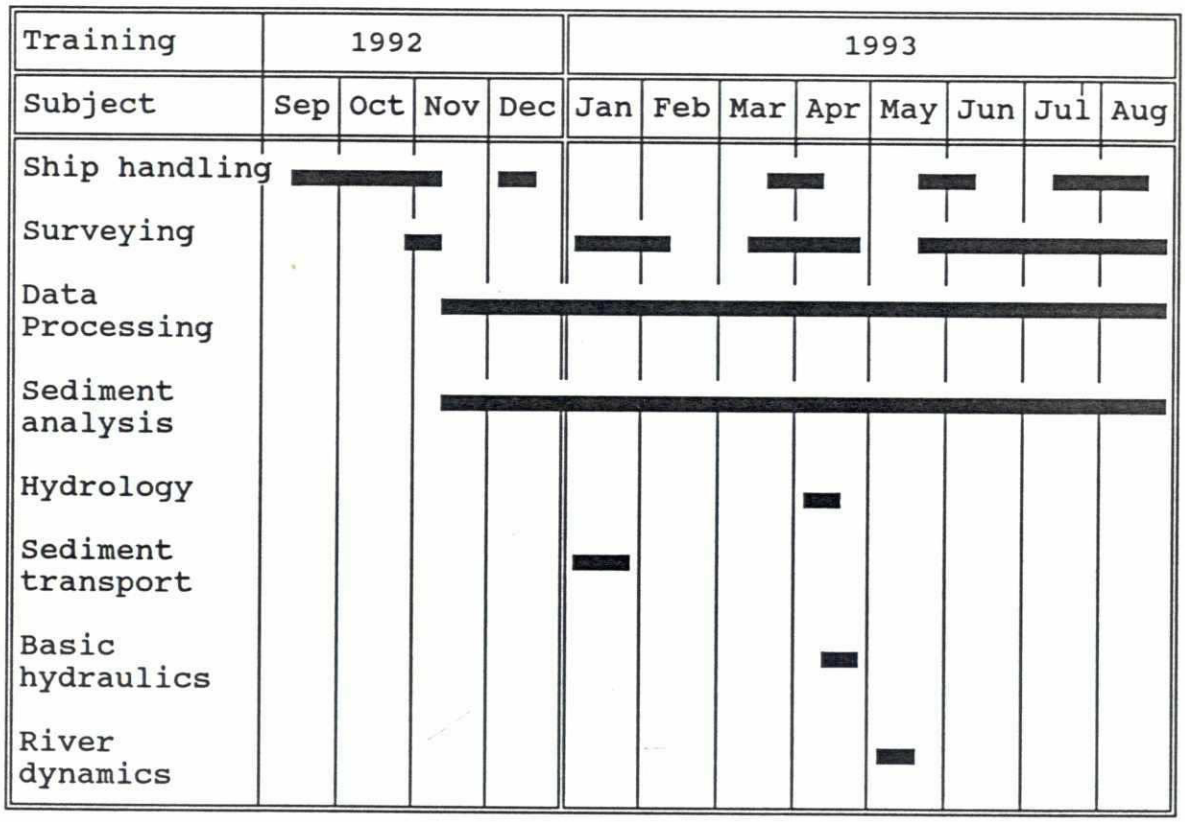


Figure 8.1: Training programme phase 1

8.2.1 Ship handling

On-the-job training was given by a professional master, mr. L.P.Schoonenberg, to the crews of the two survey vessels. In 1992, the training focussed on the basics of ship handling, maintenance and repair, including the use of the computerized autopilot and communication systems. During the monsoon of 1993, much attention was paid to manoeuvering in high currents including anchoring.

This training is completed, and the crews are fully capable to operate and maintain their vessels independently. In case of a fleet expansion, the training will be repeated.

8.2.2 Surveying

The training on surveying in phase 1 was mainly on-the-job training in the field given by expatriate surveyors, hydrographers and electronic engineers. The main part of the training was given to the project's own survey staff, including staff of the sub-contractor Hydroland. Main survey training activities are summarized as follows:

- In October and November 1992, the training emphasized the use of the new equipment, especially the instrument range for velocity/ discharge measurements may be mentioned, such as the ADCP, the EMF, the S4 and the Ott propeller current meter.

- A lot of attention was also paid to the on-line data processing aboard the vessels.

- In January and February 1993, the training focussed on the DGPS positioning system and on other land survey activities such as second order levelling and the use of the so-called total stations for topographical work.

- In March 1993, special attention was paid to the sediment measurements.

- Measurements were executed simultaneously with the BWDB survey team to compare techniques and give introduction to the equipment of the River Survey Project. Such simultaneous measurements were done a number of times and at various locations:

Bahadurabad	January	1993
Khulna	April	1993
Bhairab Bazar	April	1993
Bahadurabad	August	1993

- In May and June 1993, the training emphasized the water line survey and the bathymetric work. Also, instructions were given on the installation, operation and maintenance of the Automatic Water-level Recorders (AWLRs).

- In July and August 1993, the training focussed on the HW routine measurements and the test gaugings.

8.2.3 Data processing

The training on data processing started in November 1992, when the data processing office became operational. Training was given on:

- Systems software, such as SCO UNIX, E-mail system, Oracle, and GKS (Graphical package)
- DELFT/DHI software, such as Fieldman, MIKE 21, HYMOS, and various plot and load programmes

This training was mainly carried out as in-house training for the staff of the data processing office and is largely completed. Only when important software modifications or new software tools are implemented, some additional training is envisaged.

8.2.4 Sediment analysis

Training was given to the staff of the sediment laboratory to execute the types of analysis shown in Table 8.3.

Samples / Type	Suspended load	Bed load	Bed material
o Concentration	+	-	+
o Dry sieving	+	+	+
o Wet sieving	-	-	+
o Settling tube	+	-	+

Table 8.3: Training, sediment laboratory

This training is completed. Additional training is envisaged when new types of analysis are introduced in phase 2 of the project.

8.2.5 Courses on river engineering

As indicated in Figure 8.1 some refreshment courses were given as follows:

January, 1993:	Sediment transport
April, 1993:	Hydrology
April, 1993:	Basic hydraulics
May, 1993:	River dynamics

These were mainly in-house courses organised in the office of the River Survey Project. Via FPCO, also staff from other organizations were invited to participate.

Most of the material used in the courses is collected in lecture notes, see the next chapter. For the content of the various courses reference is made to the *1°Interim Report, Annexure 8.*

8.2.6 Other training related activities

Other activities comprise

- Presentations on seminars arranged by other parties
- Advise to BWDB/WRIS on selection of survey equipment
- Assistance to BIWTA with positioning systems

8.3 Training programme phase 2

8.3.1 Introduction

As shown in Table 8.1, it is proposed to carry out external training in phase 2 within the fields of survey techniques, data handling, and river engineering (studies).

To overcome the limitations mentioned in Section 8.1.3, two measures are taken:

- Cooperation is sought with the UNDESD project Water Resources Information System (WRIS) of the BWDB in order to strengthen our training activities
- It is indicated which activities can be undertaken within the present contract of the River Survey Project. Additional funding is proposed for the remaining activities

In this section, first the cooperation with WRIS is briefly discussed (Section 8.3.2), then the main training subjects are outlined (Sections 8.3.3 to 8.3.5), leading to the programme of phase 2 (Section 8.3.6).

8.3.2 WRIS

Simultaneously with the River Survey Project (from mid 1992 to mid 1996) the UNDESD project Water Resources Information System (WRIS) started. The duration of WRIS is three years from mid 1992 to mid 1995. As there are interesting overlaps between the River Survey Project and WRIS, especially in the field of training, some project characteristics of WRIS are outlined below.

Objectives
'Training of Trainers' as directed in the Project Document. Emphasis will be placed on transfer of new appropriate technologies and on correcting perceived deficiencies in current field practices of Hydrology Service.

Participants
Subdivisional Engineers of the Hydrology Service, BWDB (in principle)

Related project activities (not necessarily in sequential order)

- Defining training needs. (The Hydrology Service through River Morphology Directorate runs the current training programme at Bhagyakul. They must submit to the Project their current Annual Training Programme and the training material (texts) used as part of this activity)
- Adoption of standards for the full range of data collection activities within the Hydrology Service
- Selection and purchase of equipment (such as moving boat system, GPS) which require special training to operate
- Coordination with related projects such as FAP 24 of training scope and division of responsibilities
- Formulation of the Hydrology Service Training Programme for Trainers (Subdivisional Officers who will instruct field technicians)
- Drafting the 'Training for Trainers' manual
- Implementing the training programme in Bhagyakul
- Feedback from trainers from experience of applying what they learned from the programme
- Revision of programme and/or manual

Approximate timetable

- Preparatorion (defining needs, setting standards, purchasing equipment, etc): May-September 1993

- o Formulation of courses structure and content, preparation of manuals: October-December 1993
- o Implementation of training programme in Bhagyakul: January-April 1994
- o Feedback and adjustment of training programme: October-December 1994
- o In 1995, training by the trainers to the operational level

General scope of training programme

Coverage of procedures performed by Sectional Engineers and other field technicians and for which they will be instructed by the Subsectional Engineers. The courses will include additional material that will strengthen the conceptual and practical background of Subdivisional trainees. Ideally, this should also facilitate their envisioned role as primary checkers of data quality.

Tentative topics

1. Measurement of water-level

- o Water-level instruments
- o Site investigations for location of staff gauges and water-level recorders
- o Field procedures and precautions
- o Possible errors

2. Measurement of water discharge

- o Selection of measuring sites
- o Velocity measurements (methods, instruments, applicability)
- o Cross-sections
- o Methods of discharge quantification (area-velocity and others)
- o Positioning methods
- o Conventional current-meter measurement (fixed station)
- o Moving-boat systems
- o Discharge measurements under tidal conditions
- o Discharge measurements under flood conditions (applicability of floats?)
- o Typical problems in large alluvial rivers (multiple channels, when a section becomes inadequate, relocation of stations)
- o Discharge measurements of flashy rivers
- o Stage-discharge relationship
- o Possible errors

3. Measurement of sediment discharge

- o Concepts of sediment transport, relevance to Bangladesh
- o Instruments for direct measurement

- o Field procedures and precautions
- o Elements of sediment analysis
- o Possible errors

4. Measurement of rainfall

- o Siting/maintaining a rainfall gauging station
- o Rainfall gauges (types, use and maintenance)
- o Field procedures and precautions
- o Possible errors

5. Measurement of water quality parameters including salinity

6. Measurement of climatological variables

- o Evaporation (equipment, procedures, errors)
- o Temperature (instruments, procedures, errors)
- o Sunshine hours (instruments, procedures, errors)

Similarities and differences

Comparing the future training activities of FAP 24 and WRIS a number of similarities and differences can be detected.

- o The training in both projects is directed towards river surveying of hydrological and morphological parameters. There is also a possible overlap in training on data-processing depending on future similarities in software
- o The training may include all staffing levels
- o Both projects will give training to BWDB staff; FAP 24 will also give training to BIWTA and BUET staff
- o WRIS is focussing on execution of routine measurements, while FAP 24 will emphasize more on the physical processes and special measurements
- o WRIS training is concentrated in 1994 and FAP 24 continues up to mid 1996

Fields of cooperation

The fields of cooperation are especially in training on subjects of surveying and data processing and perhaps studies.

A special staff member has been nominated to elaborate and implement the common training activities. He is working parttime in the WRIS office and parttime in the office of the River Survey Project. The following outline on training is drafted in cooperation with WRIS.

8.3.3 Survey

The external survey training is given to BWDB and BIWTA staff. The main part of the training will be given to trainers, which are staff members at the field level: Sub-divisional engineers.

Methods of survey training comprise

- Introductory training
- Special exercises in the field
- Seminars, courses, lectures
- On-the-job training
- Study tours

Introductory training
It is proposed to organize introductory training for the decision level (see Table 8.2). The training consists of a combination of a few lectures on principles of measurements combined with survey demonstrations aboard the vessels.

