INTER BASIN WATER TRANSFER AND WATER BALANCE STUDY OF MAHANADI BASIN AT MANIBHADRA

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

WATER RESOURCES DEVELOPMENT (CIVIL)

By

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CANDIDATE'S DECLARATION

I hereby certify that the dissertation entitled "**INTER BASIN WATER TRANSFER AND WATER BALANCE STUDY OF MAHANADI BASIN AT MANIBHADRA**", is being submitted by me in partial fulfillment of requirement for the award of degree of "Master of Technology in Water Resources Development" at the Water Resources Development Training Centre, Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period from July, 2003 to June 2004 under the supervision of Dr. Nayan Sharma, Professor and Dr. M.L. Kansal, Associate Professor, WRDTC, Indian Institute of Technology, Roorkee.

The matter embodied in this dissertation has not been submitted for the award of any other Degree.

Place: Roorkee

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This is to certify that above statement made by the candidate is correct to the best of our knowledge.

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CONTENTS

SYNOPSIS

According to the National Water Policy 2002 of India, water resources development and management will have to be for hydrological unit such as drainage basin as a whole or a sub-basin, taking into account surface and ground waters for sustainable use incorporating quantity and environmental consideration. All individual development projects and proposals should be formulated and considered within the frame work of such an overall plan keeping in view the existing agreements/awards for a basin or sub-basin so that the best possible combination of options can be selected and sustained. Water should be made available to water short areas by transfer from other areas including transfers from one river basin to another, if necessary, based on a national perspective, after taking into account the requirements of all areas/basins. Integrated and coordinated development of surface water and ground water resources and their conjunctive use, should be envisaged right from the project planning stage and should form an integral part of the project implementation. Irrigation intensity should be such as to extend the benefits of irrigation to as large a number of farm families as possible, keeping in view the needs to maximize production. Irrigation being largest consumer of fresh water, the aim should be to get optimal productivity per unit of water. In view of the vital importance of water for human and animal life, for maintaining ecological balance and for economic and development activities of all kinds, and considering its increasing scarcity, the planning and management of this resource and its optimal and equitable use has becomes a matter of the utmost urgency.

To identify water surplus and water deficit in the basin, water balance studies are generally carried out on an annual basis, and are usually done on a lumped manner. In conventional water balance studies it may not be possible to consider, the aerial variability and distribution of the surface and ground water available and its use in the basin, with respect to the locations of the various reservoirs and water use points.

The objective of the present study is the water balance study of Mahanadi Basin at Manibhadra. The Mahanadi - Godavari links is one of the 16 proposed links of Penisular component of NWDA. In the present study the balancing has been done on monthly basis with 75% and 90% dependability with and without ground water in the basin. The Mahanadi is an inter state river in India having 10 sub-basins and the catchment area is 141,589 km^2. From the monthly 75% and 90% dependability flow series the annual surface water potential found out are 32717 MCM and 22654 MCM respectively. The utilizable groundwater is 2602.92 MCM. The total water requirement to meet different needs comes to 36126.90 MCM.

From the water balance study it has been found that the Mahanadi basin at Manibhadra is a deficit basin and to solve this problem it is suggested to develop the groundwater potential, so that the deficit condition can be meet.

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Ha	Hectare
Kg	Kilogram
Km	Killometer
MCM	Million cubic meters
mm	Millimeters
ham	Hectormeters
MW	Megawatts
MWH	Megawatt hours
TCM ft	Thousands million cubic feet

ABBREVIATIONS

CCA	Culturable command area
G&D	Gauge and discharge
LINDO	Linear Programming solve soft ware package
NWDA	National Water Development Agency, the society under the Ministry of Water Resources, Government of India.
NCIWRD	The National Commission for Integrated Water Resources Development under the Ministry of Water Resources, Government of India.

INTRODUCTION

1.1 GENERAL

Water is not only essential for the existence of all forms of life on the earth and other planets (if any) but it is also a vehicle for the progress and prosperity of a nation. Water is also required in almost all the activities of man and livestock for drinking and municipal use, for irrigation to meet the growing food and fiber needs, for industries, hydropower generation, environmental purposes, navigation and recreation. The development, conservation and use of water, therefore, forms one of the main elements in the country's development planning. In India, rainfall is confined to the monsoon season and is unevenly distributed both in space and time even during the monsoon season. As a result, frequent droughts and floods affect the country's economy. Thus, it is desired to store and divert water for later use in space and time. Also, it is required to harness the water resources in a most scientific and efficient manner.

Water balance is a quantitative study of balancing available inflow with the different uses to be met from thereof. It gives an idea about the surplus and deficit of resources within a stipulated time period.

1.2 OBJECTIVE OF THE STUDY

The main objective of this study is as follows:

1. To study the proposed inter-basin transfer of water through various links in India and study the characteristic of one of the proposed link, i.e. Mahanadi Godavari, and in particular at Mahanadi at Manibhadra.
2. To carry out the hydrological analysis and the estimation of surface water potential with 75% and 90% dependability yield.
3. To estimate the water demands the year 2050 for different uses.
4. Estimation of groundwater potential.
5. Monthly water balance study for 75% and 90% dependable water year with groundwater.
6. Monthly water balance study for 75% and 90% dependable water year without groundwater.

1.3 ORGANIZATION OF THE DISSERTATION

Chapter –1: Introduction. This chapter describes the objectives of the proposed study.

Chapter –2: Inter Basin Water Transfer in India – A Review: This chapter describes about the historical background of the inter-basin water transfer in India and the ongoing works being carried out by NWDA and other National Agencies. Out of the various proposed links, in the present study the water balance study about one of the proposed links i.e., Mahanadi – Godavari links has been considered.

Chapter – 3: General Features and Characteristics of Mahanadi Basins : This chapter describes the general features of Mahanadi Basin which is focus of the present study.

Chapter – 4: Hydrological Analysis and Water Availability : In this chapter the hydrological analysis of the historical river flow data has been reported and the water availability for the 75% and 90% dependability has been estimated. Also the utilizable groundwater has been estimated.

Chapter – 5: Estimation of Water Requirements : In this chapter the demands for various proposes has been estimated for the year 2050. The various uses are irrigation, domestic, industrial uses, environmental uses which are considered in the study.

Chapter – 6: Estimation of Water Balance by 2050 and discussion of results: This chapter describes the monthwise water balance for year 2050 based in the availability of water and demand as carried out in chapter – 4 and 5. Such water balance has been estimated with 75% and 90% dependability flow with and without groundwater availability.

Chapter – 7: Conclusions: From the water balance study it has been found that the water balance by 2050 will be deficit. So the Mahanadi Basin will be a deficit basin. Under such condition it is desired to develop the groundwater resources so that the deficit conditions can be meet. Also further study are required with additional data and one should carried out the effect of irrigation efficiency in the Mahanadi Basin.

INTER BASIN WATER TRANSFER IN INDIA – A REVIEW

2.1 GENERAL

There are large disparities in rainfall and river flows in different parts of the country with space and time. In view of the disparities in different river basins of India, inter-basin transfer of water has been receiving attention from Indian water resources planners for diversion of water from surplus river basins to water deficit basins.

For a sustainable development, perspective planning taking into account various issues of population growth vis-à-vis increased food and fiber requirements through agricultural development, irrigation needs, industrial growth, domestic needs, etc. requires commitment to future generation.

Though river basin could be a basic unit for water resources planning, this may not lead to the optimal utilization of the surplus water resources in various regions of the country. There are many basins in the country that would be surplus in water resources even in the ultimate stage of development while other basins would already facing situation of water shortage. For meeting the shortages water in deficit regions, long distance inter-basin transfer of water may be necessary.

This will lead to equitable distribution and optimum utilisation of our water resources. Long distance transfer of water are characterized by;

(a) The large amount of water involved
(b) Long distance covered.
(c) Higher costs involved.
(d) Their likely impact on environmental aspects which will need to be considered.

The national water policy adopted by the Govt. of India states that, "Resources planning in the case of water has to be done for a hydrological unit such as a drainage basin as whole or a sub-basin. All individual development projects and proposals should be formulated by the states and considered within the frame work of such an over all plan for a basin or sub-basin so that the best possible combinations of options can be made".

Inter-basin transfer of water will make an important impact for equitable distribution and optimum utilization of water which otherwise is going waste to the sea. With the present efforts for ensuring enhanced food production, there is a possibility that long distance inter-basin water transfer through interlinking of rivers will becomes an unshakable part of India n strategy for having a strong agriculture base, and to bridge the gap between demand and supply.

2.2 RAINFALL

Rainfall in India is dependent largely on the South-West and North-East monsoons, on shallow cyclonic depressions and disturbance and on violent local storms. Most of the rainfall takes place under the influence of southwest monsoon between June to September expect in Tamilnadu and some other southern states, where it occurs under the influence of North-East monsoon during October and November.

The rainfall shows great variations, unequal seasonal distribution, still more unequal geographical distribution and frequent departures from the normal. As much as 21 percent of the area of the country receives less than 750 millimeter (mm) of rain annually, while 15 percent receives rainfall in excess of 1500 mm. It generally excess 1000 mm in areas towards the east of longitude 78^0E. It extends to 2500 mm along almost the entire east coast and over most of Assam and Sub-Himalayan West Bengal. The large areas of peninsular India have rainfall less than 600 mm. Actual rainfall of less than 500 mm is experienced in Western Rajasthan and adjoining parts of Gujrat, Harayana and Punjab. Rainfall is equally low in the interior of the Deccan plateau east of the Sahyadris. The third area is low precipitation is around Leh in Kashmir. Rest of the country receives moderates rainfall. Snowfall is restricted to the Himalayan region (Fig. 2.1).

2.3 FLOOD AND DROUGHT

There is vast variation both in space and time in the availability of water in different regions of the country, some areas suffering from flood and other areas facing actuate water shortage. Flood and drought occur in vast areas of the country, transcending state boundaries. The drought prone area in the country is of the overall above of 51.12 Mha, while the area susceptible to floods is around 40 million hectares. The states of Karnataka, Tamilnadu, Rajastha, Gujrat, Andhra Pradesh and

Maharashtra are the worst drought prone states. The State of Uttar Pradesh, Bihar, West Bengal, Orissa and Assam face the severe flood problems (Fig. 2.2).

2.4 PER CAPITA WATER AVAILABILITY

The utilizable surface and ground water flows in the country are 690 and 432 BCM respectively giving total of 1122 BCM. It was decided that in the year 2000 the average per capita availability was 1122 m^3 for the country as a whole (Fig. 2.3).

2.5 HISTORICAL PERSPECTIVE OF INTER-BASIN TRANSFER

2.5.1 Cotton's comprehensive Navigation Plan

Lt. General Sir Arthur Cotton was the pioneer of water resources development in India, starting in1839 and was held in high esteem. Cotton was very enthusiastic regarding water resources development as in his judgment it could earn fabulous returns. He categorically stated that waster in India is more valuable than gold (Cotton, 1885). Water resource development had been undertaken for irrigation and had been found to be very profitable. He considered that beside irrigation, development of water resources for navigation was of utmost importance as this would contribute to increase of production and economic development through improved transportation (Cotton, 1884; 1885; Rao, 1975). He accordingly developed a plan to interlink the rivers of India.

Canal navigation was a very profitable activity in England at that time. Attracted by the profitability of navigation in England and irrigation in India, and reposing trust in the authority of Cotton, two companies planned irrigation and navigation on a grandiose scale. Their aim was link Karachi to Calcutta via Kanpur and Cuttak to Bhattkal, Manglore and Madars. But all that they were able to achieve was series of disconnected waterways, like Midnapore Canal, Orissa high Level Canal and the Kurnool –Cudappah Canal the venture ended in a failure and had to be taken over by the Government (GOI, 1972, pp. 60).

2.5.2 National Water Grid

Dr. K.L. Rao, one of the most eminent engineers of independent India, and the Union Minister of Irrigation proposed a National Water Grid for providing and ameliorating the spatial disparities in the availability of the water in different river basins. It was based on work done earlier in the Central Water and Power Commission. It was noted that the general location of regions of surplus water and deficit is such that transbasin transfer will be necessary from north and east towards west and south.

Accordingly, Ganga-Cauvery link, off taking near Patna, after it has been joined by its major tributaries Ghagra, Gandak and Sone, passing enroute through the basins of the Sone, Narmada. Tapi, Godavari, Kishna , and Pennar, was to connect Ganga and Cauvery link essentially envisaged the withdrawal of 1680cumecs (60,000) of the flood flows near Patna for about 150 days in a year and pumping about 1400cumecs (50,000 cusecs) of this water over ha head of 449 meters (1800ft) for transfer to the peninsular region and utilizing the remaining 2800 cumecs (10,000 cusecs) in the Ganga Basin itself. The proposal envisaged utilization of 2.59 million hectare meters of Ganga waters to bring under irrigation an additional area of 4.1 M.ha. Dr Rao had also proposed few additional links like (a) Brahmaputra – Ganga link to transfer 1800 to 3000cumecs with a lift of 12 to 15 m,(b) Link transferring 300cumecs of Mahanadi waters Southern wards (c) canal from the Narmada to Gujarat Western Rajasthan with a lift of 275m and, (d) links from rivers of the Western Ghats towards east. The National Water Grid was also considered a network for inland navigation. Dr Rao had estimated has proposals to cost about Rs.12,500 crores (NWDA,1998).

A UNDP team was invited to study the proposal and it was endorsed (Rao, 1975 pp 221). However, later study of the National Water Grid by the Central Water Commission, found that the Ganga-Cauvery link alone will cost about Rs.70,000 crores at 1995 prices. The annual cost including cost of power would be around Rs 30,000 per hectare. While the present NWDA proposal for interlinking rivers between Ganga and Cauvery at 1996 prices has been estimated to cost only around Rs 15,000 per hectare annually (NWDA1998). Therefore the scheme has not been pursued.

2.5.3 Garland Canal

Captain Dastur, an air pilot, proposed an impressionistic idea to interconnect the rivers of India. His idea was to form a Garland around the peninsula and a long canal at the foothills of the Himalayas. The two were proposed to be joined by proposed to be joined by pipes. The Himalayan canal was to be 4200 km long 300 m wide at constant bed level between 335m. and 457m. above mean sea level aligned along the southern slopes of the Himalayas running from Ravi in the west to

Brahmaputra and beyond in the east. It was visualized to be fed by the Himalayas to the same level as the bed of the canal, with another 40 lakes beyond Brahmaputra. The proposal envisaged a storage capacity of 247 BCM to control and distribute 617 BCM of water. The Central and Southern Garland canal was proposed at a constant elevation of between 244 m. and 305m. above the mean sea level, with about 200 lakes having a storage capacity of about 497 BCM to control and distribute 864 BCM of water, The Himalayan and Garland canals were proposed to be interconnected at two points , Delhi and Patna, by five 3.7m. diameter pipes to transfer the water, fig3.2 Captain Dastur claimed that all the surplus water in the country will be utilised to irrigate 219 M. ha. About 16.8 million volunteers were expected to complete the work in 3 to 4 years. The proposals was estimated to cost Rs. 24,095 crores at 1974 prices (NWDA,1998). Apparently the Ministry could not give sound opinion on its own. Committees were therefore set up, the proposal was detailed and then estimating that it will cost about Rs.12 million crores (1979) was dropped.

2.6 EXAMPLES OF SOME INTER-BASIN TRANSFER SCHEMES IMPLEMENTED IN INDIA

The earliest successful work of this category is Shenbagavilli Anicut built about two centuries ago by some enterprising Chieftains in the Sivangiri Zamin in the head reaches of Vaippar basin which a is minor river south of Vaigai. A small Wear called the west. A short canal cutting across the ridge was excavated. This scheme serves 4423 ha. Under 40 minor irrigation tanks.

The Periyar Project is the most notable endeavor of the last century in transbasin division. A masonry gravity dam 47.28 m high constructed across a gorge on west flowing Periyar river. A 1740 m long tunnel with a discharging capacity of 40.75 m^3/s has been driven across the mountain barrier to convey the waters eastwards to Vaigai basin. The project was commissioned in 1895 and provided irrigation to 57,923 ha initially which has since been extended to 81,69 ha. There is also a power station of 140 M.W capacity.

2.6.1 Parambikulam Aliyar

Project is a complex multi-basin multi-purpose project seven streams. Five flowing towards the west and two towards the east, have been dammed and their reservoirs interlinked by tunnels. The water is ultimately delivered to drought prone areas in Coimbatore district of Tamilnadu and the Chittur Reaf Kerala state. The command area for irrigation is presently 1,62,000 ha, though water can normally be given to each zone in alternate years. There is a total of 185 M.W power generation capacity at four power houses. This project was built during the second and third five year plans.

2.6.2 Kurnool Cudappa Canal

This scheme was started by a private company in 1863 at 8.23 m high Anicut was built on river Tungbhadra upstream of Kurnool town. A 304 km long canal with a capacity of 84.9 m^3/s at its head extends from Krishna to Pennar basin and irrigation 52.746 ha . The scheme was taken by Govt of India in 1882.

2.6.3 The Telgu Ganga Project

This project has been recently implemented primarily to meet the pressing need water supply Chennai metropolitan area. It brings Krishan waters from Srisailam reservoir through an open canal:, first to Somasila reservoir in Pennar Valley. This involves rick upto 35m deep. From Somasila water is taken through a 45 km canal to Kanduleru and thence to Poondi reservoir in Tamilnadu through another 200 km long. By mutual agreement 12 TMC or 0.34 BCM of water will be delivered to Tamilnadu at eh border from Krishna basin. This will greatly augment the water supply for Chennai city. The canal also irrigation 2.33 lakh ha in Andhra Pradesh enroute.

The project was made possible by Maharashtra and Karnatka and Andhra Pradesh voluntarily foregoing 5 T.M.C. each from their entitlement. This project as a fine example not only of hydraulic engineering but also of inter-state co-operation.

2.6.4 Inter Sub-basin transfers in the Indus basin

Under the Indus Water Treaty , waters of three eastern rivers viz, Sutlej, Beas and Ravi were allocated to India. As land to be benefited in India lies mostly to the east and south of these rivers, the rivers, had to be interlinked and waters conveyed to canal systems serving vast tracts in India. The main storage on Sutlej is at Bhakra, while that on Beas is at Pong. Bhakra system provides irrigation to 26.3 lakh ha of new area besides stabilization of existing irrigation on 9 lakh ha. The aggregate generating capacity on Bhakra Nagak Project in 1354 M.W. Direct benefits of Pong include 16 lakh ha irrigation and 360.M.W. Power. A diversion dam, Pandoh, 140 km upstream of Pong on Beas, enables diversion of water Beas to Bhakra reservoir, and generates 165 M.W of power on the way, The Beas-Sutlej link is 37.25 km long of which 25.45 km is tunnel through difficult rock formations. The capacity of the tunnel is 254.7 m^3./s Ranjit Sagar now nearing completion on Ravi will provide additional water to Beas, and also generate a large block of power. It is no exaggeration to say that the Indus Valley water resources development has transformed the entire economy of Punjab, Haryana and Rajasthan So far as power benefits are concerned , these are shared by the entire Northern grid.

The projects cited above have been highly beneficent and have not resulted in any noticeable environmental damage. The major reservoirs at Bhakra, Pong and Ranjit Sagar dam, and involve considerable rehabilitation problems which have been largely satisfactorily resolved

2.7 LARGE SCALE WATER TRANSFERS IN OTHER COUNTRIES

Many scheme of large scale water transfer have been planned, and some of them implemented in other countries.

Sixteen major inter-basin transfer schemes have been implemented in Canda, mainly for hydro-power. In USA, the longest and best known schemes implemented so far in California State Water Project. It regulates the one seasonal flow in Sacramento river in North California by storage reservoir and transfer it Southwards to meet domestic industrial and irrigation demands. The major conveyance feature is 715 km long California aqueduct which includes a 1000 m lift pumping facility. There are major plans for transfer of water from Missouri –Mississippi system to the high plain region in Colorado, Kansas, New Maxico, Oklahoma and Texas States. These have not been implemented, as with nearly stable population and surplus food production there is no imperative needs to do so. The most ambitious plan is the North America Water and Power Alliance (NAWTPA) which would link water rich Alaska/ and North Western Canada and ultimately transfer 136 BCM to Central and Western USA and finally to Mexico. Although it was initially received favourably in USA, the chances of its implementation are considered remote.

Large scale water transfer schemes were implemented, and were under consideration in erstwhile USSR. These included transfer of water from North flowing rivers to Volga basin and large scale diversion of Siberian river waters for irrigation of Central Asian Republics and Kazakhstan. The former had the objective of maintaining and increasing the sturgeon fish population (yielding valuable caviar) which is suffering due to reduced discharge form kolga into the Caspian sea. The latter would irrigation 4.5 Im ha , but would cause large environmental changes which have to be studied.

Similarly, in China there are schemes existing from ancient times, and supplemented by modern construction which transfer water from south to north through Grand canal to the Eastern Coast.

There schemes give us confidence in planning schemes in our country. At the same time lesion have to be learnt from actual performance, economically and environmentally .The decision in India should be made taking la holistic view of the India situation.

2.8 NATIONAL PERSPECTIVE

The idea to interlink the rivers to overcome the spatial imbalance persisted. A National perspective for water Development was framed in August 1980 by the Ministry of Water Resources. It was discussed at various governmental levels and a National Water Development Agency was set up as an Autonomous Society to promote scientific development for optimum utilisation of water resources of the country and in Particular to carry out detailed studies in the context of the National Perspective. Considerable work has been done and the National Perspective had been development in great detail. On the basis of these studies, briefly described as follows, the proposal is critically examined.

2.8.1 Approach

The broard approach adopted in the National Perspective is as follows: (NWDA, 1998)

i) Existing uses have been kept undisturbed

ii) Normally water development under the existing legal and constitutional framework is assumed to take place fully by the turn of the country.

iii) The development envisaged is within the frame work of all the existing agreements between the states.

iv) While planning inter-basin and inter-state transfer of water, reasonable needs of the basin states for the foreseeable future have been kept in view and provided for.

v) Most efficient use of land and water in the existing irrigation and hydro power station has been kept as a principal objective to be achieved.

2.8.2 National Perspective Plan

The national perspective plan comprises of two components, namely:

i) Himalayan Rivers Development, and

ii) Peninsular Rivers Development

NWDA identified 30 links, 16 Himalayan, 14 Peninsular, Both to be connected at a later date. Pre-feasibility studies completed for all. Feasibility reports covering technical feasibility and economic viability completed for 6 links. Ongoing 24. In 2003 – 2 nos.; 2004 -11 nos.; 2005 -11 nos. Out of 30 links some links involve lifting of water though height up to 120 m. Some links will run North to South and a few in each to West direction in navigable open canals and through a few tunnels. Flow carrying capacity of each link various from 100 to 1500 m^3/s. The pre-feasibility reports is in progress. Present cost of project is estimated Rs. 5,60,000 crores.

2.8.3 Himalayan Rivers Development

The Himalayan Rivers Component envisage construction of storages on the main Ganga and Brahmaputra rivers and their principal tributaries in India and Nepal so as to conserve monsoon flows for flood control, hydro-power generation and irrigation. Interlinking canal systems will be provided to transfer surplus flows of the Kosi, Gandak and Ghagra to the west. In addition, Brahmaputra-Ganga link will be constructed for augmenting dry weather flows of the Ganga. Surplus flow available on account of inter-linking of Ganga and Yamuna are proposed to be transferred to the drought prone area of Haryana, Rajasthan and Gujrat. The scheme will also enable large areas in South Uttar Pradesh and South Bihar to obtain irrigation benefits from the Ganga with a moderate lift at less that 30 m. further, all land in Tarai area of Nepal would also get irrigation apart from generation of about 30 million kw of hydro-power in Nepal and India. It will also provide flood moderation in the Ganga, Brahmaputra system. With this proposal, about 140 BCM of additional water would be available from these river system for irrigating an estimated 22 million ha. In the Ganga Brahmaputra basin, apart from Haryana, Punjab, Rajasthan and Gujarat. It would also provide 1120cumecs (40,000 cusecs) to Calcutta Port and would provide navigation facilities across the country. The scheme will benefit not only parts of India but also neighbours Nepal and Bangladesh (NWDA 1998) Fig.2.4.

2.8.4 Peninsular Rivers Component

Amongst the peninsular rivers, the Mahanadi and Godavari are considered to have sizeable surplus after meeting the existing and projected needs of the states within these basins It is therefore, proposed to provided terminal storages on Mahanadi and Godavari rivers to divert surplus flows of Mahanadi to the Godavari system and to further transfer surplus from the Godavari systems to water short rivers namely , Krishna, Pennar and Cauvery. the link from Mahanadi to Godavari will be along the east coast and will not involve any lift, the link between Godavari and Krishna will be the partly by gravity and partly in the ultimate stages, by lifts of the order of 120 m (maximum), the transfer of the waters would enable irrigation in drought prone areas of Maharashtra , Karnataka, Andhra Pradesh land of Tamil Nadu by successive exchange. The component is shown in Fig. 2.5.

The second component of this proposal to divert a part of the waters of the west flowing rivers of Kerala to the east for irrigation the drought prone areas of Tamil Nadu, apart from bringing new areas under irrigation in Kerala.

The third component is to construct storages and inter-link small rivers flowing along the west coast, north of Bombay and south of Tapi. This will enable partial release of waters from Tapi and Narmada which will enable extensions of irrigation to Saurashtra and Kutch areas. It will also enable provision of extra water to meet the growing needs of metropolitan area of Bombay as well as providing irrigation to the costal areas in the Maharashtra.

The fourth component envisages inter-linking of the southern tributaries of the Yamuna like the Ken and the Chambal in addition to construction of small storages on intermediate tributaries and a dam on the Yamuna at Panchnad . This will enable irrigation in Ujjain and Indore areas of Madhya Pradesh as well as Upper areas in Rajasthan.

The proposal of Peninsular River development will enable additional use of about 84 BCM of water to benefit the states of Orissa , Andhra Pradesh, Mahaasrashtra Karnataka, Tamil Nadu, Madhya Pradesh etc. This will provide additional irrigation benefits of over 13 million ha.

The distinctive features of the National Perspective is that the transfer of water is essentially by gravity and only in small reaches by lift not exceeding 120m.

2.8.5 Follow up Action of National Perspective Plan

1980: National Perspective Plan Prepared by ministry of Irrigation and Central Water Commission (CWC) with two components (a) Himalayan river components (b) Peninsular river components.

1982: National Water Development Agency (NWDA) was setup by the Government for detailed planning of the link proposal as preparing the feasibility reports of the various components.

1996: Govt. of India Ministry of Water Resources constituted a ten member high power commission for preparation of an integrated water resources development plan under the chairman of Dr. J. V. K. Rao former member planning committee.

Dr. Bharat Singh: Retired Vice Chancellor University of Roorkee was one of the member of that committee and Chairman of Working group on (Inter Basin Transfer) with five other members

August 2002: On the above independence day president of India **Mr. A. P. J. Abdul Kalam** declare for interlinking of rivers and for the first time the issue came up to the supremecourt.

31-10-2002 Justics B. N. Kirpal the then Chief Justices of India issued notice to the centre and the states for interlinking of rives. By the order of supreme court the high power tax force was formed as follows.

Chairman: Shri Suresh Prabhu, in cabinet Minister's rank.

Vice-Chairman: Dr. C. C. Patel, former Secretary MoWR

Member Secretary: Dr. C. D. Tjhatte, former secretary MoWR

Full time member Dr. Kasturirangan (NRSA); Dr. Pachuri (TERI); G. C. Sahu former E in C, Orissa; K. V. Kamat

(ICICI), B. G. Verghese (Journalist), B. R. Chauhan (Law),

Piyush Goval (CA), Hari Babu MLA.

Co-ordenator – M. Gopalkrishnan, former Member CWC.

Milestones for ILR Programme

Action plan –I: End April 2003, giving schedule for Frs, DPRs, costs, construction benefits.

Action Plan-II: End July 2003, giving funding options, method of cost recovery.

Meting of chief minister for developing co-operation and consensus-May/June, 2003.

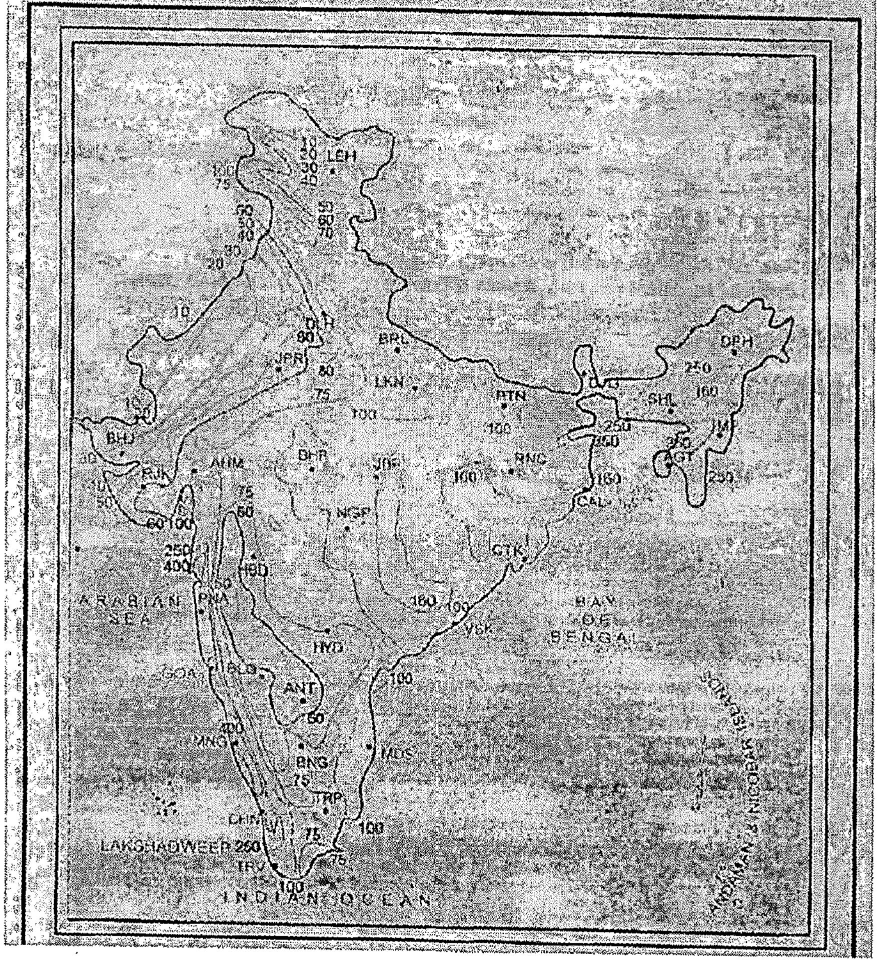
Completion of feasibility studies: December 2005.

Completion of DPRs: December 2006

Start of construction: December 2007.

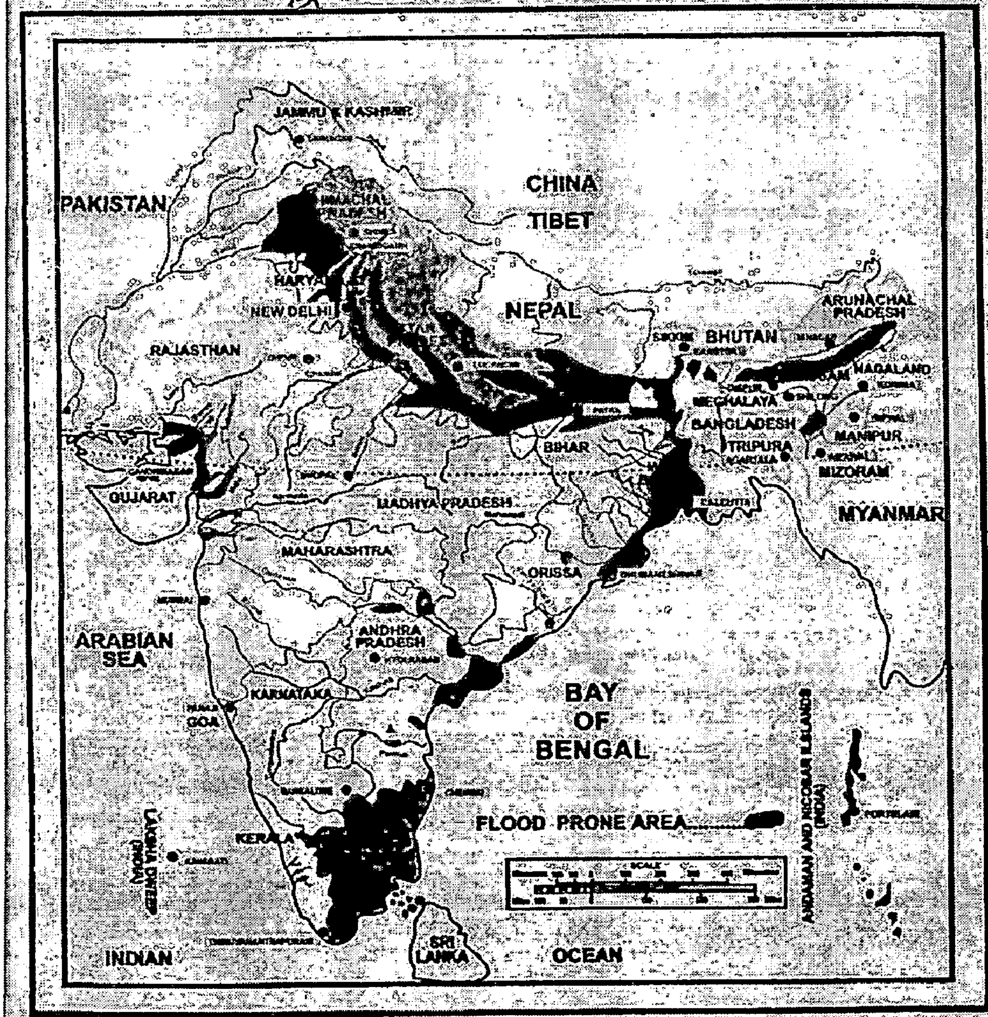
Completion: December 2016.

