FAP24

Government of the People's Republic of Bangladesh

Water Resources Planning Organization

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RIVER SURVEY PROJECT

Special Report No.20

Joint measurements BWDB/RSP morphology

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Joint BWDB/RSP measurements, morphology

Joint cross-sectional profile measurements in the Jamuna River at Bahadurabad by Morphology and Research Circle of BWDB and the River Survey Project, RSP during March 24 - 26, 1995

October 1996

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Acronyms and Abbreviations

ADCP	: acoustic Doppler current profiler
BM	: bench mark
BWDB	: Bangladesh Water Development Board
DGPS	: differential (high-accuracy) GPS
DHA	: (name of a survey vessel of RSP)
EDM	: electronic distance meter
FAP	: Flood Action Plan
FAP24	: FAP project no. 24 (= the River Survey Project)
FPCO	: Flood Plan Coordination Organisation (presently merged with WARPO)
GoB	: Government of Bangladesh
GPS	: Global Positioning System (satellite-based)
PWD	: Public Works Department (also the name of the datum of PWD)
RSP	: The River Survey Project (= FAP24)
TBM	: temporary bench mark
UNDP	: The United Nations' Development Programme
WARPO	: Water Resources Planning Organisation (under Ministry of Water Resources)

1 Introduction

The River Survey Project (RSP, or FAP24) was initiated in June, 1992, and was completed after 4 years. The project was executed by the Flood Plan Coordination Organisation (FPCO), today merged with the Water Resources Planning Organisation (WARPO), under the Ministry of Water Resources (formerly the Ministry of Irrigation, Water Development and Flood Protection). Funding was granted by the European Commission. The Consultant was DELFT-DHI Joint Venture in association with Osiris, Hydroland and Approtech. Project supervision was undertaken by a Project Management Unit with participation by WARPO/FPCO, a Project Adviser, and a Resident Project Adviser.

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

The project consisted of three categories of activities:

- A survey component, comprising 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; and
- a training component.

The study programme of the project was developed in a close dialogue with the Client and the Project Adviser. Objectives and scope of the programme were gradually identified and adjusted, and were eventually summarised in a Study Programme submitted to the Client in February 1995.

The present report was prepared as a monograph within this study programme. Related reports are *RSP Special Report 7: 'Geomorphology and channel dimensions', RSP Special Report 19: 'Joint BWDB/RSP measurements, hydrology'*, and *RSP Special Report 24: 'Morphological processes in Jamuna River'*. For a general discussion of survey techniques and their applicability, please refer to *RSP Final Report Annex 2: 'Sustainable survey techniques'*.

The study was been carried out and reported by Mominul Haque Sarker.

The present report was first submitted in November, 1995, as *RSP Survey Report 14*. It was reviewed on behalf of WARPO by the PA, prof. J. J. Peters, and by prof. J. U. Chowdhury, BUET. To the extent practical, the comments received have been incorporated in the present edition. Some more far-reaching professional questions raised by the reviewers have been addressed elsewhere in the final reporting of the RSP.

The author wishes to thank the reviewers for good advice and valuable comments.

2 Background

The Morphology and Research Circle of Bangladesh Water Development Board (BWDB) executes cross-sectional profile measurements of some 34 transects along the Jamuna River. These sections have been monitored annually since 1966. The data, forming a reasonably long time-series, provide a very useful information about the morphological processes, and have been used in different projects and by researchers.

There is a potential for an upgrading of the monitoring, with respect to the overall data accuracy, measurement techniques, data analysis, and documentation. Therefore, a discussion was held at a meeting in January, 1994, between the BWDB Morphology and Research Circle and RSP. At this meeting, a number of issues were discussed: The definition of the standard cross-sections and their network, accuracies of the measurements, data processing and elaboration, and data validation and documentation (see Appendix 1). Further, a joint BWDB/RSP survey of a specific standard cross-section was agreed on.

The BWDB standard cross-section J#13_1 in the Jamuna River was selected for the purpose, and the survey took place in March 24-26, 1995. The joint activities comprised two parts, one being the field measurements and the other being the post-processing of raw data. During the data processing, a RSP representative was present in the Morphology Division office in Mymensingh on August 30-31, 1995.

The joint activities are described in Appendix 3, and the itinerary of the RSP survey group is presented in Appendix 4. The present report gives an outline of the experiences and observations of RSP in the field, as well as during the data processing. The following chapters present the objective of the joint survey, the BWDB and RSP survey procedures, and the quality checking of the surveys, as a basis for a discussion, conclusions and recommendations.

3 Objectives

The objective of the joint measurements is to obtain an impression of the BWDB standard cross-section survey methodologies, and the accuracies of the presented resulting data. Hereby, a particular attention has been given to identifying the monuments/pillars on both banks, the land area survey procedure, the wet area survey procedure, a comparison with the RSP survey, data elaboration in the office, and sources of possible errors introduced in the field and in the office (Appendix 2).

4 BWDB cross-section survey procedure

According to the proposal (Appendix 2), it was not intended to complete the J#13_1 cross-section survey jointly within the scheduled three days period. The length of the J#13-1 section is about 16.4 km (see Figure 1), out of which the RSP and BWDB survey teams jointly surveyed a distance of 6 km. Out of this length, the BWDB survey team surveyed 3.6 km from the left bank monument before the arrival of the RSP team at Bahadurabad.

Initially, at the left bank monument, the BWDB survey team explained to the RSP team how they use to start their survey from a defined monument of a cross-section. Also, the approximate alignment of the initial 3.6 km length of the cross-section over the floodplain and chars was demonstrated. The rest of the survey, a distance of about 2.4 km (see Figure 1), was simultaneously performed by both survey groups. For details, please refer to Appendices 3 and 4.

The field experience gathered from the discussion with the BWDB survey team and from observations during the work are presented in the next sections in the way outlined in the proposal on the joint survey, together with some features which have drawn the attention of different users of the BWDB morphology data.

4.1 Identification of the cross-section

As the cross-sections for the Jamuna River were defined already in 1965 and 1966, no information regarding the applied criteria for their identification could be retrieved from the BWDB staff involved. Presumably, an interspacing of about 4 miles, and an orientation almost perpendicular to the course of the river in those years have been the main conditions. Local circumstances may have forced the survey team involved to deviate slightly from these requirements.

In the early seventies, five additional cross-sections were introduced in between cross-sections J#12 and J#13, with an interspacing of about one mile, for a study of a barrage near Bahadurabad, but these additional soundings are not performed regularly.

It should be realized that the present courses of the river branches may well differ considerably from the state in 1965/66, so that the cross-sections defined at that time are not necessarily perpendicular to the present main courses.

4.2 Horizontal and vertical control

The location of a cross-section is fixed in the field by two monuments/pillars at one bank of the river and a third one at the other bank. The elevations of both left bank monuments/pillars for the examined cross-section J#13-1 were expressed in m PWD. Their positions are not related to the national grid, but are defined by the names of the land owners, the mouza, the police station, and the district in which each monument/pillar is placed.

The monuments of cross-section J#13-1 are located at a considerable distance from the main channel(s) of the river. Hereby, in this case, the monuments M-1 and M-2 were located about 3.5 km from the present bank line, whilst the distance between the right bank of the right channel and monument M-3 was some 2.6 km, see Figure 1.

The orientation (or bearing) of a cross-section has been defined presumably when erecting the monuments, but is checked during the yearly survey. All bearings are expressed relative to magnetic north, using a compass in the past and a theodolite with a built-in compass at present. The bearing for cross-section J#13-1 had been registered at 261 degrees, while, during this survey, a bearing of 259°14' was recorded. This bearing was found by positioning the theodolite over monument M-1 and focusing on a 5 m bamboo positioned at monument M-2. The distance between the monuments of this cross-section was 189 m only, but, due to a levee in between, it was not possible to aim directly at the nail on monument M-2. The difference between the official and the practical bearing of this survey line represents a deviation of about 500 m at monument M-3, at a distance of 16.4 km, see Figure 1.

The reference levels of the monuments/pillars were connected with PWD bench-marks in the mid sixties. In case of a shifting of monuments, the reference plane is transferred from the nearby GTS or from the nearby BWDB bench-mark.

Starting at monument 1, the vertical control is maintained by a levelling instrument, measuring the elevation of various temporary pegs, until the first channel is reached. There is no means for intermediate checking.

4.3 Measuring the dry part of a cross-section

The basic procedure for measuring the dry part of a cross-section is the same for surveying the floodplain starting at monument 1, as for surveying a char, starting at the water line:

- The survey line is established from the nails in the two monuments by means of a theodolite with a built-in compass
- Temporary pegs are placed at conspicuous points where there is a discontinuity in the longitudinal profile. Their position relative to the survey line is controlled by means of the theodolite
- The distances between the pegs are measured by means of a measuring tape
- The elevation of the ground is determined by means of a levelling instrument. The interspacing is about 60 m for level ground and less in case of level discontinuities
- This procedure is repeated until the next water line is encountered. Then, the elevation of the water line is determined
- When crossing a channel, the survey line is controlled by means of the theodolite, while the vertical control is maintained by assuming that the elevation of the water line on both sides of the channel is the same

4.4 Sounding of the water part of a cross-section

After determination of the elevation of the water line, as described above, the water part of a cross-section is sounded as follows:

- The survey line is indicated by erecting two bamboos of different height in the line of the cross-section, with an interspacing of some 20 to 40 meters
- A base line perpendicular to the line of survey, with a length of about 150 to 300 m, depending on the width, is established
- The theodolite is positioned at the end of this base line
- The shallow section (up to a depth of about 0.6 m) is sounded by wading, whilst the location is determined by reading the angle between the base line and the levelling staff
- A portable Raytheon echo-sounder is installed on board a motorized country boat with a draft of 0.5 m
- The transducer is hand-held along the side of the country boat, only secured by a tether line. The vertical position is controlled by a mark on the transducer pipe. The vertical orientation is depending on the experience and attention of the staff member in charge
- The country boats starts sailing from the opposite bank towards the bank where the base line has been established
- The man at the echo-sounder commands for a fix or mark at major discontinuities in the bed profile; following this command, a bamboo with a flag is raised by a man on the roof of the country boat and the man at the theodolite is expected to read the angle. The marks are indicated on the echo-sounder recording paper by a marker line, and at the theodolite by an entry. When these two sources do not match, there is no other information available for correction
- Meanwhile, the helmsman controls the in-line position of the boat
- When arriving at the nearest bank, the remaining shallow section is again surveyed by wading
- The vertical control is maintained by measuring the elevation of the water level at one bank only

5 RSP survey procedure

RSP started their survey at BWDB chainage 3638 m from the left bank monument with the same bearing as BWDB, i.e. 259°14' magnetic north.

The land survey was performed by an electronic distance meter (EDM). After calibration, the EDM can display on a digital monitor the co-ordinates, distance, and the vertical and horizontal angles of the point where the reflector is placed. For calibration, at least two points of known co-ordinates are required. During the joint measurements, the first setting of the EDM was at EDM-1 (see Figure 2) at chainage 3638 m as measured by BWDB. The position of EDM-1 was calibrated by focusing two survey vessels placed at three different locations that were positioned by DGPS (see Figure 2). The level was calibrated assuming a zero gradient of the water level.

From setting EDM-1, the land part of the nearest bar and the shallow water part of channel 1 was surveyed. For the next setting, EDM-2, the position and the reference level were known from EDM-1, and were further checked by focusing two known points (survey vessels). Consequently, the land part of the next bar was surveyed from EDM-2 (see Figure 2).

The water part of the survey was performed by echo-sounder and DGPS positioning system. Hence, the water part survey line consists of several points with known co-ordinates and depths of water. The vessel sailed approximately with a pre-defined bearing, from near the points where the land survey ended. The RSP survey line, both the water and the land parts, followed the co-ordinate system applied by RSP (the modified Bangla projection), as shown in Figure 3.

6 Data elaboration and processing

6.1 BWDB data processing

One person from the RSP study team visited the BWDB Morphology Division office in Mymensingh on August 30-31, 1995, in order to participate in the processing and elaboration of the data from cross-section J#13_1. During the visit, discussions were held with Executive Engineer, Mr. Hossain, Sub-Divisional Engineer, Mr. Shaha, and Sub-Assistant Engineer, Mr. Anam. Observations from the participation in the data processing and from the discussion with the BWDB representatives are compiled in the present chapter.

Field documents
The raw data from the BWDB survey were kept in two certified notebooks: One is the *'Field Book'*, where the following information is recorded:

- descriptions of monuments/pillars
- information about different permanent or temporary offsets and chainages of temporary bench marks
- positions of pegs
- the position of the theodolite in the case of obstructions (such as homestead, forest etc.) over land
- distances of the theodolite from the survey line during the water part survey
- the angle of the sounding boat for each fix
- echo-sounder depth recordings are entered and sketched, and echo-sounder record sheets are attached

Hence, the *'Field Book'* is the complete document of the water part survey.

Another note book is named the *'Level Book'*. Here, the back, intermediate and fore level readings are recorded with corresponding chainages. Later, the levels are converted to the PWD reference level. In the *'Level Book'*, different features (such as the toe or top of road/embankment, the high bank, and the water line) are recorded against the corresponding point. hereby, the *'Level Book'* contains almost the complete features of the land part survey. Between them, the *'Field Book'* and the *'Level Book'* form the complete field documentation of a BWDB standard cross-section survey.

