3.3 River Morphology

3.3.1 Methodology

Two methodological approaches are conceivable to scrutinize the river morphological behavior in the Brahmaputra. The first one refers to the conventional ground survey such as hydrography or geomorphology that has been conducted by the River Morphology Circle under Chief Engineer of Hydrology in BWDB during long period. (See Figure A2.3-1) This method is described in terms of Cross Sections in the subsection 3.3.2.

The second one denotes photogrammetry represented by the remote sensing technology or satellite image processing. EGIS has been recognized as a professional organization with high standard of technical capability to carry out the research and development in this field. (See Section 2.10) WARPO/EGIS/Delft Hydraulics Report (See Reference (4) in Contents) presents the elaboration of the river morphology study in the Brahmaputra based on this methodology. Summary of the Report concludes the study outcomes as per subsection 3.3.4.

3.3.2 Cross Sections

The River Morphology Circle of BWDB has been conducting survey around 1,000 cross sections of the rivers of Bangladesh only in the dry season during November to June, and processing starts in July with hard copy format. The survey cross sections are collected at 6.4 km intervals as a rule but in special cases the interval comes to less than 1.0 km. The cross section sites along the Brahmaputra are shown in Map A3.2-1. The survey results are tabulated and plotted on graph paper for publication.

The cross sectional data were collected for the Study as summarized in Table A3.3-1 and their locations are presented in Map A3.2-1. The original cross section data of the selected seven sites are completely listed in Appendix Table AA2 together with their profile drawings. J8 site was excluded during the course of file arrangement due to scarcity of data quantity and similarity of data nature with J8-1 site.

The cross sectional profiles of J14 site are illustrated as per Figure A3.3-1, because J14 site traverses over Fulchari Upazila where is a probable candidacy for the feasibility study area of the forthcoming phase. Figure A3.3-1 indicates shift of the profiles during consecutive two observation years together with the water level of the cross section site. However, it is hard task to distinguish the Char shifting situation from the profile data only. It means that a combined analysis of the cross sectional profiles with the satellite image processing are substantial requirement for the exact river morphological study.

3.3.3 Char Behavior

Satellite images of the Brahmaputra are shown in Maps A3.3-1 and A3.3-2. They cover the river section between the India border and the confluence with the Ganges during 1973 to 2000. As far as J14 site concerns remarkable Char shifting situation can be recognized from the images. However the scale of the images correspond to 1/1,200,000 that is too extensive for analytical purposes.

A Char is defined as a large vegetated island (island-char) or an area of vegetated land within the braid belt that is attached to the floodplain (attached-char). Further following terms are used in this Section.

- Water: low flow anabranch channel
- Sand: braid bar or recently deposited sediment or char
- Land: island-char or attached-char

The total area within the banklines increased by 37% between 1973 and 1996. The trend of increase within bank area has been remarkably steady. (See Table A3.3-3)

Map A3.3-3 shows that the spatial distribution of char age within the braid belt is not random. The existence of land more than 20 years old is limited almost exclusively to six areas occupied by large individual island-char and clusters of smaller island-char.

The enlarged portion in Map A3.3-3 corresponds with J8 to J9-1 sections in Map A3.2-1. J14-1 to J14 sections where represent the island-char within Fulchari Upazila seem to be similar with the Map A3.3-3 in general features of the age distribution. The charland area in MapA3.3-3 is tabulated in Table A3.3-3.

3.3.4 Summary of Morphological Dynamics

The rivers of Bangladesh are a resource of major benefit as well as a source of threat to the land, people and infrastructure along their courses. Riverine characteristics and behaviour, both natural and in response to human intervention, can be better understood and predicted through the study and monitoring of river morphology and dynamics.

A River Morphology and Resource Information System (RMRJS) was developed with a spatial database and analysis capability for storing and analyzing satellite images, historical maps, topographic and hydrometric data, river inorphology and other information about the major rivers of Bangladesh. In this project RMRIS was used to study the morphology of the Brahmaputra-Jamuna, a braided river system characterized by rapid and substantial changes in planform, with particular emphasis on bank line and width changes, channel braiding characteristics and char development. The databases and analysis tools of the RMRIS were designed to meet the requirements of a number of development projects, including the Jamuna Bridge, the River Bank Protection Project and several programs related to the Flood Action Plan, and for general planning for the river chars and adjacent floodplain areas. The database took years to develop and has, in addition to the results obtained in this study, much potential for related analysis including predictive modelling of the future morphodynamic behaviour and morphological evolution of the river.

A substantial portion of the spatial database was derived from a time series of satellite images consisting of 26 Landsat image frames, acquired between 1973 and 1996. The study area covers the entire Brahmaputra-Jamuna River in Bangladesh from the northern border with India to the confluence of the Ganges, a distance of 240 km. The data were geo-referenced to a common map projection, classified by computer image processing, and interpreted and analyzed using a geographic information system (GIS). The satellite image time series was supplemented with hydrometric data, including water levels and discharge for the period of study, historic maps and results of other studies.

A number of key findings, observations and predictions are presented by topic below. These are derived from the direct factual information and analysis of this study, along with results and findings of other studies, field study and the experience ofthe authors ofthis report.

River Width

The river is becoming wider through retreat of both right and left banks.

- The average width of the river has increased about 130 m per year since 1973.
- Recent widening has occurred through retreat of both left and right banks. The average width of the river has increased from about 8 km to 11 km since 1973, an increase of 3 km or nearly 40 percent.
- Relative to the mean width increase, the minimum width is increasing faster and the maximum width is increasing slower. Thus, the overall river is becoming wider and more uniform.

Widening of the river is likely to continue.

- Since adopting its present course sometime before 1830, the river has been widening. It seems to be creating an active corridor 16 kilometres across, a width sufficient to contain its braiding channels, bars and chars.
- Based on historical and current trends, widening will continue for at least another two decades and possibly three or more.

Bank Erosion

Both river banks are retreating and eroding floodplain land.

- Bank erosion is twice as likely to occur as bank accretion at any place along the river in any two to three year period.
- The right bank has retreated to the west by an average of 1.5 km since 1973, at an average rate of about 65 meters per year.
- Westward migration of the right bank has been particularly severe between Fulchari and Sirajganj.
- The left bank has also retreated since 1973, but not at all locations. Eastward retreat is

worse in the northern and southern thirds of the river. In the middle third, between the Old Brahmaputra offtake and Bhuapur, retreat through bank erosion and advance through bank accretion are almost matched.

Erosion risks are high for those dwelling along the river banks.

- On average, bank erosion has occurred in two out of three years for most reaches of the river.
- The rate and extent of erosion may be very severe, with about a one in ten chance annually that more than 400 meters of retreat will occur.

River bank erosion will continue unabated without additional river bank protection and river training.

- Unless bank protection currently under construction at Mathurapara and Sariakandi are completed, a breakthrough of the Jamuna to the Bangali River is inevitable, probably before the end of the century.
- In the longer-term, other locations will be threatened with river breakthrough requiring consideration of further bank protection works.

The cost for bank protection and river training will increase.

- The river's tendency to widen, particularly through retreat of the right bank, will continue. This means direct attack on existing and future bank protection and training structures, and accompanying maintenance costs.
- As river banks continue to erode up and downstream of river training and protection structures, the threat to those structures will become more acute. Further works will be required, in part to protect the existing structures.

River Braiding

Some investigators have suggested that the river may be changing in form from braided to meandering. There is no evidence to support this; in fact, braiding is increasing.

- The average number of low flow channels, between which low flow season discharges are divided, has increased by 40 percent since 1973 and their average length has increased by 30 percent.
- The intensity of the river's braiding has particularly increased in the last decade and is now at the highest level during the study period (1973-96).

The increase in braiding will likely continue increasing in the future.

- *The intensity of braiding observed in some reaches suggests that the maximum braiding intensity for the river has not yet been reached and that a further increase of about 25 percent is possible for those reaches.

The river form is different for the reaches above and below Sirajganj, but there is no reason to expect a single channel to form below Sirajganj and the Jamuna Bridge site.

- Upstream of Sirajganj the river is weakly anastomosed. Major left and right bank anabranches have semi-independent planforms that alternate between braided and meandering.
- For much of the 1980s, the river downstream of Siraigani followed a meandering path with wide point bars and multiple chute and back channels, but recently it has developed more braiding tendencies.
- The rapid widening of the river at the Jamuna Bridge site is part of a general shift from meandering to braiding in the 1990s.