The differences of the various available techniques to measure either water or sediment transport will highlighted. The possibilities, pros and cons will be discussed in order to assess the sustainability in Bangladesh.

In principle, an introductory training session will take one day. It is envisaged to have two such sessions per year, if possible one during the monsoon.

Special exercises
Special survey training will be organized for the trainers (the field level, see Table 8.2). In the field a number of exercises have to be elaborated and carried out using available equipment and vessels. Training sessions with a duration of one week in combination with lectures (see below) are envisaged.

Possible training topics are:

- Set up of AWLR station
  location versus morphology; case studies; slopes and other hydraulic effects; comparison of various instruments
- Importance of bathymetric and topographic measurements
- Bathymetry and remote sensing
- Optimization of hydraulic measurements; data density and accuracy
- Optimization of suspended sediment measurements; effects of bed forms
- Methods of bed load measurements including dune tracking

Training packages will be developed together with WRIS. A distribution of work will be elaborated in detail. Probably, different packages need to be prepared for BIWTA and BWDB.

It is proposed to organise two training sessions per year, one of 5 days and one of 3 days with special exercises. The sessions should be in the dry season.

Lectures
Lectures, seminars, courses will be organized as part of the introductory training for the decision level or more extensively as part of the field exercises for the trainers.

The lectures will compare different available techniques and elaborate the physical processes of water and sediment transport.

The lectures for the trainers are given in the BWDB training center in Bhadyakul. The subjects ar mentioned above. The time for lecturing is included in the time mentioned under exercises.

On-the-job training
On-the-job training is possible throughout the year. It means that a very limited number of people, say 2 per boat, may board one of the vessels of the River Survey Project to participate in the survey work. There are a few practical restrictions:

- The training should not hamper the on-going survey work (therefore only two trainees per boat are allowed)
- There is no extra accommodation aboard for trainees, which implies that trainees should disembark at the end of each day. This means that on-the-job training for more than one consecutive day is only feasible at survey locations with a nearby guesthouse
- Special land transport need to be organized. Participation up to one month per year is envisaged

Study tours
Study tours to some rivers where special measurements are carried out are of interest for both decision level and trainers. River surveys of interest are amongst other expected on the Mississippi, the Rhine and the Yangtze. Three tours of 8 persons are proposed. Study tours are not included in the Contract of the River Survey Project. Hence, additional funding is required, see Section 8.3.7.

8.3.4 Data handling

The training characteristics regarding data handling in general and off line data processing in particular are as follows:

- o Training will focus on operational staff of the BWDB/WRIS data-processing office
- o Training topics will concentrate on the use of several common software packages (used by both WRIS and FAP 24)
- o Timing will depend on actual realization of the BWDB/WRIS data processing facilities and staff availability
- o Use of FAP 24 facilities may be considered

Two methods of training are proposed:

- o Workshops
- o Long term ad hoc assistance

In 1994, two workshops will be organized, each of one week, to familiarize the BWDB software engineers with the common software packages.

During one year, ad hoc assistance will be given by FAP 24 to BWDB staff in getting their data processing office started. In total one manmonth will be used for the purpose.

8.3.5 Studies

For training on study subjects various possibilities exist.

- o Lectures, seminars (short term) in Bangladesh
- o Seminars abroad
- o Long term participation of BWDB and BUET staff in RSP studies
- o Study abroad

A number of lectures, seminars and workshops held by other organizations/projects in Bangladesh will be attended. Especially FPCO, BUET and FAP projects can be mentioned in this context. Besides, the River Survey Project will organize lectures and workshops to discuss project results.

Some international seminars are of high interest for the project, for instance the one in Australia in December 1994 on flow variation and sediment transport. One such seminar per year for a small group of about 4 persons is recommended.

Both BWDB Hydrology and BUET expressed their keen interest in transfer of knowledge from the River Survey Project. Especially, trainees like to participate in some parts of the study programme, including the related special surveys. For this reason, some BUET staff members of the Department of Water Resources Engineering visited the River Survey Project office to explore the possibilities.

The Consultant is of the opinion that a substantial transfer of knowledge is only possible via long term participation. It is therefore proposed to involve BUET and BWDB staff in the study programme of the River Survey Project. We think of active, daily participation in selected study topics under strict control (in progress and quality) of our own study team. It is proposed to have in phase 2 rather continuously up to a maximum of 4 trainees working at least 50% of their time in the FAP 24 office. To make it a success, sufficient FAP 24 time needs to be allocated for the transfer of knowledge. 4 manmonths expat staff and 8 manmonths local staff is proposed.

Training abroad is of interest for the project in the 94/95 season. It is proposed to send one person from our study team to the IHE course in the Netherlands.

8.3.6 Training programme

An outline for the proposed training programme in phase 2 of the River Survey Project is given in Figure 8.2 below.

Some particulars regarding this training schedule are mentioned hereafter:

- Introductory training is given during one day per season
- One exercise for BWDB staff and one for the BIWTA staff will be organized in the lean season
- Lectures coincide with the previous introduction and exercises
- On-the-job training will total one month per year
- For the study tour one destination per year is assumed
- The timing for training in data processing is somewhat uncertain and depends on the progress in the WRIS project
- Study abroad to be scheduled for 1994/95 in order to let the project profit from the result

Year / Subject	1994	1995	1996
SURVEY			
o Introduction	●	●	●
o Exercises	▬	▬ ▬	▬
o Lectures	▬ ●	● ▬ ▬ ●	▬
o On-the-job	----------	----------	-------
o Study tour	▬	▬	
DATA HANDLING			
o Workshop	▬ ▬		
o Support	----------		
STUDIES			
o Lectures, etc.	●	● ▬ ●	▬ ●
o Seminar	▬	▬	
o Participation	.....	.....	.....
o Study abroad	****	********	

Legend :

●	day
▬	up to one week
-----	on ad hoc basis
.....	at least 50% of time
****	full time
¦	end of project

Figure 8.2: Training programme, phase 2

8.3.7 Contractual and financial aspects

Below is given a summary of the resources that are required in order to realize the training programme that is proposed in the previous sections. Also, it is indicated which part of the resources that is available within the contract (notably the manmonths and the vessel days) and which part needs additional funding (other resources).

MAIN ACTIVITIES	RESOURCES			
	MANMONTHS		VESSEL DAYS	OTHER
	EXPAT	LOCAL		
* DEFINITION •	½	1	-	-
* PREPARATION				
o Survey exercise + lectures	1	3	-	-
o Data processing workshops	(½)	1½	-	-
o Study lectures	1	3	-	-
* IMPLEMENTATION				
o Survey				
- introduction	¼	1	5	-
- exercises + lectures	1	3	24	1)
- on-the-job	-	-	-	2)
- study tour	1	3	-	3)
o Data handling				
- workshop	(½)	1½	-	_
- ad hoc support	¼	1	-	-
o Study				
- lectures	½	1	-	-
- seminar	½	1	-	4)
- participation	4	8	-	5)
- study abroad	-	12	-	6)

- in consultation with FPCO, BWDB, BIWTA and WRIS

Figure 8.3: Resources for training

In the following, the required resources as proposed in Figure 8.3 are commented on.

Manmonths
The total manmonths required to realise the training programme amount at 11 for expat and 40 for local staff. It is noted that 1 expat manmonth related with the workshops on data processing and handling is the activities mentioned under external data base in the contract. The main part may be covered by study manmonths. It means that about 25% of the study manmonths will be spent on training. If that is acceptable, the required input fits within the available resources according to the contract.

Vessel days
It is proposed that the 29 vessel days mentioned can be payed applying the unit rates of hydrometric vessel. Included in these rates are the standard crew and survey staff (these are consequently not counted under man-months). It is expected that the vessel days fit within the Contract.

Other resources
Other resources required to implement the training programme are summarized hereafter (using the numbers out of Figure 8.3). These cost are not covered by the Contract:

1) Additional costs to organise special training sessions in the training center Bagyakul are related with
   - rent of facilities (to be shared with WRIS)
   - tuition materials
   - field/daily allowances
   - land transport

2) Additional costs related with on-the-job training are for
   - field/daily allowances
   - land transport

3) For study tours the main costs are related with:
   - international travel
   - daily allowances (hotel, food, etc.)

4) External seminar
   - international travel
   - seminar fees
   - daily allowances (hotel, food, etc.)

5) For long term participation of staff from BWDB and BUET, the project has to supply facilities such as office room, furniture, aircon and 2 computers.

6) Cost involved for training abroad are:
- international travel
- fees
- cost of housing, etc.
- home salary

Cost estimate

Based on the required resources mentioned in Table 8.3, the following cost estimate has been made, distinguishing cost covered by the Contract and other resources to be covered by additional funding.

Expat and local manmonths	230,000 ECU
Vessel days (including crew and survey team)	260,000 ECU
Total cost covered by the contract	490,000 ECU

Type of training	Duration	No. of participants	Cost (ECU)
Exercises	3 x 8 days	12	10,000
On-the-job	2½ x 30 days	2	6,000
Study tours	3 x 8 days	8	80,000
Seminars	3 x 8 days	4	45,000
Participation	2½ year	4	14,000
Study abroad	1 year	1	15,000
Total cost to be covered by additional funding			170,000

The figures show that the total cost for training is ECU 660,000 of which about 75% is covered by the Contract and 25% needs additional funding.

9. Reporting

Besides the reporting on activities and results of the River Survey Project, the Contract requests a proposal for the format of the annual reporting of river data. Therefore, this chapter consists of two sections:

- Project reports
- Format of annual reports

9.1 Project reports

A number of reports, notes, etc. has been published by the River Survey Project during the reporting period. The reports are divided into the following categories:

- General Project Reports
- Progress Reports (with Survey Bulletins)
- Survey Reports
- Study Reports
- Survey Notes
- Working Papers
- Various
- Workshop contributions
- Lecture Notes

The general project and progress reports are scheduled in the ToR and aim at reviewing the project activities, summarizing the results, and planning the further work.

The results of the surveys are summarized in so-called 'Survey Bulletins' which are appended to the progress reports.

The results of the work are described in detail in the survey and study reports.

The survey notes are often preparatory notes for the coming field campaigns. Working papers are intermediate draft papers on subjects worth to be published at an early stage. The final versions of these papers become part of the survey or study reports.

The lecture notes are used for in-house training sessions for project staff and external staff.

The 'various' category comprises some reports with an individual, specific purpose that have been published by the River Survey Project, as shown in the list below. The 'reporting format' is an in-house instruction for the staff on the layout and editing of project reports. The 'compilation of papers' was published as a courtesy gesture to improve the distribution of important papers on the morphological processes in the Bangladesh river system. The publication 'Towards

an improved understanding of the rivers in Bangladesh' is a brochure giving an introduction to the River Survey Project.

The workshop contributions were made and presented during the International Workshop on the Morphological Behaviour of the Major Rivers in Bangladesh, held from 6 to 8 November 1993 in Dhaka.

The reports, notes, etc. published by the River Survey Project so far, are listed below.