Post-processing
The standard procedure of the primary data processing is that the raw data should be recorded in the *'Field Book'* and the *'Level Book'*, and that the surveyor will process the raw data in the Sub-Divisional Office. This part of the data processing includes the following operations:

- For the land part survey: Reducing the level readings into the PWD level, and distributing the closing error in both the vertical and the horizontal direction

- For the water part survey: Converting the theodolite angle and offset into chainage, and reducing the water depth from the echo-sounder into PWD level

This part of the raw data processing was completed by BWDB staff before the visit of the RSP study team member. No information about the closing error or its distribution was recorded in the *'Field Book'* or *'Level Book'*.

The next part of the data processing comprises copying of the primarily processed data from the *'Field Book'* and the *'Level Book'* into the *'Data Processing Sheets'*, and plotting the ground level in PWD datum against the chainage from the left or the right bank monument in the *'Comparison Map'*. In the *'Data Processing Sheets'*, the levels are entered with their corresponding chainages, while the important features are noted in the remarks column. generally, the comparison plots contain four consecutive years of survey plots of a standard cross-section.

Another sheet, named the *'Channel Characteristics Sheet'*, contains channel-wise information, such as the water width, the maximum depth, the average depth, the cross-sectional area, etc. Channels that are dry during surveys in the lean period are excluded in the *'Channel Characteristics Sheet'*. The standard practice for estimating the cross-sectional area of the water part is to multiply the arithmetic average of the water depth by the water width. For the cross-section in question, this procedure differed by 4 % and 3 % for channels 2 and 3 respectively, as compared with estimates by other methods, i.e. the trapezoidal or the Simpson method.

Typing, compiling and printing the *'Data Processing Sheet'*, the *'Channel Characteristics Sheet'*, and the *'Comparison Map'* provide the final format of the processed data, as published by the Morphology Division of BWDB.

6.2 RSP data processing

RSP raw data are generally stored on Computer Compatible Tape, and the surveyor keeps his notes from the survey. With the aid of these notes, the raw data are retrieved and processed in the office of RSP. The EDM data for the land survey and the echo-sounder data are stored on tape and after processing, the data from the land and the water part are combined.

7 Quality checking of the joint survey data

Evaluation and quality checking of the surveys were done (i) by comparison between the BWDB and the RSP surveys, (ii) by comparison between both surveys with SPOT images, and (iii) by comparison between BWDB surveys in different years.

The monument/pillar of a BWDB cross-section is not defined by geographical co-ordinates, so it is difficult to fix the cross-section on satellite images. During the joint measurement, however, the starting point of the RSP survey (with known geographical coordinates) was a point also applied by the BWDB survey (BWDB chainage 3638 m from left monument M-1). This point and the observed bearing have been located on the tracing of SPOT images.

A part of the BWDB survey of cross-section J#13_1 and the RSP survey are compared in Figure 4. The survey line of RSP and the alignment of the BWDB survey are shown in Figure 3. The maximum deviation between the lines is about 35 m, for which reason the water lines could hardly vary by more than a few meters. The comparison plot shows that the shifting of the BWDB survey line relative to the one of RSP increases along the chainage, and that the maximum shifting is about 150 m. A comparison with the SPOT images (Figures 6 and 7) indicates that some error was introduced in the BWDB distance measurement over the bar.

When comparing the water parts of the surveys only (see Figure 5), the lateral variation along the chainage of the surveys in channel 2 increases rapidly in the shallow part from 30 m at chainage 4500 m to more than 100 m within the next 300 m. In contrast, in channel 3, the overall lateral variation between the surveys is negligible, while the level variation at different points at the river bed is considerable. The level difference between the surveys in channel 3 may be due to the survey lines being not identical (see Figure 3), or due to an error introduced during the distance measurement in the water part of the BWDB survey (Appendix 5).

In Figure 6, the RSP survey is compared with the tracing of SPOT images of 24th March, 1995. The time lapse between the SPOT images and the survey is only two days, and the corresponding water level variation is 0.02 m at Bahadurabad. This difference can shift the water line by a few meters only, and does not influence the comparison. Figure 6 shows that both water lines of channel 2 and the left water line of channel 3 of the RSP survey matches the SPOT images. A comparison between the BWDB survey and the SPOT images (Figure 7) shows a considerable difference with respect to water lines. From these figures, it is evident that the RSP survey is more reliable, while the BWDB survey exhibits a lateral deviation of more than 150 m during the 2240 m length of the joint survey. The RSP survey has the limitation that it could not follow a perfect straight line.

The total survey by BWDB of cross-section J#13_1 is compared with the tracing of SPOT images in Figure 8. The impression of the overall survey from this figure is rather good. The differences of the extreme two channels relative to the SPOT images are within 100 m. However, internal inconsistencies are sometimes higher, for example, the shifting of the channel 3 water line is more than 300 m. It is observed from the figure that an error, once introduced, can be subsequently compensated, so that successive errors do not accumulate. For example, the error introduced in channel 2 continues up to the left bank water line of channel 4. During the survey of channel 4, a new error was probably introduced, which results in a shifting of more than 300 m of the right bank water line relative to the SPOT imagery; in channel 5, this error is almost compensated, while again in channel 6, a new error is introduced, see Figure 8. The reason behind this type of error cannot be explained without knowing the closing error of BWDB and its compensation over the cross-section.

BWDB surveys of 1993, 1994 and 1995 of cross-section J#13_1 were plotted in Figure 9. The distance between the monuments is the same for all the surveys (probably due to error compensation), and the lateral shifting pattern of bank lines of the deep channels seems to be consistent. Only one

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exception is observed in Figure 9, where in 1995, a steep bank had proceeded towards the river by about 50 m as compared with 1994. It is observed from Figure 10 that the floodplain and the permanent char level in 1995 is less than in 1993 and in one case, it is less than 1994. The highest range of variation is 1 to 2 m, see Figure 10. One possible explanation of the deviation is that probably, the surveys of different years did not follow the same line; another is an erroneous level indication during the survey.

8 Discussion

The quality of the data depends on the efforts allocated to collecting, processing and evaluating those data. In principle, the resources available to collecting and elaborating the data depend on a balance between the costs and the desired accuracy. For example, in terms of quality, an accuracy of ±5 m along the alignment of a section, ± 5' in bearing, and ±0.01 m in level per km length of a BWDB cross-section, can be considered as an acceptable range.

In Chapter 7, some significant errors in the BWDB survey were identified. During the joint field work, and during the visit to the BWDB data processing office in Mymensingh, a number of probable causes of such errors were noted. These aspects are discussed in the following sections.

8.1 Field experience

Below, aspects of introducing errors in the field are discussed in three sections: General, land part survey, and water part survey.

General

- The reason for establishing the monuments outside of the floodplain of the river is understandable. However, the absence of any intermediate points, although vulnerable, eliminates the possibility for any intermediate check. Consequently, a possible error is not detected until arriving at the third monument at the other river bank, making it close to impossible to adjust or to correct the data in an appropriate way.

- The absence of a basic line elaboration in the field precludes a means of correction, if errors are detected in the office during data processing.

- It should be realized that the operating conditions in the field can be very hard for the survey party. This increases the risk of errors.

- No impression could be obtained of the magnitude of the closing error when finally arriving at the last monument. It was stated that the vertical closing error was compensated in proportion to the distances. However, it was also mentioned that the observations in the nearest (= right) channel were corrected by the full closing error.

Surveying the dry part of a cross-section

- The bearing of a cross-section is fixed in the field by nails in two monuments on the left bank of the river. At cross-section J#13-1, the distance between the two monuments was only 189 m. It was impossible to observe the nail of monument M-2 when standing at monument M-1, so a vertical bamboo pole was applied to mark its position. Assuming an error of 0.05 m, this would result in an error in the bearing of the survey line of 0.0153". This is a likely explanation of the question how the bearing of 261° could change into 259°14'. This type of deviation from year to year with respect to bearing can dislocate the survey line by up to nearly 500 m at its end. In principle, the distance between the monuments should be much longer, and the free line of sight between them should be retained. From a practical point of view, however, this would be nearly impossible. Perhaps, instead of measuring the bearing at each survey, it would be better to start the survey with a pre-defined bearing.

- Distances are measured by a measuring tape. The surveyor in charge has to record the number of times that he has travelled over the full length of this tape. Under the hard conditions in the field, it is rather likely that some errors are made. Examples of such errors can be seen in Figure 8.

- It is clear from the field experience and the quality checking of the data that just as there is a possibility of a closing error in the vertical direction, a similar closing errors are equally likely with respect to the direction of the survey alignment and a lateral deviation between the survey line and the fixed alignment. It is not clear how BWDB compensates those errors in three dimensions.

Sounding of the water part of a cross-section

- It appeared that the BWDB surveyors seldom calibrate their echo-sounder.

- The transducer was held in position by hand, which can result in measuring a too large water depth: Any deviation from the correct vertical alignment will have such an effect.

- The bamboo poles with flags marking the line of survey were positioned with an interspacing of 20 to 50 m only; during sounding, a deviation of up to 40 m out of line was estimated. In between two consecutive fixes, this type of deviation from the survey line can cause an error that is two to three times as large, see Appendix 2.

- The time lag between marking the fix on the echogramme and measuring the angle at the theodolite was sometimes considerable.

- The assumption that the water level is the same at both banks of a channel may not be correct. The more the cross-section alignment deviates from the perpendicular direction, the higher the possibility of a water level difference across the river.

8.2 Data processing

- As discussed earlier, there is a lack of information about line data processing and intermediate control. There is always a risk of errors in both the horizontal and the vertical direction. BWDB does not retain the records of such errors, nor of their compensation over the cross-section. The lack of this documentation is the reason why a number of inconsistencies, mentioned in the previous chapters, could not be explained properly.

- During the conversion of levels into PWD datum, the copying of the data into the *'Data Processing Sheets'*, and the typing of the data for printing, there is always a risk of errors. Such errors are often observed while plotting the published BWDB data in a graphical form.

- The procedure applied for calculating the water area in the *'Channel Characteristics Sheet'* is the arithmetic depth average method, which is a rather crude method. The Simpson method or the trapezoidal method are more appropriate.

The accomplishments of the Morphology Division of BWDB at Mymensingh are impressive, and even more so in view of the available resources. The number of standard cross-sections along the Jamuna River is 34, with an average length of about 14 km. It is really a hard job to survey over land consisting of bare sand in hot weather, and to change the mode of survey (between land and water) frequently with the traditional procedures and instruments.

It is evident that the accuracy of the surveys can be improved by placing intermediate pillars at some suitable locations. Hereby, it is realized that every year, a few of those intermediate pillars would be lost. The appropriate number of intermediate pillars depends on the length of cross-section.

A precise survey of a cross-section with a length of more than 16 km in 5 to 6 working days is nearly impossible with the present procedures and manpower allocation. The required additional work for the BWDB survey team comprises: (i) always carrying a few spare pillars for replacement of lost ones, (ii) checking the position of intermediate pillars, (iii) day-to-day data elaboration (iv) frequent re-surveying of a few parts of a cross-section in between two pillars, in case of errors beyond an acceptable range, (v) keeping the records of closing errors in three directions and their distribution in between the two adjoining pillars. These extra activities impose an additional need of 2 to 3 working days per cross-section, which means that BWDB Morphology Division requires more manpower.

Adjustment of the field procedures is not the only means to improve the data quality. Also, data validation, and documentation of errors and error compensation, are very important factors, which are presently missing in the BWDB office. Data validation can be made by comparing the survey data with Satellite imagery, and by comparing surveys of different years. Such additional work, which also includes acquisition of the satellite images, requires that additional resources are made available.

9 Conclusion and recommendations

On the basis of the data quality checking of the joint surveying, and the discussion presented in the previous chapters, the following conclusions are made:

- The position of monuments/pillars of the BWDB cross-sections are not defined within a geographical co-ordinate system. Whenever data are used for different purposes, the problem arises of how to locate the cross-sections on maps, satellite imagery, or chainages.

- Considering the methodology, the instrumentation and the manpower employed by BWDB for a cross-section survey in the Jamuna River, the over-all results are quite impressive. However, the accuracy of the survey, as observed from the comparison with the RSP survey and the tracing of SPOT images, is less than adequate.

- The overall accuracy of the field survey could not be estimated due to a lack of documentation of the closing errors in different directions.

- It is evaluated that the following measures could particularly reduce the risk of errors and improve the data quality: (i) intermediate controls in a cross-section, (ii) a basic line data elaboration in the field, (iii) a data validation procedure in the office.

The following recommendations are made in order to improve the accuracy of the BWDB surveys:

- At least two monument/pillars of each BWDB cross-section should be defined by geographical co-ordinates.

- Intermediate pillars or monuments should be erected on the floodplain closer to the river, as well as on permanent or semi-permanent chars, and should be levelled, to serve as an intermediate check of the horizontal and vertical control.

- A field calibration of the echo-sounder should be made before and after a days survey. In case of a distinct difference, a full range calibration by means of the calibration bar should be executed.

- Fixes and depth marks should be recorded on a time base, so that missing fixes can subsequently be identified.