FIG 2.1: NORMAL ANNUAL RAINFALL ISOHYETS



Annual average rainfall of India : 1170mm
Sub-Himalayan, Assam, West Bengal : >1500mm
Rajasthan Gujrat, Harayan and Punjab : <500mm

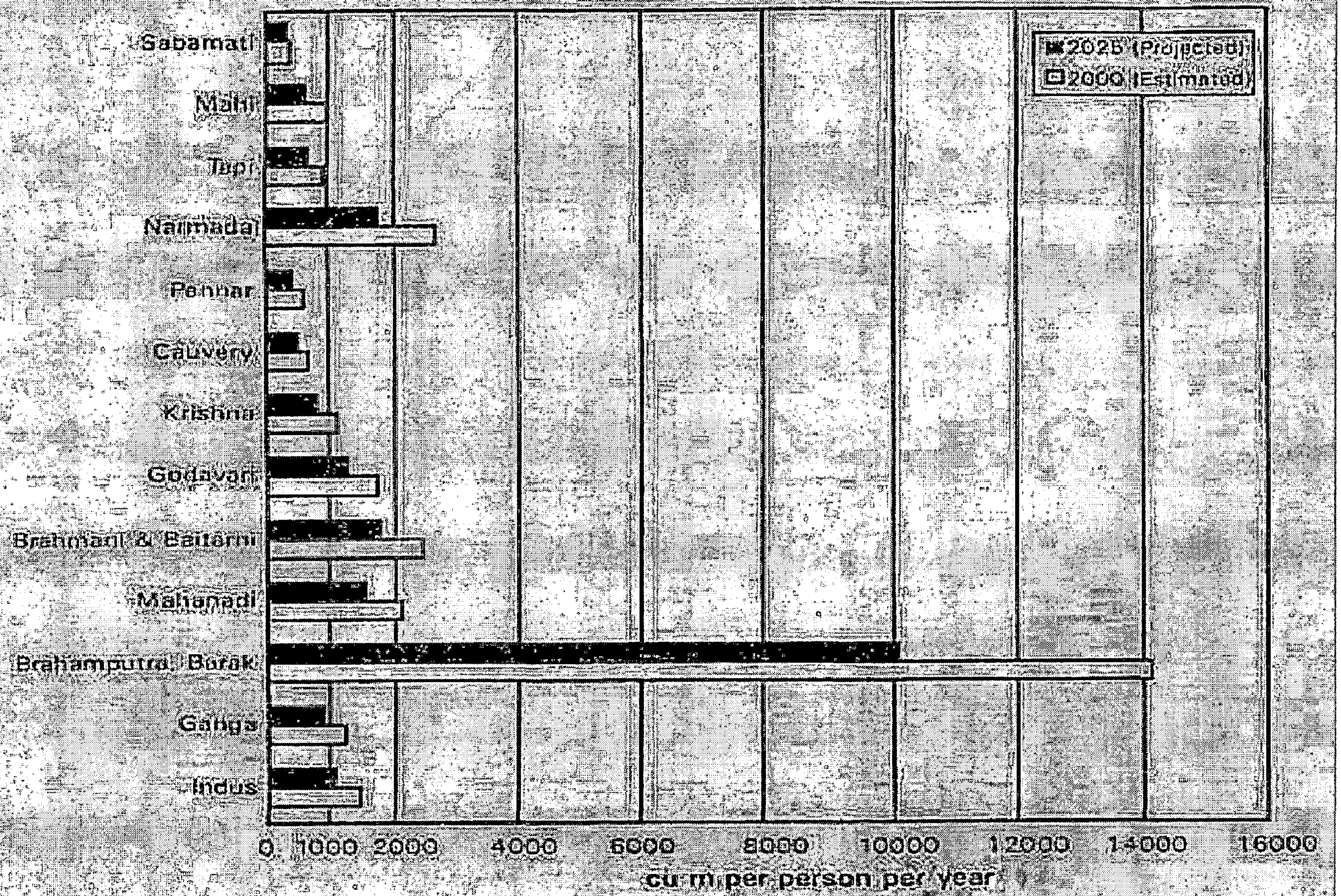
FIG 2.2 : FLOOD PRONE AREAS



Source : Central Water Commission

- Flood Effected Area : 40 MHA
  (Flood effected states : Utter Pradesh, Bihar, Orissa, Assam & West Bengal)
- Drought Effected Area : 51.12 MHA
  (Drought effected states : Karnatak, Tamilnadu, Rajashthan, Gujarat, Andhra Pradesh & Maharashtra)

Basinwise Per Capita Water Availability



Source : Ministry of Water Resources, 2002

2.4

FIG ~~7.5~~ : PROPOSED LINKS UNDER STUDY
(HIMALAYAN COMPONENT)

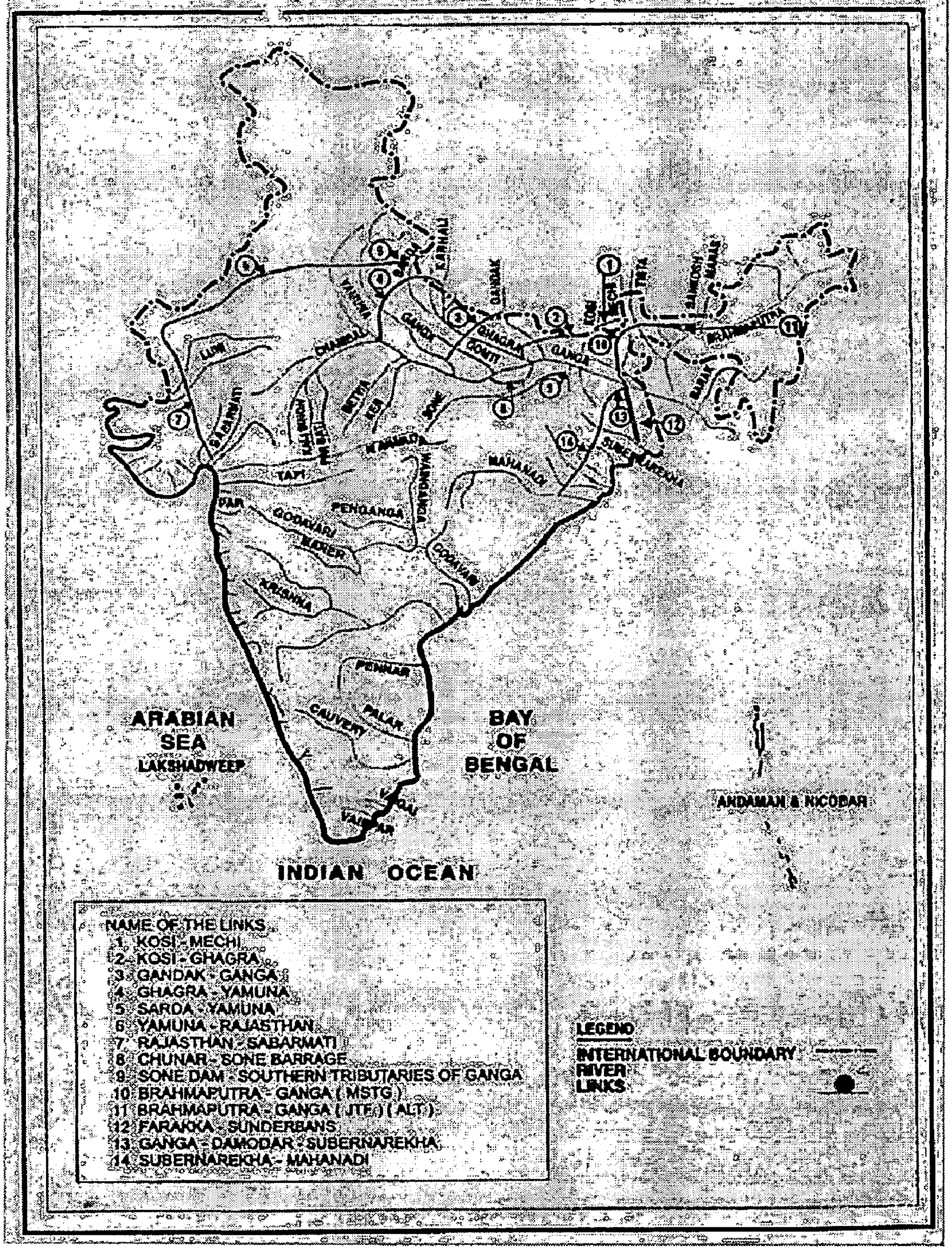
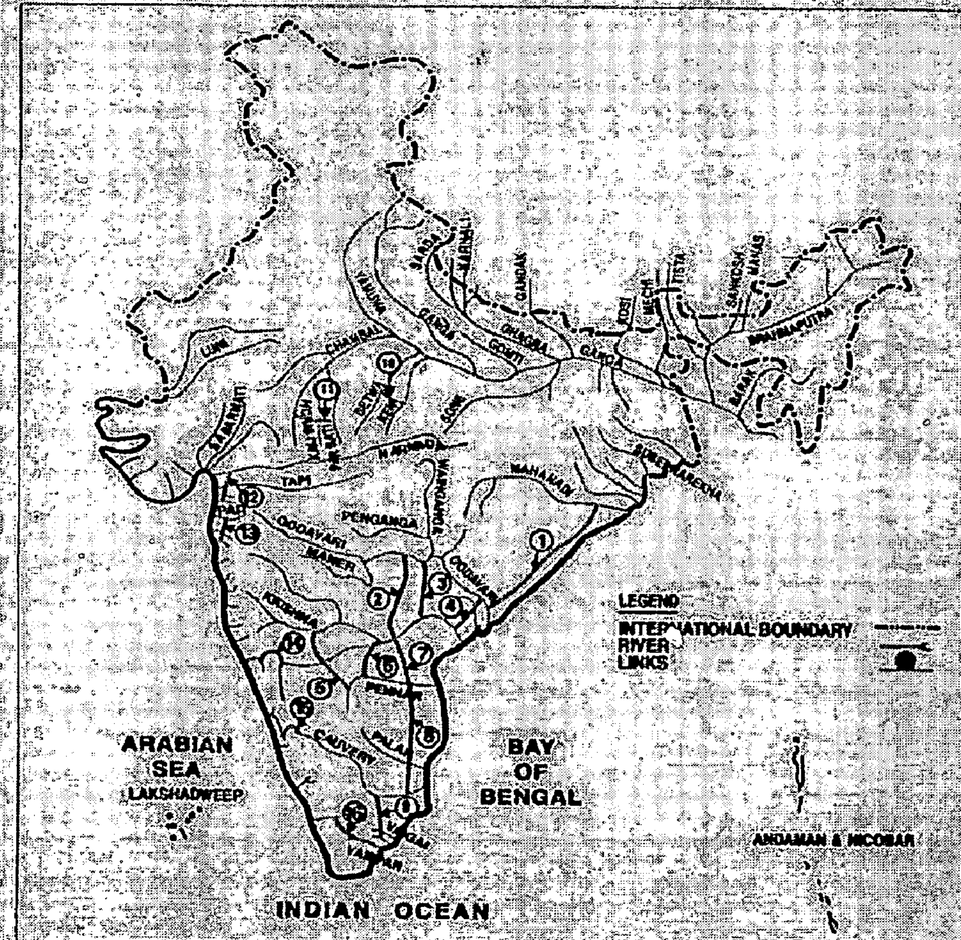


FIG ~~7.4~~ 2-5 : PROPOSED LINKS UNDER STUDY (PENINSULAR COMPONENT)



NAME OF THE LINKS

1. MAHANADI (MANIBHADRA) - GODAVARI (DOWLAISWARAM)
2. GODAVARI (INCHAMPALLI) - KRISHNA (NAGARJUNASAGAR)
3. GODAVARI (INCHAMPALLI LOW DAM) - KRISHNA (NAGARJUNASAGAR TAIL POND)
4. GODAVARI (POLAVARAM) - KRISHNA (VIJAYAWADA)
5. KRISHNA (ALMATTI) - PENNAR
6. KRISHNA (SRISAILAM) - PENNAR
7. KRISHNA (NAGARJUNASAGAR) - PENNAR (SOMASILA)
8. PENNAR (SOMASILA) - CAUVERY (GRAND ANICUT)
9. CAUVERY (KATTALAI) - VAIGAI - GUNDAR
10. KEN - BETWA
11. PARBATI - KALISINDH - CHAMBAL
12. PAR - TAPI - NARMADA
13. DAMANGANGA - PINJAL
14. BEDTI - VARDA
15. NETRAVATI - HEMAVATI
16. PAMBA - ACHANKOVIL - VAIPPAR

GENERAL FEATURES AND CHARACTERISTICS OF MAHANADI RIVER BASIN AND METHODOLOGY FOR WATER BALANCE STUDY

3.1 MAHANADI RIVER BASIN

The Mahanadi is one of the major rivers in the country flowing towards east and draining into the Bay of Bengal. Among the Peninsular rives, it ranks second to the Godavari in respect of water potential.

The Mahanadi rises in a pool, 6 km from Kharsiya village near Nagri town in Raipur district of M. P. at an elevation of 457m. The Mahanadi basin extends over an area of 1,41,589 km^2 and lies between East longitudes 80^{0}30' and 84^{0}50' and North latitudes 19^{0}20' and 23^0 35'. The basin lies in the North-Eastern parts of Deccan plate and covers large areas in Madhya Pradesh and Orissa and comparatively small areas in the states of Bihar and Maharashtra. The total length of the river from its origin to outfall in the sea is about 851 km of which 357 km is in Madhya Pradesh and 494 km is in Orissa. State wise distribution of the basin area is given in Table 3.1.

Table 3.1 The State Wise Coverage of Drainage Area of the River Mahanadi

State	Area in sq km	% to total basin
1. M. P. & Chhatishgarah	75136	53.24
2. Orissa	65628	46.50
3. Maharastra	238	0.17
4. Jharkhand	132	0.09

The Mahanadi basin is bounded in the North by the Central India hills, in the South and East by the Eastern Ghats and in the West by Maikala range. The basin is roughly circular in shape with a diameter of about 4000 km. and an exit passage 60 km. wide and 160 km. long. The entire Mahanadi basin has been divided in 10 hydrological units or sub-basins as follows.

1. Sheonath Sub basin
2. Jonk sub-basin
3. Hasden sub-basin

4. Mand sub-basin
5. IB sub-basin
6. Upper Mahanadi basin (comprising of free catchment of Mahanadi from source to Hirakud excluding catchments of Sheonath, Jonk, Hasden, Mand and IB)
7. Ong sub basin
8. Tel sub-basin
9. Middle Mahanadi Sub basin (Comprising of free catchment of Mahanadi free on Hirakud to Tikarpara excluding Ong and Tel.
10. Lower Mahanadi Sub-basin (From Tikerapara to Sea).

The Mahanadi river basin and its principal sub-basins are shown in Fig. 3.1 to 3.6.

3.2 MAHANADI BASIN UPTO MANIBHADRA SITE

The catchment area of the Mahanadi river form its source to Manibhadra lies between North latitudes $19^{0}20'$ and $23^{0}35'$ and East latitudes $80^{0}30'$ and $84^{0}50'$. The catchment area of this basin upto Manibhadra is 125820 sq.km. which consists of the catchment areas of Sheonath sub-basin (30761 sq.km.), Jonk sub-basin (3484 sq.km.), Hasdeo sub-basin (9856 sq.km.) Mand sub-basin (5200 sq.km.), Ib sub-basin (12447) sq.km.), Upper Mahanadi sub-basin (21652 sq.km.), Ong sub-basin (5128 sq.km.), Middle Mahanadi sub-basin (12654 sq.km.), Tel sub-basin (22818 sq.km.) and Lower Mahanadi sub-basin upto Manibhadra (1820 sq.km.)

Brief description of various sub-basin upto Manibhadra is as follows: The river Sheonath is the largest tributary of the Mahanadi. It rises in the midst of undulating country with numerous small groups of hills at an elevation of about 532 m near kotgal in the Chandrapur district of Maharashtra and flows for about 383 km to join the Mahanadi on its left near Searinsrayan. Some of its important tributaries are Hamp and Apra the Seonath drains an area of about 30761 km^2 which is nearly 25% of the total area of the Mahanadi basin. The sub-basin lies between north latitudes of 20^{0}-21' and 22^{0}-40' and east longitudes of 80^{0}-26' and 82^{0}-34'.

The river Jonk originates in the Nawapara Tahsil of the Kalahandi district of Orissa state at an elevation of 700 m after traversing a distance of about 182 km in Kalahandi (Orissa) & Raipur (M. P.) it outfalls into the river Mahanadi near Sheorinarayan in Madhya Pradesh upstream of the Hirakud dam. It drains an area of about 3484 Km^2 which is nearly 2.46% of the total area of the Mahanadi basin. The sub-basin lies between the north latitude of 20^0-28' and $21^0$44' and the east longitude of 82^0-20' and 82^0-51'.

The river Hasdeo rises at an elevation of about 900 m at a place nearly 10 km. north of Raipur town in the Sarguja district of Madhya Pradesh. The Hasdeo flows for about 320 km to join the Mahanadi from its left near village Chanderpur. It drains an area of about 9856 Km^2 which is nearly 6.96% of Mahanadi catchment area. The sub-basin lies between north latitudes of 21^0-44' to 23^0-24' and east longitudes of 82^0-04' to 83^0-0'.

The river Mand rises in the Sarguja district of Madhya Pradesh at an elevation of about 700m and flows for about 220 km. to its confluence with the Mahanadi on its left near Chandarpur. The river has a catchment area of abut 5200 km^2, which is nearly 3.7% of Mahanadi basin. The sub-basin lies between the north latitudes of 21^0-40' to 23^0-03' and east longitudes of 82^0-41' to 83^0-37'.

The Ib rises in the hills near pandrapat, at an elevation of about 762m. in the Raigarh District of Madhya Pradesh. It is about 251 km. long and falls into the Hirakud Reservoir on its left. The total area drained by the Ib is 12447 km^2 which is nearly 8.798% of Mahanadi basin. For about 40 km. in the lower reaches, a part of the catchment is submerged by the reservoir.

The basin spread over 23 districts out of the total 30 districts of the state as shown in Table 3.2.

Table 3.2: Distribution of Mahanadi Basin

Sl. No.	Name of the basin	Total geographical area (sq km)	Basin area in district (sq km)	Percentage of basin area to district area
1	Bargarh	5834	5834	100
2	Bolangir	6569	6569	100
3	Boudh	3444	3444	100
4	Jagatsinghpur	1973	1973	100
5	Nawapara	3408	3408	100
6	Sonepur	2344	2344	100
7	Jharsuguda	2200	2200	100
8	Cuttack	3733	3713.58	99.48
9	Kalahandi	8364	8088.43	96.7
10	Nayagarh	4242	4079.3	96.16
11	Sambalpur	6698	6111.78	91.25
12	Puri	3051	2780.56	91.14
13	Khurda	2889	2109.42	73.02
14	Sundergarh	9712	5475.66	56.38
15	Kandhamal	7650	3436.39	44.92
16	Kendrapara	2548	1061.13	41.65
17	Angul	6232	1305.96	20.96
18	Nawarangpur	5294	889.78	16.81
19	Dhenkanal	4595	428.83	9.33
20	Deogarh	2784	131.16	4.71
21	Jajpur	2888	128.38	4.45
22	Rayagada	7580	85.67	1.13
23	Ganjam	8706	29.97	0.34
Total		112738	65628	

3.3 TOPOGRAPHY, PHYSIOGRAPHY AND GEOLOGY

The upper reaches of the sub-basin lies in a very undulating plateau and sloping with outcrop of hillocks and eroded mounds. There are distinct ridges and valleys with sloping medium land in between. The south of the plateau is open, but to the East and the West there are a number of hill ranges which have steep slopes as a result of which water from these hills and long ridges ate directly drained to the Manibhadra is continuously sloping towards the main valley and therefore, no drainage congestion is anticipated. The basin up to Manibhadra mainly consists of the eastern and the northern plateau physiographially the land of the basin can be divided into five groups viz.

(i) Hill top & slope

(ii) Upland

(iii) Medium land

(iv) Low land

(v) River banks

The study reveals that the catchments up to Manibhadra mostly comprises of arching terrain and consolidated gneiss rock formation greatly influenced by geomorphic features. Alluvium is also found in the catchment. The hills have igneous and Metamotphic rocks under Gangpur series, the important types being granites granite. Ground water us available In the region of alluvium in confined and unconfined below 300m.

3.4 CLIMATE

The climate of the entire basin is of tropical monsoon type with four distinct seasons as shown in Table 3.3

Table 3.3 Climate of Mahanadi Basin

Summer	March to May
Monsoon	June to Sept.
Post monsoon	Oct. to Nov.
Winter	Dec. to Feb.

3.4.1 Rainfall

Most of the rainfall is received from the South West Monsoon. Depression in the Bay of Bengal affect the basin in the monsoon season causing cyclones and wide spread heavy rain. There are 163 rain gauge stations in and around the basin.

3.4.2 Temperature

There are mainly 9 IMD observatories situated with in the basin. They are Ambikapur, Champo, Kanker, Pendraroad, Raigarh, Raipur, Jharsuguda, Titlagarh and Sambalpur. The average monthly maximum and minimum temperature values for the 6 of the nine observatories is considered in the study and furnished in Table 3.4.

3.4.3 Relative Humidity

Mean monthly maximum and minimum relative humidity values observed at the above six IMD observatories are furnished in Table 3.4.

3.4.4 Wind Velocity

Mean monthly wind velocity values at the above six observatory IMD stations are furnished in Table 3.4.

3.4.5 Sunshine

Monthly maximum and minimum cloud cover data in Oktas for the above six observatory stations are furnished in Table 3.4.

3.4.6 Evapotranspiration

The monthly normal evapotranspiration values of the six observatory IMD stations are furnished in Table 3.4.

Table 3.4 Climatic Parameter

Month	Temperature in ^{0}C		Relative humidity in %		Cloud cover in Oktas.		Wind velocity km/hr.	EP value in mm
	Max.	Min.	Max.	Min.	Max.	Min.		
Jan.	27.25	12.36	67	49	1.5	1.7	2.81	80.4
Feb.	31.05	15.12	58	41	1.3	1.3	3.39	99.2
Mar.	35.17	18.19	50	33	1.6	1.8	3.81	147.6
Apr.	39.52	13.52	34	32	1.7	2.3	4.90	179.0
May.	40.65	26.56	47	32	2.0	2.9	6.37	205.0
Jun	37.64	27.16	67	57	4.9	5.6	7.75	156.2
Jul.	31.56	25.09	84	76	6.4	6.7	7.59	105.2
Aug.	31.31	24.84	85	82	6.5	6.6	7.12	102.5
Sep.	31.85	24.02	81	79	5.3	5.9	5.72	103.9
Oct.	31.61	21.35	75	70	3.3	3.7	3.87	113.0
Nov.	29.85	15.90	68	58	1.7	2.3	2.77	87.2
Dec.	2767	12.15	67	53	1.6	1.6	2.52	72.7

3.5 MANIBHADRA IRRIGATION PROJECT

3.5.1 Salient Features

The salient features of Manibhadra Irrigation project prepared by Govt. of Orissa is given below

(i) Location

States	-	Orissa, Chhatisgarh, Bihar and Maharashtra	
Location	-	At Gania in Nayagarh District of Orissa right side Narasingpur in Cuttak District on left side.	
River		-	Mahanadi
Co-Ordinates	Latitude	-	20^0-27'-30"N.
	Longitude	-	85^0-00-00"E.
Topo Sheet		-	73 H/3, 73 D/15.

(ii) Hydrology

Catchment area Gross	-	1,25,820 sq.km
Catchment area between Hirakud Dam & Manibhadra Dam	-	42,420 sq.km
75% dependable Yield	-	32,556 Million cum
Design Flood	-	80,000cumecs.

3.6 METHODOLOGY USED FOR WATER BALANCE STUDY

The data requirement for water balance study, the total annual irrigation requirement of ongoing, existing and proposed major ,mediums, and minor irrigation projects, exports and imports, rural, urban, livestock population, regeneration from irrigation projects, hydropower use etc, were collected from the various reports of preliminary water balance studies and feasibility reports of Mahanadi Basin from NWDA, and Govt. of Orissa

If the monthly water availability is more than the monthly water utilization in a basin then it is known as water surplus basin and if the monthly utilization is more than the monthly water availability then it is known as water deficit basin.

The following steps were used for computation of water balance on monthly basis for the Mahanadi basin at Manibhadra diversion point [Orissa portion]

1. The total monthly water availability in a basin is computed by summing monthly imports from other basin, monthly regeneration from irrigation,

domestic and industrial water uses, monthly surface water and ground water yields.

a) The monthly imports are computed by distributing of total annual import in the proportion of the importing sub basin.

b) The monthly regeneration from irrigation water uses are computed as 10 per cent to 20 percent of the monthly irrigation water requirements. Regeneration from domestic purpose is computed as 80 percent of the domestic water use. The monthly regeneration from industrial water use is taken as 80 percent of the monthly industrial water use.

c) Surface yield - The monthly surface water yield in the basin is taken in the proportion of the monthly observed run off in the basin.

d) Groundwater - The monthly ground water yield in a basin is computed by distributing the annual ground water yield in the proportion of the monthly irrigation water requirements.

2. The monthly gross water requirements are computed by summing all the monthly water requirements for irrigation, domestic, industrial, environmental and exports.

a) The monthly net irrigation requirements for the proposed major, medium and minor irrigation projects are estimated by using modified penman method. The gross irrigation requirements were estimated by adding 20 percent of the net irrigation requirements for accounting for the reservoir evaporation losses,

Water requirements : The monthly gross irrigation requirements for the existing major, medium and minor irrigation projects are calculated by distributing the annual irrigation requirements of the projects in the same proportion as of the monthly gross irrigation requirements of the proposed irrigation projects

The monthly gross irrigation requirements for the ongoing projects are calculated by distributing the annual irrigation requirements of projects in the same proportion of the monthly irrigation requirements of the proposed irrigation projects.

b) The requirements of domestic consumption in the rural and urban as well as for the livestock has been obtained by projecting the rural, urban and livestock population of the basin to the 2050 AD. The requirements of water per capita per day for rural and urban and livestock population is considered as 70 liters, 200 liters and 50 liters respectively.

c) Due to non availability of the data, the monthly and total water requirements of industrial water use are taken equal to the water requirements for domestic purpose.
d) The monthly environmental water requirements are taken equal to one percent of the monthly surface water available in the basin.
e) Exports: The monthly exports are calculated by distributing the total annual exports in a basin in the proportion of the monthly available of the surface water in that basin.

3.7 ASSESSMENT OF WATER REQUIREMENT

3.7.1 Estimate the domestic, irrigation, and industrial water requirements

3.7.1.1 Domestic water requirements.

Urban	200liters/day/capita
Rural	70 liters/day/capita
Livestock	50 liters/day/capita.

3.7.1.2 Irrigation Water Requirement

Existing	As per projects designed
Ongoing	As per projects reports designed
Future	[water depth in meter]
Major projects	[Irrigation intensity 150%]
Medium projects	[125%]
Minor projects	[100%].

The details of gross command area, culturable command area, designed annual irrigation and utilization for the existing, ongoing and proposed projects were collected for major, medium and minor projects falling in the catchments unto Manibhadra. The designed annual irrigation and utilization in respect of all he existing and ongoing were kept undisturbed in assessing the surface water requirements. The annual irrigation from future identified major, medium and minor projects was assessed considering the irrigation intensities to be 150%, 125% and 100% respectively.

3.7.1.3 Industrial water requirements

The water needs for all existing and future industries located or which are going to be located in the basin upto Manibhadra were collected from respective state Govts. In the absence of information regarding water needs of the industries, the industrial water requirement in that area was assumed to be of the same order as that of the domestic water requirements. The entire industrial water needs was proposed to be met from surface water resources and the 80% of the surface water utilized or to be utilized was considered as regeneration.

These are calculated on the same basis as these for domestic. The industrial water is supplied from the surface water.

3.7.1.4 Evaporation Losses

[i] Existing and ongoing reservoirs = As per actual
[ii]Proposed = 20% of utilizable water

3.8 FINAL WATER BALANCE

Finally, the water balance at the specified site [Manibhadra diversion point] has been done in the following manner
Surplus or deficit = [The 75% water year dependable flow/yield + Ground water availability + Regeneration +Imports] – [Total water needs + Exports].

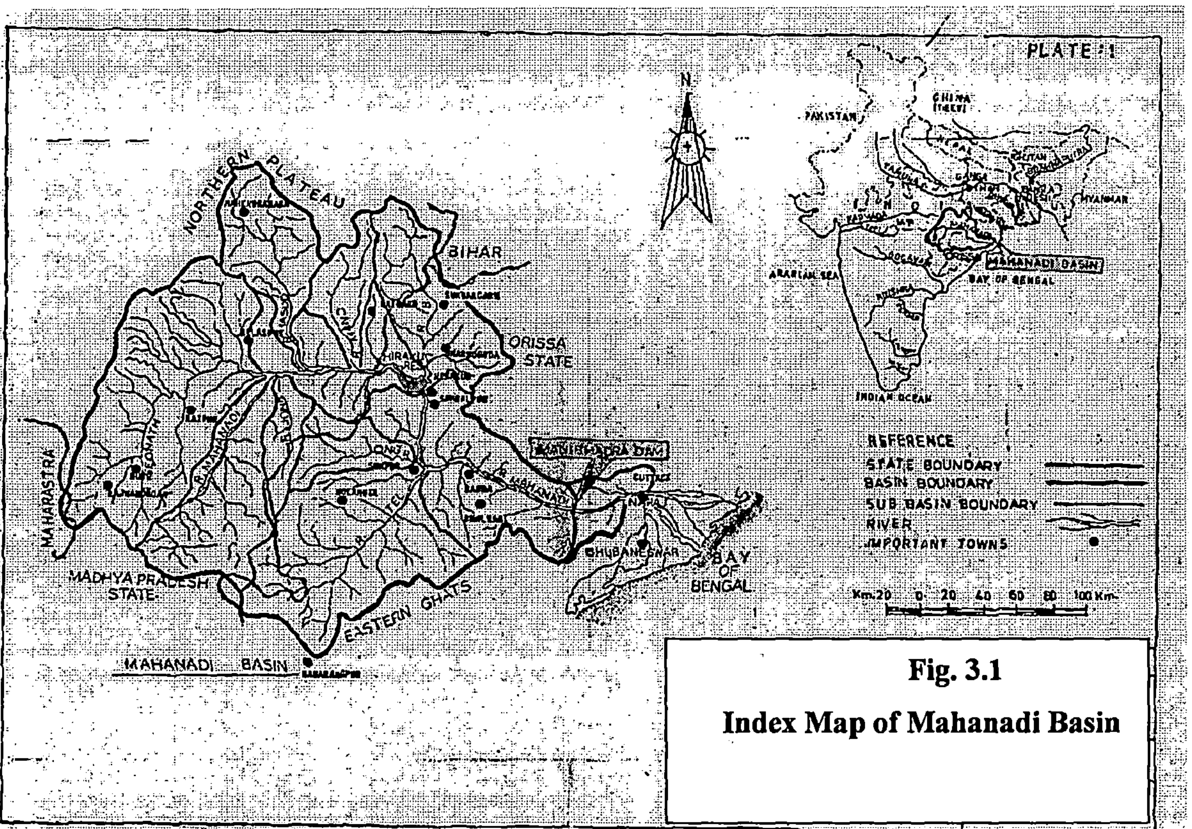


Fig. 3.1

Index Map of Mahanadi Basin

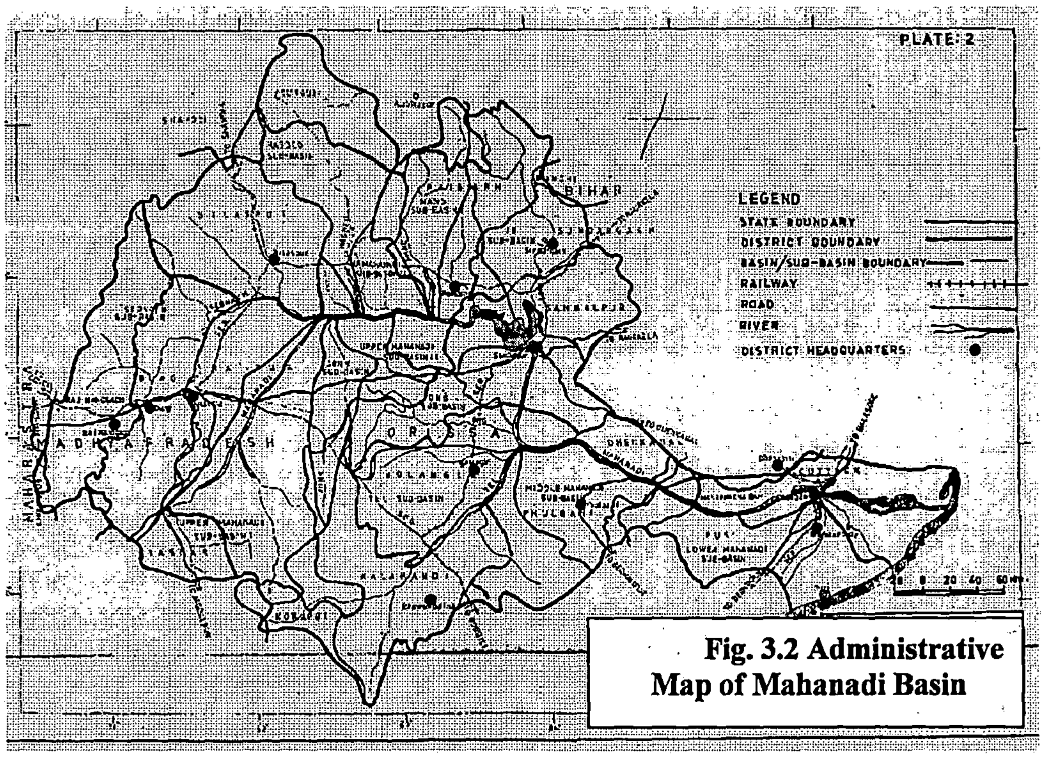


Fig. 3.2 Administrative Map of Mahanadi Basin

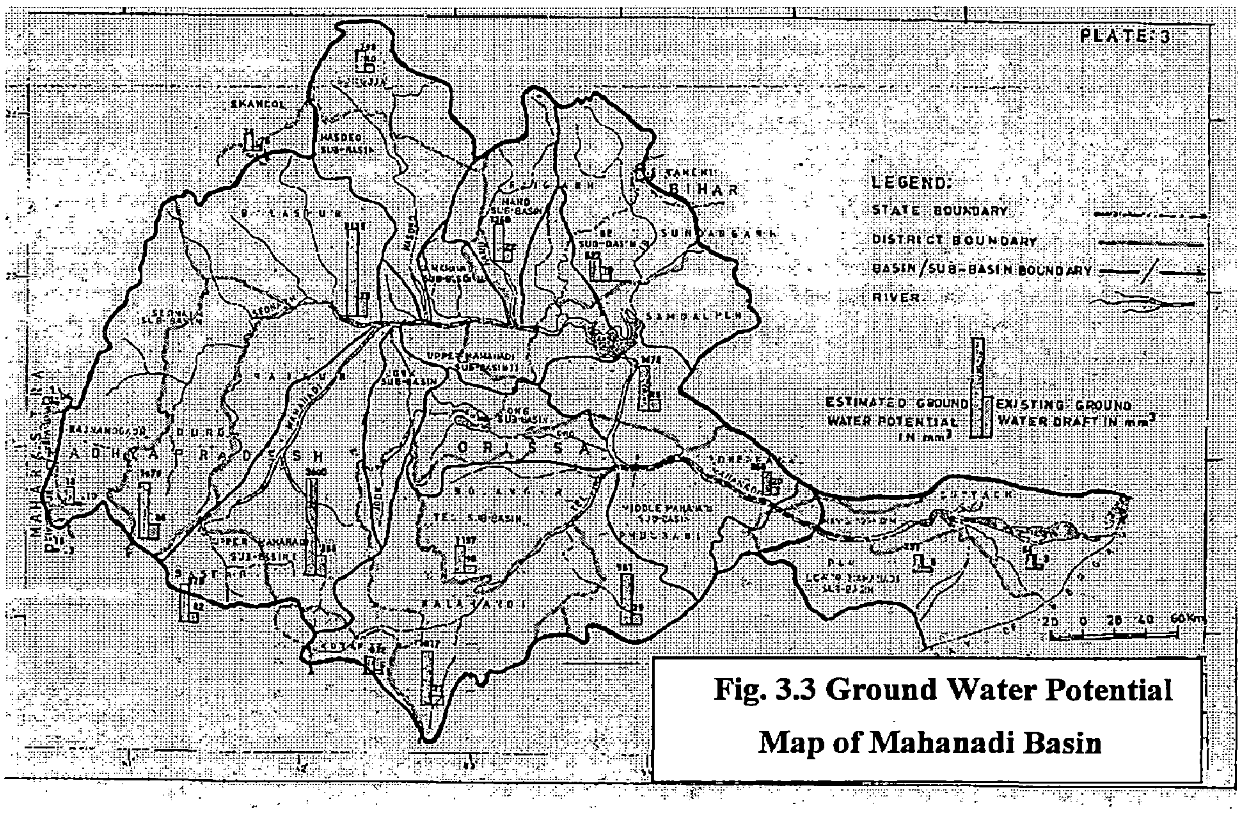


Fig. 3.3 Ground Water Potential Map of Mahanadi Basin

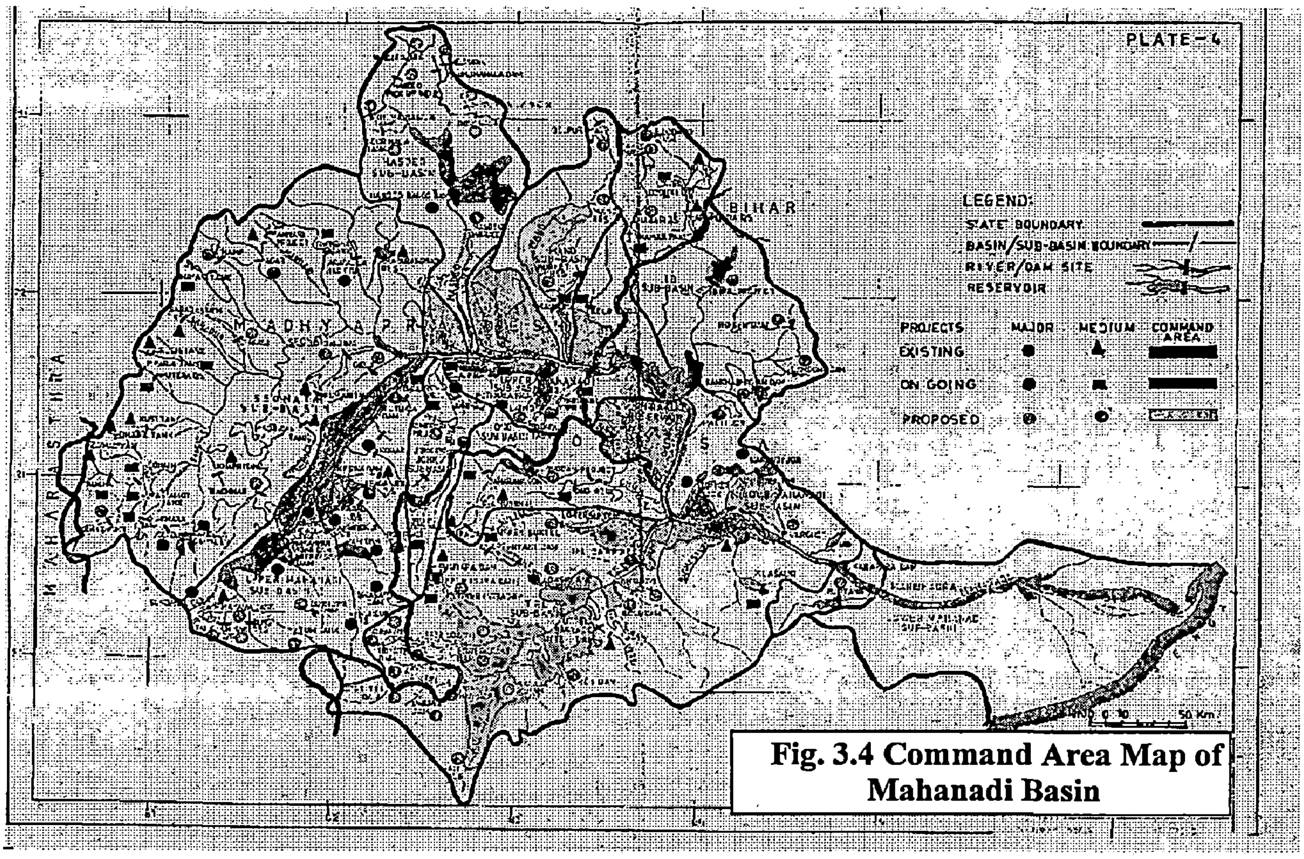


Fig. 3.4 Command Area Map of Mahanadi Basin

HYDROLOGICAL ANALYSIS AND WATER AVAILABILITY

4.1 HYDROLOGICAL ANALYSIS

The inflow data of Mahanadi basin at Manibhadra from 1958 to 1987 has been taken from the report of water availability studies for Mahanadi basin at three sites, final report Vol. 1, 1987, from National Institute of Hydrology (NIH). The National Institute of Hydrology, Roorkee in March, 1986 assessed the monthly yield at Tikkerpara site, just upstream of the proposed Manibhadra site. The water availability at Tikkerpara has been estimated without considering the Hirakud dam effect. The monthly flow series at Tikerpara site after considering the dam effect as recommended by N.I.H. has been adopted as the availability at Manibhadra site for the years 1958 to 1987. The data is reproduced in Table 4.1. The data has been statically analysed using Microsoft Excel sheet. The various statistical parameters of the data all represented in Table 4.2. These parameters are graphically represented in Fig. 4.1 & Fig. 4.2.

