STUDY ON CHANGES IN RIVER-SECTION CHARACTERISTICS OF BRAHMAPUTRA-JAMUNA AT SELECTED STATIONS

Submitted by

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In partial fulfilment of the requirements for the degree of Master of Engineering (Water Resources)

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We hereby recommend that the project thesis prepared by SWAPAN KUMAR HALDER entitled 'STUDY ON CHANGES IN RIVER-SECTION CHARACTERISTICS OF BRAHMAPUTRA-JAMUNA AT SELECTED STATIONS' be accepted as fulfilling this part of the requirements for the degree of Master of Engineering (Water Resources).

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ABSTRACT

The present study is an attempt to investigate the changes in river section characteristics of Brahmaputra-Jamuna within the territory of Bangladesh.

The analysis carried out is mainly based on hydraulic and hydrogeometric data for a few selected stations. Only five cross-sections namely J-4, J-7, J-9, J-14 and J-16 near Porabari, Sirajganj, Jagannathganj, Bahadurabad and Chilmari stations respectively for the years 1965-66, 1976-77, 1978-79, 1980-81, 1983-84 and 1985-86 have been studied. The analysis is also based on the water level and discharge data for the years 1964-65, 1974-75, 1978-79, 1980-81, 1983-84, 1986-87 and 1987-88.

The study of cross-sectional area and effective width showed that no systematic change in cross-sectional area and effective width has occurred during the period 1965-66 to 1985-86 on any of the sections.

Study of mean bed levels indicate that there is a trend of rise in the mean bed level in sections J-7 and J-9, and fall in sections J-4, J-14 and J-16 during the period 1965-66 to 1985-86. The highest rise (about 1.5 ft) and fall (about 9.0 feet) of mean bed level occurred at the section J-7 (near Sirajganj) and J-4 (near Porabari) respectively.

Study of changes in water level for same discharge over the years from 1964-65 to 1987-88 has shown an over all rising trend in all the stations.

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NOTATION AND ABBREVIATIONS

ASCE	American Society for Civil Engineers
BWDB	Bangladesh Water Development Board
BUET	Bangladesh University of Engineering and Technology
cm	cent imeter
D,d	Average flow depth, sediment size
ft	feet
ft^2	feet square
km	Kilometer square
mm	milimeter
m^3/s	meter cube per second
PWD	Public Works Department
S	energy slope
sq	square
V	Average flow velocity
γ	Specific weight of water

Every year the Brahmaputra-Jamuna carries a heavy sediment load from upstream of the river. Erosion and deposition takes place on the river during the passage of flood. In general as discharge increases, two channels, generally located adjacent to the river banks, tend to scour, while the central part of the channel is the site of deposition. As flood water subsides one channel tends to fill rapidly, forcing water down the other, thus maintaining a single deep channel. After the flood has passed little change takes place except for some filling and reduction in cross-sectional area of the main channel.

To understand such changes in river-section characteristics, researchers working in the field of river engineering have tried to develope relations among the various parameters involved in the river-section characteristics. But so far it has not been possible to develope any such general relations specially in case of a braided river. Under such a condition an attempt to study each river seperately is expected to give answer for the individual river. Keeping this in mind, the present study have been undertaken to know the river-section characteristics of Brahmaputra-Jamuna at few selected stations.

1.2 Importance of the study

Rivers have played a very important role in every stage of human development. It's importance has thus been recognised since time immemorial. Rivers have always been the major sources for satisfying our domestic, municipal, irrigation and other demands and that is why most of our cities were established in the vicinity of rivers. In the primitive times, there was absolutely no control of these rivers, and hence, time to time they used to cause tremendous devastations and troubles to human beings.

Natural rivers cover a wide range of discharge and slope. Cross-sectional area, width and depth of the rivers changes xx every year in an alluvial river. The changes in these characteristics are very prominent in the big alluvial rivers like the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna. Brahmaputra being a braided river has its problem more complicated as regards its changes in river-section geometry and the river migration patterns. Erosion & depositiondoes not necessarily occur on opposite banks as in a meandering river. Both banks may experience deposition or erosion at the same time. Owing to a number of complex factors involved in the river geometry, river researchers and hydraulic engineers have not been able to develop or predict any general rule predicting river behaviour specially of a braided type. Under such circumstances each braided river need to be studied seperately to know its characteristics sufficiently well for its utilization in water resources development.

1.3 Objectives of the study

The objectives of the study have been set as follows:

i. Study of variation of width, area and average depth with respect to elevation.

ii. Analysis of the nature and extent of erosion and deposition at each section.

iii. To know how the water levels at different stations are changing with time for the same discharge in different years.

CHAPTER-2

BRIEF HISTORY OF THE BRAHMAPUTRA-JAMUNA RIVER

2.1 Introduction

The Jamuna is the name given to the Brahmaputra-Jamuna river between the offtake of the Old Brahmaputra river and the confluence with the Ganges. Upstream of the offtake of the river is known as the Brahmaputra river. The Brahmaputra is the largest river of Indo-Bangladesh subcontinent. The total length of the Tsanpo-Brahmaputra-Jamuna river upto Goalundo is 1600 miles (2575 km). The total drainage area down to Aricha is 2,24,000 sq. miles (5,80,455 km^2) of which 1,13,000 sq. miles (2,29,819 km^2) in Tibet, 93,000 sq. miles (2,40,999 km^2) in India and only 18,000 sq. miles (46,644 km^2) in Bangladesh. The average annual peak discharge is about 19120 m^3/s. The highest flood flow of 91000 m^3/s was recorded at Bahadurabad on the 6th August, 1974. The average slope of the Brahmaputra river in Bangladesh varies from 0.5 ft/mile (9.5 cm/km) near Nunkhowa to 0.14 ft/mile (2.65 cm/km) near Chandpur.

2.2 Description

The Brahmaputra originates from the famous Manas-Sarowar in Chemayungedun glacier as Tsangpo which flows eastward for about 775 miles (1248 km) in a constricted valley through Tibet. The river Tsangpo takes a sharp bend southward before meeting

Dibang, enters Assam from the north and meets with the Dibang and Luhit some 30 miles (48 km) northeast of Dibrugarh. This combined flow assumes the name Brahmaputra and continues to flow through Assam towards sout-east before entering Bangladesh from the north.

In Bangladesh the river flows south and takes on the flows of the Teesta just south of Chilmari and the Hurasagar in between Porabari and Nagarbari and then joins the mighty Ganges near Goalundo. Within Bangladesh important distributaries of the Brahmaputra are the Old Brahmaputra leaving the left bank south of Bahadurabad and the Dhaleswari also leaving the left bank just below Sirajganj. The combined flow of the Brahmaputra and Ganges, with the name Padma, flows towards southeast before meeting another big river, the Meghna, at Chandpur. From Chandpur the combined flow, one of the largest in the world - only exceeded by the Amazon and Congo, flows southward with the name Meghna and falls into the Bay of Bengal. The Ganges, Brahmaputra and Meghna, rivers combined have formed one of the largest deltas in the world, comprising some 23,000 sq.miles (59,600 km^2) (Coleman 1969). The course of the river is shown in figure 2.1.

2.3 Change of course of the Brahmaputra

The Brahmaputra changed its course through Bangladesh drastically over the years. So did the Ganges, using several sets of aerial photo-mosaics, Coleman, (1969) investigated the changes

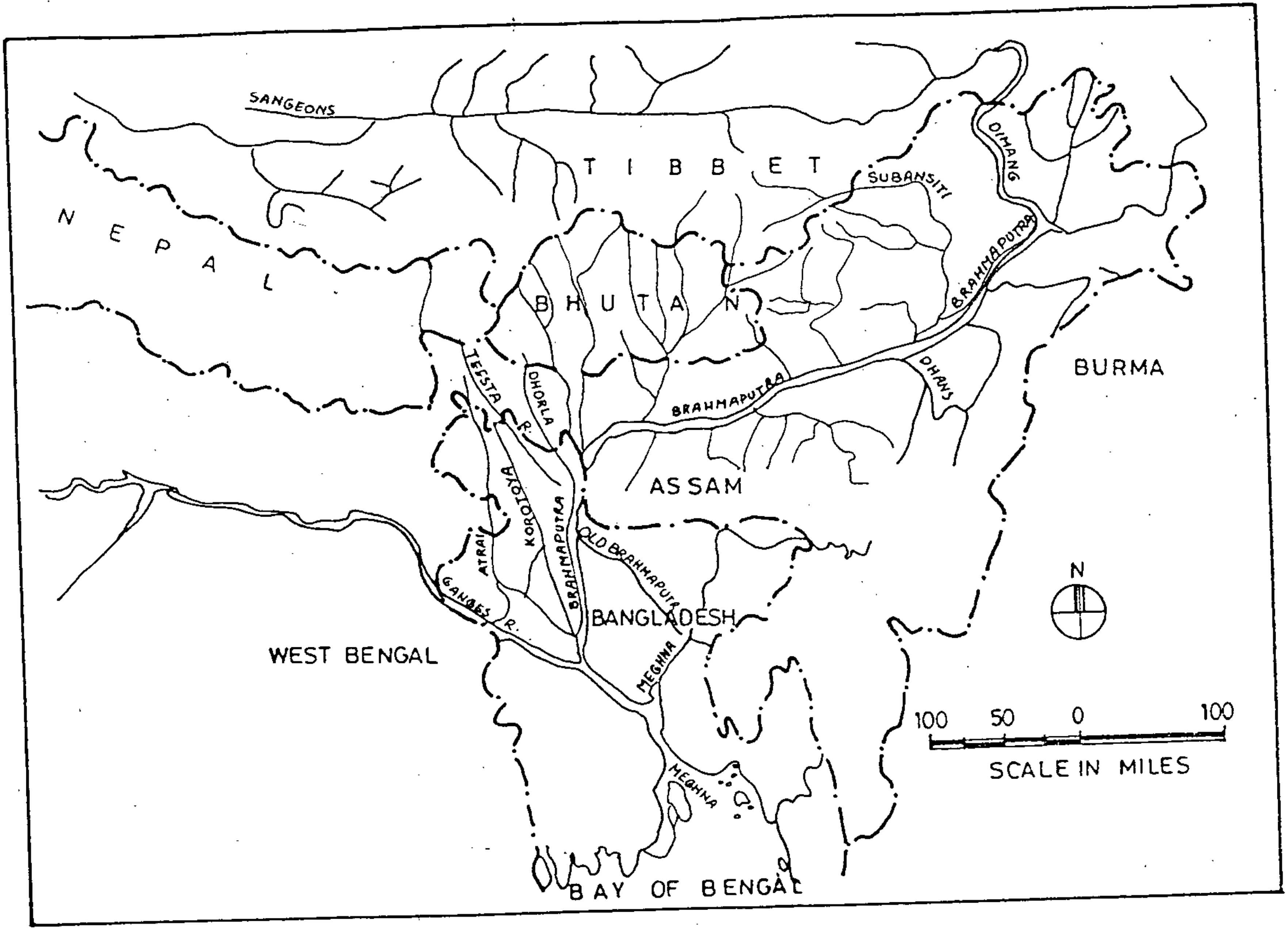

FIG. 2.1 COURSE MAP OF THE BRAHMAPUTRA

of the river course in Bangladesh over hundreds of years. Without going into detail it can be said generally that over the centuries the Brahmaputra river system shifted south-westward. The most recent remarkable change happened about 200 years ago when the Brahmaputra shifted to its present course abandoming the previous one through the Old Brahmaputra to its confluence with the Meghna river at Bhairab Bazar. There is little agreement among the researchers about the exact time of this diversion. According to most of them the diversion was gradual starting from 1787 and completing by around 1830 when in joined the Ganges near Goalundo. In relation to this diversion, the year 1787 is specifically mentioned because one of the reasons of Brahmaputra's diversion is said to be the joining of Teesta with the Brahmaputra in that year when a severe flood changed its (Teesta's) original course. Before this change the Teesta used to fall into the Ganges. Apparantly, the Brahmaputra reinforced the combined flow in the Old Brahmaputra channel passing through the heart of Mymensingh and developed a new channel diverting in between Bahadurabad and Dewanganj more or less along the Jenai which is now called the Jamuna.

The recent findings of Morgan and Mointire (1959) should be mentioned in this connection. They made a geological reconnaiss-ance of Bangladesh and West Bengal from November 1955 through April 1956 to determine the morphology of the deltaic complex of the

Ganges, Brahmaputra and Meghna rivers and their distributaries. Study indicated that structural activity, primary faulting has significantly influenced quaternary geology. Changes in the course of the Ganges and Brahmaputra through Bengal during the last few hundred years was attributed to faulting and resultant tilting of fault blocks. These changes have caused the Ganges to abandon numerous western distributaries in favour of joining the Brahmaputra-Meghna system to the south-west.

The subsidence is also bed responsible for the large depression in the Brahmaputra basin. It is also a reasonable explanation that these depressions are signs of incomplete delta building process of the Brahmaputra when it changed to a new course.

CHAPTER-3

LITERATURE REVIEW

3.1 River pattern classification

River patterns are normally classified from their top views as meandering, braided and straight. It should be remembered, however, that the differences between any two patterns are usually not distinct, and not all rivers can be easily classified as having one of these patterns. A river may exhibit, as it normally does, different patterns by its different reaches at a given time, and a given river reach may also exhibit different patterns at different time periods. Rivers can also be divided into two classes, single channel streams, and multiple channel streams.

3.1.1 Braided river

Braided rivers are characterized by a steep shallow course with multiple branches seperated by islands or bars (Figure 3.1.A). Braided rivers with the channel branches taken as a whole have large width-depth ratios than the unbraided ones.

Lane (1957) concluded that there are two primary causes for braided rivers or streams. Either one of these two causes alone may be responsible for the braided patterns or they may both be acting to cause it. These causes are:-

1. Overloading, i.e., the stream may be supplied with more sediment than it can carry and part of it may be deposited.
2. Steep slopes causing a wide, shallow channel in which bars and islands readily form.

Lane (1957) observed that all steep slopes braided channels have many characteristics in common, in addition to that of multiple channels. These are as follows:
(a) relatively straight course of the main channel, (d) steep longitudinal slopes, (c) wide channels (d) shallow depth, (e) flat bottom, (f) sand or coarses bed material (g) usually relatively high sediment load.

Rivers having these characteristics may be overloaded, but all overloaded rivers do not necessarily have this braided from, nor are all braided rivers necessarily overloaded.

Vedula (1969) presented a basic course of braided channels based on the considerations of bank erosion and sediment transport. They showed that in an aggrading channel, the shear stress can actually decrease with time. If there is no sediment supply from upstream, the channel may attain stability with no transport taking place in it. However if there is a sediment supply at the upstream end, the channel may widen so much that the depth may become shallow to the point that the flow can not take place in a single channel, thus developinga tendency to braid.

3.1.2 Straight river

Straight rivers are those which have, at the bankfull stage, a negligible sinuosity over a distance many times the river width. The thalwege (line of maximum depth) of straight river is generally sinuous , in plan, moving from one bank to the other. As a result, lateral bars are formed and are arranged alternatively along the banks (Figure 3.1.B). Steep river gradients, large variations in stage, a periodic floods, and small bed load are characteristics of straight rivers.

3.1.3 Meandering river

Meandering river is a river in which channel alignment consists principally of pronounced bends (Figure 3.1.C), the shapes of which have not been determined predoninantly by the varying nature of the terrain through which the channel passes. According to Leopold, Wolman and Miller (1957), meander rivers have a sinuosity of 1.5 or greater, Sinuosity is defined as the ratio of the length of the stream channel to the length of the streams measured along the axis of the valley.