Increased braiding will continue to have impacts on navigation.

- *Increased braiding helps explain why navigation conditions during the low flow season have become more difficult despite best efforts to maintain feny and shipping routes. These conditions are likely to continue to deteriorate.

Floodplain Destruction and Charland Growth

River bank retreat and widening is eroding floodplain land

- The river has consumed over 70,000 ha of mainland floodplain since 1973 and created only about 11,000 ha of land through accretion along its banks.
- Large monsoon floods have especially harsh impacts on the floodplain. For example, between 1987 and 1989 the rate of mainland floodplain erosion rose to over 8,000 ha per year.

Expansion of the river is taking place primarily through destruction of mainland floodplain and creation of short-lived charland.

- Much of the lost floodplain land is going into the creation of new charland. On average, 2,000 hectares of charland appeared in the braided course of the river each year since 1973. The new char areas are typically less productive than the eroded mainland and are under constant threat of flooding and loss due to river erosion.
- With exception of the 10 percent of stable char land more than 20 years old, chars are frequently destroyed at one location and created at another. The average age of a given area of charland is only four years. This means that the homesteads, lands and infrastructure of most char dwellers are destroyed by erosion every few years.

Table A3.3-1: Summary Table of Cross Sections in the Brahmaputra

L: Measured from Left Bank R: Measured from Right Bank

Year	J 8-1	J 9	J 9-1	J 14	J 14-1	J 16	J 16-1
1964							
1965	L-Dec	L-Nov	L-Dec	R-Dec		R-Oct	
1966				R-Dec	R-Jan;R-Dec	R-Oct	
1967		L-Jan	L-Jan			R-Nov	R-Mar;R-Dec
1968	L-Jan	L-Jan	L-Jan	R-Feb	R-Jan	R-Nov	R-Nov
1969	L-May	L-Jan	L-May	R-Jan	R-Jan	R-Nov	R-Nov
1970	L-May	L-May	L-May	R-Mar	R-Apr		
1971							
1972							
1973							
1974							
1975							
1976						R-Oct	
1977	L-Jan	L-Jan	L-Jan	R-Dec;R-Apr	R-Apr;R-Dec	R-Nov	R-May;R-Nov
1978	L-Feb;L-Mar		L-Mar	R-May	R-May	R-May	R-Jun
1979							
1980	L-Nov	L-Dec			R-Dec		
1981			L-Jan	R-Nov		R-Feb	R-Mar
1982	L-Feb	L-Jan	L-Jan	R-Feb	R-Feb	R-Jan	R-Jan
1983							
1984							
1985							
1986	L-Nov	L-May	L-Nov	R-May	R-May	R-Jul	R-Jun
1987							
1988							
1989							
1990							
1991	L-Jan	L-Jan		L-Jun	R-Jun	R-Jun	R-Jun
1992	L-Apr	JL-an	L-May	L-Mar	R-May	R-Mar	R-Jun
1993	L-Mar	L-Mar	L-Mar	L-May	R-May	R-May	R-May
1994	L-Mar	L-Mar	L-Mar	L-Feb	R-Mar	R-Mar	R-Mar
1995	L-Apr	L-Apr	L-Apr	L-Mar	R-Mar	R-Apr	R-Apr
1996	L-Mar	L-Jan	L-Jan	L-Feb	R-Mar	R-Mar	R-Mar
1997							
1998	L-Feb	L-Feb	L-Feb	L-Mar	R-Mar	R-Apr	R-Apr
1999	L-Mar	L-Mar	L-Mar	L-Apr	R-Apr	R-May	R-May
2000							
2001							

Table A3.3-3: Distribution of Land Cover Within the Banklines

Year	Area (ha)				Total Area as of 1973 (%)	Percentage		
	Water	Sand	Land	Total		Water	Sand	Land
1973	48467	44057	77752	170277	100	28	26	46
1976	58547	37952	73395	169894	100	34	22	43
1978	51881	44851	84076	180807	106	29	25	47
1980	58313	43264	84478	186054	109	31	23	45
1983	54676	55380	86437	196493	115	28	28	44
1984	55740	54009	89580	199329	117	28	27	45
1985	60321	41387	103646	205354	121	29	20	50
1987	57046	46519	98633	202198	119	28	23	49
1989	65811	57605	95588	219004	129	30	26	44
1992	61236	70237	98761	230234	135	27	31	43
1994	62054	49122	119757	230933	136	27	21	52
1995	57439	42786	130723	230947	136	25	19	57
1996	61817	75127	96257	233201	137	27	32	41
Mean	57950	50946	95314	204210	120	29	25	47
Std. dev.	4600	11268	16044	23203	14	2	4	4

(Source: Morphological Dynamics of the Brahmaputra- Jamuna River, February 1997, EGIS)

Table A3.3-4: Age of Chars

Age (year)	Char Land		Cumulative Area (%)
	Area (ha)	Percent	
0	18648	19	100
1	10741	11	81
2	19464	20	69
4	13294	14	49
7	6661	7	35
9	6112	6	28
11	3496	4	22
12	1787	2	18
13	2712	3	17
16	1965	2	14
18	1625	2	12
20	1598	2	10
23	7994	8	8
Total	96067	100	

(Source: Morphological Dynamics of the Brahmaputra- Jamuna River, February 1997, EGIS)