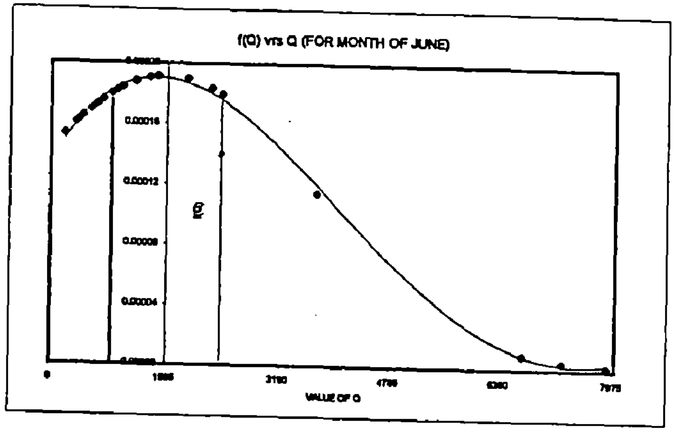
Table 4.2 Abstract of Statistical Parameters

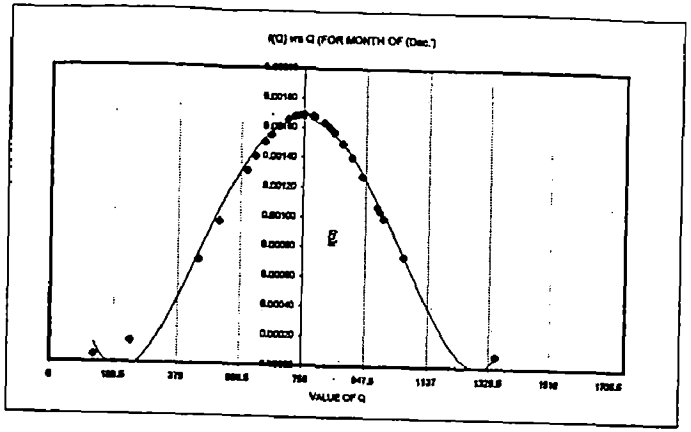
Month	Mean	Standard Deviation	Skewness	Kurtosis
1	2	3	4	5
June	1595.27	2080.34	2.281	4.287
July	11670.30	7283.60	0.968	1.233
August	17831.87	7555.42	-0.060	-0.330
September	12417.20	8734.51	1.216	1.581
October	3866.80	2850.40	1.087	0.170
November	1323.80	677.99	2.261	8.276
December	758.33	236.13	-0.468	1.915
January	731.53	158.80	-0.103	0.996
February	675.67	133.16	-0.007	0.504
March	794.73	130.21	-0.512	2.541
April	714.77	180.74	-0.660	3.143
May	581.90	146.99	-1.165	2.485

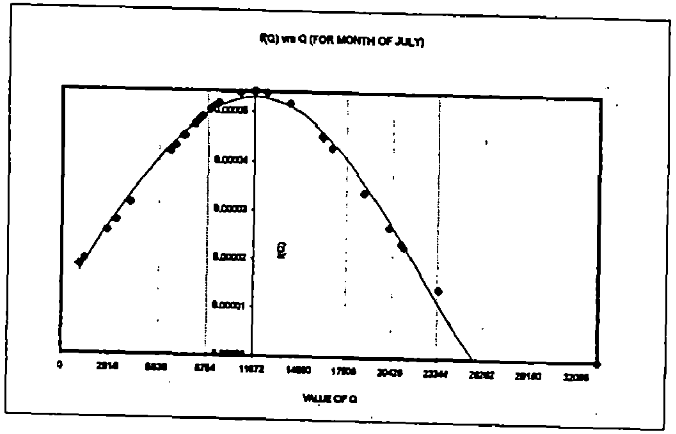
Table 4.1 Data Mahanadi Basin at Manibhadra form 1958 to 1987

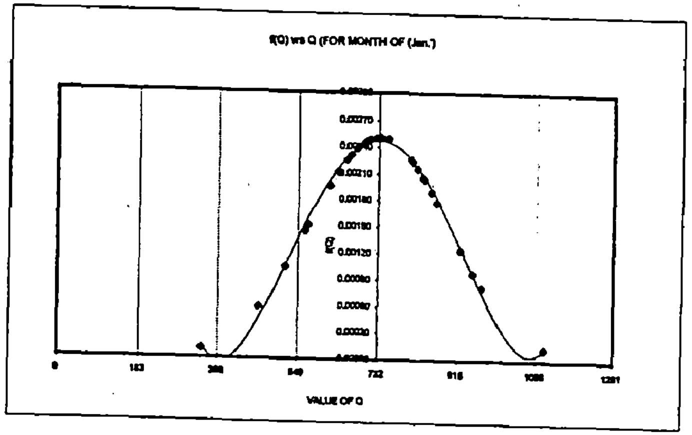
Sl.No	Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1958	819	678	728	734	568	193	20248	14284	19051	8856	1905	936	69000
2	1959	808	590	855	722	613	397	9477	20399	25098	4132	1373	849	65313
3	1960	851	904	798	760	601	923	15952	28955	7324	7347	1537	903	66855
4	1961	949	703	831	729	601	7280	33291	19964	38870	10563	2250	1346	117377
5	1962	667	633	849	653	547	1365	9433	12269	7400	1765	1240	784	37605
6	1963	725	615	830	663	562	1167	9136	15746	19486	5349	1539	836	56654
7	1964	832	620	922	828	593	1883	21167	31927	12498	6572	1940	708	80490
8	1965	680	628	704	645	616	439	8230	2702	6247	1128	807	588	23414
9	1966	620	549	733	745	587	3710	13868	10080	3665	2543	965	760	38825
10	1967	864	817	855	690	615	847	11646	29368	12026	1686	1258	991	61663
11	1968	658	594	758	673	601	375	7990	14674	5089	3903	1010	683	37008
12	1969	709	598	835	665	543	565	12436	14632	4880	1304	1115	735	39017
13	1970	750	683	805	714	606	2354	21016	20484	13400	2771	1219	790	65592
14	1971	751	671	746	669	546	6718	16580	20889	8371	5539	1434	876	63790
15	1972	1117	964	1066	1130	553	446	8334	7243	11968	3192	1736	1002	38751
16	1973	920	831	772	703	560	353	16016	16895	18235	10290	4042	984	70601
17	1974	329	360	388	291	195	653	1064	12225	1631	1032	331	237	18736
18	1975	735	679	683	701	686	402	8403	22490	8227	5254	1956	709	50925
19	1976	521	731	869	709	452	642	8899	23808	11325	1104	649	444	50153
20	1977	712	687	941	799	741	1471	10778	19098	20247	2912	1079	748	60213
21	1978	834	726	764	870	733	726	7305	29682	10673	2117	1068	819	56317
22	1979	460	422	680	178	171	995	2804	10939	1263	973	435	129	19449
23	1980	699	785	983	852	660	1173	18672	10725	29500	1989	961	614	67613
24	1981	682	650	865	939	827	563	3277	15997	8124	3458	911	660	36953
25	1982	565	824	1038	1054	544	578	1395	22264	11158	1554	989	506	42469
26	1983	705	695	720	678	580	358	4123	16641	19010	8502	1202	832	54046
27	1984	639	550	619	550	338	2210	11789	27685	6189	1635	758	729	53691
28	1985	969	887	761	649	775	558	6512	22974	21971	4600	1251	1063	62970
29	1986	804	668	720	616	627	7906	23455	17083	3268	2340	1293	846	59626
30	1987	572	528	724	834	816	608	6813	2834	6322	1594	1461	643	23749
Avg		731.533	675.667	794.73	714.8	582	1595.3	11670.3	17831.9	12417.2	3866.8	1323.8	758.3333	
Std		158.803	133.157	130.21	180.7	147	2080.3	7283.6	7555.42	8734.509	2850.396	677.9935	236.1292	

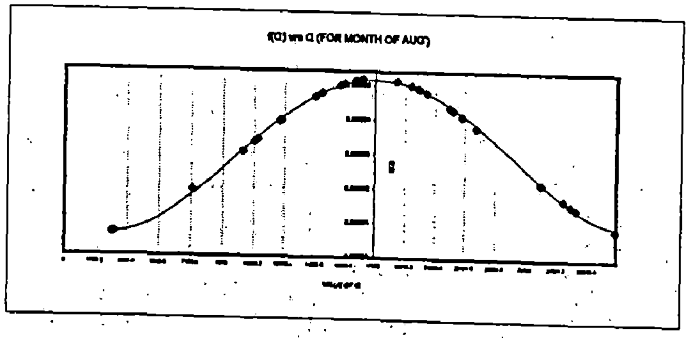
4.1 Normal Distribution

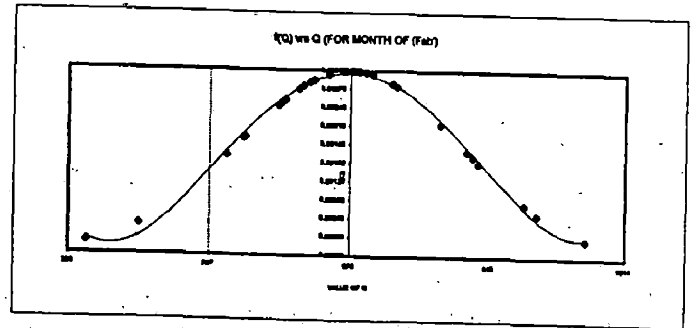




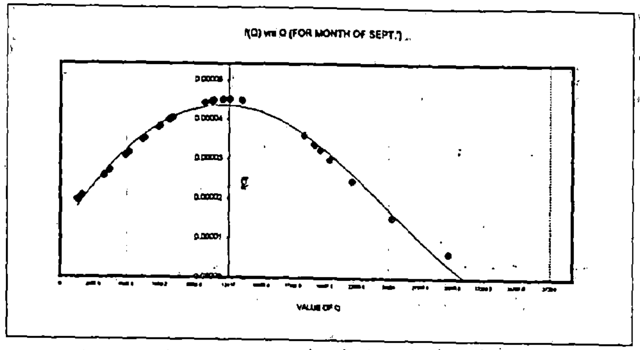


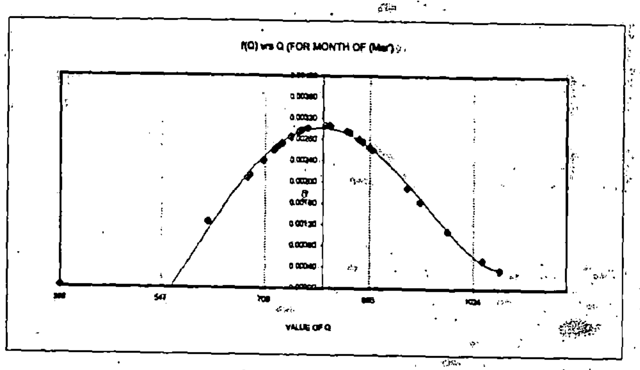


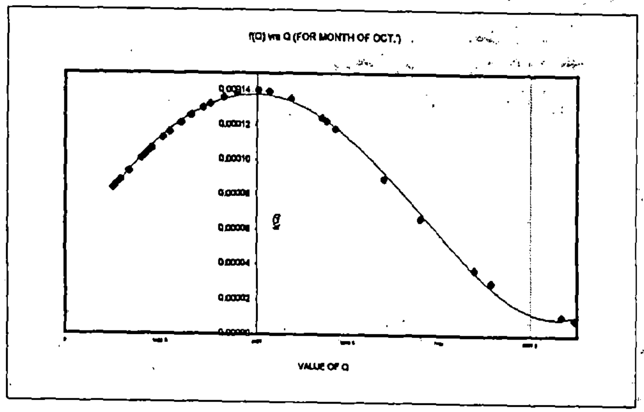


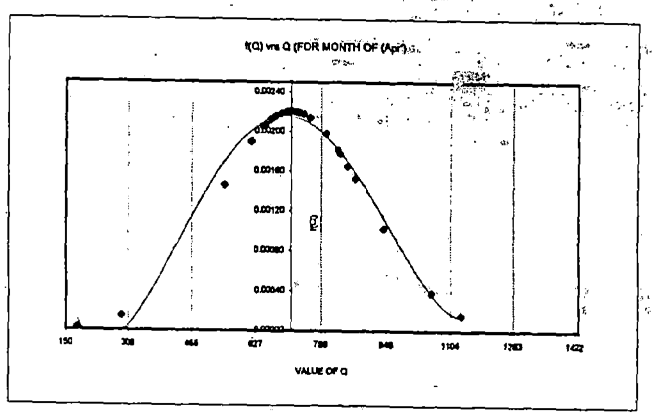


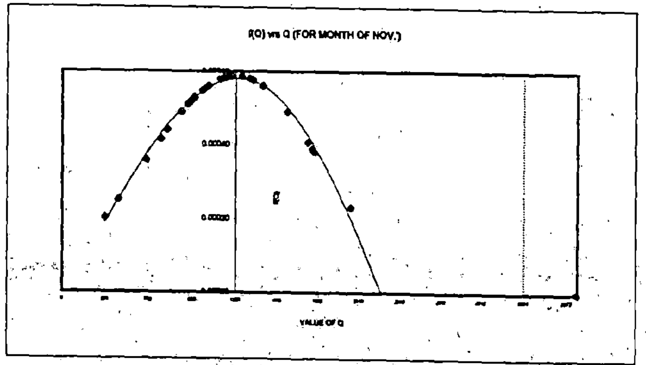
4.1 Normal Distribution











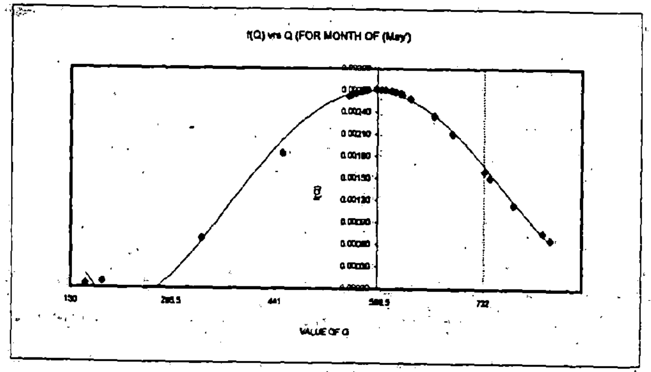
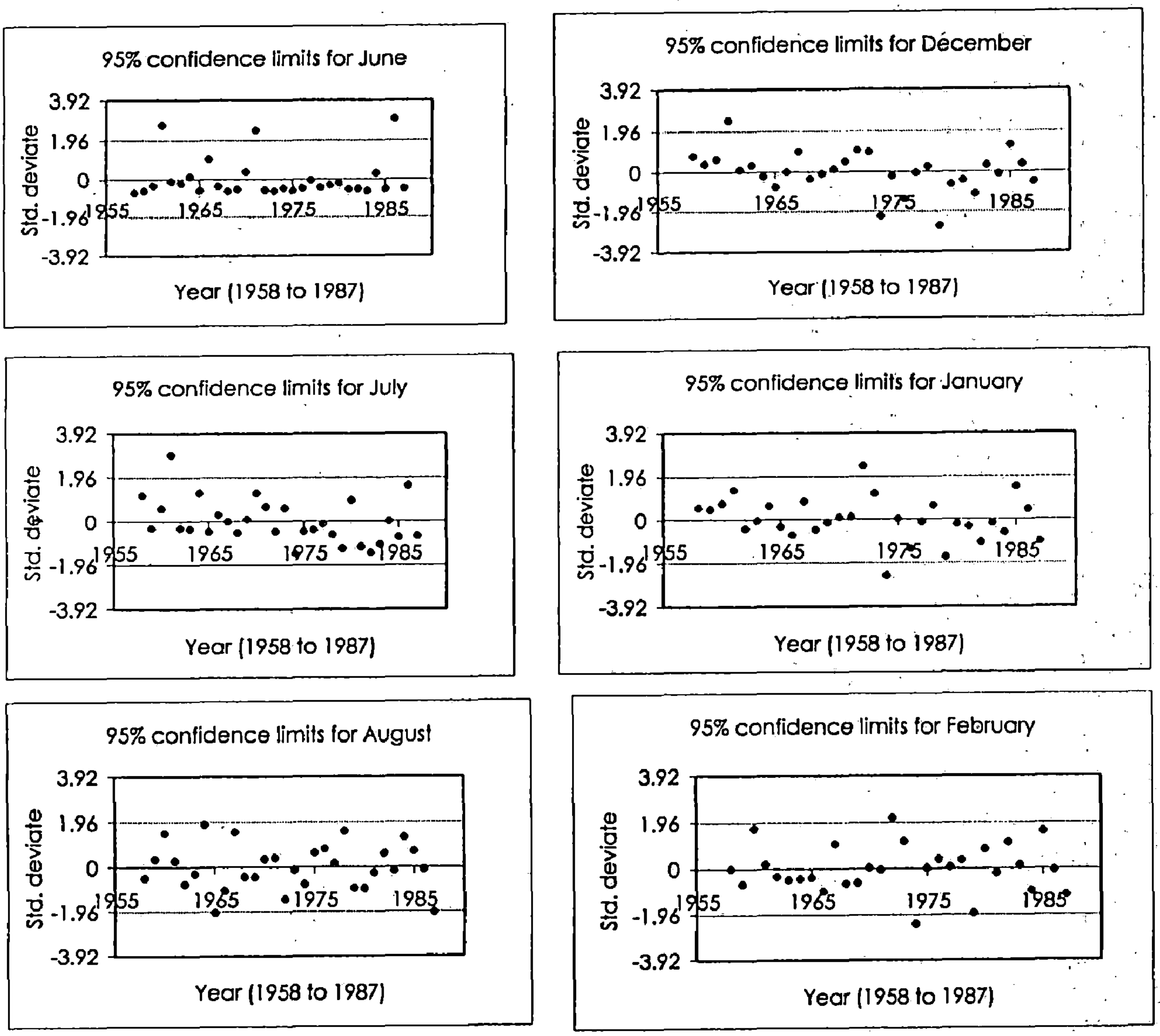
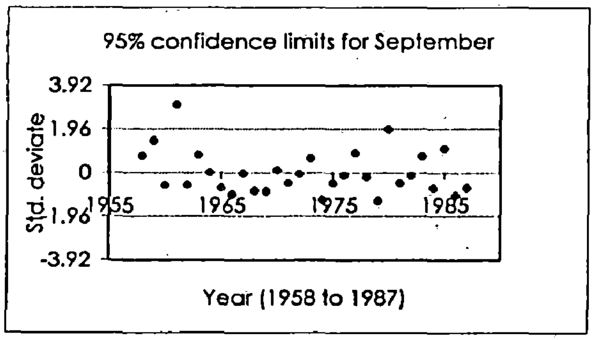
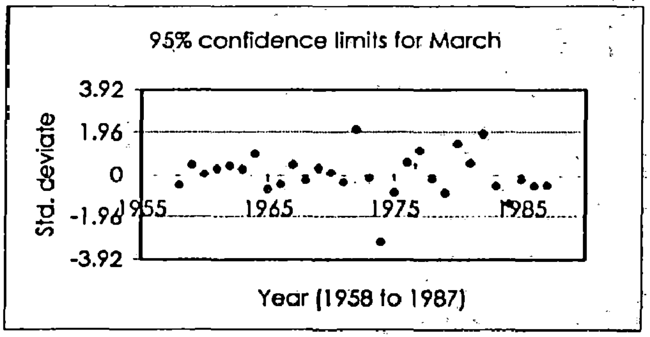
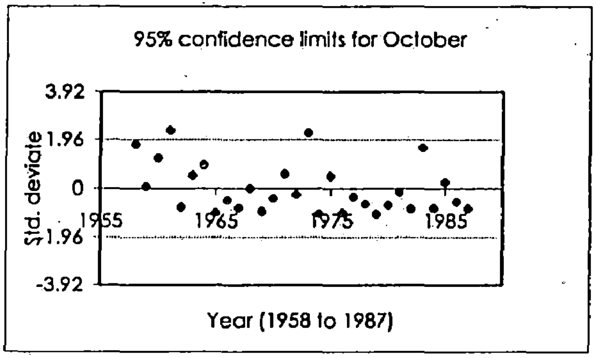


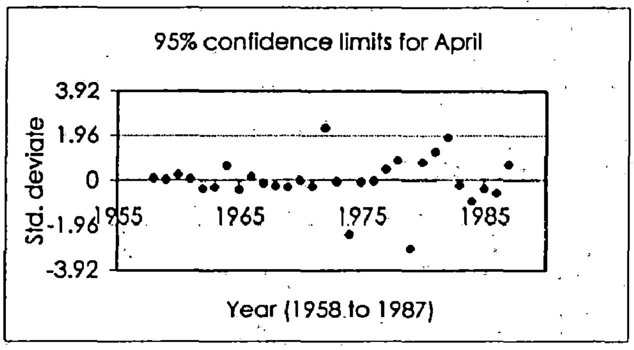
Fig. 4.2 PLOT FOR 95% CONFIDENCE LIMITS

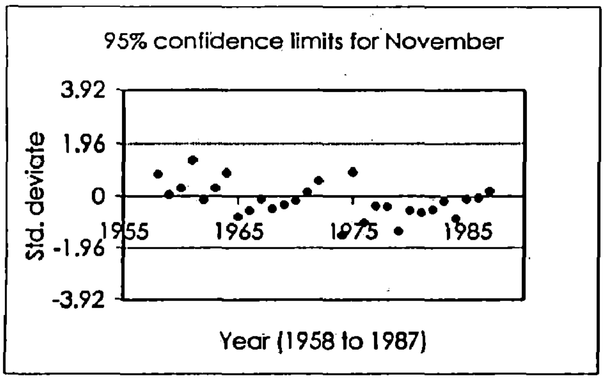


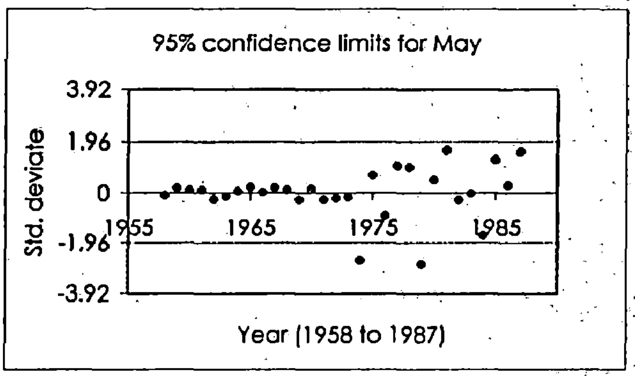

95% confidence limits for September
3.92
1.96
0
-1.96
-3.92
Std. deviate
1955
1965
1975
1985
Year (1958 to 1987)


95% confidence limits for March
3.92
1.96
0
-1.96
-3.92
Std. deviate
1955
1965
1975
1985
Year (1958 to 1987)


95% confidence limits for October
3.92
1.96
0
-1.96
-3.92
Std. deviate
1955
1965
1975
1985
Year (1958 to 1987)


95% confidence limits for April
3.92
1.96
0
-1.96
-3.92
Std. deviate
1955
1965
1975
1985
Year (1958 to 1987)


95% confidence limits for November
3.92
1.96
0
-1.96
-3.92
Std. deviate
1955
1965
1975
1985
Year (1958 to 1987)


95% confidence limits for May
3.92
1.96
0
-1.96
-3.92
Std. deviate
1955
1965
1975
1985
Year (1958 to 1987)

4.2 SURFACE WATER RESOURCES ASSESSMENT

For overall assessment of the water balance of a river basin, availability of both Surface water and Ground water is required to be assessed. To establish the surplus/deficit in a river basin with reasonable reliability, it is necessary to take in to consideration, the total available of water, the present water utilization and the utilization, which could possible be made in the foreseeable future.

The Surface water and Ground water availability of Mahanadi River Basin at the Manibhadra Diversion Site has been estimated as given below

4.2.1 Estimation of 75% And 90% Dependable Flow

The dependable flows have been estimated by taking the monthly flow for 30 years. The flow is arranged in descending order and ranking is done by assigning the first rank to the highest value and last rank to the lowest value. The probability of exceedance of a particular value is obtained by dividing its rank by total number of values and is reported in Table 4.4 to 4.15 and is shown in Fig 4.3. The graph is plotted between flow and percentage of time the flow is equaled or exceeded and represented in Fig. 4.4. As per the rank provided, the dependability for 75% and 90% has been worked out. The abstract of the same is in Table 4.3.

Table 4.3 75% and 90% dependability flow at Manibhadra site

MONTH	75% DEPENDABLE FLOW	90% DEPENDABLE FLOW
June	446	375
July	7305	3277
August	12269	10080
September	6247	3665
October	1635	1128
November	965	758
December	660	506
January	658	565
February	598	549
March	724	683
April	663	616
May	547	452
Total	32717.00	22654.00

The 75% and 90% monthly dependable flow series, average monthly flow series has been carried out and shown in Fig. 4.5. The monthly 75% and 90% dependable flow has been estimated in the descending order. The monthly flow duration curve at Manibhadra (1958-87) has been carried out. The annual hydro graph have been plotted and shown in Fig. 4.6 to 4.18.

But in salient features of Manibhadra Irrigation project, the 75% dependable yield is estimated to 32,556 MCM which is shown in Chapter 3.

4.2.2 Estimation of Ground Water Potential

The estimation of utilizable ground water potential including annual draft has been calculated with the data collected from Central Water Board and Govt. of Orissa and has been shown in the Table 4.16. The monthly ground water yield in Mahanadi Basin is computed by distributing the annual ground water yield in the proportion of the monthly irrigation water requirements.

Table 4.16 Ground Water Availability

Month	Available Ground Water (in MCM)	Month	Available Ground Water (in MCM)
Jun	71.14	Dec	39.49
Jul	224.64	Jan	39.49
Aug	224.64	Feb	39.49
Sep	224.64	Mar	0.00
Oct	66.69	Apr	0.00
Nov	39.49	May	71.14

4.2.3 Estimation of Regeneration of Flow from the Upstream Water Utilization

The quantum of return flows to the stream has been considered as below:

- 10% of gross utilization for irrigation from on going and proposed major and medium projects.
- 18% of the gross water utilized for irrigation from the existing major and medium irrigation projects.

(However, in this study 10% of total irrigation utilization has been considered as regeneration to the stream)

- 80% of domestic and industrial needs to be meet from surface water recourses is considered as regeneration to the stream. The total regeneration from upstream water utilization has been shown in Table 4.17.

Table 4.17 Estimation of Regeneration

Month	Regeneration from uses				Month	Regeneration from uses			
	Irr.	Domestic	Industrial	Total		Irr.	Domestic	Industrial	Total
Jun	220.354	41.6	66.4	328.354	Dec	122.32	41.6	66.4	230.32
Jul	695.855	41.6	66.4	803.855	Jan	122.32	41.6	66.4	230.32
Aug	695.855	41.6	66.4	803.855	Feb	122.32	41.6	66.4	230.32
Sep	695.855	41.6	66.4	803.855	Mar	0	41.6	66.4	108
Oct	206.585	41.6	66.4	314.585	Apr	0	41.6	66.4	108
Nov	122.32	41.6	66.4	230.32	May	220.354	41.6	66.4	328.354

4.3 TOTAL WATER AVAILABILITY

The total water available from surface water and ground water including regeneration from the upstream water utilization is given in Table 4.18 to 4.21.

Table 4.18 Total Water Availability (MCM) 75% Dependability with Ground Water

Water availability								
Regeneration from uses				Surface water yield	Ground water available	Ground water recharge	Total Ground Water	Gross water available
Irr.	Domestic	Industrial	Total					
1	2	3	4	5	6	7	8	9
220.35	41.60	66.40	328.35	446.00	71.14	232.19	303.32	1077.68
695.86	41.60	66.40	803.86	7305.00	224.64	413.52	638.16	8747.02
695.86	41.60	66.40	803.86	12269.00	224.64	481.79	706.43	13779.28
695.86	41.60	66.40	803.86	6247.00	224.64	234.18	458.82	7509.68
206.59	41.60	66.40	314.59	1635.00	66.69	64.57	131.26	2080.84
122.32	41.60	66.40	230.32	965.00	39.49	18.04	57.52	1252.84
122.32	41.60	66.40	230.32	660.00	39.49	5.76	45.25	935.57
122.32	41.60	66.40	230.32	658.00	39.49	12.53	52.02	940.34
122.32	41.60	66.40	230.32	598.00	39.49	17.19	56.68	885.00
0.00	41.60	66.40	108.00	724.00	0.00	18.04	18.04	850.04
0.00	41.60	66.40	108.00	663.00	0.00	18.83	18.83	789.83
220.35	41.60	66.40	328.35	547.00	71.14	45.44	116.58	991.94
3224.14	499.20	796.80	4520.14	32717.00	1040.85	1562.07	2602.92	39840.06

Table 4.19 Total Availability (MCM) of 90% Dependability with Ground Water

Water availability								
Regeneration from uses				Surface water yield	Ground water available	Ground water recharge	Total Ground Water	Gross water available
Irr.	Domestic	Industrial	Total					
1	2	3	4	5	6	7	8	9
220.35	41.60	66.40	328.35	375.00	71.14	232.19	303.32	1006.68
695.86	41.60	66.40	803.86	3277.00	224.64	413.52	638.16	4719.02
695.86	41.60	66.40	803.86	10080.00	224.64	481.79	706.43	11590.28
695.86	41.60	66.40	803.86	3665.00	224.64	234.18	458.82	4927.68
206.59	41.60	66.40	314.59	1128.00	66.69	64.57	131.26	1573.84
122.32	41.60	66.40	230.32	758.00	39.49	18.04	57.52	1045.84
122.32	41.60	66.40	230.32	506.00	39.49	5.76	45.25	781.57
122.32	41.60	66.40	230.32	565.00	39.49	12.53	52.02	847.34
122.32	41.60	66.40	230.32	549.00	39.49	17.19	56.68	836.00
0.00	41.60	66.40	108.00	683.00	0.00	18.04	18.04	809.04
0.00	41.60	66.40	108.00	616.00	0.00	18.83	18.83	742.83
220.35	41.60	66.40	328.35	452.00	71.14	45.44	116.58	896.94
3224.14	499.20	796.80	4520.14	22654.00	1040.85	1562.07	2602.92	29777.06

Table 4.20 Total Water Availability of (MCM) 75% Dependability without Ground Water

Water availability					
Regeneration from uses				Surface water yield	Gross water available
Irr.	Domestic	Industrial	Total		
1	2	3	4	5	6
220.35	41.60	66.40	328.35	446.00	774.35
695.86	41.60	66.40	803.86	7305.00	8108.86
695.86	41.60	66.40	803.86	12269.00	13072.86
695.86	41.60	66.40	803.86	6247.00	7050.86
206.59	41.60	66.40	314.59	1635.00	1949.59
122.32	41.60	66.40	230.32	965.00	1195.32
122.32	41.60	66.40	230.32	660.00	890.32
122.32	41.60	66.40	230.32	658.00	888.32
122.32	41.60	66.40	230.32	598.00	828.32
0.00	41.60	66.40	108.00	724.00	832.00
0.00	41.60	66.40	108.00	663.00	771.00
220.35	41.60	66.40	328.35	547.00	875.35
3224.14	499.20	796.80	4520.14	32717.00	37237.14

Table 4.21 Total Water Availability of (MCM) 90% dependability without ground water

Water availability					
Regeneration from uses				Surface water yield	Gross water available
Irr.	Domestic	Industrial	Total		
1	2	3	4	5	6
220.35	41.60	66.40	328.35	375.00	703.35
695.86	41.60	66.40	803.86	3277.00	4080.86
695.86	41.60	66.40	803.86	10080.00	10883.86
695.86	41.60	66.40	803.86	3665.00	4468.86
206.59	41.60	66.40	314.59	1128.00	1442.59
122.32	41.60	66.40	230.32	758.00	988.32
122.32	41.60	66.40	230.32	506.00	736.32
122.32	41.60	66.40	230.32	565.00	795.32
122.32	41.60	66.40	230.32	549.00	779.32
0.00	41.60	66.40	108.00	683.00	791.00
0.00	41.60	66.40	108.00	616.00	724.00
220.35	41.60	66.40	328.35	452.00	780.35
3224.14	499.20	796.80	4520.14	22654.00	27174.14

4.4 CONCLUSION

In this chapter the past inflow data t Mainbhadra site was analysed to estimate at 75% and 90% dependable flow with and without ground water availability. Also, the regeneration of flow based on the upstream water utilization has been estimated and uncorrupted for estimating the possible total inflow, for the purpose for water balance study it has been assumed that this much inflow will be available in year 2050 also.

Table 4.4 DEPENDABLE FLOW FOR MONTH OF JUNE

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	7
1	1958	193	1	7906	3.23%	
2	1959	397	2	7280	6.45%	
3	1960	923	3	6718	9.68%	
4	1961	7280	4	3710	12.90%	
5	1962	1365	5	2354	16.13%	
6	1963	1167	6	2210	19.35%	
7	1964	1883	7	1883	22.58%	
8	1965	439	8	1471	25.81%	
9	1966	3710	9	1365	29.03%	
10	1967	847	10	1173	32.26%	
11	1968	375	11	1167	35.48%	
12	1969	565	12	995	38.71%	
13	1970	2354	13	923	41.94%	
14	1971	6718	14	847	45.16%	
15	1972	446	15	726	48.39%	689.5
16	1973	353	16	653	51.61%	
17	1974	653	17	642	54.84%	
18	1975	402	18	608	58.06%	
19	1976	642	19	578	61.29%	
20	1977	1471	20	565	64.52%	
21	1978	726	21	563	67.74%	
22	1979	995	22	558	70.97%	
23	1980	1173	23	446	74.19%	444.25
24	1981	563	24	439	77.42%	
25	1982	578	25	402	80.65%	
26	1983	358	26	397	83.87%	
27	1984	2210	27	375	87.10%	359.7
28	1985	558	28	358	90.32%	
29	1986	7906	29	353	93.55%	
30	1987	608	30	193	96.77%	

Table 4.5 DEPENDABLE FLOW FOR MONTH OF July

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	7
1	1958	20248	1	33291	3.23%	
2	1959	9477	2	23455	6.45%	
3	1960	15952	3	21167	9.68%	
4	1961	33291	4	21016	12.90%	
5	1962	9433	5	20248	16.13%	
6	1963	9136	6	18672	19.35%	
7	1964	21167	7	16580	22.58%	
8	1965	8230	8	16016	25.81%	
9	1966	13868	9	15952	29.03%	
10	1967	11646	10	13868	32.26%	
11	1968	7990	11	12436	35.48%	
12	1969	12436	12	11789	38.71%	
13	1970	21016	13	11646	41.94%	
14	1971	16580	14	10778	45.16%	
15	1972	8334	15	9477	48.39%	9455
16	1973	16016	16	9433	51.61%	
17	1974	1064	17	9136	54.84%	
18	1975	8403	18	8899	58.06%	
19	1976	8899	19	8403	61.29%	
20	1977	10778	20	8334	64.52%	
21	1978	7305	21	8230	67.74%	
22	1979	2804	22	7990	70.97%	
23	1980	18672	23	7305	74.19%	7182
24	1981	3277	24	6813	77.42%	
25	1982	1395	25	6512	80.65%	
26	1983	4123	26	4123	83.87%	
27	1984	11789	27	3277	87.10%	2851.3
28	1985	6512	28	2804	90.32%	
29	1986	23455	29	1395	93.55%	
30	1987	6813	30	1064	96.77%	

Table 4.6 DEPENDABLE FLOW FOR MONTH OF August

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	
1	1958	14284	1	31927	3.23%	
2	1959	20399	2	29682	6.45%	
3	1960	28955	3	29368	9.68%	
4	1961	19964	4	28955	12.90%	
5	1962	12269	5	27685	16.13%	
6	1963	15746	6	23808	19.35%	
7	1964	31927	7	22974	22.58%	
8	1965	2702	8	22490	25.81%	
9	1966	10080	9	22264	29.03%	
10	1967	29368	10	20889	32.26%	
11	1968	14674	11	20484	35.48%	
12	1969	14632	12	20399	38.71%	
13	1970	20484	13	19964	41.94%	
14	1971	20889	14	19098	45.16%	
15	1972	7243	15	17083	48.39%	16989
16	1973	16895	16	16895	51.61%	
17	1974	12225	17	16641	54.84%	
18	1975	22490	18	15997	58.06%	
19	1976	23808	19	15746	61.29%	
20	1977	19098	20	14674	64.52%	
21	1978	29682	21	14632	67.74%	
22	1979	10939	22	14284	70.97%	
23	1980	10725	23	12269	74.19%	12258
24	1981	15997	24	12225	77.42%	
25	1982	22264	25	10939	80.65%	
26	1983	16641	26	10725	83.87%	
27	1984	27685	27	10080	87.10%	7526.7
28	1985	22974	28	7243	90.32%	
29	1986	17083	29	2834	93.55%	
30	1987	2834	30	2702	96.77%	

Table 4.7 DEPENDABLE FLOW FOR MONTH OF September

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	
1	1958	19051	1	38870	3.23%	
2	1959	25098	2	29500	6.45%	
3	1960	7324	3	25098	9.68%	
4	1961	38870	4	21971	12.90%	
5	1962	7400	5	20247	16.13%	
6	1963	19486	6	19486	19.35%	
7	1964	12498	7	19051	22.58%	
8	1965	6247	8	19010	25.81%	
9	1966	3665	9	18235	29.03%	
10	1967	12026	10	13400	32.26%	
11	1968	5089	11	12498	35.48%	
12	1969	4880	12	12026	38.71%	
13	1970	13400	13	11968	41.94%	
14	1971	8371	14	11325	45.16%	
15	1972	11968	15	11158	48.39%	10915.5
16	1973	18235	16	10673	51.61%	
17	1974	1631	17	8371	54.84%	
18	1975	8227	18	8227	58.06%	
19	1976	11325	19	8124	61.29%	
20	1977	20247	20	7400	64.52%	
21	1978	10673	21	7324	67.74%	
22	1979	1263	22	6322	70.97%	
23	1980	29500	23	6247	74.19%	6232.5
24	1981	8124	24	6189	77.42%	
25	1982	11158	25	5089	80.65%	
26	1983	19010	26	4880	83.87%	
27	1984	6189	27	3665	87.10%	3307.7
28	1985	21971	28	3268	90.32%	
29	1986	3268	29	1631	93.55%	
30	1987	6322	30	1263	96.77%	

Table 4.8 DEPENDABLE FLOW FOR MONTH OF October

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Table 4.7 Value of 50%, 75% and 90%
1	2	3	4	5	6	
1	1958	8856	1	10563	3.23%	
2	1959	4132	2	10290	6.45%	
3	1960	7347	3	8856	9.68%	
4	1961	10563	4	8502	12.90%	
5	1962	1765	5	7347	16.13%	
6	1963	5349	6	6572	19.35%	
7	1964	6572	7	5539	22.58%	
8	1965	1128	8	5349	25.81%	
9	1966	2543	9	5254	29.03%	
10	1967	1686	10	4600	32.26%	
11	1968	3903	11	4132	35.48%	
12	1969	1304	12	3903	38.71%	
13	1970	2771	13	3458	41.94%	
14	1971	5539	14	3192	45.16%	
15	1972	3192	15	2912	48.39%	2841.5
16	1973	10290	16	2771	51.61%	
17	1974	1032	17	2543	54.84%	
18	1975	5254	18	2340	58.06%	
19	1976	1104	19	2117	61.29%	
20	1977	2912	20	1989	64.52%	
21	1978	2117	21	1765	67.74%	
22	1979	973	22	1686	70.97%	
23	1980	1989	23	1635	74.19%	1624.75
24	1981	3458	24	1594	77.42%	
25	1982	1554	25	1554	80.65%	
26	1983	8502	26	1304	83.87%	
27	1984	1635	27	1128	87.10%	1106.4
28	1985	4600	28	1104	90.32%	
29	1986	2340	29	1032	93.55%	
30	1987	1594	30	973	96.77%	