3.2 Bed configuration

The bed configurations (roughness elements) that may form in an alluvial channel are plane bed without sediment movement, ripples, ripples on dunes, dunes, plane bed with sediment movement, antidunes and chutes and pools. These bed configurations are listed

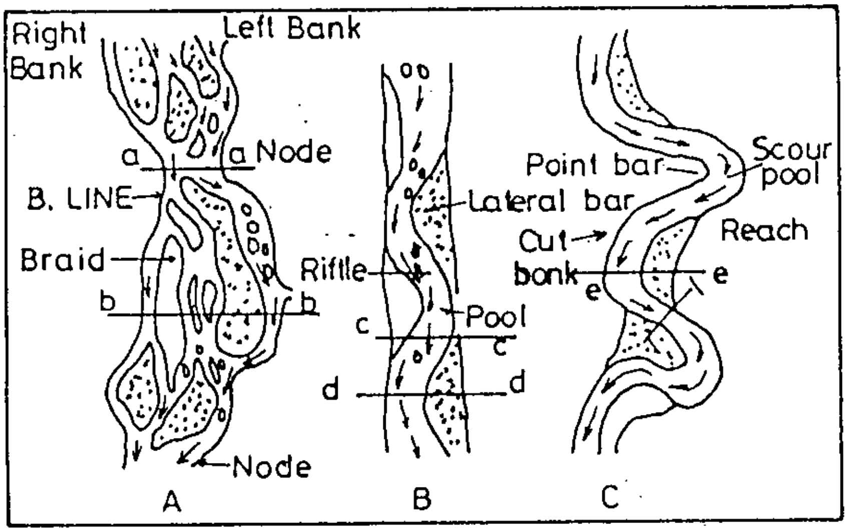

FIG. 3.1 RIVER CHANNEL PATTERNS : A. BRAIDED; B. STRAIGHT ; C. MEANDERING (AFTER COLEMAN, 1969)

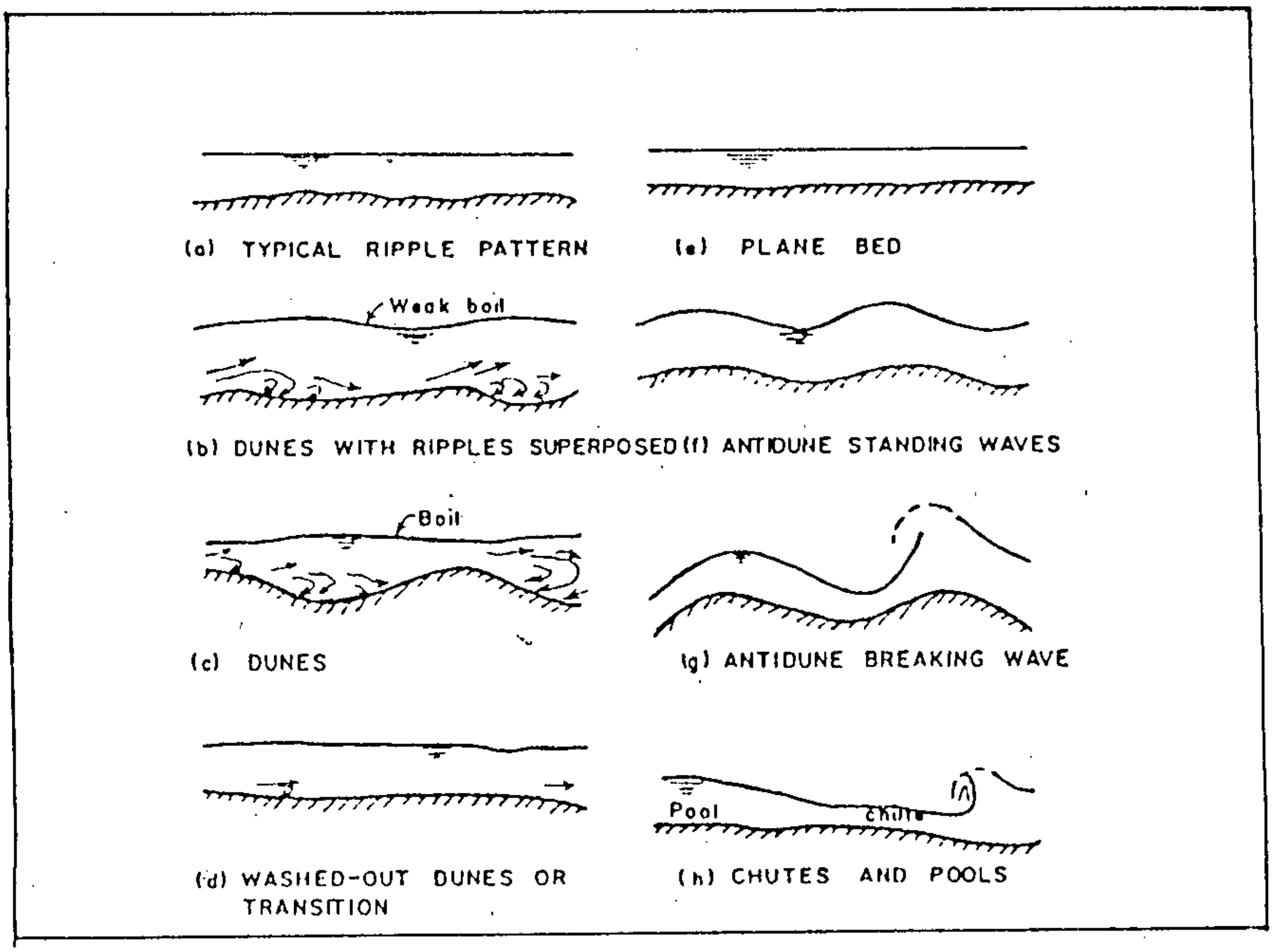

FIG. 3.2 BED FORMS (AFTER SIMON AND RICHARD SON, 1961)

in their order of occurrence with increasing values of stream power (V DS) for bed materials having d_{50} less than 0.6 mm. For bed materials coarser than 0.6 mm dunes form instead of ripples after begining of motion at small values of stream power. The typical form of each bed configuration is shown in figure 3.2.

These bed roughness elements are not mutually exclusive occurrence in time and space in a flume or a natural river. They may form side by side in a cross-section or reach of a natural stream giving a multiple roughness or they may form in sequence, in time, producing variable roughness.

3.3 Hydraulics of erosion

Erosion in a concave bends by the formation of helicoidal secondary (or reflected) current which can be stated to be a normal process of meandering for getting rid of excessive bed materials to be opposite convex bend. In the concave bend, the flow lines are considerably compressed together resulting in concentration of velocities, while across the shoals (or crossing) the flow lines are spread out so as to decrease the flow and result in temporary deposition of bed materials. However, for Brahmaputra Jamuna river, as a braided river, excessive fluetuation of sediment and water flow as well as water levels may cause undesirable concentration of flow in one of the main channels where the increase of discharge may not be accompanied by the proportionate increase of sediment supply through the particular channel. Also undesirable shoal movement opposite to this channel may cause excessive concentration of the flow in a narrow concave channel. Severe erosion is essentially caused due to concentration of water flow in a concave channel when the bank materials are not capable of withstanding the said velocity. Such velocities increase with periodic increase of discharge, while the type of bank materials as well as of saturation of these materials are also very important factors in the erosion process. Thus major erosion starts when heavy increment of velocity in the eroding channel occurs in a short period with quick rise of velocity in the begining of the flood. Also essentric bank slips of saturated silty materials occur when the water levels quickly fall after the monsoon. As such the bank erosion may be stated to be due to one or more of the following causes:

i. concentration of velocity in a concave bend
ii. nature of flood hydrographs of the particular river
iii. type of bank material
iv. ground water table and saturation of the bank materials.

3.4 Variations in current direction

The direction of flow in the Brahmaputra-Jamuna river is controlled predominantly by bank slumping during rising stage and by deposition and formation of sand bars during falling stage, uneven bank slumping causes the current to be deflected from one of the channel banks to the other. As this is a continuous process along both banks of the entire river, numerous changes in flow direction result. During falling stage deposition of both bedload and suspended load restricts the channel drastically and causes the current to split and change direction. The presence of numerous such islands results in complex flow direction at any section along the river causing the river section change its geometry in an unpredictable manner.

3.5 Formation and movement of sand bars

A braided channel is characterised by innumberable sand bars and mid channel islands which seperate the flow into several channels. Such a condition exists in the Brahmaputra channel, which is laterally chocked with sand bars (Figure 3.3). Oncoming load is greater than the sediment carrying capacity of the flow and results in an aggrading channel bed characterized by such bars and islands. The sand bars are generally diamond shaped in plan-view, and their long axes are oriented parallel to the average flow direction of the channel in which they form (Figure 3.3.A). The slope of the upstream end of the island is very steep, and quite often the island is characterized by a relatively deep scour pool immediately upstream. The longer downstream faces of the islands generally have very low slopes, and the surface is covered with ripples and larger bedforms. The height of the islands can be no greater than the heights of the highest flood, since the islands are constructed under flood conditions.

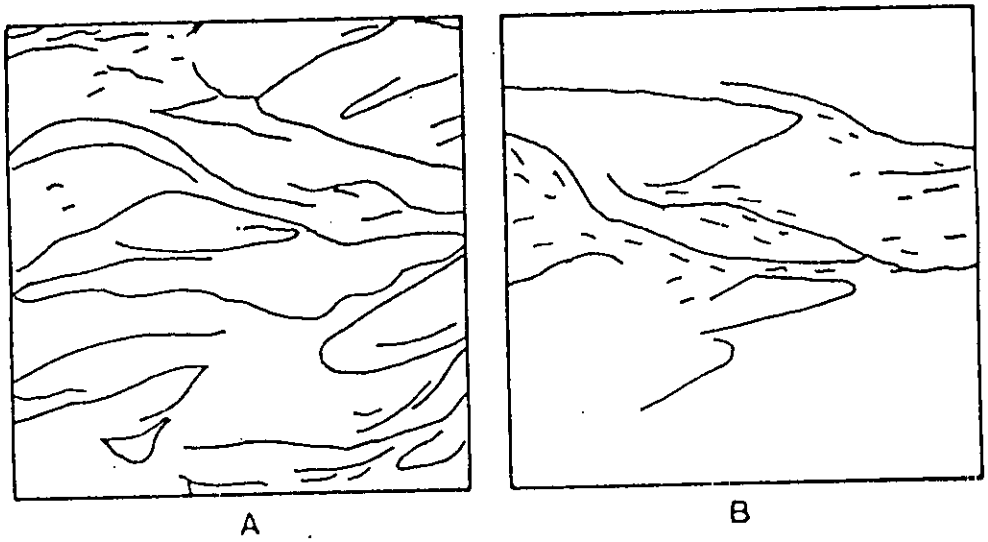

FIG. 3.3 AERIAL VIEWS OF SAND BARS AND MID CHANNEL ISLANDS : A. DIAMOND-SHAPED CHAR
B. SMALL CHAR (AFTER COlEMAN 1969

The initial location and formation of the sand bars are determined during the flood; they are possibly the result of the formation of two scour channels huging each channel bank. However, the area of deposition in the central part of the channel is undoubtedly caused by slack-water conditions. During the flood this area receives deposition and the bed is aggraded significantly. Since the flood water subside rapidly, there is not enough time for this material to erode, and hence it is soon exposed as a shoal.

During the next flood, the island is once more inundated. In some cases it is completely removed by erosion, but more commonly it suffers erosion on its upstream face and deposition on its downstream end. This generally causes the island to migrate in a downstream direction.

In most cases the total area of the island remains approximately the same from one flood to another, and only its position and shape change. In some instances, however, whole islands disappear or new islands form that were not present in the previous year. Thus during flood, the sediment is shifted as bed load, causing the islands to migrate. The large number of bed forms present on the surface of these islands when they are exposed indicates that the sediment had moved as migratory dunes during flood.

3.6 Channel migration

The Brahmaputra-Jamuna river is a large braided channel, and during low flow the channel shifts back and forth between the main stream banks. Aerial photographs of the river show numerous channels, shoals, and islands which indicate a river of low hydraulic efficiency and a heavy sediment load. Water flows in a number of branching and resisting channels with one or two often serving as major channels. The mid channel islands and sand banks shift rapidly with the ever changing flow regions, and in consequence there is day to day variation in channel configuration. The position of the main current in a braided stream is extremely unstable and causes the river course constantly to shift its position.

Within the Brahmaputra the total amount of sediment provided by the catchment far exceeds the ability of the flow to carry the sediment. Thus there is a general aggradation of the channel bed which causes the channel to become wider and shallower. The aggradation constantly causes the main current to seek better gradients, new alignments and paths of least resistance. A new channel is formed and is at first narrow and deep. With time, however, it too will begin to aggrade, and the whole process is repeated. In this manner the channel is in a state of constant migration eroding and redepositing sediment of its own making as well as older deposits of previous channels.

CHAPTER-4

DATA COLLECTION AND ANALYSIS

4.1 Introduction

To study the changes in river-section characteristics of Brahmaputra-Jamuna, cross-sections at five different stations covering the distance between Noonkhawa and Goalundo have been collected from the Directorate of Surface Water Hydrology-I. Bangladesh Water Development Board (BWDB). The water level and discharge data have been obtained from the Directorate of Surface Water Hydrology-II, BWDB, Dhaka.

The cross-sectional data which was collected covered the year 1965-66 and the period 1976-77 to 1985-86. The cross-sectional data for the period 1966-67 to 1975-76 could not be collected as these data are reported to be missing. Water level data were collected only for four stations out of the five selected stations and discharge data were collected only for one station. It is to be mentioned here that water level data were not available for all the selected stations and discharge data are only recorded at Bahadurabad station. Due to the limitation of data availability, analysis has been kept limited within some selected stations.

4.2 Description of the selected stations for this study

Bangladesh Water Development Board has been collecting cross-section data of the Brahmaputra-Jamuna river at various sections from the confluence of the river with the Ganges to Charantua, an upstream section of Bangladesh.Cross-sections are numbered as J-1 to J-17. For this study only five cross-sections namely J-4, J-7, J-9, J-14 and J-16 near Porabari, Sirajganj, Jagannathganj, Bahadurabad and Chilmari respectively were selected. Their locations are shown in figure 4.1.

Bangladesh Water Development Board has also been collecting water level data from a few selected stations and discharge data only from one station of the Brahmaputra-Jamuna river since 1965. Water level study concentrates on the analysis of data collected at Chilmari, Bahadurabad, Jagannathgamj and Sirajganj gauging stations of the river. The Chilmari, Bahadurabad and Jagannathganj gauging stations are located near Chilmari Railway Station, Bahadurabad Railway Station and Jagannathganj Railway Station respectively. Sirajganj gauging station is located at about 3 km down of Sirajganj Railway Station. The analysis of water level data were made with respect to discharge data collected at Bahadurabad station.

4.3 Data collection

Water level data were collected only for four stations namely Sirajganj, Jagannathganj, Bahadurabad and Chilmari stations. The water level data at station Porabari were not available for most of the years and therefore were not collected. The discharge data were available only for one station namely Bahadurabad. Thus only this discharge data were used in the analysis wherever it was necessary.