A. GENERAL PROJECT REPORTS

1. Inception Report, 22 August 1992
2. Revised Inception Report, 20 October 1992
3. 1° Interim Report, Volume I: Main Report, February 1993
4. 1° Interim Report, Volume II: Annexures on survey work, February 1993
5. 1° Interim Report, Volume III: Annexures on studies, etc., February 1993
6. Draft Notes on Planning, June 1993
7. Final Report Phase 1

B. PROGRESS REPORTS

1. 1° Quarterly Progress Report, September - November 1992
2. 2° Quarterly Progress Report, December 1992 - February 1993
3. 3° Quarterly Progress Report, March - May 1993
4. 4° Quarterly Progress Report, June - August 1993
5. 5° Quarterly Progress Report, September - November 1993

C. SURVEY REPORTS

1. Additional Survey, September 1992, 31 October 1992
2. Report on Land Survey: Water-level Gauging, June 1993
3. Test Gauging Report: Survey Procedures and Data Presentation, October 1993

4. Selection of Survey Techniques, November 1993

5. Dry season 1992/93, December 1993

6. AWLR Stations: Site selection, installation and O&M (not yet published)

7. Transfer of Bench-Mark Levels across Jamuna River at Bahadurabad, December 1993

8. Flood Season 1993, July 1994

9. Bathymetric Pilot Surveys on Jamuna River at Bahadurabad, July 1994

D. STUDY REPORTS

1. Selection of Study Topics for Phase 2, September 1993

2. Hydrological Study Phase 1, June 1993

3. Morphological Studies Phase 1

E. SURVEY NOTES

1. Proposal for Additional Survey Bahadurabad, July 1992

2. Anwesha Survey, Technical Guidelines, September 1992

3. Proposal, Additional Field Tests December 1992, 28 November 1992

4. Programme Outline for Test Gauging, August 1993

5. Bathymetric Survey for the Jamuna Bridge Project, October 1993

F. WORKING PAPERS

1. Technical Recommendation and Verification of the Acoustic Sensor type of AWLR, October 20, 1993

2. Qualitative Impact Assessment of FAP Implementation, January 1994

G. VARIOUS

1. Reporting Format (regularly updated)

2. Morphological Processes in The Bangladesh River System. A Compilation of Papers. October 25, 1993

3. Towards an Improved Understanding of the Rivers in Bangladesh (RSP brochure)

H. WORKSHOP CONTRIBUTIONS 6-8 NOV 1993

1. Klaassen, G. J: *On prediction methods for alluvial rivers with particular reference to planform changes*

2. Olesen, K. W.: *2-D mathematical modelling of bifurcations*

3. Mosselman, E., and G. J. Wensink: *River Bathymetry observation with radar remote sensing*

4. Iversen, C.: *Survey techniques selected by FAP 24*

5. Kuehl, S. A. and M. A. Allison: *Subaqueous delta of the Ganges-Brahmaputra river system and the holocene sediment budget: Implications for flood plain subsidence and sedimentation*

6. Executive summary - Selection of study topics for phase 2

I. LECTURE NOTES

1. On Sediment Transport and Hydraulic Roughness

2. River Dynamics. Lecturer: G. J. Klaassen

3. River Hydraulics. Lecturers: S. Mahmood & P. van Groen

4. Advanced River Processes, by G. J. Klaassen, October - November 1993

9.2 Format of annual reports

In the Contract (ToR, Subsection 4.4.3) a proposal is requested on the format of annual reports:

quote
'The report at the end of the phase 1 will also present proposals for a format for annual reporting on the hydrology and morphology of the main rivers. The aim of such report would be to provide each year all data of interest on water levels, discharges, change in morphology, notable events (scour and filling at critical points). In addition to provide a continuous record, it would serve as a reference for planners and designers.'
unquote

To prepare such a format, the following approach has been applied:

- Some yearbooks were collected as examples, notably:
  - *Lower Mekong Hydrologic Yearbook*
  - *Jaarboek van Afvoeren, Waterstanden, Golven en Waterkwaliteit (in Dutch)*
- These yearbooks were compared with survey reports of the River Survey Project:
  - Survey Report 5: Dry Season 1992/93
  - Survey Report 8: Dry Season 1993
- Then, a first draft of a format of the 'yearbook' was made, considering the following:
  - The hydrologic and morphological characteristics of the river system of Bangladesh are quite different in the dry and in the flood season
  - In view of the size of the volumes, seasonal reporting is preferred above annual
  - The format should preferably fit both BWDB and FAP 24 reporting
  - The text of the yearbooks is short. The data is given in graphs and tables; usually, daily values are presented
  - The previous survey books of the River Survey project are difficult to read because of the comprehensive text and the detailed data presentations

On this basis, it is proposed to organise the data book in three volumes, as follows:

Part A: Water-level, flow, and sediment transport
- main text
- survey programme
- summary tables of water-levels, flow, and sediment transport
- rating curves (flow and sediment transport)

Part B: Routine gaugings
- survey bulletins (new format)
- cross-sectional flow velocity distribution
- grain size distribution summaries

Part C: Data catalogue
- lists of all routine gaugings, indicating location and time, type of measurement, and file name, as a reference to the raw data or for easy access to the edited data

This structure will be applied in Survey Report 10 of the River Survey Project: *'River data, lean season 1993/94'*. A specimen of the format is attached as Annexure 1.

Finally, it should be mentioned that the proposed set-up allows a high degree of automation.

10. Work plan

10.1 General

For technical as well as administrative reasons, the mobilization for phase 2 had to be postponed from the first half of 1993 to the lean season following the monsoon period of 1993. For further details, reference is made to Annexure 9 of the *1° Interim Report*. The consequences have been that some revisions of the over-all work plan as well as of the detailed work plans have been made during the course of the project

An updated over-all work plan and detailed work plans for the survey and study activities for the year 1994 are presented in Figures 10.1-3.

10.2 Implications and scope of revisions

The availability of a reduced equipment package during the monsoon of 1993 forced a reduction of the number of measurements which could be carried out in that period. With a present contractual completion date of June 9, 1996, this means that the number of floods getting a 100% coverage as specified in the Contract will be reduced to two only (1994 and 1995).

As a result, it has from a professional river morphological point of view been strongly recommended not to terminate the project just before the monsoon of 1996 but to extend the project period until at least the peak flow of the monsoon has been measured.

The main revisions may be summarized as follows:

- Shifting the comparative test gaugings from 1992 to 1993
- About halving the HW routine gaugings and corresponding bed load measurement in 1993 as well as the bathymetric surveys
- Shifting the remaining HW routine gaugings of 1993 to 1996 which for capacity reasons will require an extension of the project period
- Therefore, if possible, extending the project period with 5 months (about 3 months survey and 2 months demobilization) (subject to the available resources)

This will make it possible to execute the number of surveys in accordance with the BoQ.

Some secondary revisions were :

- Further reconnaissance survey work than originally expected.

- Starting earlier with the bathymetric survey work (already before and during the floods of 1993) at Bahadurabad, in order to define the final need and optimize this type of survey work

The above listed main and secondary revisions are mainly dealing with the survey component of the project. The study and training component have been affected where they were related to the survey component. Therefore, the present discussion on the revisions has focused on the survey component. The revisions indicated in this section are summarized in the over-all survey work plan hereafter. For more details, reference is made to Annexure 9 in the *1° Interim Report.*

In general terms, the implications of the revisions are as follows:

- The phase 1 measurement programme has in principle not been affected. The routine gaugings missed in 1992 are transferred into the subsequent periods.

- Between phase 1 and Phase 2, viz June 1 and October 31, 1993 a transition phase of five months was determined with a mixed survey programme comprising :
  - The contractual HW test gauging
  - HW routine gaugings at all sites but with a much lower measuring frequency as compared with the specifications
  - Bathymetric pilot surveys at Bahadurabad

  The programme resulted in a substantial number of outstanding routine gaugings - missed measurements - which, for capacity reasons, may hardly be filled into the subsequent flood season programmes.

  The survey programme as made within this transition phase is summarized in Chapter 4 of the present report.

- Phase 2 started with another mobilization period preparing the extended survey capacity. Phase 2 covers approximately 2½ years. The first LW routine gaugings had to be carried out with phase 1 equipment only, and, for the same capacity reasons, the bathymetric surveys were only partly covered.

- Supplementary measurements related to the study programme have also been included.

The routine gauging programme aims at catching the rising phase and peak of the flood in the Jamuna River during the monsoon in 1996.

The similar flow conditions in the Ganges River normally occur later and may therefore hardly be covered.

10.3 Over-all work plan

The previous valid over-all project work plan was firstly presented in the *Draft Notes on Planning* dated 7 July 1993. Since then, a few modifications regarding the installation of AWLRs and the reporting schedule have been made as shown in Figure 10.1. A similar over-all work plan addressing the individual study topics is shown in Figure 7.6.

The over-all work plan also shows the activities as made up to the end of 1993.

Phase 2 activities remain more or less unchanged. Actual changes appear in the more detailed work plans as briefly described below.

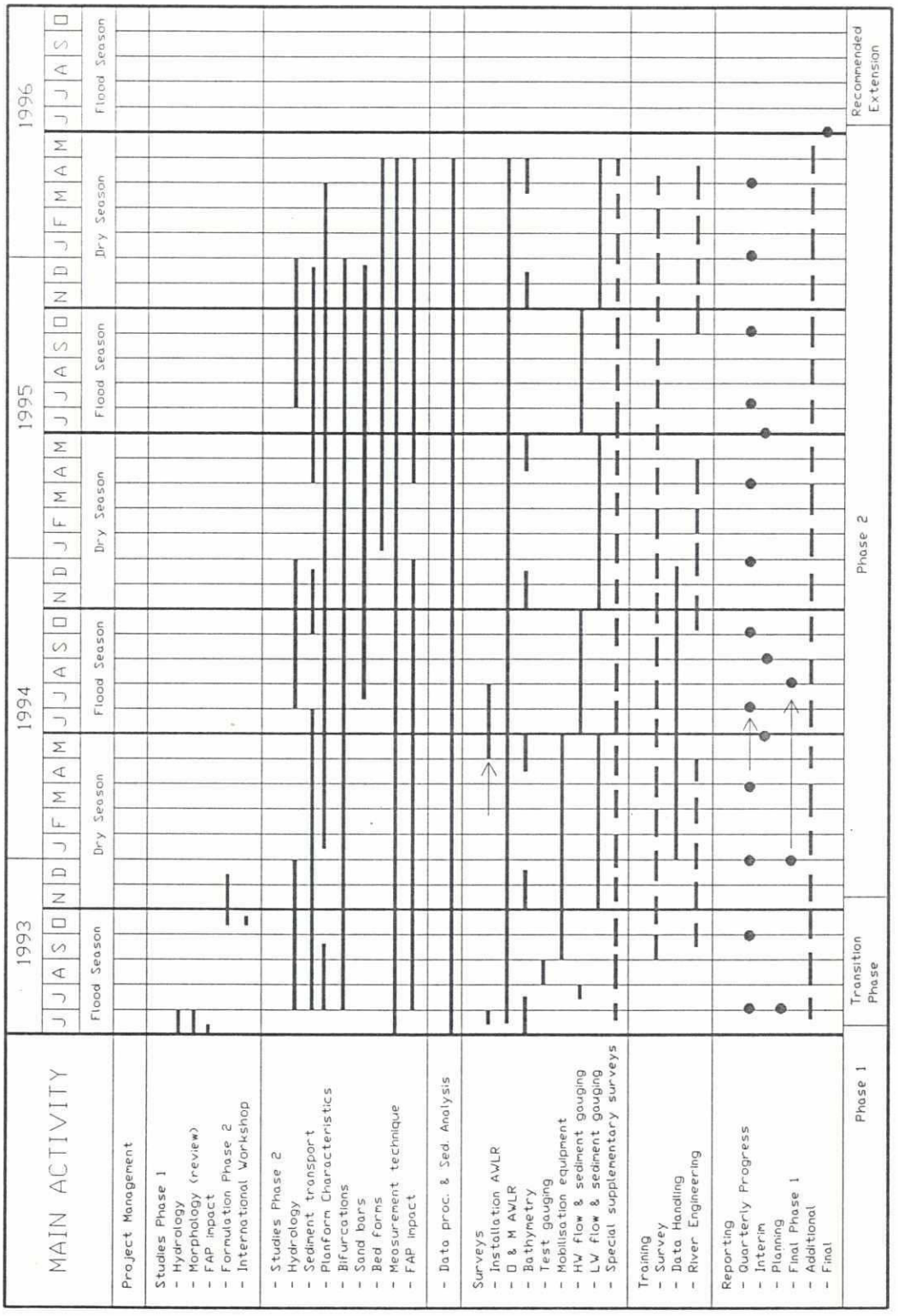


Figure 10.1 :Over-all work plan (dated 31/12/93)