Table 4.9 DEPENDABLE FLOW FOR MONTH OF November

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	
1	1958	1905	1	4042	3.23%	
2	1959	1373	2	2250	6.45%	
3	1960	1537	3	1956	9.68%	
4	1961	2250	4	1940	12.90%	
5	1962	1240	5	1905	16.13%	
6	1963	1539	6	1736	19.35%	
7	1964	1940	7	1539	22.58%	
8	1965	807	8	1537	25.81%	
9	1966	965	9	1461	29.03%	
10	1967	1258	10	1434	32.26%	
11	1968	1010	11	1373	35.48%	
12	1969	1115	12	1293	38.71%	
13	1970	1219	13	1258	41.94%	
14	1971	1434	14	1251	45.16%	
15	1972	1736	15	1240	48.39%	1229.5
16	1973	4042	16	1219	51.61%	
17	1974	331	17	1202	54.84%	
18	1975	1956	18	1115	58.06%	
19	1976	649	19	1079	61.29%	
20	1977	1079	20	1068	64.52%	
21	1978	1068	21	1010	67.74%	
22	1979	435	22	989	70.97%	
23	1980	961	23	965	74.19%	964
24	1981	911	24	961	77.42%	
25	1982	989	25	911	80.65%	
26	1983	1202	26	807	83.87%	
27	1984	758	27	758	87.10%	659.9
28	1985	1251	28	649	90.32%	
29	1986	1293	29	435	93.55%	
30	1987	1461	30	331	96.77%	

Table 4.10 DEPENDABLE FLOW FOR MONTH OF December

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	
1	1958	936	1	1346	3.23%	
2	1959	849	2	1063	6.45%	
3	1960	903	3	1002	9.68%	
4	1961	1346	4	991	12.90%	
5	1962	784	5	984	16.13%	
6	1963	836	6	936	19.35%	
7	1964	708	7	903	22.58%	
8	1965	588	8	876	25.81%	
9	1966	760	9	849	29.03%	
10	1967	991	10	846	32.26%	
11	1968	683	11	836	35.48%	
12	1969	735	12	832	38.71%	
13	1970	790	13	819	41.94%	
14	1971	876	14	790	45.16%	
15	1972	1002	15	784	48.39%	772
16	1973	984	16	760	51.61%	
17	1974	237	17	748	54.84%	
18	1975	709	18	735	58.06%	
19	1976	444	19	729	61.29%	
20	1977	748	20	709	64.52%	
21	1978	819	21	708	67.74%	
22	1979	129	22	683	70.97%	
23	1980	614	23	660	74.19%	655.75
24	1981	660	24	643	77.42%	
25	1982	506	25	614	80.65%	
26	1983	832	26	588	83.87%	
27	1984	729	27	506	87.10%	450.2
28	1985	1063	28	444	90.32%	
29	1986	846	29	237	93.55%	
30	1987	643	30	129	96.77%	

Table 4.11 DEPENDABLE FLOW FOR MONTH OF January

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	
1	1958	819	1	1117	3.23%	
2	1959	808	2	969	6.45%	
3	1960	851	3	949	9.68%	
4	1961	949	4	920	12.90%	
5	1962	667	5	864	16.13%	
6	1963	725	6	851	19.35%	
7	1964	832	7	834	22.58%	
8	1965	680	8	832	25.81%	
9	1966	620	9	819	29.03%	
10	1967	864	10	808	32.26%	
11	1968	658	11	804	35.48%	
12	1969	709	12	751	38.71%	
13	1970	750	13	750	41.94%	
14	1971	751	14	735	45.16%	
15	1972	1117	15	725	48.39%	718.5
16	1973	920	16	712	51.61%	
17	1974	329	17	709	54.84%	
18	1975	735	18	705	58.06%	
19	1976	521	19	699	61.29%	
20	1977	712	20	682	64.52%	
21	1978	834	21	680	67.74%	
22	1979	460	22	667	70.97%	
23	1980	699	23	658	74.19%	653.25
24	1981	682	24	639	77.42%	
25	1982	565	25	620	80.65%	
26	1983	705	26	572	83.87%	
27	1984	639	27	565	87.10%	525.4
28	1985	969	28	521	90.32%	
29	1986	804	29	460	93.55%	
30	1987	572	30	329	96.77%	

Table 4.12 DEPENDABLE FLOW FOR MONTH OF February

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	
1	1958	678	1	964	3.23%	
2	1959	590	2	904	6.45%	
3	1960	904	3	887	9.68%	
4	1961	703	4	831	12.90%	
5	1962	633	5	824	16.13%	
6	1963	615	6	817	19.35%	
7	1964	620	7	785	22.58%	
8	1965	628	8	731	25.81%	
9	1966	549	9	726	29.03%	
10	1967	817	10	703	32.26%	
11	1968	594	11	695	35.48%	
12	1969	598	12	687	38.71%	
13	1970	683	13	683	41.94%	
14	1971	671	14	679	45.16%	
15	1972	964	15	678	48.39%	674.5
16	1973	831	16	671	51.61%	
17	1974	360	17	668	54.84%	
18	1975	679	18	650	58.06%	
19	1976	731	19	633	61.29%	
20	1977	687	20	628	64.52%	
21	1978	726	21	620	67.74%	
22	1979	422	22	615	70.97%	
23	1980	785	23	598	74.19%	597
24	1981	650	24	594	77.42%	
25	1982	824	25	590	80.65%	
26	1983	695	26	550	83.87%	
27	1984	550	27	549	87.10%	530.1
28	1985	887	28	528	90.32%	
29	1986	668	29	422	93.55%	
30	1987	528	30	360	96.77%	

Table 4.13 DEPENDABLE FLOW FOR MONTH OF March

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	
1	1958	728	1	1066	3.23%	
2	1959	855	2	1038	6.45%	
3	1960	798	3	983	9.68%	
4	1961	831	4	941	12.90%	
5	1962	849	5	922	16.13%	
6	1963	830	6	869	19.35%	
7	1964	922	7	865	22.58%	
8	1965	704	8	855	25.81%	
9	1966	733	9	855	29.03%	
10	1967	855	10	849	32.26%	
11	1968	758	11	835	35.48%	
12	1969	835	12	831	38.71%	
13	1970	805	13	830	41.94%	
14	1971	746	14	805	45.16%	
15	1972	1066	15	798	48.39%	785
16	1973	772	16	772	51.61%	
17	1974	388	17	764	54.84%	
18	1975	683	18	761	58.06%	
19	1976	869	19	758	61.29%	
20	1977	941	20	746	64.52%	
21	1978	764	21	733	67.74%	
22	1979	680	22	728	70.97%	
23	1980	983	23	724	74.19%	723
24	1981	865	24	720	77.42%	
25	1982	1038	25	720	80.65%	
26	1983	720	26	704	83.87%	
27	1984	619	27	683	87.10%	680.3
28	1985	761	28	680	90.32%	
29	1986	720	29	619	93.55%	
30	1987	724	30	388	96.77%	

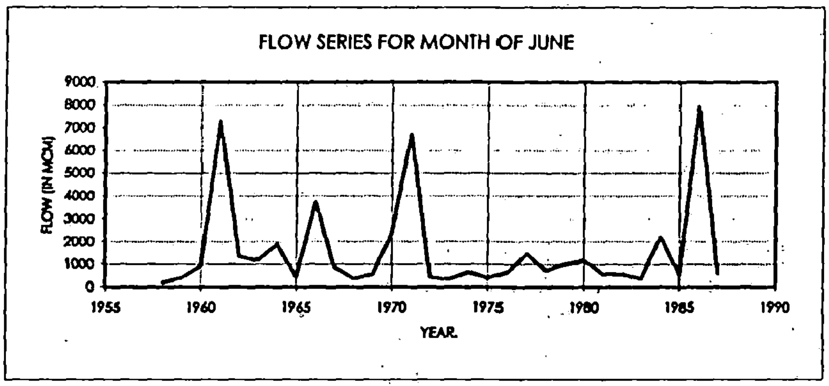
Table 4.14 DEPENDABLE FLOW FOR MONTH OF April

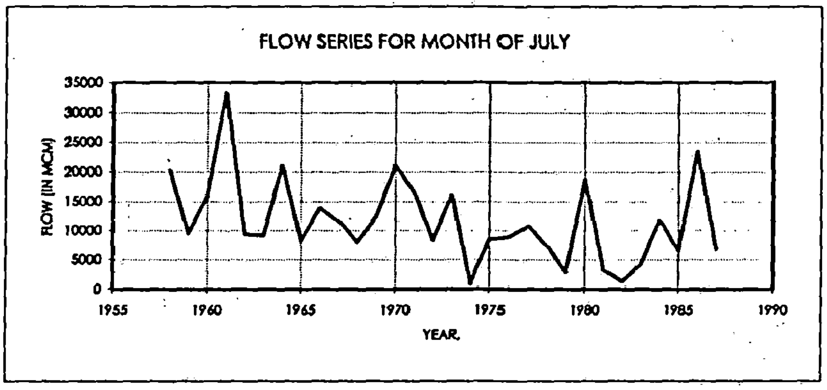
Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	
1	1958	734	1	1130	3.23%	
2	1959	722	2	1054	6.45%	
3	1960	760	3	939	9.68%	
4	1961	729	4	870	12.90%	
5	1962	653	5	852	16.13%	
6	1963	663	6	834	19.35%	
7	1964	828	7	828	22.58%	
8	1965	645	8	799	25.81%	
9	1966	745	9	760	29.03%	
10	1967	690	10	745	32.26%	
11	1968	673	11	734	35.48%	
12	1969	665	12	729	38.71%	
13	1970	714	13	722	41.94%	
14	1971	669	14	714	45.16%	
15	1972	1130	15	709	48.39%	706
16	1973	703	16	703	51.61%	
17	1974	291	17	701	54.84%	
18	1975	701	18	690	58.06%	
19	1976	709	19	678	61.29%	
20	1977	799	20	673	64.52%	
21	1978	870	21	669	67.74%	
22	1979	178	22	665	70.97%	
23	1980	852	23	663	74.19%	660.5
24	1981	939	24	653	77.42%	
25	1982	1054	25	649	80.65%	
26	1983	678	26	645	83.87%	
27	1984	550	27	616	87.10%	556.6
28	1985	649	28	550	90.32%	
29	1986	616	29	291	93.55%	
30	1987	834	30	178	96.77%	

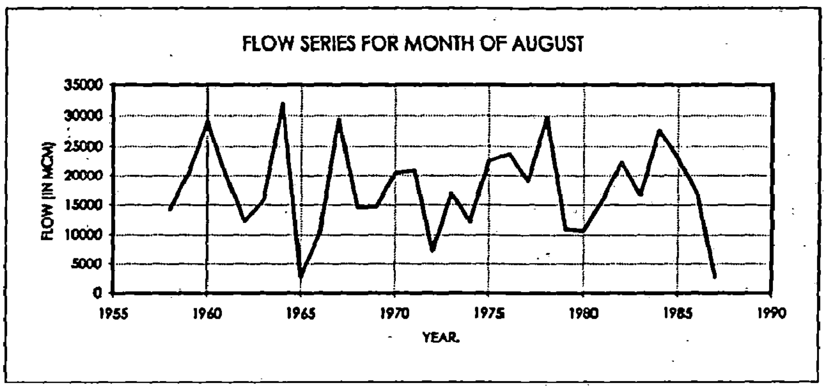
Table 4.15 DEPENDABLE FLOW FOR MONTH OF May

Sl.No.	Year	Monthly Flow	Rank (m)	Flow in Descending Order	m/(n+1) (n=30)	Value of 50%, 75% and 90%
1	2	3	4	5	6	
1	1958	568	1	827	3.23%	
2	1959	613	2	816	6.45%	
3	1960	601	3	775	9.68%	
4	1961	601	4	741	12.90%	
5	1962	547	5	733	16.13%	
6	1963	562	6	686	19.35%	
7	1964	593	7	660	22.58%	
8	1965	616	8	627	25.81%	
9	1966	587	9	616	29.03%	
10	1967	615	10	615	32.26%	
11	1968	601	11	613	35.48%	
12	1969	543	12	606	38.71%	
13	1970	606	13	601	41.94%	
14	1971	546	14	601	45.16%	
15	1972	553	15	601	48.39%	597
16	1973	560	16	593	51.61%	
17	1974	195	17	587	54.84%	
18	1975	686	18	580	58.06%	
19	1976	452	19	568	61.29%	
20	1977	741	20	562	64.52%	
21	1978	733	21	560	67.74%	
22	1979	171	22	553	70.97%	
23	1980	660	23	547	74.19%	546.75
24	1981	827	24	546	77.42%	
25	1982	544	25	544	80.65%	
26	1983	580	26	543	83.87%	
27	1984	338	27	452	87.10%	349.4
28	1985	775	28	338	90.32%	
29	1986	627	29	195	93.55%	
30	1987	816	30	171	96.77%	

Fig. 4.3 MONTHLY FLOW SERIES (1958-87)







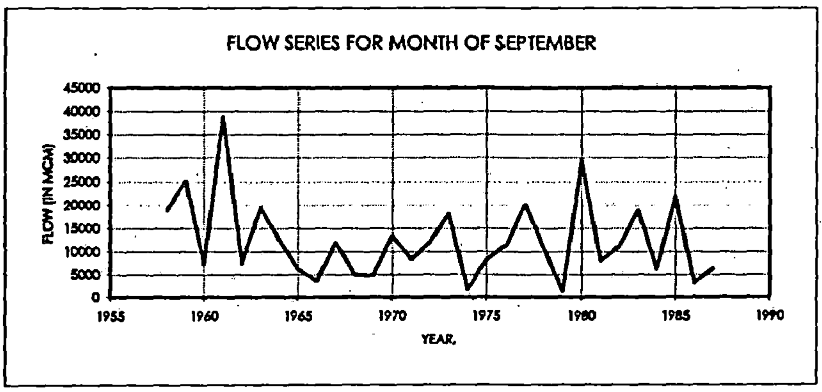
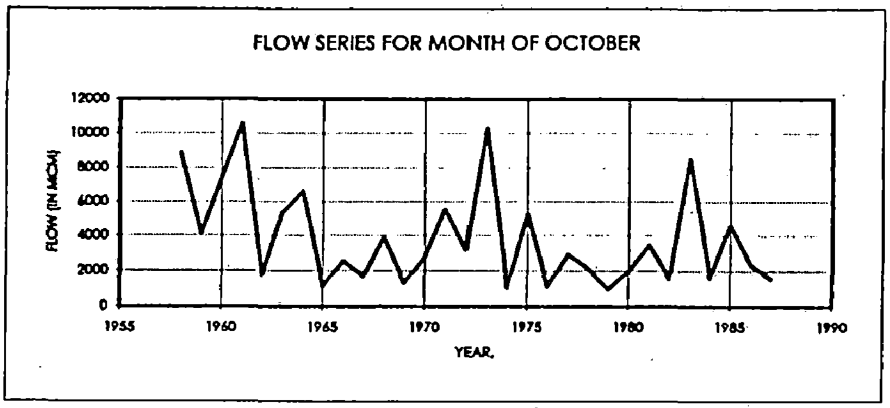
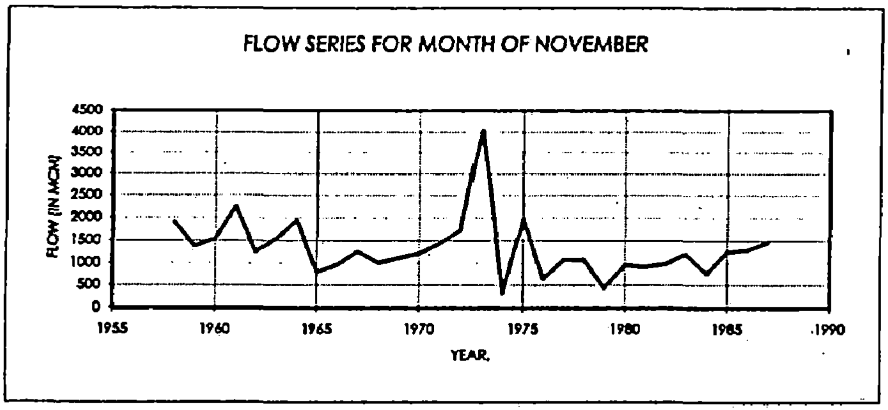
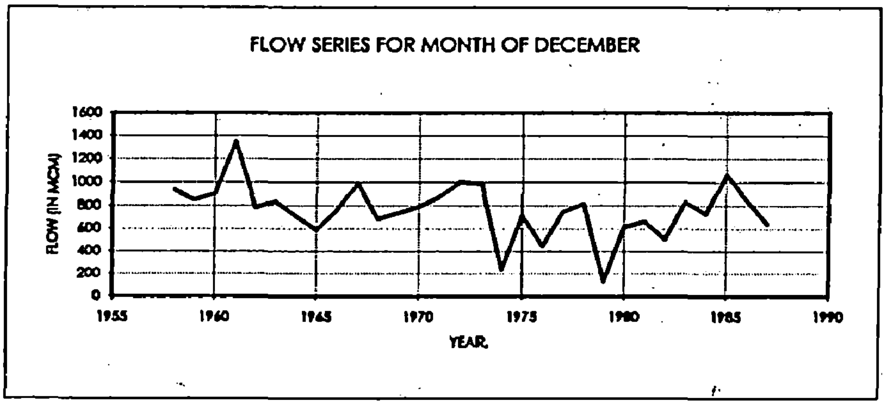


Fig. 4.3 MONTHLY FLOW SERIES (1958-87)







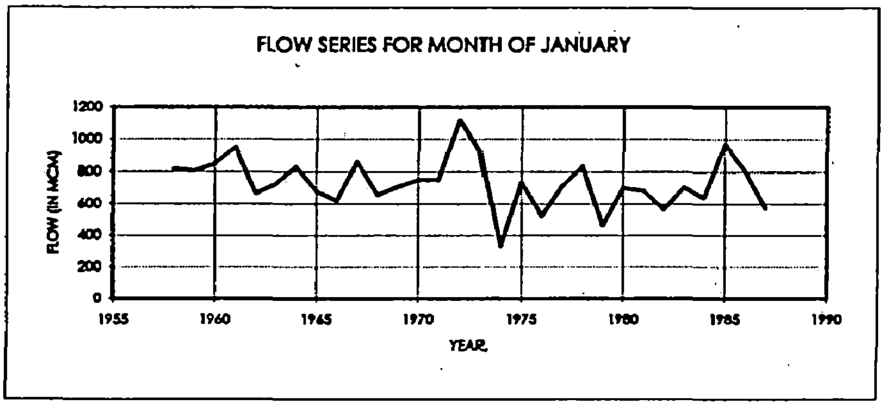
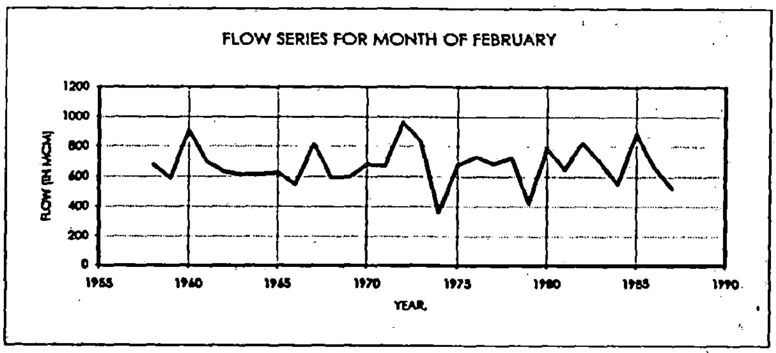
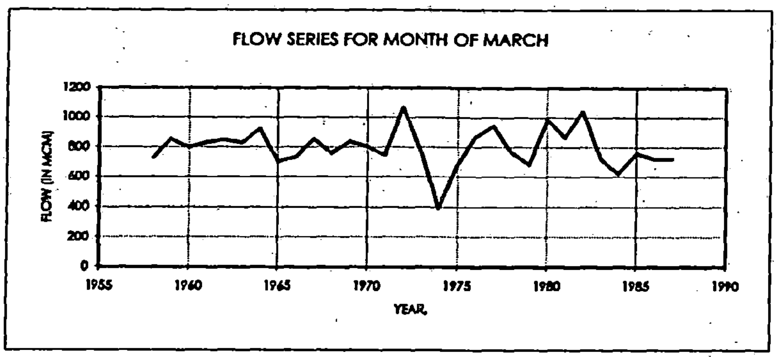
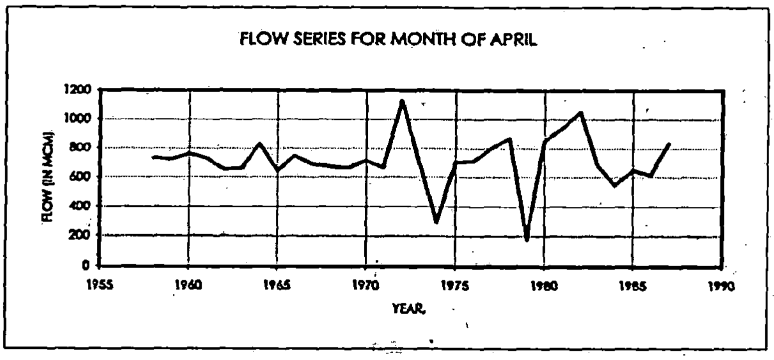


Fig. 4.3 MONTHLY FLOW SERIES (1958-87)







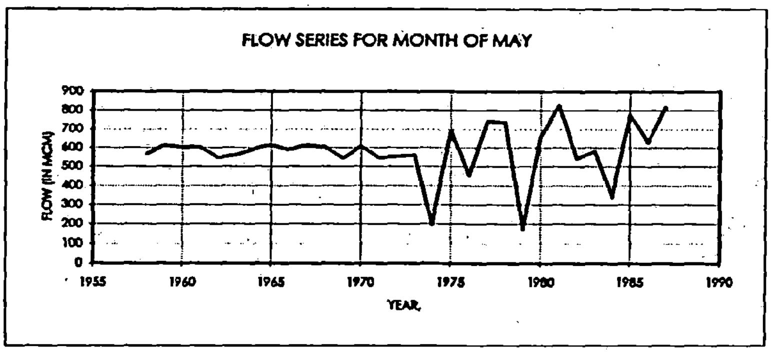


Fig. 4.4 MONTHLY FLOW DURATION CURVE AT MANIBHADRA (1958-87)

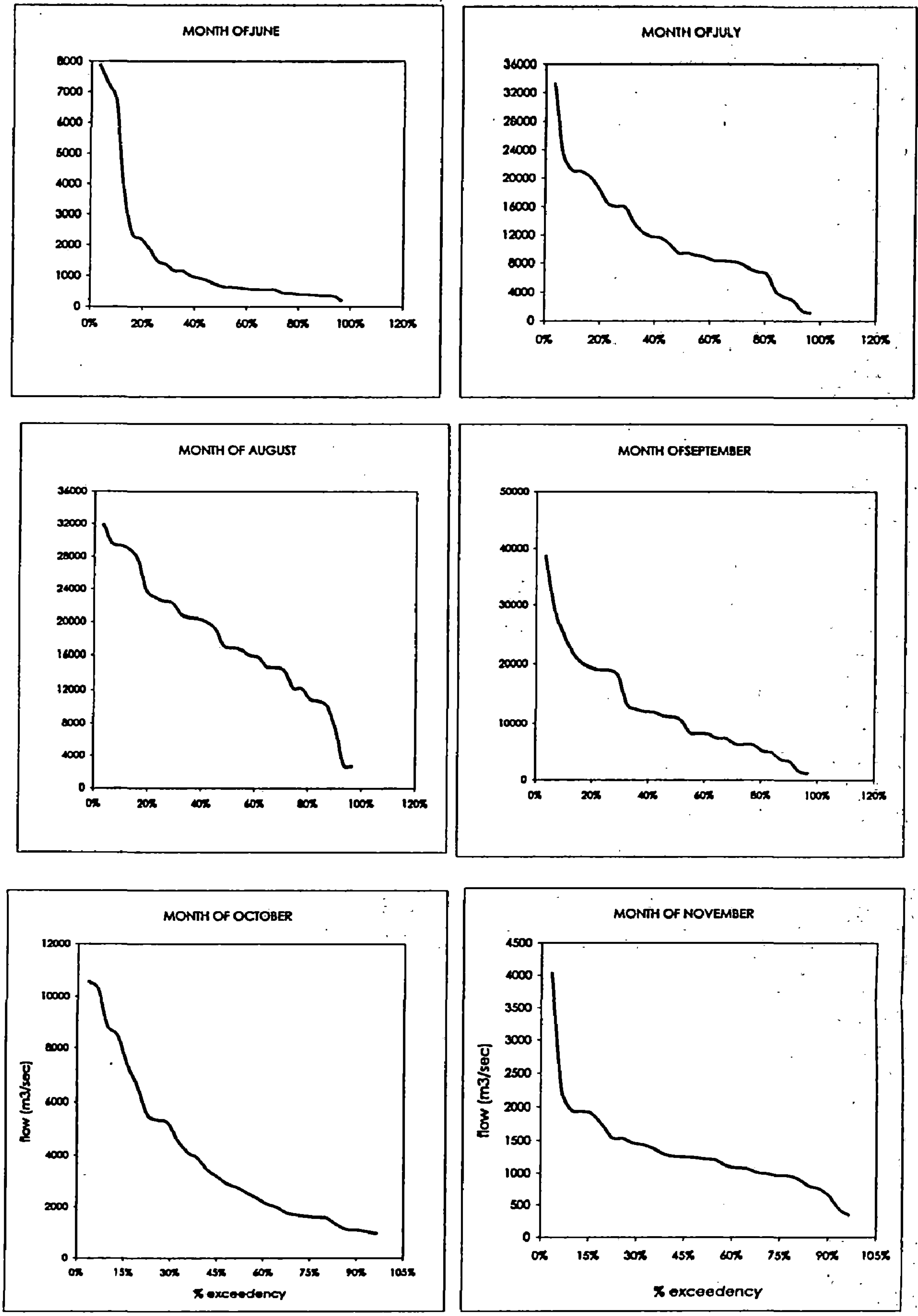


Fig. 4.4 MONTHLY FLOW DURATION CURVE AT MANIBHADRA (1958-87)

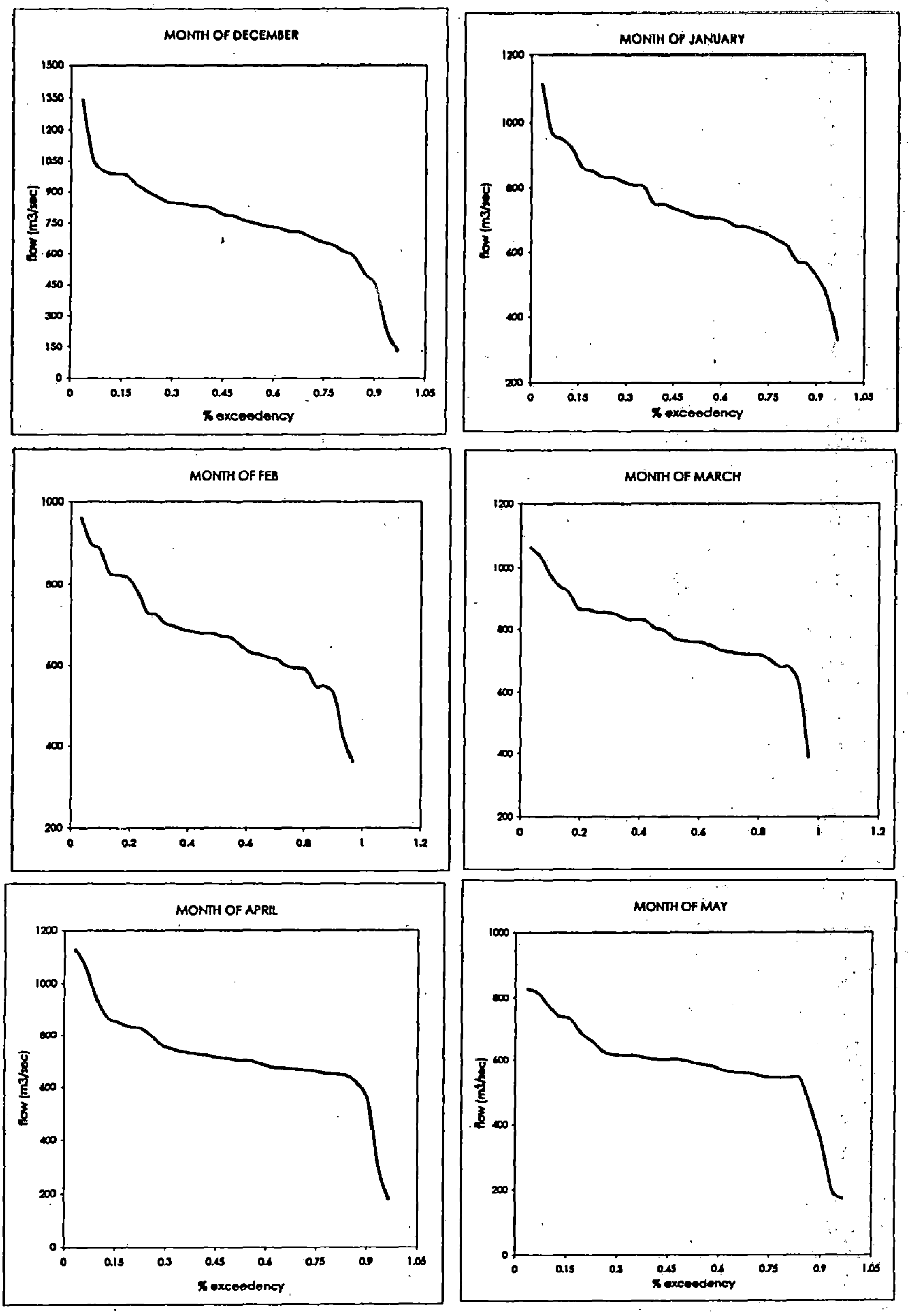


Fig. 4.5 75% & 90% MONTHLY DEPENDABLE FLOW SERIES

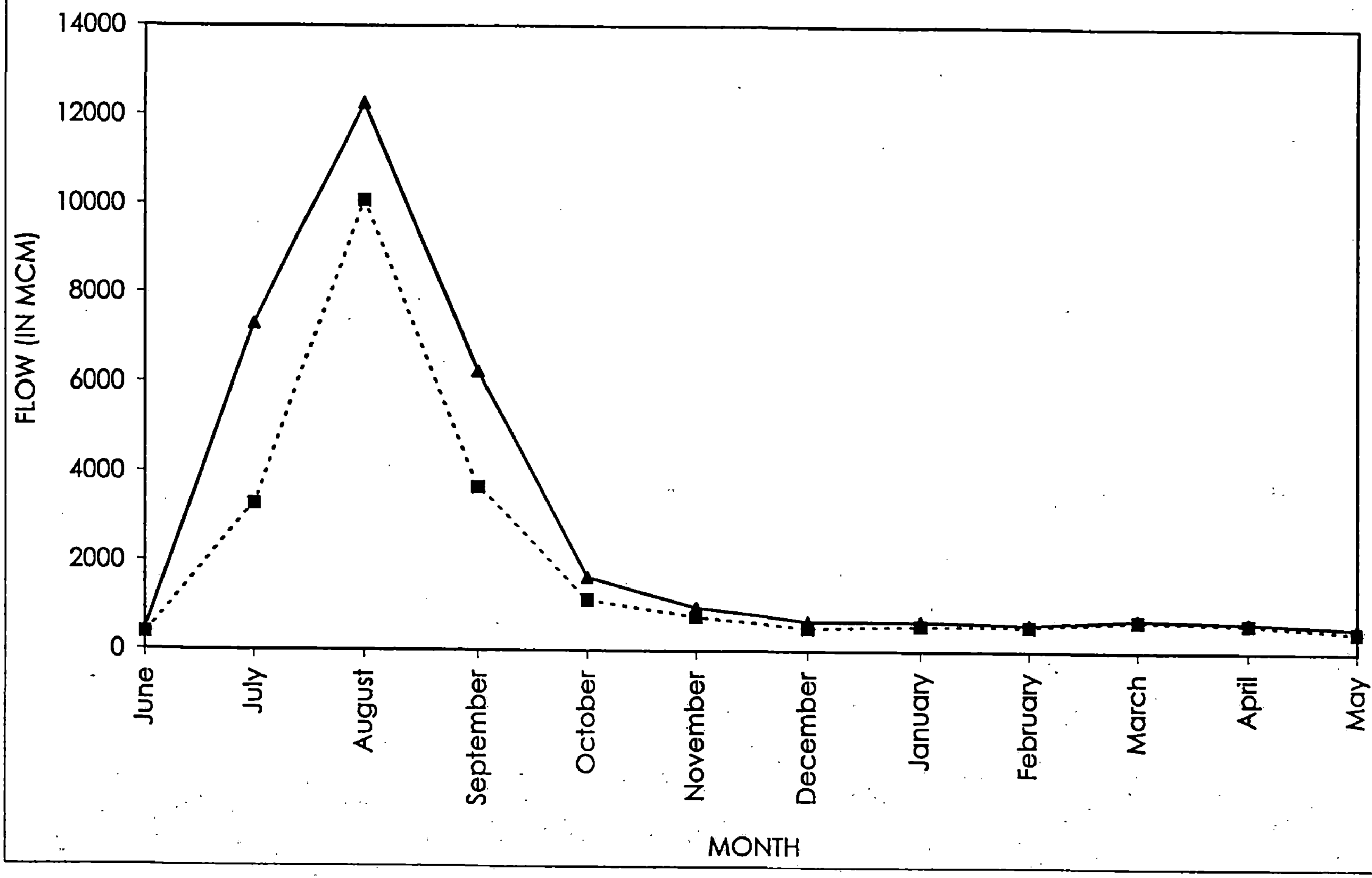


Fig. 4.6 HYDROGRAPHS (1958 - 1967)

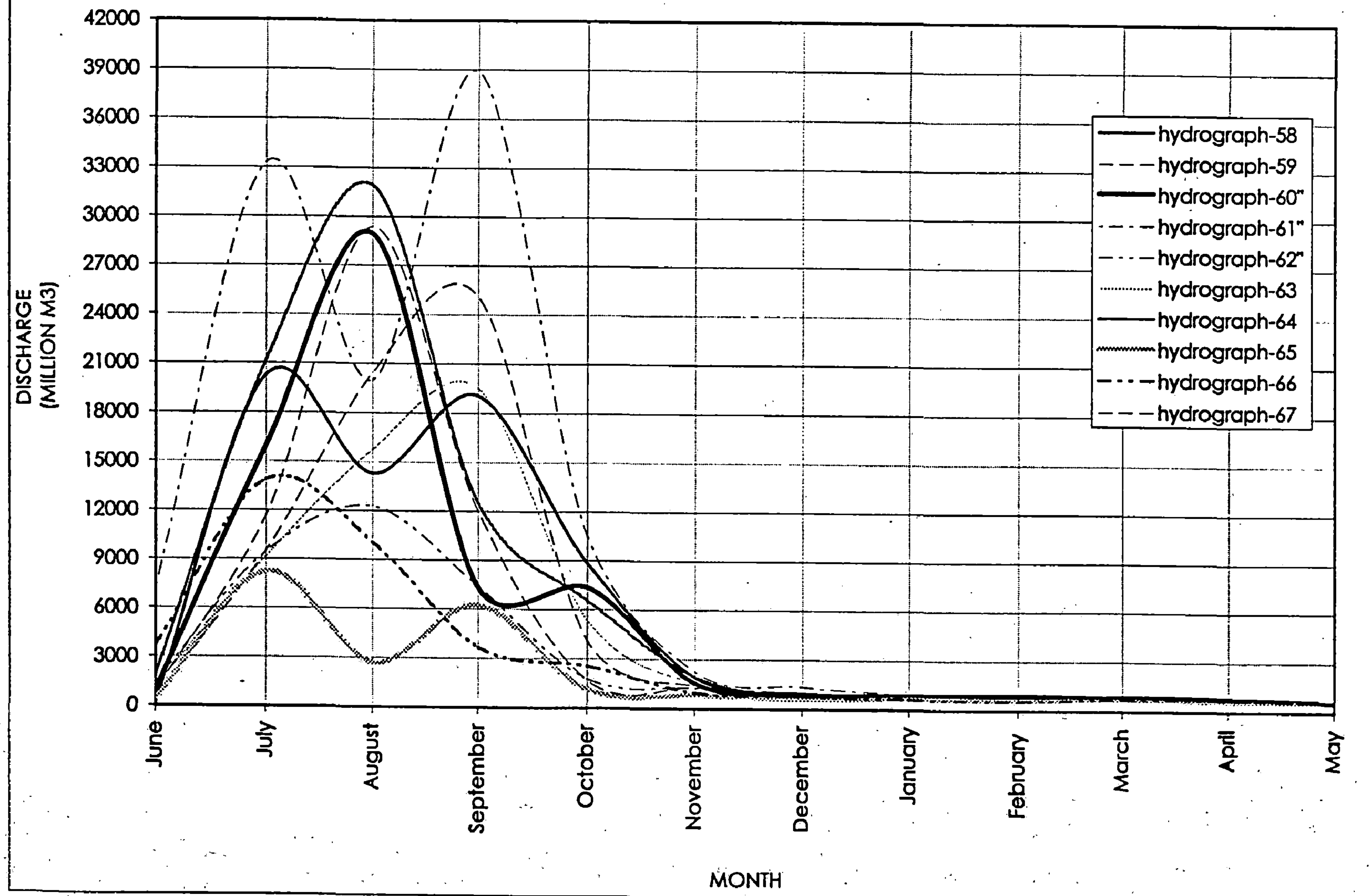


Fig. 4.7 HYDROGRAPHS (1968 - 1977)