- For positioning of the soundings in the water part survey, two theodolites should be applied instead of one, and the base line should be extended in both directions.

- A basic line elaboration of the data should be executed in the field for a check on errors. For this purpose, the survey team needs information about all pillars (elevation and distance).

- The entire field survey record should be well documented in the respective Morphology Division offices.

- A data validation system should be established and implemented in the Morphology Division or in the Morphology and Research Circle office.

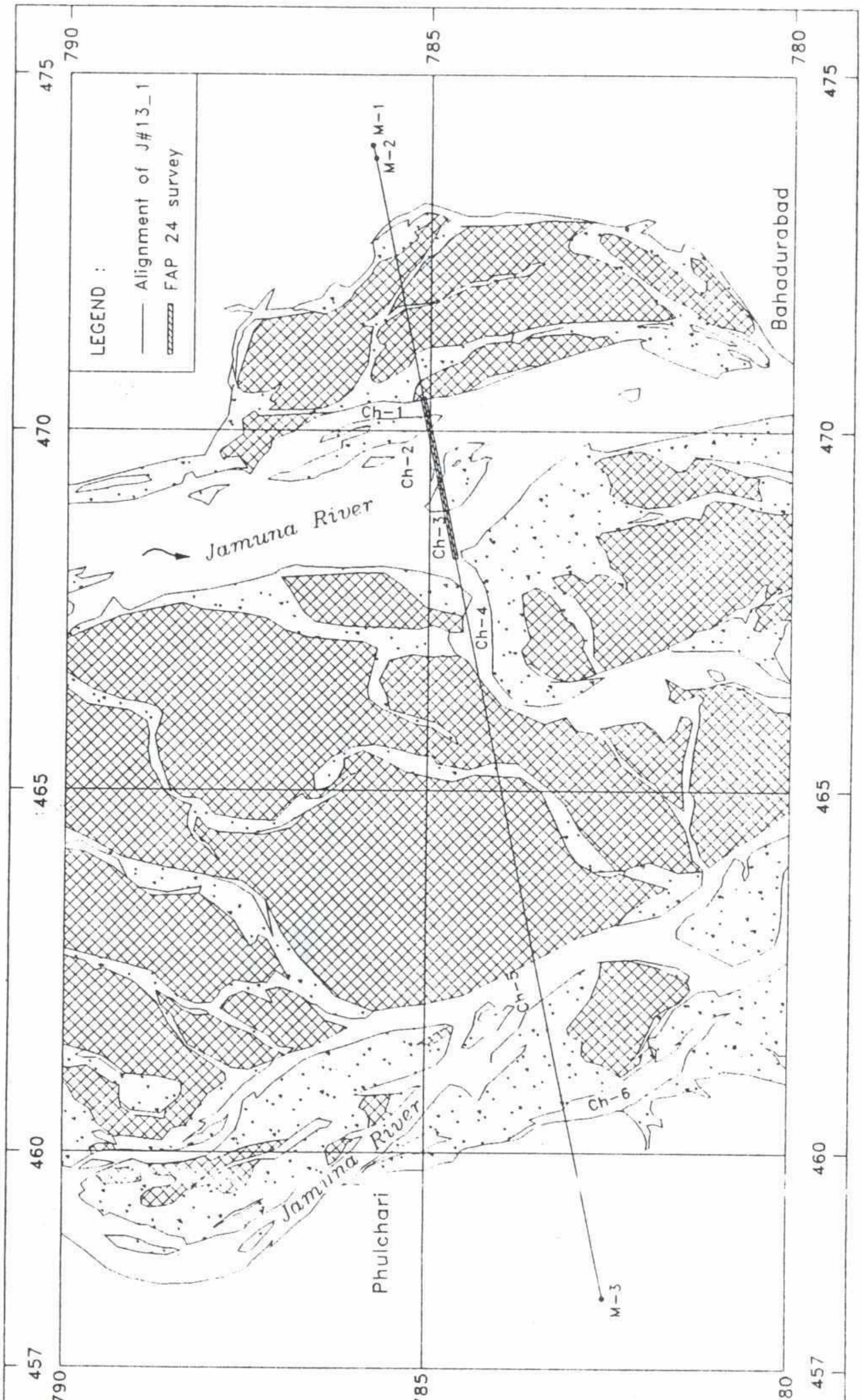

Figure 1: Alignment of BWDB cross-section J#13_1 as compared with SPOT mapping, March 1995

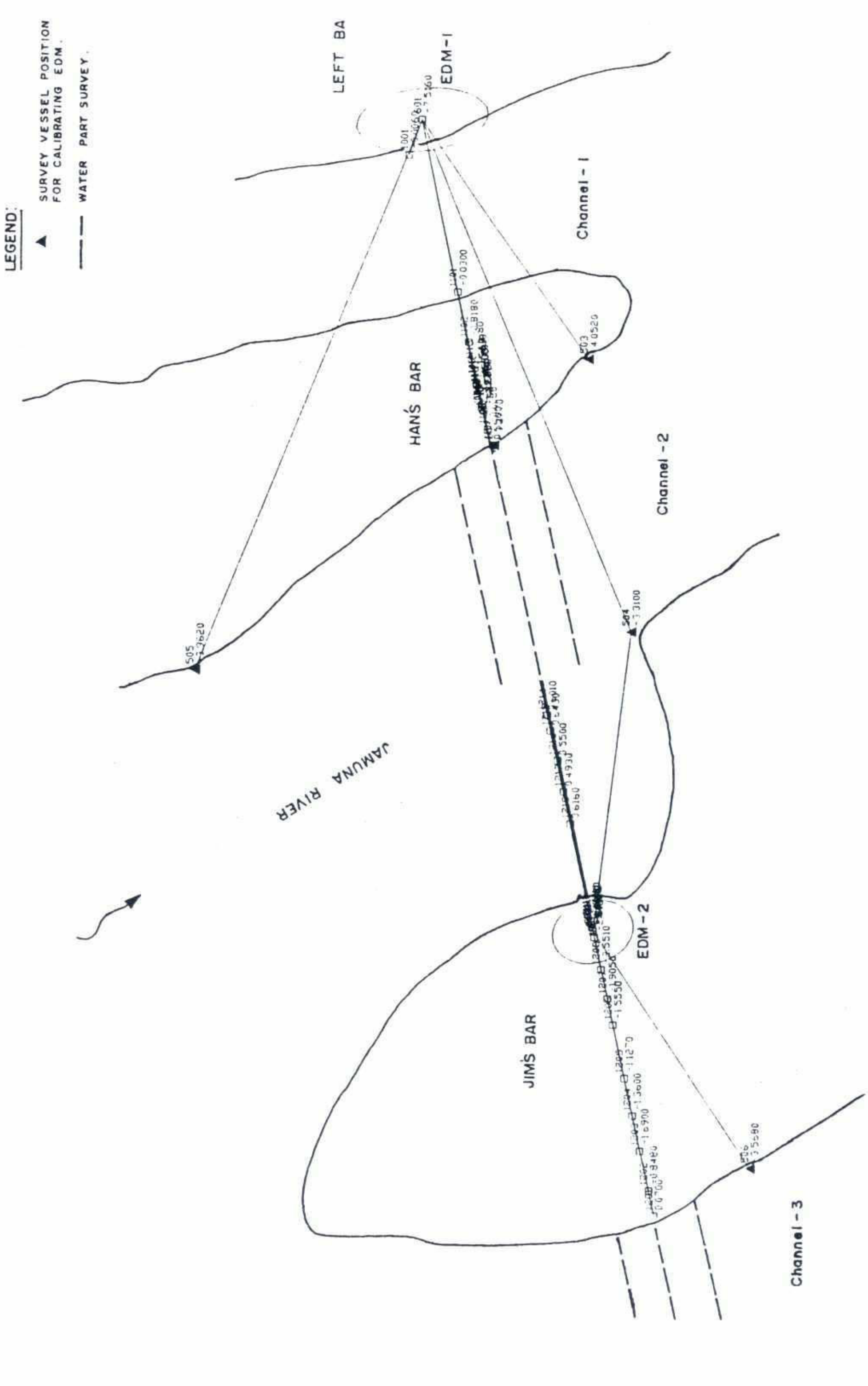

Figure 2: A sketch of the RSP cross-section of the joint measurements

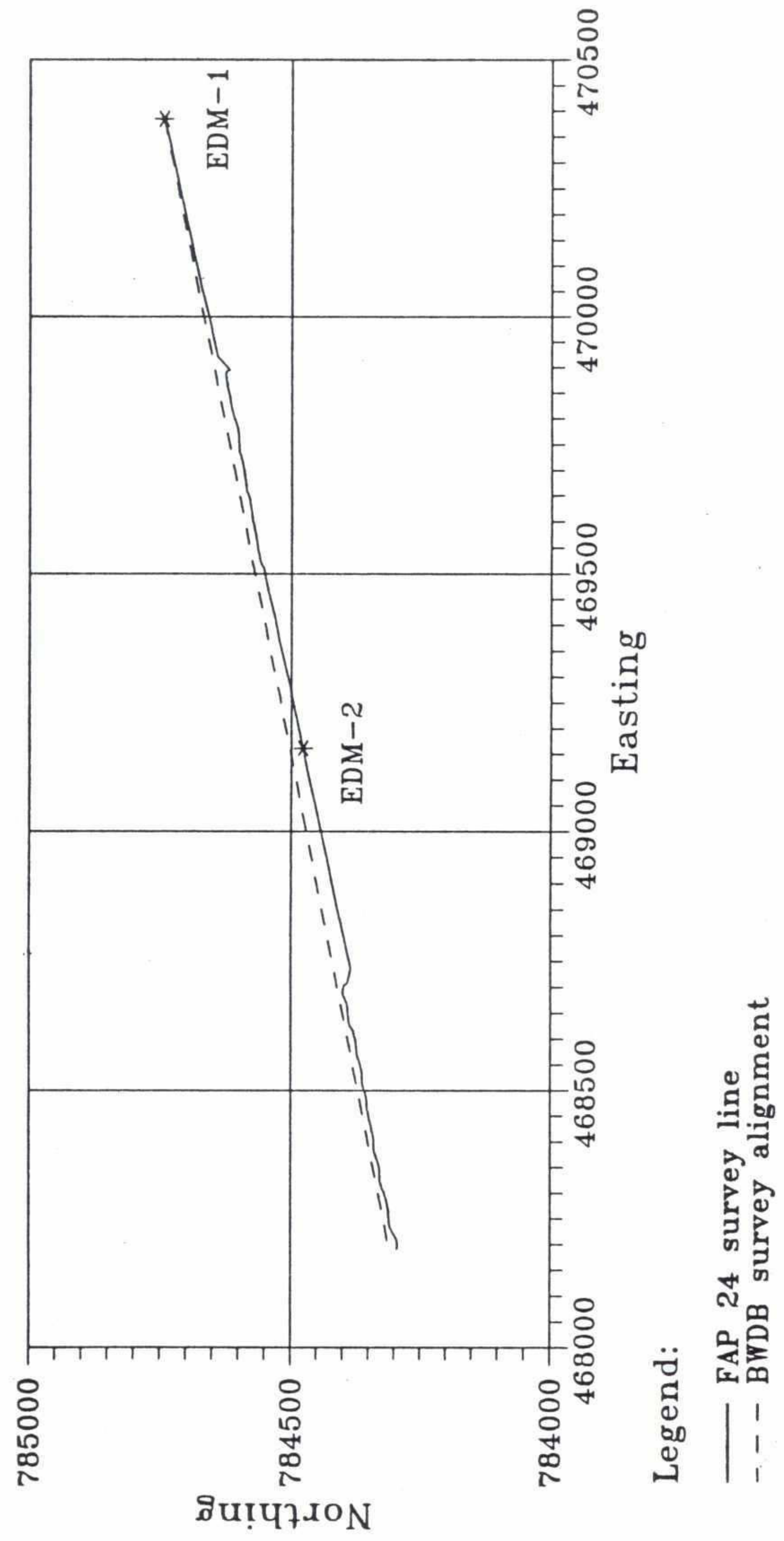

Figure 3: The RSP survey line and alignment of the BWDB survey in the co-ordinate system used by RSP (modified Bangla projection)