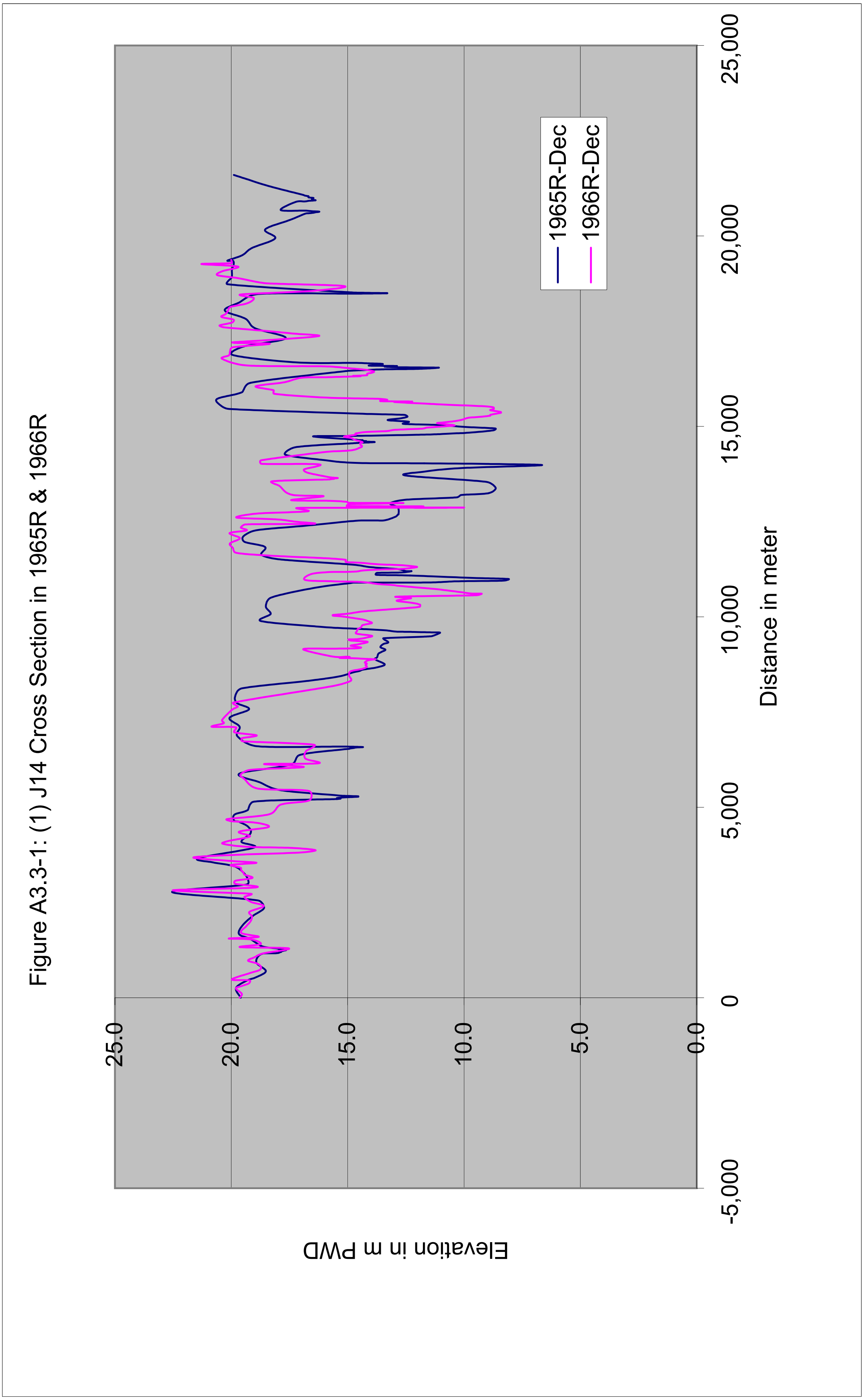
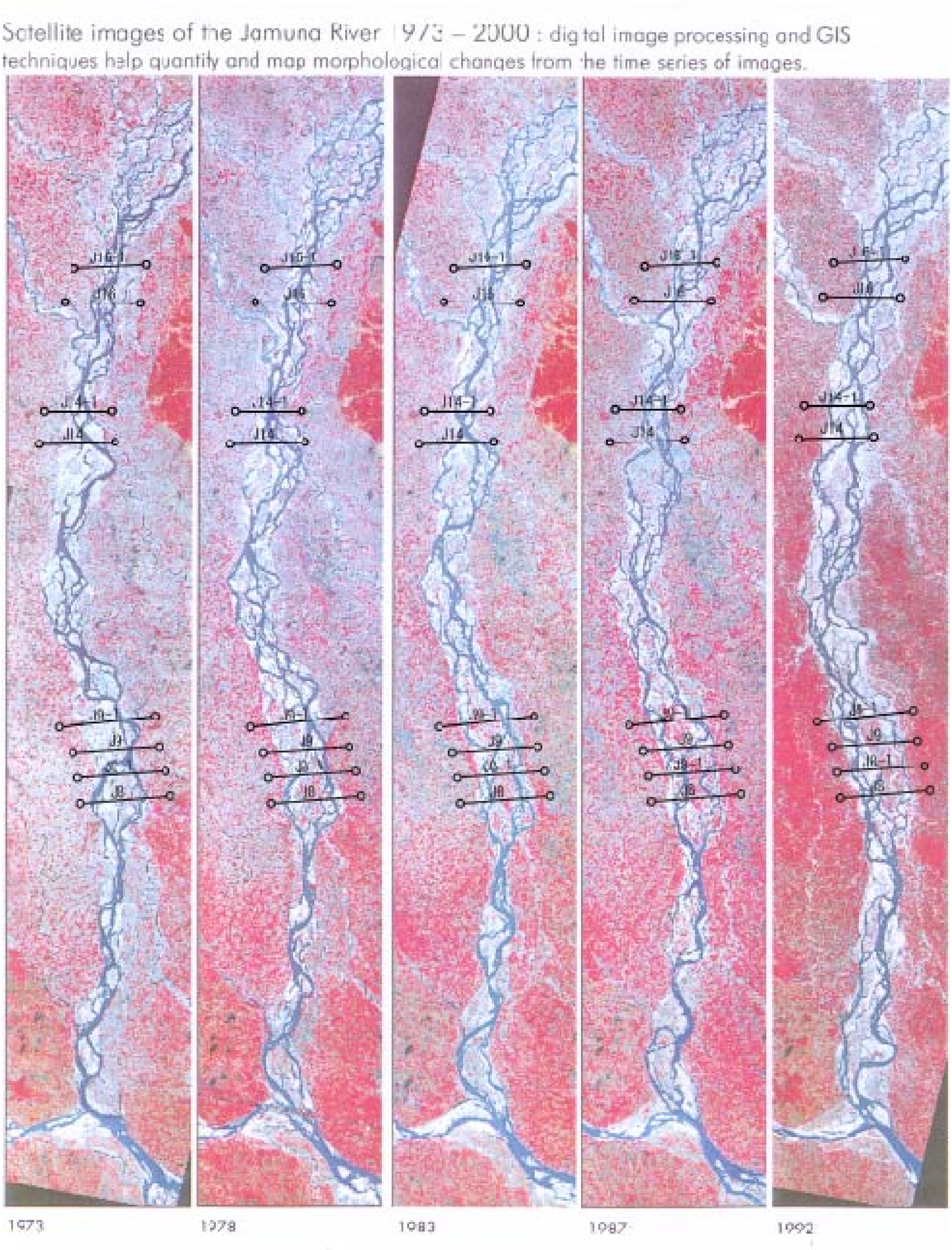
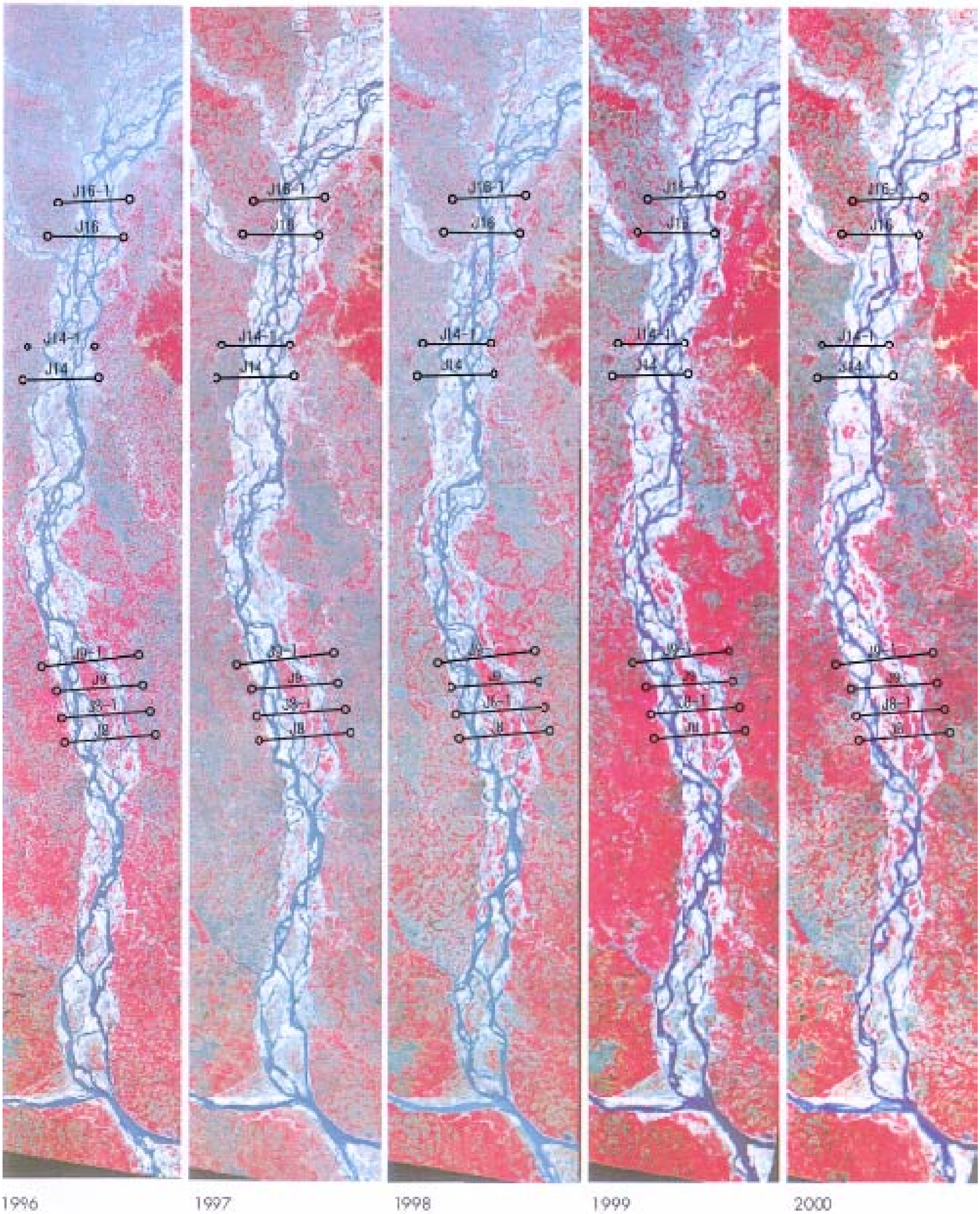


