MANAGEMENT OF GANGA WATERSFOR IRRIGATION AND COMMUNITY USES IN NORTHERN ALLUVIAL PLAIN

A DISSERTATION

submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF ENGINEERING
in
WATER RESOURCES DEVELOPMENT

By
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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this report entitled, **"MANAGEMENT OF GANGA WATERS FOR IRRIGATION AND COMMUNITY USES IN NORTHERN ALLUVIAL PLAIN"**, in partial fulfillment of the requirement for the award of Degree of "Master of Engineering", in Water Resources Development (WRD,Civil) is an authentic record of my work carried out from July 16th, 2000 to December 15, 2000 under the guidance of Professor R.P.Singh, Water Resources Development Training Centre, University of Roorkee, Roorkee.

The matter embodied in this report has not been submitted by me for the award of any other degree.

(INDU BHUSHAN JHA)

Candidate

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

Place: Roorkee,
Date : Dec 22, 2000

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(I.B. JHA)
Trainee Officer,

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SYNOPSIS

Ganges is the holiest river. It represents the history and culture of the region. After the advent of science and technology and consequent population growth water of this river is being utilized for various purposes; domestic and municipal use, irrigation, hydropower generation etc. Effluents are also coming to the river from various municipalities and industrial areas.

The river is under high pressure of extraction of water. Water quality is continually deteriorating. The glacier (source of river) is also said to be severely affected.

It is proposed to study the management of Ganga waters for irrigation and other community uses over a long time and to assess its present capability and remedial measures to save ecology, water quality of the river, which is rather a life line of the vast population along its long enroute through northern alluvial plain in India.

CHAPTER – 1

INTRODUCTION

1.1 GENERAL

The Ganges is the great river of India. It is held sacred by a larger number of worshippers than any other river in the world perhaps none of the rivers have so much impact on the lives of so many as the Ganges. Its volume exceeds 500,000 h-m. annually over 300 million people live on its plain and delta.

Under the name Bhagirathi the river rises in the Tehri (lat 30^0 55'N: Long 79^0 7'E) from an ice bed near Gangotri 7,010 m above sea level. After receiving the Jahnavi and the Alaknanda, it enters the plains passing Hardwar. Upto Hardwar River traverses 280 kilometers. The upper Ganga Canal takes off from a barrage at Harwar, 250 Km below that is Narora barrage from where lower Ganga canal takes off. After another 530 Kms to Allahabad, past the famous ghats of Mirzapur, the Yamuna Joins the Ganga. It sweeps for another 245 Kms to Varanasi. In the Upper region, the Ganga receives the Ramganga, the Gomti and the Tons from the north and the Chambal, the Betwa, the Sinda and the Ken from the south. The Ganga enters Bihar in the middle region, about 155 Kms from Varanasi. In this region, it receives the very important tributaries of the Ghagra, Gandak, Burli Son, Bagmati and Kosi. In the lower Ganga basin, only the Mahananda joins. Later,100 Kms down stream from Rajmahal, the river bifurcates into Bhagirathi, the lower portion of which beyond Kalna is known as Hooghly and the padma which forms the boundary between India and Bangladesh. After traversing 220 Kms further down in Bangladesh, the Brahamputra joins it, at Goalundo, and after meeting the Meghna 100 Kms down stream the Ganga enters the Bay of Bengal. The total length of the Ganga from its source to its outfall into the sea, is 2525 Kms of its total length 1450 Kms is in UP, 445 Kms in Bihar, and 520 Kms in West Bengal.

1.2 TRIBUTARIES

The Ramganga River rises at an altitude of 3,110 meter in Gharhwal district and emerges from the hills into the plains at Kalagarh. It is at this place that the Ramganga

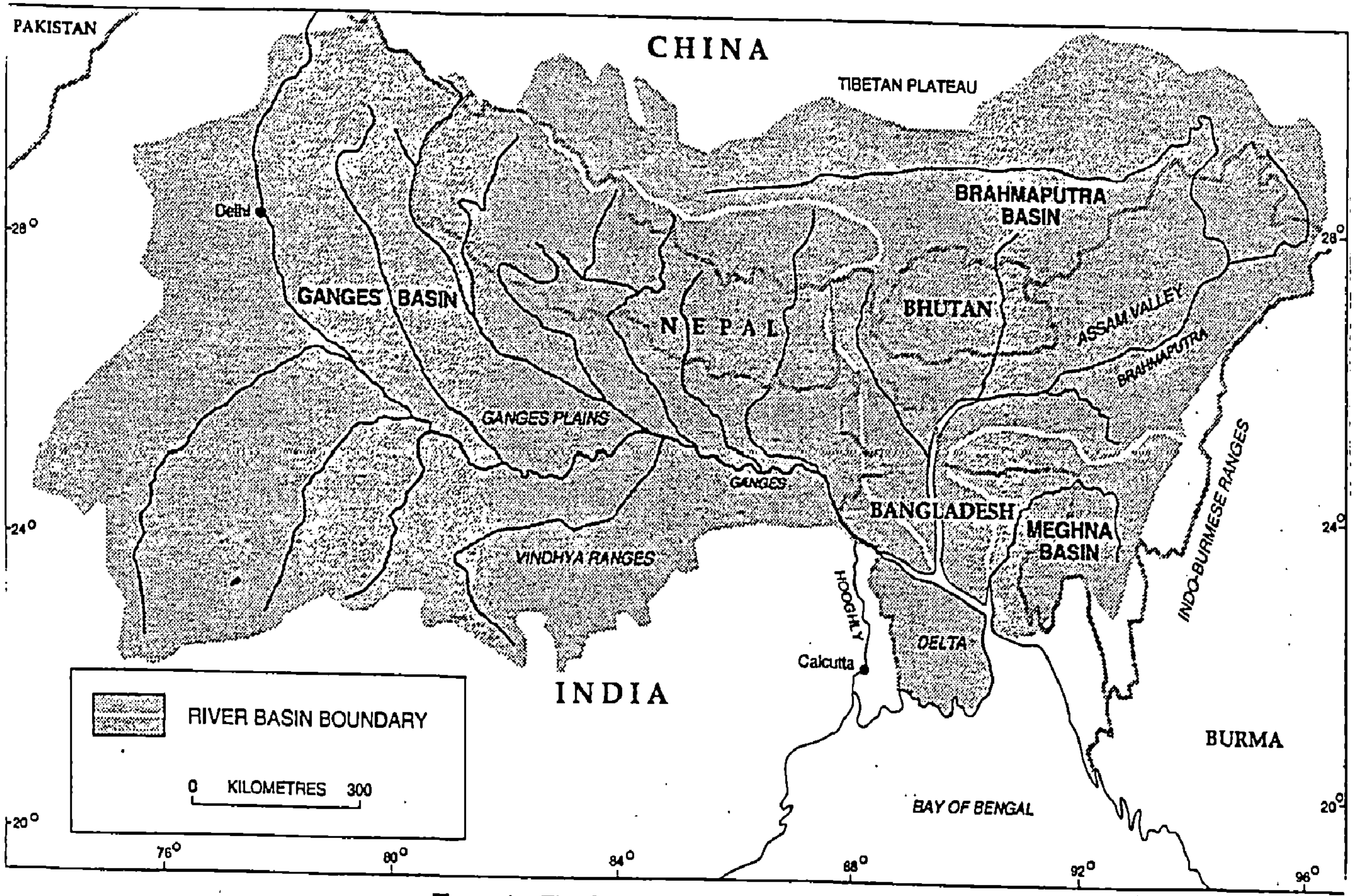


Figure 1 The Ganges and Brahmaputra basins

dam has been constructed. After traversing some more districts of U.P., it joins the Ganga at Kanoj a number of tributaries join the river, mostly from the left. The Gomti rises about 3 Kms east of Pilibhit in U.P. at an elevation of 200 meters. It drains the area between the Ramganga and the Ghaghra systems.

Lucknow is located on the banks of Gomti. The length of the river is 940 kms. The Ghaghara has its source near Lake Mansarovar. Its total catchment area is 127,950 sq.kms. Its important tributaries are the Sarda. The other tributary is the Sarju, famous for the location of Ayodhya on its banks. It spills and causes flooding every year in the Azamgarh and Balia districts. The other tributaries are the Rapti and the little Gandak. The Rapti joining the Ghaghara on the left rises in Nepal at an elevation of 3,600 m and decends to the plains at the boundary of India and Nepal. Its depth is shallow, and it causes heavy flooding in the districts of eastern U.P. The little Gandak starts as an old channel of the Gandak at an elevation of 300 metres. Joins the Ghaghara in Sahjahanpur and carries little discharge except in the monsoon months. The Ghaghara joins the Ganga a few kms downstream of Chhapra down in Bihar. The length of Ghaghara is 1,080 kms and it carries more water than the Ganga before its confluence.

The Gandak is also known as Kali in Nepal and rises at 7.620 metres in Tibet near Nepal border over looking Dhaulagiri peak. The drainage area is 46,300 sq. kms. It joins the Ganga near Patna. The Burhi Gandak rises in Champaran district of Bihar at an elevation of 300 metres. It has a drainage area of 10,150 sq.km and a length of 320 kms. It joins Ganga opposite Monghyr town.

The Bagmati rises in the Sivpuri Hills of Nepal at an elevation of 1,500 metres. cuts across the Mahabharat range of hills and enters India in Muzaffarpur district. It has a drainage area of 13,400 sq. kms on the banks of this river is the famous temple of Pashupati Nath in Nepal. It joins Kosi in lower reaches.

The Kamala rises in Nepal at an elevation of 1,200 metres. It has a number of tributaries in Nepal. It enters India near Jayanagar in Darbhanga district and joins the Kosi.

The Kosi is formed by the confluence of seven rivers the Sunkosi, the Arun Kosi, the Tamur Kosi, the Bhoste Kosi, the Tama Kosi, the Indrawati and the Dudha Kosi. The total drainage area is 74,500 sq.kms. Mount Everest and Mount Kanchanjangha lie in the catchment of Arun Kosi. After the confluence, the river flows through a narrow gorge for 10 kms and enters the plain at Chatra. After traversing another 25 kms, it enters India near Hanuman Nagar. As its water is heavily soiled and the river has a steep gradient, there is a tendency for it to move side ways. As a matter of fact, in about 200 years the river has moved laterally 112 kms from Purnea to its present position. The Kosi project was taken in 1954 to prevent this lateral shift.

The Mahananda rises in the hills of Darjelling district at 2,100 metres with a number of tributaries i.e. the Balran, the Mechhi, the Ratna and the Kankai. The total drainage area of Mahananda is 20,600 sq.kms. The river formes a boundary between India and Bangladesh in the last reaches before it enters Bangladesh to join the Ganga at Godajiri.

The Yamuna is the most important tributary of the Ganges joining it on the right bank. It receives in its turn on the right a large tributary, the chambal and four other tributaries the Hindon, the Sarda, the Betwa, and the ken. It rises from the Yamunotri Glacier in the Tehri Garhwal district of U.P. at an elevation of 6,330 metres. The tons, the longest tributory, rises at an elevation of 3900 metres and joins the Yamuna below Kalsi. The Giri River rises near Simla and joins the Yamuna near Paonta. The Yamuna emerges from the Hills near Tajewala where the water is taken off by western and Eastern Yamuna canals. It flows further 280 kms down to Okhla in Delhi, from where the Agra canal takes off. The Hindon, 256 kms long, rises in the district of Saharanpur and joins the Yamuna on its left bank 40 kms below Okhla. It flows in the southeasterly direction till it reaches Allahabad.

The total length of the Yamuna from its origin to Allahabad is 1,376 kms. The drainage area is 366,223 sq.kms of which 139,468 sq.kms are the drainage area of the Chambal alone.

The chambal rises in the Vidhya ranges and flows for 965 kms before it joins the Yamuna. It flows through the flat fertile Malwa plateau and then enters a gorge at Chaurasigarh. The gorge is 96 kms long and stretches upto Kolah City. The river runs for another 34 kms flowing through the plains.

The Sindh rises in the vidisha district of Madhya Pradesh at an elevation of 543 m. It is 415 kms long and drains an area of 25,085 sq.kms. It joins the Yamuna downstream of the confluence of the chambal with the Yamuna.

The Betwa rises at an elevation of 470 metres in the district of Bhopal in M.P. It joins Yamuna near Hamirpur after flowing 590 kms. The total catchment area is 45,580 sq.km.

The Ken rises in the Kaimur Hills of Satna district in M.P. It is 360 kms long up to its point of confluence with the Yamuna near Chilla. It drains an area of 28,224 sq.km.

The Tons has a drainage area of 16,860 sq.km. It rises in a tank at Tamakund in the Kaimur range of hills at an elevation of 610 metres and flows through the fertile lands of the Rewa and Satna districts. It joins Ganga at about 311 kms down stream of the confluence of the Ganga and the Yamuna. The total length of river is 264 kms.

The Karmanasa rises in the Kaimur range in Mirzapur district at an elevation of 350 metres. It joins the Ganga at Chanusa. It's tributaries are the Durgavati, the Chandraprabha, the Karunuti, the Nadi the Khajuri and other small rivers rising in Mirzapur and Allahabad districts, with lengths of about 50 kms and join the Ganga in the same district. The drainage area of the Karamnasa and other small stream is 11,709 sq.kms.

The Son basin extends over an area of 71,259 sq.kms and rises at Sonabhadra in M.P. at an elevation of 600 metres. After passing in cascades over the hill reaches, it receives the Rihand tributary Kanhar and Ghaghar tributary. It passes through the Palamu district of Bihar. Where it receives the tributary north Koel, it joins the Ganga about 16 kms upstream of Danapur in Patna district. The total length of river is 784 kms. The impotant tributaries of son are the Mahanadi, the Banas, the Gopat the Rihand, the Kankar, the North Koel. Below the son, on the right side of the Ganga, there are a large number of tributaries. Of these the Punpun and Kaul are the large ones.

The total catchment area of the Ganges comes to 985,000 km^2.

1.3 LEGENDS / SANCTITY

The sanctity of river date from the earliest vedic period. The Ganga is mentioned in Rigveda: in one passage its high bank form the subject of a simile, but in the hymn to the river it is invoked with the Yamuna, Sarasvati, Sutudri (Sutlej) Parusni (Ravi) Asikni (Acescines, Chenab), vitas (Jhelum) and Arjikiya (Bias). The land between the Ganga and the Yamuna is considered as Holy Land.

In the Mahabharat the sanctity of the river and its holy places is fully established.

In this age Ganges in holy. He who bathes in Ganges purifies seven decedents. As long as the bone of a man touch Ganges water, so long that man is magnified in heaven. No place of pilgrimage is better than the Ganges.

The 'heavenly' Ganges is mentioned and the river is spoken of as 'mother of rivers' known among men as Bhagirathi.