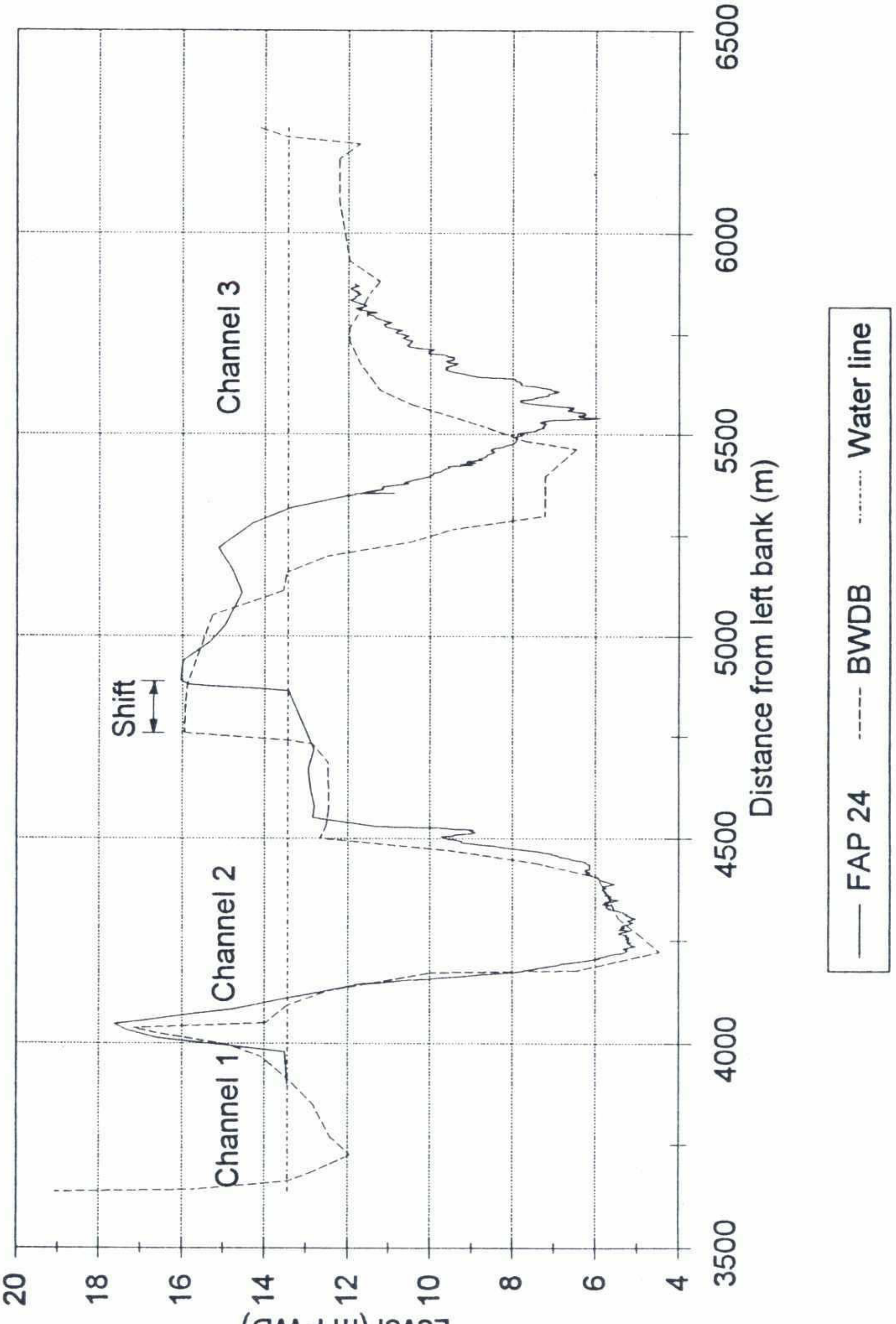

Figure 4: Comparison between the RSP survey and a part of the BWDB survey

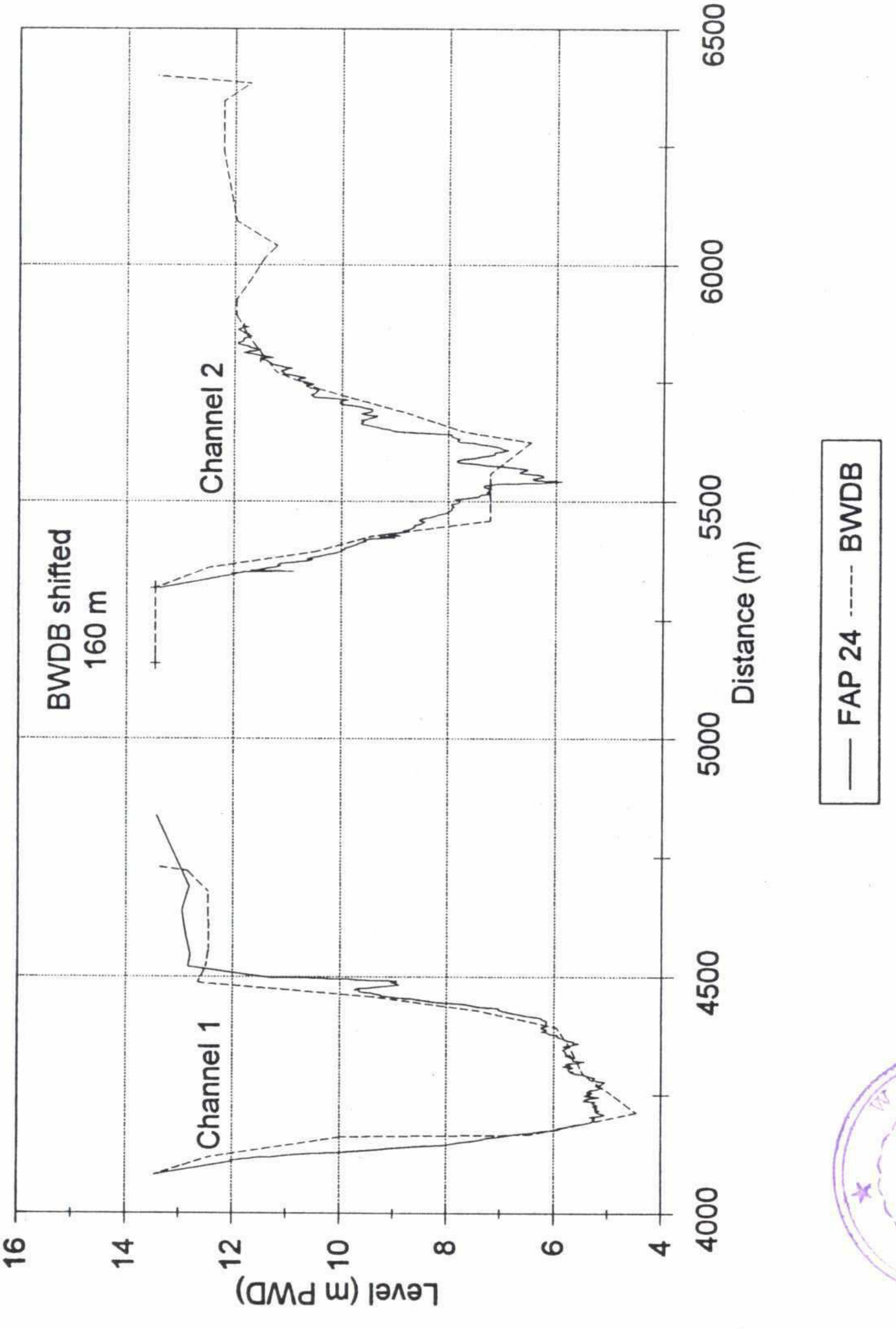

Figure 5: Comparison between the RSP survey and the water part of the BWDB survey

2b

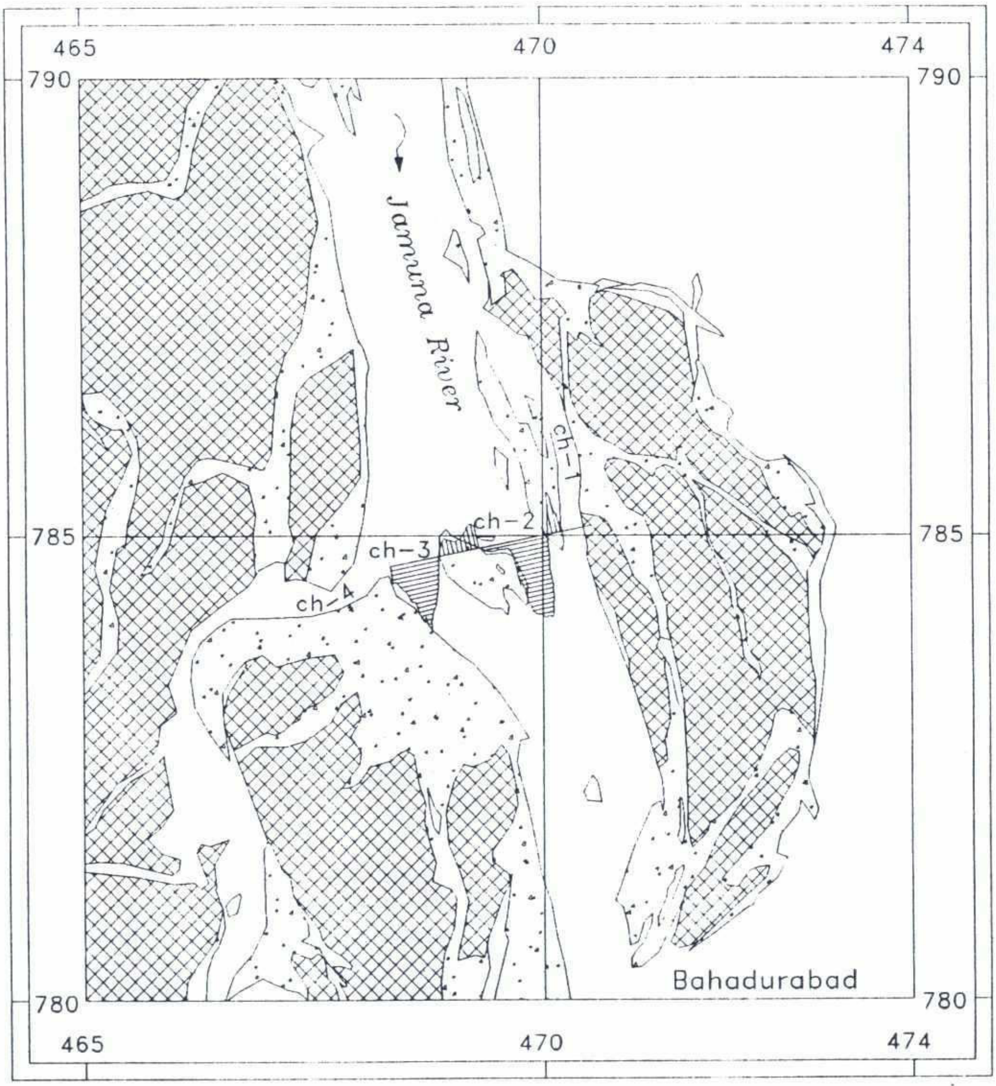

Figure 6: Location of the RSP cross-section as compared with SPOT mapping, March 1995

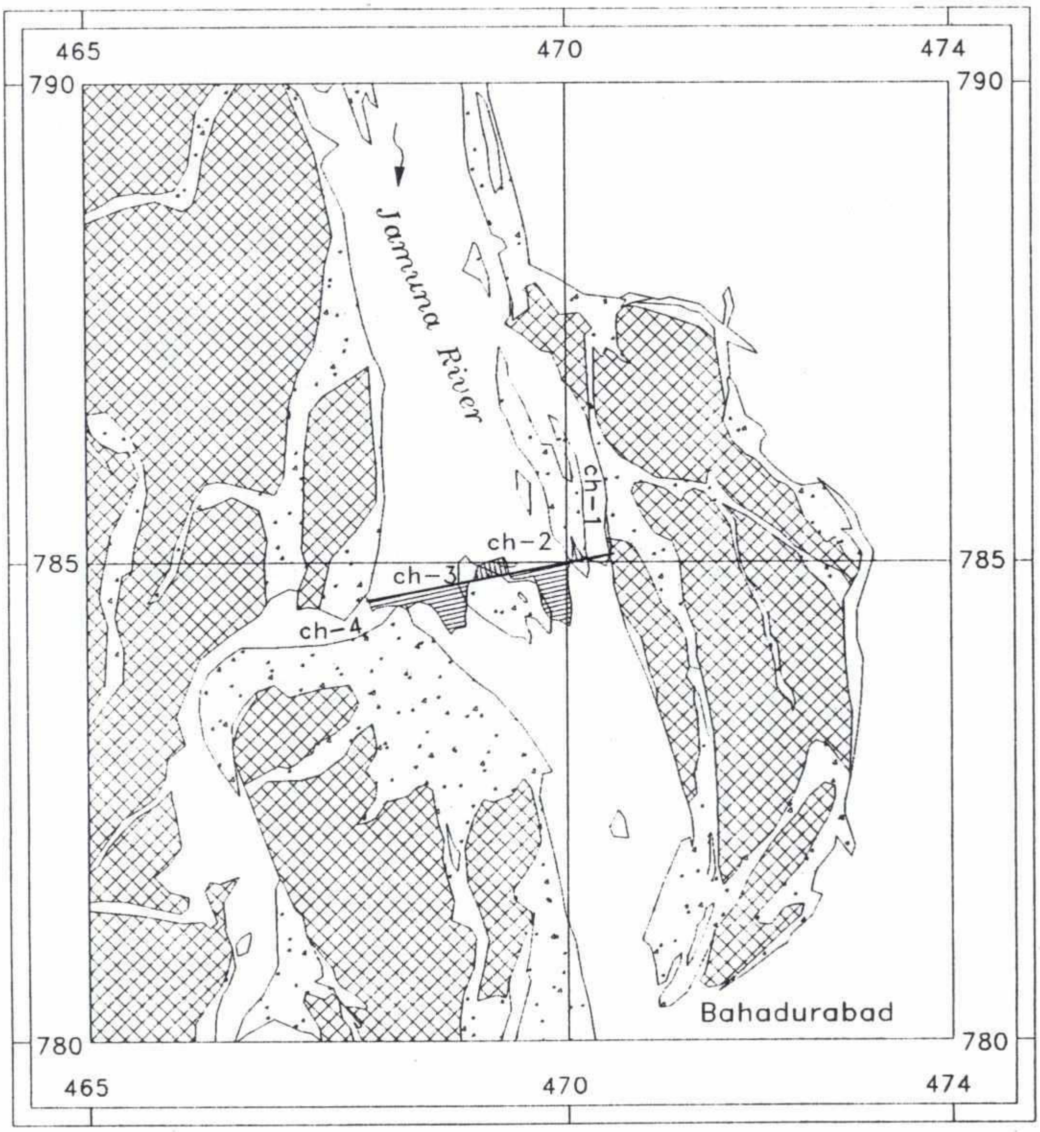

Figure 7: Location of the joint measurements part of the BWDB survey as compared with SPOT mapping, March 1995