Figure A3.3-1: (1) J14 Cross Section in 1965R & 1966R



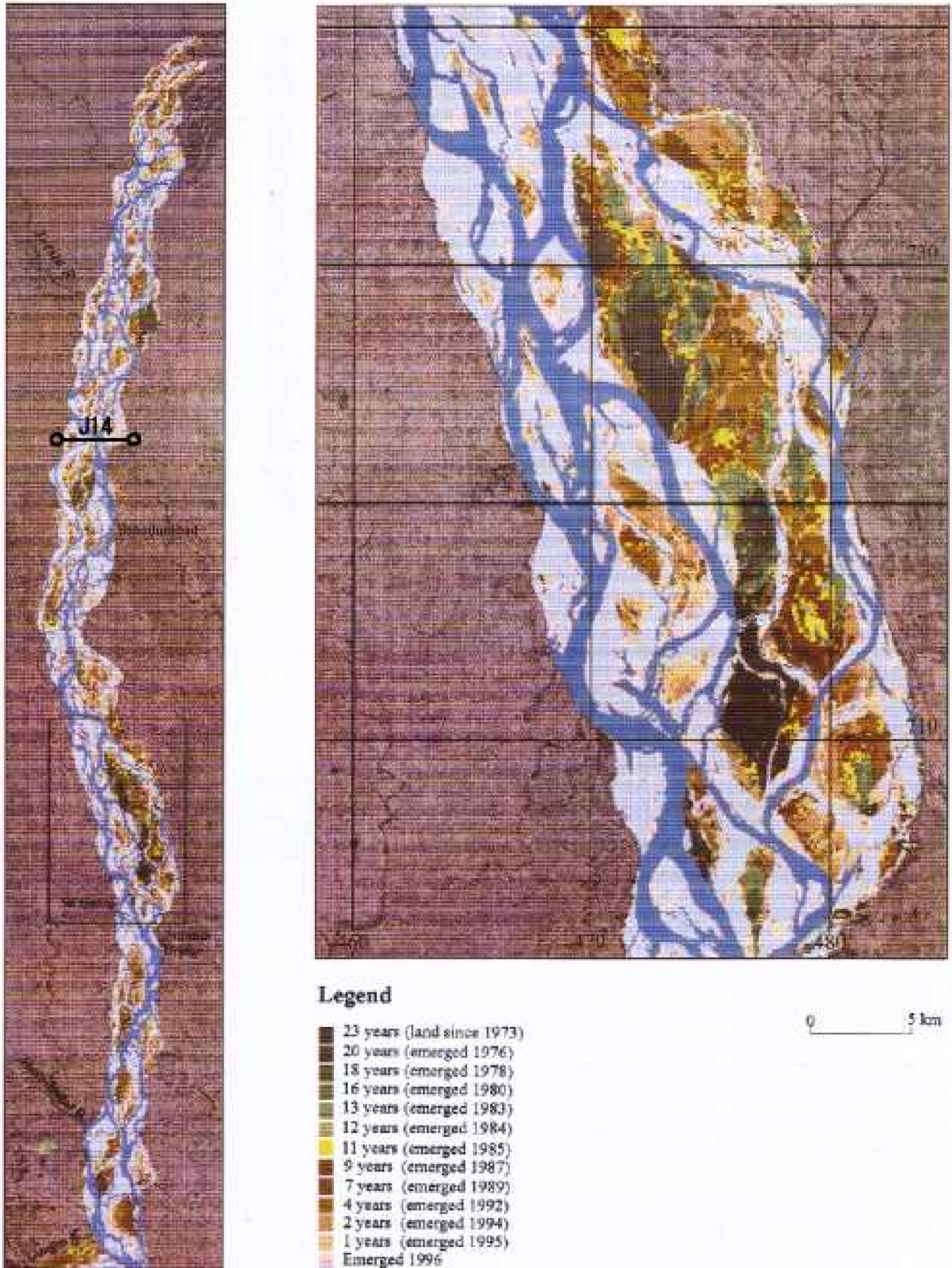
(Source: EGIS Brochure)

Map A3.3-1: Satellite Images of the Brahmaputra (1973-1992)



(Source: EGIS Brochure)

Map A3.3-2: Satellite Images of the Brahmaputra (1996-2000)



(Source: Morphological Dynamics of the Brahmaputra-Jamuna River, February 1997, EGIS)

Map A3.3-3: Age of the 1996 Char

3.4 Water Level at Cross Section

3.4.1 Data Verification

In order to verify the water level shown in Appendix Table AA2, the water level at cross section site was estimated by interpolating the relevant observed values at hydraulic stations. The calculation process is as presented in Table A3.4-1 that indicates in case of December 1965. In Table A3.4-1, columns (1) to (4) are fixed values but only column (5) is variables linked with corresponding month/year of Appendix Table AA1-01 to Table AA1-24. Figure A3.4-1 was drawn from Table A3.4-1 to represent the longitudinal profile of the Brahmaputra in same month/year.

The water levels at each cross section site are not always equal because there are a couple of flow channels between the island-chars. Such differences in the water levels by channel courses had been recorded before 1986, but after 1991 the only one water level has been documented.

Table A3.4-1: Estimated Water Level at Each Cross Section Site (In Case of Dec. 1965)

(Unit: Distance in km; Water Level in m PWD)

Hydraulic Station	Morphology Station	Section Length	Cumulative Length	Section Length from DownStream	Distance Parameter	UpStream Water Level	DownStream Water Level	Water Level Difference in HydrauSta	Water Level Difference in MorphSta	Water Level at MorphSta
HS	MS	SL (1)	CL (2)=sig(1)	SLfrDS (3)	DP (4)=(3)/sig(3)	USWL (5)	DSWL (6)	WLDinHS (7)=(5)-(6)	WLDinMS (8)=(4)*(7)	WLatMS (9)=(6)+(8)
45 Noonkhawa		0	0	41		22.27	17.85	4.42		22.27
	J16-1	30	30	11	0.268				1.19	19.04
	J16	8	38	3	0.073				0.32	18.17
45.5 Chilmari		3	41	42		17.85	14.09	3.76		17.85
	J14-1	21	62	21	0.500				1.88	15.97
	J14	7	69	14	0.333				1.25	15.34
46.9L Bahadurabad		14	83	53		14.09	9.40	4.69		14.09
	J9-1	50	133	3	0.057				0.27	9.67
49A Kazipur		3	136	87		9.40	3.74	5.66		9.40
	J9	3	139	84	0.966				5.46	9.20
	J8-1	5	144	79	0.908				5.14	8.88
	J8	5	149	74	0.851				4.81	8.55
50.6 Teota		74	223			3.74	–			3.74
Total		223								