The earliest knowledge of the river gained by the people of West was due to Megasthanese. Who describes the river greater than the Indus and possessing seventeen tributaries.

Many legends naturally gathered round the sacred river. In the Ramayna the Royal saint Bhagiratha descendant of Sagara, performs austerities to induce Ganga to descend from heaven and purify the ashes of Sagara who had been destroyed by the offend of sage Kapila and thus elevate them to paradise. On his failure Brahma advices him to propiate. Siva, who alone could sustain the shock of the falling Ganga. Accordingly Siva ascends the Himalya and calls upon the Goddess to come down. In her rage she tries to sweep the God down with her to Patala, the nether world. But Siva compels her to circle for ages in the labyrinth of his matted locks perhaps the icicles at the river source. Hence, he is nammed "Gangadhara" 'Ganga – Supporter'. At last, being again propitiated by Bhagiratha, Siva allows her to flow to the sea and purify the ashes of Sagara sons.

Ganga is every where regarded as benign, the river of healthy children and other prosperity, the great purifier from the pollution of sin. The pollution of her water is regarded as a hineous outrage on Hindu feeling.

The water is carried to the all parts of country by pilgrims. It is used as a charm to repel evil spirits, dropped in the mouth of dying, sprinkled at marriage over bride and bride-groom, poured into new tanks and it is used as a medium for taking oath.

1.4 LIFE LINE

River Ganga is worshiped as mother sustainer. It supports a chain of life. It has enormous water potential if managed well. Ganges water is believed to have extra-ordinary life giving qualities.

1.5 CLIMATE

The climatic environment varies from semi arid to subhumid continental in the region with moderate (500 mm to 1200 mm) rainfall, 80 to 85% of which is received during July to September the mean maximum monthly temperature is 41°C and the mean minimum monthly temperature is 7.3°C. The temperature increases and rainfall decreases as the distance from the Himalaya increases.

CHAPTER - 2

USE OF THE GANGA WATER IN ANCIENT TIME

2.1 GENERAL

We have archeological evidence of canals tanks and wells for irrigation during the Mauryan period. Such a Canal existed at Kumrahar probably from Ganga.

Inhabitants on the bank of the river learnt to excavate channels through higher land on the immediate bank of the stream to irrigate land in the vicinity. This system of irrigation (inundation canals) was used from unknown ages by which irrigation water was used for irrigation.

Advantage of irrigation and deposition of fine fertile silt deposition was enjoyed all along the length of the river. While in high Stage River used to replenish soil moisture and deposit fine silt on the adjacent land. It was due to of this advantage that large population accumulation was there on its banks.

2.2 Thus it can be said that in ancient time the Ganga water was under following beneficial uses:

* Drinking water without treatment
* Bathing, swimming and religious
* Agricultural
* Fish culture and wild life
* Boating Navigation

Drinking Water without Treatment

Ganga water was considered most pious water for drinking purposes. It was quite healthy and beneficial. As the population was scarce and there was no industrialization pollution was nil. Further the inherent self-purifying system of the river kept itself quite clean.

Bathing, Swimming and Religious Purposes

From time immemorable people come to have a bath in this river. It is said to be purifying and the devotee fells fresh. This river has religious regards.

Agricultural

Though the river was benefiting agriculture along its plain by imparting silt deposits and outflanking water. The river was indirectly harvested through the shallow tube wells in its basin, where river used to replenish water through soil strata.

In modern times, while, upper and lower Ganga canals were implemented areas adjacent to the river having lots of shallow wells were not included into the canals command, due to the efficient working of the system. After the green revolution shallow tube wells along the river are much in function and are in conjunctive use. This conjunctive use puts an ideal example.

Fish Culture/ Wild Life

While there were no interfering structures across the river there was abundance of Perennial River flow. There were pools of water. This facility was enjoyed by the aquatic life they were in abundance all through.

As there existed natural Green River corridor along the Ganges, wild life was flourishing all along the riverbank. The description can be cited in contemporary literature.

It is after the advent of industrialization and population growth that pollutants are increasing, free flow of river is decreasing and so the fish culture and wild life are diminishing.

Boating, Navigation

Navigation is an example of in stream utilization of water. Transport by water is cheaper than by road and rail.

The Ganga was navigable for boats from Farakka to Benearas and upto Kanpur. Following deteriorated conditions steamers can now ply upto Baxur 185 kms upstream of Patna on its tributaries country boats ply on the Yamuna upto Agra, on the Gomti upto Lucknow, upto Nepal and Kosi rivers in monsoon months, and to shorter distance in other months

CHAPTER -3

USE OF THE GANGA WATER IN MODERN TIMES

3.1 GENERAL

In addition to the continuing use of river water new endeavors to utilize the water resource of the river dates back to mid of 19th century. It was initiated by British military engineers.

During British regime upper Ganga canal, and Lower Ganga canal were mainly constructed. At some places intake structures for drinking water and/or for cooling system of electric generating plants were constructed.

During post independence period we find that utilization of Ganga water has increased. Thus the lower Ganga canal system was rehabilitated. More water was utilized on upper Ganga canals. Diversion of water was done at Farakka for the benefit of Calcutta port and population. Water abstraction for municipal water supply increased due to population growth.

In mountainous reach water is being impounded to generate hydropower at Birbhadra and Maneri. Similar attempt is underway for Tehri power project.

Following are being dealt in detail

* Upper Ganga Canal
* Lower Ganga Canal
* Lift Irrigation
* Kanpur Barrage
* Faraka Barrage

3.2 UPPER GANGA CANAL

This canal system was completed in 1854. It off takes from Right Bank of the Ganges at the famous ghats. This was the largest irrigation system at the time it was constructed all over the world.

Upper Ganga Canal was formally opened on 8th April 1854. This system was constructed to provide protective irrigation and thus to prevent recurrence of famine conditions. Initially design discharge was 6750 cusecs.

There was no permanent diversion structure during dry season river was forced to enter canal system by making obstructions across the river in the form of wooden cribs packed with boulder and gravel etc. Irrigation was targeted for Rabi crops. The temporary bunds were made across the river by 15-20 November every year. This process continued till 1922 for 68 years. In 1922 a strong weir was erected across the river. Further in 1980 a fresh, modern barrage has replaced the old weir.

Presently, the barrage can divert about 15,000 cusec for canal beneficial purposes but the canal can carry only 10,500 cusec. However the important aqueduct on river Solani can not carry over 9000 cusec without serious over loading. The newly constructed barrage has canal systems on both banks.

Upper Ganga canal system has a C.C.A. of 92,400 hectares, which is aimed to be extended to 1.2 lack hectares. The main canal is 286 Km long. The system has a nominal design duty of 1 cusec/100 hectare. The system has more than 20,000 outlets most of them (>95%) are pipe outlets. Cumulative length of watercourse is 41,000 Kms. Length of distributory and minors is 5380 kms.

Bhimgoda Barrage

Design discharge

For profile - 4,65,000 cusec

For cut off, energy dissipaters and apron - 6,75,000 cusec.

For free board - 7,00,000 cusec.

There are 23 barrage bays having gates size 15 m x 7.8-m. Right canal system has 5 under sluice gates, Left canal system has 3 under sluice. Size of under sluice gates are 15 m x 8.4 m, one of the bays on each side has silt excluder consisting of four tunnels with clear duct of 1.5 m height.

Initially the canal is in deep cutting and it has to cross 4 major drains. It is after Roorkee (28 Kilometer) that canal flows over a ridge.

The existing system conveys water to distributory canal heads through the main canal and three major branches, which have the following characteristics.

Main Conveyance channel	Number of Distributaries	C.C.A on outlets ha (1000)
Main canal (Including supply channel and Kanpur stumps)	46	470.0
Anupsahar Branch	31	141.0
Mat Branch	23	1940.0
Hathras Branch	15	119.0

Initial U.G.C. system extended beyond Mainpuri. After lower Ganga canal (L.G.C) became operational in 1878 much of the southern extensions were transformed to L.G.C command. However, augmentation can be done by U.G.C. (Kanpur Branch system is known as Kanpur stump)

The U.G.C. system supplements Agra Irrigation System served from the Okhla barrage on the Yamuna River. Other demand on the U.G.C system includes cooling water for Harduaganj thermal power station. 200 cusecs of water is also supplied for the sake of Delhi water supply system.

With the exception of short reach in high fill near Solani Aqueduct on the main canal, the entire U.G.C. conveyance and distribution system is unlined. One important feature is the long, narrow command area. This is because the major internal drainage channels within the Ganga Yamuna doab largely run parallel to the boundary rivers and form elongated irrigation sub commands.

Salient Features of U.G.C.

1. Formation of project and preliminary arrangements	1838-48
2. Main Construction period	1848-1854
3. Date of Commissioning of project	8 April 1854
4. Date of start of irrigation	15 May 1855
5. Initial gross command area	15 lac Acre
6. Present gross commands are	50 lac Acre
7. Present culturable command area	25 lac Acre
8. Initial head discharge	6750 cusec
9. First major remodeling of canal	1954
10. Present head discharge	10,500 cuses
11. Length of main canals	286 Kms.
12. Type of canal	unlined earth
13. Total length of branch canal	1150 Km
14. Total length of channel in present system	6540 Km
15. Total length of watercourse	41,000 Km
16. Important structures	Solani Aqueduct at 29 Km Ranipur siphon 8.2 Km Pathari super passage15.6Km Ratmau aqueduct (20.5 Km)
17. Design concept of channel	Protective Rabi irrigation design on 3-4 core weeks.
18. Design concept for major works	Massive structure with simple bold designs mainly with brick arches in lime surkhi mortar.

19. Other important feature	First major and large canal system of the country. Major irrigation system of 19th century.
20. i) Heavy damage of H/W at Hardwar (Gohna flood)	1894
ii) Heavy damage of H/W and other important structure on canal	1924
iii) Silting in head each of canal required disilting operation	1970
21. Addition of new H/W Bhimgoda barrage	1978-1984
22. Addition of subsequent hydropower station (Pathri,Mohammadpur, Nirganjni, Chitora, Salawa, Bhola, Patra, Sumera)	1930-1955
23. i) Modernization project of U.G.C. finalization	June -1984
ii) Commencement of project	Sept-1984
iii) Total cost of project	1313 Crore
iv) Intensity of irrigation in the modern system	Av. 55% of gross cropped area.
v) Districts to be benefited	Hardwar Saharanpur, Muzaffarnagar, Meerut, Ghaziabad, Bulandsahar, Aligarh, Etah, and Mathura
vi) Improvement in operation efficiency	38% to 60%

Outstanding features:-

Upper Ganga canal system has some outstanding features (1) selection of off take site and channel (2) Dynamic equilibrium of ground water

Selection of off take site:-

Off take site is at Hardwar where river runs upon shingle on a high inline. This site was being utilized for diverting water from ancient times. It is usual practice in hills to off take water from higher level regions. Where the bed of the rivers consist of boulders and shingles situated on heavy slopes.

The channel adopted was the same, which the inhabitants of Hardwar and Kankhal used to divert water to their ghats. Similar procedure of forcing water by constructing bunds and spurs in river was adopted.

Specialty, which got incorporated for merit, was that the bed slope upto Mayapur (3 miles down stream) is same as of the natural river, velocity is high and depths are shallow. This reach gets cleansed periodically and works as sediment traps. This adds to the quality of water for ghats due to high velocity and bed renewals.

The zero of canal is at Mayapur and up to this point the supply channel for feeding the canal maintains river characteristics.

Dynamic equilibrium of ground water

Water and power consultancy service (WAPCOS) while preparing the feasibility report has studied water balance for upper Ganga canal system.

According to them, there is no much change over the years in the water table levels indicating that the system is a dynamic equilibrium conditions i.e. the fall in water table during non-monsoon is nearly annual to the rise in water table during monsoon. Hence, the annual recharge is all most equal to annual discharge.

The main / branches / distributaries are proposed to be lined to save seepage losses and paddy irrigation is to be increased substantially (from 6 to 35 percent) with lining of the system recharge of ground water shall be reduced but due to extensive paddy irrigation and increase in the intensity of irrigation recharge to groundwater shall be much more then existing.

Ground water resources, estimated conservatively indicate that existing groundwater development and that proposed under the project would still use only about 62 percent of exploitable amounts. Thus the project requirements of groundwater would be insured, also the contribution to recharge components by seepage from main / branch / distributory canal seepage is limited to 10 percent of mean annual recharge thus lining of conveyance system in upper Ganga canal would not affect the ground water balance of the command significantly.

3.3 LOWER GANGA CANAL

The upper Ganga canal was followed by lower Ganga canal with its head works at Narora some four miles below Rajghat. The work was under taken in 1875 and completed in 1878. The diversion weir so constructed failed in 1898 under pond level operation conditions.

This canal system was brought to divert winter supplies in river Ganga, for providing irrigation facilities to lower Ganga- Yamuna inter-basin

After 1898 mishap the weir was remodeled at that time on the basis of Bligh's theory. Real nature of failure by piping as demonstrated by Terzaghi and later by Khosla were, however, unknown at that time and therefore no special features necessary as a safeguard against failure by piping were then introduced. Narora head works suffered gradual deterioration all along and, remained in constant danger of sudden failure. Consequently, the question of strengthening of the headwork's continued to engage attention of engineers for a long time, but the urgency become prominent only with the starting of work on Ram Ganga canal system. Consequently the decision was taken in then year 1960 to rejuvenate the Narora Headworks. The various alternatives were studied and project for construction of a new barrage on modern concepts was finalized and approved in 1961. Construction of new barrage was competed in 1968.