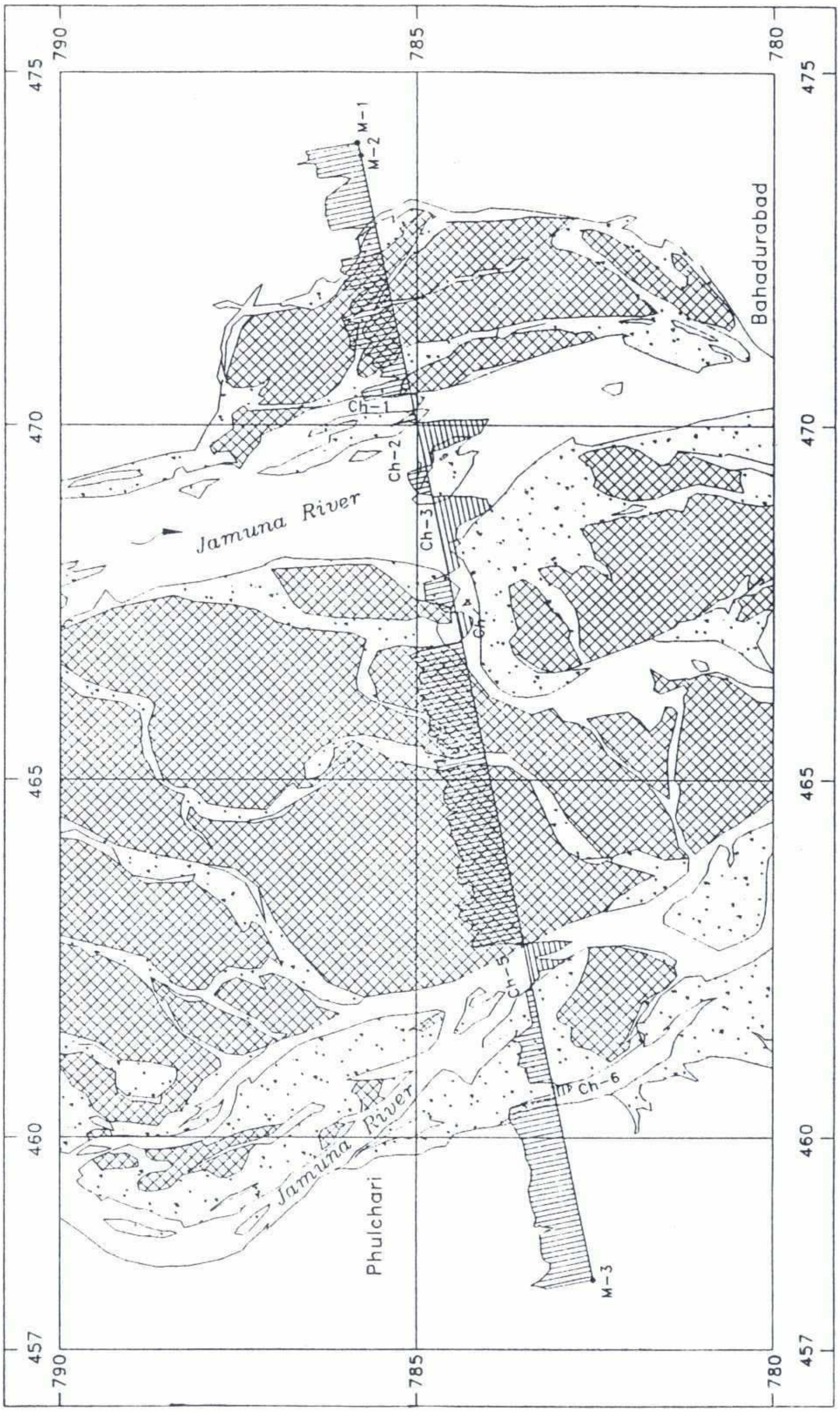

Figure 8: Location of the entire BWDB cross-section J#13_1 as compared with SPOT mapping, March 1995

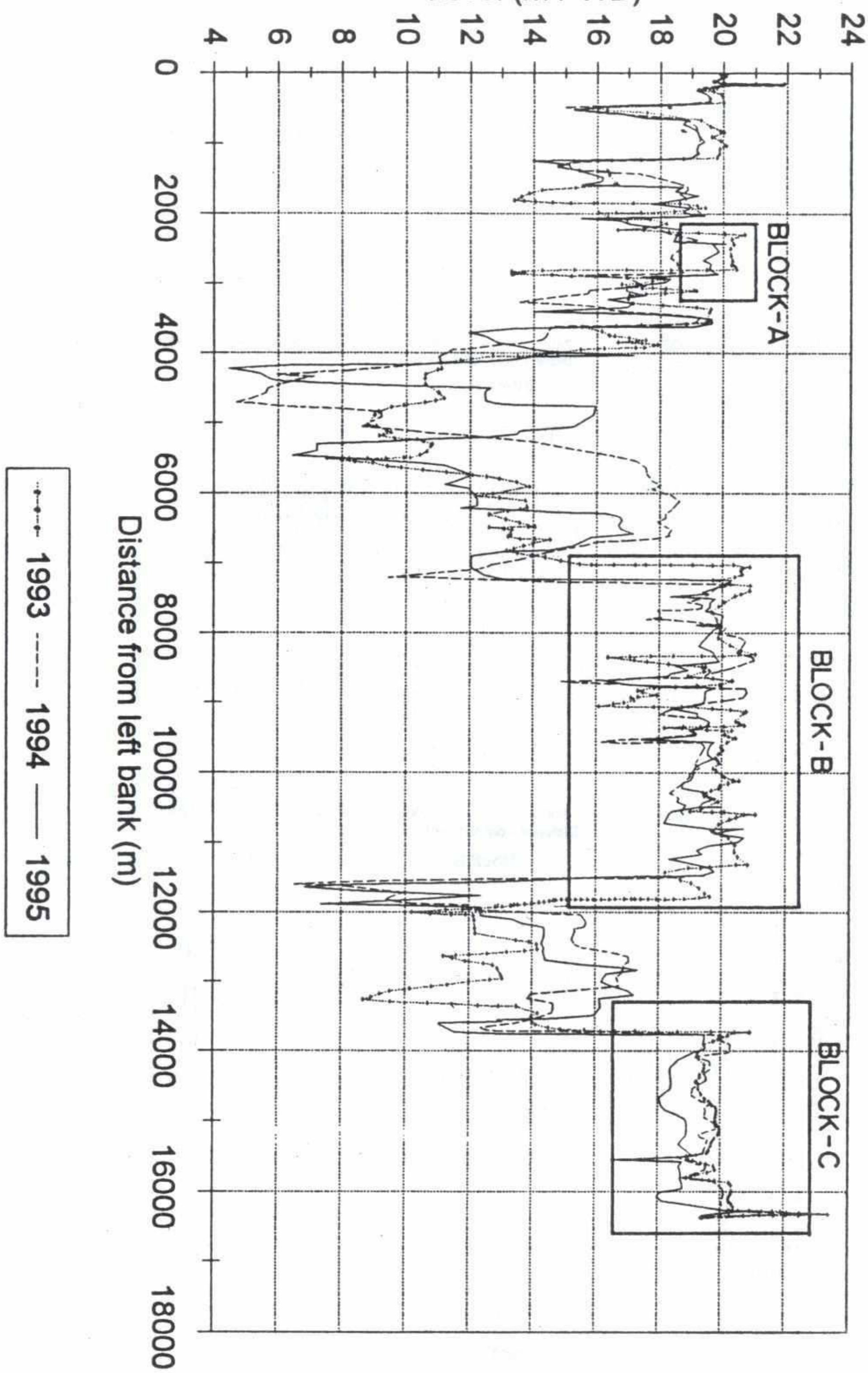

Figure 9: Comparison between BWDB surveys of cross-section J#13_1 in different years

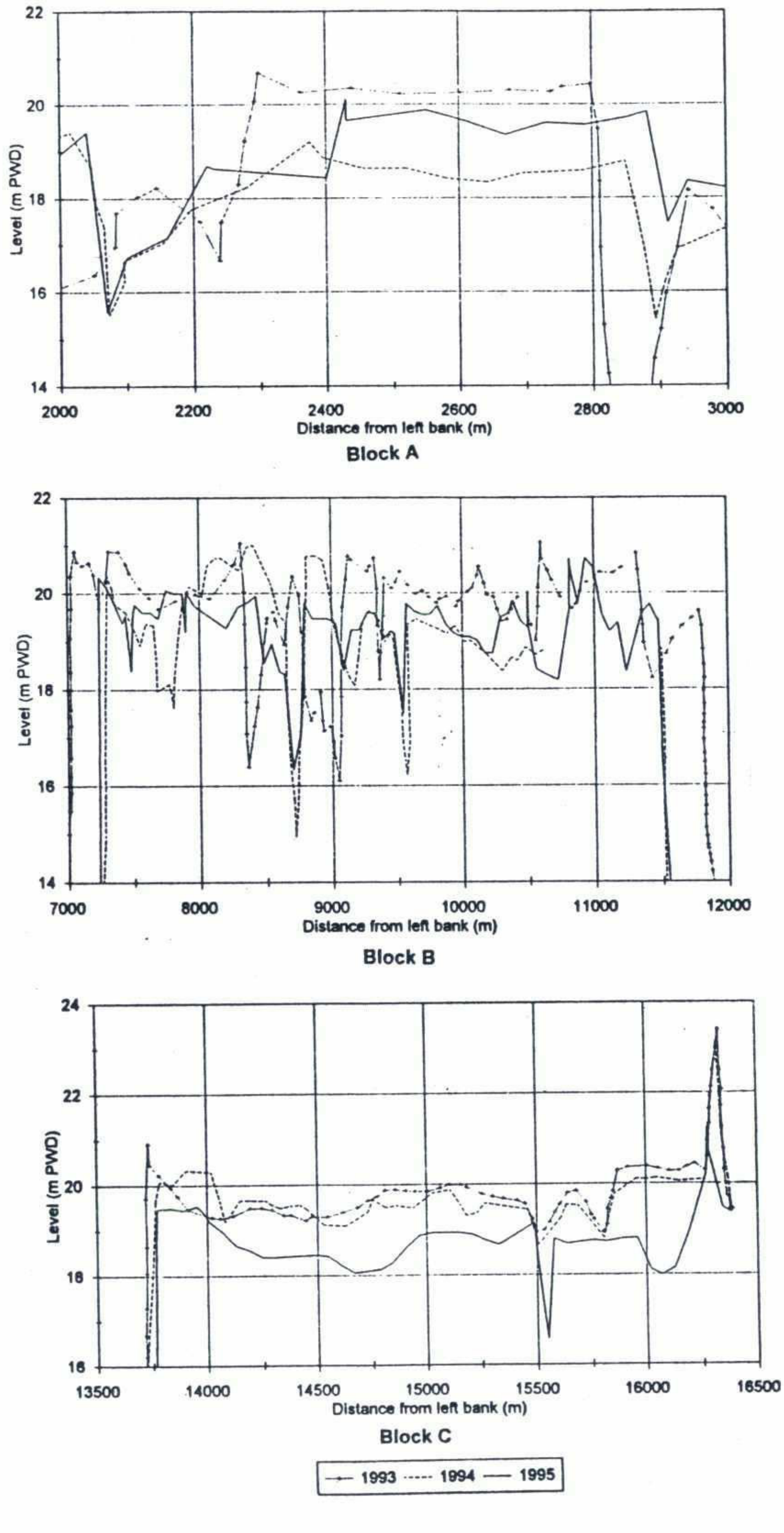

Figure 10: Comparison between char levels of cross-section J#13_1 surveyed in different years

Appendix 1

Minutes of Meeting
Between FAP24 and BWDB

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River Survey Project FAP 24

Minutes of the Meeting

Date	:	January 19, 1994
Time	:	10:30 a.m.

A meeting was held between FAP-24 and Morphology Circle of BWDB on 19/01/94 in the Conference Room of FAP-24 office. Agenda of the meeting was as follows :

1. Cross-sectional network and the definition.
2. Methods and accuracy of measurement
3. Data processing & elaboration
4. Data validation
5. Documentation and dissemination
6. Joint recommendations.