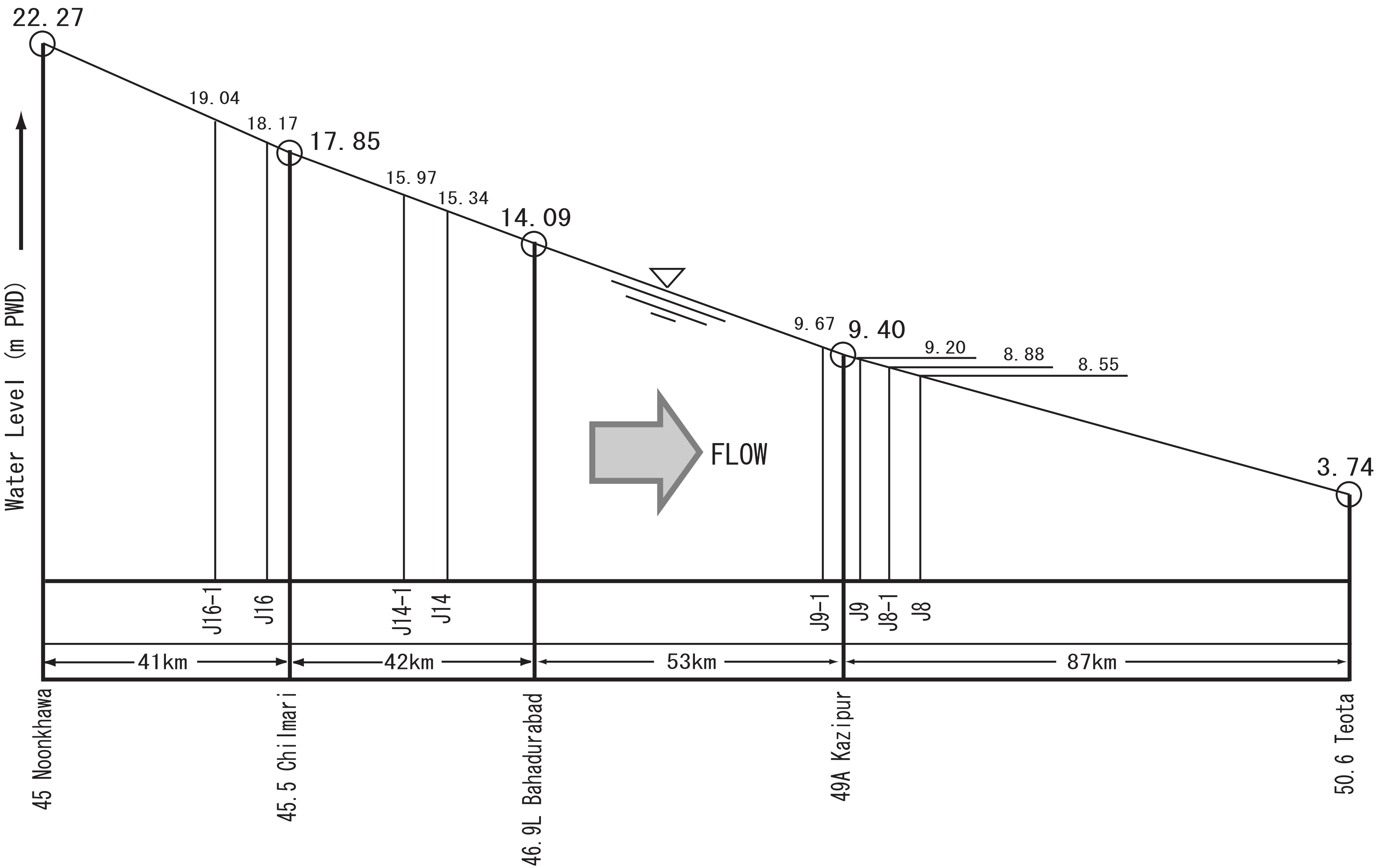


Figure A3.4-1: Estimate of Water Level at Cross Sections along the Brahmaputra

3.5 Probability Analysis

3.5.1 Probability Analysis of Flood Extents

A probability analysis was conducted for historical flood extents in Bangladesh shown in Figure A2.6-1. The area flooded listed in Xi column of Table A3.5-1 was arranged with descending order as shown Xid column in the same table. The result of analysis is presented in upper portion of Figure A3.5-1 after applying the Hazen formula.

The analysed data are not on a straight line as expected, but seems to be acceptable enough. The flood extent in 1998 corresponds with 1/100 years return period and the second maximum flood in 1988 would be identical with 1/30 to 1/50 years frequency.

So far as the Haor Area concerns, water level at Sunamganj station was used for the probability analysis as listed in Table A3.5-1. It was proved that July 1974 was the most critical month and the runoff pattern was quite different from the nation-wise flood phenomena due to the effect of the flash flood that indicates specific flow regime in the area.

Table A3.5-1: Probability Analysis of Flood Occurrence in Bangladesh

(Unit: Area: sq. km ; WL: m PWD)

Year	Flood Extents in Bangladsh					Water Level at Sunamganj Station				
	Xi	Ix	Xid	Hx=(Ix−0.5)/N	1/Hx	Yi	Iy	Yid	Hy=(Iy−0.5)/N	1/Hy
	Area Flooded	Order	Descending Order	Hazen Formula	Return Period	Sunamganj Water Level	Order	Descending Order	Hazen Formula	Return Period
1949	–					7.48	1	9.46	1.02	98
1950	–					7.24	2	9.30	3.06	33
1951	–					8.71	3	9.30	5.10	20
1952	–					8.73	4	9.13	7.14	14
1953	–					8.26	5	9.10	9.18	11
1954	37,000	1	101,000	1.25	80	8.65	6	9.03	11.22	9
1955	51,000	2	90,000	3.75	27	8.55	7	9.02	13.27	8
1956	36,000	3	58,000	6.25	16	8.56	8	8.98	15.31	7
1957	–	4	53,000	8.75	11	7.89	9	8.92	17.35	6
1958	–	5	51,000	11.25	9	8.20	10	8.90	19.39	5
1959	–	6	44,000	13.75	7	8.21	11	8.90	21.43	5
1960	28,000	7	43,000	16.25	6	8.64	12	8.88	23.47	4
1961	29,000	8	41,000	18.75	5	7.67	13	8.81	25.51	4
1962	37,200	9	37,400	21.25	5	–	14	8.80	27.55	4
1963	44,000	10	37,200	23.75	4	–	15	8.76	29.59	3
1964	31,000	11	37,000	26.25	4	8.75	16	8.76	31.63	3
1965	28,000	12	36,800	28.75	3	8.35	17	8.75	33.67	3
1966	33,300	13	36,000	31.25	3	8.60	18	8.73	35.71	3
1967	26,000	14	36,000	33.75	3	8.41	19	8.72	37.76	3
1968	37,400	15	33,500	36.25	3	8.39	20	8.72	39.80	3
1969	41,000	16	33,300	38.75	3	8.32	21	8.71	41.84	2
1970	43,000	17	32,900	41.25	2	8.59	22	8.68	43.88	2
1971	36,800	18	32,000	43.75	2	8.26	23	8.65	45.92	2
1972	21,000	19	31,000	46.25	2	8.62	24	8.64	47.96	2
1973	30,000	20	30,000	48.75	2	8.61	25	8.63	50.00	2
1974	53,000	21	29,300	51.25	2	9.46	26	8.62	52.04	2
1975	17,000	22	29,000	53.75	2	8.68	27	8.61	54.08	2
1976	29,000	23	29,000	56.25	2	8.76	28	8.60	56.12	2
1977	12,200	24	29,000	58.75	2	8.48	29	8.59	58.16	2
1978	11,000	25	28,000	61.25	2	8.34	30	8.56	60.20	2
1979	–	26	28,000	63.75	2	8.76	31	8.55	62.24	2
1980	32,900	27	28,000	66.25	2	8.52	32	8.52	64.29	2
1981	–	28	26,000	68.75	1	8.90	33	8.50	66.33	2
1982	3,000	29	21,000	71.25	1	8.63	34	8.48	68.37	1
1983	11,200	30	17,000	73.75	1	8.98	35	8.41	70.41	1
1984	28,000	31	12,200	76.25	1	9.10	36	8.39	72.45	1
1985	12,000	32	12,000	78.75	1	8.88	37	8.38	74.49	1
1986	7,000	33	11,200	81.25	1	8.50	38	8.35	76.53	1
1987	58,000	34	11,000	83.75	1	9.13	39	8.34	78.57	1
1988	90,000	35	7,000	86.25	1	9.30	40	8.32	80.61	1
1989	6,000	36	6,000	88.75	1	8.92	41	8.26	82.65	1
1990	4,000	37	4,000	91.25	1	8.38	42	8.26	84.69	1
1991	29,000	38	3,000	93.75	1	8.80	43	8.21	86.73	1
1992	2,000	39	2,000	96.25	1	8.81	44	8.20	88.78	1
1993	29,300	40	1,000	98.75	1	9.02	45	8.15	90.82	1
1994	1,000					8.72	46	7.89	92.86	1
1995	32,000					9.30	47	7.67	94.90	1
1996	36,000					8.15	48	7.48	96.94	1
1997	–					9.03	49	7.24	98.98	1
1998	101,000					8.90				
1999	33,500					8.72				