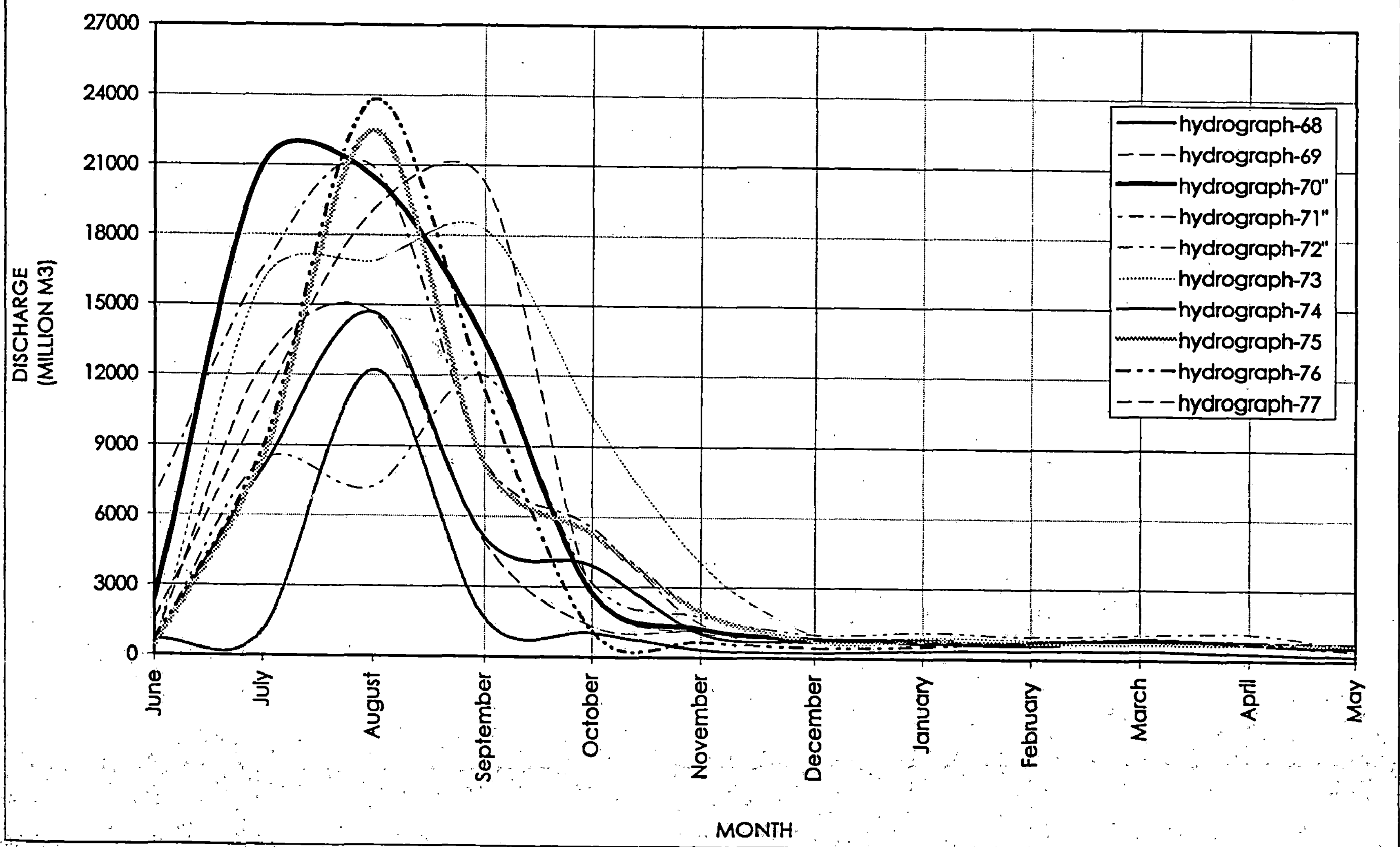
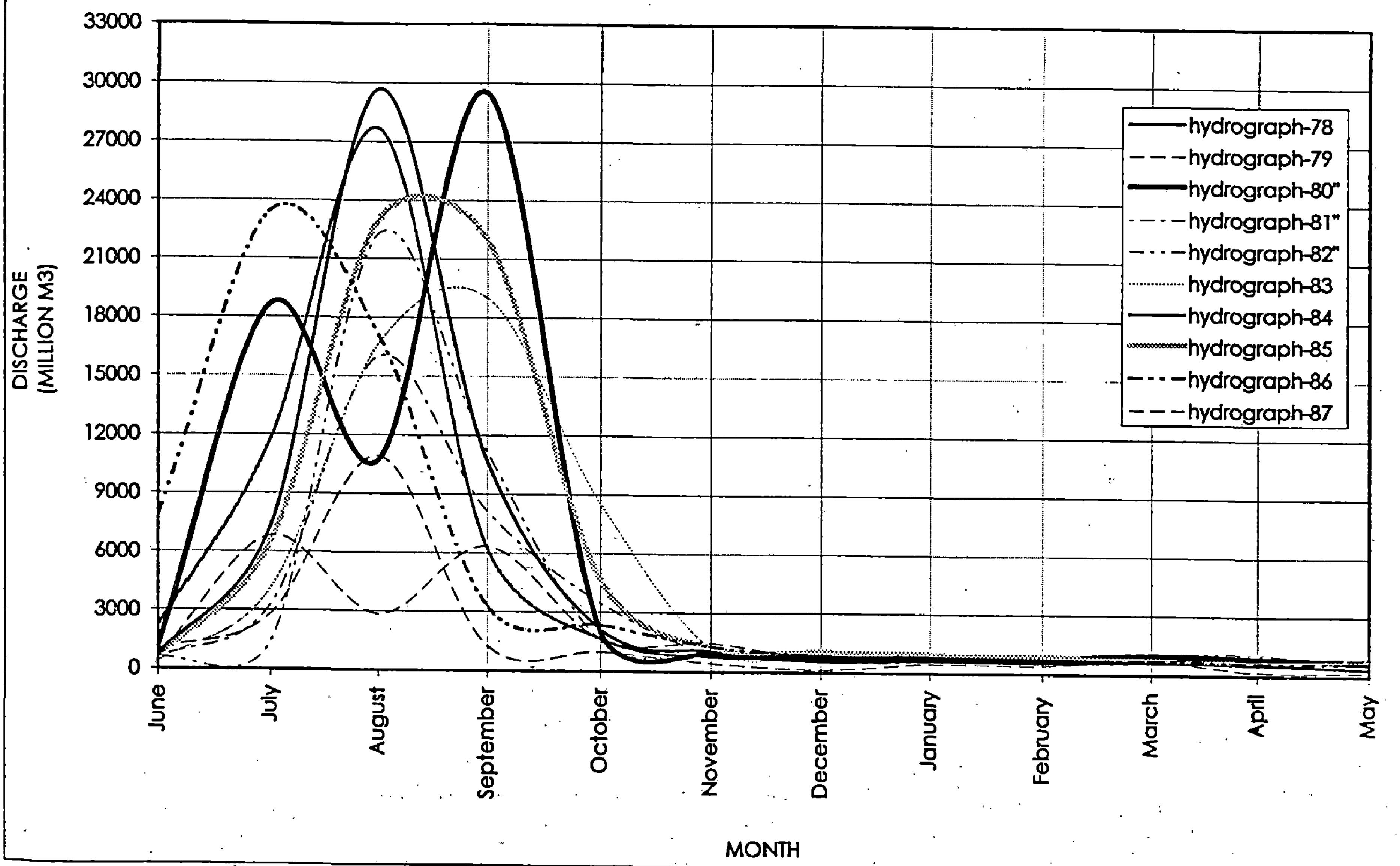
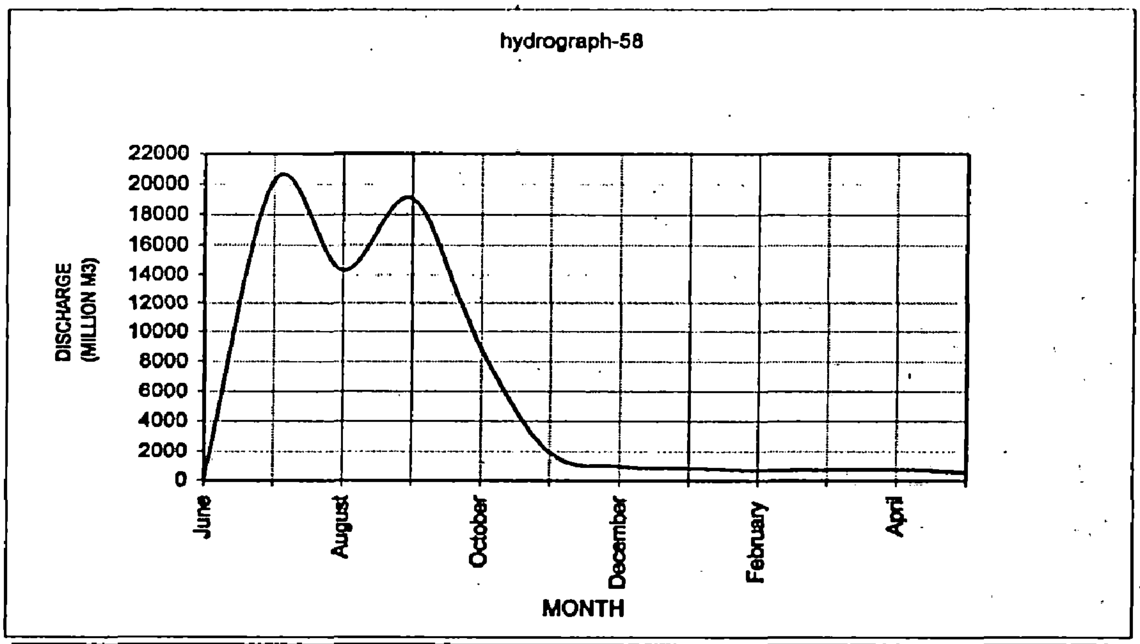
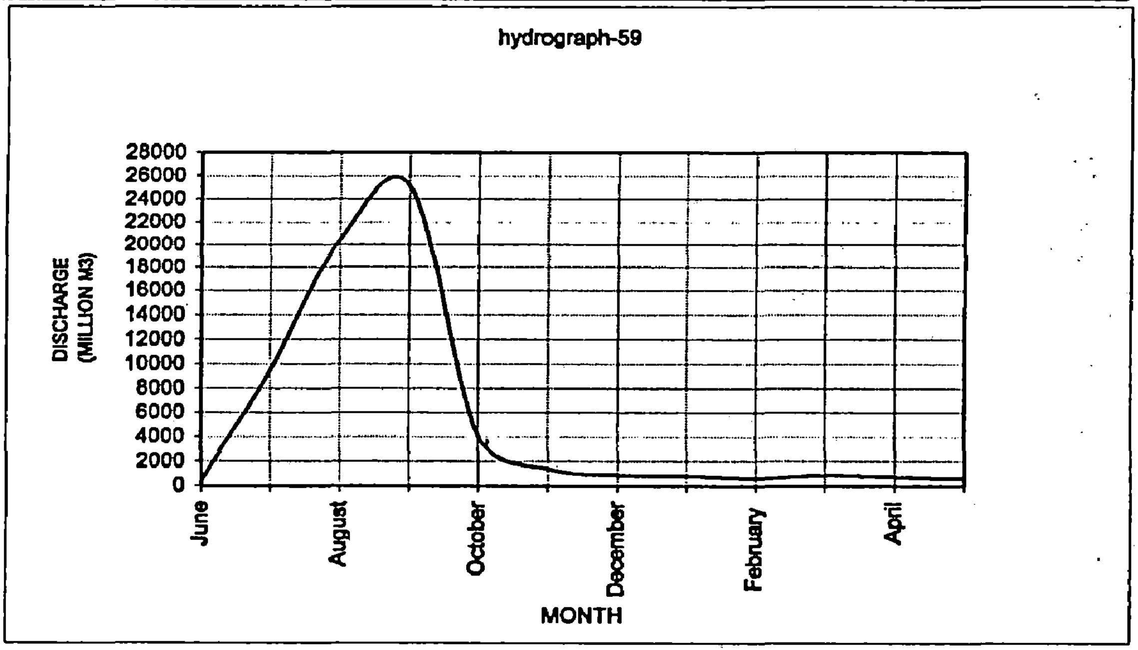


Fig. 4.8 HYDROGRAPHS (1978 - 1987)







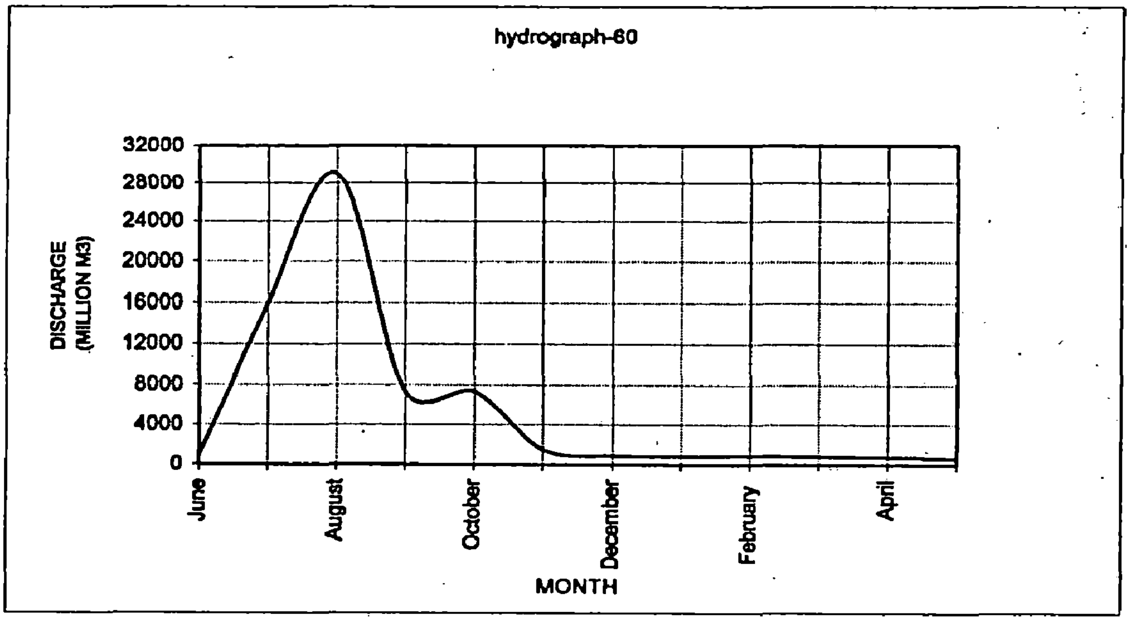
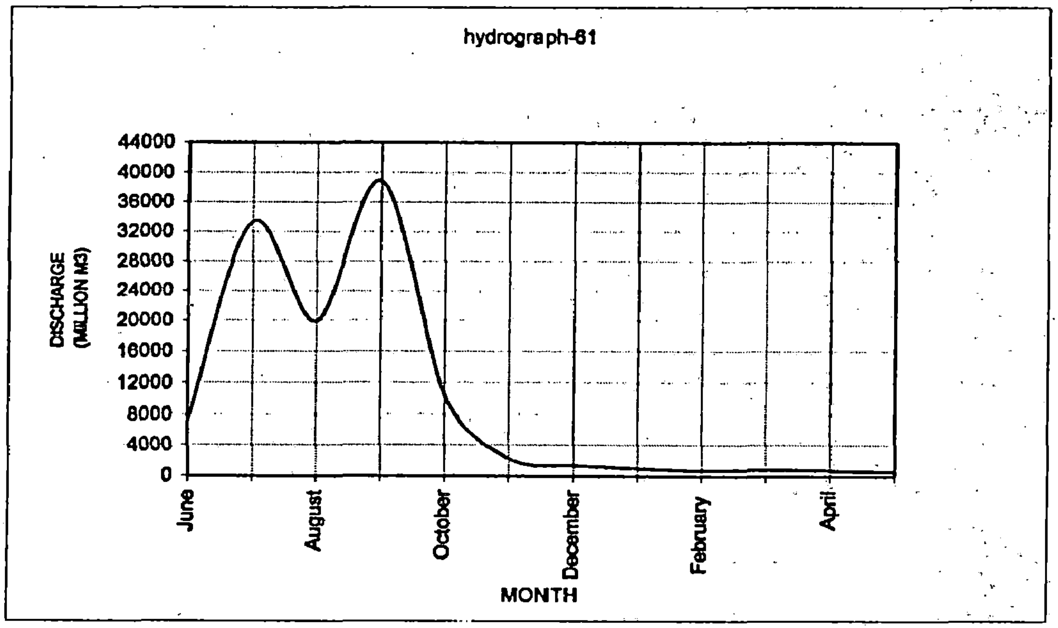
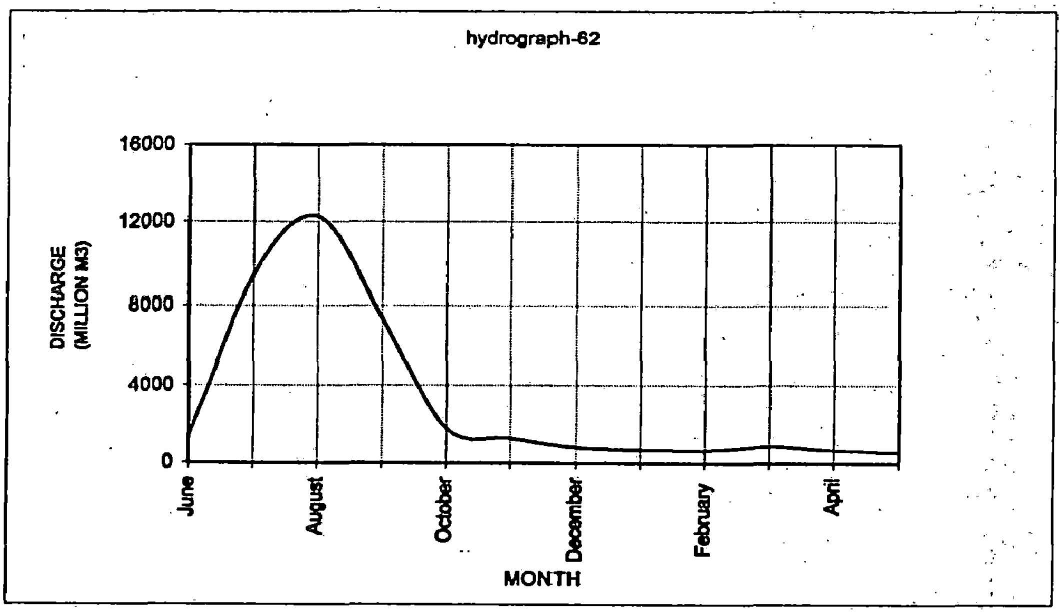


Fig. 4.9 Hydrograph





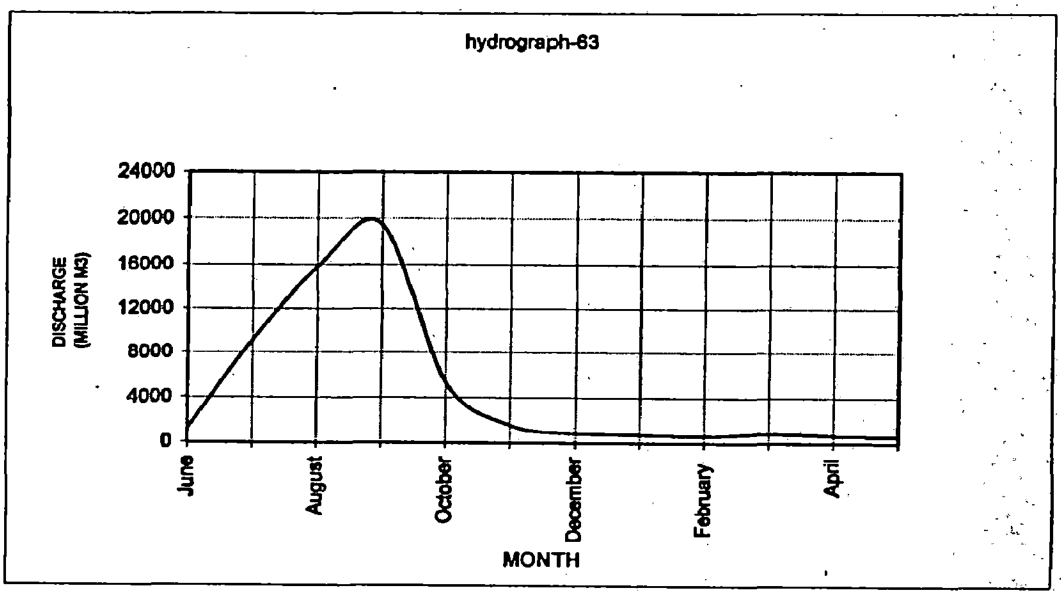
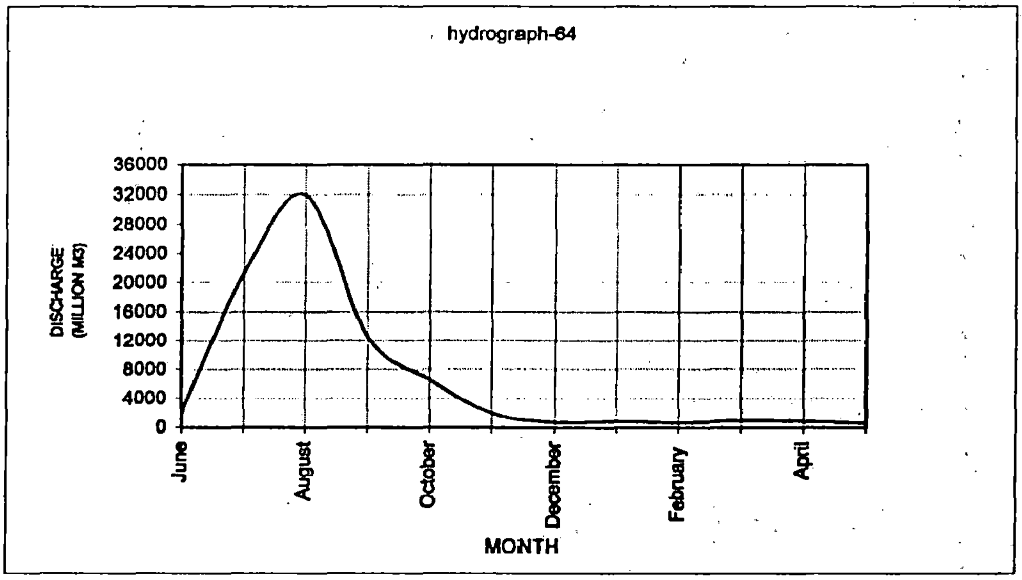
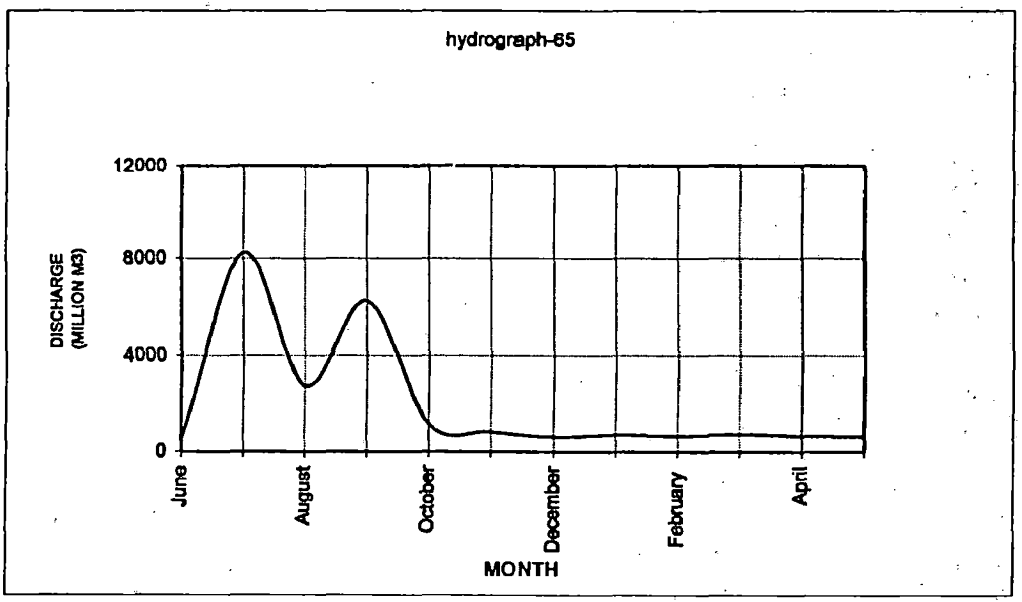


Fig. 4.10 Hydrograph





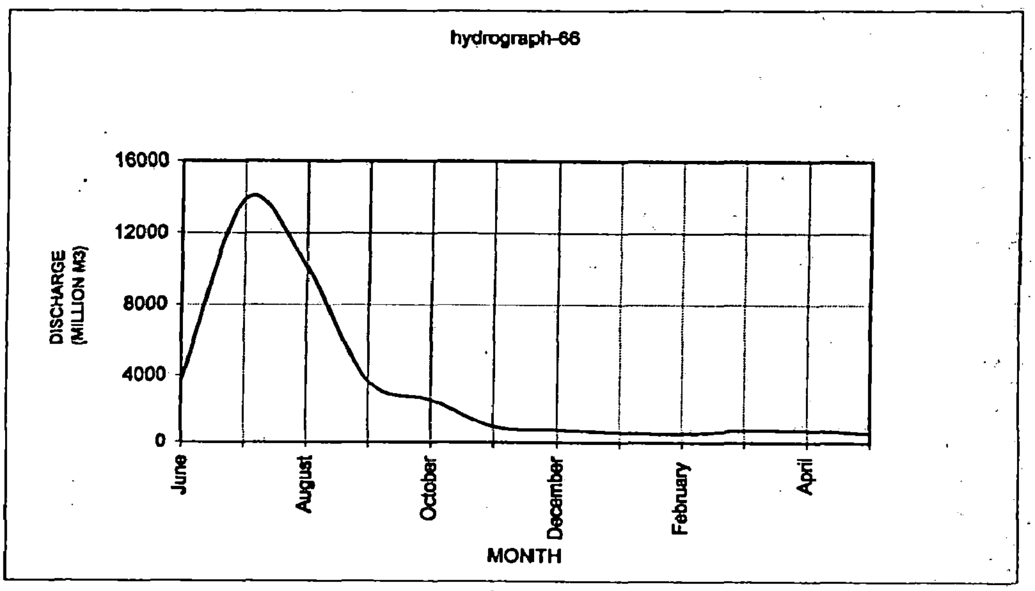
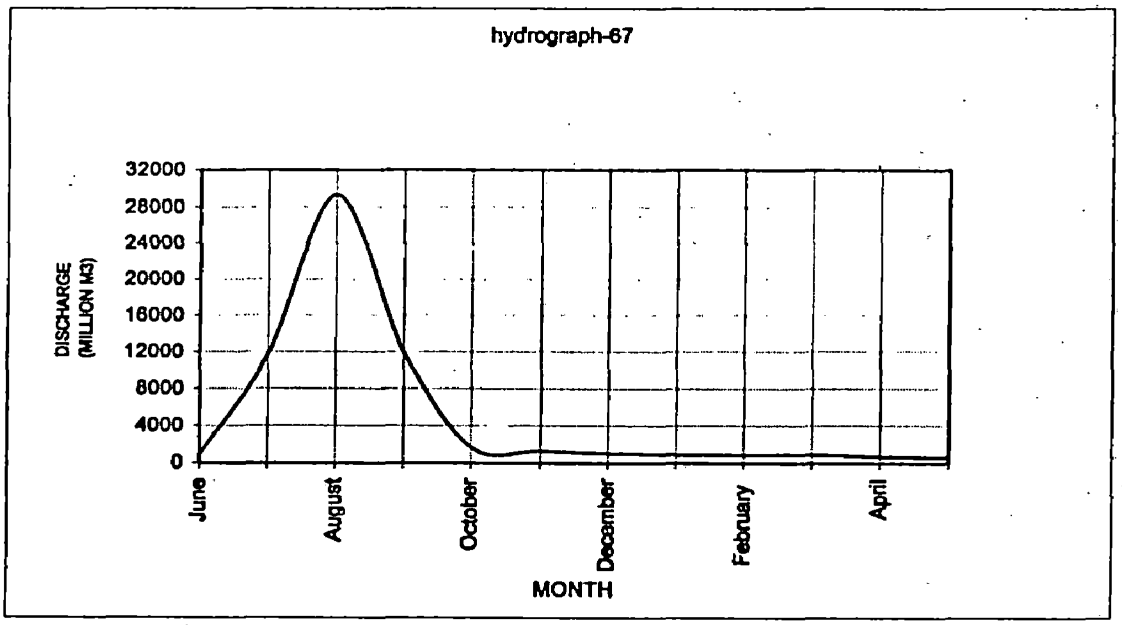
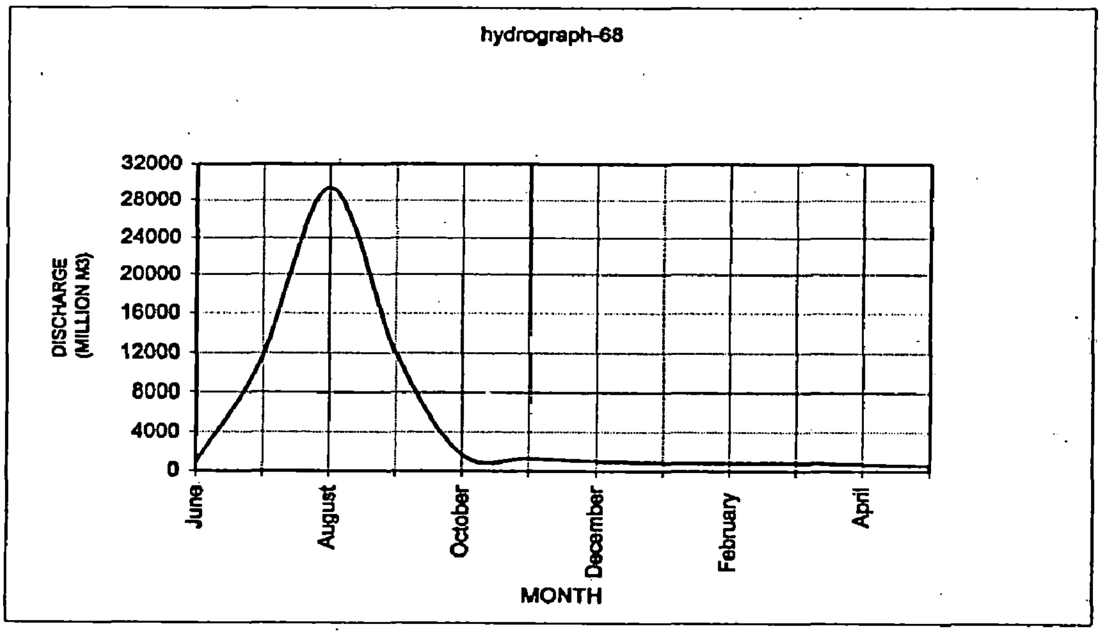
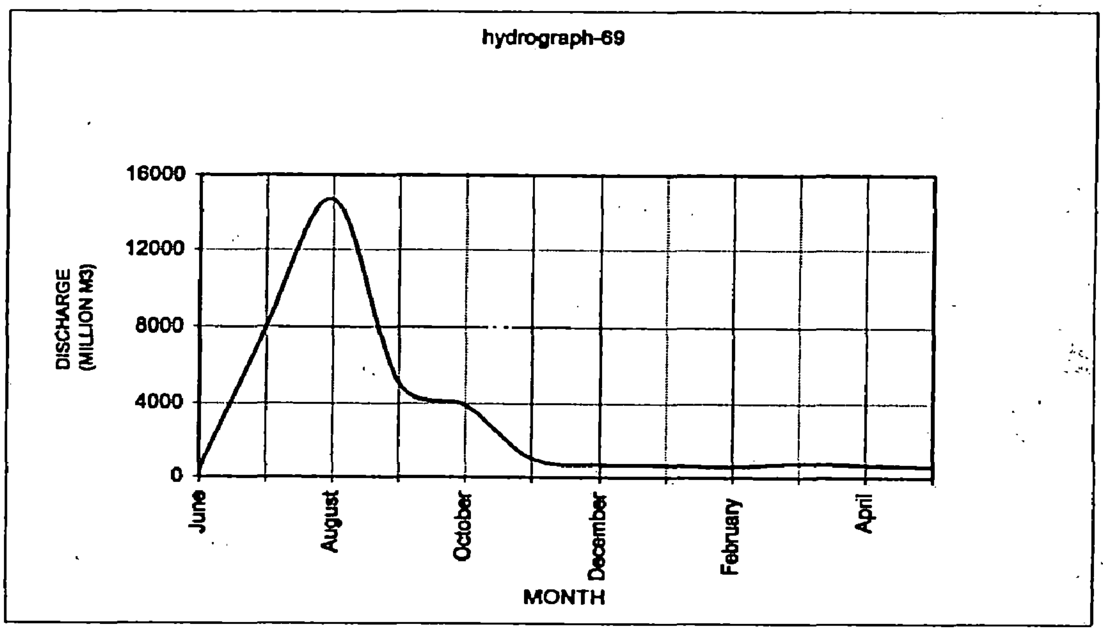


Fig. 4.11 Hydrograph







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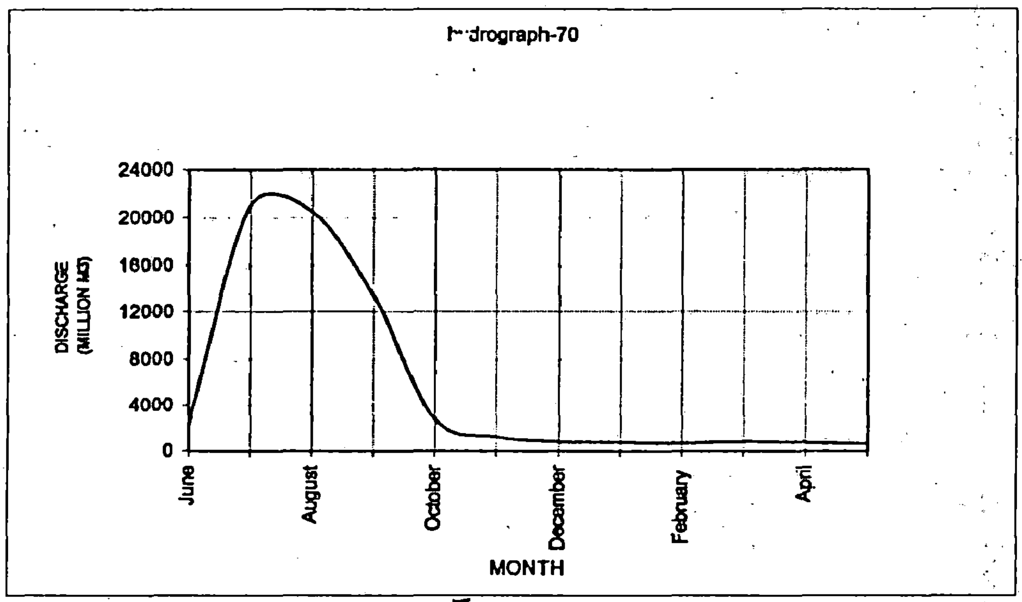
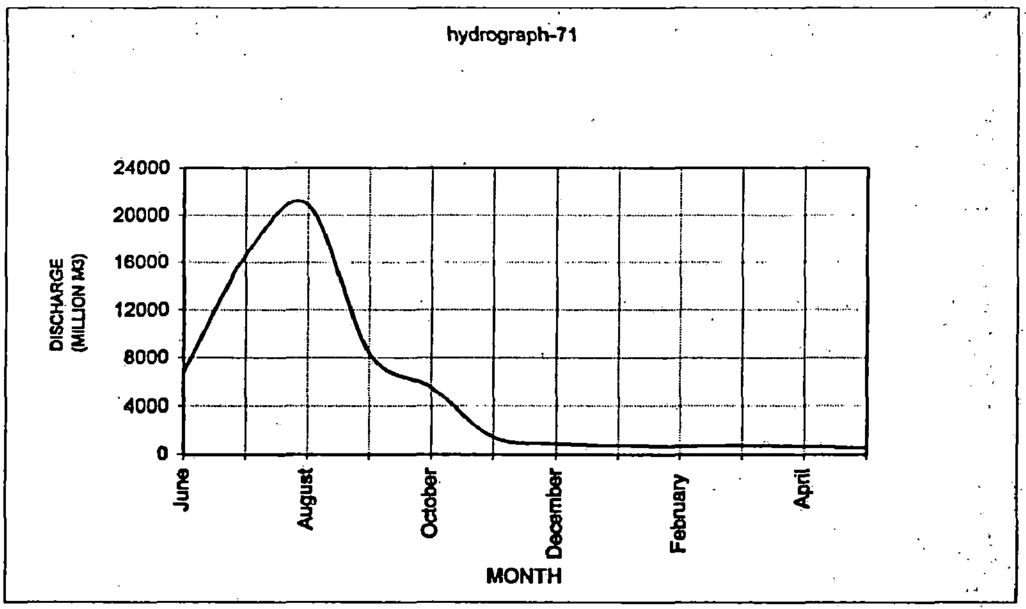