Area commanded by this system is 1-lack hectares. Where as design discharge is 8000 cusecs each in two main canals. Salient features of the project is as below

Narora had works - salient features

River

1.	Catchment area	32,512 Km^2
2.	Maximum flood (1924)	11,045 cumecs.
3.	River slope	1:4000
4.	Assumed design afflux	0.91 m
5.	U/S H.F.L for design discharge	180.79 m
6.	D/S H.F.L for design discharge	179.88 m

Barrage

7.	Length between abutments	922.71 m
8.	Normal pond level (R.L.)	178.96 m
9.	Future Pond level (R.L.)	179.27 m
10.	Lowest Pond level (R.L.)	178.43 m
11.	Clear Roadway over bridge	7.32 m
12.	Road Level	182.93 m
13.	Design discharge for barrage	14,150.00 m^3/sec
14.	Design discharge for training works	16,980.00 m^3/sec

Under Sluices

15.	Length between abutments	125.00 m
16.	Size of bay (7 Nos.)	15.24 m
17.	Size of gates	15.24 x 4.79 m
18.	Crest level (R.L)	174.63 m

19.	Length of impervious floor	57.93 m
20.	Depth of U/S cutoff	10.52 m
21.	Depth of D/S cutoff	5.18 m
22.	Cistern level (R.L)	172.56 m
23.	Discharging capacity	2832 cumecs

Other Barrage Bays

24.	Length	794.66 m
25.	Size of bays (54 Nos.)	12.20 m
26.	Size of gates (54 Nos.)	12.20 m x 3.23 m
27.	Crest level (R.L)	176.20 m
28.	Length of impervious floor	48.17 m
29.	Depth of U/S cutoff	3.96 m
30.	Depth of D/S cutoff	4.27 m
31.	Cistern level (R.L)	173.78 m
32.	Discharging capacity at H.F.L.	41328 cumecs

Canal Head Regulator

33.	Length between abutments	62.50 m
34.	Size of bays (7 Nos.)	7.49 m
35.	Size of gates 7 nos. in two tiers	7.49 m x 3.05 m
36.	Crest level (R.L)	176.37 m
37.	Length of impervious floor	16.54 m
38.	Depth of D/S cutoff	4.88 m
39.	Discharging capacity at normal pond level	240.72 cumecs

Silt Excluder

40.	Width of tunnels (6 Nos.)	4.21 m
41.	Width of tunnel at exit	1.83 m
42.	Height of tunnel	1.43 m
43.	Maximum length of tunnel	8000 m

44. Discharging capacity 56.64 cumecs

Special features:

Lower Ganga canal has following outstanding features. (1) Selection of barrage alignment (2) General layout (3) Head regulator (4) River training works

Selection of barrage alignment:

Alignment of the new barrage was kept at a safe distance (305 m) downstream of existing weir so that difficulties of barrage during working season may not be experienced on the account of proximity of standing water behind the weir, and that there may be sufficient space for provision of bunds upstream of the barrage for diversion and care of water and for locating construction facilities in the work area during working season.

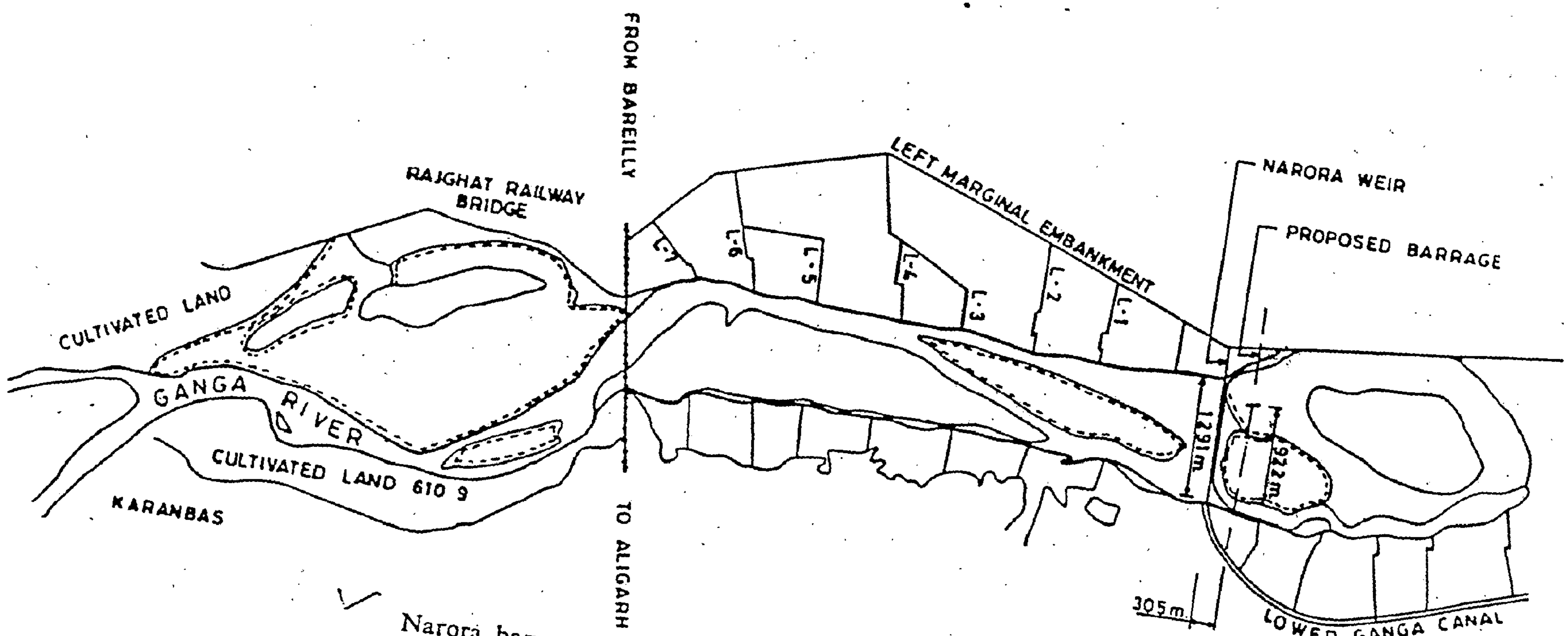
General layout:

The Narora barrage having canal off taking on one bank was to be so sited that right bank of Lower Ganga canal offtakes, forms the concave side of the curved stretch of the Ganga river. With such layout the river would normally flow along the Right Bank even in low stage and favorable bend conditions would be created and sediment exclusion devices operating at good efficiency can be provided.

For this purpose extremity of the Narora Barrage was terminated 54.84 m inside the river channel and the new head regulator was located on a 457.2 m radius curved wall extension of the concave bank from the old weir to the barrage.

Head regulator:

The alignment of head regulator with respect to barrage plays a vital part in prevention of entry of silt into the canal. The angle of offtake normally varies from 15^0 to 20^0. For Narora model experiments were carried at Irrigation Research Institute Roorkee to decide on the appropriate offtake angle for head regulator from consideration of



Narora barrage alignment and old weir and training works.

Fig – 2

sediment exclusion from water entering the canal. The head regulator inclined at an angle of 107^0 to the barrage axis was adopted.

River training works:

As shown on the attached diagram training of the Ganges at Narora is done by a series of Denehy's groynes. Initially it was (in upstream of weir) applied in 1887 by Mr. Denehy the objective of providing Denehy's groynes was to produce a permanent affect on the river regime to have a straight river flow towards barrage. Similarly groynes in down stream are provided to protect the canal from river attack.

3.4 **Lift irrigation:**

After the separation of the country most of the irrigated land in sind valley went to Pakistan. To come over the difficult situation of production deficiency several lift irrigation stations were established along the bank of the river to contribute to irrigation. A substantial amount of water of the river gets utilized through lift irrigation.

3.5 KANPUR BARRAGE

Kanpur City is situated on the Right Bank of river Ganga. A number of ghats exist along the Right Bank of the river near Kanpur City. Domestic and industrial water supply mostly, of the city is met by river Ganga since 1894. There is a powerhouse on the Right Bank of 80 M.W., installed in 1923. It draws water for its cooling purposes from the river. River Ganga has a tendency to meander from one bank to other in this Khadir. At present the river is flowing at a distance of about 6-Km from Kanpur City. This has caused serious problems regarding water supply to the city, powerhouse and desertation of Kanpur ghats. To over come this problem a committee headed by chairman CWC (1988) recommended construction of a barrage across the river 1.5-Km up stream of Bhairoghat. The scheme is under implementation.

Following advantages are to be taken from the barrage:

1. Water supply to the city of Kanpur
2. Supply of water to powerhouse

3. Dilution of municipal and industrial effluents.
4. Flowing water at ghats
5. Protecting the erosion of left bank i.e. Unnao area
6. The safety of existing bridge at Kanpur downstream of barrage
7. Measure for augmenting dry weather flow.
8. Reducing Traffic congestion at Kanpur by providing additional 4-lane bridge over Ganga.
9. Providing additional 1610 Ha area on right and left bank of the river out of its flood plain for further development of Kanpur city.

Kanpur water supply works was constructed in the year 1894 on the main course of the river along Kanpur and near the ghats on the Right Bank.

River is migrating away from Kanpur right from 1859. The migrating tendency upstream of the bridge came to be noticed in a more pronounced manner only in 1910.

Due to the shifting of the river course, which was quite pronounced since 1945, Kanpur Jalsansthan started facing the problem of feeding the water supply, works at Kanpur by Natural River course.

An artificial channel was excavated in 1953 to divert part of the river from left bank to the Right Bank upto water supply works. This practice has been continued since then almost every year as the river has continued to hug the left bank during the post monsoon period.

Even though the river has started swinging towards the left since the year 1945 some flow continued along the Right Bank upto 1951. The curvature of the river in the fifties was favorable and could straightway bring needed water to the powerhouse and the water supply intake works. During the 1953 flood the Right Bank was considerably eroded above sambaldas Ghat, but there after the river course swung fully to the left bank and has not regained its course along the Right Bank so far.

After 1953, a 7-Km long channel was required to be excavated from the left bank course of the river to the water supply works and the Thermal Power House. A fleet of dredges (about 17 Nos.) is maintaining channel. The capacity of dredged channel is of the order of 8 cumes. The yearly cost of dredging and maintaining the channel is around 60 lacs. Since the channel is almost oblique to the flow of the river, it gets silted up every year. The excavated material dumped on the either side of the channel has probably worked as a barrier and has induced the river to shift further away to the left.

The plan showing river course of Ganga at Kanpur (1910-11) shows that the river course was clearly on the Right Bank. Later the course of the river was mapped by Survey of India in the year 1947, 1950, 1967, 1978, and 1981 as shown in Fig. 3. The later maps highlight the migration of the river from the right bank to the left bank across the bed width of the river about 4½ Kms opposite the water works compared to this the width of river at Bithoor is only about 1.5 Km. The river bed is wide opposite the power house and is about 5 Kms. The river has built alluvial bed of an average width of about 2½ to 3 Kms between Bithoor and the railway bridge. Compared to this the bed width occupied by the flow in summer is hardly 170 meters. However in the summer the entire bed width is occupied.

Considering the attack of the river on the lift bank the railway has provided a guide bund on up stream of the Railway Bridge in continuation of the left abutment. This bend suffered from the continued attack from the flows concentrating on the bank and had to be repaired after 1984 to avoid erosion near the bridge and to arrest the baying in of the river northwards. The guide bund is seen to have provided the desired protection, because subsequent siltation has been taking place in the bayed area.

Sand excavation on the left bank of river Ganga on Unnao side has been going on for some years but mainly sand is taken from the D/S of the Railway Bridge.

The River Meander

The following calculation emerged from the study of the change in river course between 1947 and 1982.

i) It has a history of running of mender from one bank to the other bank between the three model points Bithor Fatehpur and Railway Bridge.

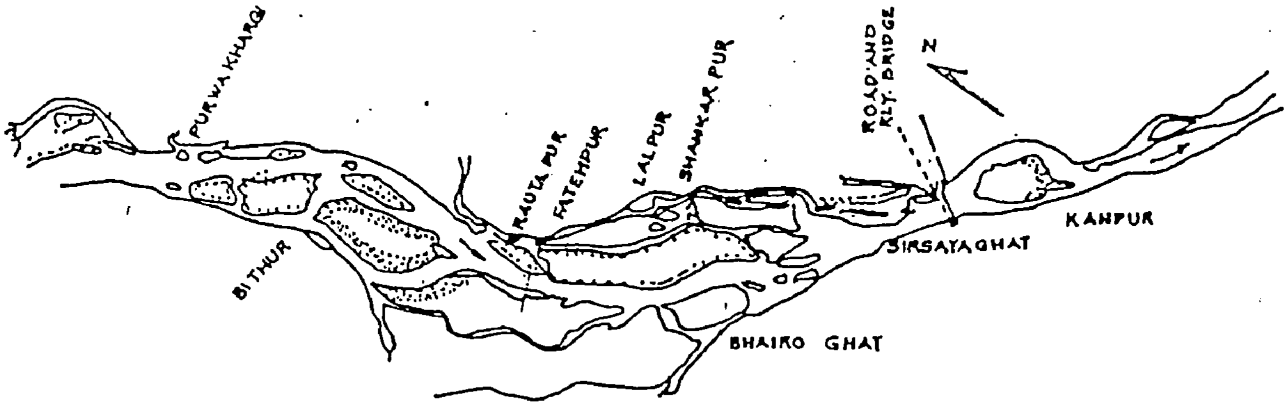
ii) Looking at the apex of the meander running between Bithoor and the central nodal point of railway bridge it can be seen that the apex point clearly indicate travelling of the meander in the downstream direction. The total distance traveled by the meander is around 4.0 Kms in the case of both the swings. However lateral shifting in the case of Kanpur swing is around 7.0 Km on width of 5.7 Km whereas to the Bithoor swing is about 4.5 Km only.

iii) Turtuosity of the meander in both swings appears to be normal upto 1967 survey. Afterwards turtiosity of the meander appears to be progressively increased in the Kanpur swing whereas it remained the same in the case of Bithoor swing. It appears that this may be due to rigid control imposed by the bridge downstream end on Kanpur swing resulting in the squaring of the meander and accentuating the meander width. The Right Bank of river Ganga at Kanpur is high while on the left bank there are low lying areas on Unnao side, which gets flooded during high stage of the river. This is also one of the reason for the easy erodibility noticed on the bank.

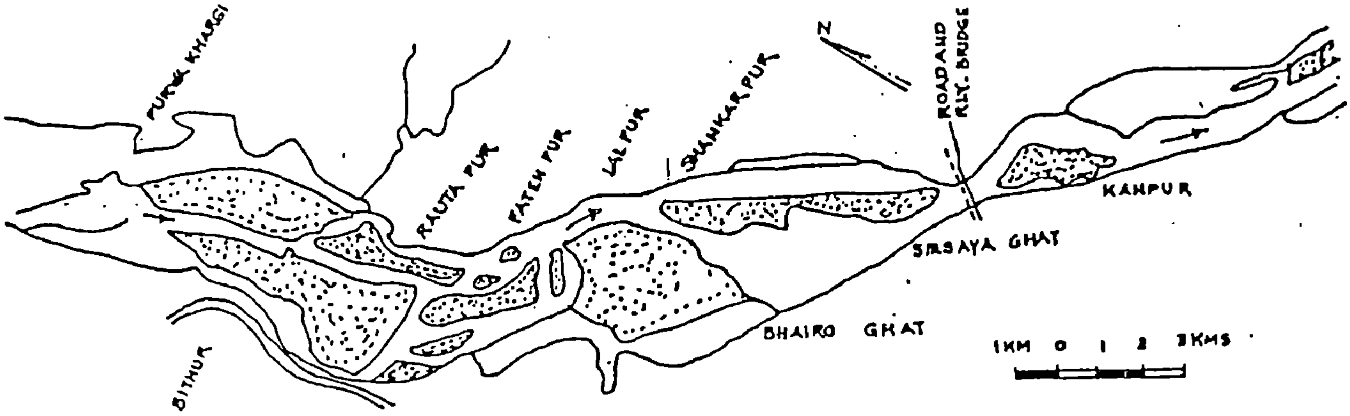
The river spills over the shoals on the left when it rises above 113.0 m corresponding to a discharge of above 5000 cumec.