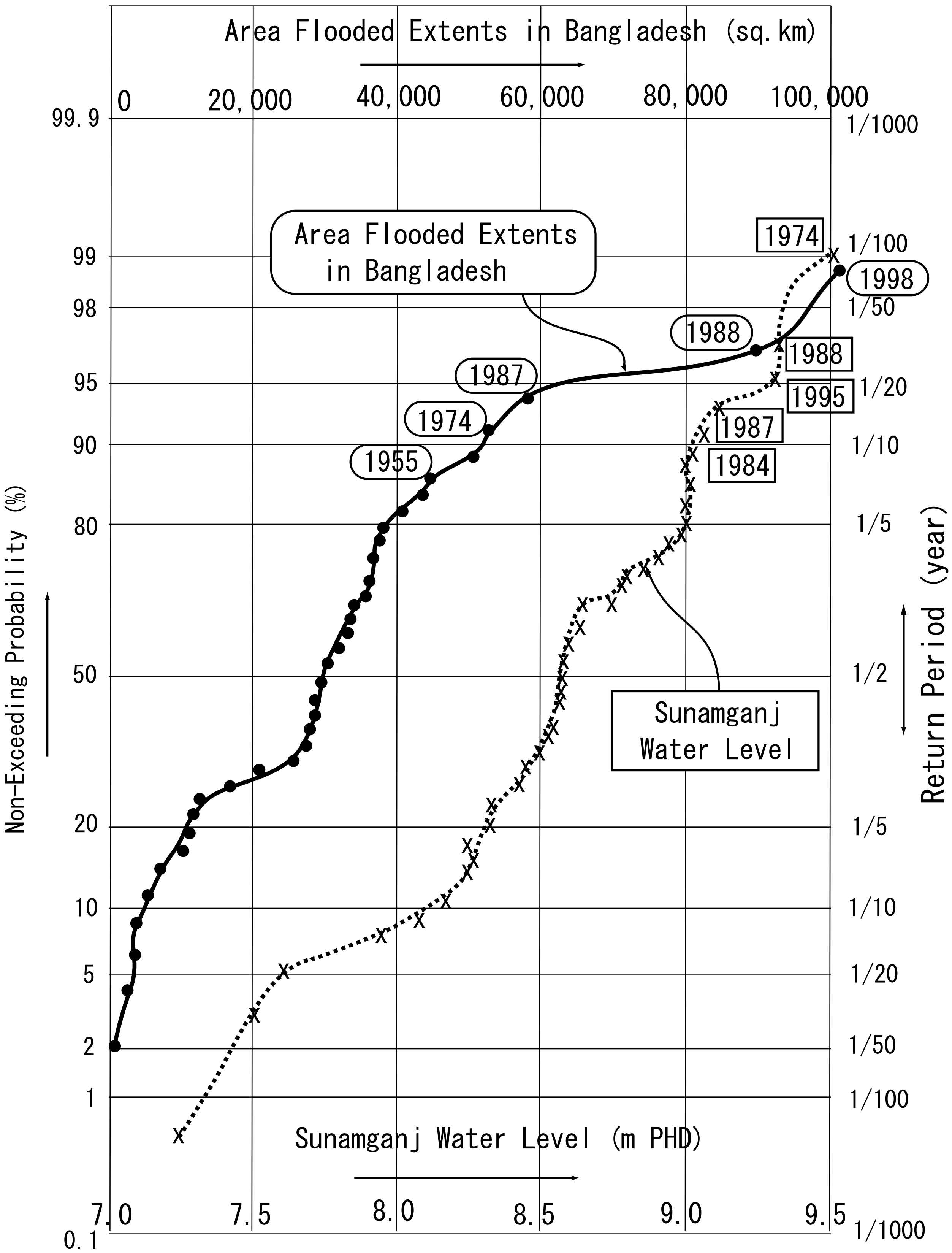


Figure A3.5-1: Probability Analysis of Flood Occurrence

3.6 Hydraulic Models

3.6.1 About Hydraulic Models

There are two types of hydraulic models: one is physical model and the other is mathematical model. The former is mostly managed by RRI and the latter indicatively by SWMC. The mathematical models refer to computer simulation softwares applied to hydraulic phenomena represented by river flow and flooding. They have been extensively developed in Bangladesh since 1986 through DHI's technical assistance. FAP-25 synopsis in the FAP Summary Report describes background of the model development as presented in the following section

3.6.2 Synopsis of Flood Modelling and Management under FAP-25

(1) Background of Flood Modelling

Mathematical models of the surface water systems are powerful tools for an integrated approach to water management. It was desirable to have a mathematical model available in Bangladesh for simulation of unsteady flow process in complex river-floodplain systems as an instrument to comprehensive planning of water resources. A Surface Water Simulation Modelling Programme (SWSMP) was started in April 1986 at the Surface Water Modelling Centre (SWMC) of the Master Plan Organization (MPO). In 1993, SWMC was transferred to the River Research Institute (RRI). The first phase of SWSMP was completed at the end of 1988 and the second phase at the end of 1993. The third phase of three-year duration started in January 1994. The second and the third phases are financed by DANIDA.

The surface water models being developed under the SWSMP at SWMC (Map A3.6-1) were used extensively in the FAP studies. It has in fact supported general analysis and recommendations of about half of the projects under FAP, notably regional studies. Regional Planning would hardly been possible had the surface water simulation modelling programme existed and been well into its Second Phase. Model predictions of hydraulic impacts provide the basis for comparing alternative planning options. Flood Modelling and Management (FAP-25) has been drawn up to advise, assist and coordinate all FAP activities in mathematical modelling.

The overall objectives of the project are:

- to achieve consistency, compatibility and continuity in all modelling activities;
- to coordinate the supply of models as tools to the various FAP projects and the feedback of relevant data and information from FAP projects to SWMC;
- to provide the hydrological basis for establishing unified engineering designs for FAP; and
- to develop a flood management model (FMM).

Modelling in FAP Studies: All surface water modelling activities in FAP studies have been done by using the MIKE11, a software package developed by the Danish Hydraulics Institute (DHI). The

MIKE11 software consists mainly of two modules: a rainfall-runoff module NAM and a one dimensional hydrodynamic module MIKE11-HD. Two additional modules - a salinity module and a sediment transport module - are also available. Two-dimensional modelling is also taking place using the SYSTEM21 software of DHI.

The SWMC has been given the responsibility of developing a General Model (GM) which covers the main rivers and regional models. The SWMC delivers the calibrated and verified models to the consultants of FAP components. Models were developed for the six FAP regions. The GM provides boundary conditions for regional models and is also the basis for an upgrading of flood forecasting. The regional models provide a finer resolution of the regional rivers than does the GM. Several sub-regional models were also developed to obtain better representation of floodplain systems and drainage khals. The regional models are used as planning tools within the particular region to predict hydraulic impacts of alternative engineering interventions.

The MIKE11 computes water level and flow rates as a function of time at specified locations along a river which are analyzed to obtain depth, area and duration of flooding. Then the results are utilized to determine land types based on depth of flooding according to MPO land classification. The predicted change in the distribution of land types due to engineering interventions in an area provides the basis for comparing alternative options. Model-predicted results are used as input to agricultural, fisheries and environmental analyses. Model results are also utilized in the hydraulic design of river training, flood control and drainage structures.

(2) Results of Flood Hydrology Study (FHS):

This component of FAP-25 started in January 1991 and was completed at the end of 1992. The objectives of FHS (Map A3.6-2) were to establish the hydrological basis for engineering design criteria along the major rivers and to recommend a unified methodology for establishing such a basis along regional rivers. Important outcomes of FHS were:

- validation of General Model (GM) for the period 1965 to 1989 and determination of design flood levels based upon model results along major rivers;
- provision of boundary conditions for regional models and development of a methodology for establishing hydrological design flood levels and predicting hydraulic impacts for regional studies;
- establishment of safety margins, accounting for uncertainties due to model error and random morphological changes; and
- indicative analysis of the effects of alternative flood protection scenarios on water levels and discharges along the major rivers.

(3) Flood Management Model (FMM):

This component started in October 1992 and had a duration of two years. The goal of the FMM is to provide a tool which, through prediction and analysis of the behaviour of floods, assists in the management of flood mitigation measures. The objectives are to develop a MIKE11-GIS interface as the main FMM tool to assist in flood modelling and management, to integrate the developed technology with other activities and apply it on a test basis at national, regional and compartment levels. The FMM is a combination of four modules: River and Floodplain Modelling Module, Impact Assessment Module, FCD Structure Operation Module and Flood Forecasting Module.