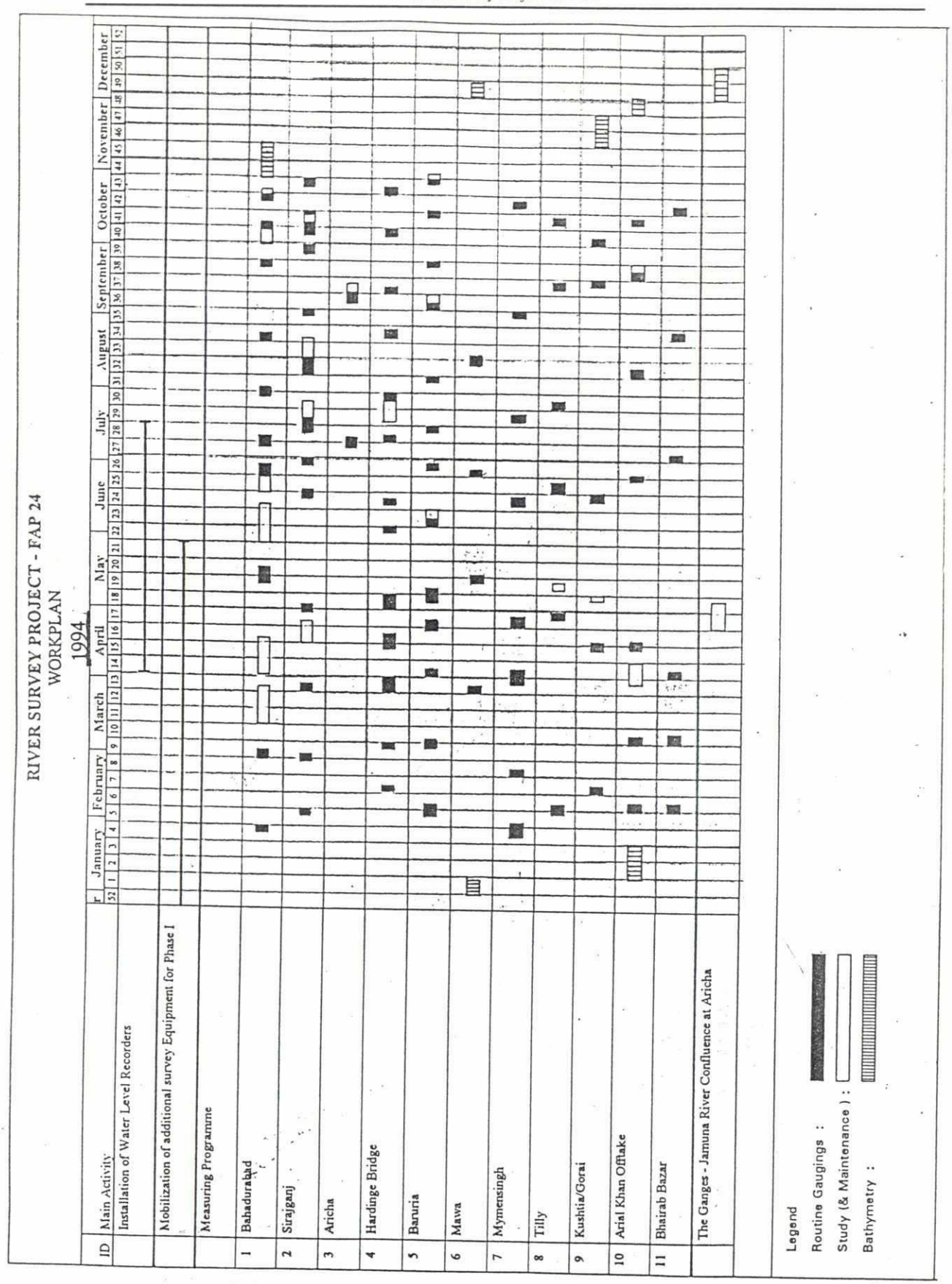


Figure 10.2: Survey work plan

10.4 Detailed work plan - surveys

A detailed work plan covering the survey activities during the period January 1993 until the flood season of 1994 is shown in Figure 10.2.

For a summary of the survey work as made up to the end of 1993, reference is made to Chapter 4 of this report. A few key activities are described in more detail in the following sub-sections.

10.4.1 Automatic Water Level Recorders (AWLRs)

According to the Contract, one water-level recorder had to be installed in phase 1 at Bahadurabad and another 10 during phase 2 covering the remaining stations.

In order to test an alternative instrumentation of the originally proposed water-level pressure transducers, the consultant by the end of May, 1993 installed one pressure cell station just upstream of Bahadurabad Ghat and, by the beginning of July, a combined acoustic and pressure cell type recorder was in operation at Gabgachi in the right channel of the Jamuna River opposite Bahadurabad Ghat; ref. section 4.2.

The installation of the remaining 10 stations will start in May 1994 and the target is to have all of them in operation by the end of July 1994.

10.4.2 HW routine gaugings

The main revision of the survey work plan has concentrated on the activities during the monsoon season of 1993, since the available phase 1 equipment was insufficient to cover the specified HW routine gauging including the HW test gauging as well as the bathymetric pilot surveys agreed upon.

The HW routine gaugings comprise flow and sediment transport measurements (including suspended load and bed load) at the 11 locations.

The number of measurements accomplished during the flood season of 1993 are summarized in Chapter 4 of the present report.

The test gauging programme was carried out according to the Contract from 16 till 22 August 1993.

On the condition that the additional survey vessels and equipment for Phase 2 will be available in time the coming flood and dry season survey programmes may be accomplished according to BoQ in the Contract. Besides the survey work plan for 1994 accommodates quite some special survey activities related to the study programme; ref. Figure 10.3 below.

10.4.3 Bathymetry

The locations and frequency of measurements are given in the contract indicatively.

The measurements were originally scheduled to start in phase 2. However, in order to obtain some operational experience and to collect some bathymetric data for study purposes as early as possible, it was agreed to include some bathymetric pilot surveys at Bahadurabad already during the flood season of 1993.

The surveys were made as follows:

1st survey	:	10-26 June 1993	Flood season
2nd survey	:	25 August - 5 September 1993	Flood season
3rd survey	:	1-20 November 1993	Dry season

Other routine bathymetric survey activities carried out until the end of 1993 have been summarized in Chapter 4.

Together with the morphologists a special bathymetric programme will be prepared in phase 2 considering aspects such as :

- Sounding area, density and frequency
- Contour (water line) measurements
- Topographic methods
- Connections with remote sensing techniques

10.4.4 Recommended extension of the project period

As also mentioned above it is recommended to maintain a phase 2 period of three years, which indicatively implies an extension of the project by 5 months (the duration of the transition period) consisting of about 3 months of surveying and 2 months for reporting and demobilization.

The main purpose of the extension is to catch the flood of 1996, thus compensating for the reduced flood measurements of 1993.

Considering that the River Survey Project should emphasize the floods, it seems rather logical not to terminate the project just before the flood of 1996 but just after the flood.

The matter of a project extension has been discussed intensively with the Client's Representatives and is still subject to further clarification.

10.5 Detailed work plan - studies

The detailed workplan for the period June 1993 to June 1994 is shown on Figure 10.3 below. It is derived from the framework of the study programme (Chapter 7), but includes some minor modifications:

- The study topic 'Effect of tectonics on planform characteristics' (topic no 3.6) has been deleted, as it is considered to be too distant from the scope of the River Survey Project

- Because of sickness of one of the members of the study group the topics 'Sediment transport predictors' (topic 2.2) and 'Integration of existing knowledge' (topic 2.3) have been delayed by a few months

- Some work for the topic 'Rating curves and balances' (topic 2.1) has been done in November and December 1993 according to the presented study programme, but it is planned to update these rating curves and balances each year after the monsoon. Also, efforts are continuing to develop seasonal sediment rating curves.

	Study topics	1994											
		J	F	M	A	M	J	J	A	S	O	N	D
1.1	Improved discharges and rating curves												
1.2	Improved historical discharges												
1.3	Water balances and overland flow												
1.4	Water-level profiles and slopes												
1.5	Phase 2 updating												
2.1	Sediment rating curves and balances												
2.2	Sediment transport predictors												
2.3	Interaction of existing knowledge via 1-D morphological model												
2.4	Long-term development of river branches												
2.5	Flood plain subsidence												
3.1	Planform classification and meandering and braiding characteristics												
3.2	Channel dimensions												
4.1	Discharge and sediment transport distribution												
4.3	Influence of bars												
6.1	Occurrence, dimensions, and dynamics of bars												
6.2	Time dependency of bars												
7.4	Roughness and bed forms												
9.1	Selection of measurement sites												
9.2	Optimization of hydraulic measurements												
9.3	Optimization of sediment measurements												
9.4	Bed load transport with dune tracking												
9.5	Bathymetry and remote sensing												
9.6	Sustainable survey techniques												

Figure 10.3: Study work plan

Annexure 1:

Sample format of River Data Book

River Data Book
November 93 - May 94
(Dry season 93/94)

Contents

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Part B: Data summaries

Part C: Data catalogue

Acronyms, abbreviations and symbols

ADCP	:	Acoustic Doppler current profiler
AWLR	:	Automatic water-level recorder
BM	:	Bench mark
BTM	:	Bangladesh Transverse Mercator (a geodetic grid)
BWDB	:	Bangladesh Water Development Board
DELFT	:	Delft Hydraulics
DGPS	:	Differential Global Positioning System
DHI	:	Danish Hydraulic Institute
EMF	:	Electromagnetic flow meter
FAP	:	Flood Action Plan
FAP24	:	FAP project 24 = The River Survey Project
FM	:	Finnmap (a geodetic survey company)
FPCO	:	Flood Plan Coordination Organization
h	:	Stage (m +PWD)
MEX	:	A specific turbidity meter
MV	:	Motor vessel
PWD	:	Public Works Department datum
Q	:	Flow rate (m^3/s)
S	:	Sediment transport rate (kg/s), please refer to Figure 4
S4	:	A specific electromagnetic flow meter
US BM-54	:	A specific bed material sampler
TBM	:	Temporary bench mark

1 Introduction

1.1 Use of this Data Book

The aim of the present Data Book is to give an outline of the data collected during the routine programme of the River Survey Project. Brief data summaries are presented, and catalogue entries are listed for the entire programme.

The book is divided into

- *Part A,* which describes the data coverage and presents summary tables of water-levels, flow and sediment transport
- *Part B,* with summary presentations of flow and sediment transport from the individual surveys
- *Part C,* which contains a full listing of the collected data and their storage

The activities described in the present Data Book have produced more than one giga-byte of raw data, and only a very superficial presentation of the findings has been made. For an in-depth analysis of the results, the user is referred to the underlying data base.

1.2 The River Survey Project

The River Survey Project (FAP24) was initiated on June 9, 1992. The project is executed by the Flood Plan Coordination Organisation (FPCO) under the Ministry of Irrigation, Water Development and Flood Protection, with funding by the Commission of the European Communities. Consultants are DELFT-DHI joint venture in association with Osiris, Hydroland and Approtech. Project supervision is undertaken by a Project Management Unit with participation by FPCO, a Project Advisor, and a resident Project Advisor.

The objective of the project is to establish the availability of detailed and accurate field data to form part of the basis for the FAP projects, as well adding to the basis for any other planning, impact evaluation and design activities within water resources and river engineering in Bangladesh.