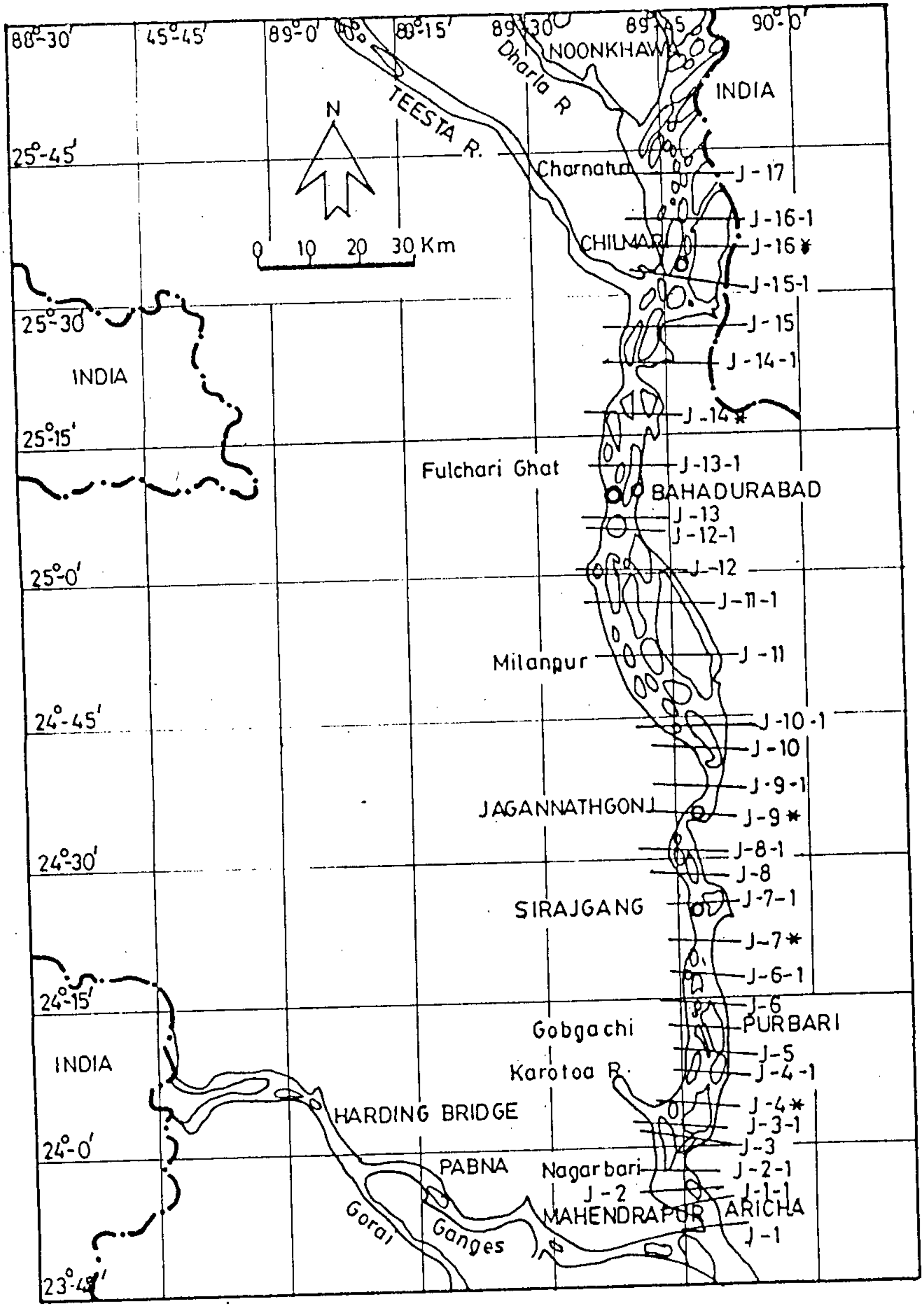

FIG. 4.1 LOCATION OF CROSS-SECTIONS FROM GANGES-JAMUNA CONFLUENCE TO NOONKHAWA AND WATER LEVEL AND DISCHARGE GAGING STATIONS

Because of time limitation and non availability of data for all the years, the analysis was done by using data for the years as mentioned below :

i. Cross-section maps for the years 1965-66, 1976-77, 1978-79, 1980-81, 1983-84 and 1985-86.

ii. Water level data for the years 1964-65, 1976-77, 1978-79, 1980-81, 1983-84, 1986-87 and 1987-88.

iii. Discharge at Bahadurabad for the years 1964-65, 1974-75, 1978-79, 1980-81, 1983-84, 1986-87 and 1987-88.

4.4 Data analysis

Cross-sectional area of the river upto various elevations at different sections were measured by using a planimeter. Then elevation versus cross-sectional area graphs were plotted to show how the cross-sectional area changes with elevation at different sections. By superimposing the cross-sections for each section for different years erosion and deposition were calculated by using planimeter. An increase in cross-sectional area compared to a previous year's value indicates net erosion in that section over the period whereas a decrease implies deposition. At various elevations the corresponding total widths of water surface were also calculated. Average depth of each river-section near about bank elevation were calculated by dividing the cross-sectional area with water surface width assuming a rectangular section. Tables have been prepared showing the variation of area, effective width, total width, average depth and average bed elevation, each corresponding to near about bank elevation, for each section to show changes of these parameter in different years. Elevation versus width graphs were plotted to study the variation in width of the river at different sections. All elevations refer to PWD datum.

Water level at Chilmari, Bahadurabad, Jagannathgonj and Sirajgonj stations corresponding to some selected discharge at Bahadurabad were determined by studying data obtained from BWDB. Then water level data at each station were plotted against the selected discharge data at Bahadurabad for different years to study the change in water level for the same discharge over the years.

CHAPTER-5

RESULTS AND DISCUSSIONS

5.1 Cross-sectional area, width and average depth

Figure 5.1.1(a) to 5.1.5(a) have been prepared to study the changes in cross-sectional area with elevation for different years for different sections. In each figure there are six cross-sectional profiles for the years 1965-66, 1976-77, 1978-79, 1980-81, 1983-84 and 1985-86. For a particular elevation, a point on a profile gives cross-sectional area of the section upto that elevation. The figures show that the area- elevation curves rise sharply with high gradients at lower elevation i.e. near the channel bottom and become flatter with increase of depth towards the top. This particular pattern of the profile is mainly because of faster increase of width with elevation.

Figures 5.1.1(b) to 5.1.5(b) have been presented to study the change in width with elevation. For a particular elevation, a point on a profile gives the effective width of the channel section at that elevation. The figures show that for each section width increases at a faster rate with elevation.

Tables 5.1.1 to 5.1.5 show the cross-sectional area. effective width total width, average depth and mean bed level for different sections for different years. Total width refers the distance from one bank to another near about bank elevation. Average depth is calculated by dividing the corss-sectional area with effective width assuming a rectangular section. Mean bed level refers to PWD datum.

From the study of figure 5.1.1(a) and 5.1.1(b) showing area-elevation and width-elevation curves for section J-4 near Porabari, it is seen that no systematic change in any of the parameters such as area and width with elevation has occurred over the years. At higher elevations cross sectional area and width decreased from the year 1965-66 to 1976-77. The cross-sectional area and width however increased from the year 1976-77 to 1980-81. Again the cross-sectional area decreased from the year 1980-81 to 1985-86 but the width remained more or less unchanged. Considering the overall changes during the period 1965-66 to 1985-86 it is observed that cross-sectional area and width at relatively higher elevations has decreased. It is interesting to note that at about 25 ft elevation the cross sectional area remained more or less same over the years from 1965-66 to 1985-86. But the width has decreased at that elevation during that period.

From figures 5.1.1(a) and 5.1.1(b) it is also observed that the cross sectional area at relatively lower elevations increased from the year 1965-66 to 1976-77 and decreased from the year 1976-77 to 1980-81 and then increased from the year 1980-81 to 1985-86. The width at lower elevations however followed different trendsat different time. It is also here interesting to note that during the period when the cross sectional area decreased at higher elevations, the cross-sectional area increased at lower elevations and vice-versa. Considering the total changes during the period from

1965-66 to 1985-86 it is observed from these figures that the cross-sectional area and width decreased at higher elevations. and increased at lower elevations. It is therefore evident that deposition has occured at higher elevations and erosion has occured at lower elevation.

From the study of table 5.1.1 at Section J-4 it is revealed that near about bank level elevation cross sectional area, effective widthand total width decreased during the period 1965-66 to 1985-86. Average depth has however increased during that period with the result that the average bed level has gone down.

Figures 5.1.2(a) and 5.1.2(b) represent the area elevation and width elevation curves for section J-7 near Sirajgang. By observing the curves it is found that at relatively higher elevations there has been almost no change in the cross sectional area from the year 1965-66 to 1978-79 but the width has decreased during that period. The cross-sectional area and width then increased substantially from the year 1978-79 to 1980-81. For example, at 40 ft elevation, the cross-sectional area in 1978-79 was 296480 ft^2 whereas cross-sectional area in 1980-81 was 439870 ft^2. The width during that period changed from 17250 ft to 27350 ft. The cross-sectional area and width then again decreased from the year 1980-81 to 1985-86. During the period 1965-66 to 1985-86 it is however observed that the cross-sectional area and width decreased at higher elevation. At, lower elevations cross-sectional area remained more or less unchanged from the year 1865-66 to 1980-81 and then increased in the year 1983-84 and again decreased in the year 1985-86. Width however remained more or less unchanged during the period from 1965-66 to 1985-86.

From table 5.1.2 it is revealed that at section J-7 near bank elevation, there is not much change in the cross-sectional area and effective width over the years from 1965-66 to 1985-86 except in the year 1980-81 when both area and effective width increased substantially. Total width during the period 1965-66 to 1985-86 decreased from a value of 45000 ft to 39300 ft. It is also observed from table 5.1 that the average depth as obtained by dividing the cross-sectional area by effective width has decreased from the year 1965-66 to 1985-86 and there has been a rise in mean bed level.

Figures 5.1.3(a) and 5.1.3(b) represent area elevation and width elevation curves for section J-9 near Jagannathgonj. From figure 5.1.3(a) it is found that cross-sectional area increased at relatively higher elevations from the year 1965-66 to 1978-79 and decreased from the year 1978-79 to 1980-81 and then again increased from the year 1980-81 to 1985-86. However, width increased at relatively higher elevation from the year 1965-66 to 1976-77 and decreased from the year 1976-77 to 1980-81 and again increased from the year 1980-81 to 1985-86. It is thus evident that in most of the time the increase or decrease of area in section J-9 was also accompanied by increase or decrease of width. At lower elevations the cross sectional area and the width decreased from the year 1965-66 to 1976-77. But after 1976-77 there has been not much change in the cross-sectional area and the width at lower elevations. It is interesting to note that at 30 ft elevation cross-sectional area and width have remained more or less unchanged after 1978-79. Comparing the curves for the years 1965-66 and 1985-86 it is apparent that there has been erosion at higher elevations and deposition at lower elevations.

From the study of table 5.1.3 it is observed that no systematic change in average depth has occurred at section J-9. As a result mean bed level did not follow any trend to rise or fall but comparing the mean bed level data from the years 1965-66 to 1985-86 it can be said that bed level has an average tendency to go up. It is interesting to note that total width has remained more or less constant even though the effective width changed substantially from year to year. This is possibly because of the fact that at that toal width the bank material is more resistant to erosion . The effective width is however changing possibly due to different magnitude of erosion and deposion in different years.

By observing the curves in figures 5.1.4(a) and 5.1.4(b) for the section J-14 near Bahadurabad it is found that cross-sectional area at relatively higher elevations did not change substantially as it happened in other sections. However the width decreased considerably from the year 1965-66 to 1976-77 and did not show significant change after 1976-77. The cross-sectional area and width at lower elevations have however not changed during the period 1965-66 to 1985-86 even though changes occurred year to year. Considering all the curves from figure 5.1.4(a) and 5.1.4(b) for the year 1965-66 and 1985-86 it can be concluded that cross-sectional area and width have not significantly changed.

From table 5.1.4 it is revealed that the total width remained more or less unchanged at section J-14. Average depth decreased from the year 1965-66 to 1978-79 and increased from the year 1978-79 to 1985-86. Considering the years 1965-66 and 1985-86 it is also observed from table 5.4 that mean bed level has gone down.

From the study of figure 5.1.5(a) and 5.1.5(b) showing curves for section J-16 near Chilmari it is found that cross-sectional area and width at relatively higher elevations increased from the year 1965-66 to 1976-77 and decreased from the year 1976-77 to 1978-79 and there increased from the year 1978-79 to 1985-86. At lower elevations cross-sectional area decreased from the year 1965-66 to 1978-79 and increased from the year 1978-79 to 1985-86. The width however decreased from the year 1965-66 to 1980-81 and then increased from the year 1980-81 to 1985-86. Considering the curves for the year 1965-66 and 1985-86 it can be concluded that erosion has occured at higher elevations and deposition at lower elevation.

From table 5.1.5 it is seen that even though the cross-sectional area near bank elevation did not show much changes over short period, it increased from 347875 ft^2 to 430160 ft^2 from the year 1965-66 to 1985-86. Total width however remained unchanged during that period. Average depth decreased from the year 1965-66 to 1978-79 and the increased from the year 1978-79 to 1985-86. It is thus observed from the table 5.1.5 that the mean bed level has gone down from the year 1965-66 to 1985-86.

5.2 Water level and discharge

Water levels data of the Brahmaputra-Jamuna river are recorded by BWDB at different stations namely Sirajganj, Jagannathganj, Bahadurabad and Chilmari. But discharge data are recorded only at Bahadurabad station. As discharge data were not available in other station, it became necessary to relate the water level data at a station with discharge data at Bahadurabad for the study relating to trend in stage for same discharge over the years. Typical high discharge value at Bahadurabad was selected and the corresponding water level at Chilmari, Bahadurabad, Jagannathganj and Sirajganj stations were determined. Then these water level data at different stations were plotted against discharge data at Bahadurabad for different years.

Figures 5.2.1 to 5.2.4 have been prepared on the basis of data so selected from available water level data at Sirajganj. Jagannathganj, Bahadurabad and Chilmari and discharge data at Bahadurabad. For each station there are two figures which are designated as (a) and (b). In each figure there are four curves to show variation of water level with discharge except the station Chilmari for which data were not available for the year 1964-65. Figure (a) represents the curves for the years 1964-65, 1974-75, 1978-79 and 1980-81. Figure(b) represents the curves for the years 1980-81, 1983-84, 1986-87 and 1987-88.

From figure 5.2.1(a) it is observed that for the same discharge water level at Sirajganj did not show any noticeable change from 1964-65 to 1978-79. But the water level increased appreciably from the year 1978-79 to 1980-81. From figure 5.2.1(b) it is observed that water level showed a rising tendency from the period 1980-81 to 1986-87 and then decreased in the year 1987-88. From all curves in figure 5.2.1(a) and 5.2.1(b) it is apparent that water level has shown a rising trend.

Figures 5.2.2(a) and 5.2.2(b) show the variation of water level at Jagannathgonj with discharge. By observing the curves it is found that water level increased from the year 1964-65 to 1974-75 and decreased from the year 1974-75 to 1980-81 for the same discharge. Water level again increased from the year 1980-81 to 1985-86 for the same discharge. From the study of all curves in figures 5.2.2(a) and 5.2.2(b) it may be stated that water level shows a rising trend after 1980-81.

Study of curves in figure 5.2.3(a) and 5.2.3(b) for Bahadurabad shows that water level at Bahadurabad increased from the year 1964-65 to 1974-75 and decreased from the year 1974-75 to 1980-81 for the same discharge. After 1980-81 water level remained more or less unchanged upto the year 1986-87 even though in 1987-88 water level again decreased.

From the study of figures 5.2.4(a) and 5.2.4(b) it is apparent that water level remained more or less unchanged from the year 1974-75 to 1980-81. But water level increased from the year 1980-81 to 1986-87 and decreased in the year 1987-88.

From study of all the curves in figures 5.2.1 to 5.2.4 it is apparant that water level has shown an over all rising trend in all the sections even though the curves for 1987-88 have shown lower water levels in most of the stations.

5.3 Erosion and deposition

Tables 5.3.1 to 5.3.5 indicates area in erosion and area in deposition in different periods for sections J-4, J-7, J-9, J-14 and J-16 respectively. These areas were determined by superimposing cross-sections for different years. For the determination of area under erosion and deposition, cross-section maps for six different years were analysed except for the section J-4, for which cross-section maps were used only for four years. The cross-section maps for other two years for this station could not be used as they are in different scale from the others.