FMM is an improvement of previous models in flood plain flow representation, rainfall runoff simulations, representation of output in more user friendly terms (flood map etc.). It is a step forward in applying the present simulation capacities to the complexity of Bangladesh situation.

A Coordination Advisory Team (CAT) as a component of FAP 25 advised, coordinated and participated with the Flood Hydrology Study (FHS) and Flood Management Model. The team had all together six missions in Bangladesh each for a duration of about 10-15 days. The CAT has given their valuable services in FMM, and recommended valuable suggestion for the sustainability of FMM.

Three workshops on FMM were arranged, two in 1993 and the final one in October 1994. The objectives were to present FMM concepts, to identify needs and targets of FMM in relation to flood management decisions and to obtain feedback for effective use of FMM. Representatives from MWR, BWDB, LGED, WARPO, RHD, RRI, DOE, DAE, BARC, BMD, SWMC, BUET, SPARRSO, FAP Components, NGOs, FPCO, POE and CAT attended.

The FMM project has been completed in October 1994. The output of the project is an integrated MIKE11-GIS modelling system which has the potential to assist in clarifying and disseminating through enhanced mapping of impacts on flood levels, communities agriculture, fisheries and the environment. The MIKE11-GIS software has been used for test demonstration of various flood management scenarios for the North Central Region model and the General Model. After the project completion, the FMM has been transferred to SWMC for further applications.

3.6.3 Mathematical Modelling Proposed by SWMC

In response to the request of the Survey Team, SWMC has proposed “Flood and River Morphology Analysis” in March 2001. The substance of SWMC’s proposal (under the title of Mathematical Modelling & Flood Depth Mapping) related to the hydraulic model is as follows:

(1) Strategy of Mathematical Modelling

MIKE11 one-dimensional river modelling system, developed at the Danish Hydraulic Institute (DHI) is being used in this study to compute water level and discharge in the river/drainage system inside the project area and in its periphery. After a successful calibration of the model, various scenarios will be tested to see the impact of alternative measures for achieving controlled drainage, controlled flooding and irrigation. Model results will be post-processed using MIKE11-GIS to develop flood maps/inundation maps, and impact maps in getting qualitative assessment of the project benefit. FigureA3.6-1 outlines the sequence of mathematical modeling study.

Computation in the MIKE11 modelling system takes place in two steps.

- Computation of the rainfall runoff by MIKE11-NAM and
- Computation of the river flows and water level by MIKE11-HD.

(2) MIKE11-NAM Model

NAM Rainfall Runoff Model is applied to estimate the runoff generated from rainfall occurring in the catchment. The model takes into consideration the basin characteristics including specific yield, initial soil moisture contents and initial ground water level and irrigation/abstraction from the surface or ground water sources.

The catchments of the rainfall runoff model are delineated according to the topographic barriers/water shed boundaries, roads and river networks.

The best way to calibrate NAM model is by comparing the runoff generated from the model with that observed at the tail end of the catchment. But in many occasions, it is not possible to isolate one catchment from the influence of other catchments, and in many cases it is not possible to observe discharge at tail end of the catchment due to accessibility and other reasons. Under such conditions the model is indirectly calibrated against observed ground water data.

(3) MIKE11-HD Model

The Hydrodynamic (HD) Model takes into account schematized rivers/channels of the area. The connectivity of the river systems and influence of other rivers outside the model area is identified from the river network maps. The external boundary conditions (inflow - discharge/water level and outflow - water level) are applied to the model from observed data. The river slope and flow direction is computed in the model by considering cross sections and tail water conditions. The flood plain depression within the model area is defined as flood cell/storage cells. In the absence of defined a channel, connection between the flood cell and the river is defined by artificial 'Link Channel'. The rivers/channels schematized for the model (NERM) has been finalized after collecting sufficient field information.

Calibration of the MIKE11-HD model is carried out by comparing the time series of water level and discharge computed in the model with that observed in the field. Importance is given to the recently surveyed data for morphologically active areas.

(4) MIKE GIS

MIKE GIS is a specialized software developed by the DHI which uses outputs of the MIKE11 HD model, i.e. water levels, and information of land topography. Combining these two types of data, MIKE GIS produces flood maps. For a specific area, the flood depths are computed taking into account the flood levels (water levels) in the designated rivers/channels, etc., which are interpolated linearly.

These levels are superimposed on the land levels to be found from the DEM of the area concerned. Final processing of the flood maps like designation of F0, Fl, F2, F3 lands are carried out using GIS technology.