The project consists of three categories of activities:

- a survey component, comprising development, implementation, and operation of a comprehensive field survey programme of river hydrology, sediment transport, and morphology
- a study component, comprising investigations of processes and effects within river hydrology, sediment transport and morphology
- a training component

The field programme may be regarded as a quantitative and qualitative supplement to the permanent registration of flow and water-level which has been carried out by Bangladesh Water Development Board (BWDB) for many years all over Bangladesh. By application of advanced technology, such as accurate DGPS positioning and high capacity ADCP flow measurements, the programme has added to the general data coverage and has provided a new insight into the time and space variation of the flow and sediment transport processes.

1.3 Summary of survey programme

The survey programme comprises the following activities:

a. automatic water-level recordings (AWLR) at 11 stations
b. routine dry season survey covering 11 locations (November through May)
c. routine flood season survey covering 11 locations (June through October)
d. bathymetry surveys at selected locations
e. special surveys and monitoring programmes with specific, individual objectives

The present Data Book is part of a series dealing with activities a, b, and c. Activities d and e are reported separately.

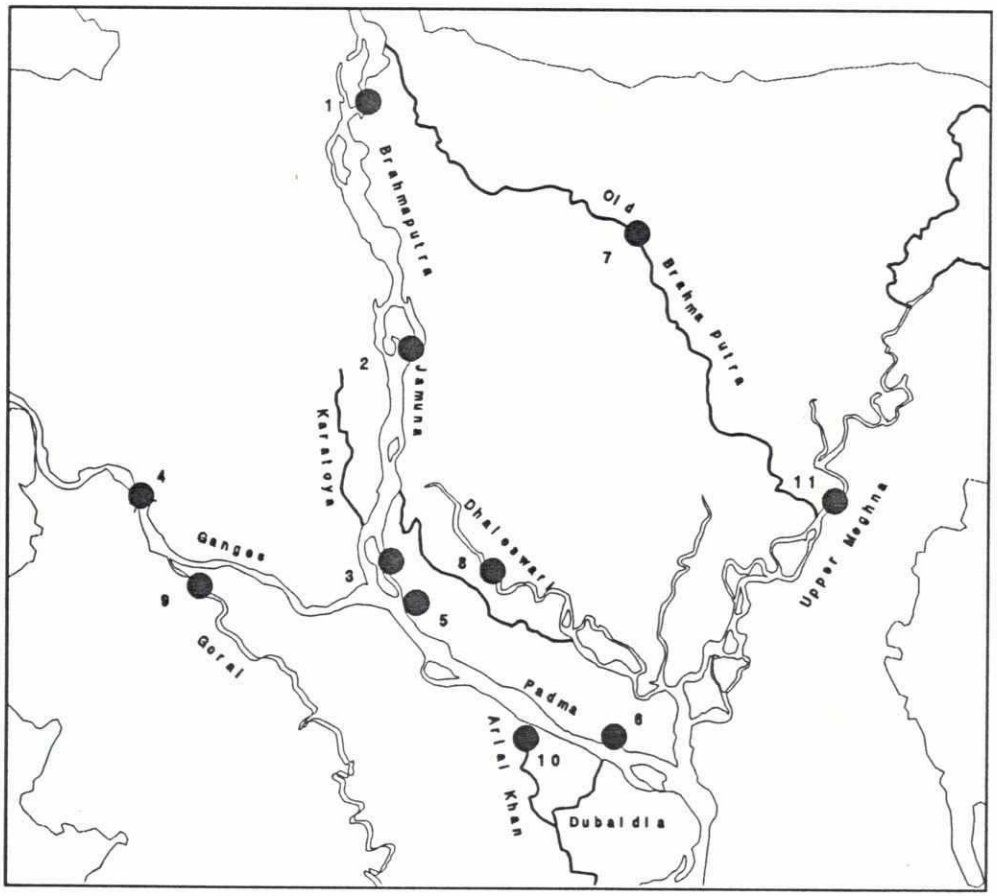
1.4 Summary of collected data

	1993		1994				
	N	D	J	F	M	A	M
AWLR water-level records:							
1a Gabgachi							
1b Bahadurabad							
2 Bhuyanpur							
3 Teota							
4 Hardinge Bridge							
5 Baruria							
6 Mawa							
7 Mymensingh							
8 Tilly							
9 Gorai							
10 Arial Khan							
11 Bhairab Bazar							
Routine surveys:							
1 Bahadurabad							
2 Sirajganj							
3 Aricha							
4 Hardinge Bridge							
5 Baruria							
6 Mawa							
7 Mymensing							
8 Tilly							
9 Kushtia/Gorai							
10 Arial Khan off-take							
11 Bhairab Bazar							

Figure 1: Summary of data collection

2 Water-levels

2.1 Measuring stations



LEGEND

1	Bahadurabad	Jamuna	7	Mymensingh	Old Brahmaputra
2	Bhuyanpur	Jamuna	8	Tilly	Dhaleswari
3	Aricha (Teota)	Jamuna	9	Gorai off-take	Gorai
4	Hardinge Bridge	Ganges	10	Arial Khan off-take	Arial Khan
5	Baruria	Padma	11	Bhairab Bazar	Megna
6	Mawa	Padma			

Figure 2: Location of AWLR gauges

Station	Type 1)	River	Established	Location	Benchmark and benchmark datum (m +PWD) 2)
1a Gabgachi	P & A	Jamuna	15/7 93 3)	mid char opposite of Fulchari	FAP24 C_2RE 19.998 m
1b Bahadurabad	P 4)	Jamuna	6/6 93	700 m upstream of ghat	FAP24 TBM O1 21.999 m
2 Bhuyanpur	P	Jamuna	29/5 94	left channel, opposite of Sirajganj	FAP24 TBM 14.249 m
3 Aricha (Teota) B)	P	Jamuna	13/5 94	2 km upstream of Aricha	FMBM 8122 10.202 m
4 Hardinge Bridge	A	Ganges	5)	at bridge	
5 Baruria T)	P	Padma	28/5 94	6 km downstream of Aricha	BWDB BM 91.9L 7.793 m
6 Mawa T)	P	Padma	10/5 94	near ferry ghat	FAP24 TBM 1708 6.314 m
7 Mymensingh	A	Old Brahmaputra	5)	railway bridge	
8 Tilly	P	Dhaleswari	28/5 94	10 km upstream of bridge	BWDB BM 10.466 m
9 Gorai	A	Gorai (near Ganges)	5)	railway bridge at off-take	
10 Arial Khan T)	P	Arial Khan	3/6 94	Koshabhaya, 3 km from off-take	BWDB TBM 6.145 m
11 Bhairab Bazar B), T)	A	Megna	5)	railway bridge	

1): P = pressure cell gauge, A = acoustic (ultrasonic) gauge
2): All AWLR recordings are referred to PWD datum
3): Out of operation Nov. 93 - May 94; station abandoned in June 94 due to river erosion
4): Replaced by a staff gauge from 2/8 93
5): Not yet installed (by end of June 94)
B): Influenced by back-water
T): Tidal effect can occur; please refer to Section 3.4

Table 1: AWLR gauges

2.2 Data tables

Summary tables of the data are given below for the stations that were in operation in the period covered by the present Data Book.

1 Bahadurabad

June - October 1993

file abc12345

m +PWD

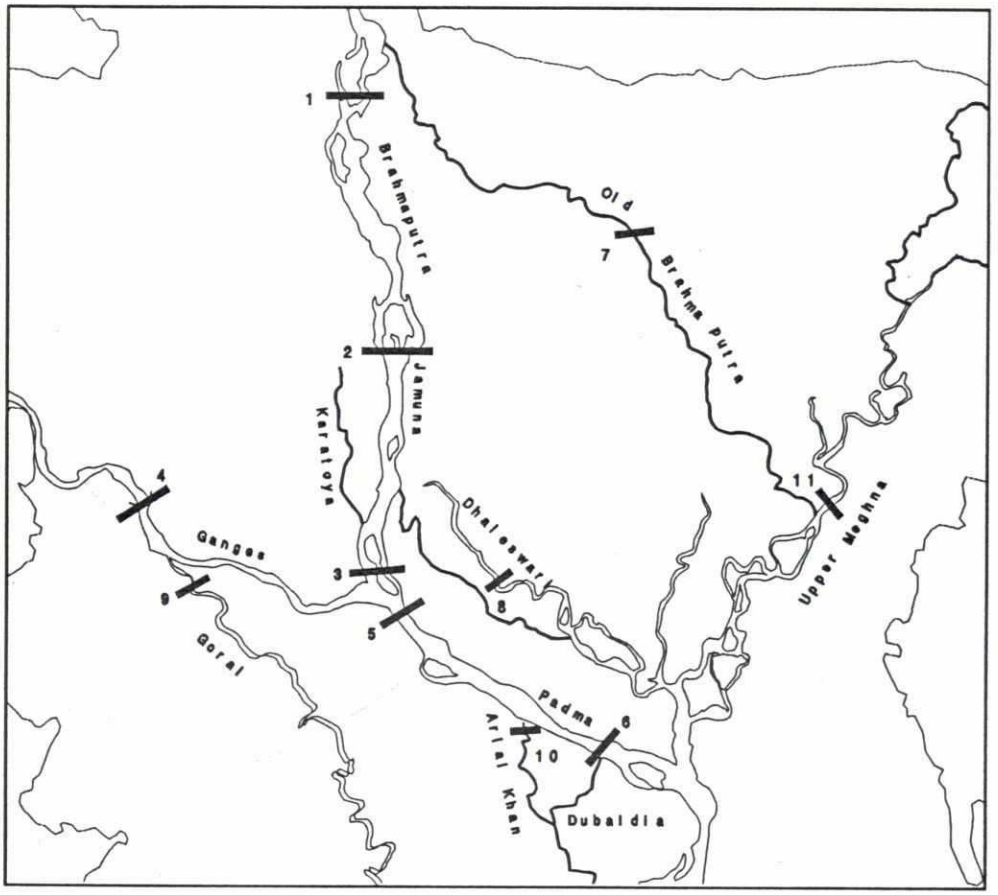
JUN	JUL	AUG	SEP	OCT

date	JUN	JUL	AUG	SEP	OCT
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					

Numbers indicate daily mean stage level (m +PWD)

3 Flow and sediment transport

3.1 Location of routine surveys



LEGEND

1	Bahadurabad	Jamuna	7	Mymensingh	Old Brahmaputra
2	Bhuyanpur	Jamuna	8	Tilly	Dhaleswari
3	Aricha (Teota)	Jamuna	9	Gorai off-take	Gorai
4	Hardinge Bridge	Ganges	10	Arial Khan off-take	Arial Khan
5	Baruria	Padma	11	Bhairab Bazar	Megna
6	Mawa	Padma			

Figure 3: Location of routine surveys

3.2 Description of measurements

A routine survey consists of some combination of the following elements:

- Positioning by DGPS
- River stage by AWLR or by staff gauge
- Cross-sectional depth contour by echo sounder
- Cross-sectional distribution of current and turbidity by ADCP, and horizontal distribution of surface current by EMF
- Vertical current profile by S4 current meter
- Vertical current profile by ADCP
- Vertical current profile by Ott current meter
- Vertical profile of suspended sediment concentration by 'pump-bottle' sampling
- Vertical turbidity profile by MEX turbidity meter
- Suspended sediment transport and grain size distribution by depth integrating bottle sampler
- Suspended sediment transport and grain size distribution by collapsible bag sampler
- Suspended sediment /near-bed transport and grain size distribution by Delft Bottle
- Settling velocity of suspended sediments by Andreasen settling tube
- Bed load transport by dune tracking
- Bed load transport and grain size distribution by Helley-Smith sampler
- Bed material grain size distribution by US BM-54 bed sampler
- Bed material grain size distribution by van Veen (grab type) bed sampler

The actual combination applied in each survey is given in Part B.

Sediment analyses are carried out by standard methods in the sediment laboratory of the River Survey Project.

Surveying of cross-sectional transects is done with an operation speed of around 4 knots (or around 2 m/s, or around 7 km/hour). A short characteristic of some of the instruments applied in the routine programme is given in Table 2.