Aggradation and Degradation of River

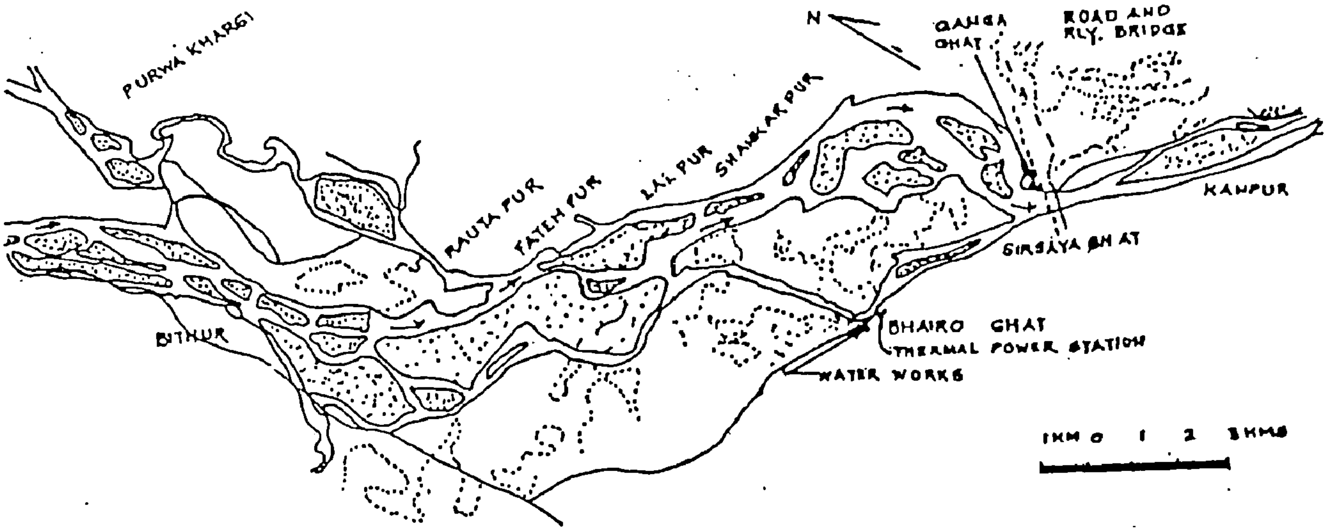
Study of the super imposed cross-section of CWC gauging site reveals that riverbed has been fairly in action.



PLAN SHOWING GANGA RIVER COURSE AT KANPUR (1910-11)



PLAN SHOWING GANGA RIVER COURSE AT KANPUR (1954-56)



PLAN SHOWING GANGA RIVER COURSE AT KANPUR (1982)

Fig. 3 Ganga River Course at Kanpur

On Right Bank there is only marginal erosion but over the years the river has cut a deeper thalwegs without any significant change in the bed elevation towards the left bank. There is periodic scouring and filling tendencies in the thalwegs portion of the channel.

It appears that with a flood discharge of 1200 cumec (and a velocity of 1.2 m/sec) the bed load starts moving. This means that for a major period of the flood season the riverbed is in mobile phase. The morphology of the riverbed is therefore in a very delicate condition and needs to be handled very carefully. Any significant cut across the river channel or deposition of excavated material in the river channel are likely to affect the flow conditions and initiate changes in the bed profile during the flood period. Hence the dumping or excavation in the river will create adverse effect.

Recommendation of Various Committees

The subject matter of training the river Ganga in the Kanpur reach has the purposes (i) to ensure flow to the right bank (ii) supply sufficient and suitable water to bathing ghats (iii) supply water for municipal purposes.

To concentrate on the above said problem various expert groups were deployed. on his inspection of the river in 1941, Sir Claude Ingus had stated that the unfavorable meander condition of the river indicated that no permanent remedy could be evolved.

Quality of River Water

The population of Kanpur is around 2.8 million. There are 191 water polluting industries located on the banks of the Ganges in U.P. out of this 149 units are located in Kanpur alone. Around 270 mld (3.13 cumecs) of effluents are coming into the Ganges in this town. About 16 nallahs collecting sludge water, sewage waste water from industries etc are discharging into the river at present without any treatment.

It is being proposed that out of total wastewater presently flowing into the river 87% will be directed and treated under the Ganga action plan.

The efficiency of dilution by the flow passing along Kanpur channel will greatly depend upon the quality and quantity of the effluents admitted into Ganga from the Kanpur bank. At least 30 cumec of flow is needed to upgrade the water quality at Kanpur.

The basic, issue is to access the quantum of flow needed for the dilution purposes. The prescribed water quality for the purposes in view is that BOD should not be more than 3 mg/lit. The BOD of natural river at Kanpur upstream of the meeting point of city effluents had been found between 2 to 2.50 mg/lit, so the required quantity of effluents that can be dumped into can be worked out. If the flow on the right channel is at least 509 cumecs and its BOD 2.5 mg/lit and the affluent from city is 0.30 cumec then to ensure that the combined flow would not have still BOD of 3.0 mg/lit then the quality of effluent should be such that its BOD is less than 80 mg/lit.

If the proposed measures for bringing the flowing course to the right bank are implemented successfully and even if 50% of the seasonal flow will be ensured on the right bank channel along Kanpur there should be low flow of 50 cumec on an average (50% probability) or definitely more than 20 cumec on most occasions.

Likely adverse effects on the underlying shallow unconfined aquifer due to the construction of the Ganga barrage at Kanpur

Study on this regard was done by Bipin Dutta, Professor Deptt of Civil Engineering IIT (Kanpur). This study was done based on the earlier records of G.W. table locations in Kanpur area, in the vicinity of the Ganga barrage construction site on the Right Bank. This reveals that the gradient of flow through the hydraulically connected riverbed and the shallow unconfined acquirer causes flow from the acquifer during the dry season. Again the direction is reversed in wet season. Preliminary inquires show that W.T. fluctuations on an average are between 108 m dry season, 112 m wet season. This seasonal variation in water table support the conjecture that a significant stream aquifer hydraulic connection exists and substantial amount of recharge to the shallow unconfined aquifer occurs during the wet season, when the river stage is high.

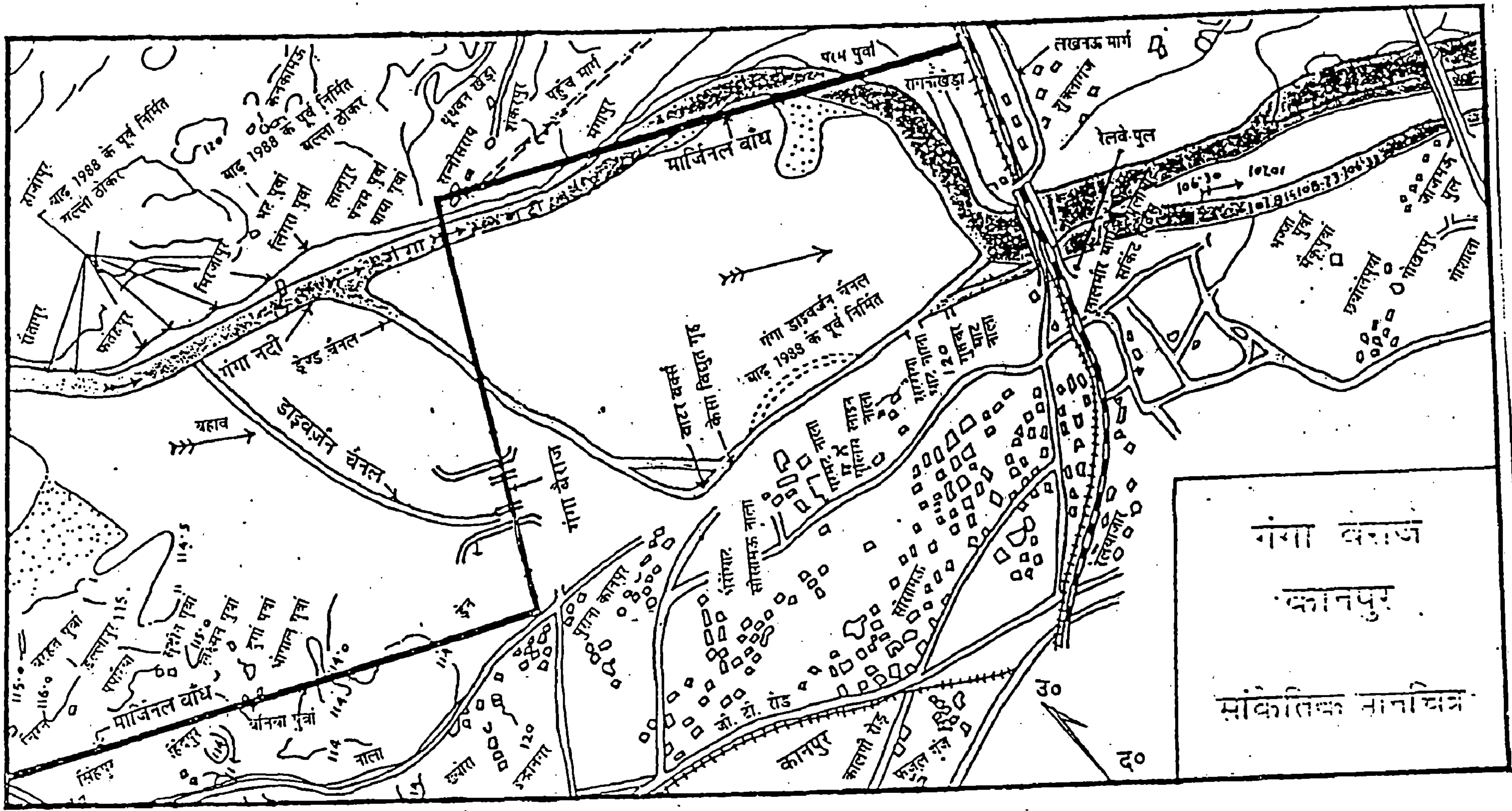


Fig. 4 : Index Map of Ganga Barrage at Kanpur

The pond level in the barrage is to be maintained as 113 m. the 100 year design flood level is 116.85 m for a discharge of 18,840 m^3/sec. the marginal bund will be constructed with a top level of 118.50 m. the 1 in 2 year flood level is 113 m, the normal flood level (1 in 5 year) is 113.50 m while the moderate flood level (1 in 10 years) is 114 m. Therefore all these floods exceeds the pond level to be maintained upstream of the barrage with the modification that the existing ground water table may rise after the barrage construction and therefore the amount of recharge of the river water into the aquifer will be smaller during the floods due to reduced gradient.

Due to the sustained pool level of 113 m generally throughout the year in comparison to the river stage as low as 110 m during dry season at present the amount of recharge of river water to the shallow unconfined aquifer situated along the banks in the vicinity of the barrage site is expected to increase at least during the initial years after the barrage construction. It is also expected that the quasi- steady state of the groundwater table will be maintained after the barrage becomes operational.

The groundwater levels on the right bank of the river is around 115 m, based on the local inquiry it has been reached at a stage where it can be hypothesis that the ground water table will reach a quasi- steady state around 111 m to 112 m i.e. 3 m to 4 m below the ground surface.

The study has been made that the effluents discharged into the river through the nallas will not pollute the river up-stream of barrage. As per the data collected between May 1986 to October 1987 the river water quality at two nearby monitoring stations (Jageshwar temple upstream of Ranight Nalla) the D.O. concentration even in the dry season is around 7-8 mg/liter and BOD is less than 3.0 mg/liter (permissible value) Further improvements of BOD and DO concentration is envisaged due to the subsequent implementation of Ganga Action plan.

However, the rise in water table is expected to have some adverse impacts on the sorption of pollutants, infiltrating through the upper soil layer into the aquifer poorly maintained land fills (garbage dumps) are subject to leaching by percolating rain water during wet season. Also sewage disposal on land or sewage placed on or below the land surface through drains and septic tanks may cause increased pollution of the groundwater due to rise in water table throughout the year following barrage construction.

Especially due to the presence of clay and fine silt in the top 3 m to 4 m on the right bank in the vicinity of barrage site pollution of ground water caused by percolation and leaching may increase as the depth of soil column in the unsaturated zone is expected to decrease due to the rise in the water table. The cationic and anionic species of pollutants being absorbed earlier (prior to barrage construction may be removed to a lesser extent, pesticides, animal waste etc are the other potential source of pollution due infiltrating water.

The likely rise in ground water table in the area on the Right Bank adjacent to the barrage site may not significantly affect the existing groundwater quality in the shallow aquifer.

3.6 FARAKKA BARRAGE

At Farakka, close to the apex of the Ganga delta, the government of India constructed a barrage with the object of diverting a portion of the flow of the Ganges down the Bhagirathi - Hooghly. The increased flow in the Bhagirathi-Hooghly was intended, by the government of India, to flush siltation from the lower reaches of the river. These lower estuarine reaches provide access from the port of Calcutta to the sea and siltation of the river was hampering the trade of the port. The Indian government announced that it planned to construct the Farakka barrage in 1961 and the project was completed in 1975.

In second phase Bangladesh and India had a discussion about augmenting the dry season flow in the Ganges. This focus dominated discussion from 1977 to 1982. After 1978 the two governments were committed to mutually exclusive proposals for augmentation. Bangladesh wanted the solution to be found within the Ganges basin by building reservoirs in river headwaters, primarily in Nepal. India wanted to meet the shortage in the Ganges by transferring water from the Brahamputra.

The force behind the dispute has been the inexorable rise in demand for irrigation water to sustain the growth of green revolution cereals. By diverting some Ganges water into Hoogly India came into conflict with Bangladesh's interest in maintaining the ecology of the Ganges delta and its promotion of irrigation, industries and navigation.

India as the upper repairian state had the power to implement projects, which would provide its needs. Augmentation of water could be of equal benefit to both sides.

The problem of Calcutta port has been studied for more than a century. Inquiries into the problem were started as early as 1853 by Sir Arthur cotton and continued by a long series of experts and expert commissions. All of them concluded the only means of saving the port from its impending destruction was by increasing and regulating the head water supply through the construction of a barrage over the Ganges near Farakka.

The Back Ground

The initial problems arouse due to deterioration of the river Hooghly on which lie the docks of the port of Calcutta. Ships docking in Calcutta have to travel 125 miles up the Hooghly from the sea, so any deterioration in this channel would have very serious consequences.

Between 1853 and 1961 numerous investigations were undertaken. In 1864 Hugh Leonard Superintending Engineer for the department of public works in Bengal concluded that evidence of deterioration in the Hooghly was negligible, but he supposed that it was likely to happen slowly.