From the study of table 5.3.1 to 5.3.5 it is evident that deposition is higher than erosion for section J-4 and for section J-14 erosion is higher than deposition. But for other sections sometimes erosion was higher than deposition and vice-versa. From the study of all the tables for the entire period from 1965-66 to 1985-86 it can be stated that there has been net erosion in sections J-14, J-16 and net deposition in section J-7.

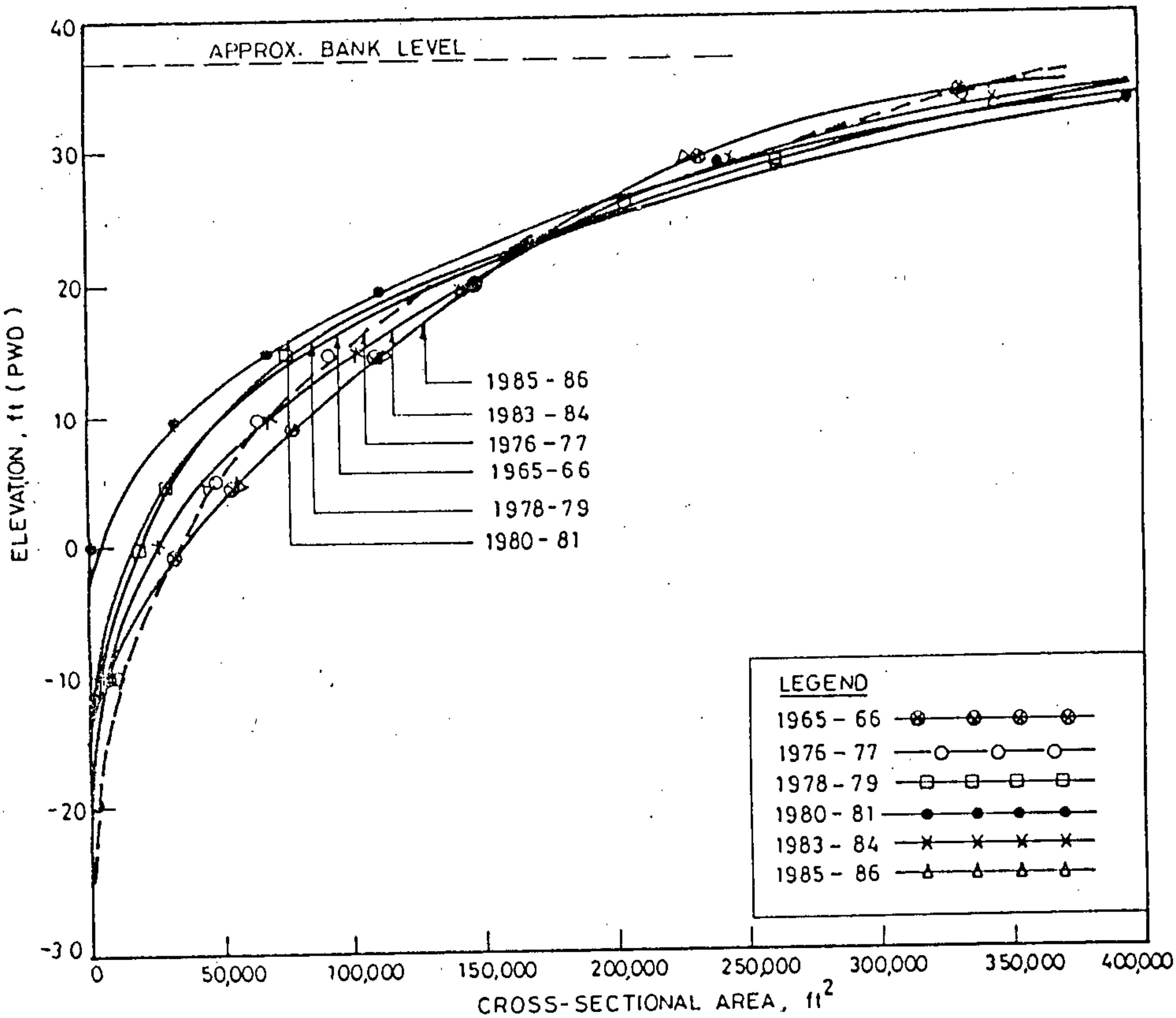

FIG. 5. 1. 1(a) AREA-ELEVATION CURVES FOR SECTION J-4 NEAR PORABARI

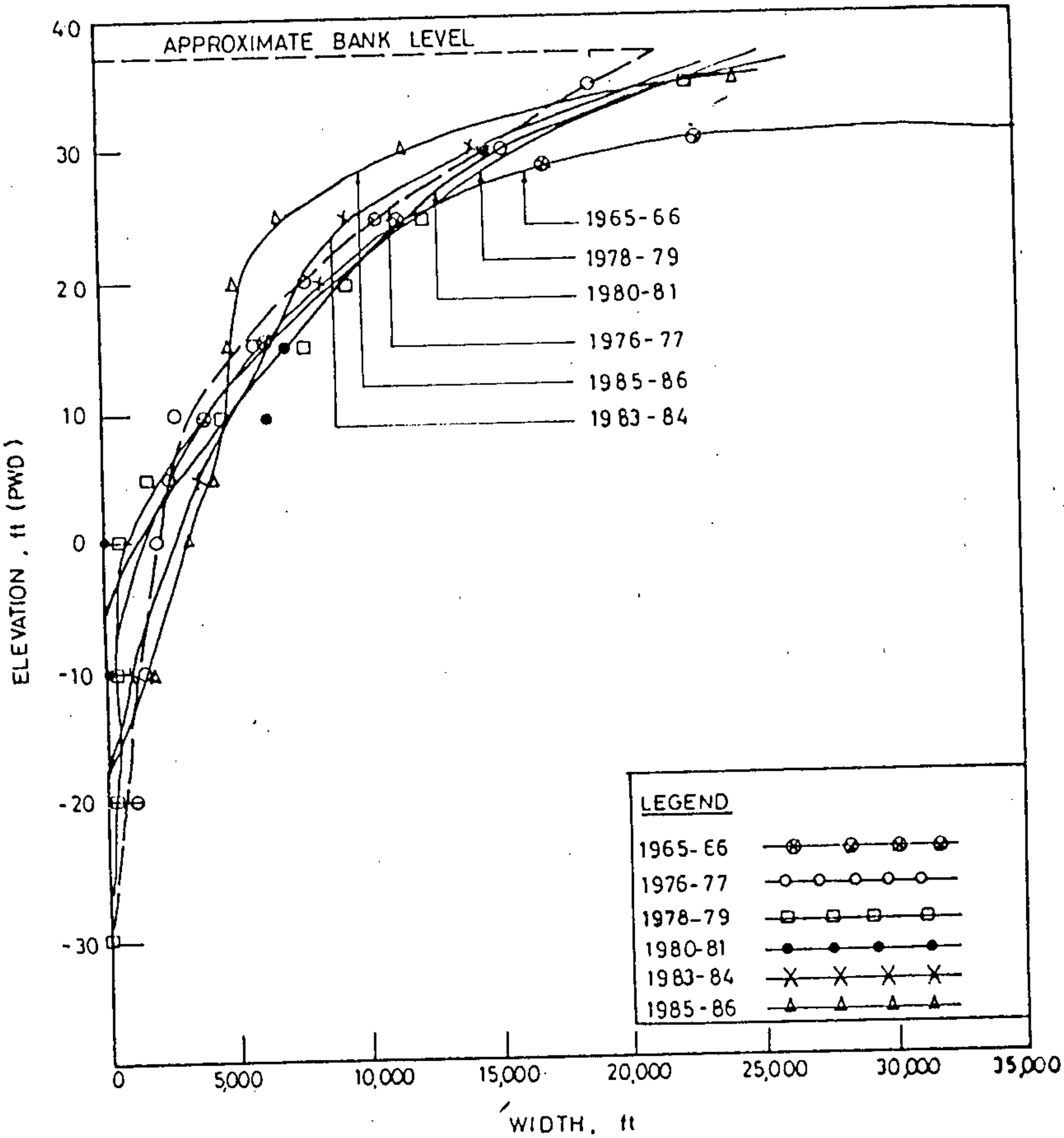