For details about procedures, instrumentation, and analyses, please refer to the reports listed as references at the end of the present Data Book.

Instrument	accuracy 1)	resolution 2)	sampling duration/ averaging period	sampling interval
DGPS	3 - 5 m	< 1 m	< 1 s / < 1 s	1 s
AWLR, pressure cell type	1 cm	< 1 cm	12 s / 1 min	30 min
AWLR, acoustic type	1 cm	< 1 cm	12 s / 12 s	30 min
Echo sounder	8 cm	< 1 cm	<< 1 s / << 1 s	1 s
ADCP	5 - 10 cm/s	5 - 10 cm/s	<< 1 s / 6 s	1 s 3)
EMF 4)	2 %	1 cm/s	<< 1 s / 6 s	1 s 3)
S4 5)	2 %	1 cm/s	<< 1 s / 3 x 50 s	-
Ott current meter	3 - 10 % 6)	1 - 2 cm/s	50 s / 6 x 50 s	-

Note: All values are approximate. The values relate to the specific deployment, procedures, and application conditions during the River Survey Project, and do not directly reflect the potential capability of each instrument. The over-all accuracy of a recording can be different from the listed values due to for example repeated measurements (which can improve the over-all accuracy), or validity and time scale effects (which can reduce the over-all accuracy)

< = 'less than', << = 'much less than'

1): Standard deviation between true value and registered value
2): Smallest increment of the true value that can be registered by the instrument
3): 6 s average value is updated every s
4): When used for cross-sectional transects or 'moving boat'
5): When used for individual vertical current profiles
6): Mainly depending on the mooring of the vessel

Table 2: Characteristics of some instruments

3.3 Positioning and datum

Positions are relative to the BTM grid. Stages are referred to PWD datum. Depths are relative to the stage.

3.4 Tidal effects

Some stations are influenced by the astronomical tide in the lean season, most pronouncedly at spring tide, while in the flood season, tidal effects are insignificant at the stations covered by the project.

In Table 1, some stations are pointed out where the astronomical tide is of some practical significance. It should be noted, however, that the distinction between tidal stations and non-tidal stations is not sharp. Tidal effects occur in part of the time only at the stations identified in Table 1, and may well occur occasionally for stations that are not pointed out in the table.

3.5 Sediment transport terminology

The terms applied are summarised in Figure 4.

Wash load is characterised by a grain size diameter less than 0.063 mm.

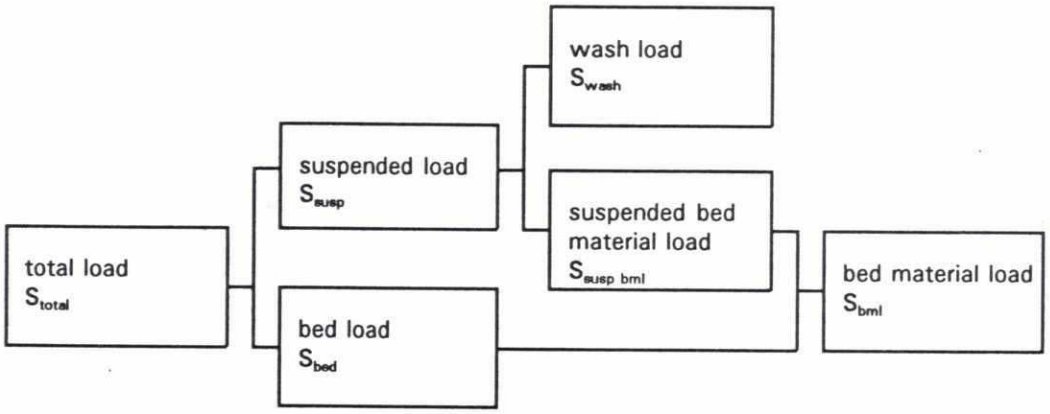


Figure 4: Sediment transport terms

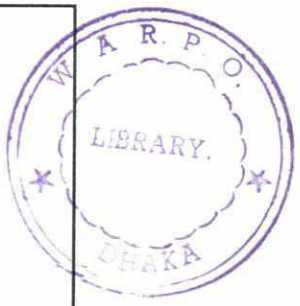
3.6 Rating curves

Rating curves for the stations that were in operation in the period are shown on the following pages.

1 Bahadurabad

June - October 1993

(Q-h)



(S_{total}-Q, $S_{susp\ bml}$-Q)

date	h (m + PWD)	Q (m^3/s)	S_{wash} (kg/s)	$S_{susp\ bml}$ (kg/s)	S_{bed} (kg/s)	S_{total} (kg/s)

References

River Survey Project, FAP 24: Additional Survey, September 1992. Measurements on the Jamuna River near Bahadurabad with MV Anwesha. Survey Report no. 1, 31 October 1992

River Survey Project, FAP 24: Test Gauging Report, Survey Procedures and Data Presentation. Survey Report no. 3, October 1993

River Survey Project, FAP 24: Selection of Survey Techniques. Survey Report no. 4, October 1993

River Survey Project, FAP 24: Phase 1, Dry Season 1992/93. Survey Report no. 5, December 1993

River Survey Project, FAP 24: AWLR Stations. Site Selection, Installation, and O&M. Survey Report no. 6 (not yet published)

River Survey Project, FAP 24: Hydrological Study, Phase 1. Study Report no. 2, June 1993

River Survey Project, FAP 24: Morphological Studies, Phase 1. Study Report no. 3, March 1994

River Survey Project, FAP 24: Bed Load Measurements for Phase 2. Working Paper no. 3 (not yet published)

Iversen, C.: Survey techniques selected by FAP24. River Survey Project Workshop Contributions no. 4. Submitted at the International Workshop on Morphological Characteristics of Alluvial Rivers and their Behaviour with Special Reference to Bangladesh Rivers, Flood Plan Coordination Organization, Dhaka, 6-8 November, 1993

River data November 93 - May 94 (Dry season 93/94)

Contents

Part A: **Water-level, flow, and sediment transport**

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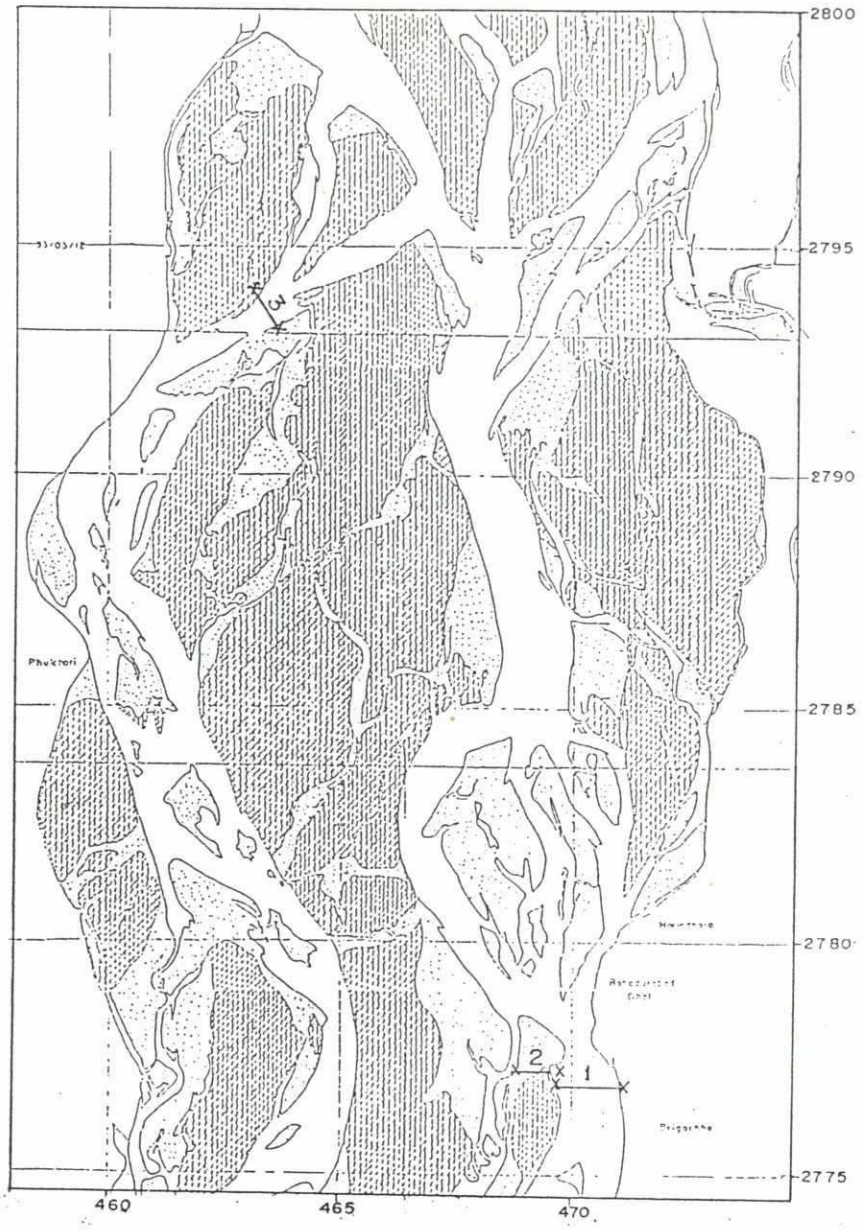
10 Arial Khan off-take
11 Bhairab Bazar

Part C: **Data catalogue**



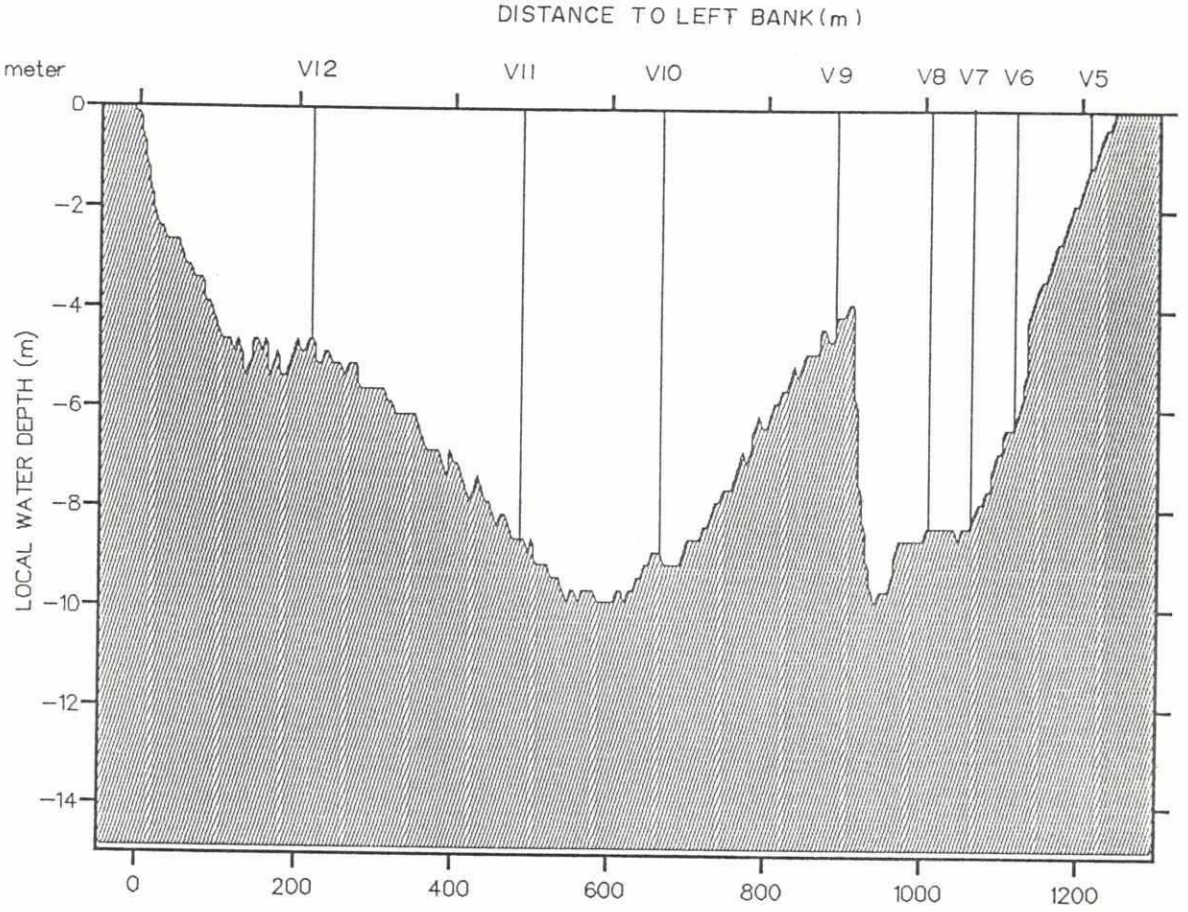
LEGEND:-

- Measurement cross section
- High land
- Unstable/low char
- BWDB Embankment

5000m 2500m 0

Map is based on most recent satellite images of March, 1993.