In 1946 A. Webster, Chief Engineer (special) of the port commissioners noted that the river was dependent for its existence" on the fresh water supplied by the Ganges through Nadia rivers. His comment reflect general belief that, by some fairly simple mechanism, additional freshwater from the Ganges could " flush-out" the silt which was creating the obstacles to navigation.

The level of anxiety, in the commercial community and in the government of Bengal was such that action was generally thought desirable to stave off the possibility that the river might deteriorate.

After the independence in 1947, further research into siltation took place using models of the Hooghly and Calcutta port which were constructed for this purpose at the central water and inland Navigation Commission (CWINC) Research Station, Poona. The experiments conducted with these models were reviewed in 1952 by a committee of eminent Indian Hydraulic Experts under the chairmanship of Shri Man Singh. While noting the lack of hydraulic evidence of deterioration the committee found that the Hooghly had deteriorated in the stretch between Nawadwip and Calcutta, although the sign of deterioration were less pronounced lower down the river. The conclusion was that there was deterioration, largely on the basis of reduced headwater flow in Bhagirathi.

It was this committee's diagnosis of the problem for which the Farakka Barrage project was chosen as a remedy.

"Preservation of the port of Calcutta" the Indian governments official report on the Farakka project published in 1961 assets that:

1. Sustained high discharge of water flowing from the Ganges into the Bhagirathi was calculated to have fallen by about 45 percent between 1936 and 1956.
2. The Hooghly's capacity was shown to have reduced by between 1 percent and 0.3 percent per annum.
3. Despite intensive dredging, the depths over the river bars have substantially decreased.

In addition to the difficulties for navigation of the Hooghly the former report noted two further consequences of deterioration: increase in the intensity and frequency of bore tids and increase in the salinity of Calcutta's water supply.

Tidal bores caused damage to Jetties and ships moored in the river. Calcutta's water supply comes from the Hooghly. By 1936, the salinity of this water was sometimes above the potable limit and by 1959 salinity of almost 10 times this limit had been recorded.

The Indian government saw the issue in clear-cut terms. It concluded "... the only means of saving the port of Calcutta from checking up with silt and eventual destruction is the construction of a barrage across the Ganga near Farakka, located about 400 Km north of Calcutta. According to Indian government the idea of diverting water from the Ganges had a long pidgree, having first been proposed by Sir Arthur cotton, a British military engineer in 1853.

DREDGING

The lower Hooghly has been continuously dredged since 1906 in an attempt to maintain navigable channel. Almost in-variably shallow bars were dredged and the silt redeposited in deeper section of channel. The Indian government with their experience of size and cost of dredging already being carried out in the Hooghly, which did not prevent the deterioration of the navigable channel did not believe that more effective dredging represent any real alternative.

K.K.Framji in his study of the alternatives to Farakka, concluded that dredging could be no more than a temporary palliative.

The amount of dredging being undertaken in 1961 can be envisaged from the US$ 2 million being spent annually and Framji estimated that in order dredging to be effective, a dumping ground would have to be found for 100 million cubic feet of silt per year. He did not think that would be possible.

Ippen and wicker's report (1962) concluded that existing dredging practice was contributing to silting in the Hooghly. However, they thought that permanent removal of dredged spoil from the river could provide "effective control of navigable depths"

AN ALTERNATIVE PORT

In 1955 there was a suggestion that an auxiliary port should be established. Framji gave two reasons for his dismissal of a new port as alternative to Farakka. First, he thought that such a port would require a century to develop then, second, he argued that even the port of Haldia would be doomed as deterioration will positively travel downstream without the beneficence of the Farakka barrage.

TECHNICAL DOUBTS

In 1957 Professor Walter Hensen was invited by the Indian government to examine the problem of Calcutta. Port. Reported conclusion is

The best and only technical solution of the problem is the construction of a barrage across the Ganga at Farakka with which the upland discharge into the Bhagirathi Hooghly can be regulated as planed and possibly converted into a gradual improvement."

Hensen also explicitly predicted improvement in certain sand supply, together some other benefits, including the decline in the frequency and intensity of tidal bores and a reduction in flood hazards.

Two American experts Arthur T. Ippen and Clarence F. Wicker accused the Farakka project. They were engaged by Pakistan government. The important questions before them were

1. Whether the proposed diversion from the Ganges into the Hooghly would have a beneficial or a harmful effect on the problem of Calcutta port; and

2. Whether the proposed diversion could be reduced without adversely affecting Calcutta port?

Ippen and Wickers conclusions included the following:-

- Dredging requirement would be as high or higher.
- There is no evidence that economic benefits would justify the cost of the barrage whether siltation improved or not.
- The "salinity infusion phenomenon in relation to fresh water flow" played a major role in siltation in the Hooghly.
- Dredging practice had further contributed to the pattern of shoaling.
- There was no evidence that the average fresh water flow into the Hooghly had decreased at least in the previous 15 years
- Salinity conditions near the Paltra water supply intake would improve with increased fresh water flow.

It was finally concluded: "The entire complex of problems for the preservation of Calcutta port has not adequate technical investigation by model studies simulating salinity fresh water mixing and penetration. It is suggested that a major project costing US$ 117 million should not be undertaken without receiving alternation in view of many precedents which revealed unforeseen consequences.

Hensen's view corresponded with that of Man Singh expert committee. Which argued that the strong flood tide in Hooghly brought sediment up the estuary, which the weaker ebb, tide was not capable of carrying back towards the sea. As the flood currents in the upper reach is of shorter duration than the ebb. It is therefore stronger and brings with it material in suspension, which tends to deposit in the channel in the region of slacker water. In order that the channel may be kept permanently open, the ebb current must be reinforced by upland discharge so that all the material brought up the tide is carried back by the ebb.

SALINITY

A fresh question of existence of salinity gradient came into existence in the Hooghly. The greater density of saline (Sea) water creates a tendency in all estuaries for seawater to intrude as a wedge beneath river water flowing towards the sea. This tendency can create water "Strata" of different salinity and different densities. If a saline wedge exists then there will be a net landward movement of water near the bed of the river and a landward current in this region can cause sediment deposition. However, the picture may be complicated by turbulence in an estuary. If turbulent mixing is intense then the vertical density gradient will be slight. Instead there will be a horizontal or longitudinal density gradient, varying from density of seawater to the density of fresh water. This is the condition for an estuary described as well mixed.

Indian government stated that Hooghly estuary was well mixed without stratification or density current.

Having introduced this new variable salinity into the explanation of sedimentation Ipper and wicker further exerted that "Any small discharge, such as visualized for the diversion scheme at Farakka will be inadequate to accomplish a reversal of the upstream bottom velocities engendered by salinity intrusion and will result only in a downstream shift of the shoaling areas from the upper crossing for a relatively small distance. The prediction of the exact location for the new shoaling concentrations is beyond present knowledge, but from experiments it is known that the infusion length is insensitive to changes in the fresh water flow.

They argued however that although increased fresh water flows might cause the salinity intrusion to recede, they would also cause the salinity gradient to be steeper. Stronger upstream bottom currents and increased shoaling may be associated with steeper salinity gradients. This conclusion land Ippen and Wicker to argue, in complete contradiction of the theory of flushing that the introduction of fresh water into estuary increases sedimentation.

They further said that the sediment introduced into an estuary will in the major part be retained in the estuary and this will accumulate progressively and indefinitely unless removed from it by dredging.

In 1962, on the advice of (and with financial support from) the World Bank, a well-equipped Hydraulic study department was established under the aegis of the port commissioners. It began to work with measurements of flow, sediment transport, temperature and salinity at a few selected cross-sections, with simultaneous measurements at three or more points in any cross-section, in addition to measurements of tidal level and surveys of the bed, which supplemented the routine surveys. Radioactive tracer tests were used to determine local rate of sand transport.

INTERNAL OPPOSITION

Kapil Bhattacharya a Bengali engineer living in Calcutta, for many years opposed the Farakka barrage. In 1961 he wrote a pamphlet, "silting of Calcutta port" citing out the reason for his opposition.

Essentially, Bhattacharya believed that the deterioration of the Hooghly was caused not by a natural decline of the river head water, but by human interventions in building dams on the Damodar and Rupnarayan rivers western tributaries of the Hooghly.

Nevertheless, Bhattacharya argued that the control of these rivers took away the main flushing action of the river Hooghly. He believed that the Rupnarayan and Damodar provided much greater velocity in flood than did the freshets of the Hooghly.

In a paper read to the 1965 Annual General Meeting of the Association of Engineers Calcutta. Bhatttacharya explained his main point.

Prior to DVC dams withholding the Damodar floods, the ebb flow used to be swifter and continuous during the monsoon months of June to September and there used to be a little flood flow upwards in those months. Thus the bars, especially in the lower

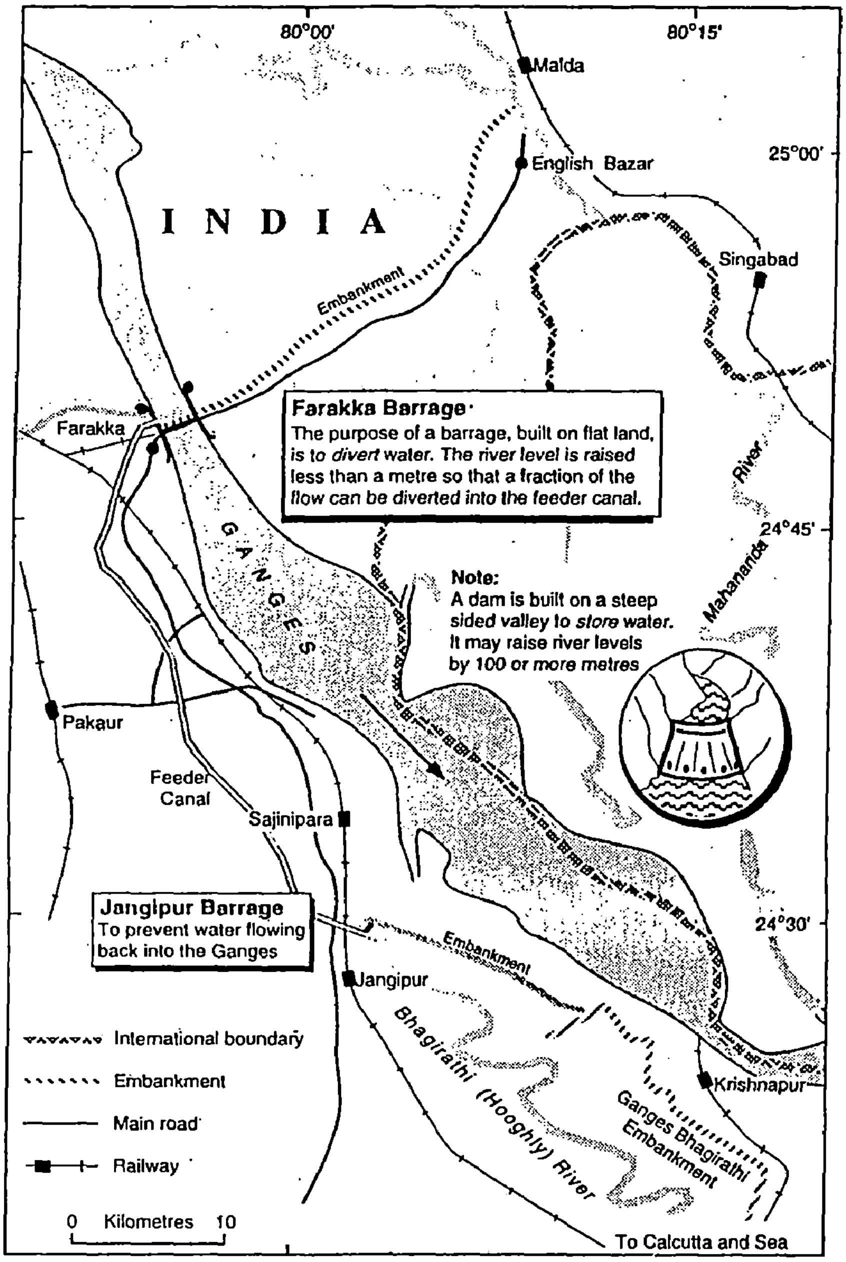


Figure 5 Plan of the Farakka Barrage and the feeder canal taking water to the Hooghly reach of the river (Hooghly) were scoured and the navigable channels were naturally maintained with occasional help of dredges at required points. With DVC (Damodar Valley Carbonation) dams this natural hydraulic operation has been practically stopped with progressive deterioration of channels.

CONFLICT AND DISAGREEMENT

The insufficiency of water during the dry season for India and Bangladesh is the root cause of the conflict; Farakka was only the occasion of the dispute.

India has maintained for much of the dispute, that the Ganges is not an "inter National River". To have entered into negotiations with Pakistan would have been a denied of this line of agreement.

However after creation Bangladesh first phase of conflict came to an end

- The feeder canal of the barrage was completed in 1973. (The barrage being completed in 1970)
- For five years after (1973) that 40,000 cusecs could be diverted down the Hooghly and for the following two years, the diversions would be varied experimentally
- At the end of seven year there would be a review.

JOINT RIVER COMMISSION

Through JRC Bangladesh and India both were of the opinion of augmenting dry weather flows of the Ganges. Bangladesh insisted on construction of storage reservoirs on the river's Himalayan tributaries. The Indian team opposed this concept, arguing that a canal to transfer surplus water from Brahamputra into he Ganges was a more practical alternative

NEW CONCLUSION

- Bangladesh insisted that augmentation should take place within the Ganges Basin.
- India did not accept that Bangladesh had a right to veto upstream withdrawals.

- The two sides differed over length of the dry season.
- India rejected any notion that Nepal should participate on the discussion. Experimental use of Farakka Barrage was made in 1975 only.

THE EFFECTS OF FARAKKA

- Deforestation and bad agricultural practice in the catchment areas of the Ganges in India and Nepal are also believed to have changed the ratio of maximum to minimum flow in these rivers and increased their sediment loads. Ground waters storage and percolation in the basins and may lead to increased flooding and decreased dry season flows.

THE EFFECT OF FARAKKA DIVERSION ON GROUND WATER

The Bangladesh government claimed "the hydraulic cycle of surface and ground water are inter dependent. In 1976 the ground water level in the highly affected area went down by 5 feet on average with a range of 3 to 8 feet below normal.

Attached figure is an idealized section showing the sort of water conditions, which prevail below the ground surface. An aquifer receives water both from rainfall and from surface, river and ponds. Ground water is extracted from an aquifer through a well. It flows into the sea and into rivers and ponds. In a flat region like a Ganges delta, ground water may increase river flow during the dry season and the same river may contribute water to recharge adjacent aquifers during the wet season. A river will receive ground water if the adjacent water table is higher than the water level in the river and vice versa. These flows will be large or small and the influence of reduced river discharges will be correspondingly extensive or localized according to the permeability of the soil constituting the aquifer.