FIG. 5.1.1(b) WIDTH-ELEVATION CURVES FOR SECTION J-4 NEAR PORABARI

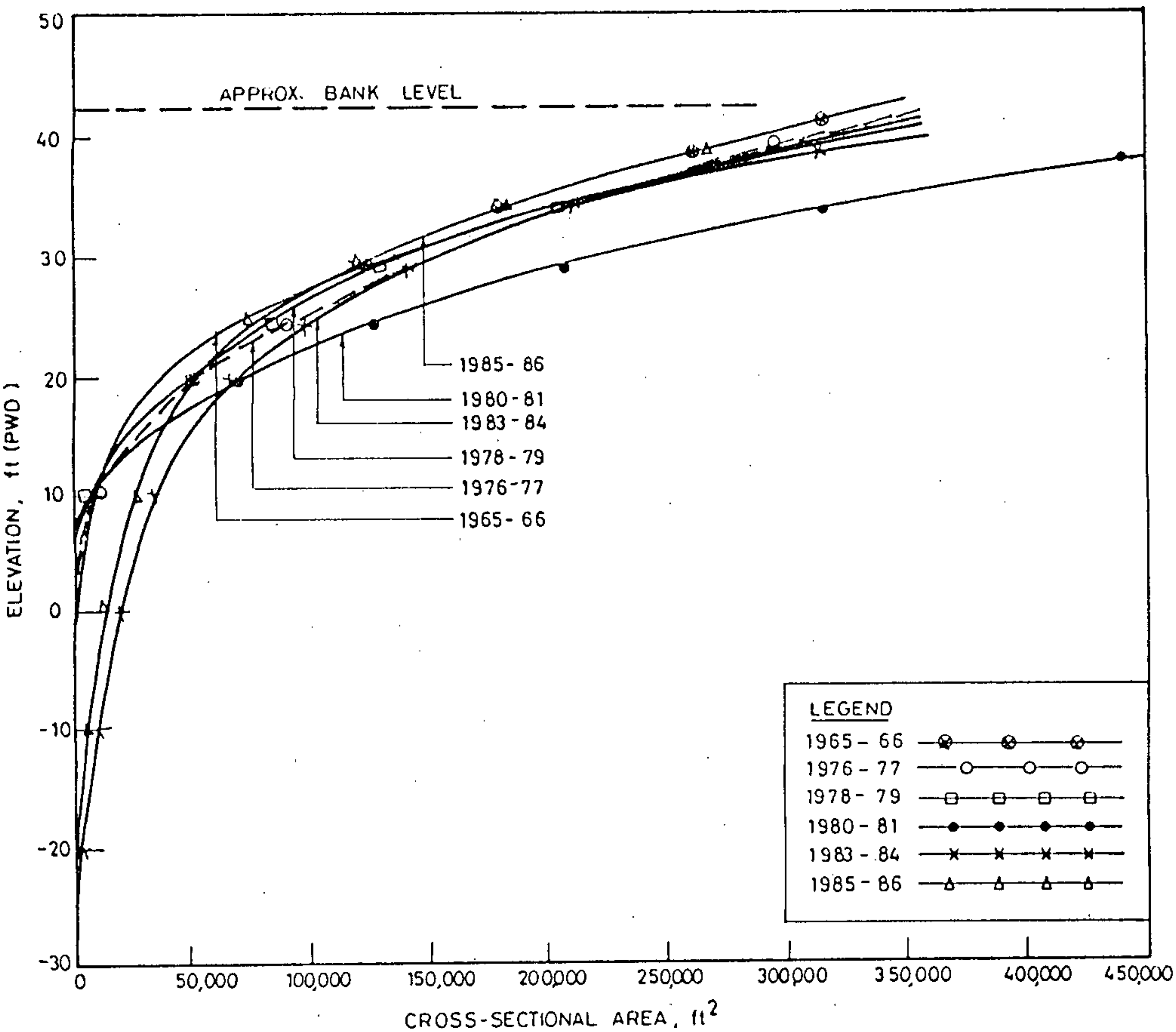

FIG. 5.1.2(a) AREA-ELEVATION CURVES FOR SECTION J-7 NEAR SIRAJGONJ

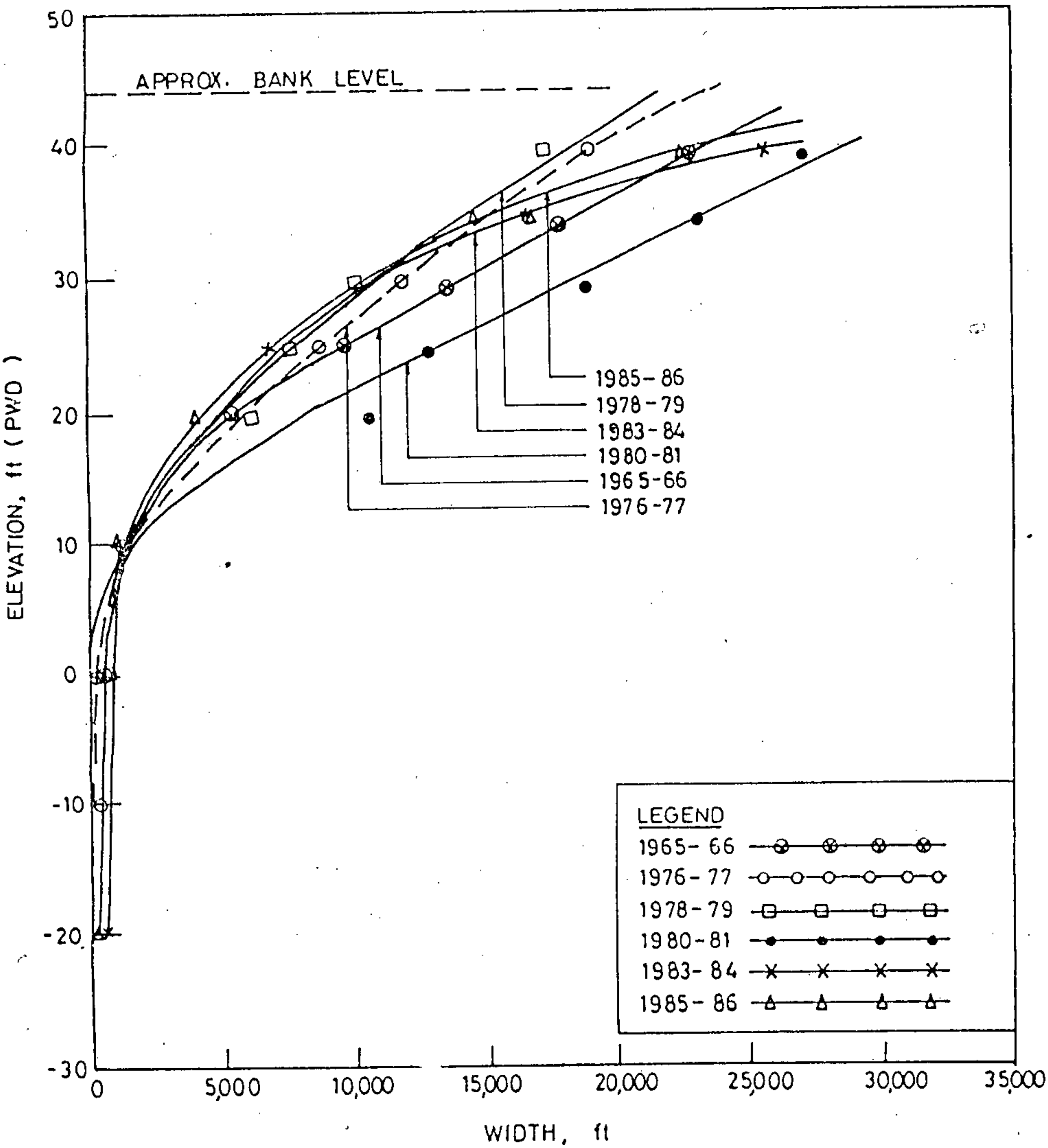

FIG. 5.1.2(b) WIDTH-ELEVATION CURVES FOR SECTION J-7 NEAR SIRAJGANJ

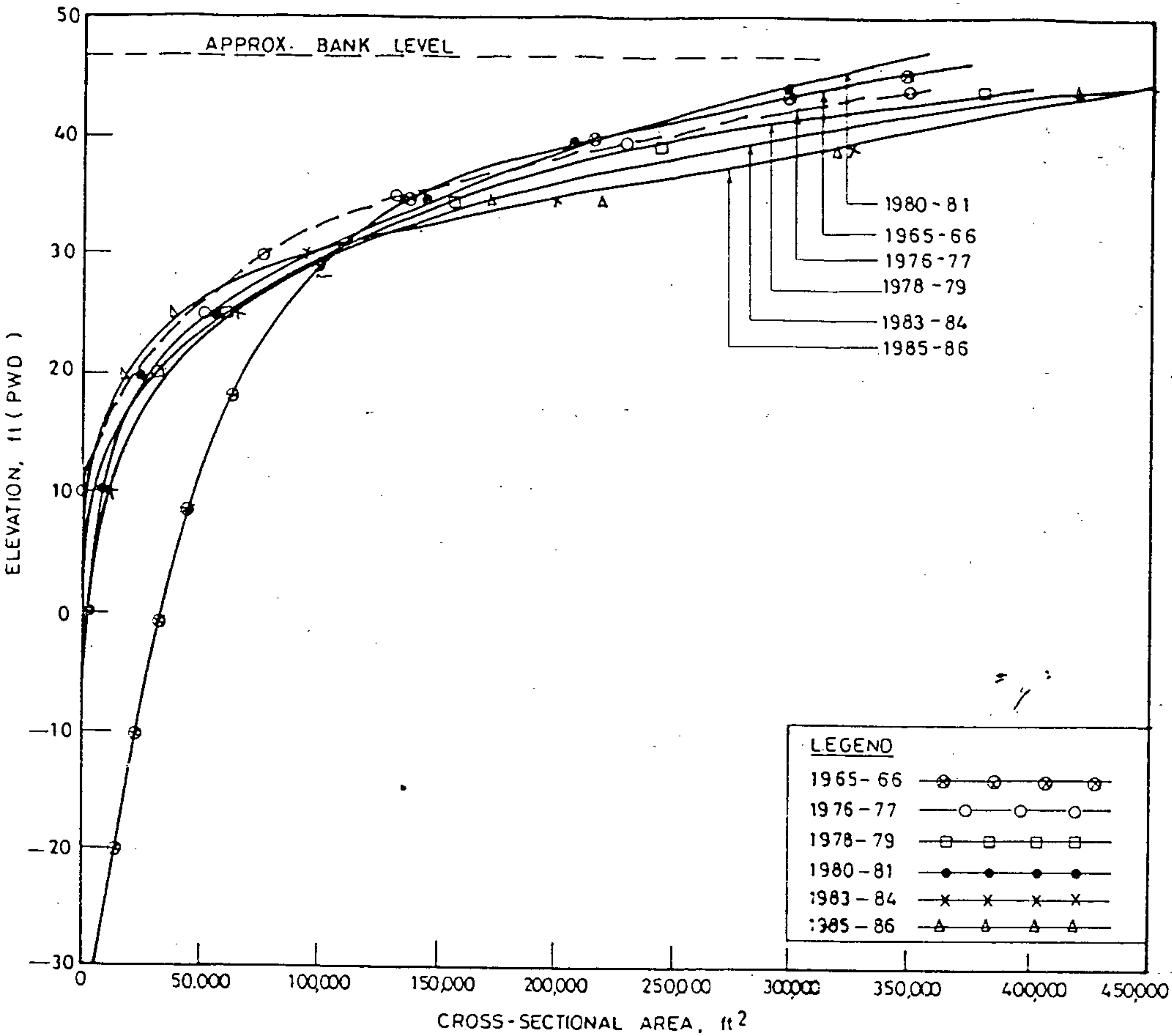

FIG. 5.1.3(a) AREA-ELEVATION CURVES FOR SECTION J-9 NEAR JAGANNATHGONJ

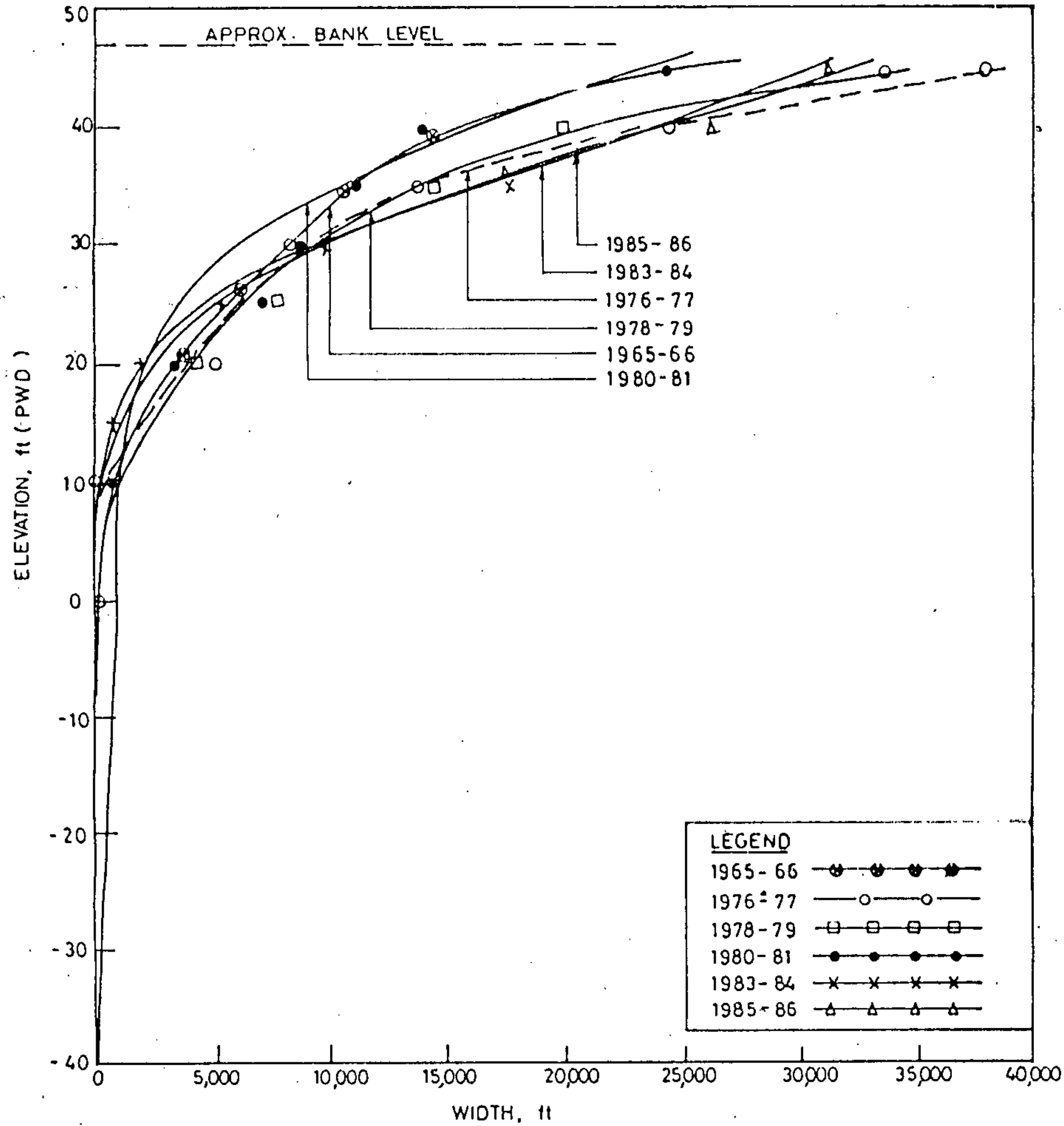

FIG. 5.1.3(b) WIDTH-ELEVATION CURVES FOR SECTION J-9 NEAR JAGANNATHGANJ

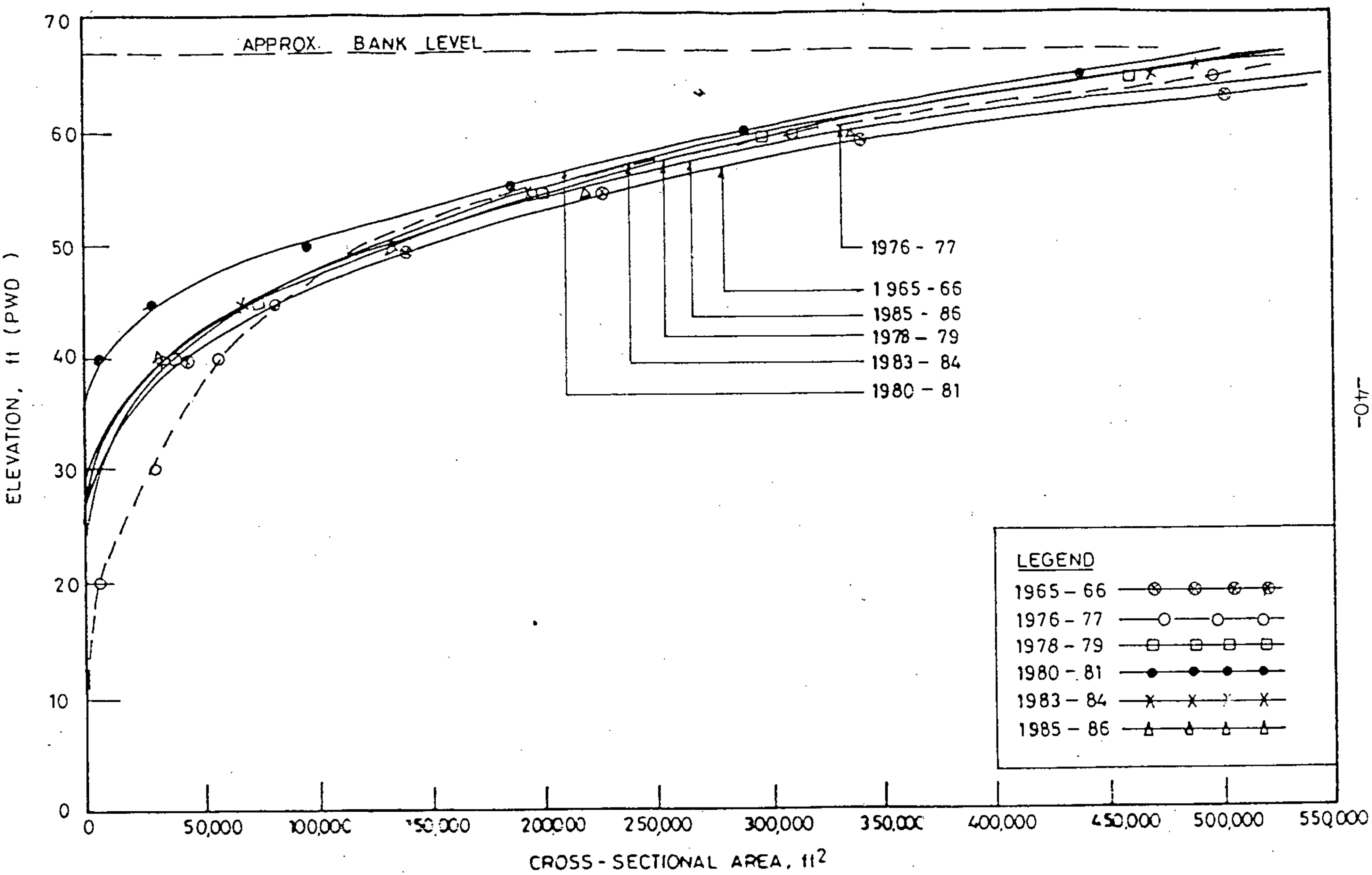

FIG. 5.1.4 (a) AREA-ELEVATION CURVES FOR SECTION J - 14 NEAR BAHADURABAD