The list of the participants is shown below:

No	Name of participants	Organization
1.	Shafiur Rahman, SE	BWDB, Morphology
2.	A.H.M Kauser, XEN	do
3.	A.K.M Sayeed Uddin, XEN	do
4.	Md. Tofazzal Ali, SDE	do
5.	Pieter van Groen, Team Leader	FAP 24
6.	Martin van der Wal	do
7.	Dr. D.K Barua	do
8.	Maminul Haque Sarker	do

Team leader of FAP 24 Mr. van Groen welcomed the participants. He described the background of arranging such type of meeting between FAP-24 and Morphology Circle of BWDB. He mentioned that it is the first meeting with Morphology Circle and we can meet again in future to inform each other about the work. He expressed that for study purpose the consultant is analyzing the cross-sectional data of the major rivers which were surveyed by BWDB for the last 25 years. Therefore the consultant is interested to know the methodology and the procedures of the data collection. During the analysis of these data the consultant faced some problems which can be discussed in a meeting between the parties.

Mr. Shafiur Rahman, SE. Morphology Circle, distributed a brief note regarding the Methodology of Morphological survey which is added as Annex-1.

Mr. van Groen proposed a draft agenda of the meeting and the participants approved it. The meeting then followed as per agenda. The major conclusions of the meeting are described in the following.

1. The standard cross-sectional network and the definition of the section.

o The location of pillars/monuments.

- The location of the cross-sectional pillars/monuments on the major rivers such as the Ganges, the Jamuna, the Padma and the Meghna Rivers is defined by approximate co-ordinates at the time of placement of the pillars/monuments.

- The co-ordinate connection were made in the sixties (when BWDB started their cross-section measurements) with the help of SOB mouza maps which are referred to a geographical co-ordinate system. The procedure seems to have a rather low level of accuracy.

- There are standard 3 to 5 numbers of pillars/monuments in a cross-section which have geographical co-ordinates.

- BWDB requested the consultant to check the position of few pillars/monuments with the help of modern positioning equipments (DGPS).

- BWDB will have GPS equipment in the near future (being processed for UNDP funding) and then the position of the pillars/monuments would be corrected and re-established, if necessary.

- The position of the pillars/monuments with respect to geographical co-ordinate and mouza maps could be obtained from Morphology Circle,BWDB.

o The direction/alignment of the standard cross-section.

- The cross-sectional alignment is fixed and did not change after it was established. The alignment is always determined by the bearing of the magnetic north.

  In case of displacement/removal of the pillars/monuments, it is tried to place the new pillar/monument in its previous position. In case of bank erosion the pillar position is shifted landward to a new position in the same alignment.

- The record of the changes of the pillar/monument position are filed and it can be made available to the users.

o Chainage :
  - Distance between cross-sections was 8 miles at the beginning. But later on the standard cross-sectional distance was reduced to average 4 miles unless otherwise mentioned.
  - BWDB took 9 additional cross-section measurements about 1 mile apart from both sides of the center line of the proposed Jamuna Bridge for 5 times in two years during the study phase of the Bridge.
  - Questions arose from the consultant about the utility of measuring too many cross-sections at the cost of decrease in accuracy.

o Fixed cross-section or changed according to change in flow direction.
  - Cross-sectional alignment is fixed and it does not change with the change of the flow direction of the river and the changes in the planform.
  - But a cross-sectional alignment normal to the main flow direction in a channel is preferred for hydraulic and morphological analysis.
  - The consultant proposed to take at least three additional cross-section measurements simultaneously parallel to the established cross-section (Fig:1a) or to measure along a broken alignment which is normal to the main flow direction in each individual channel (Fig:1b).

2. Accuracy of measurement

A standard cross-section survey consists of a water part and a land part.

o Water part
  - BWDB uses an echosounder and a theodolite or a sextant during the survey of the water part of the cross-section.
  - A survey is not continued or carried out during foggy weather when the visibility is reduced.

o Land part
  - A level and a theodolite are used during the survey of the land part of a cross-section.

- The interval of level reading varied with the relief of the land. The maximum interval is about 60 m.

- The cross-sectional closing error is distributed over the cross-section. If the error is considerable then the measurements should be repeated.

o Accuracy of the bench mark (BM) and reference plane, its stability, shifting etc., use of one BM or both banks BMs.
  - The reference level of the pillar/ monument with the PWD bench-mark was connected by IECO/BWDB in 1964 - 1968.

  - In case of displacement of pillars/monuments the reference plane is connected from the nearby GTS.

  - Used BM of one bank or the other is recorded in the measurement sheets.

o Timing of measurement
  - BWDB generally carries out cross-sectional survey during the lean period, once in a year for the main rivers and also of those rivers when desired by BWDB or interested 'Projects'.

3. Data processing and elaboration

o At present there is no data processing unit within BWDB Morphological Circle. The discussion is going on with UNDP for enriching Morphological Circle with modern survey, positioning and processing equipment including training of the BWDB personnel.

o An advanced training programme is drafted for trained BWDB personnel in data analyzing and processing by FAP-24.

4. Data validation

o About 25% of the field data are generally checked by respective SDE.

o The data validation process is rather insufficient in BWDB.

5. Documentation and disseminations

o The survey data are being preserved from the beginning of the morphological data collection, but due to shifting of the office for several times a few earlier data might be missing now.

o Recently BWDB started to document the survey data river wise with cross-sectional profile and tables with digitized data.

6. Joint recommendations :

a) The definition of the standard cross-sections with respect to the geographical coordinates of the monuments or the alignment of the cross-section is not adequate. This was observed during analyses of cross-sectional data by several investigators/consultants. The situation should be improved by using, for example, global positioning system, and maintaining a proper record of the shifting of monuments. At the same time a formal definition of the chainage of the river will facilitate the determination of river parameters.

b) Accurate measurements of a cross-sectional profile in a wide and braided river like Jamuna need considerable effort. This involves a strenuous job of surveying in the land part and in the water part, and integration of the two. Surveying one section within about 5 days seems inadequate. It should be considered if the number of the standard cross-sections can be reduced in order to measure some key cross-sections with a greater accuracy with the same personnel capacity. The emphasis should be both on the quantity of data and on the quality of data.

c) Initially, the cross-sections were aligned perpendicular to the channel alignment. Due to planform changes in the meantime, the channel alignment might have changed, although the cross-sections remained fixed. But for some morphological computations, a perpendicular cross-section is desired, although a fixed cross-section has the advantage to study temporal developments at the same location. The angle between the existing cross-section alignment and the main flow direction in each channel should be measured. To check this method it is suggested that around some key cross-sections (considering recommendation b) some more alignments should be surveyed (for example, two or more sections at both side of the original one at 100 - 200 m interval depending on channel alignment and channel geometry). This can mean for example three or more sections have to be surveyed instead of one. With this approach, while the cross-section remain fixed, a perpendicular section may be interpolated from the three surveys. From quality control point of view, this is a very attractive solution, because three nearby cross-sections measured at the same time would provide a good quality check.

d) Data validation should become a regular and rigorous exercise. There are several ways to do this which include different kinds of comparison of cross-section and cross-section perimeter to ensure realistic values.

e) Cross-sectional survey results were published earlier but recently, they were discontinued. The reporting should continue with some improvements and some inclusions are necessary in the reporting:

   Description and value of the primary network bench-mark from which the monument is connected.

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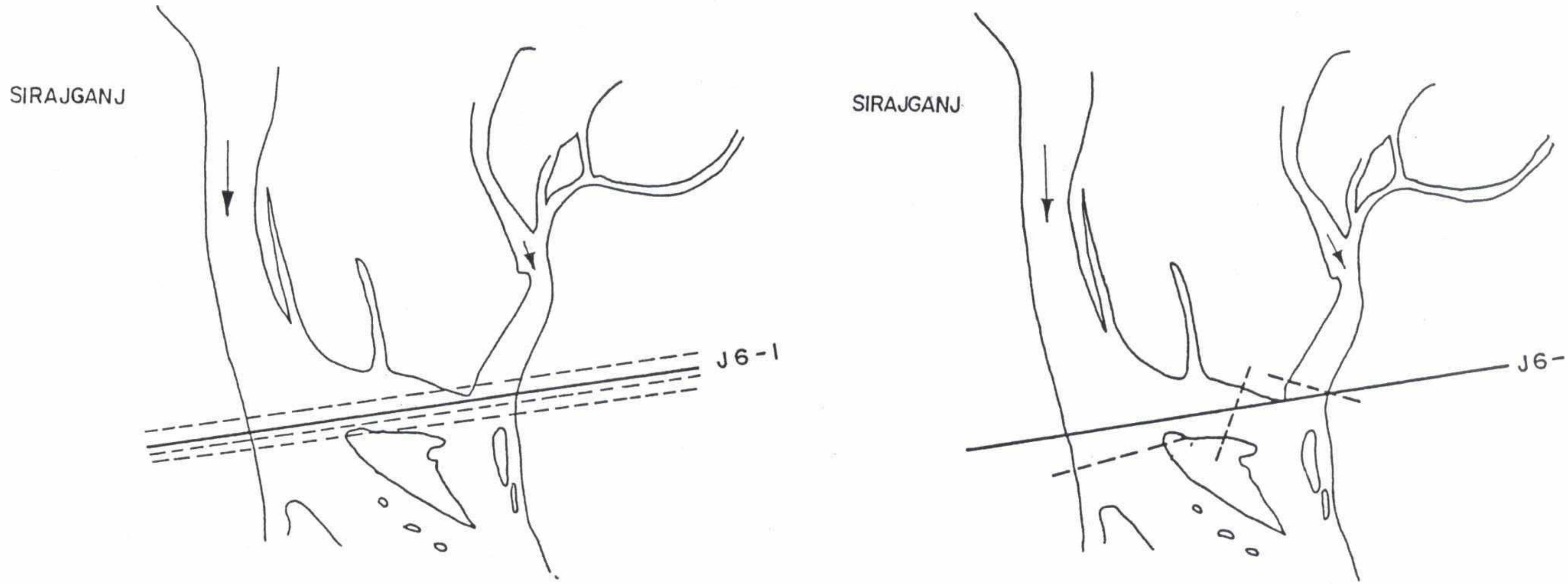
- BM values of the monuments
- Geographical coordinates of the monuments
- Closing error between one bank to the other
- Description of the shifting of monuments, if any
- Angle between alignment and main flow direction in each channel.

cc to : Participants



— — — Additional parallel cross-section line

(a)

— — — Additional cross-section line perpendicular to flow direction.

(b)

Figure : 1

METHODOLOGY OF MORPHOLOGICAL SURVEY AS ADOPTED BY MORPHOLOGY DIVISION, BWDB, MYMENSINGH.

Morphological Survey aims at estimation of the morphology of a river. It locates bank position as well as bed configuration of a river. Generally ground/bed level is taken along some cross-section lines. The location & direction with respect to north of the cross-section lines are predetermined which may be perpendicular either to flow or bank. The spacing of cross-section lines depend on nature of the river & purpose which is 4 miles in general unless otherwise specified.

The procedure of field survey is deserired as follows :-

i) At least 3 Nos. RCC Pillars/Monuments, 2 Nos. on one bank and 3rd one on the other bank are erected at river bank along the proposed cross-section line. These pillars/monuments are placed at a safe distance away from the river course on permanent bank so that it may not be eroded within reasonable long time span.

ii) Survey is started from pillar/monument 1 or pillar/monument 3 towards the river. The cross-section line is set by theodolite following the prefixed bearing.

iii) Levelling is carried out along the cross-section line and distance is measured by taping on land portion. If any obstruction is faced along the cross-section line(like homestead, bush etc.) it is crossed by making 90° angle with the line moving towards left or right and then reaching the original line by another 90° line.

iv) When a river channel is reached point A is fixed (Fig-1) on the cross-section line on more or less plane land and two Red and White survey flag (F-1 and F-2) are fixed so that the other bank of the river along the cross-section is visible clearly. From point A, a base line AB is laid such that AB is approximately $\frac{1}{3}$ of the corresponding channel width. One theodolite is set at B.

v) Engine boat or launch moves to the other bank (B-2). Two survey flag (F-3 and F-4) are erected on the other bank on the cross-section line on nearby high bank about 100 m apart.

vi) Water level is recorded simultaneously by two levelling instrument set on either bank just before sounding starts. Same time of levelling is maintained by standard signalling.

vii) Sounding : Sounding is done by rope and weight in case of ~~small channel or by Echo-Sounder in case of prominant~~ channel. Launch or engine boat starts moving from bank B-2 following the cross-section line by ranging the flags F-1 and F-2 or F-3 & F-4.

C.O.