Undoubtedly, the construction of a massive barrage across the river Ganges at Farakka must have altered the way in which the development of the river takes place. The Farakka barrage incorporated several high velocity sluices, known or silt excluders who

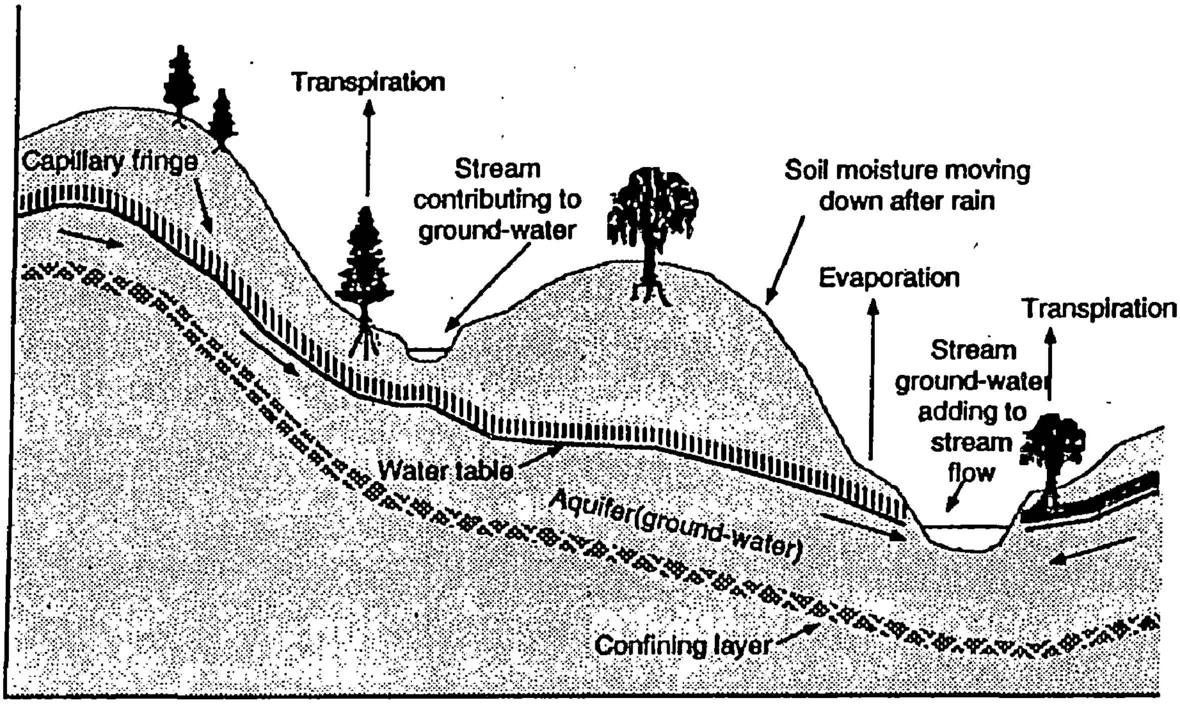


Figure 6 Idealised section of land surface showing ground-water features were intended to allow silt to flow down the Ganges. The sediment load of the Ganges is relatively small during the dry season. So net effect of silting is slight.

Navigation, fisheries and ecology: Bangladesh claimed that due to Farakka barrage inland navigation was interrupted

Similarly, it was claimed that the withdrawals reduced the fish catches. Probably because of the disturbance of the historic food chain and the inability of the fish to tolerate shallow depths and unprecedented level of salinity. It was found that reduced flows could effect the fishes spawning and therefore reduce stocks.

Finally Bangladesh argued that health of the population and the ecosystem was effected.

Proposal for Augmentation:

The Indian scheme for augmenting the dry season flow of the Ganges consisted of a barrage across the river Brahamputra and a canal to take water from that river to the Ganges at Farakka. At a later stage the Indian government intended to construct three storage reservoirs in the eastern foothills of the Himalayas to supplement the dry season flow of the Brahamputra. Each if these five structures the barrage, the canal and the three dams-would be large and altogether would cost in excess of US 6000 million.

The Indian government's justification for this scheme rested on a number of interrelated points. First of all, the government argued that there was a shortage of water in the Ganges basin, which could not be over come by schemes within that basin. Accordingly, it stated all feasible reservoir sites within the basin could not store enough water for the needs of the two countries. Second, Indian planners asserted that the needs of Indian drought areas outside the Ganges basin must be considered and the Ganges was the nearest source of water. Finally, India argued that there was water available and unused in the Brahmaputra and Meghna rivers at times of the year when the shortage in Ganges basin were most acute.

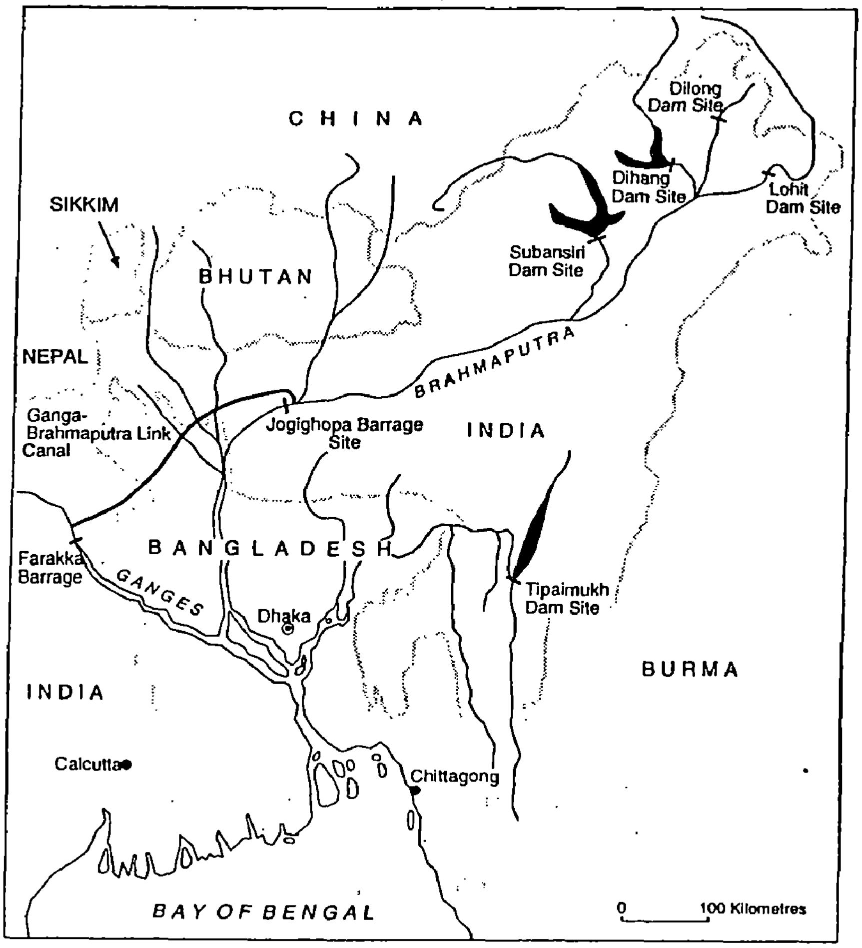


Figure 7 The 1978 Indian *Proposal*

A. Barrage

Indian proposed to build a barrage across the river Brahmaputra at Jogighopa in Assam 70 miles downstream of the state capital, Guwahati. At one and half miles long, the barrage would be slightly longer than the Farakka barrage.

This site was chosen because the river was narrow and its bank stable at the point but also in order to maximize the benefits of the project to both countries. India's estimate of dry season water demand.

Table 1

Countries	Use	Demand (cusecs)
India	Irrigation (Rabi season) Calcutta Port	32,000 40,000
Bangladesh	Irrigation For the river Gorai	50,000 5,000
	Total	~~4,15,000~~ 1,27,000

The Bangladesh Proposal

The Bangladesh government believed that the transfer of water from the Brahmaputra was not the best way of increasing the dry season flow of the Ganges. The Bangladesh proposal suggested instead that the monsoon season flow of the tributaries of Ganges could be stored for use later in the year when it would be most needed Bangladesh argued that there was surplus water in the Ganges basin and that enough of it could be stored in reservoirs for the needs of India, Nepal and Bangladesh. It was not therefore necessary to consider using water resources outside the Ganges basin.

The proposal concentrated primarily on the calculation of the flow, which could be generated by the reservoirs. For the 12 major reservoirs in Nepal, Bangladesh engineers made two estimates. Each of these dam sites had already been investigated and a design proposed by a firm of Japanese consulting engineers acting for the Napalese government. Bangladesh engineers used these designs, which were made with a primary objective of hydroelectric power generation. It was suggested that a maximum of 310,000 cusecs of additional flow would be made available during the dry season. The updated proposal submitted for discussion in 1983 costed a revised construction programme at US$ 17 billion.

The context of the Bangladesh scheme was set in the opening paragraph of the proposal. The dry season flows in the Ganges Basin have been diminishing in the lower reaches as diversion for irrigation are taking place in the upper reaches. The low flows must not be allowed to decrease any further at the same time measures must be taken to increase the dry season flow of the river to meet the present and future needs of riparian countries.

The Bangladesh government was concerned not with the threat of the Farakka diversion but by the threat posed by future irrigation developments in India.

Table 2 : Bangladesh's Estimates of the Land and Water Resources of the Ganges Basin

Country	Culturable area million acre	Present irrigated area million acre	Ground water availability	Water million acre feet
India	148	44	88 M.A.F.	150
Nepal	4.5	1.5	Large not known	24
Bangladesh	9.0	7.4	Not too bright	33

It further states, "The present dry season flow of the three major rivers from Nepal has an average of 53,000 cusecs from November to May or 22.3 M.A.F. which should be sufficient to irrigate the available land in the Tarai area in Nepal and India under command of these rivers. In addition to this the existing flow of the rivers from the Mahabharat range would continue to serve the areas. Therefore most of the increased dry season flow from storage in Nepal as shown above would be available at Farakka and downstream in Bangladesh.

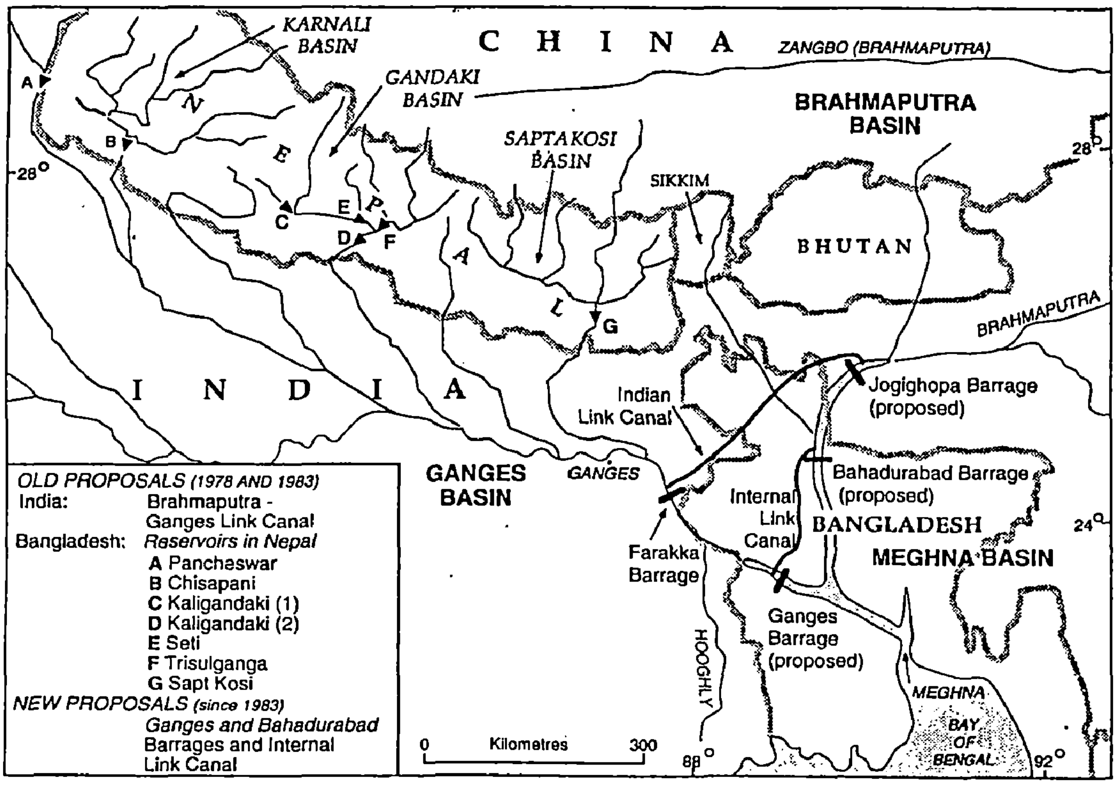


Figure 8 The three river development proposals

"In this paragraph Bangladesh claimed the water generated by reservoirs in Nepal for its own use".

The Case Against the Bangladesh Proposal

Verghese summarized the Indian critique of the Bangladesh scheme citing three objections, "A third country, Nepal, should not and need not be involved". India needs all the water that can be stored in the Ganges basin. The Indian government also doubted the practicability of building the reservoirs, it questioned whether Nepal would agree to such a large number of reservoirs.

The case for the Indian scheme rested on the assertion that "enough" water could not be stored within the Ganges basin the Bangladesh case was founded on the belief that it could. It was confirmed that the dry season flow in the Ganges could be enhanced only through the bilateral efforts of India and Nepal.

The New Bangladesh Line

New line was seeking for a permanent sharing formula, but the new approach was not limited to the Ganges. In part this was recognition of changing reality. As time passed and irrigation projects came up stream, the dry season flow of the Ganges was falling.

Criticism of the Old Line

In 1984 the Bangladesh side of the Joint River Commission published a document which criticized their line as

1. It offered a solution only in the distant future.
2. It would submerge a considerable area of Nepalese land.
3. It required construction of some of the largest dams in the world at a time when such constructions were increasingly subject to question on social and environmental ground.
4. It required co-operation from India and Nepal for the foreseeable future.

Bangladesh technical experts evaluated likely growth of irrigation off-take in India with the rate at which augmentation water could be made available from dams in Nepal. This picture showed that even if every thing goes well they could have augmented water only after 2015.

A second area of concern, which told against the Bangladesh proposal for storage in Nepal, was the scale of inundation of land. It was estimated reservoirs would inundate significant area of productive land; 203 square kilometers of cultivable land and 417 square kilometer of forests. Lost production was estimated as US $ 89 million for agriculture and US $ 262 million for forests. In addition seven of the dams in Nepal which were proposed by Bangladesh would have been amongst the largest in the world. The tallest at 327 m. Even the smallest 180 m high opposition to such dams is now wide spread in South Asia.