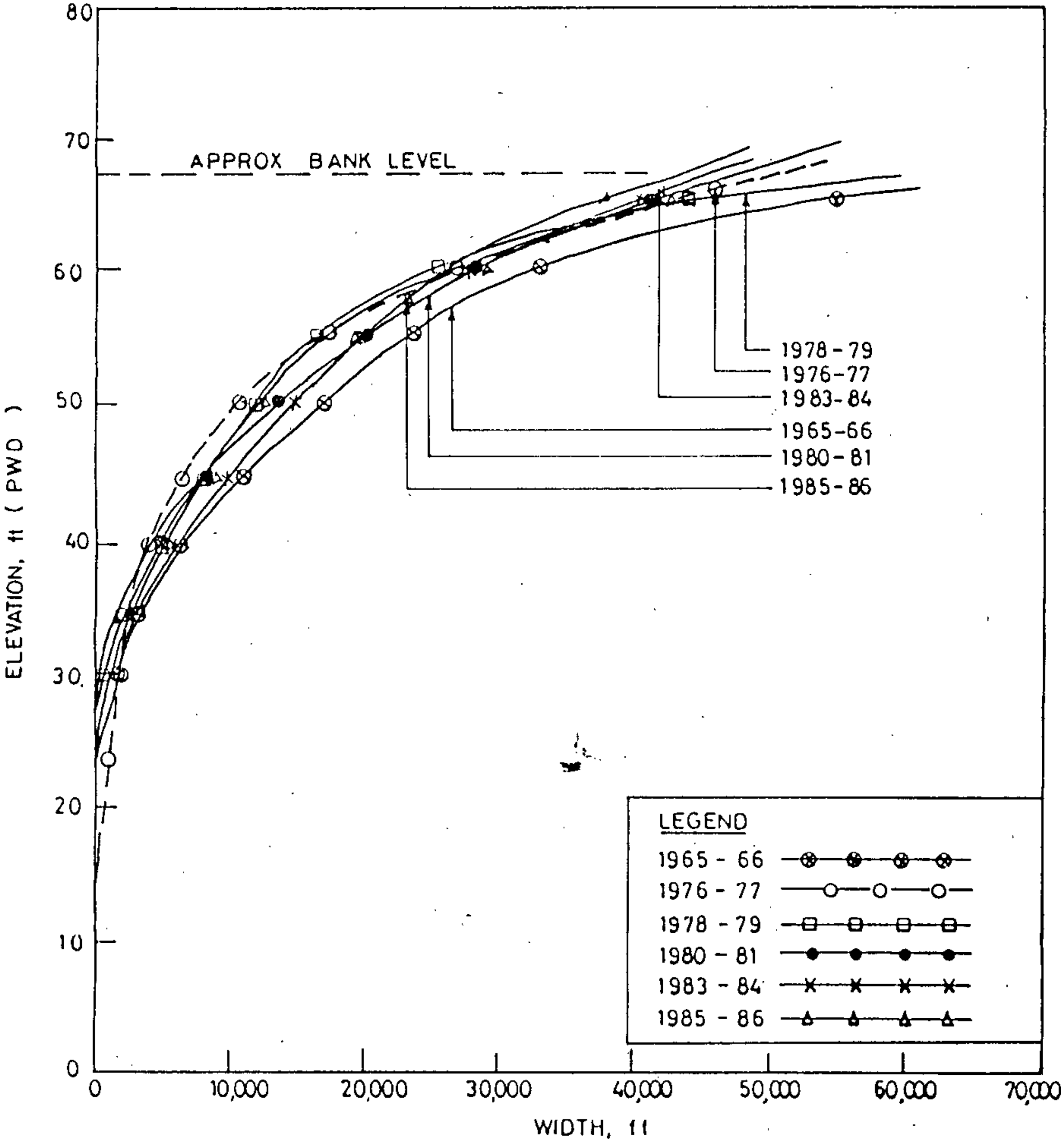

FIG. 5.1.4(b) WIDTH-ELEVATION CURVES FOR SECTION J-14 NEAR BAHADURABAD

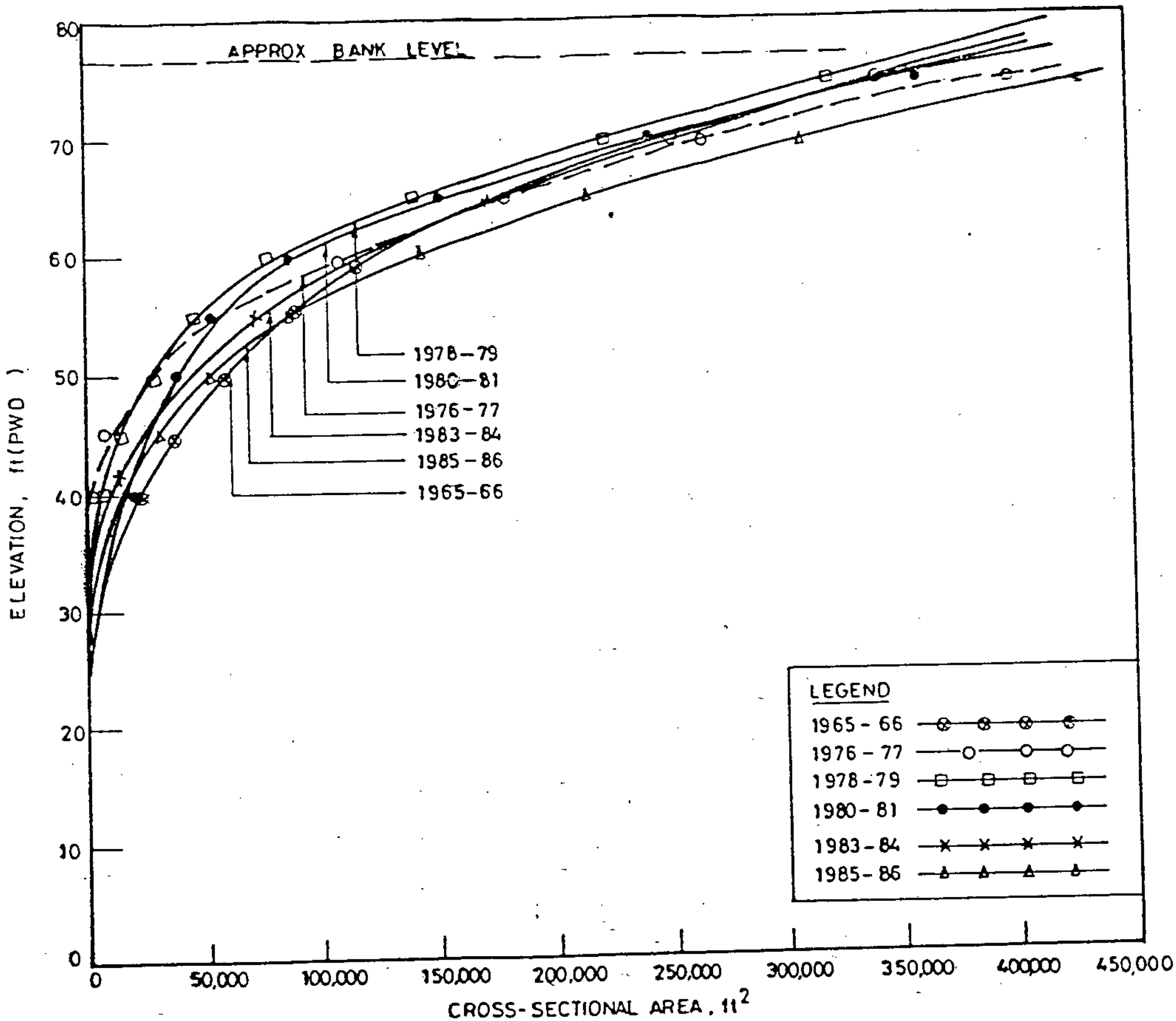

FIG. 5.1.5(a) AREA-ELEVATION CURVES FOR SECTION J-16 NEAR CHILMARI

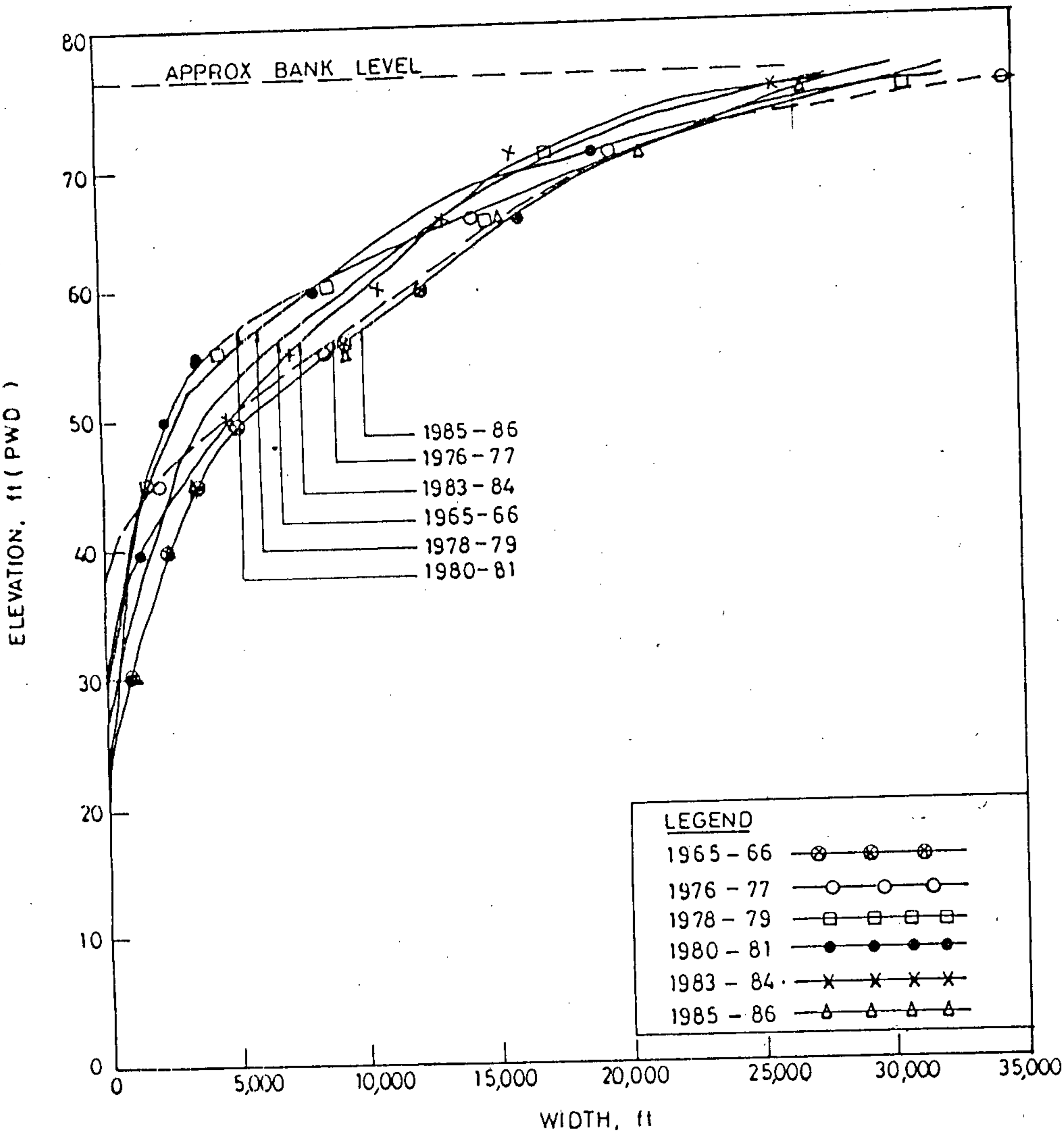

FIG. 5.1.5(b) WIDTH-ELEVATION CURVES FOR SECTION J-16 NEAR CHILMARI

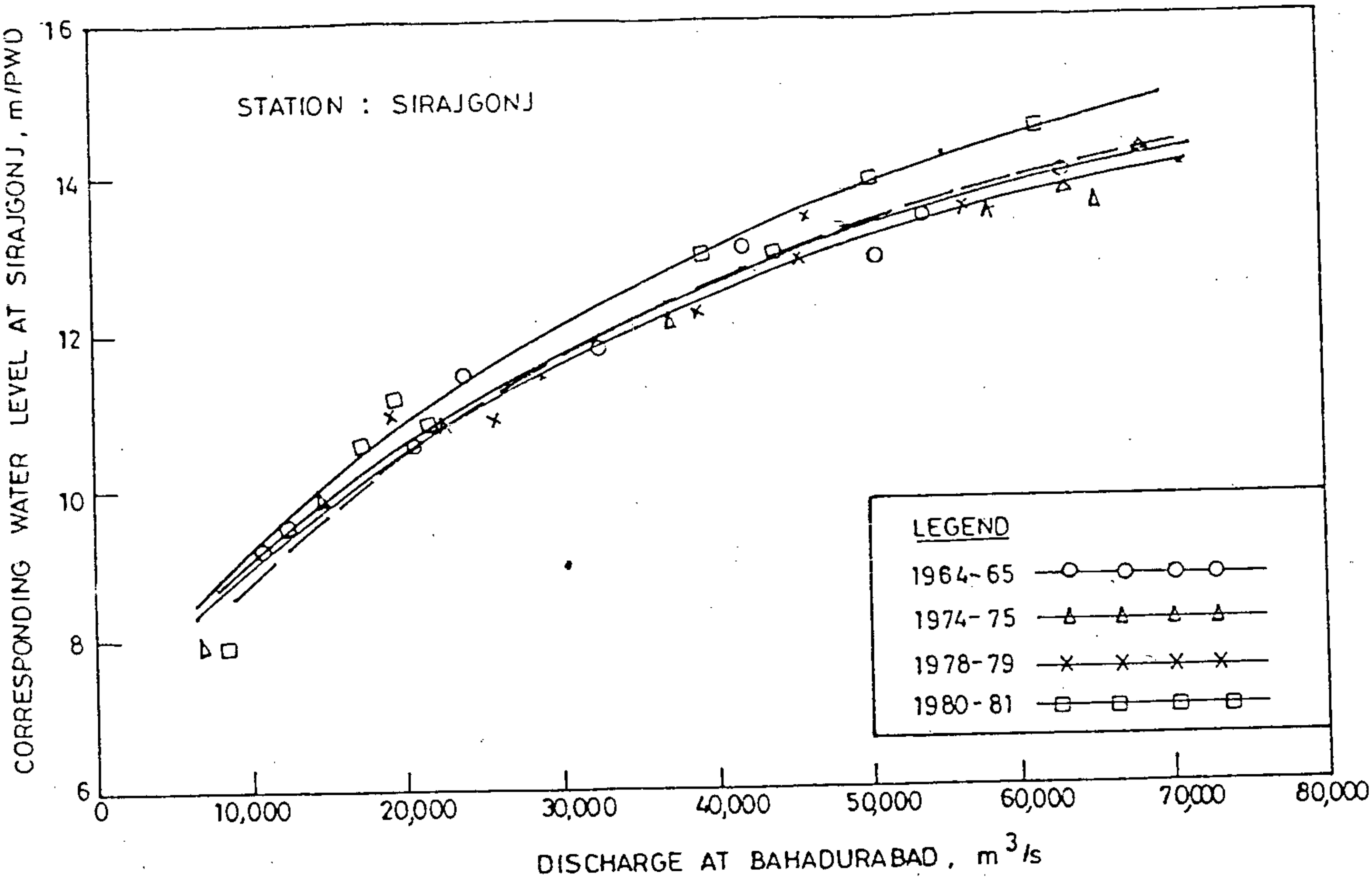

FIG. 5.2.1(a) VARIATION OF WATER LEVEL AT SIRAJGONJ WITH DISCHARGE (1964-65, 1974-75, 1978-79, 1980-81)

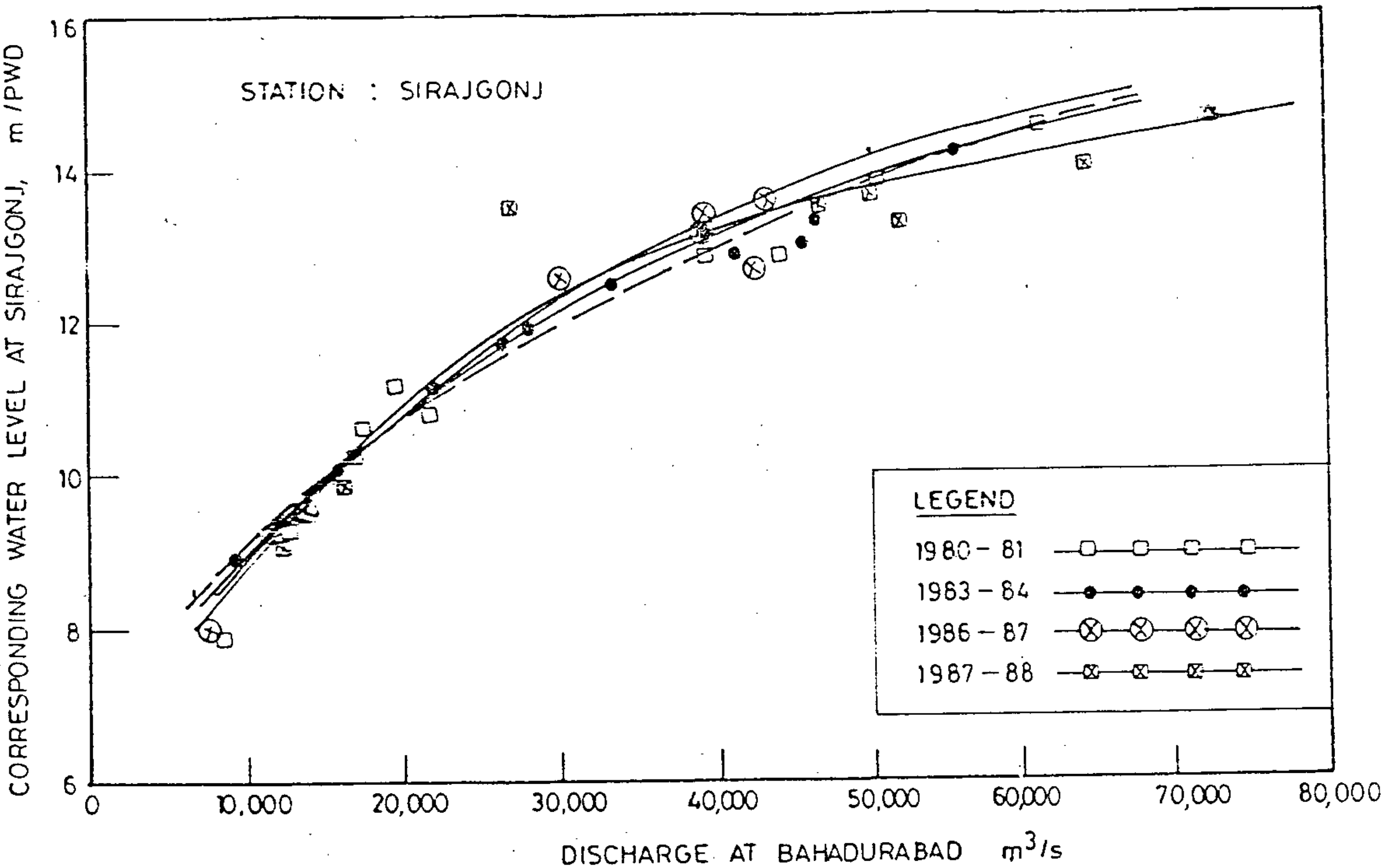

FIG. 5.2.1(b) VARIATION OF WATER LEVEL AT SIRAJGONJ WITH DISCHARGE (1980-81, 1983-84, 1986-87, 1987-88)