FAP 24 RIVER SURVEY PROJECT Flood Plan Coordination Organization Commission of the European Communities DELFT - DHI		Annexure 1: Sample format of River Data Book	
		Part B: Data summaries	
	9 June 1994	Sample presentation of location map	page B.1
	CI		

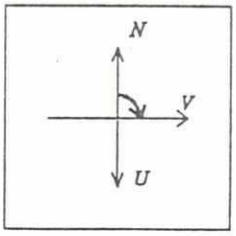

DISTANCE TO LEFT BANK (m)
meter
V12
V11
V10
V9
V8 V7 V6
V5
0
-2
-4
-6
-8
-10
-12
-14
LOCAL WATER DEPTH (m)
0
200
400
600
800
1000
1200

Type of measurement	Method	No. of measurements in channel		
		1	2	3
flow transect	ADCP transect	10	8	8
	EMF transect	10	8	8
vertical current profile	no. of verticals in channel	20	4	7
	ADCP	20	4	7
	S4 current meter	17	4	7
	Ott current meter	-	-	-
vertical sediment profile	pump bottle sampling	87	19	35
	Andreasen settling tube	10	2	3
	MEX turbidity meter	20	4	7
	integrated bottle sampling	-	-	-
	collapsible bag	-	-	-
bed load	dune tracking	-	-	-
	Helley-Smith sampler	-	-	-
	Delft Bottle	-	-	-
bed material	US BM-54 bed sampler	10	2	3
	van Veen bed sampler	-	-	-

Table B.1: Survey programme, Bahadurabad, 2-4 April, 1994 (Survey Bulletin 48)

	width (m)	area (m^2)	stage h (m + PWD)	flow rate Q (m^3/s)	bed load transport S_{total} (kg/s)	sediment transport S_{total} (kg/s)
channel 1	1235	7458	15.29	6429	34	4099
channel 2	453	2328	15.21	2169	8	1179
channel 3	582	2256	15.10	1946	3	661

Table B.2: Key figures, total flow and sediment transport, Bahadurabad, 2-4 April, 1994 (Survey Bulletin 48)

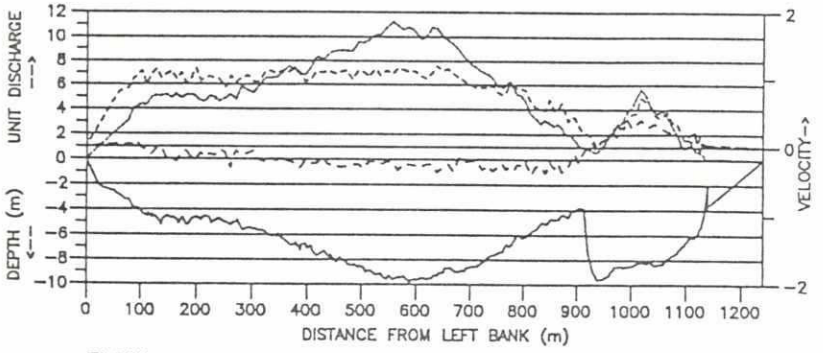


TRANSECT AZIMUTH = 90°

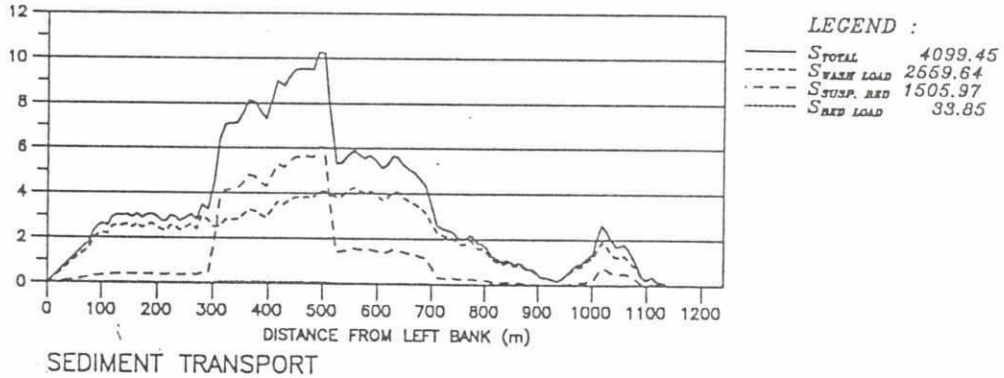
U – VELOCITY NORMAL TO TRANSECT (m/s)

V – VELOCITY PARALLEL TO TRANSECT (m/s)

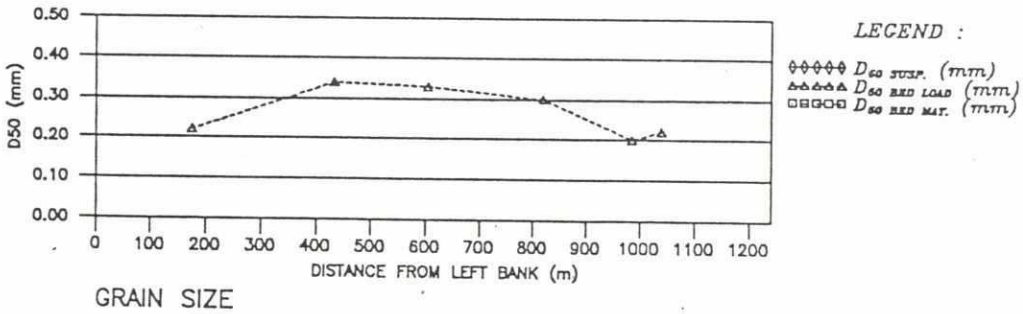
N – MAGNETIC NORTH



FLOW

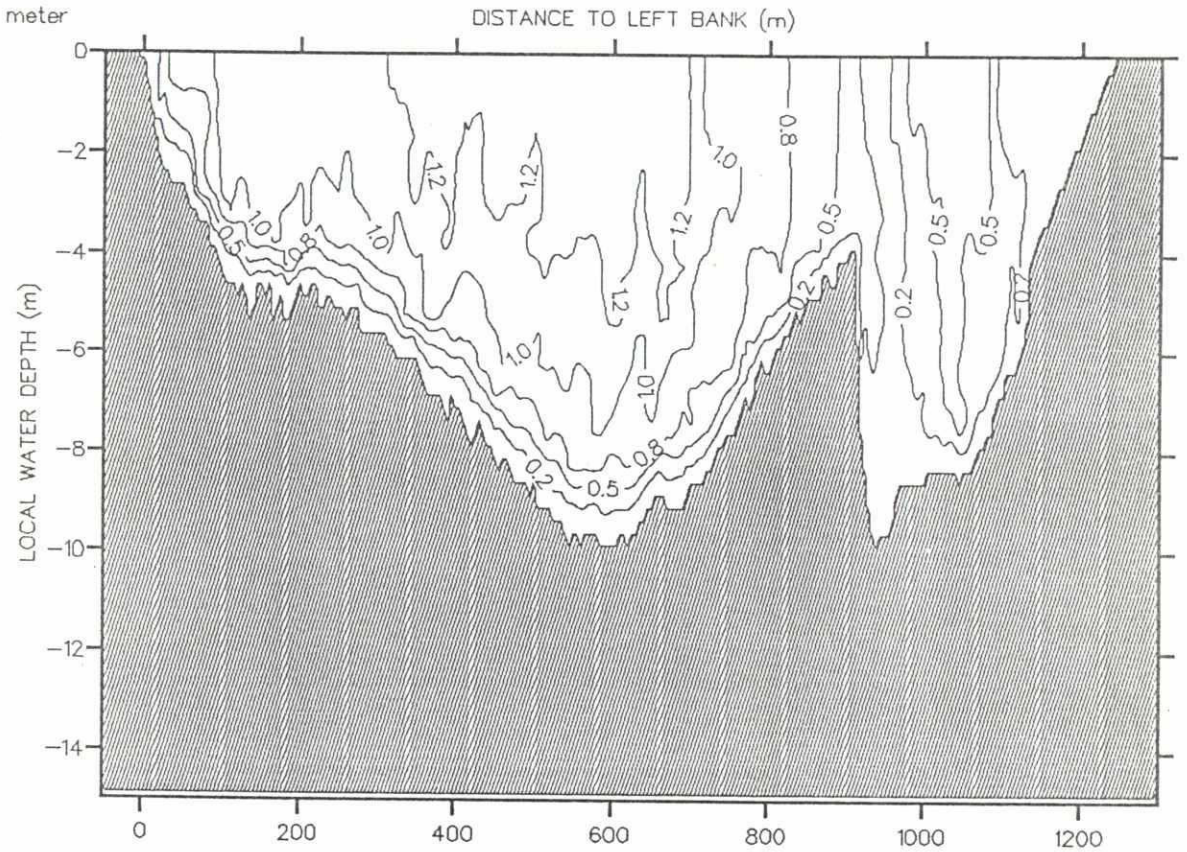


SEDIMENT TRANSPORT



GRAIN SIZE

FAP 24 DELFT - DHI RIVER SURVEY PROJECT Flood Plan Coordination Organization Commission of the European Communities		Annexure 1: Sample format of River Data Book	
		Part B: Data summaries	
	9 June 1994	Sample presentation of horizontal distribution of flow and sediments	page B.4
	CI		