CHAPTER – 4
SURVEY OF LITERATURE

4.1 RESOURCE MANAGEMENT

General

Each country /economy, whether developed, developing or underdeveloped, tries to attain some goals by making use of some means. These goals may be of full employment, price stabilization social justice, reduction in income disparity in society, a rise in the standard of living etc the ultimate goal being of economic development. Among the means available for attaining these objectives, some may be natural gifts with which that county is endowed, and others may be man-produced. Both of these categories of means constitute the overall resources.

Land, water air, sunlight, mines oil and gas in the earth are examples of natural resources. The natural resources, in their broadest sense, include all the freely given material phenomena of nature within the zone of means activities, plus the additional non-material quality of situation or location. The association of these elements of land Air Sea and situation is a single area is commonly identified as its resource base or resource endowment.

The utilization of these resources depends upon technology, culture, the stage of economic growth, time and space etc. If an economy owns large stocks of natural resources, but if the technology available in that economy is such that most of them are not accessible, then, only a small portion of these stocks will be exploitable thus the contribution of natural resources to economic growth varies in different economics.

The demand for resources is changing in the light of the changing technology, changing population growth, and changing social institution.

The change in the rate of population growth is an important factor which influences the demand for natural resources.

Table – 3 **Population Growth in India**

Year	Population (in crores)	Increase in population crore	Average annual rate of population growth
1901	23.83	-	-
1911	25.20	1.37	0.5
1921	25.13	-0.07	-0.02
1931	27.89	2.76	1.09
1941	31.86	3.97	1.42
1951	36.10	4.24	1.33
1961	43.92	7.82	2.16
1971	54.81	10.89	2.47
1981	68.39	13.58	2.47
1991	84.63	16.24	2.37

Sources: Publication Division Government of India

Population growth depends on change in birth and death rates. The efforts made in the field of family planning tend to reduce the birth rate; but the advances in medical knowledge and better facilities have ushered in decline in mortality rate and increased life expectancy. The net result is a rapid growth in population. For this rapidly increasing population, we have to arrange for the supply of various commodities, which demand an increasing use of natural resources, i.e. a large area of land to be cultivated, more land for residential purposes and for establishing new industries, water for purposes of drinking, irrigation and industry, more fuel and more solar energy and so on, in brief more of everything.

The change in social institutions, too, have had an impacts on the demand for natural resources as society has moved, its way of life, its customs and traditions, its requirements of various commodities, its organizational changes over time and consequently the demand for natural resources, too, have been affected.

In light of changes in the demand for natural resources, the supply of these resources, in relation to the demand, has declined. The rate of decline in the relative supply (or rate of exhaustibility) of natural resources varies according to the nature of the resources and the rate of its utilization over time.

Renewable Resources

If different units of a resource are available at different interval of time a resource is said renewable.

There are flow resources that are affected by human action and having a critical zone, which give rise to serious socio economic problems and are very sensitive to social institutions.

Water a Natural Resource

By its presence in the atmosphere, it tempers the sun's heat; the rain that falls scours the hills and carries the sediment into the river valleys and deltas; the streams remove almost unbelievable amounts of solid matter from the rocks in solution, and carry these dissolved matter from the rocks in solution, into the sea. Water performs very important functions and influences not only human life but entire ecosystem in various ways. The Hydrological system is the largest natural system.

Water Resource Economics

It is concerned with three aspects of water resource i.e. management, conservation and administration and policy formulation. Under the management aspect we try to maximize the efficiency of water use. Water is a key resource in agriculture production and is also required for several other purposes, such as industrialization, drinking and navigation. The rational use of water or most efficient use of water may be obtained by maximizing the output per-unit of water and by minimizing the wastage of water while using it.

The maximization of output per unit of water depends upon so many factors; for instance, the area irrigated per unit of water, the cropping pattern inter spatial allocation of water the use of other inputs as fertilizers, plant protection materials etc. the ownership of water the incentive to irrigators for rational water use, the techniques of water use, such as the method of water application, land leveling, mode of conveyance of water etc, the source of water and the uncertainty involved in the availability of water for irrigation purposes.

If the area irrigated per unit of water is very large, the availability of water to crops per unit area will be inadequate to keep the crops alive during days of moisture stress, and it may die without yielding any production, the irrigation water in such a case goes waste. On the other hand, if the irrigated area per unit of water is very small, the available water may not be fully used, some of it is bound to be unused or wasted. The cropping pattern, too, is an important determinant of water use efficiency. We have therefore to adopt a cropping pattern, which is most suitable in terms of the availability of water. That is, we have to select crop varieties and crop rotation in such a way that the available water is fully used.

Productivity of Water

The productivity of water does not depend only on the level of water use. It also depends on the level at which other production inputs are used. For instance, the productivity of irrigation water is considerably influenced by the use of fertilizers in different quantities. A higher use of fertilizer increases the productivity of water. The water production function also shifts following improvements in production technology say, following the use of a particular variety of seed, inter culture the method of sowing, the time of sowing etc. The ownership of water and water rights, too, influence the efficiency of water use. Lack of appropriate and well-defined water rights may create great many problems its water distribution among irrigators. The degree of efficiencies of water use differs under state and private ownership of water resource.

Water charges should be such that the irrigators have some incentives to make a rational use of the resource. A very low water charge may lead to an over use of it. In canal irrigation, where farmers have to pay a fixed charge irrespective of the number of irrigation facilities enjoyed by them, the marginal cost of irrigation becomes zero, and the farmer may go on irrigating crops till they get a positive marginal return. The farmers located at head reach of a distributory have no incentives to improve the field distribution system, because enough water becomes available to them even for the purposes of flooding the fields, on the other hand, the farmers located at the tail-end of the distributory have no incentive to invest in field channels, because they are not sure of getting water.

Technique of Water Use

The technique of water use is closely related to water use efficiency. Water losses may be considerably reduced by adopting a suitable method of water application, of leveling the irrigable land properly and of selecting an appropriate mode of water conveyance. Improved techniques help farmers to irrigate their fields in less time, with less quantity of water and with a more uniform spread. All this increases water use efficiency obviously, the water so saved can be used to irrigate additional land.

The irrigated area and the availability of water per unit area, varies from source to source of irrigation. This results in a charge in the cropping pattern in the command areas of different sources, and finally affects the water use efficiency.

The uncertainty involved in the availability of water has an impact on water use efficiency if the availability of water (at least for some minimum number of irrigation) is not ensured, the farmers avoid taking the high investment risk involved in the purchase and use of fertilizers etc. and the productivity of water goes down. Under the condition of uncertainty the farmers prefer to take those crops/varieties which do not suffer form a shortage of water. The full advantage of irrigation is therefore not availed of because farmers do not take the cultivation of more remunerative crops.

Conservation of Water

The economic aspect of conservation of water resources is based on the doctrine of scarcity. Supply of water is becoming increasingly limited in view of the continually increasing demand for it. The supply of and ~~the~~ from the cost involved in making the water available for the use and wants of the people, both of these changes over time, mainly because of technical improvement and changes in the consumption pattern. The green revolution in the last two decades has greatly changed the demand pattern of the irrigation water.

Administration and Policy

The ultimate goal to be achieved by using natural resources is to maximize the general welfare of the people of the country. in order to maximize this general welfare, our natural resources must be utilized in the most efficient manner. Governmental intervention is required to improve the efficiency of resource allocation by the application of appropriate decision rules.

Water resource management is, thus, a multidisciplinary subject dealing with decision making in the areas of the most efficient use of water, conservation of water and administration and formulation of public policies. The disciplines of engineering, agronomy, soil science, biology, biochemistry provide alternative technologies for the manipulation of physical entities and the discipline of economics assists in the making of optimum choices based on these alternatives.

National Water Policy (1987)

The national water policy adopted by the national water resource council in September 1987 has highlighted the importance of planning of water resources with river basins as rational units because all the water related activities in a river basin are inter connected and inter dependent. Further it also envisages that appropriate organization should be established for the planned development and management of river basin as a whole. Special multi-disciplinary units should be set up in each state to prepare comprehensive plans taking into account not only the needs of irrigation but, also harmonizing various other water uses, so that the available water resources are determined and put to optimum use having regard to subsisting agreements or awards to tribunals under relevant laws.

Integrated River Basin Planning an Overview

Planners should formulate comprehensive co-ordinated and integrated basin plan for short and long range conservation, utilization, planning, development and management of basin water and related resources in optimum ways. Individual water projects, whether single or multipurpose, can neither be undertaken nor managed with optimum benefit to promote human welfare unless there is a broad plan for the entire basin.

Integrated river basin planning calls for multi disciplinary approach to the planning and management of the water related activities.

Planning Process

Planning is the orderly consideration of a project from the original statement of purpose through the evaluation of alternatives to find decision on course of action.

Generally, speaking the planning process comprises of four steps, namely

(i) definition of objective

(ii) project studies

(iii) projection for planning

(iv) project formulation

- **Definition of objective** : All possible use of water i.e. domestic and municipal supply, irrigation, Industrial use, Hydro power development, stock water, Recreation, Religious, fisheries and wild life, navigation, water storage for stream flow regulation are pertinent to the problem.
- **Project Studies :** Studies ought to be undertaken for arriving at sound economic decision which will meet the requirement of the project in optimum way.
- **Projection for Planning :** The projects should be planned to meet future needs. Projection should be more than a simple extrapolation of past growth curves for social, economics and technological development may cause significant changes in trends. Every effort to anticipate such changes must be under taken.
- **Project Formulation:** Once the basic data and the projection of future conditions are assembled, actual formulation of project can be taken up. This is the most important

phase of planning where imagination is required. The important first consideration is the compilation of a comprehensive list of alternatives. The planning process should be evaluation of all possible alternative with respect to project feature and water use. Project formulation comprises of four steps namely ,

(i) Fixing boundary condition with respect to project,
(ii) Definition of alternative land use plan;
(iii) Listing of possible projects, and
(iv) Preliminary cost estimate, on the basis of which any of the alternative may prove to be undesirable and ultimately be discarded.

CASE STUDIES

Several case studies can be cited from a number of countries, wherein the concept of integrated approach to river management has been attempted.

Case Study I

'The three Gorge project China'.

The San Xia Gong Cheng or the three Gorge project is the most important and the backbone project in the development and harnessing of the Yangtze (Chang Jiang) river, China. The three gorges are the Qutang Xia, Wu Xia, Xiling Xia.

The preliminary investigation and planning were done in 1940's. From the middle of 1950's onwards, over a period of more than 40 years, extensive efforts were made for investigation, planning, design and scientific research for the three Gorges project. The project is huge in scale and complicated in technology and involves several scientific and technical disciplines, social, economical and environmental protection aspects.

The feasibility study was completed in 1989. Examination of design for each individual item was finished by the end of 1995. Work on the project began in 1994.

The TGP is a multi-purpose hydro-development project, producing comprehensive benefits mainly in flood control, power generation and navigation improvement.

The project will have 22.15 billion m^3 of flood control storage capacity in the reservoir. There will be 26 generating units in the power houses each of 700 MW. The 660 km long water way will be improved. Reservoir regulation will augment dry season discharge from 3000 m^3/sec to 5000 m^3/sec. Transportation costs will be reduced. The project will promote the development of fishry in the reservoir as well as tourists and recreational activities. It will improve the water quality of the middle and lower reaches of the river during the dry season and shall create favourable conditions for the south to north water transfer which is another massive and ambitious project of China.

Strategy of reservoir operation is discharging the turbid impounding the clean. The experience gained from the Gezhouba project on the sediment management has laid foundation for the sediment study of the TGP. According to long term observations, the sediment load in the Yangtze river changes periodically on random basis.

According to overall planning of the Yangtze Valley, a number of large-sized reservoir will be built in the foreseen future in the upper Yangtze and its tributaries. It is expected that combined with soil conservation works (Forestry) less sediment will enter the river water in future.

Environmental Impact Assessment (EIA)

1. The total capacity of the TGP reservoir amounts to 39.3 billion m^3, accounting to 8.7% of the yearly runoff at the dam site and its effective capacity is 16.5 billion m^3 accounting to 3.6%. Therefore, reservoir is of a seasonal regulation one with low run-off regulation capability.
2. The reservoir is of a canyoned and river-like reservoir with a total length of about 600 km and average width of 1.1 km which is less than twice the width of the

natural alluvial channel. The surface area of reservoir will be 1084 km^2 and the land area to be inundated will be 632 km^2.

3. The annual runoff downstream of reservoir will not change after the operation of the reservoir, therefore, the annual flow going into the sea will not be affected. The monthly flow downstream of the dam will basically remain unchanged except in October when the flow decreases slightly because of impoundment and the period from January to May when the flow increases slightly. The monthly flow after the operation of the reservoir will still be controlled within the natural amplitude, so that the influence on the hydrological regime downstream of the dam will not be significant.

The environmental impact assessment has considered the Yangtze valley as an integrated system by dividing it into sub-systems. The impacts on the natural and social environmental factors such as local climate, water quality, biota, rare species, inundation and resettlement, landscapes, historical relics and so on have been analyzed, qualitatively or quantitatively. The analysis has been performed according to the Chinese legislation and referring to the international practice. The mitigation measures have been recommended to alleviate the negative impacts.

The main conclusion of the EIA is that the TGP will exert both positive and negative impacts on the environmental and ecological system, the former mainly in the middle and lower reaches of the Yangtze and the latter concentrating on the reservoir area.

Major Environmental Benefits

1. The chief purpose of project is flood control. It will provide a safe guard against 100 year flood. It will provide a safety cover to 15 million population (Jigjian region) and 1.53 m.ha fertilized farm land.
2. The project will produce huge quantity of clean energy. Thus effects of burning 50 million tons of coal will be prevented.

3. Local climate and water quality down stream will get improved. The operation of the project would cease the salt water intrusion in the estuary region. The increase of water surface area will promote the aquatic farming in the reservoir.
4. Better navigation condition will provide access to new scenic views.

Main Negative Impacts

1. Landscape and cultural heritage : The impoundment will affect 44 archaeological sites and ancient monuments. Efforts will be made to salvage the cultural heritage that may be inundated.
2. Rare Species : There is little natural vegetation in the inundated area. The impoundment, therefore, will not bring about serious losses. About 26 rare animals protected by the nation live in the remote and mountainous areas and will not be affected by the project.
3. Water quality in reservoir : Slower flow velocity and higher water level caused by TGP will aggravate shore line pollution, which needs mitigating by better wastewater treatment measures.

Rehabilitation and Resettlement

According to 1992 survey, the TGP reservoir will inundate 27.82 thousand ha of farm land and 8,46,200 residents living in the inundated area.

The Chinese government has declared that the development oriented resettlement policy should be adopted for TGP. It also assures the protection of the host communities from adverse impacts.

The government plans to invest heavily in this region during the construction period and will give them preferential policies. Besides after completion of TGP, a portion of profits from power generation will be allocated as development funds to this region for promotion of local economy.