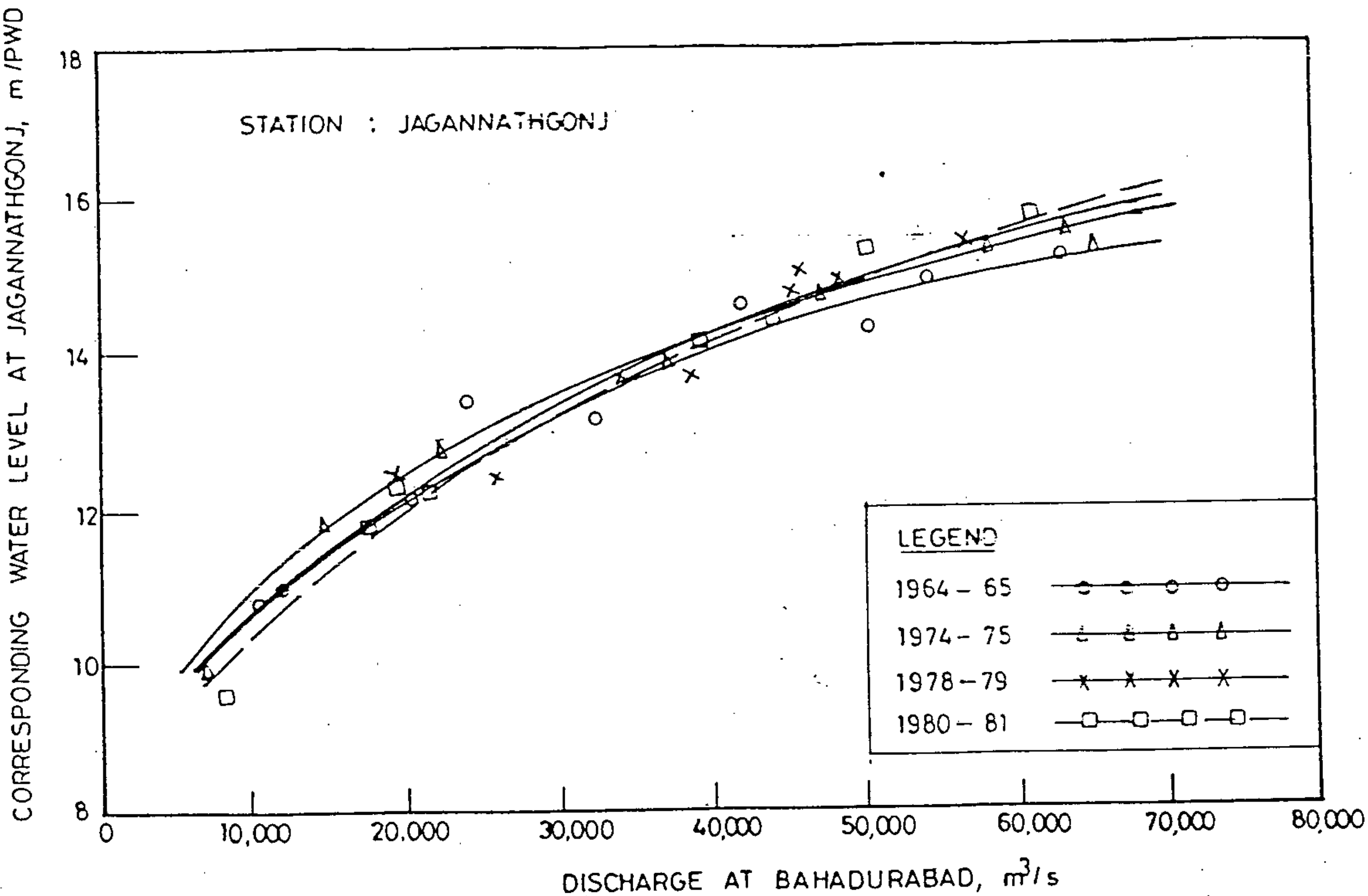

FIG. 5.2.2(a) VARIATION OF WATER LEVEL AT JAGANNATHGONJ WITH DISCHARGE (1964 - 65, 1974 - 75 , 1978 - 79, 1980 - 81)

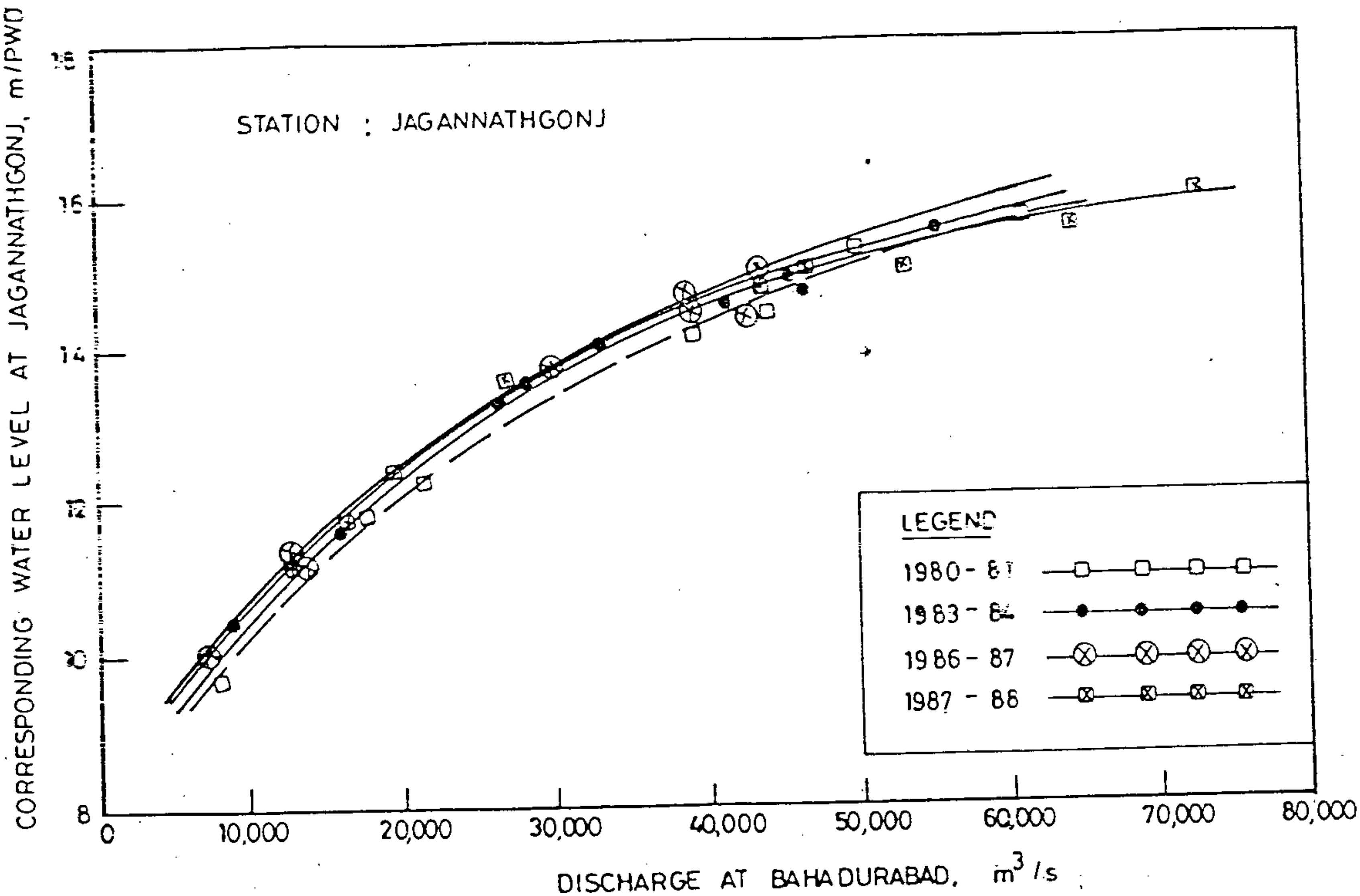

FIG. 5.2.2(b) VARIATION OF WATER LEVEL AT JAGANNATHGONJ WITH DISCHARGE (1980-81 1983-84, 1986-87, 1987-88)

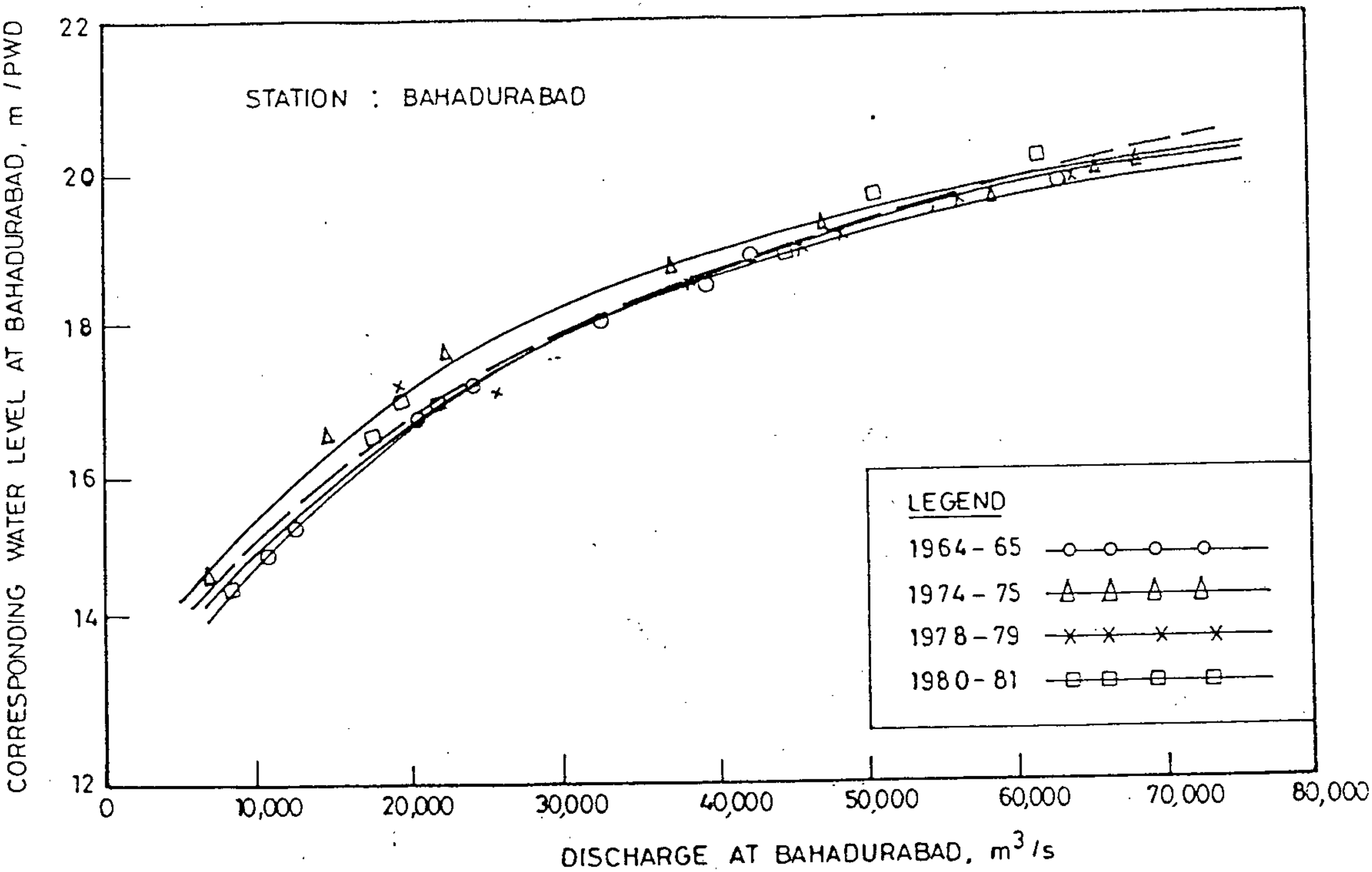

FIG. 5.2.3 (a) VARIATION OF WATER LEVEL AT BAHADURABAD WITH DISCHARGE (1964-65, 1974-75, 1978-79, 1980-81)

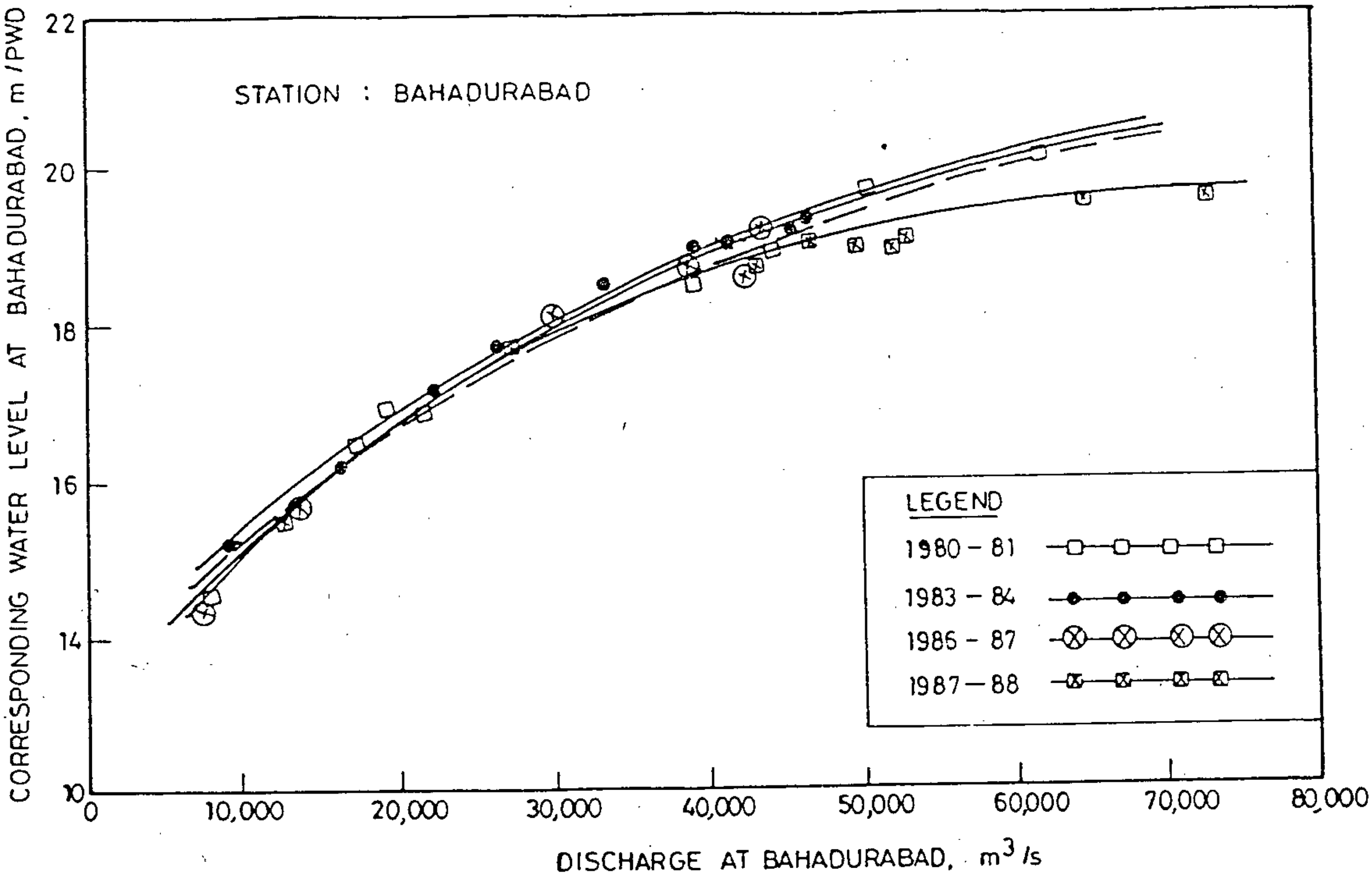

FIG. 5.2.3(b) VARIATION OF WATER LEVEL AT BAHADURABAD WITH DISCHARGE (1980-81, 1983-84, 1986-87, 1987-88)