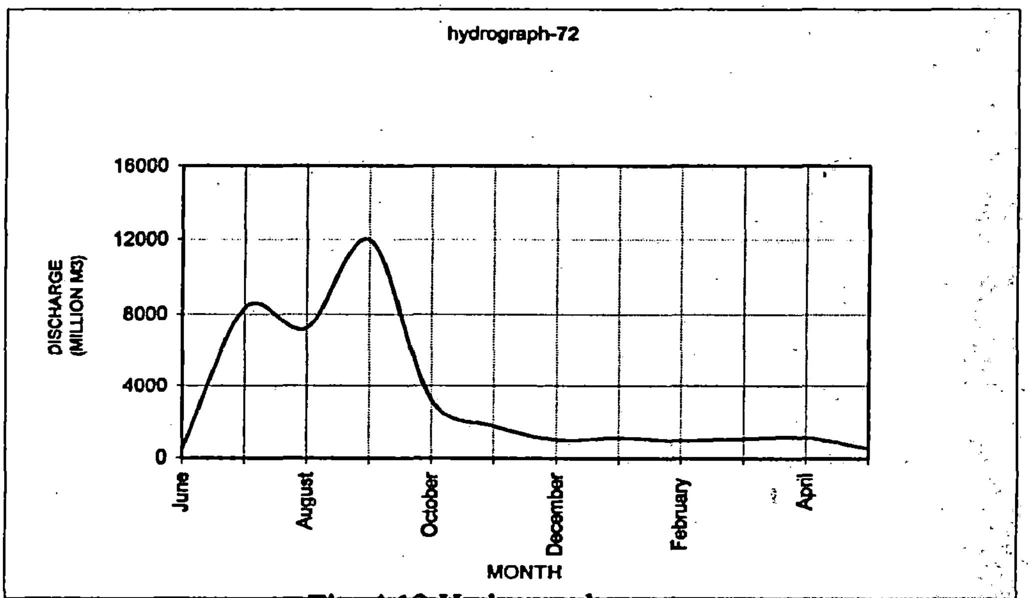
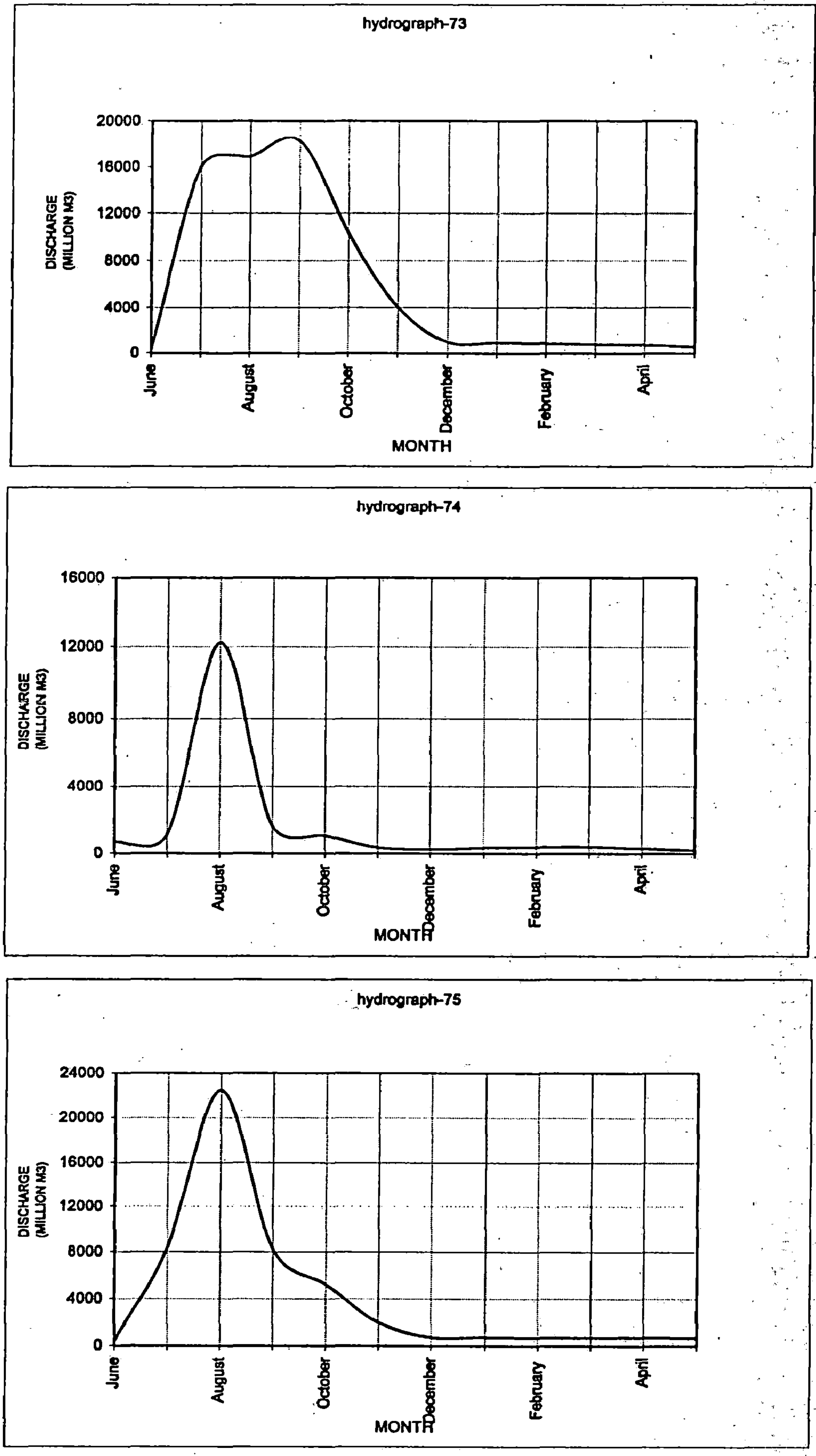


Fig. 4.13 Hydrograph



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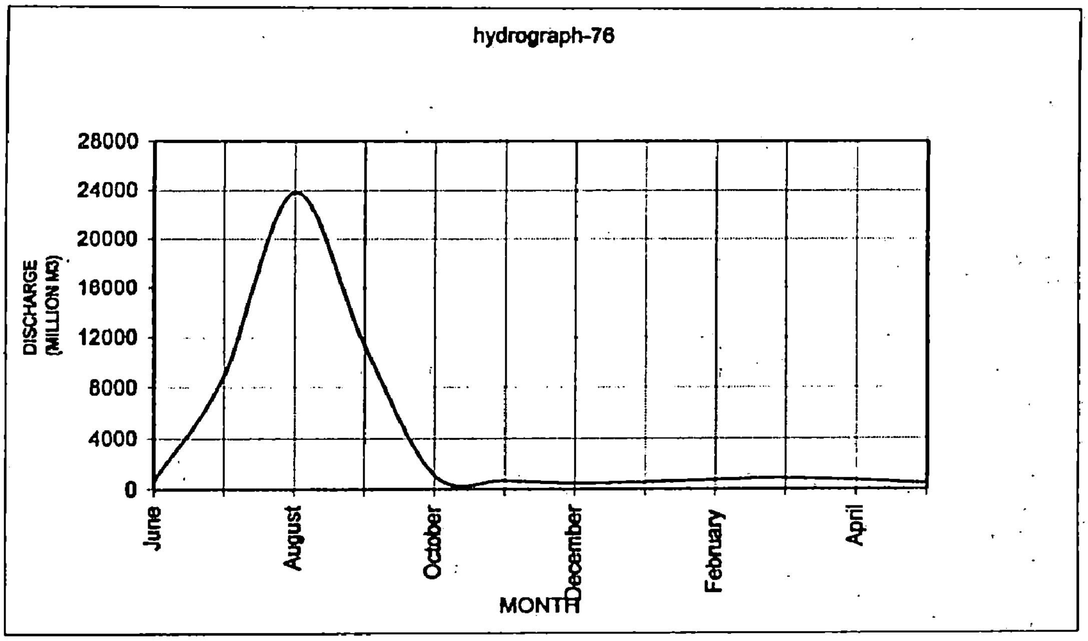
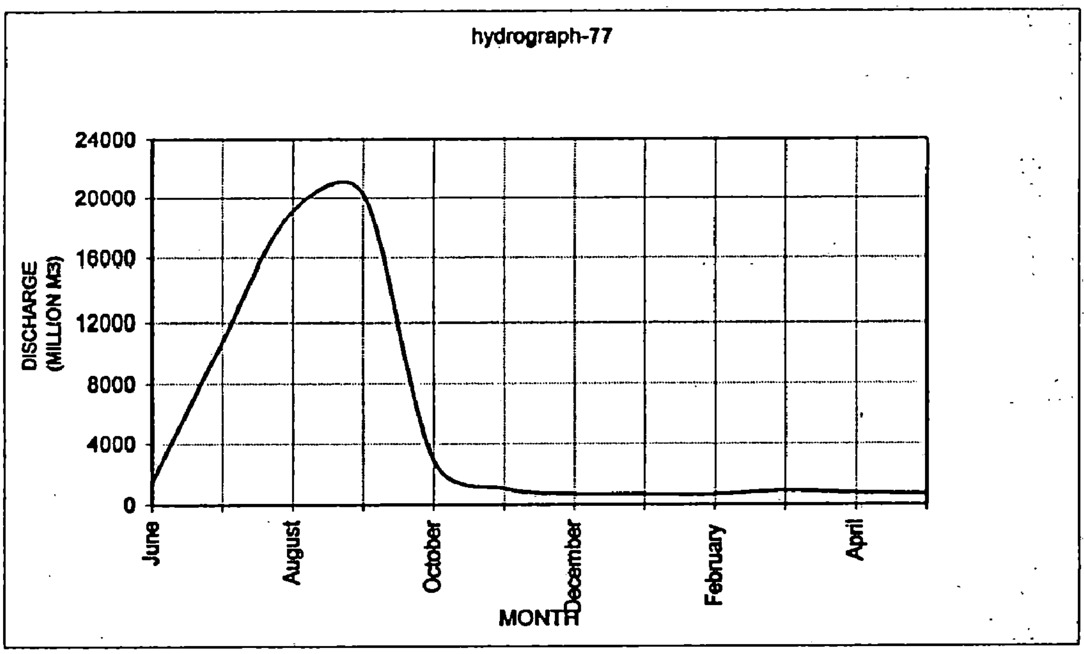




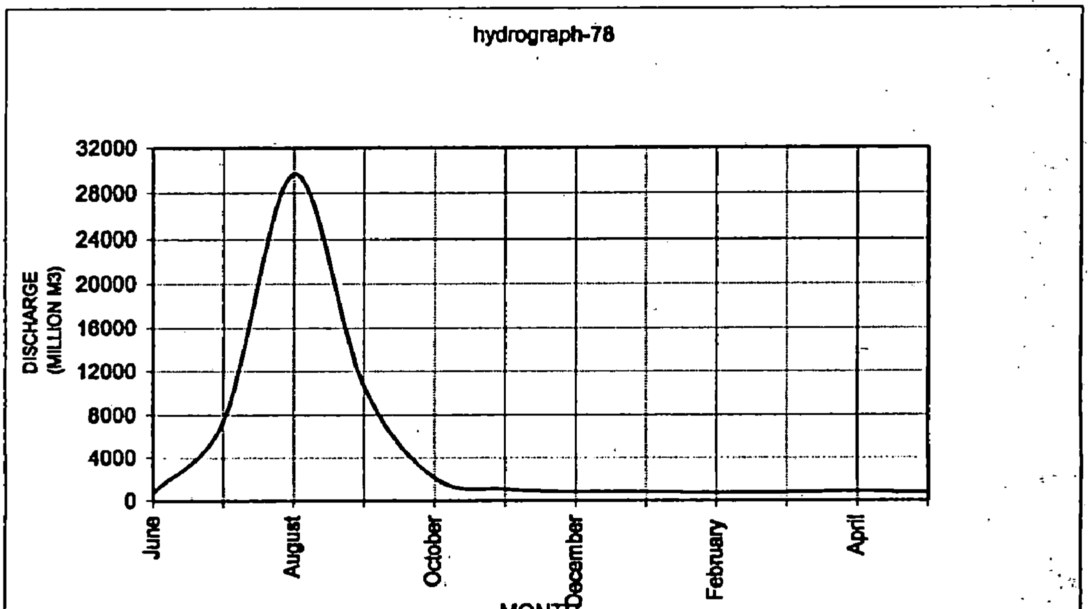


Fig. 4.15 Hydrograph

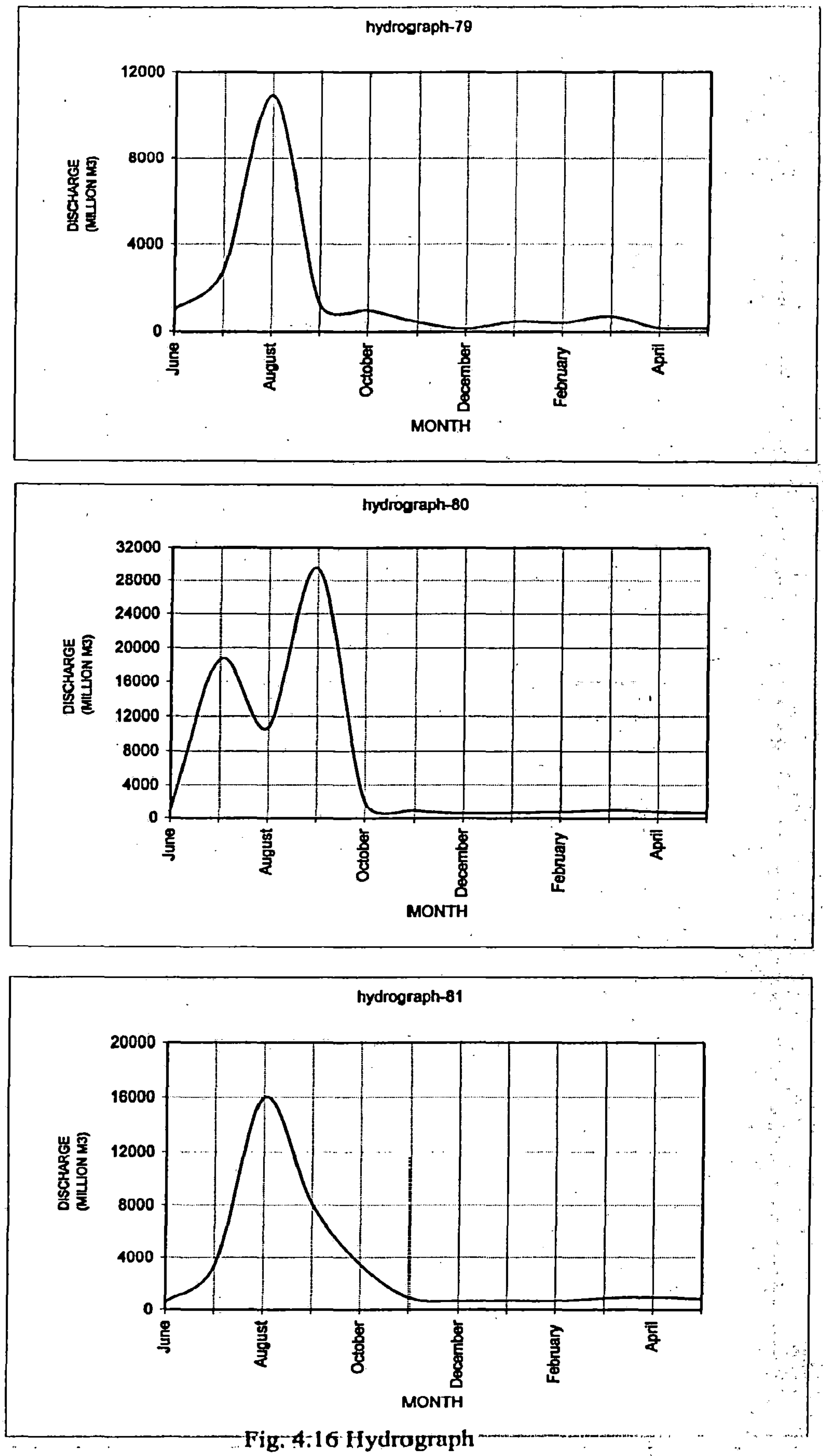
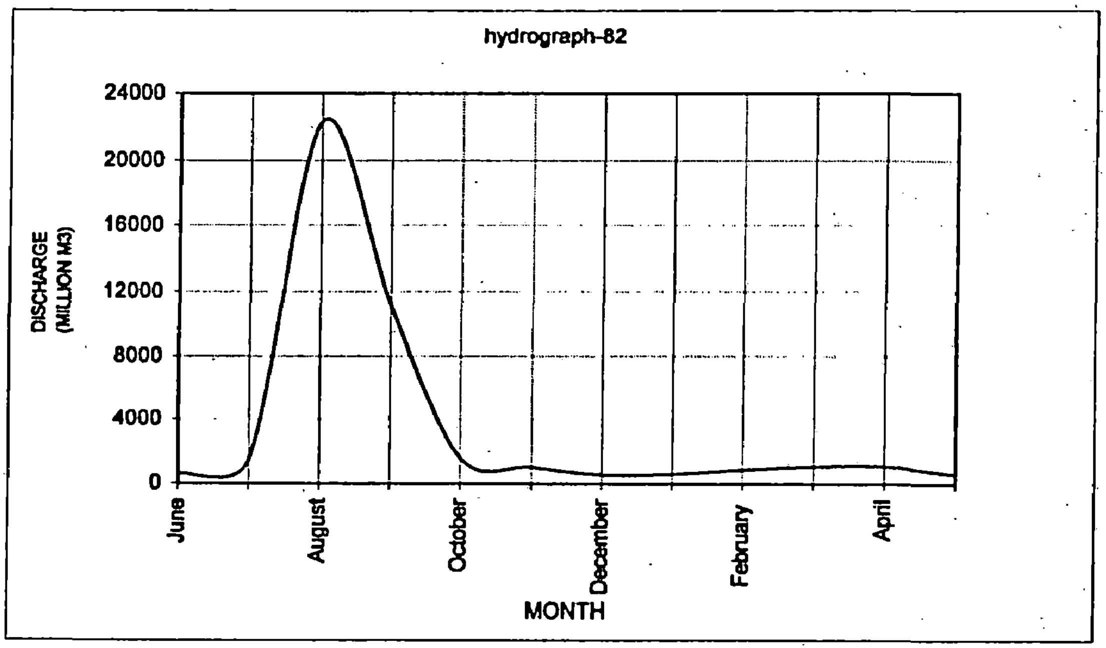
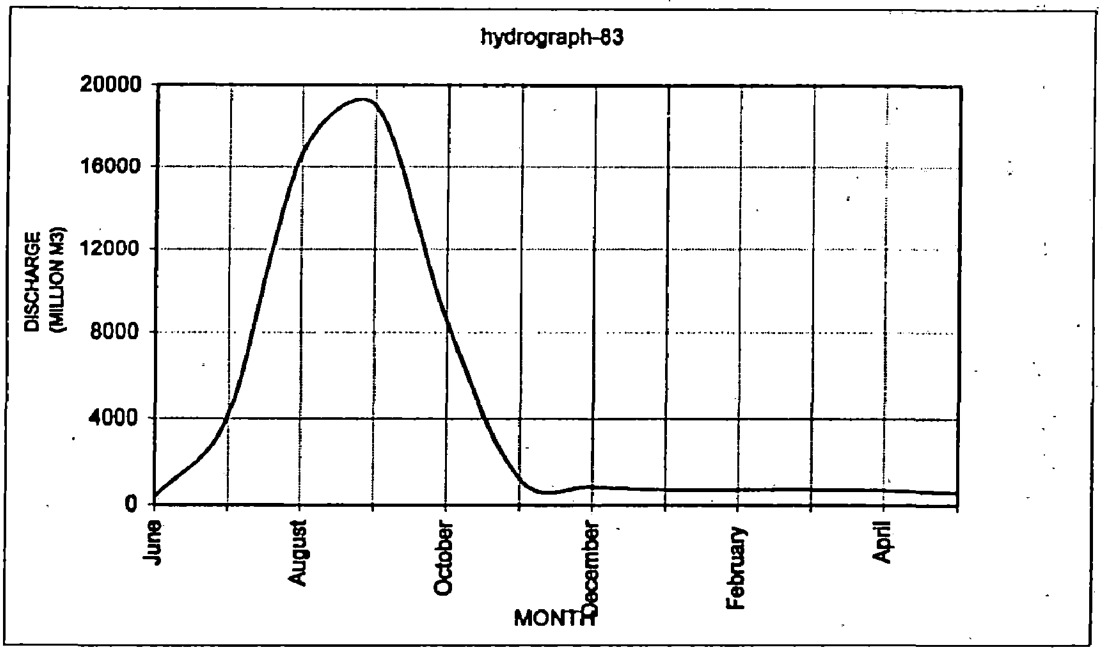


Fig. 4.16 Hydrograph





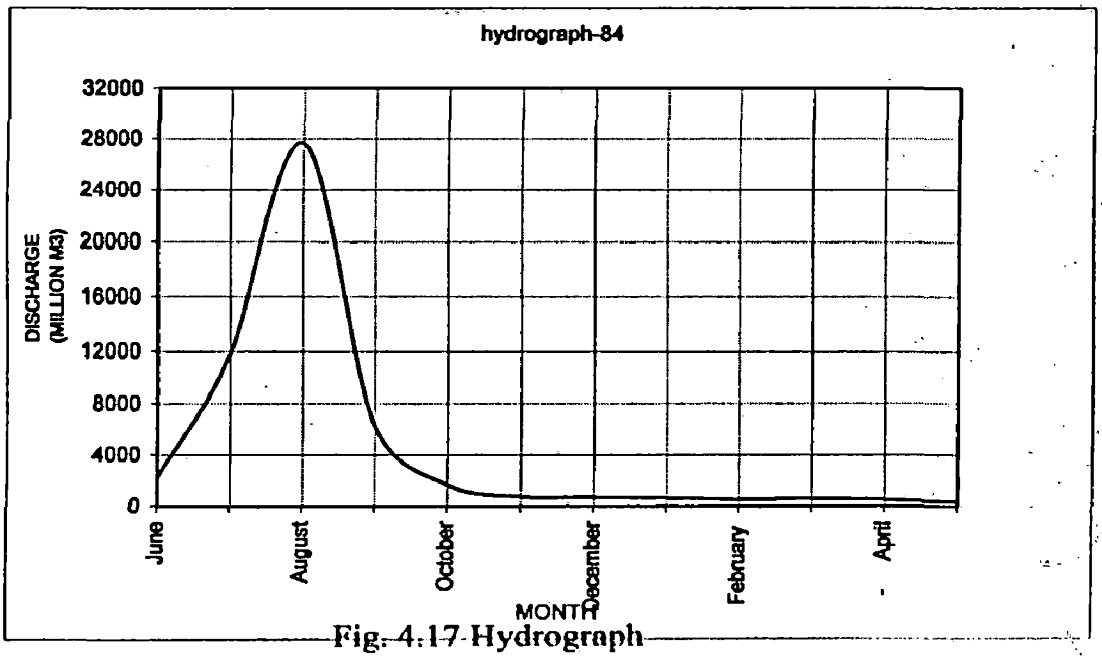
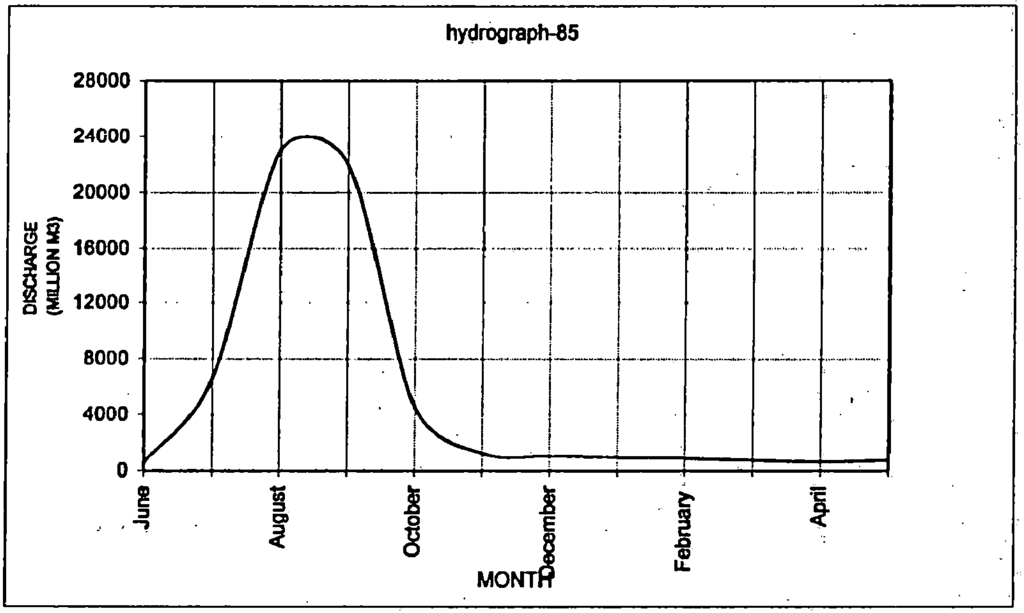
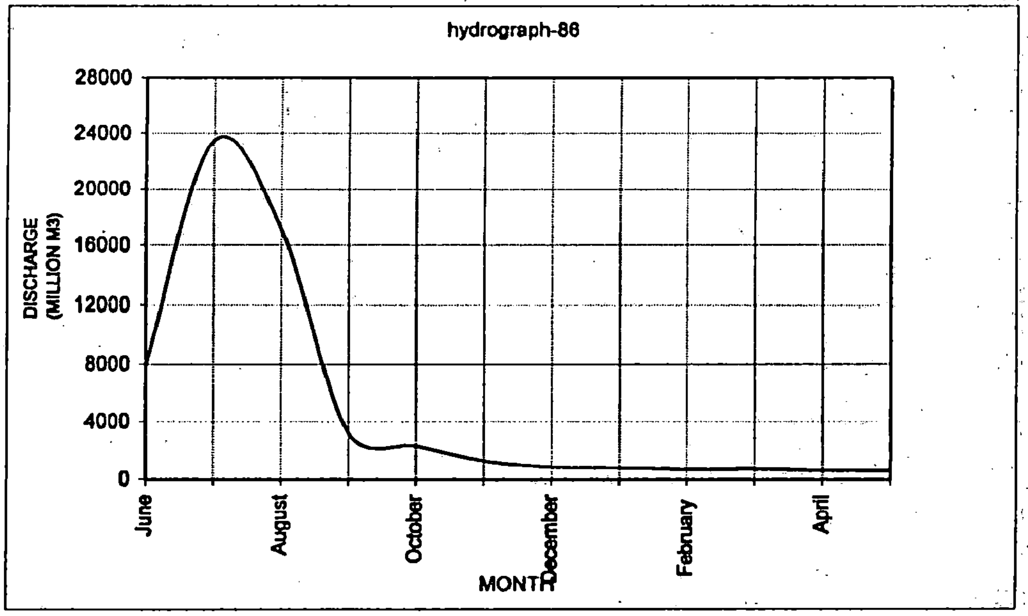


Fig. 4.17 Hydrograph





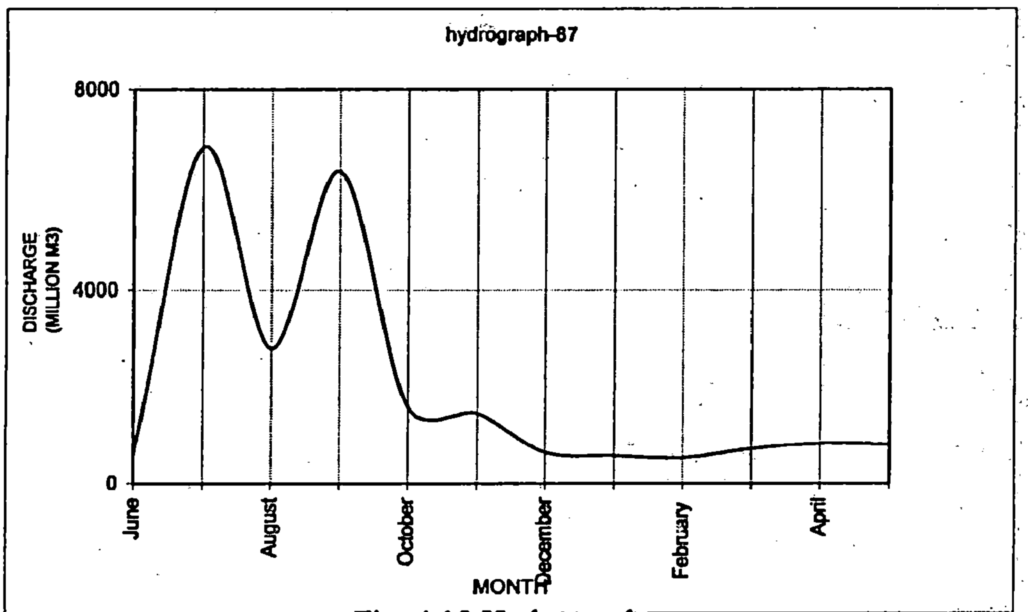


Fig. 4.18 Hydrograph

Table 4.22 : Mahanadi Basin

DISTRICTWISE STATUS OF GROUND WATER RESOURCES & STRUCTURES FEASIBLE IN THE BASIN

Sl. No.	DISTRICT	Ground water resource assessed (HM)	Utilisable resource for domestic and industrial use (HM)	Utilisable resource for irrigation use (HM)	Nos. of existing GW structures for irrigation use						Annual draft for irrigation use (HM)	Balance resource for irrigation use as of 1999 (HM)	Gross annual draft for all uses (HM)	Stage of GW development (%)
					DW	FPTW	BW	STW	MDTW	DTW				
1	Angul	35430	777	34652	6193	0	0	0	0	0	2016	32637	2641	7.45
2	Baragarh	71432	3004	68428	5275	0	0	72	0	0	3281	65147	4953	6.93
3	Bolangir	75643	3696	71947	7898	0	0	0	0	0	4089	67858	5808	7.68
4	Boudh	40669	1207	39462	13607	0	0	2	0	0	4950	34512	5691	13.93
5	Cuttack	114019	5147	108872	9152	1011	0	0	246	0	9979	98894	13215	11.58
6	Deogarh	1554	45	1509	287	0	0	0	0	0	90	1419	120	7.73
7	Dhenkanal	7256	440	6816	2092	0	0	0	0	0	921	5895	1203	16.58
8	Ganjam	711	26	685	83	0	0	2	0	0	57	628	73	10.23
9	Jagatsinghpur	1[illegible]5920	2564	134356	4261	543	0	279	34	0	7921	126435	9840	7.1[illegible]
10	Jajpur	2800	224	2576	219	14	0	2	10	0	279	2297	406	14.5[illegible]
11	Jharsuguda	18984	1642	17342	6258	0	6	0	0	0	2309	15033	3270	17.2[illegible]
12	Kalahandi	90773	5804	84969	21462	0	0	0	0	0	7680	77289	10865	11.[illegible]
13	Kendrapara	19226	493	18733	487	0	0	484	0	0	5020	13713	5606	29.[illegible]
14	Khurda	74355	6192	68164	7528	173	0	9	0	8	3365	64799	6676	8.93
15	Nawarangpur	15265	656	14609	840	0	0	0	0	0	339	14271	687	4.5[illegible]
16	Nayagarh	46405	1965	44440	9691	0	0	1	0	0	4270	40170	5691	12.2[illegible]
17	Nuapara	24813	1253	23560	8012	0	0	0	0	0	3181	20379	4135	16.5[illegible]
18	Phulabani	55136	1579	53557	10930	0	0	0	0	0	4206	49351	5154	9.3[illegible]
19	Puri	89900	2719	87181	2849	708	10	30	58	0	4381	82800	6451	7.[illegible]
20	Rayagada	727	71	656	49	0	0	0	0	0	16	640	71	9.8[illegible]
21	Sambalpur	68937	2404	66533	7792	0	10	0	0	0	2820	63713	4400	6.[illegible]
22	Sonepur	40943	1646	39297	4995	0	0	0	0	0	1959	37338	2996	7.[illegible]
23	Sundargarh	30431	1105	29326	7290	0	29	0	0	0	3479	25846	4134	13.[illegible]
	TOTAL	1062328	44657	1017671	137249	2448	55	881	348	8	76609	941062	104085	9.[illegible]

NB: *Calculations are based on Groundwater Estimation Committee Norms - 1997. All figures are subject to Study Group / Govt. approval.*
GW=Ground Water, HM=Hectare Metre, DW=Dug Well, TW=Tube Well, FPTW=Filter Point TW, BW=Bore Well, STW=Shallow TW, MDTW=Medium Deep TW, DTW= Deep TW.

ESTIMATION OF WATER REQUIREMENTS

5.1 GENERAL

Mahanadi basin in Orissa is considered to be the food bowl of the state since last many centuries. It caters to the need of about 45% of the population of Orissa, and export the excess produce to the faraway places. But due to increase in population the pressure on food production is also increasing and production in excess of requirement of different crops is declining which is adversely affecting the economy of the basin population. therefore there is a need to make improvement in this sector not only to become self-sufficiency with time but also to add up to the economy through export of food grains produced in excess of the requirement.

5.2 FACTORS CONSIDERED FOR DEMAND CALCULATION

The following factors are considered during demand calculation

a) Population
- i) Human population
- ii) Live stock

b) Catchment Area
- i) Major Irrigation Project
- ii) Medium & Minor Irrigation Project
- iii) Lift Irrigation Project

c) Crop water requirement

5.3 POPULATION

5.3.1 Human Population

The human population is generally be projected by the year 2050 using the following formula

$$P_{2050} = P_{2001}\left[1+\frac{R}{1000}\right]^N$$

where P_{2050} = Population in 2050 AD

P_{2001} = Population (Known) in the year 2001

R = Compound rate of Growth of population

and N = Number of years

But for the present study, the population has been considered at 2051. The population data for past years as well as the forecasted population have been found out from census data and from the 3rd spiral study made by Orissa Govt respectively. As such the population at different years are as in Table 5.1

5.1 Population at different year

Year	Rural	Urban	Total	% of Urban
1	2	3	4	5
1991	12033954	2212881	14246835	15.5%
2001	13024909	3177223	16202132	19.6%
2011	13859635	4073071	17932706	22.7%
2021	14451031	4872940	19323971	25.2%
2031	14857496	5454705	20312201	26.9%
2041	15037724	5767269	20804993	27.7%
2051	15082946	5847177	20930123	27.9%

The population of human and live stock have been project to the year 2050.

5.3.2 Live Stock Population

The live stock population, which is used for finding out industrial water demand is taken from past data and forecasted by taking 1% rate of growth to forecast its future value and given in Table 5.2 & 5.3.

Table 5.2 Live Stock Population in Different Year

Year	Total	Remark
1	2	3
1977	4878223	Rate of growth 1% per year
2001	6194049	
2025	7864798	
2051	10186930	

Table 5.3 Live Stock Population of Orissa

Sl. No.	District	Year	Live Stock Population
1	Kalahandi District	1977	947501
2	Koraput District	1977	161054
3	Sambalpur District	1977	1099897
4	Sundargarh District	1977	503198
5	Bolangir District	1977	1128550
6	Phulbani District	1977	564848
7	Dhenkanal District	1977	274815
8	Puri District	1977	149509
9	Cuttack District	1977	48851
	Total		4878223

5.4 CATCHMENT AREA

Table 5.4 Catchment are of Mahanadi Basin

	Major and Medium		Minor (lift and flow)	
	Khariff	Rabi	Khariff	Rabi
Existing	548749	361269	302513	110219
Future	879716	381960	439147	178244
Ongoing	149393	55598		

5.5 DOMESTIC WATER REQUIREMENTS.

Urban 200liters/day/capita

Rural 70 liters/day/capita

Livestock 50 liters/day/capita

The district/Tahsilwise population in all the nine sub-basins of the Mahanadi basin upto Tikarapara and for the portion from Tikarapara to Manibhadra was projected to 2025 AD based on population as per the 1981 Census figures and by using a suitable compound growth rate. These projected population figures of each sub-basin as given in their preliminary water balance reports, which were already circulated and accepted by TAC and the projected population figures for the portion upto Manibhadra was added to obtain the total projected population of Mahanadi basin upto Manibhadra. The live stock population was projected to 2025 AD based on the latest available census data and using 1% growth rate.

The per capita daily requirement of water for the urban, rural and live stock population as per the recommendations of the Ministry of Works and Housing in its annual "Water Supply and treatment" was taken to be 200 ltrs, 70 ltrs. and 50 ltrs. respectively and the domestic requirement was worked out. The requirement of water for the urban population and for 50% of the rural population was considered to be met from surface water resources. The needs for livestock and for 50% of remaining rural population was to be met from ground water resources. 50% of surface water utilized for domestic purposes was considered to be available as return flow to the streams. The domestic water demand of Mahanadi Basin is presented in Table 5.5.

Table 5.5 Domestic Water Demand

Month	Domestic Demand	Month	Domestic Demand
May	52.00	Nov	52.00
June	52.00	Dec.	52.00
July	52.00	Jan	52.00
Aug	52.00	Feb	52.00
Sept.	52.00	Mar	52.00
Oct.	52.00	Apr	52.00
Total :-			624.00

5.6 WATER REQUIREMENT FOR IRRIGATION

Water requirement for irrigation is a derived demand. The key determining variables are

1) Requirement for food production
2) Requirement for non food production
3) Efficiency of water use and
4) Productivity per unit of Land.
5) Net cultivable area
6) Cropping intensity
7) % of irrigated to gross cropped area
8) Total irrigated cropped area

9) Total un-irrigated cropped area

10) Total cropped area

11) Food cropped area as % of irrigated area

12) Food cropped area as % of un-irrigated area

13) Average yield (i) irrigated food cropped area

(ii) un-irrigated food cropped area

14) Food grain production

(i) from irrigated area

(ii) un-irrigated area

15) Irrigated area from surface water

16) irrigated from ground water

17) Assume delta for ground water

18) Surface water requirement for irrigation

19) Ground water requirement for irrigation

20) Total water requirement for irrigation

Requirement of flood production would main depends upon the

a) Country population

b) Per capita in come and

c) Change in dietary habits

5.6.1 Depth and Efficiency of Irrigation

1) The irrigation commission (1972) estimated water requirement for irrigation assumed on average value of delta (or irrigation depth as 0.76 m at national level for surface and ground water combined.

2) Subsequently the national commission on agricultural (1976) assumed that on an average 0.65 ham of ground water is required to irrigate a cropped area and 0.9 ham of the source is surface water as conveyance losses are higher in the latter.

3) NIR The net irrigation requirement (NIR) varies with the

   i. Crop

   ii. Climatic factor

   iii. Effective rainfall during the crop growing period.