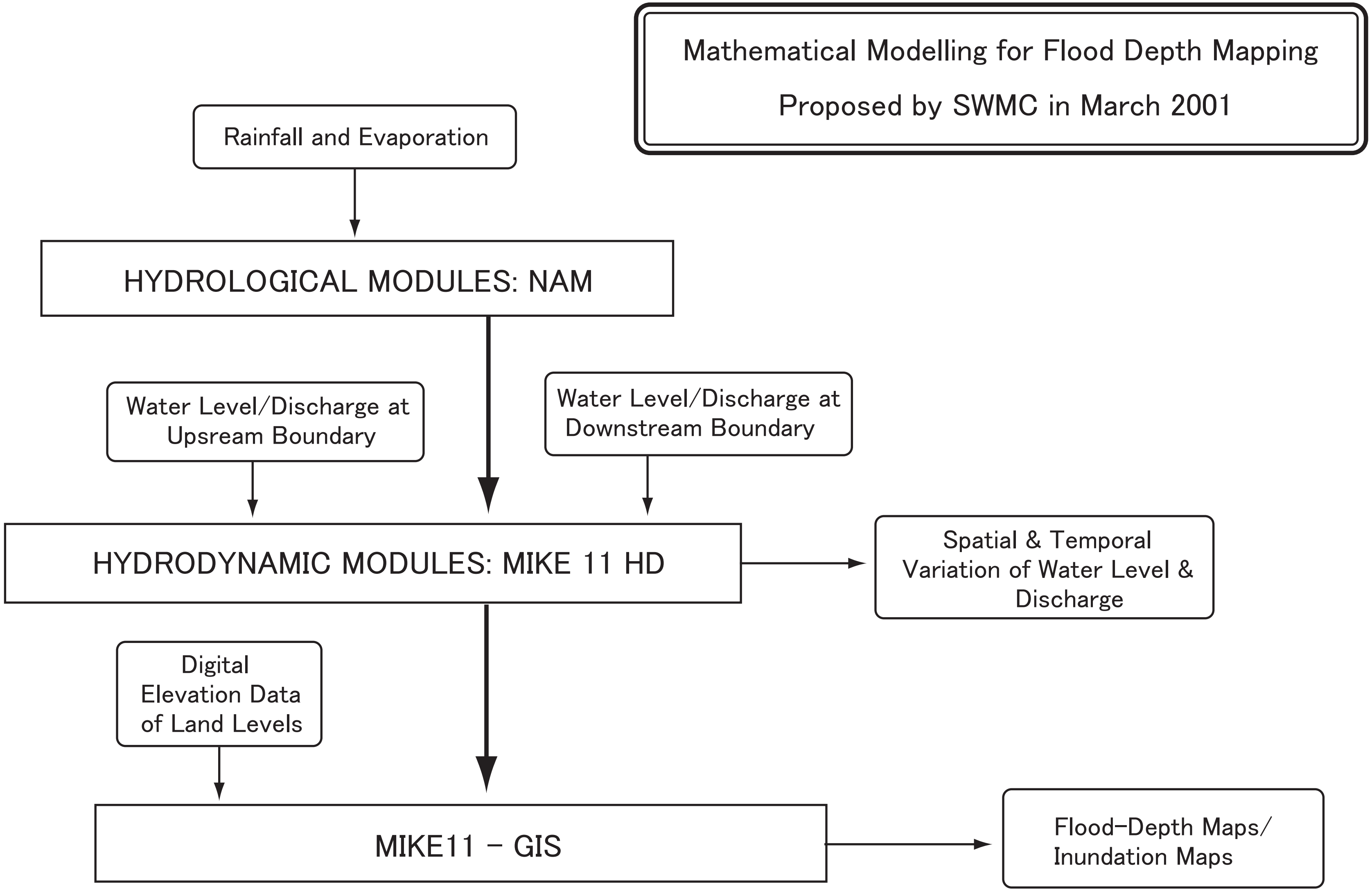
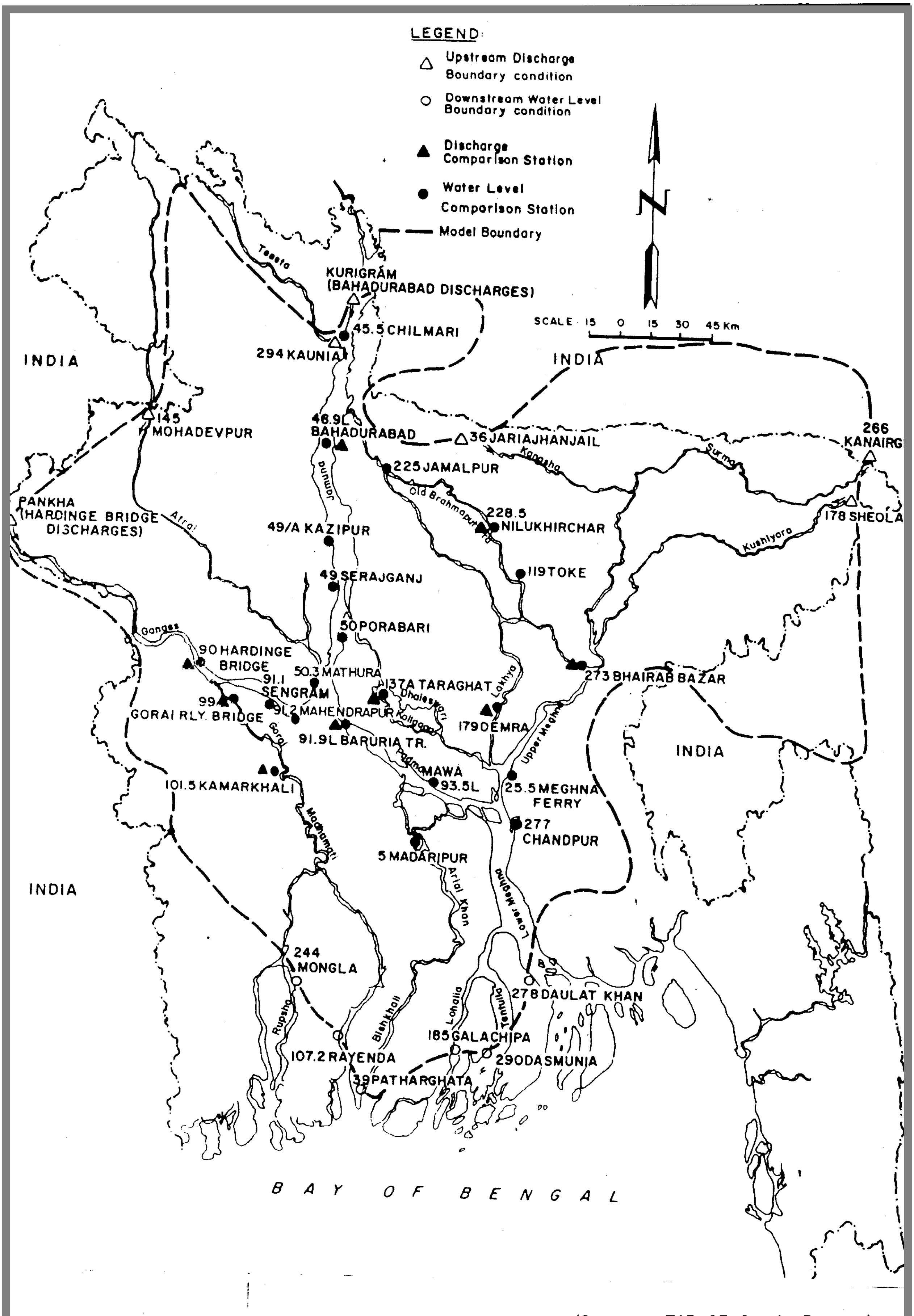
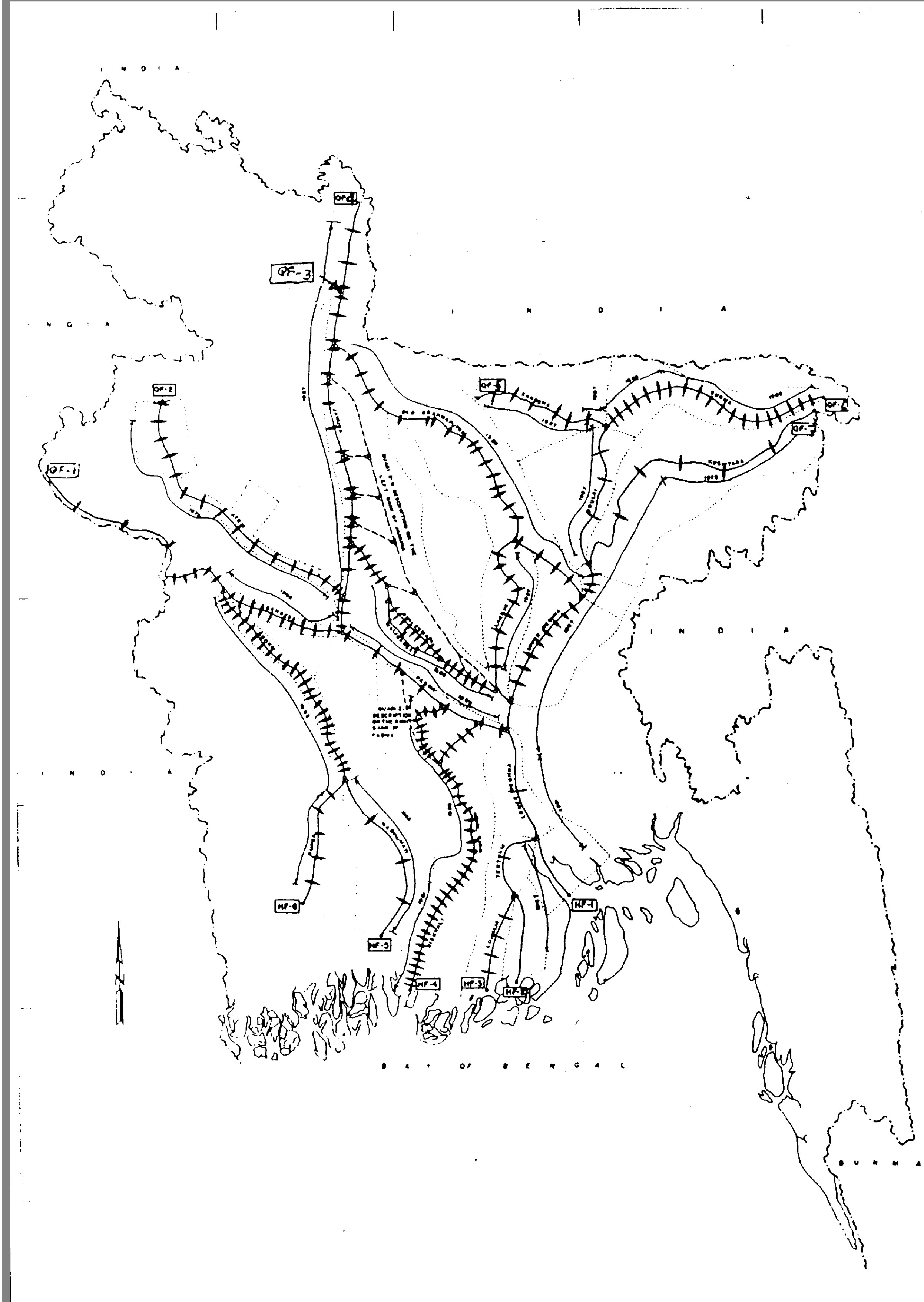


Figure A3.6–1: Sequence of Mathematical Modelling for Flood Depth Mapping



(Source: FAP-25 Study Report)

MAP A3.6-1: Flood Hydrology Study (FAP-25)



(Source: FAP-25 Study Report)

Map A3.6-2: Location of Model Cross Sections in the General Model (FAP-25)