FAP 24 DELFT - DHI RIVER SURVEY PROJECT Flood Plan Coordination Organization Commission of the European Communities		Annexure 1: Sample format of River Data Book	
		Part B: Data Summaries	
	9 June 1994	Sample presentation of cross-sectional flow velocity distribution	page B.5
	CI		

channel	vertical	time (YYMMDDHHMM)	depth (m)	Weight percent < 0.06 mm	Weight percent > 0.06 mm	D_{35} (mm)	D_{50} (mm)	D_{65} (mm)
1	6	9404031617	8.1	7.4	92.5	0.17	0.22	0.28
	6	9404031619	8.1	9.0	91.0	0.17	0.22	0.28
	7	9404031500	8.6	5.8	94.2	0.17	0.22	0.28
	7	9404031502	8.6	6.6	93.4	0.16	0.20	0.24
	9	9404031230	5.9	1.4	98.6	0.24	0.29	0.34
	9	9404031232	5.9	0.6	99.4	0.28	0.32	0.37
	10	9404031117	9.8	0.1	99.9	0.31	0.35	0.39
	10	9404031119	9.8	0.3	99.7	0.31	0.35	0.40
	11	9404031034	7.2	0.2	99.8	0.29	0.33	0.39
	11	9404031036	7.2	0.2	99.8	0.31	0.35	0.41
	12	9404031012	4.8	1.5	98.5	0.18	0.23	0.29
	12	9404031014	4.8	1.7	98.3	0.18	0.22	0.28
2	1	9404020910	3.4	0.1	99.9	0.28	0.32	0.37
	1	9404020912	3.4	0.2	99.8	0.27	0.31	0.36
	2	9404020954	5.6	0.1	99.9	0.31	0.35	0.39
	2	9404020956	5.6	0.2	99.8	0.31	0.35	0.39
	3	9404021106	9.0	0.2	99.8	0.31	0.34	0.39
	3	9404021108	9.0	0.3	99.7	0.30	0.34	0.39
	4	9404021210	5.0	0.3	99.7	0.18	0.22	0.27
	4	9404021212	5.0	0.4	99.6	0.21	0.26	0.32
3	1	9404041015	4.4	0.2	99.8	0.21	0.27	0.33
	1	9404041017	4.4	0.3	99.7	0.27	0.31	0.36
	2	9404041102	4.8	0.7	99.3	0.29	0.33	0.38
	2	9404041104	4.8	0.2	99.8	0.30	0.34	0.39
	3	9404041144	6.0	0.2	99.8	0.30	0.34	0.38
	3	9404041146	6.0	0.2	99.8	0.30	0.34	0.38
	4	9404041355	5.5	0.2	99.8	0.30	0.32	0.37
	4	9404041357	5.5	0.5	99.5	0.28	0.32	0.37
	5	9404041435	4.0	0.8	99.2	0.25	0.30	0.35
	5	9404041437	4.0	0.8	99.2	0.24	0.29	0.34

Table B.3: Grain size of bed load (by Helley-Smith sampler)
Bahadurabad, 2-4 April, 1994 (Survey Bulletin 48)

River data November 93 - May 94 (Dry season 93/94)

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9 Kushtia/Gorai
10 Arial Khan off-take
11 Bhairab Bazar

Data names: File name example: B2AL1T08.ACQ

B	:	Bahadurabad (location code) (see Below)
2	:	1992 (year)
A	:	10 (month) (alphanumerical)
L	:	21 (day) (alphanumerical)
1	:	DHA vessel (vessel code) (see below)
T	:	transect (type code) (see below)
08	:	sequence number
ACQ	:	file name extension (see below)

Location codes:

A	:	Aricha	R	:	Hurasagar
B	:	Bahadurabad	S	:	Sirajganj
H	:	Hardinge Bridge	T	:	Tilly
K	:	Kushtia	U	:	Baruria
M	:	Mawa	Y	:	Mymensingh
O	:	Arial Khan off-take	Z	:	Bhairab Bazar

Vessel codes:

0	:	alu-craft	2	:	DHC
1	:	DHA		:	DHB

Type codes:

B	:	bathymetry	T	:	transect
P	:	profile			

File name extensions of primary data files:

ACQ	:	DGPS, ADCP, EMF, S4, MEX data (raw data format)
HOD	:	echo sounder data (ASCII)

File name extensions of PSD24 data files:

ASE	:	ADCP, S4, EMF data (ASCII)
AWL	:	AWLR data (Quattro)
BDL	:	bed load sediment analyses (Quattro)
BDM	:	bed material analysis (Quattro)
BTH	:	fixed grid bathymetry data (Quattro)
CT2/DT2	:	iso-velocity plot data (Mike21), or fixed grid bathymetry data (Mike21)
ECH	:	echo sounder data (ASCII)
GAG	:	staff gauge readings (Quattro)
SED	:	sediment transport data (ASCII)
SSC	:	suspended sediment concentration analysis (Quattro)
SSZ	:	suspended sediment size distribution analysis (Quattro)
TRS	:	transect plot data (ASCII)

Method	channel	vertical	time (YYMMDDHHMM-HHMM)	easting (m)	northing (m)	depth (m)	file name
ADCP & EMF transect	1	-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01 *
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
			9310310938-1001	-	-	-	B3AV1T01
	2	-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01 *
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
	3	-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01 *
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01
		-	9310310938-1001	-	-	-	B3AV1T01

Table C.1: ADCP & EMF transects, Bahadurabad, 2-4 April, 1994 (Survey Bulletin 48)

* : transect in PSD24 and presented on p. ...

Method	channel	vertical	time (YYMMDDHHMM-HHMM)	easting (m)	northing (m)	depth (m)	file name
Verical current & turbidity profiles (ADCP/S4/MEX)	1	1	9310310938-1001	470503	777504	20.8	B3AV1T01
		2	9310310938-1001	470503	777504	20.8	B3AV1T01
		3	9310310938-1001	470503	777504	20.8	B3AV1T01
		4	9310310938-1001	470503	777504	20.8	B3AV1T01
		5	9310310938-1001	470503	777504	20.8	B3AV1T01
		6	9310310938-1001	470503	777504	20.8	B3AV1T01
		7	9310310938-1001	470503	777504	20.8	B3AV1T01
		8	9310310938-1001	470503	777504	20.8	B3AV1T01
		9	9310310938-1001	470503	777504	20.8	B3AV1T01
		10	9310310938-1001	470503	777504	20.8	B3AV1T01
		11	9310310938-1001	470503	777504	20.8	B3AV1T01
		12	9310310938-1001	470503	777504	20.8	B3AV1T01
		13	9310310938-1001	470503	777504	20.8	B3AV1T01
		14	9310310938-1001	470503	777504	20.8	B3AV1T01
		15	9310310938-1001	470503	777504	20.8	B3AV1T01
		16	9310310938-1001	470503	777504	20.8	B3AV1T01
		17	9310310938-1001	470503	777504	20.8	B3AV1T01
		18	9310310938-1001	470503	777504	20.8	B3AV1T01
		19	9310310938-1001	470503	777504	20.8	B3AV1T01
		20	9310310938-1001	470503	777504	20.8	B3AV1T01

Table C.2: Vertical profiles, Bahadurabad, 2-4 April, 1994 (Survey Bulletin 48) (continued)

Method	chan-nel	verti-cal	time (YYMMDDHHMM-HHMM)	easting (m)	northing (m)	depth (m)	file name
Verical current & turbidity profiles (ADCP/S4/MEX)	2	1	9310310938-1001	470503	777504	20.8	B3AV1T01
		2	9310310938-1001	470503	777504	20.8	B3AV1T01
		3	9310310938-1001	470503	777504	20.8	B3AV1T01
		4	9310310938-1001	470503	777504	20.8	B3AV1T01
	3	5	9310310938-1001	470503	777504	20.8	B3AV1T01
		6	9310310938-1001	470503	777504	20.8	B3AV1T01
		7	9310310938-1001	470503	777504	20.8	B3AV1T01
		8	9310310938-1001	470503	777504	20.8	B3AV1T01
		9	9310310938-1001	470503	777504	20.8	B3AV1T01
		10	9310310938-1001	470503	777504	20.8	B3AV1T01
		11	9310310938-1001	470503	777504	20.8	B3AV1T01
	4	12	9310310938-1001	470503	777504	20.8	B3AV1T01
		13	9310310938-1001	470503	777504	20.8	B3AV1T01
		14	9310310938-1001	470503	777504	20.8	B3AV1T01

Table C.2 (continued)

Method	chan-nel	verti-cal	time (YYMMDDHHMM-HHMM)	easting (m)	northing (m)	depth (m)	file name
Suspended sediment (pump bottle)	1	1	9310310938-1001	470503	777504	15.3	B2AL1T08
		2	9310310938-1001	470503	777504	15.3	B2AL1T08
		3	9310310938-1001	470503	777504	15.3	B2AL1T08
		4	9310310938-1001	470503	777504	15.3	B2AL1T08
		5	9310310938-1001	470503	777504	15.3	B2AL1T08
		6	9310310938-1001	470503	777504	15.3	B2AL1T08
		7	9310310938-1001	470503	777504	15.3	B2AL1T08
		8	9310310938-1001	470503	777504	15.3	B2AL1T08
		9	9310310938-1001	470503	777504	15.3	B2AL1T08
		10	9310310938-1001	470503	777504	15.3	B2AL1T08
		11	9310310938-1001	470503	777504	15.3	B2AL1T08
		12	9310310938-1001	470503	777504	15.3	B2AL1T08
		13	9310310938-1001	470503	777504	15.3	B2AL1T08
		14	9310310938-1001	470503	777504	15.3	B2AL1T08
		15	9310310938-1001	470503	777504	15.3	B2AL1T08
		16	9310310938-1001	470503	777504	15.3	B2AL1T08
		17	9310310938-1001	470503	777504	15.3	B2AL1T08
		18	9310310938-1001	470503	777504	15.3	B2AL1T08
		19	9310310938-1001	470503	777504	15.3	B2AL1T08
		20	9310310938-1001	470503	777504	15.3	B2AL1T08
	2	1	9310310938-1001	470503	777504	15.3	B2AL1T08
		2	9310310938-1001	470503	777504	15.3	B2AL1T08
		3	9310310938-1001	470503	777504	15.3	B2AL1T08
		4	9310310938-1001	470503	777504	15.3	B2AL1T08
	3	1	9310310938-1001	470503	777504	15.3	B2AL1T08
		2	9310310938-1001	470503	777504	15.3	B2AL1T08
		3	9310310938-1001	470503	777504	15.3	B2AL1T08
		4	9310310938-1001	470503	777504	15.3	B2AL1T08
		5	9310310938-1001	470503	777504	15.3	B2AL1T08
		6	9310310938-1001	470503	777504	15.3	B2AL1T08
		7	9310310938-1001	470503	777504	15.3	B2AL1T08

Table C.3: Suspended sediments, Bahadurabad, 2-4 April, 1994 (Survey Bulletin 48)

Method	channel	vertical	time (YYMMDDHHMM)	easting (m)	northing (m)	depth (m)	sample no.
Andreasen settling tube	1	1	9310310938	470503	777504	10.1	A1847
		2	9310310938	470503	777504	10.1	A1847
		3	9310310938	470503	777504	10.1	A1847
		4	9310310938	470503	777504	10.1	A1847
		5	9310310938	470503	777504	10.1	A1847
		6	9310310938	470503	777504	10.1	A1847
		7	9310310938	470503	777504	10.1	A1847
		8	9310310938	470503	777504	10.1	A1847
		9	9310310938	470503	777504	10.1	A1847
		10	9310310938	470503	777504	10.1	A1847
	2	1	9310310938	470503	777504	10.1	A1847
		2	9310310938	470503	777504	10.1	A1847
	3	1	9310310938	470503	777504	10.1	A1847
		2	9310310938	470503	777504	10.1	A1847
		3	9310310938	470503	777504	10.1	A1847
	4	1	9310310938	470503	777504	10.1	A1847

Table C.4: Near bed suspended sediments (0.3 m above river bed), Bahadurabad, 2-4 April, 1994 (Survey Bulletin 48)

Method	channel	vertical	time (YYMMDDHHMM)	easting (m)	northing (m)	depth (m)	sample no.
US BM-54 bed samples	1	1	9310310938	470503	777504	20.8	A1847
		2	9310310938	470503	777504	20.8	A1847
		3	9310310938	470503	777504	20.8	A1847
		4	9310310938	470503	777504	20.8	A1847
		5	9310310938	470503	777504	20.8	A1847
		6	9310310938	470503	777504	20.8	A1847
		7	9310310938	470503	777504	20.8	A1847
		8	9310310938	470503	777504	20.8	A1847
		9	9310310938	470503	777504	20.8	A1847
		10	9310310938	470503	777504	20.8	A1847
	2	1	9310310938	470503	777504	20.8	A1847
		2	9310310938	470503	777504	20.8	A1847
	3	1	9310310938	470503	777504	20.8	A1847
		2	9310310938	470503	777504	20.8	A1847
		3	9310310938	470503	777504	20.8	A1847
	4	1	9310310938	470503	777504	20.8	A1847

Table C.5: Bed material, Bahadurabad, 2-4 April, 1994 (Survey Bulletin 48)