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a) Echo-Sounder is switched on simultaneously with engine boat/launch movement. The engine boat/launch is run slowly and steadily as far as practicable. Since survey is being carried out usually in winter disturbance by wave is insignificant. Another signal flag F-5 is carried by one experienced survey assistant standing beside the tranducher pipe on the boat. Echo-sounder is run by one experienced surveyor The surveyor with theodolite at B keeps the ranging line on the tranducher pipe of Echo-Sounder by slow horizental movement of ~~the theodolite.~~

To mark any point on the river bed, the surveyor with the Echo-Sounder shouts " MARK ". Immediately the survey assistant with flag hoist his signal flag F-5 and the surveyor with the theodolite read the angle momentrily. The same procedure is continued until the boat reaches bank B 1.

b) Sometimes sextant is used in stead of theodolite in that case the surveyor with sextant stands near tranducer pipe and reads angle BCA for marking desired point.

c) In case of small channels sounding weight and rope is used for sounding. In this case marking of desired point is done by using theodolite/sextant as mentioned in (a)/(b).

viii) Level is recorded generally 30 to 50 m interval if variation in level is mild. For steep variation, level is recorded at shorter interval (5 m or less even) so that exact profile may be represented by the survey. Angle at marked point and sounding are recorded in the field book and R.L. is calculated later on. Location of the marked points are found out by solving traingle ABC(n).

ix) From field data river cross-section is plotted on graph paper and verticals are tabulated and finally published in Book Form.

22/12/82

Executive Engineer
Morphology Division,
WDB, Mymensingh.

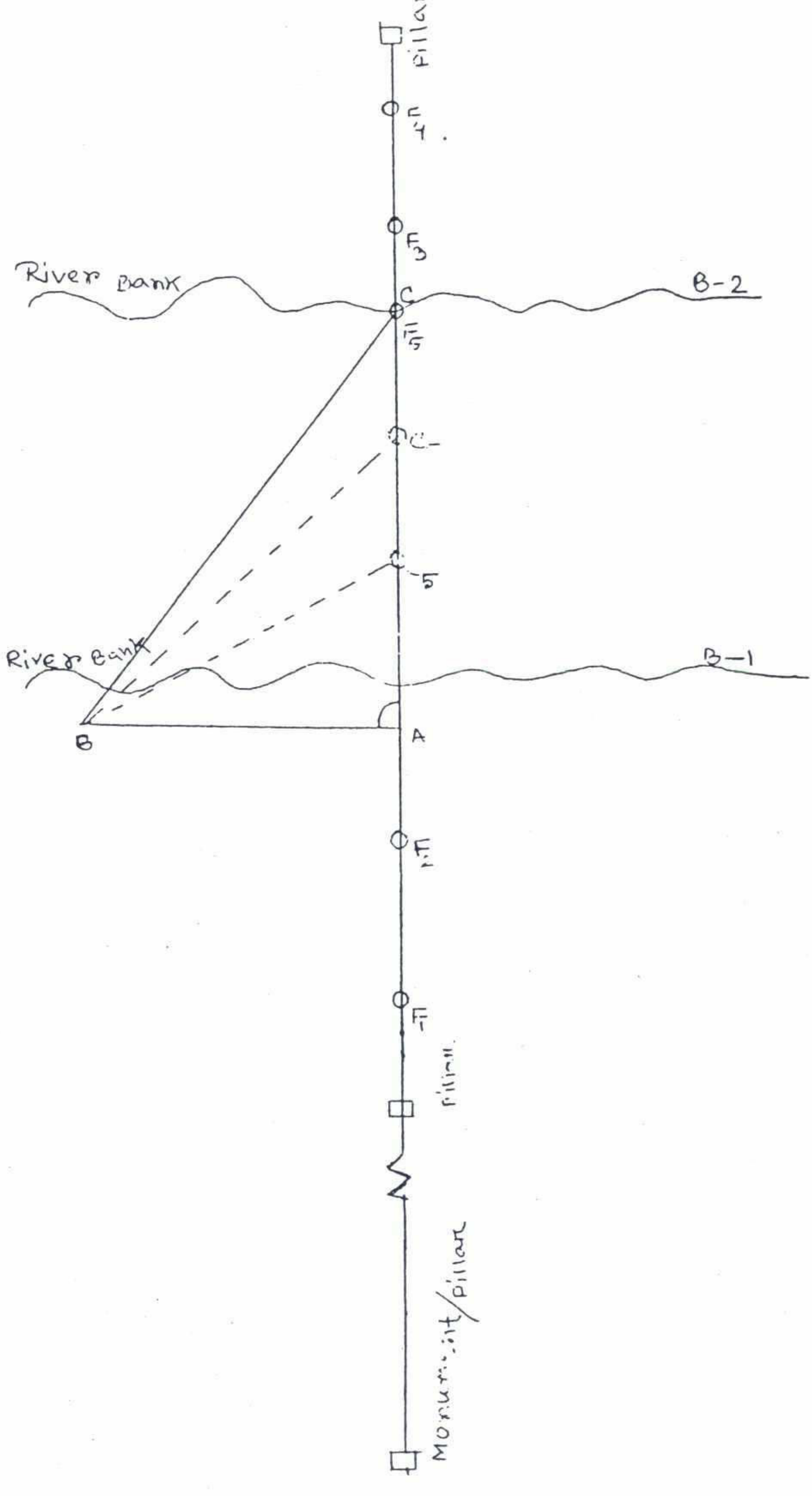

FIG-1-Sketch explaining method of river channe crosing.

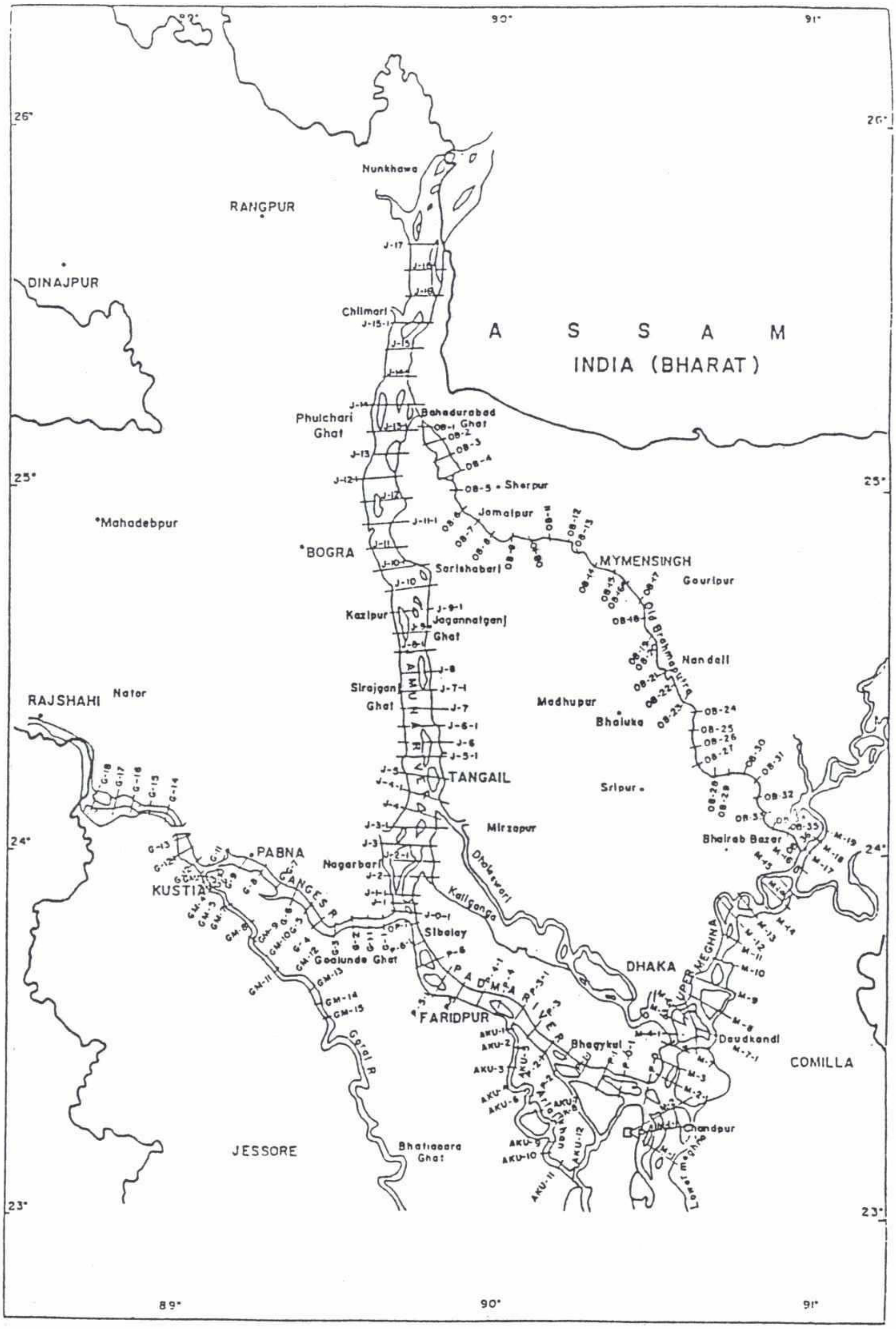
RANGPUR
DINAJPUR
Nunkhawa
Chilmari
A S S A M
INDIA (BHARAT)
Phulchari Ghat
Bahadurabad Ghat
Sherpur
Jamalpur
Mahadebpur
BOGRA
Sarishabari
MYMENSINGH
Gourlpur
Kazlpur
Jagannatganj Ghat
Old Brahmaputra
Nandail
RAJSHAHI
Nator
Sirajganj Ghat
Madhupur
Bhaluka
TANGAIL
Sripur
Mirzapur
Bhairab Bazar
PABNA
Nagarbari
KUSTIA
GANGES R
Dhaleswari
Kaliganga
Sibalay
Goalundo Ghat
PADMA RIVER
DHAKA
UPPER MEGHNA
FARIDPUR
Bhagykul
Daudkandi
COMILLA
Gorai R
Chandpur
Lower Meghna
JESSORE
Bhatiapara Ghat
JAMUNA RIVER
26°
25°
24°
23°
89°
90°
91°

Figure 1

Appendix 2

Proposed Special Cross-section Profile Measurements on the Jamuna River at Bahadurabad with Morphology and Research Circle of BWDB

Proposed Special Cross-sectional Profile Measurements on the Jamuna River at Bahadurabad with Morphology and Research Circle of BWDB

(Draft February 12, 1995)

1 Introduction

The Morphology and Research Circle of Bangladesh Water Development Board executes cross-sectional profile measurements of some 34 transects (at every 6 km) along the Brahmaputra-Jamuna River. Most of them are measured annually. These data forming a long time-series, are very useful to see morphological developments and have been used extensively by different projects and researchers. However, the data suffer from limitations on certain aspects such as the overall accuracy, measurement techniques, data elaboration, documentation, etc. Realizing the importance of these data, FAP 24 arranged a discussion meeting with the BWDB Morphology and Research Circle in January 1994. Among others, the concerned director BWDB and Team Leader of FAP 24 were present in the meeting. The meeting discussed the following matters.

- *The standard cross-sectional network and the definition of the sections.*
- *Accuracies of measurements.*
- *Data processing and elaboration.*
- *Data validation.*
- *Documentation and dissemination.*

The meeting discussed the possibility of making a joint exercise between FAP 24 and Morphology Circle of BWDB to assess the accuracies of the measurements and the need for improvement of the survey methods. This proposal is framed for this joint measurement after further consultation between FAP 24, BWDB Morphology Circle and FPCO.

2 Objectives

The objectives of this joint measurement are to provide a quality check on the survey methodologies adopted by different parties. The attention will be focused on understanding the various aspects of survey such as positioning of the monuments (on both sides of the cross-section as well as on chars), wet-area surveying (positioning, depth-measuring), land-area surveying (positioning, levelling), etc. Specifically, the objectives are to focus on works identified as follows.

1. *Monument and transit mark positioning*
2. *Monument (Bench mark) heights*

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3 *Water-part (channel) surveying*
- *positioning*
- *depth-measurements*
- *cross-section alignment (perpendicularity)*

4 *Land-part surveying*
- *positioning*
- *levelling*

5 *Linking the water-part and the land-part*

6 *Field recording*

7 *Office processing*

8 *Documentation and publication*

3 Proposed Measurements and Schedule

BWDB completes a cross-sectional measurement in about 5 days. It is proposed that FAP 24 spends 3 days in the field doing simultaneous measurements. To discuss the matter and develop a schedule, a meeting was held in the office-room of the Director of Morphology and Research Circle, BWDB on 7/2/95 at 11:00. The following officials were present.

1 Mr. Abdus Salam
Director, Morphology and Research Circle, BWDB

2 Mr. Afzalur Rahman
Director, Flood Plan Coordination Organization, Ministry of Water Resources, GoB

3 Dr. Dilip K. Barua
Deputy Team Leader, River Survey Project

4 Md. Ferdous Hossain
Executive Engineer
Morphology Division, BWDB at Mymensingh

5 Mr. Proddyut K. Saha
Sub-divisional Engineer
Morphology sub-division, BWDB at Jamalpur
Tel. 0981-3260

It was decided that measurements will be made from 24 to 28th March at cross-section # 13-1 near Bahadurabad (Fig. 1). FAP 24 will participate in the measurement from 24th to 26th March. FAP 24 resources will include:

- *one survey vessel (DHA) and a communication vessel*
- *survey crew-members*
- *land surveyors*
- *portable DGPS-system*
- *and two study group members.*

During the 3-day joint exercise, FAP 24 will participate in items 1 to 5 of the proposed activities (see the objectives). Office processing and documentation will be examined later by making an office visit to Mymensingh.

4 Expected Results

The exercise will result in an improved understanding on the accuracy of cross-sectional profile measurements by BWDB. Specifically, the exercise will yield the following important information.