4) GIR – The gross irrigation requirement (GIR) or Delta i.e. depth of irrigation at canal is a function of Net irrigation requirement and

efficiency of conveyance of water through irrigation channel and application of water in the field. It may be defined as

GIR = NIR / (Conveyance efficiency x application efficiency)

= NIR/ (overall irrigation efficiency)

5.6.2 Irrigation Water Requirement

Existing : As per projects designed

Ongoing : As per projects reports designed

Future : [water depth in meter]

Major projects [Irrigation intensity 150%]]

Medium projects [125%]

Minor projects [100%]

The details of gross command area, culturable command area, designed annual irrigation and utilization for the existing, ongoing and proposed projects were collected for major, medium and minor projects falling in the catchment upto manibhadra. The designed annual irrigation and utilization in respect of all he existing and ongoing were kept undisturbed in assessing the surface water requirements. The annual irrigation from future identified major, medium and minor projects was assessed considering the irrigation intensities to be 150%, 125% and 100% respectively.

The water requirement of crops for the identified future major, medium and minor projects were assessed based on climatological approach.

It was assumed that 10% of the surface water (excluding evaporation losses from reservoirs) utilized or to be utilized from all the existing, ongoing and identified future major and medium projects would be available as return flow to the stream. The crop water required of Mahanadi basin is presented in Table 5.6 and the total Irrigation water requirement is presented in Table 5.7.

Table 5.6 Crop Water Requirement

For Khariff		
i) Kor water for (May & June) :-		0.19 m
ii) During July, Aug., Sept :-		0.9 m
For Rabi		
i) Kor water for (Oct.) :-		0.19 m
ii) During Nov. Dec. Jan. Feb. :-		0.45 m

Table 5.7 For Irrigation Demand

	Existing	Ongoing	Future	Total
May	808.70	141.92	1252.92	2203.54
June	808.70	141.92	1252.92	2203.54
July	2553.79	448.18	3956.59	6958.55
Aug	2553.79	448.18	3956.59	6958.55
Sept.	2553.79	448.18	3956.59	6958.55
Oct.	895.83	105.64	1064.39	2065.85
Nov	530.42	62.55	630.23	1223.20
Dec.	530.42	62.55	630.23	1223.20
Jan	530.42	62.55	630.23	1223.20
Feb	530.42	62.55	630.23	1223.20
Mar				
Apr				

5.7 INDUSTRIAL WATER REQUIREMENTS

The water needs for all existing and future industries located or which are going to be located in the basin upto Manibhadra were collected from respective state Govt. In the absence of information regarding water needs of the industries, the industrial water requirement in that area was assumed to be of the same order as that of the domestic water requirements. The entire industrial water needs was proposed to be met from surface water resources and the 80% of the surface water utilized or to be utilized was considered as regeneration.

These are calculated on the same basis as these for domestic. The industrial water is supplied from the surface water. The total industrial water requirement is presented in Table 5.8.

Table 5.8 Total Industrial Water Demand

Month	Industrial Water Demand	Month	Industrial Water Demand
May	83.00	Nov	83.00
June	83.00	Dec.	83.00
July	83.00	Jan	83.00
Aug	83.00	Feb	83.00
Sept.	83.00	Mar	83.00
Oct.	83.00	Apr	83.00
Total :-			996.00

5.8 EVAPORATION LOSSES

[i] Existing and ongoing reservoirs =As per actual

[ii]Proposed =20% of utilizable water

5.8.1 Environmental

The monthly environmental water requirements are taken equal to one percent of the monthly surface water available in the basin and shown in the Table 5.9

Table 5.9 Environmental Water Requirement

Month	Environmental Demand	Month	Environmental Demand
May	37.50	Nov	50.60
June	327.70	Dec.	56.50
July	1008.00	Jan	54.90
Aug	366.50	Feb	68.30
Sept.	112.80	Mar	61.60
Oct.	75.80	Apr	45.20
Total :-			2265.40

Total Water Use (100 %)

The total water requirement by the 2050 for all purposes like irrigation drinking industrial use and other purposes is given in Table 5.9 and the total water utilization including export is presented in Table 5.10 as shown in Fig. 1.

Out of the total water use

Irrigation	-	89%
Domestic	-	2%
Industrial Use	-	3%
Environmental	-	6%
		100%

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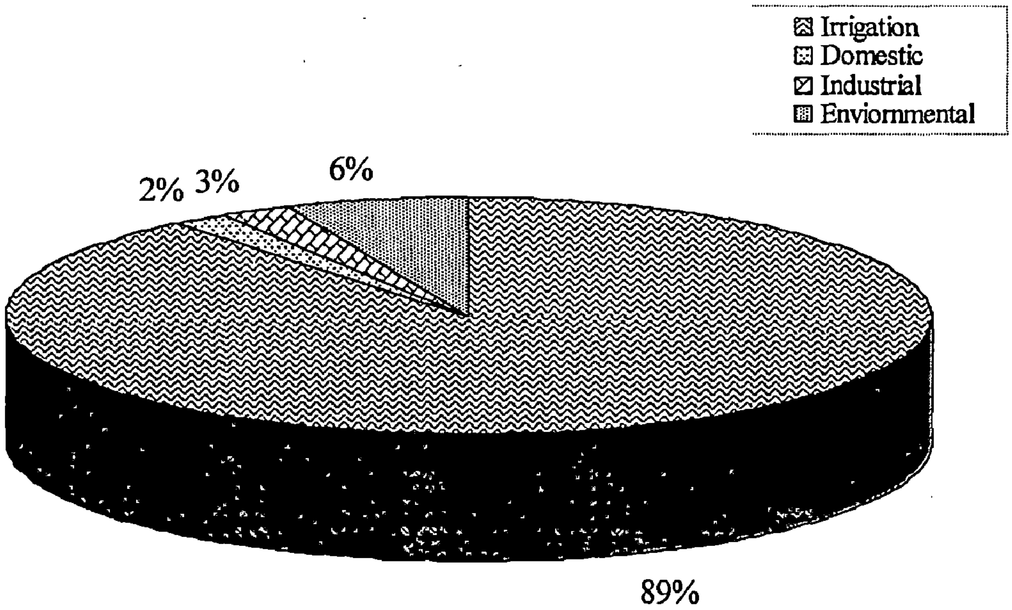

Fig. ~~6.10~~ 5.1 DEMAND AT 2051

Table 5.10 Total Water Requirement

Month	Water Utilisation							
	Water Requirement							
	Utilisation under irrigation project				Domestic	Industrial	Environmental	Total
	Existing	Ongoing	Proposed	Total				
1	2	3	4	5	6	7	8	9
Jun	808.70	141.92	1252.92	2203.54	52.00	83.00	44.60	2383.14
Jul	2553.79	448.18	3956.59	6958.55	52.00	83.00	730.50	7824.05
Aug	2553.79	448.18	3956.59	6958.55	52.00	83.00	1226.90	8320.45
Sep	2553.79	448.18	3956.59	6958.55	52.00	83.00	624.70	7718.25
Oct	895.83	105.64	1064.39	2065.85	52.00	83.00	163.50	2364.35
Nov	530.42	62.55	630.23	1223.20	52.00	83.00	96.50	1454.70
Dec	530.42	62.55	630.23	1223.20	52.00	83.00	66.00	1424.20
Jan	530.42	62.55	630.23	1223.20	52.00	83.00	65.80	1424.00
Feb	530.42	62.55	630.23	1223.20	52.00	83.00	59.80	1418.00
Mar	0.00	0.00	0.00	0.00	52.00	83.00	72.40	207.40
Apr	0.00	0.00	0.00	0.00	52.00	83.00	66.30	201.30
May	808.70	141.92	1252.92	2203.54	52.00	83.00	54.70	2393.24
Total :-	12296.28	1984.21	17960.91	32241.40	624.00	996.00	3271.70	37133.10

5.9 IMPORT AND EXPORT

All imports/exports as specifically mentioned in indicative master plans of states have been taken into account in the report. For such project in the sub-basin whose command area falls partly or wholly in adjacent sub-basin, the quantum of water required for irrigation areas outside the sub-basin has been considered as export from the sub-basin and return flow has been considered as flow the same. If command area of any irrigation project located outside the sub-basin

The import of water from other basins and the export of water to other basins, both with respect to the basin under consideration has been worked out. The total export from Mahanadi basin to other basin is presented in Table 5.10.

Table 5.11 Water Export to Other Basin

Export			
Tikira	Brahmani - Baitarani	Rushikulya	Total
1	2	3	4
98.78	72.66	47.63	219.08
311.95	229.46	150.43	691.83
311.95	229.46	150.43	691.83
311.95	229.46	150.43	691.83
0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00
98.78	72.66	47.63	219.08
1133.40	833.71	546.55	2513.66

5.10 HYDROPOWER NEEDS

There are no ongoing or proposed hydroelectric projects in the basin .As such the requirements of water for hydropower generation is taken as nil.

5.11 FINALLY

The water balance at the specified site [Manibhadra diversion point] has been done in the following manner surplus or deficit = [The 75% water year dependable flow/yield + Ground water availability + Regeneration +Imports] – [Total water needs + Exports]

Table 5.12 Total Water Utilization

Month	Water utilisation												
	Water requirement								Export				
	Utilisation under irrigation project				Domestic	Industrial	Environ mental	Total	Tikira	Brahm ani - Baitara ni	Rushik ulya	Total	Gross total utilisation
	Existing	Ongoing	Proposed	Total									
1	2	3	4	5	6	7	9	10	11	12	13	14	15
Jun	808.70	141.92	1252.92	2203.54	52.00	83.00	44.60	2383.14	98.78	72.66	47.63	219.08	2602.22
Jul	2553.79	448.18	3956.59	6958.55	52.00	83.00	730.50	7824.05	311.95	229.46	150.43	691.83	8515.89
Aug	2553.79	448.18	3956.59	6958.55	52.00	83.00	1226.90	8320.45	311.95	229.46	150.43	691.83	9012.29
Sep	2553.79	448.18	3956.59	6958.55	52.00	83.00	624.70	7718.25	311.95	229.46	150.43	691.83	8410.09
Oct	895.83	105.64	1064.39	2065.85	52.00	83.00	163.50	2364.35	0.00	0.00	0.00	0.00	2364.35
Nov	530.42	62.55	630.23	1223.20	52.00	83.00	96.50	1454.70	0.00	0.00	0.00	0.00	1454.70
Dec	530.42	62.55	630.23	1223.20	52.00	83.00	66.00	1424.20	0.00	0.00	0.00	0.00	1424.20
Jan	530.42	62.55	630.23	1223.20	52.00	83.00	65.80	1424.00	0.00	0.00	0.00	0.00	1424.00
Feb	530.42	62.55	630.23	1223.20	52.00	83.00	59.80	1418.00	0.00	0.00	0.00	0.00	1418.00
Mar	0.00	0.00	0.00	0.00	52.00	83.00	72.40	207.40	0.00	0.00	0.00	0.00	207.40
Apr	0.00	0.00	0.00	0.00	52.00	83.00	66.30	201.30	0.00	0.00	0.00	0.00	201.30
May	808.70	141.92	1252.92	2203.54	52.00	83.00	54.70	2393.24	98.78	72.66	47.63	219.08	2612.32
Total :-	12296.28	1984.21	17960.91	32241.40	624.00	996.00	3271.70	37133.10	1133.40	833.71	546.55	2513.66	39646.76

5.12 FOOD GRAIN SELF SUFFICIENCY (SUPPLY AND DEMAND)

The food grains, oils, vegetables, meat requirements of healthy adult male, female, children basing upon the labour they do in different professions are available in the books "nutritive value of Indian foods" by G. Gopalan, B. U. Ramasastri, S. C. Balasubramanyam (1981 edition). these figures are also accepted by the health department, Govt, of Orissa.

For planning purpose, in Mahanadi basin, the average/capita/annum food grains requirements is found out basing upon the catogorization of census figure of Orissa, 1991 combined with the provisional populations of 2001. while computing oilseed requirement, oil to seed ratio is taken as 0.30. The average per capita NPR Per Annuam in Orissa is given in Table 5.13.

Table 5.13 The Average Per Capita NPR Per Annuam In Orissa Comes To

Cereals	142 KG
Pulses	24KG
Oilseeds	45KG
Vegetable	70KG

Basing upon the said food grains requirement, to fulfill the nutritional requirement in Mahanadi basin the demand on food grain at the end of the planning horizon i.e. at 2050 with the expected population of the Mahanadi basin of 2093023 nos. the food grain requirement as per the NPR and expected population from the basin itself are given in the Table 5.14.

Table 5.14 Food Grain Demand and Production

Grains	Demand in lakh MT	Production in lakh MT	Remarks
Cereal	29.72	72.52	Surplus
Pulses	5.02	1.94	Deficit
Vegetables	14.65	15.47	Surplus
Oilseeds	9.42	4.64	Deficit

5.13 FOOD AND AGRICULTURE

The Mahanadi basin of Orissa portion has a total geographical area of 6562800 ha. The cultivable area of the basin is 3020770. which is 46.03% of the total geographical area of the Mahanadi basin in Orissa. And 46.06% of the total cultivable area of the of Orissa. (65.59)lakhs.

As per the statistics currently available the yield rate of rice in Orissa is 13.39Qtl per Ha. And consumption of fertilizer is 32.51 kg per ha as against the National average of 28.14 qtl/ha and 77.5 kg/ha. respectively. The irrigation potential created upto June 2001 through major and medium irrigation project in Orissa is 11.55 lakhs ha in Kharif and 4.59 lakhs ha. in Rabi.

Paddy is the predominant crops in the khariff . in Rabi, the predominant crops are pluses vegetables, oil seed , potato.

The Hirakud dam over river Mahanadi at Hirakud in Sambalpur district of Orissa was the first water resources project constructed in a planned manner. This project is not only the first multipurpose project of Orissa but also the largest and longest earthen dam project of Asia then, in 1957. The Hirakud dam not only provides irrigation to an area of 155660ha. in Sambalpur, Bargarh , Balangir and Sonepur districts, but also protects downstream from flood.

5.13.1 Information as Obtained from Agricultural Department Govt. of Orissa Food gain demand

Nutritional per capita requirement (kg/captia/annum)

Food grains		
Cereals / Paddy		142
Pulses		24
Fats & Oils		14
Oil seeds (oils/0.3)		35
Vegetable		70
Average oil to seeds ratio	=	30%

The predominant form of cereals in Prissa is Paddy

As per local enquiry

The average production of raw rise from Paddy = 55 kg to 62 kg per 100 kg

The average production of boiled rice from Paddy = 70 kg to 72 kg per 100 kg

The average production of rice from paddy = 66%

(as per agricultural statistics)

Table 5.15 Demand of food grains (lakh MT)

Year	Population	Cereals (Paddy)	Pulses	Vegetable	Oilseeds
2001	16202133	23.01	3.89	11.34	7.29
2050	20930123	29.72	5.02	14.65	9.42

Table 5.16 Production of food grains (lakh MT)

Year	Cereals (Paddy)	Pulses	Vegetable	Oilseeds
2001	50.53	1.10	14.05	2.48
2050	72.52	1.94	15.47	4.64

Table 5.17 : List of Project (Present & Future)

Major Project

Sl. No.	Name of the Project	CCA (Ha)
	Existing Projects	
1	Ong Barrage Project	10670
2	Hirakud Dam Project	159090
3	Salki Barrage Project	19879
4	Delta Stage-I	167000
5	Delta Stage-II	136000
6	Hati Barrage Project	30000
	Total :	522639
	Ongoing Projects	
1	Hati Barrage Project	98000
2	Lower Indra Irr. Project	29900
3	Lower Suktel Irr. Proejct	23500
	Total :	151400
	Future Project	
1	Ib Irrigation Project	106279
2	Manibhardra Irr. Project	192000
3	U. Bheden Dam Project	11000
4	L. Bheden Dam Project	19000
5	Lamdora Dam Project	11200
6	Upper Tel Project	13240
7	Ong Irr. Project	30000
8	Lower lanth Dam Project	30000
9	U. Udanti Dam project	24000
10	Uttei Raul Dam Project	26474
11	Khadago Dam Project	37140
12	Surbalijore Dam Project	18000
13	L. Tel Barrage Project	61000
14	Lowr Udanti Project	14000
15	Hirakud Dam Project (lifi)	125752
16	DELTA Extension	99811
17	Ong Garland	12240
18	L. Suktel Garland Project	13700
19	Brutang Irrigation Project	23630
20	Sagada Dam project	18750
	Total	887216
	Grand Total	1561255

Total C. C. A. In Mahanadi Basin (Ha)
=15,61,255+1,53,993
=17,15,248 Ha

Medium Project

Sl. No.	Name of the Project	CCA (Ha)
	Existing Projects	
1	Talasara Irr. Project	3580
2	Saipala Irr. Project	2060
3	Dumerbahal Irr. Project	2660
4	Jharbandh Irr. Project	2130
5	Sundar Irr. Project	4450
6	Uttei Irr. Project	9626
7	U. Suktel Project	1350
8	Upper jonk Project	9078
9	Hariharjore Irr. Project	9450
10	P. Salki Irr. Project	2390
11	Kuaria Irr. Project	3600
12	B. Budhiani Irr. Project	3290
13	Dahuka Irr. Project	2740
14	Sarafgarh Irr. Project	2730
15	Sapua Irrigation Project	950
	Total :	60084
	Ongoing Projects	
1	Manjore Irr. Project	6775
2	Bagh Irr. Project	7000
3	Titlagarh Irr. Project	2000
4	KharKhari Irr. Project	2000
	Total :	17775
	Future Projects	
1	Jeera Irr. Project	4600
2	Ret Irr. Project	5500
3	Upper Lanth Irr. Project	3500
4	Dhauragoth Irr. Project	2230
5	Kutulisinga Irr. Project	2540
6	Lower Jonk Irr. Project	7500
7	Kerandijore Irr. Project	2100
8	Sankhabhang Dam Proj.	4650
9	Banjarinalah Dam Proj.	3400
10	Upper Indra Dam Project	7200
11	U. Tel Barrage Project	9610
12	M. S Garland Project	600
13	LNS Suktel Garland Project	5000
14	L. Lanth Garland Project	7000
15	Sapua Extension	150
16	Hadua Irrigation Project	3948
17	Ong Barrage Extension	6605
18	Basundhara (Water Supply Scheme)	
	Total:	76134
	Grand Total:	153993

TABLE 5.18

MAHANADI BASIN
DISTRICT WISE ABSTRACT OF M.I. PROJECTS

Sl.No.	District	No. of projects	Catchment area in sq Km	Ayacut in Ha. (Kharif)	Ayacut in Ha. (Rabi)
1	Angul	22	258.96	5011.00	892.00
2.	Bargarh	114	896.29	19818.53	3073.39
3.	Bolangir	133	980.39	16148.96	3176.43
4	Boudh	58	816.53	11596.87	1797.00
5	Cuttack	76	2673.57	17289.89	4214.71
6	Deogarh	2	3.23	142.82	20.23
7	Dhenkanal	10	108.26	2308.00	956.00
8	Ganjam	0			
9	Jagatsinghpur	0			
10	Jaipur	6	33.70	1139.40	727.40
11	Jharsuguda	30	235.77	4702.14	1140.97
12	Kandhamal	58	460.49	7857.87	3470.91
13	Kalahandi	81	1275.60	21398.00	5193.00
14	Kendrapara	1	1.50	40.00	0.00
15	Khurda	106	2261.71	15937.00	2470.24
16	Nawarangpur	7	241.56	2720.44	111.28
17	Nayagarh	93	760.77	16554.54	4216.00
18	Nuapada	46	396.24	8430.00	2583.00
19	Puri	2	3.58	67.00	16.00
20	Rayagada	0			
21	Sambalpur	56	657.60	12859.83	1963.28
22	Sonepur	62	339.44	6170.14	472.69
23	Sundargarh	54	797.04	11834.01	1428.94
	TOTAL	**1017**	**13202.23**	**182026.44**	**37923.47**

182025.44 Ha Kharif @ 109215.86 Ha.

37923.47 Ha Rabi @ 0.22754.08Ha

131969.94HAM

or 1320 Mm3

Source: Chief Engineer, Minor Irrigation, Orissa

TABLE : 5.19

MAHANADI BASIN
EXISTING L.I. PROJECTS UPTO 1998-99

Name of the Dist.	No of LIPs existing upto 1998-99			Ayacut (Area in Ha.)	
	T/W.	R/I	Total	Khariff	Rabi
1	2	3	4	5	6
Angula	0	89	89	2654.58	1593.77
Baragath	1	334	335	8304.00	4982.00
Bolangir	2	344	346	7528.00	4517.00
Boudh	0	170	170	5112.00	3067.00
Cuttack	296	478	774	19448.87	11670.69
Deograh	0	5	5	93.84	56.27
Dhenkanal	0	48	48	1186.99	712.35
Ganjam	2	2	4	83.88	50.35
Jagatsinghpur	362	155	517	7936.00	4761.00
Jaipur	11	45	56	1106.29	663.91
Jharsuguda	0	112	112	2624.00	1575.00
Kalahandi	0	382	382	9510.37	5704.62
Kandhamal	0	128	128	2555.86	1533.47
Kendrapara	110	450	559	12964.71	7779.57
Khurda	44	156	201	4773.20	2863.26
Nawarangpur	0	46	46	902.54	541.84
Nayagarh	37	193	230	5197.11	3118.73
Nuapara	3	170	173	4005.0010044.87	2403.00
Puri	74	307	381	95.36	6025.52
Rayagada	0	4	4	5500.67	57.24
Sambalpur	0	220	220	5889.00	3305.10
Sonepur	0	190	190	2969.98	3533.00
Sundargarh	0	110	110	120487.12	1780.88
Total	**942**	**4138**	**5080**		**72295.57**

120487.12 Ha. Kharif @ 0.6m = 72292 Ham

72295.57 Ha. Rabi @ 0.6 m = Total = $\frac{43377\text{Ham}}{115669\text{Ham}}$

or 1157 Mm^3

ESTIMATE OF WATER BALANCE BY 2050

6.1 GENERAL

The data requirement for water balance study, the total annual irrigation requirement of ongoing ,existing and proposed major, mediom, and minor irrigation projects, exports and imports, rural, urban, livestock population, regeneration from irrigation projects, hydropower use etc, were collected from the various reports of preliminary water balance studies and feasibility reports of Mahanadi Basin from NWDA, and Govt. of Orissa

6.2 WATER BALANCE STUDY

Based on the methodology described above, the water balance of Mahanadi basin at Manibhadra diversion point have been worked out by deducting total water needs of the basin from the overall availability of the basin at 75% and 90% dependability respectively. The overall availability has been obtained by adding imports and regeneration return flows to the annual yield of the basin at 75% and 90% dependability and deducting export from the basin.

The following steps were used for computation of water balance on monthly basis for the Mahanadi basin at Manibhadra diversion point [Orissa portion]

1. The total monthly water availability in a basin is computed by summing monthly imports from other basin, monthly regeneration from irrigation, domestic and industrial water uses, monthly surface water and ground water yields.

a) The monthly imports are computed by distributing of total annual import in the proportion of the importing sub basin.

b) The monthly regeneration from irrigation water uses are computed as 10 per cent to 20 percent of the monthly irrigation water requirements. Regeneration from domestic purpose is computed as 80 percent of the domestic water use. The monthly regeneration from industrial water use is taken as 80 percent of the monthly industrial water use.

c) Surface yield - The monthly surface water yield in the basin is taken in the proportion of the monthly observed run off in the basin.

d) Groundwater - The monthly ground water yield in a basin is computed by distributing the annual ground water yield in the proportion of the monthly irrigation water requirements.

2. The monthly gross water requirements are computed by summing all the monthly water requirements for irrigation, domestic, industrial, environmental and exports.

a) The monthly net irrigation requirements for the proposed major, medium and minor irrigation projects are estimated by using modified penman method. The gross irrigation requirements were estimated by adding 20 percent of the net irrigation requirements for accounting for the reservoir evaporation losses,
Water requirements : The monthly gross irrigation requirements for the existing *major, medium and minor irrigation projects are* calculated by distributing the annual irrigation requirements of the projects in the same proportion as of the monthly gross irrigation requirements of the proposed irrigation projects
The monthly gross irrigation requirements for the ongoing projects are calculated by distributing the annual irrigation requirements of projects in the same proportion of the monthly irrigation requirements of the proposed irrigation projects.

b) The requirements of domestic consumption in the rural and urban as well as for the livestock has been obtained by projecting the rural, urban and livestock population of the basin to the 2050 AD. The requirements of water per capita per day for rural and urban and livestock population is considered as 70 liters, 200 liters and 50 liters respectively.

c) Due to non availability of the data, the monthly and total water requirements of industrial water use are taken equal to the water requirements for domestic purpose.

d) The monthly environmental water requirements are taken equal to one percent of the monthly surface water available in the basin.

e) Exports: The monthly exports are calculated by distributing the total annual exports in a basin in the proportion of the monthly available of the surface water in that basin.

6.3 FINAL WATER BALANCE

Finally, the water balance at the specified site [Manibhadra diversion point] has been done in the following manner

Surplus or deficit = [The 75%/90% water year dependable flow/yield + Ground water availability + Regeneration +Imports] – [Total water needs + Exports].

6.4 DISCUSSION AND ANALYSIS OF STUDY

6.4.1 Analysis of Water Balance Studies for the 75 Percent Water Year Dependable Flow without Ground Water

i. The basin was found short of water in the month of **June, July, Sept., Oct., Nov., Dec., Jan., Feb., May.**

ii. Whereas the basin is surplus in its water resources in the month of **Aug., March, April.**

iii. The maximum deficit of **1827.87 Mcm (4.6%)** occurred in the month of **June.**

iv. While the minimum deficit of 26 **259.38 Mcm (0.65%)** occurred in the month of **Nov.**

v. The maximum surplus of **4060.51 Mcm (10.24%)** occurred in the month of **August.**

vi. While the minimum surplus of **564.7 Mcm(1.44%)** occurred in the month of **April.**

vii. The annual deficit in the basin is **7664.49 Mcm(19.33%)**

viii. The annual surplus in the basin is **5254.87 Mcm(13.25%)**

This has been presented in Table 6.1 and Fig. 6.1 & 6.2.

6.4.2 Analysis of Water Balance Studies for the 75 Percent Water Year Dependable Flow with Ground Water

i. The basin was found short of water in the month of **June, Sept., Oct., Nov. Dec., Jan., Feb., May.**

ii. Whereas the basin is surplus in its water resources in the month of **June, July, March, April.**

iii. The maximum deficit of **1620.39 Mcm (4.08%)** occurred in the month of **May.**

iv. While the minimum deficit of **201.86 Mcm (0.509%)** occurred in the month of **Nov.**

v. The maximum surplus of **4767 Mcm (12.02%)** occurred in the month of **Aug.**

vi. While the minimum surplus of **231.13 Mcm(0.58%)** occurded in the month of **July.**

vii. The annual deficit in the basin is **6036.0 Mcm(15.22%)**

viii. The annual surplus in the basin is **6229.30 Mcm(15.71%)**

This has been presented in Table 6.2 and Fig. 6.3 & 6.4.

6.4.3 Analysis of Water Balance Studies for the 90 Percent Water Year Dependable Flow without Ground Water

i. The basin was found short of water in the month of **Jan., July, Sept., Oct., Nov., Dec., Jan., Feb., May.**

ii. Whereas the basin is surplus in its water resources in the month of **Aug., March., April.**

iii. The maximum deficit of **4032.23 Mcm (%)** occurred in the month of **July.**

iv. While the minimum deficit of **445.68 Mcm (1.15%)** occurred in the month of

v. The maximum surplus of **2090.47 Mcm (5.41%)** occurred in the month of **Aug.**

vi. While the minimum surplus of **527.4 Mcm(1.36%)** occurred in the month of **April.**

vii. The annual deficit in the basin is **14671.89Mcm (37.97%)**

viii. The annual surplus in the basin is **3205.57 Mcm(8.29%)**

This has been presented in Table 6.3 and Fig. 6.5 & 6.6.

6.4.4 Analysis of Water Balance Studies for the 90 Percent Water Year Dependable Flow with Ground Water

i. The basin was found short of water in the month of **June, July, Sept. Oct., Nov., Dec., Jan., Feb., May.**

ii. Whereas the basin is surplus in its water resources in the month of **Aug., March, April.**

iii. The maximum deficit of **3394.07 Mcm (8.78%)** occurred in the month of **July.**

iv. While the minimum deficit of **388.16Mcm (1.00%)** occurred in the month of **Nov.**

v. The maximum surplus of **279.9Mcm (7.23%)** occurred in the month of **Aug.**

vi. While the minimum surplus of **546.23 Mcm(1.41%)** occurred in the month of **April.**

vii. The annual deficit in the basin is **12812.27 Mcm(33.15%)**

viii. The annual surplus in the basin is **3948.87 Mcm(10.21%)**

This has been presented in Table 6.4 and Fig. 6.7 & 6.8.

The water balance for position of the Mahanadi basin up to Manibhardra diversion point in Orissa portion is presented below Table 6.5.

6.5 SURFACE WATER

Availability			**unit mm³**
(a)	Grose annual yield		
	(i)	at 75% dependability	32717.00
	(ii)	at 90% dependability	22654.00
(b)	surface water export (-)		2513.66
(c)	overall availability		
	(i)	75% dependability	30203.34
	(ii)	at 90% dependability	20140.34
Surface Water Requirements For			
(i)	Irrigation		32241.40
(ii)	Domestic		624.00
(iii)	Industrial use		996.00
(iv)	Ev. Losses		2265.40
Sub total			(-)36126.80
Regeneration From (+)			
(i)	Domestic use		499.20
(ii)	Industrial use		796.80
(iii)	Irrigation use		3224.14
Sub total			(+)4520.14
Surface Water Balance			
(i)	At 75% dependability		(-) 1403.32
(ii)	At 90% dependability		(-) 11466.32

6.6 GROUND WATER

(i)	Existing draft	1040.85
(ii)	Annual recharge	1562.07
(iii)	Gross ground water potential	(+)2602.92

6.7 WATER BALANCE WITH GROUND WATER

(i)	At 75% dependability	1199.6
(ii)	At 90% dependability	(-) 8863.4

Table 6.1 MONTHLY WATER BALANCE STUDY OF MAHANADI BASIN FOR 75% DEPENDABLE FLOW WITHOUT GROUND WATER

(Unit in MCM)

Month	Water utilisation														Water availability							Monthly Water balance		Remark
	Water requirement									Export				Gross total utilisation	Import	Regeneration from uses				Surface water yield	Gross water available			
	Utilisation under irrigation project				Domestic	Industrial	Hydropower	Environmental	Total	Tikira	Brahmani - Baitarani	Rushikulya	Total			Irr.	Domestic	Industrial	Total			Deficit	Surplus	
	Existing	Ongoing	Proposed	Total																				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Jun	808.70	141.92	1252.92	2203.54	52.00	83.00		44.60	2383.14	98.78	72.66	47.63	219.08	2602.22		220.35	41.60	66.40	328.35	446.00	774.35	1827.87	-	
Jul	2553.79	448.18	3956.59	6958.55	52.00	83.00		730.50	7824.05	311.95	229.46	150.43	691.83	8515.89		695.86	41.60	66.40	803.86	7305.00	8108.86	407.03	-	
Aug	2553.79	448.18	3956.59	6958.55	52.00	83.00		1226.90	8320.45	311.95	229.46	150.43	691.83	9012.29		695.86	41.60	66.40	803.86	12269.00	13072.86	-	4060.57	
Sep	2553.79	448.18	3956.59	6958.55	52.00	83.00		624.70	7718.25	311.95	229.46	150.43	691.83	8410.09		695.86	41.60	66.40	803.86	6247.00	7050.86	1359.23	-	
Oct	895.83	105.64	1064.39	2065.85	52.00	83.00		163.50	2364.35	0.00	0.00	0.00	0.00	2364.35		206.59	41.60	66.40	314.59	1635.00	1949.59	414.77	-	
Nov	530.42	62.55	630.23	1223.20	52.00	83.00		96.50	1454.70	0.00	0.00	0.00	0.00	1454.70		122.32	41.60	66.40	230.32	965.00	1195.32	259.38	-	
Dec	530.42	62.55	630.23	1223.20	52.00	83.00		66.00	1424.20	0.00	0.00	0.00	0.00	1424.20		122.32	41.60	66.40	230.32	660.00	890.32	533.88	-	
Jan	530.42	62.55	630.23	1223.20	52.00	83.00		65.80	1424.00	0.00	0.00	0.00	0.00	1424.00		122.32	41.60	66.40	230.32	658.00	888.32	535.68	-	
Feb	530.42	62.55	630.23	1223.20	52.00	83.00		59.80	1418.00	0.00	0.00	0.00	0.00	1418.00		122.32	41.60	66.40	230.32	598.00	828.32	589.68	-	
Mar	0.00	0.00	0.00	0.00	52.00	83.00		72.40	207.40	0.00	0.00	0.00	0.00	207.40		0.00	41.60	66.40	108.00	724.00	832.00	-	624.60	
Apr	0.00	0.00	0.00	0.00	52.00	83.00		66.30	201.30	0.00	0.00	0.00	0.00	201.30		0.00	41.60	66.40	108.00	663.00	771.00	-	569.70	
May	808.70	141.92	1252.92	2203.54	52.00	83.00		54.70	2393.24	98.78	72.66	47.63	219.08	2612.32		220.35	41.60	66.40	328.35	547.00	875.35	1736.97	-	
Total :-	12296.28	1984.21	17960.91	32241.40	624.00	996.00	0.00	3271.70	37133.10	1133.40	833.71	546.55	2513.66	39646.76	0.00	3224.14	499.20	796.80	4520.14	32717.00	37237.14	7664.49	5254.87	

Fig. 6.1 MONTHLY WATER DEFICITS-SURPLUSES WITHOUT GROUND WATER (75% DEPENDABILITY)

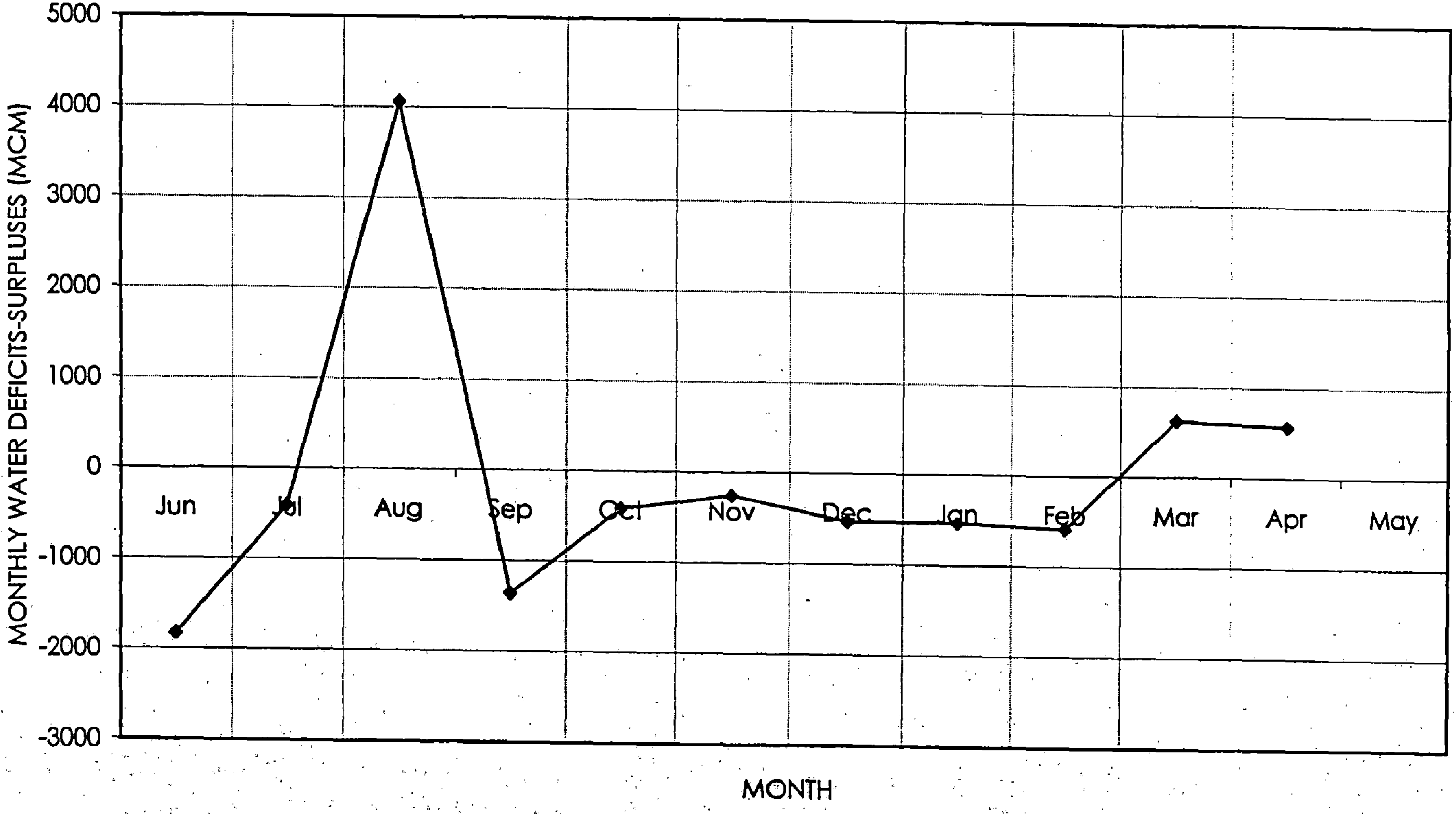

Fig 6.2 WATER BALANCE WITH 75% DEPENDABILITY (WITHOUT G.W)