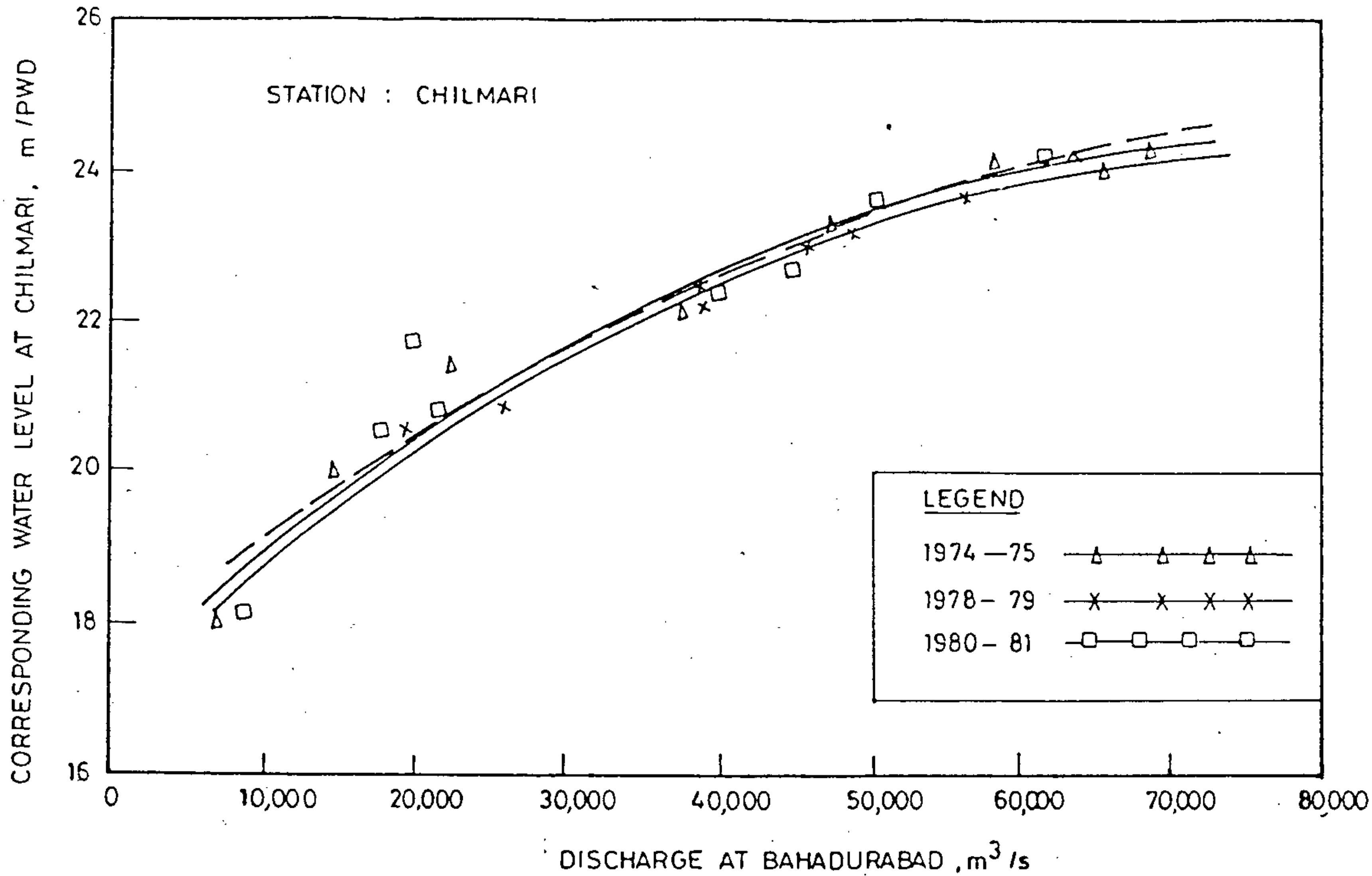

FIG. 5.2.4(a) VARIATION OF WATER LEVEL AT CHILMARI WITH DISCHARGE (1974-75, 1978-79, 1980-81)

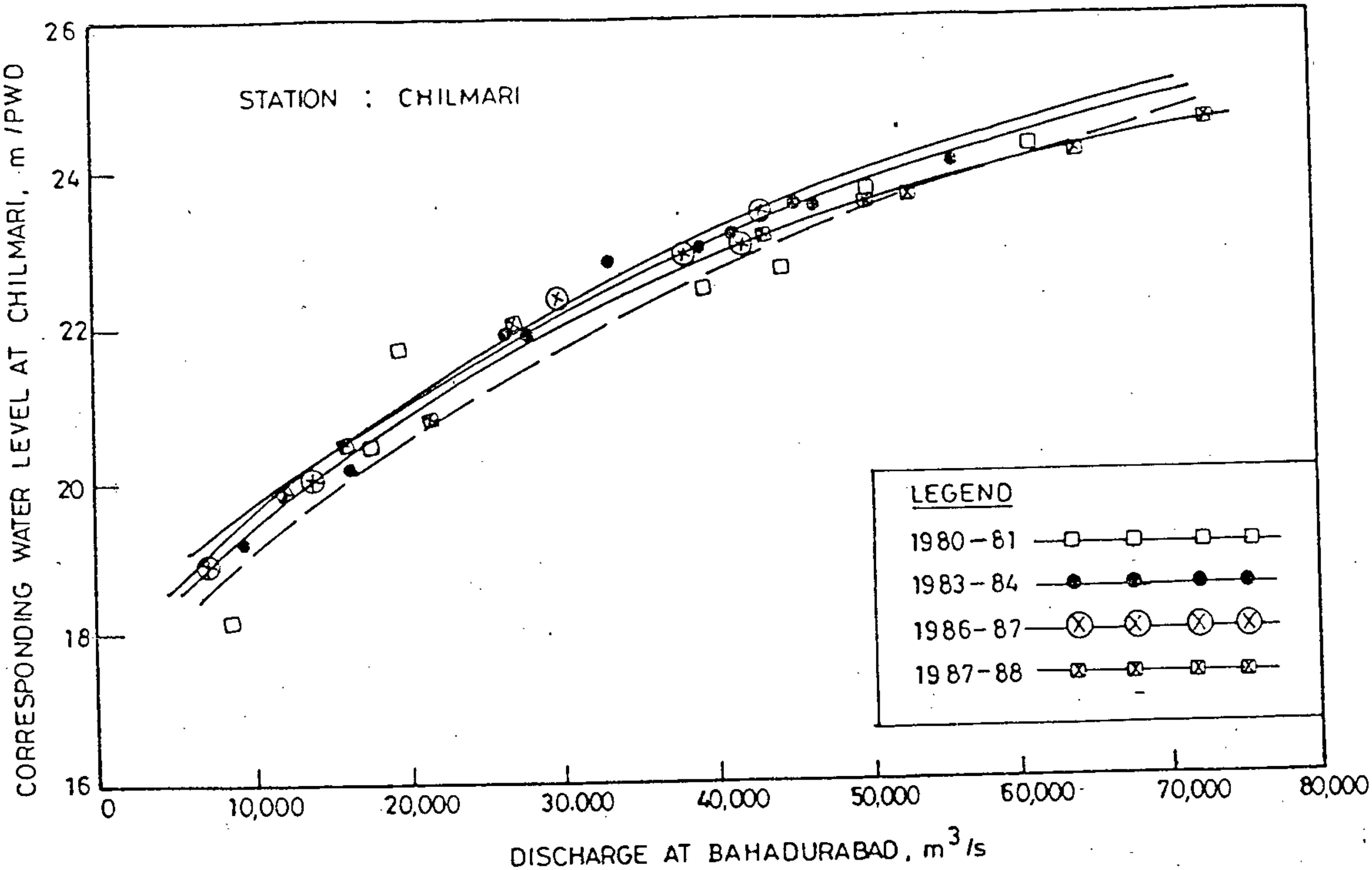

FIG. 5.2.4(b) VARIATION OF WATER LEVEL AT CHILMARI WITH DISCHARGE (1980-81, 1983-84, 1986-87, 1987-88)

Table 5.1.1

Section J-4

Year	1965-66	1976-77	1978-79	1980-81	1983-84	1985-86
Cross-sectional Area near bank level (ft^2)	279500	248850	261252	241840	243040	226600
Effective width near bank level (ft)	32650	19750	16470	15700	22500	25300
Total width near bank level (ft)	40000	25000	25000	25000	25500	30500
Average depth (ft)	8.56	15.20	15.86	15.40	15.40	17.77
Mean bed level with respect to PWD datum	21.44	14.80	14.14	14.60	14.60	12.23

Table 5.1.2

Section J-7

Year	1965-66	1976-77	1978-79	1980-81	1983-84	1985-86
Cross-sectional Area near bank level (ft^2)	310965	294400	296490	439870	314850	268500
Effective width near bank level (ft)	23200	18950	17250	27350	25650	22550
Total width near bank level (ft)	45000	42000	42000	40000	39300	39300
Average depth (ft)	13.40	15.53	17.19	16.08	12.27	11.90
Mean bed level with respect to PWD datum	26.60	24.47	22.81	23.92	27.73	28.10

Table 5.1.3

Section J-9

Year	1965-66	1976-77	1978-79	1980-81	1983-84	1985-86
Cross-sectional area near bank level (ft^2)	308165	384968	379884	297811	411298	387932
Effective width near bank level (ft)	23050	37750	33225	24355	28850	31200
Total width near bank level (ft)	51000	51000	50000	50000	49700	49500
Average depth (ft)	13.37	10.19	11.43	12.22	14.25	12.43
Mean bed level with respect to IWD datum	31.63	34.81	33.57	32.78	30.75	32.57

Table 5.1.4

Section J-14

Year	1965-66	1976-77	1978-79	1980-81	1983-84	1985-86
Cross-sectional area near bank level (ft^2)	533600	498870	462180	441124	471550	494750
Effective width near bank level (ft)	45200	43000	45600	41880	40225	38900
Total width near bank level (ft)	56300	55000	55000	54600	55000	55000
Average depth (ft)	11.80	11.60	10.14	10.53	11.72	12.72
Mean bed level with respect to PWD datum	53.20	53.04	54.86	54.47	53.28	52.28

Table 5.1.5

Section J-16

Year	1965-66	1976-77	1978-79	1980-81	1983-84	1985-86
Cross-sectional area near bank level (ft^2)	347875	399300	320754	360714	350345	430160
Effective width near bank level (ft)	26225	34650	30700	30800	25950	26800
Total width near bank level (ft)	50000	50000	50000	50000	50000	50000
Average depth (ft)	13.26	11.52	10.45	11.71	13.50	16.05
Mean bed level with respect to PWD datum	61.74	63.48	64.55	63.29	61.50	58.95

Table 5.3.1

Section J-4

Year	Area in Erosion(ft^2)	Area in Deposition (ft^2)
1965-66 - 1976-77	198250	198760
1978-79 - 1980-81	115326	116665
1983-84 - 1985-86	159534	184222
1965-66 - 1985-86	109545	116053

Table 5.3.2

Section J-7

Year	Area in Erosion(ft^2)	Area in Deposition (ft^2)
1965-66 - 1976-77	219321	258598
1976-77 - 1978-79	95356	96034
1978-79 - 1980-81	234464	68678
1980-81 - 1983-84	120237	171295
1983-84 - 1985-86	118249	180325
1965-66 - 1985-86	234226	273749

Table 5.3.3

Section J-9

Year	Area in Erosion(ft^2)	Area in Deposition(ft^2)
1965-66 - 1976-77	251795	364287
1976-77 - 1978-79	97728	138237
1978-79 - 1980-81	117507	241553
1980-81 - 1983-84	271253	130496
1983-84 - 1985-86	185725	159220
1965-66 - 1985-86	214291	223230

Table 5.3.4
Section J-14

Year	Area in Erosion (ft^2)	Area in Deposition (ft^2)
1965-66 - 1976-77	361070	328260
1976-77 - 1978-79	197732	138251
1978-79 - 1980-81	195237	187624
1980-81 - 1983-84	236035	170752
1983-84 - 1985-86	191726	170405
1965-66 - 1985-86	338750	269530

Table 5.3.5
Section J-16

Year	Area in Erosion (ft^2)	Area in Deposition (ft^2)
1965-66 - 1976-77	257022	229753
1976-77 - 1978-79	131712	188225
1978-79 - 1980-81	122710	94552
1980-81 - 1983-84	200254	194320
1983-84 - 1985-86	211230	131532
1965-66 - 1985-86	219525	143755

CHAPTER-6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the analysis based on hydraulic and hydro-geometric data for a few selected stations of river Brahmaputra-Jamuna it has been apparant that no systematic change in any of the parameters studied occur at any section. The analysis has however shown certain overall trend in the variation of some of the parameters and following conclusions are drawn.

1. The study of cross-sectional area and effective width showed that no systematic change in cross-sectional area and effective width has occured during the period 1965-66 to 1985-86 on any of the sections. Cross-sectional area and effective width near bank level decreased in sections J-4, J-7, J-14 and increased in sections J-9, J-16, during the period 1965-66 to 1985-86. The cross-sectional area and effective width with respect to different elevations, however, changed in different ways at different elevations.

2. In most of the sections cross-sectional area increased during certain period and decreased during some other period.

3. Total width of sections J-9, J-14 and J-16 has remained more or less same during the period 1965-66 to 1985-86. During the same period however the total width of section J-4 and J-7 has decreased.

4. Study of mean bed levels indicates that there is a trend of rise in the mean bed level in sections J-7, J-9 and fall in sections J-4, J-14 and J-16 during the period 1965-66 to 1985-86. The highest rise (about 1.5 ft) and fall (about 9.0 feet) of mean bed level occured at the sections J-7 (near Sirajganj) and J-4 (near Porabari) respectively.
5. Study of changes in water level for same discharge over the years from 1964-65 to 1987-88 has shown an overall rising trend in all the stations.
6. Study of change in area due to erosion and deposition shows that there has been net erosion in sections J-14, J-16 and net deposition in section J-7 over the period from 1965-66 to 1985-86. For sections J-4 and J-9 erosion and deposition has more or less balanced each other.

6.2 Recommendations for further study

To have a better picture on the changes in river section characteristics of Brahmaputra-Jamuna the following suggestions are made for further study :

1. All the cross-sections should be studied taking data over a long period.
2. Water level and discharge data should be collected for more stations over a large number of years. As discharge is recorded only at Bahadurabad station by Bangladesh Water Development Board, procedure need to be developed to relate the discharge at Bahadurabad with water level and discharge at other stations.

3. The bank line movement need to be studied along with study of cross-sectional parameters.

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