- *How accurate are the methodologies of determining positions and heights of different monuments?*
- *How accurate are the methodologies of channel depth measurements and land levelling and how effectively they are combined?*
- *How the datum is transferred across channels?*
- *How accurately all information are field recorded, processed and documented?*

5 Proposed Invoicing

3 vessel days are proposed to be invoiced for the proposed survey.

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Appendix 3

Joint Survey Activities

Joint survey Activities

A joint BWDB standard cross-section survey was performed on March 24 to 26, 1995. The descrition of both FAP 24 and BDWD team, their joint activities and compositon of both survey group are presented in this appendix.

1. Team

On behalf of the Bangladesh Water Development Board the following persons were involved:

Mr. S.M.A. Salam	Superintending Engineer, BWDB, Dhaka
Mr. M.F. Hossain	Executive Engineer, BWDB, Mymensingh
Mr. P.K. Saha	Sub-Divisional Engineer, BWDB, Jamalpur
Mr. M.Z. Islam	Assistant Engineer, BWDB, Dhaka
Mr. M.K. Anam	Sub-Assistant Engineer, BWDB, Jamalpur Team Leader of the survey party

and supporting staff of the survey.

On behalf of FAP 24 the team consisted of:

Mr. H.J. Hoyer	Survey Operation Manager
Mr. D.H. Wilkens	River Engineer / Surveyor
Mr. M.H. Sarker	River Engineer

and the survey supporting staffs are the crews of the DHB, DHC and DHE survey vessels of FAP 24.

2 Activities

After arriving of BWDB and FAP 24 team members at Bhadurabad a discussion was held between BWDB and FAP 24 team in the afternoon on 24th March, 1995. The discussion mainly concentrated on the detailed programme of the joint survey. It was decided earlier that joint measurement would be in the BWDB standard cross-section J#13_1. BWDB survey Team Leader Mr. Anam informed the meeting that they already started the survey of that section on 21st March and for the sack of Joint measurement they are ready to resurvey from the left bank monument to the main channel, distance of which is more than three and half kilometers.

The Superintending Engineer Mr. Salam and Assistant Engineer Mr. Islam, BWDB, Dhaka participated in the first day (24th March, 1995) discussion regarding the detail survey programme. Next day morning (25th March, 1995) BWDB survey group showed how they started their survey from a fixed monument and also how they continue their land part survey to the FAP 24 team. Both survey group including Mr. Hossain, Executive Engineer and Mr. Shah, Sub-Divisional Engineer, BWDB walked through the floodplain and char approximately following the alignment of the J#13_1 cross-section till where BWDB survey team ended their survey at the previous day. Rest of the day and on 26th March 1995, BWDB and FAP 24 survey group measured their own survey started from BWDB chainage 3638 m from left bank

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monument. Next two days BWDB survey team headed by Mr. Anam completed survey of the cross-section J#13_1. For detail see the itinerary of FAP 24 staff in the Appendix 4.

3. Composition of survey group

BWDB survey group

One survey team while surveying in the Jamuna river generally comprises of the following man and equipments.

-Manpower

Team leader	1	SAE	BWDB regular staff
Surveyor	2	SAE/surveyor	BWDB regular staff
Survey Khalashi	3~4		BWDB regular
Helper	4~5		Daily labour

-Vessels

Motor launch	1	accommodation and sounding
Country boat	1	sounding and transport

-Equipment

Theodolite	2
Level	2
Sextant	1
Echo-sounder	1
Measuring tape	1
Level staff	1
Sounding lead	1
Ranging pole	2
Bundle of pegs	1
Iron flat	1
Flag	6

FAP 24 survey group

Main activities of FAP 24 survey are discharge measurement, sediment gauging and bathymetry. This type of survey such as the survey of land and water part of a river is the first time exercise for FAP 24 surveyor. The man and equipment engaged in the Joint survey are as follows:

-Manpower

Surveyor	1
Helper	1
Crews of DHB and DHE	

-Vessels

Survey vessel	2

-Equipment

EDM	1
EDM stuff	1
DGPS positioning system and echosounder mounted in both survey vessels	

Appendix 4

Itinerary of RSP Survey Team

8D

Itinerary of FAP 24 survey Team

In the Joint survey of part of BWDB satandard cross-section J#13_1 following persons of FAP 24 from Dhaka office were in the field:

Mr. H.J. Hoyer Survey Operation Manager
Mr. D.H. Wilkens River Engineer / Surveyor
Mr. M.H. Sarker River Engineer

Their daily acivities are described beleow:

Friday 24/6/95	Departure from Dhaka by train for Bahadurabad. Arrival at 13.00 hrs; Reconnaissance of the site. Gauge reading at 14.20 hrs: 13.23 (?)m PWD. At 15.45 hrs discussion with the BWDB staff involved. Departure by country boat at 17.00 hrs for Fulchari Ghat, arriving there at 20.00 hrs. The country boat followed a shallow secondary channel but got grounded several times although its draft was only 0.50 m. Particularly the right channel d/s Fulchari Ghat appeared to be very shallow. Arrival at the guest house at Ghaibandha: 21.00 hrs.
Saturday 25/6/95	Departure from the guest house at 06.00 hrs. After setting up the GPS eference station at Fulchari T & T tower we left for Bahadurabad around 07.15 hrs, arriving there at 10.15 hrs. Travelled by BWDB car to the local office at Dewangang to meet the S.E. and his staff staying there. Moved by car to the two monuments of line J#13-1 on the Left Bank of the river, where Mr. Anam and his survey team were present to demonstrate the way of executing the land survey. Walked from that location about 4 km. along the line of survey to the river bank, some 4 - 5 km u/s of the gauge site. After demonstration of surveying a wet channel along the left Bank of the river we left for Fulchari ghat by E-vessel around 16.00 hrs, arriving there at 17.15 hrs. A BWDB staff member accompanied us to show the location of the monument at the Right Bank of the river. Finally this monument was found near a small village Kachua, about 4.35 km South of the railway crossing. Apparently it was established later than 1965 and it was surrounded by houses and trees. Arrived at 19.30 hrs at the guest house
Sunday 26/3/95	Departure from the guest house at 06.00 hrs arriving at Bahadurabad around 08.10 hrs where we met the BWDB party. Whilst messrs Sarker and Wilkens had a discussion with the Team Leader Mr. Anam regarding the applied procedures for surveying cross-sections, mr. Hoyer started to execute a land survey over two chars at the left

hand side of the main (= left) channel. Thereafter messrs Sarker and Wilkens observed the surveying of chars and a channel by the BWDB team.

Mr. Hoyer completed the char-survey around 14.00 hrs. Next the FAP 24 team started for sounding cross-sections in the channels left of the Central Island. In addition to the line of cross-section J#13-1 also lines at 50 m u/s and 50 m d/s were surveyed.

In the meantime the DHA-vessel arrived at Bahadurabad for routine gauging.

Travelled by E-vessel and car to the Gaibandha guest house, arriving there at 19.15 hrs.

Monday 27/3/95

Information showed that there would be no train to Dhaka leaving at a suitable time, so it was decided to travel by car via Aricha to Dhaka. In the early morning the crews of the vessels were informed concerning the altered scheme and asked to inform the office accordingly. Left Gaibandha at 08.45 hrs, arriving at Dhaka at 18.15 hrs.

Appendix 5

BWDB Water Part Measurement

BWDB water part measurement

BWDB cross-section survey line is defined by a fixed alignment, which is valid for both water and land part survey. In the water part, the survey line is identified by two flags mounted on two bamboo poles of different heights, interspacing 20 to 50 meters on the land. Generally, the near bank bamboo pole is shorter than the other. A theodolite is positioned at the end of a base line perpendicular to the line of survey, see the Figure 1.

A mechanised country boat with echosounder started sailing from the opposite bank along the line of survey line following the bamboo poles erecting on the bank ahead. The distance in the water part survey is estimated by measuring the angle between the base line and the position of the sounding boat. The angle is measured by the theodolite, while a man from the boat erect a flag and at the same time echosounder operator make a fix. In reality, it is not possible to sail in a straight line in the river. During the joint survey 40 m deviation from the line of survey was estimated. Deviation from the survey line influences the estimated distance in higher magnitude.
Say, actual distance of the boat is x from the base line and x is the estimated distance, then

$$x = (T \pm \Delta) * \tan\Theta \qquad (1)$$

$$x = T * \tan\Theta \qquad (2)$$

Combining the Equation 1 and 2, results the difference between actual and estimated distance from the base line:

$$E = x - x = \pm \Delta * \tan\Theta \qquad (3)$$

where T is the distance of theodolite from the survey line, Δ is the deviation of sounding boat from the survey line and Θ is the angle between the base line and the position of the boat.

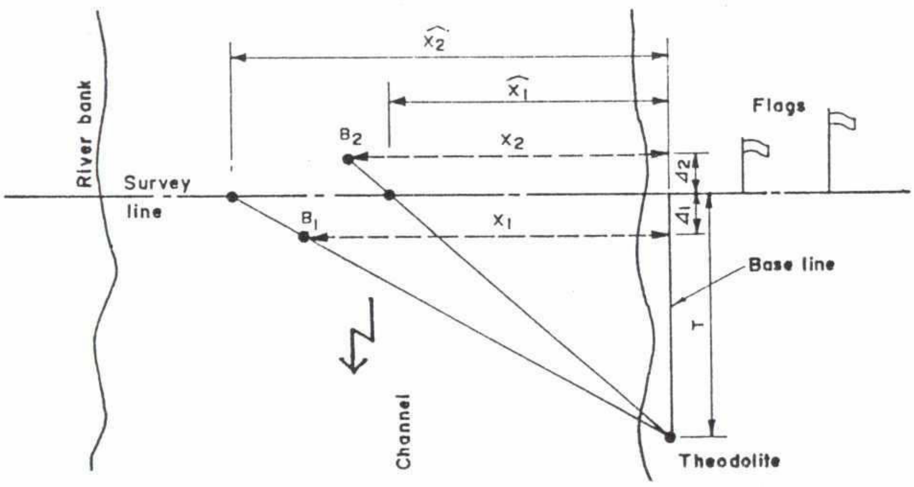

Figure 1: Introduction of error in BWDB water part survey due to use of one theodolite on the base line.

Consider the boat position at B_1 and B_2 both side of the survey line and corresponding deviations from the survey line are Δ_1 and Δ_2, see Figure 1. Assuming T is 200 m, Θ_1 and Θ_2 are 75° and 65° respectively, Δ_1 and Δ_2 are 40 m and 30 m respectively. The actual distance of B_1 and B_2 from the base line will be 597 m and 493 m, from Equation 1. As BWDB do not estimate the deviation of the boat, their estimation of distances of B_1 and B_2 from the base line will be 746 m and 429 m, from Equation 2. For position B_1 the error E in distance estimation will be 149 m and for position B error E will be 64 m. If B_1 and B_2 are two consecutive fixes, then the estimated distance between the two points will be 317 m instead of 104 m, three times higher than the actual projected distance along the survey line. The magnitude of error E is the function of the deviation Δ and the measured angle Θ (Equation 3).

The reflection of such error is noticed in Figure 2, where FAP 24 water part survey is compared with BWDB water part survey in the Channel 3. The end of both surveys coincides each other, but the mid-points are not coinciding, probably due to the reason mentioned above.

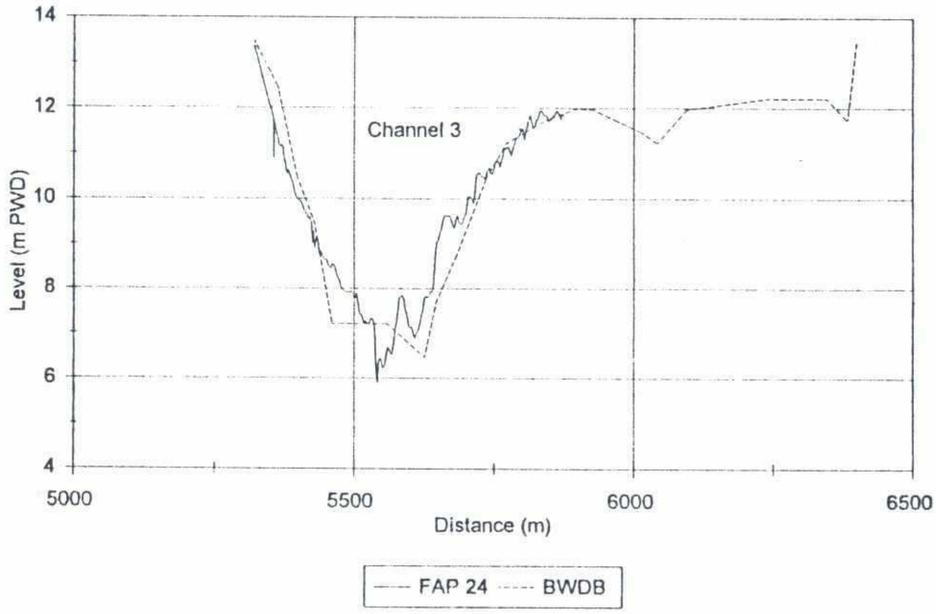

Figure 2: Comparison of FAP 24 and BWDB water part surveys in Channel 2.