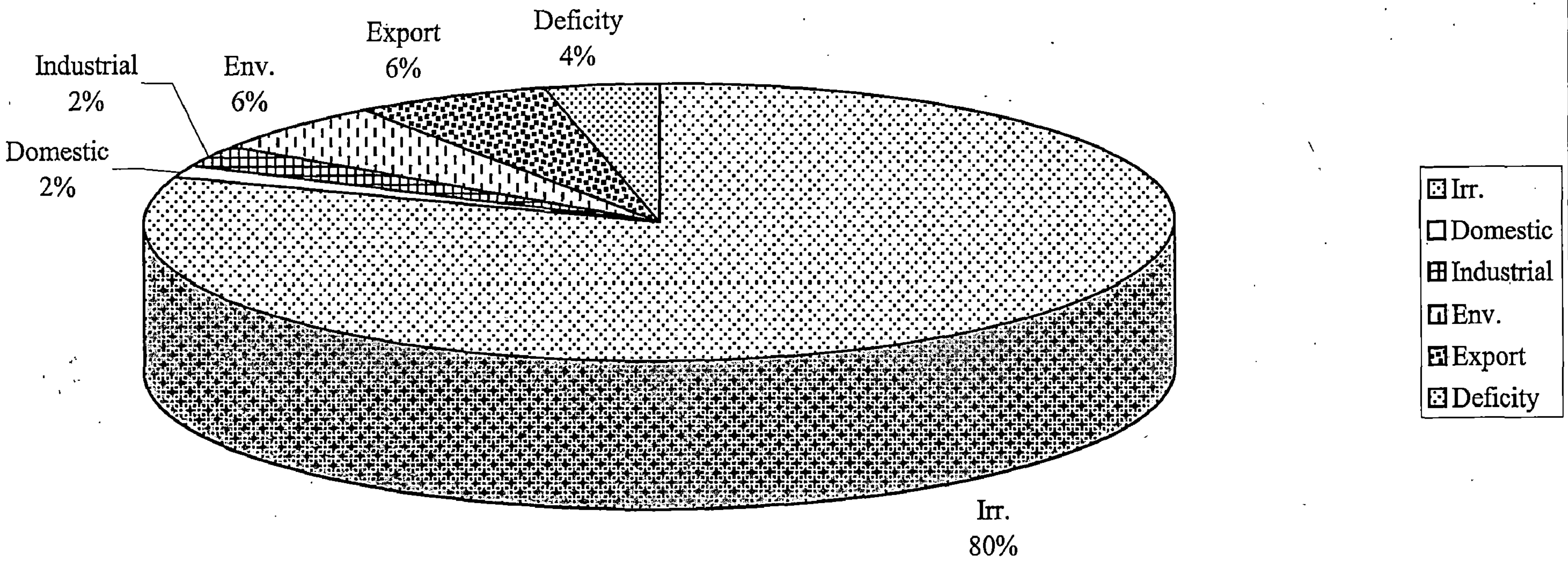

Table. 6.2 MONTHLY WATER BALANCE STUDY OF MAHANADI BASIN FOR 75% DEPENDABLE FLOW WITH GROUND WATER

Month	Water utilisation														Water availability									
	Water requirement									Export				Gross total utilisation	Import	Regeneration from uses				Surface water yield	Ground water available	Ground water recharge	Total Ground Water	Gross water available
	Utilisation under irrigation project				Domestic	Industrial	Hydropower	Environmental	Total	Tikira	Brahmani - Baitarani	Rushikulya	Total			Irr.	Domestic	Industrial	Total					
	Existing	Ongoing	Proposed	Total																				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22			23
Jun	808.70	141.92	1252.92	2203.54	52.00	83.00		44.60	2383.14	98.78	72.66	47.63	219.08	2602.22		220.35	41.60	66.40	328.35	446.00	71.14	232.19	303.32	1077.68
Jul	2553.79	448.18	3956.59	6958.55	52.00	83.00		730.50	7824.05	311.95	229.46	150.43	691.83	8515.89		695.86	41.60	66.40	803.86	7305.00	224.64	413.52	638.16	8747.02
Aug	2553.79	448.18	3956.59	6958.55	52.00	83.00		1226.90	8320.45	311.95	229.46	150.43	691.83	9012.29		695.86	41.60	66.40	803.86	12269.00	224.64	481.79	706.43	13779.28
Sep	2553.79	448.18	3956.59	6958.55	52.00	83.00		624.70	7718.25	311.95	229.46	150.43	691.83	8410.09		695.86	41.60	66.40	803.86	6247.00	224.64	234.18	458.82	7509.68
Oct	895.83	105.64	1064.39	2065.85	52.00	83.00		163.50	2364.35	0.00	0.00	0.00	0.00	2364.35		206.59	41.60	66.40	314.59	1635.00	66.69	64.57	131.26	2080.84
Nov	530.42	62.55	630.23	1223.20	52.00	83.00		96.50	1454.70	0.00	0.00	0.00	0.00	1454.70		122.32	41.60	66.40	230.32	965.00	39.49	18.04	57.52	1252.84
Dec	530.42	62.55	630.23	1223.20	52.00	83.00		66.00	1424.20	0.00	0.00	0.00	0.00	1424.20		122.32	41.60	66.40	230.32	660.00	39.49	5.76	45.25	935.57
Jan	530.42	62.55	630.23	1223.20	52.00	83.00		65.80	1424.00	0.00	0.00	0.00	0.00	1424.00		122.32	41.60	66.40	230.32	658.00	39.49	12.53	52.02	940.34
Feb	530.42	62.55	630.23	1223.20	52.00	83.00		59.80	1418.00	0.00	0.00	0.00	0.00	1418.00		122.32	41.60	66.40	230.32	598.00	39.49	17.19	56.68	885.00
Mar	0.00	0.00	0.00	0.00	52.00	83.00		72.40	207.40	0.00	0.00	0.00	0.00	207.40		0.00	41.60	66.40	108.00	724.00	0.00	18.04	18.04	850.04
Apr	0.00	0.00	0.00	0.00	52.00	83.00		66.30	201.30	0.00	0.00	0.00	0.00	201.30		0.00	41.60	66.40	108.00	663.00	0.00	18.83	18.83	789.83
May	808.70	141.92	1252.92	2203.54	52.00	83.00		54.70	2393.24	98.78	72.66	47.63	219.08	2612.32		220.35	41.60	66.40	328.35	547.00	71.14	45.44	116.58	991.94
Total :-	12296.28	1984.21	17960.91	32241.40	624.00	996.00	0.00	3271.70	37133.10	1133.40	833.71	546.55	2513.66	39646.76	0.00	3224.14	499.20	796.80	4520.14	32717.00	1040.85	1562.07	2602.92	39840.06

Fig. 6.3 MONTHLY WATER DEFICITS-SURPLUSES WITH GROUND WATER (75% DEPENDABILITY)

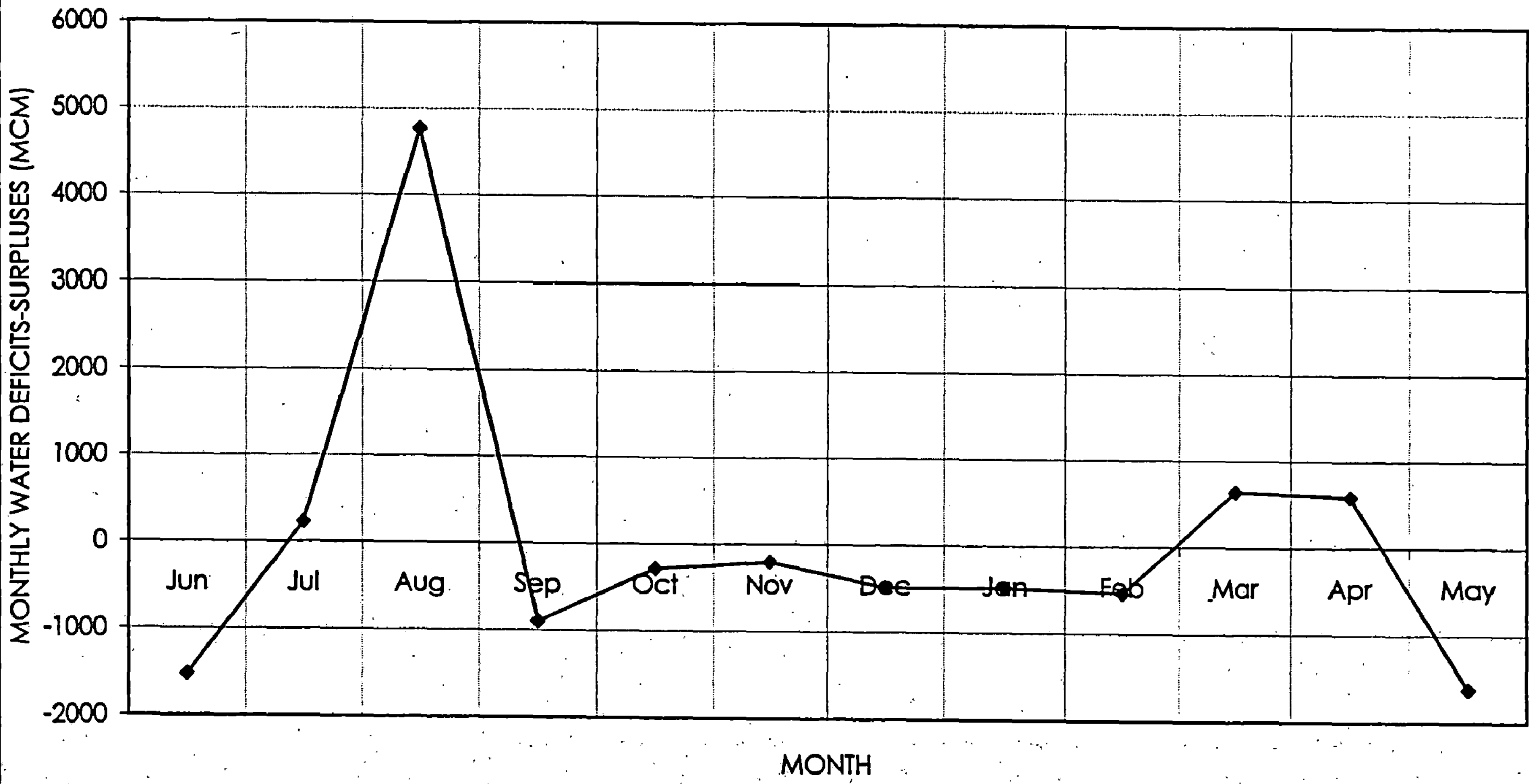

Fig.64-WATER BALANCE WITH 75% DEPENDABILITY (WITH G.W)

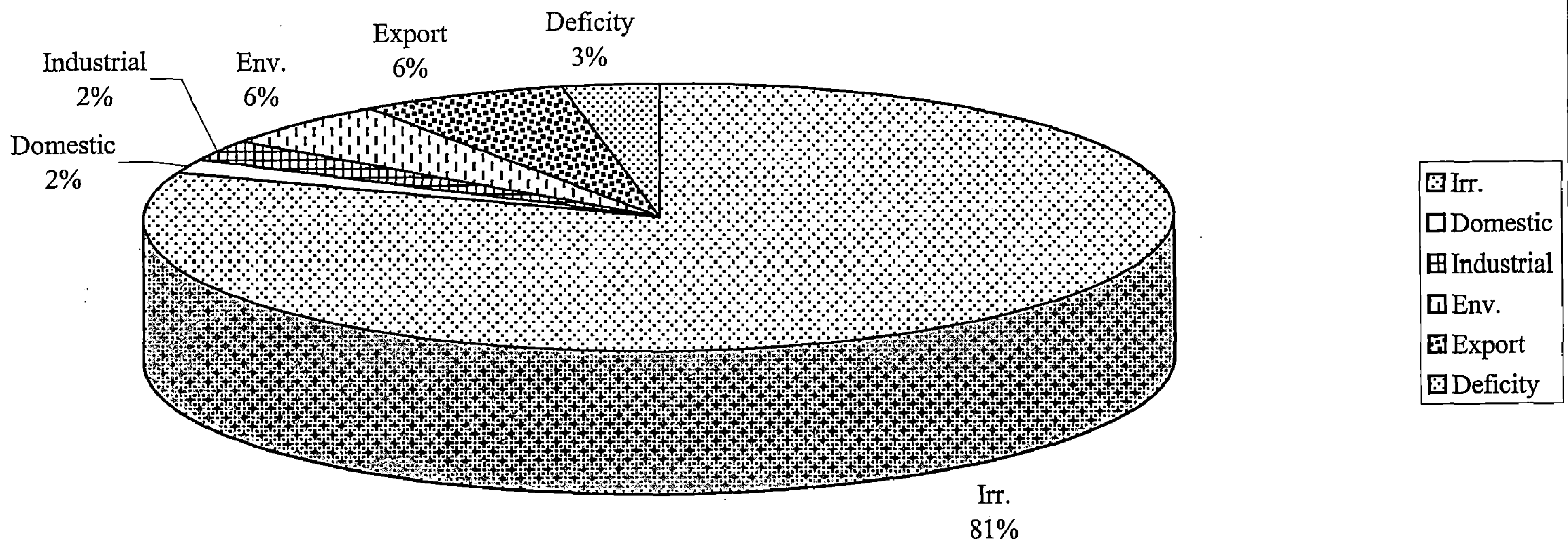

Table 6.3 MONTHLY WATER BALANCE STUDY OF MAHANADI BASIN FOR 90% DEPENDABLE FLOW WITHOUT GROUND WATER

(Unit in MCM)

Month	Water utilisation														Water availability							Monthly Water balance		Remark
	Water requirement									Export				Gross total utilisation	Import	Regeneration from uses				Surface water yield	Gross water available			
	Utilisation under irrigation project				Domestic	Industrial	Hydropower	Environmental	Total	Tikira	Brahmani-Baitarani	Rushikulya	Total			Irr.	Domestic	Industrial	Total			Deficit	Surplus	
	Existing	Ongoing	Proposed	Total																				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Jun	808.70	141.92	1252.92	2203.54	52.00	83.00		37.50	2376.04	98.78	72.66	47.63	219.08	2595.12		220.35	41.60	66.40	328.35	375.00	703.35	1891.77	-	
Jul	2553.79	448.18	3956.59	6958.55	52.00	83.00		327.70	7421.25	311.95	229.46	150.43	691.83	8113.09		695.86	41.60	66.40	803.86	3277.00	4080.86	4032.23	-	
Aug	2553.79	448.18	3956.59	6958.55	52.00	83.00		1008.00	8101.55	311.95	229.46	150.43	691.83	8793.39		695.86	41.60	66.40	803.86	10080.00	10883.86	-	2090.47	
Sep	2553.79	448.18	3956.59	6958.55	52.00	83.00		366.50	7460.05	311.95	229.46	150.43	691.83	8151.89		695.86	41.60	66.40	803.86	3665.00	4468.86	3683.03	-	
Oct	895.83	105.64	1064.39	2065.85	52.00	83.00		112.80	2313.65	0.00	0.00	0.00	0.00	2313.65		206.59	41.60	66.40	314.59	1128.00	1442.59	871.07	-	
Nov	530.42	62.55	630.23	1223.20	52.00	83.00		75.80	1434.00	0.00	0.00	0.00	0.00	1434.00		122.32	41.60	66.40	230.32	758.00	988.32	445.68	-	
Dec	530.42	62.55	630.23	1223.20	52.00	83.00		50.60	1408.80	0.00	0.00	0.00	0.00	1408.80		122.32	41.60	66.40	230.32	506.00	736.32	672.48	-	
Jan	530.42	62.55	630.23	1223.20	52.00	83.00		56.50	1414.70	0.00	0.00	0.00	0.00	1414.70		122.32	41.60	66.40	230.32	565.00	795.32	619.38	-	
Feb	530.42	62.55	630.23	1223.20	52.00	83.00		54.90	1413.10	0.00	0.00	0.00	0.00	1413.10		122.32	41.60	66.40	230.32	549.00	779.32	633.78	-	
Mar	0.00	0.00	0.00	0.00	52.00	83.00		68.30	203.30	0.00	0.00	0.00	0.00	203.30		0.00	41.60	66.40	108.00	683.00	791.00	-	587.70	
Apr	0.00	0.00	0.00	0.00	52.00	83.00		61.60	196.60	0.00	0.00	0.00	0.00	196.60		0.00	41.60	66.40	108.00	616.00	724.00	-	527.40	
May	808.70	141.92	1252.92	2203.54	52.00	83.00		45.20	2383.74	98.78	72.66	47.63	219.08	2602.82		220.35	41.60	66.40	328.35	452.00	780.35	1822.47	-	
Total :-	12296.28	1984.21	17960.91	32241.40	624.00	996.00	0.00	2265.40	36126.80	1133.40	833.71	546.55	2513.66	38640.46	0.00	3224.14	499.20	796.80	4520.14	22654.00	27174.14	14671.89	3205.57	

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Fig. 6.5 MONTHLY WATER DEFICITS-SURPLUSES WITHOUT GROUND WATER (90% DEPENDABILY)

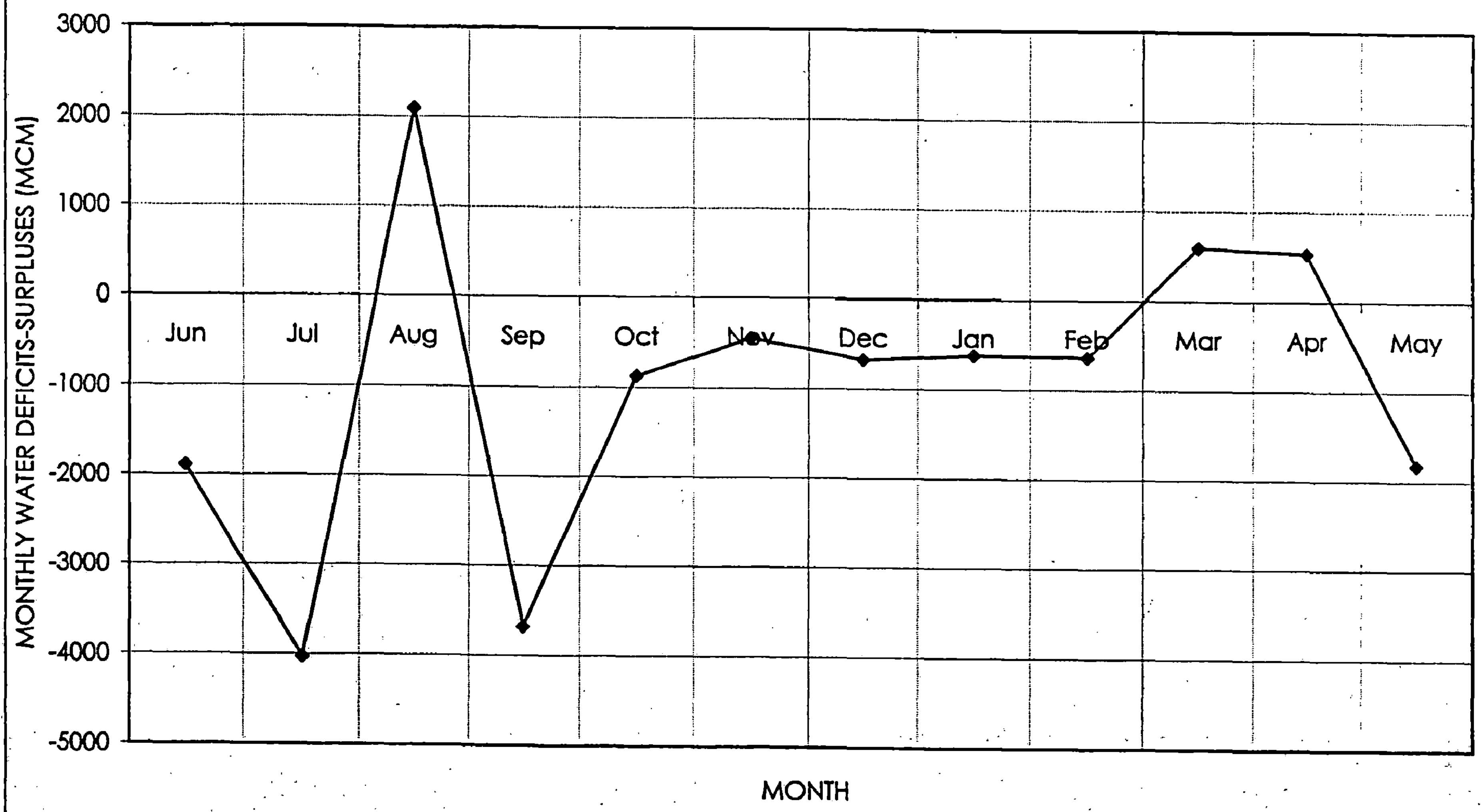


Fig.66-WATER BALANCE WITH 90% DEPENDABILITY (WITHOUT G.W)

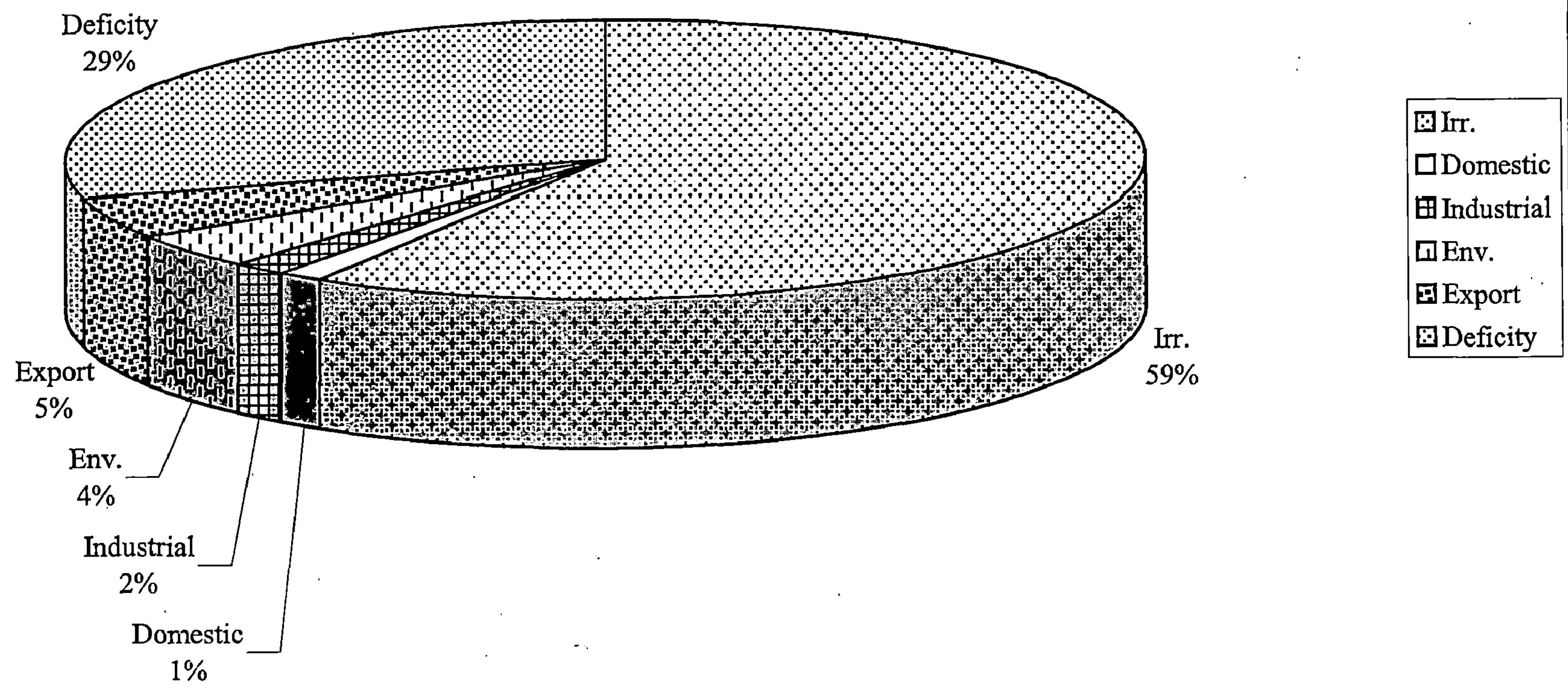


Table 6.4 MONTHLY WATER BALANCE STUDY OF MAHANADI BASIN FOR 90% DEPENDABLE FLOW WITH GROUND WATER

Month	Water utilisation														Water availability									
	Water requirement									Export				Gross total utilisation	Import	Regeneration from uses				Surface water yield	Ground water available	Ground water recharge	Total Ground Water	Gross water available
	Utilisation under irrigation project				Domestic	Industrial	Hydropower	Environmental	Total	Tikira	Brahmani - Baitarani	Rushikulya	Total			Irr.	Domestic	Industrial	Total					
	Existing	Ongoing	Proposed	Total																				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22			23
Jun	808.70	141.92	1252.92	2203.54	52.00	83.00		37.50	2376.04	98.78	72.66	47.63	219.08	2595.12		220.35	41.60	66.40	328.35	375.00	71.14	232.19	303.32	1006.68
Jul	2553.79	448.18	3956.59	6958.55	52.00	83.00		327.70	7421.25	311.95	229.46	150.43	691.83	8113.09		695.86	41.60	66.40	803.86	3277.00	224.64	413.52	638.16	4719.02
Aug	2553.79	448.18	3956.59	6958.55	52.00	83.00		1008.00	8101.55	311.95	229.46	150.43	691.83	8793.39		695.86	41.60	66.40	803.86	10080.00	224.64	481.79	706.43	11590.28
Sep	2553.79	448.18	3956.59	6958.55	52.00	83.00		366.50	7460.05	311.95	229.46	150.43	691.83	8151.89		695.86	41.60	66.40	803.86	3665.00	224.64	234.18	458.82	4927.68
Oct	895.83	105.64	1064.39	2065.85	52.00	83.00		112.80	2313.65	0.00	0.00	0.00	0.00	2313.65		206.59	41.60	66.40	314.59	1128.00	66.69	64.57	131.26	1573.84
Nov	530.42	62.55	630.23	1223.20	52.00	83.00		75.80	1434.00	0.00	0.00	0.00	0.00	1434.00		122.32	41.60	66.40	230.32	758.00	39.49	18.04	57.52	1045.84
Dec	530.42	62.55	630.23	1223.20	52.00	83.00		50.60	1408.80	0.00	0.00	0.00	0.00	1408.80		122.32	41.60	66.40	230.32	506.00	39.49	5.76	45.25	781.57
Jan	530.42	62.55	630.23	1223.20	52.00	83.00		56.50	1414.70	0.00	0.00	0.00	0.00	1414.70		122.32	41.60	66.40	230.32	565.00	39.49	12.53	52.02	847.34
Feb	530.42	62.55	630.23	1223.20	52.00	83.00		54.90	1413.10	0.00	0.00	0.00	0.00	1413.10		122.32	41.60	66.40	230.32	549.00	39.49	17.19	56.68	836.00
Mar	0.00	0.00	0.00	0.00	52.00	83.00		68.30	203.30	0.00	0.00	0.00	0.00	203.30		0.00	41.60	66.40	108.00	683.00	0.00	18.04	18.04	809.04
Apr	0.00	0.00	0.00	0.00	52.00	83.00		61.60	196.60	0.00	0.00	0.00	0.00	196.60		0.00	41.60	66.40	108.00	616.00	0.00	18.83	18.83	742.83
May	808.70	141.92	1252.92	2203.54	52.00	83.00		45.20	2383.74	98.78	72.66	47.63	219.08	2602.82		220.35	41.60	66.40	328.35	452.00	71.14	45.44	116.58	896.94
Total :-	12296.28	1984.21	17960.91	32241.40	624.00	996.00	0.00	2265.40	36126.80	1133.40	833.71	546.55	2513.66	38640.46	0.00	3224.14	499.20	796.80	4520.14	22654.00	1040.85	1562.07	2602.92	29777.06

Fig. 6.7 MONTHLY WATER DEFICITS-SURPLUSES WITH GROUND WATER (90% DEPENDABILITY)

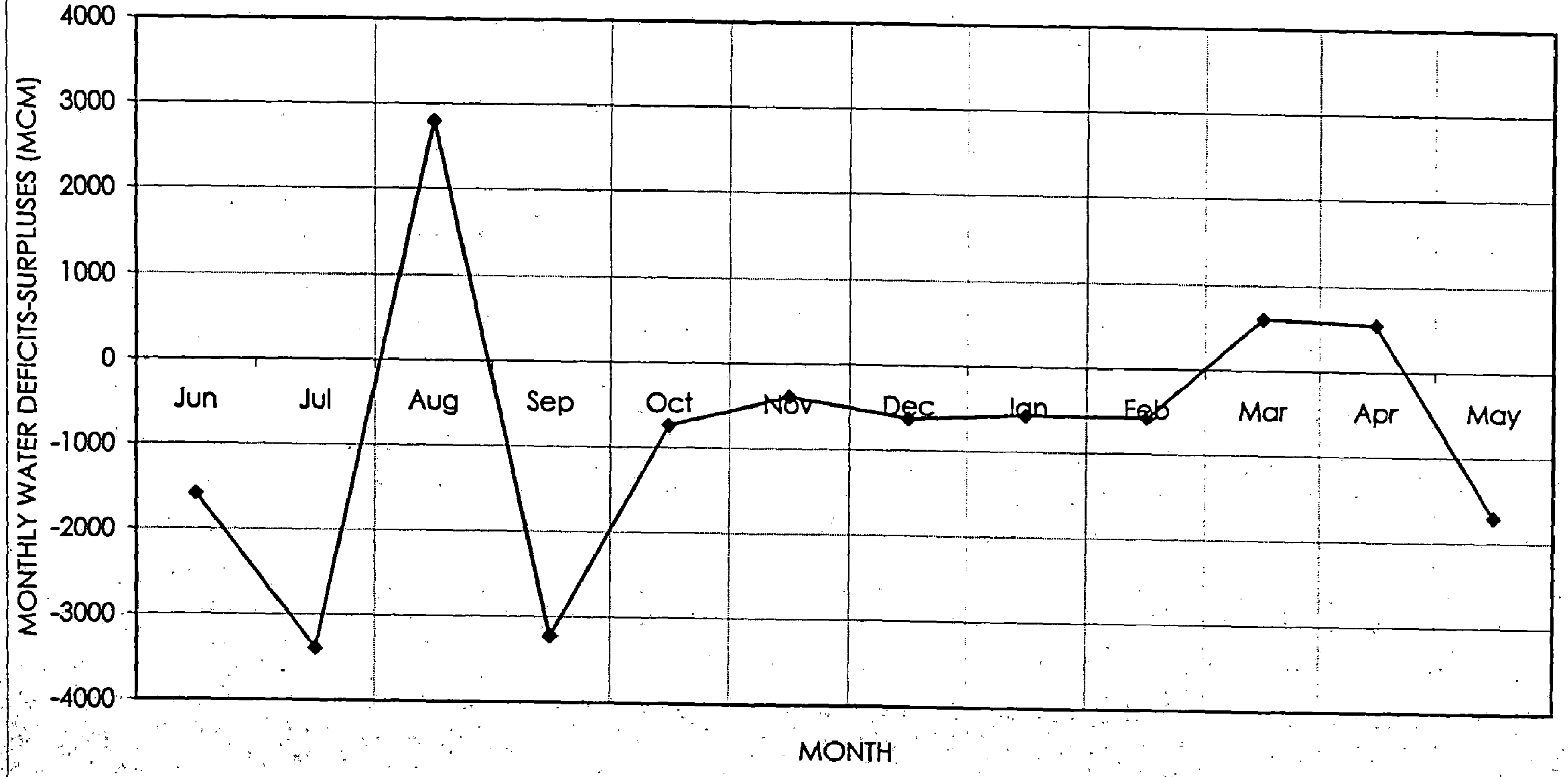
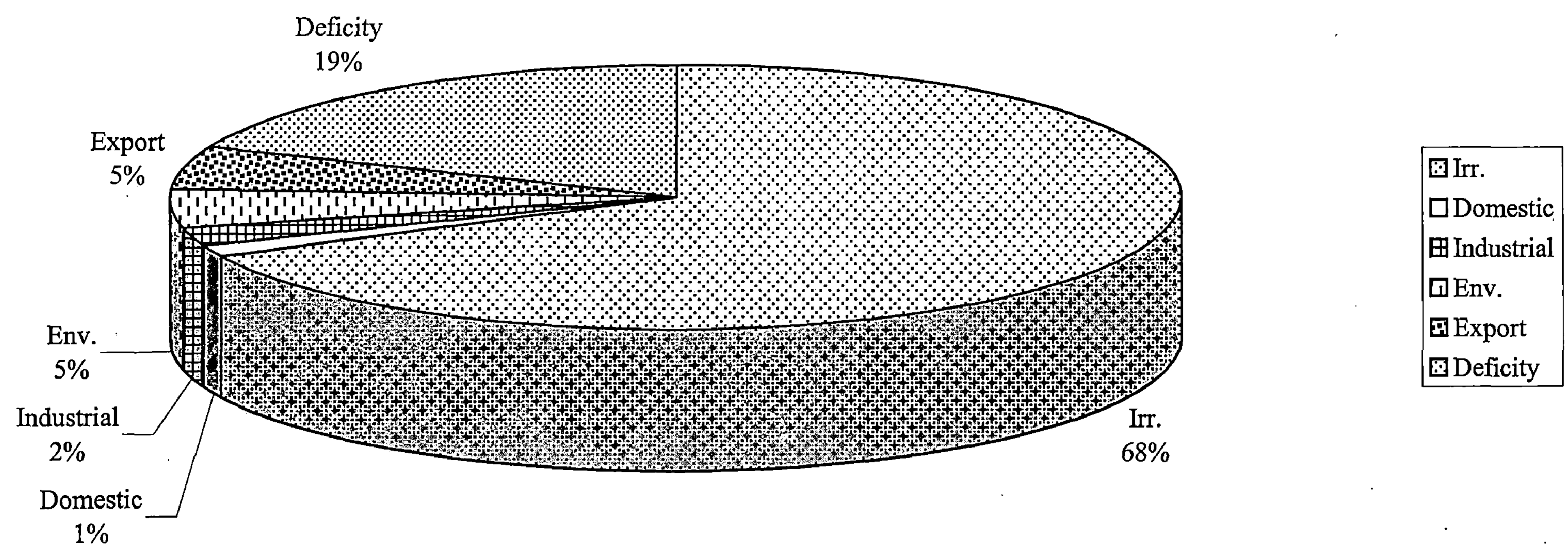


Fig.6.8. WATER BALANCE WITH 90% DEPENDABILITY (WITH G.W)



ABSTRACT OF FLOW AT VARIOUS DEPENDABILITY AND DEMAND

	90% dependibility (without G.W)		90% dependibility (with G.W)		75% dependibility (without G.W)		75% dependibility (with G.W)	
Inflow	22654.00		29777.06		37237.14		39840.06	
Irr.		32241.40		32241.40		32241.40		32241.40
Domestic		624.00		624.00		624.00		624.00
Industrial		996.00		996.00		996.00		996.00
Env.		2265.40		2265.40		2265.40		2265.40
Export		2513.66		2513.66		2513.66		2513.66
Deficity		-15986.46		-8863.40		-1403.32		1199.60

Table 6.6 Monthly Deficit And Surplus For 75% And 90% Dependability With And Without Ground Water

		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Without Ground Water	75%	-1827.87	-407.03	4060.57	-1359.23	-414.77	-259.38	-533.88	-535.68	-589.68	624.60	569.70	-1736.97
	90%	-1891.77	-4032.23	2090.47	-3683.03	-871.07	-445.68	-672.48	-619.38	-633.78	587.70	527.40	-1822.47
With Ground Water	75%	-1524.54	231.13	4767.00	-900.41	-283.51	-201.86	-488.63	-483.66	-533.00	642.64	588.53	-1620.39
	90%	-1588.44	-3394.07	2796.90	-3224.21	-739.81	-388.16	-627.23	-567.36	-577.10	605.74	546.23	-1705.89

Table 6.7 Monthly Deficit And Surplus In Descending Order For 75% And 90% Depenc With And Without Ground Water

Mahanadi Basin (Manibhadra Site)							
Without Ground Water				With Ground Water			
75 % dependibility		90 % dependibility		75 % dependibility		90 % dependibility	
Month	Quantity	Month	Quantity	Month	Quantity	Month	Quantity
Jun	-1827.87	Jul	-4032.23	May	-1620.39	Jul	-3394.07
May	-1736.97	Sep	-3683.03	Jun	-1524.54	Sep	-3224.21
Sep	-1359.23	Jun	-1891.77	Sep	-900.41	May	-1705.89
Feb	-589.68	May	-1822.47	Feb	-533.00	Jun	-1588.44
Jan	-535.68	Oct	-871.07	Dec	-488.63	Oct	-739.81
Dec	-533.88	Dec	-672.48	Jan	-483.66	Dec	-627.23
Oct	-414.77	Feb	-633.78	Oct	-283.51	Feb	-577.10
Jul	-407.03	Jan	-619.38	Nov	-201.86	Jan	-567.36
Nov	-259.38	Nov	-445.68	Jul	231.13	Nov	-388.16
Apr	569.70	Apr	527.40	Apr	588.53	Apr	546.23
Mar	624.60	Mar	587.70	Mar	642.64	Mar	605.74
Aug	4060.57	Aug	2090.47	Aug	4767.00	Aug	2796.90

DISCUSSION OF RESULTS AND CONCLUSIONS

Result of water balance study shows that the availability of 75% dependability flow is 32717.00 but in the salient features of Manibhadra Irrigation Project (Govt. of Orissa) it is calculated that the 75% dependable yield 32,556 MCM, so almost it is same. As per the calculation it is clear that in the year 2050 the basin will be deficit basin on an annual average. But as concern to monthwise, some months i.e. in monsoon, it seems to be surplus water which is available during floods which any way the proposed canal in the Mahanadi Godavari link can not carry out and has to be spiled.

The Mahanadi – Godavari link proposes a storage at Manibhadra dam which the Government of Orissa could not construct due to large scale of sub-mergence in the State. As per the view of Government of Orissa, there is no other suitable site for storage downstream.

7.1 CONCLUSIONS

i. The 75% and 90% dependable annually yield at Manibhardra dam site are 32717.00 and 22654.00 respectively.

ii. The gross ground water potential of the Mahanadi basin up to Manibhardra in Orissa portion works out to 2602.92 mm^3.

iii. 2513.666 mm^3 of water exported from Mahanadi basin.

iv. The surface water balance at 75% and 90% dependability's works out to 1199.6 mm^3 and (-)8863.4 mm^3 respectable with ground water.

v. The surface water balance at 75% and 90% dependability's works out to (-)1403.32 mm^3 and (-)114666.32 mm^3 respectable without ground water.

7.2 RECOMMENDATION AND FURTHER SCOPE OF STUDY

i. It has been found that the existing, ongoing and proposed projects in Mahanadi basin are sufficient to meet the future irrigation demand by 2050.

ii. The water balance can be increased by way of improving the irrigation efficiency. There is a need for improvement of irrigation efficiency in the basin.

iii. In future the surface water will be decrease and demand will be increase. Hence the groundwater utilization is very important for all purposes. So it is desired to develop the ground water resources so that the deficit condition of the Mahanadi basin can be meet. Also further study, one required with additional data and should carried out the effect of irrigation efficiency in the Mahanadi basin.

iv. There is a need for analyzing the reliability of the estimation. The reliability of water balance study depends on the reliability of input data. Further work can be carried out for reliability assessment of such protection.

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