Project Implementation

The China Yangtze Three Gorges Project Development Corporation (CTGPC) is an autonomous economy entity, keeping accounting, assuming sole responsibility for its profits and losses, with legal entity position, and is the owner of the project. It is responsible for the overall construction of the project and its management and maintenance after completion and also responsible for the financing and reimbursement of investment including the fund for resettlement.

Inference

From the study of this paper we conclude that project was studied for a long period. Integrated approach for flood control, navigation, fishery promotion, soil conservation is being taken. Rehabilitation and investment of profit in the basin area is also considered. For implementation of project a single body at national level is responsible for all the concerned works.

Case Study II

'River management in United States of America.'

The United States of America is one of the biggest countries in the world, not only in the size of its territory but also in its use of irrigation and drainage. Colourful varieties of topography, climate, soils, and water resources can be seen; in tandem with them, irrigation and drainage differ from region to region in importance and nature.

Water Resources

The water resources in streams and lakes are more accessible than groundwater; in fact; about 80% of the water used in the country comes from surface sources and the remaining 20% from groundwater.

About 85% of the nations water consumption is irrigation; the remaining 15% is about evenly divided between industrial and municipal uses. In the dry west, salty soils are wide spread and can damage crop growth if continuously irrigated.

Even the most arid areas sometimes suffer from local flooding, and the most humid areas occasionally experience drought and seasonal water shortage. The demand for developing water resources in the densely populated east and other industrial areas has been increasing steadily, placing the strain on water resources.

Though the country is blessed with plentiful groundwater, it can not be collected as easily as surface water.

Problems

Like other countries in the world, the United States suffers from a shortage of water resources; irrigation competes with industrial and municipal users of water as increasing population and industry make greater demands on the water supply.

Most areas of the dry west are subject to occasional flooding, while most area of the wet east experience seasonal water shortages. So the problems of improving efficiency in water use, conserving the quality of water, preventing flooding, storing water and so on are being seriously discussed.

i) Improving Efficiency in Water Use : Measures which may use water more efficiently include application of only the amount of water needed to replenish the soil moisture in the root zones or to control salinity. Other measures are also being studied.
   (a) Water application on time schedule
   (b) Water management at farm level
   (c) Water management at project level.

(ii) Trans Basin Conveyance of Water : Desalinization, and weather modification. Trans basin conveyance of water into water short regions from areas where water supplies exceed foreseeable demand has been already implemented on a large scale in several Western States.

   Research and experiments on desalinization have been carried on with the aim of finding economically feasible methods of providing fresh water from the sea. Many desalting plants are in operation for supplying fresh water to industrial and municipal fields.

(iii) Water Pollution Control : The United States has been trying to determine which farm chemicals contribute to water pollution and to investigate the use of such chemicals.

Research Institution

Research on irrigation and drainage and their development is centered mainly in the Departments of Agriculture, and Interior of the Federal Government, in many Universities of Engineering and Agriculture, and in private organizations such as Ford Foundation.

The Department of Agriculture develops effective irrigation practices which can help the farmers make irrigated agriculture a success. The Department of the Interior concerns itself with, water management at the project level, including the engineering sector of water conveyance and distribution, as well as the problem of alkali, and, acid soils, water reuse, weather modification and so on.

The Universities have conducted basic research on irrigated agriculture and hydro-structures, maintaining close contact with the various organizations of the federal government.

From the literature about America as delt above, we can conclude that water is every where scarce and it needs management. In America besides needful practice stress is on research and development too.

Case Study III

Paradox of River Management in Spain

Excerpt from the journal "World Water and Environment Engineering March April 2000" is presented here. A brief description of "The Rhone to Barcelona Water Pipe Line" is there in the text. It reads as ....

"….. A French Environment Ministry study on the pipe line feasibility questioned whether the Barcelona's water needs are as high as stated. Joseph Verges, a Catalan economist who contributed to the Frensh study, argues that the Catalonian Government has over – estimated its water needs".

One of the reasons for this project is that the province of Murcia (the driest of Spain) is desertifying fast and needs an aqueduct from the Ebro to Segura river (as set out in the National Hydrological Plan) to supply the needs of the province of Castellon de al Plana, Velencia, Alicante, (Comunidad Valenciana), Murcia, Almeria and Andalucia (which is already semi desert and full of abandoned villages).

The water situation of Southern Spain (which the Hadley Centre predicted would soon become desert) is horrendous. Murica province has few rivers worth their name, the main one being Segura which is so polluted that liquid oxygen has to be pumped in to stop the stench.

This situation has arisen because of dams being built which are supposed to allow the ecological flow of water i.e. sufficient to flush the river and not destroy ecosystems.

At the last count there were some 37 towns which pumped untreated sewage into the river, not forgetting industrial waste from the many leather factories. The regional government is fast building STPs to solve the problem.

However, the state of the river is, so bad that a Professor in the Oriheula University took the water authorities to the EU because of high heavy metal contamination. Furthermore there are high levels of radiactivity due to at least one nuclear power station near the Tagus and the hot springs in the Spa towns of Archena and Fortuna which are naturally radioactive.

The provinces of Murcia and Alicante get water for irrigation via the Tagus – Segura canal but the province of Castilla la Moncha (where the Tagus rises) refused to send water during the last draught as there was insuffficient to meet its own needs. By law Castilla la is only obliged to send excess water.

The province of Aragon (ruled by the Aragonese National Party in Coalition with socialist PSQE) refuses to allow the Ebro-Segura Aqueduct to be built and there would be problems with Portugal if anything is done via the Duero.

A project for building a desalination plant in the town of San Pedro del Pinatar to supply the neighbouring towns upto Cartagena for which planning permission was given and a contract signed with a construction company in 1998, has yet not begun because of delays on environmental grounds.

The town of Javea (Alicante) has to use Artisian wells to supply the population. These become saline due to the lack of rain and because the dry land socks up sea water like a sponge during droughts. The mayor recently had to issue a warning that the water was not fit for drinking or cooking with. A British expatriate took the matter to EC.

A visit to any green grocer in the u.K. will show that most of the agricultural produce sold comes from the provinces of Murcia, Andalucia and Almeria – the three provinces worst hit by drought.

There have been some 30 years of very low rainfall and several years of severe drought in Spain, aggravated by forest fires, some caused by dry storms, i.e. thunder and lightening without rain accompanied by 100 km/h winds which have destroyed 300,000 ha of prime forest all over Spain.

Drought alternates with floods that carry away top soil causing erosion".

Inference

In 18th and 19the Century Spain was leading country having respected water management laws. With passage of time river resources were over exploited. They were neglected. As a result Southern Spain is on the verge of desertification.

River Segura, life line of Southern Spain is dumped with waste water having chances of induced radio active pollution too. Curative measure of mixing liquid oxyen to the sewage is practiced to stop the stench. Also, measures to combat river flow pollution by establishing STPs are now going on.

Reservoir regulation to flush out the pollutional load of river has proved itself null. From the text we can learn some thing for our selves. We can hardly achieve the physical development status as of Spain (which we are trying enough) even then if we over exploit our rivers and do not keep pace with nature, our tropical climate will drag us to desertification much faster than Spain is being dragged.

Case Study – IV

"The Need for Integrated river Management – A Case Study from Eastern Europe"

The river Warta cuts across the Central and Western part of Poland, with a length of 808.20 km it is the third longest river in the country.

The catchment of the Warta is an agricultural and industrial region, nearly 60% of its area is arable fields. The Character of the relief in the basin is shaped by the Scandinavian glacier. The average annual precipitation in the Warta basin ranges from 450 mm to more than 600 mm.

Essentially all problems with water in the world concern inappropriate quantity and/or quality in a particular site and at a particular time (too much – too little – too dirty). The last two types of problem are of growing importance in the basin of river Warta.

The scanty water resources are effectively further reduced by water pollution. The quality of water in the whole drainage basin of the river Warta does not actually meet the requirements set by polish standards for the lowest (third) water quality class. The principal reason is a massive discharge of untreated sewage directly into water courses : there is a serious lack of sewage treatment plants. For example, is 1990 the town of Lodz (8,49,000 inhabitants) discharged 99.7% of its sewage requiring purification (117.5 x 10^{-6} m^3) to a tributary of the river Warta without any treatment. The scarcity of water in the river is an additional natural factor rendering the problem of water pollution more critical.

The most common factor causes of water pollution in the area are :

- Biodegradable substances (BODs) downstream of lumped sources of pollutants (Municipal sewage, industries).
- Heavy metals most often zinc.
- Nutrients, nitrogen compounds and phosphates
- Bacteriological indicators of faecal pollution (chloroform bacteria).

The contribution of agricultural pollution to the overall pollution of surface and ground waters of the river Warta is growing. Runoff pollutants from agricultural areas threatens surface waters, and initially the small tributaries of river Warta. This results in a considerable growth in the amount of nitrogen, phosphorus, organic compounds and the general quantity of mineral compounds in the water. The situations is aggravated by poor waste management.

A number of consecutive snow-free winters and a series of years with warmer summers and precipitation below average, aggravated the water supply shortage in Wielkopolska – a large area of Central Western Poland within the drainage basin of the Warta.

The consequences of the drought were manifold and comprised :

- Significant crop reduction on a regional scale.
- Numerous and extensive wild fire of an extent never experienced before.

- A dramatic reduction of flows in river and streams, destroying habitat for fish and other river fauna. Flow in smaller river dropped to zero. Water quality problem was aggravated because of insufficient dilution.
- Ground water level dropped considerably.
- Most ponds and smaller lakes in the region dried out completely.
- Wind erosion in early spring.

The administrative division of the river Warta catchment has been an additional drawback in rational water management. The drainage basin of the river belongs to as many as 19 administrative units (provinces). It was therefore very difficult to conduct integrated water management with so many independent players.

On Ist February 1991, the Minister of Environmental protection launched seven boards of water management in the country. The principal issues was

- To combat pollution of surface waters and ground waters.
- To protect sources of drinking water
- To aid water users (population, agriculture, industry) in rational water management.

The Regional Boards of water management are executive organs of the councils of water management, which play the role of water parliaments. They consist of three groups of partners: state administration, local authorities and water users. It is novel feature that not only the state administration but also local authorities and water users are partners in making decisions on water management. The basic tasks of the councils are :

- Setting programmes of water management in the catchment.
- Pricing policy.

The Regional Boards of water management cut across the traditional administrative units of water management instead they are arranged within the hydrographic boundaries of major river basins. They promote rational water management based on principles well established in Western Europe (e.g. the polluter pays) promotion of water saving, integrated management embracing water quantity and quality, surface water and groundwater and several components of environment; (water, air, soil). The policy for planning and investment focuses on the priority objects, granting the most advantageous cost / benefit ratio, and on simultaneous investing in the upstream parts of the catchment and in the most critical links of the chain.

Basic tasks of the Regional Board of water management are :

- Determination of principles and conditions of water use.
- Development of intervention programming aimed at the improvement of water quality, setting priorities, sequencing and scheduling.
- Carrying out periodical analysis of water quality.
- Proposing fees for water use and in flow of effluents.
- Promotion and execution of studies and research projects, and ecological education.

Although the present environmental situation in the catchment of the river Warta is far from satisfactory some positive changes have already been observed. First of all environmental awareness has risen considerably and need for an improvement in the environment has become a major issue in the perception of society.

From this literature we find that irrespective of administrative boundaries there should be single body to look after a river from head to tail. However, administration should achieve conservation of water, it should also be strict to pollution abatement.

Case Study – V

"Ganga the most self purifying River".

All rivers after getting polluted from the various activities of the man, undergo natural purification. The potentially pollutional strength of rivers is mainly accounted for by the process of suspended matter (both organic and inorganic), pathogens, toxic materials etc. The Biochemical oxygen Demand (BOD) of the river waters is met by the Dissolved Oxygen (DO) and reaeration mainly,. And is stabilized through the agencies of aerobic bateria. The suspended and, colloidal matter is removed through physico-chemical operations such as coagulation and settling. The coliform group of organisms along with pathogens are reduced gradually in the streams. The toxicants in rivers are diluted to low concentrations. BOD however remain the greatest means in the evaluation of the natural purification of rivers.

A water quality survey of the great Indian rivers viz. Ganga and Yamuna was undertaken (Bhargava 1977) and during this several interesting phenomenon were observed yielding significant conclusions about the extremely fast natural purification of these rivers. The various aspects of such high natural purification of these rivers are projected herewith from an analysis of the data on these rivers.

Huge amount of organic matter that exert BOD are discharged into the rivers through the domestic and industrial sources mainly, just after the sewage disposal points at the urban centres, the BOD assimilation rate in these rivers is found to be very high in the initial stages presumably due to bioflocculation, the exocellular polymers already present in streams with previous pollution history and having strong coagulating properties are found to coagulate the colloidal BOD into larger flocs which are subsequently removed by settling. This phenomenon is found to remove as much as 60% of the total BOD added at the out-falls within a short time of as little as 30 to 60 minutes. Such a comparison is presented in the table.

Time	Percentage BOD removals in			Ratio of BOD removals	
Days	Ganga	Yamuna	Normal	Ganga: Normal	Yamuna : Normall
0.01	25.4	20.4	0.5	50.6	40.6
0.02	50.8	40.7	1.0	50.8	40.7
0.025	63.6	50.9	1.3	49.0	39.0
0.03	64.0	61.7	1.5	42.7	40.1
0.05	66.4	62.7	2.5	26.5	25.1
0.10	72.0	65.2	5.0	14.4	13.04
0.50	93.2	80.2	22.0	4.2	3.6
1.0	98.8	90.2	99.4	2.5	2.3
Half life of BOD	0.02 Days	0.025 Days	1.4 Days	1.70	1.56

Table 4 : Comparative BOD Assimilation Rates in Ganga and Yamuna

The figures in the table clearly indicate that the BOD removals are extremely fast in Ganga and Yamuna when compared to normal BOD removals thus far known, and even faster in Ganga when compared with Yamuna.

Such high values of the BOD rate constants in the second stage are thought to be due to the presence of large amounts of well adopted microorganisms in these rivers, and which when little inhibited by the discharge of minute concentrations of heavy metals may somewhat lower the BOD rate constant value as can be seen in Yamuna at Delhi

Little after the sewage outfall points in these rivers, the DO dropped to very low values (sometimes even touching zero), but the DO values were found to recover within rather short distances and nowhere anaerobic conditions were observed, which avows that these rivers have extremely high reaeration. The reaerantion rate constant $k_e$was found to be as high as 9 day^{-1} for Ganga and 5 day^{-1} for Yamuana (Bhargava 1977), in order to meet the oxygen requirements from the extremely high BOD removals of the stunted order.

Ganga can therefore, accept very high BOD loads, as a result of which the waste treatment costs can be greatly minimized. The accurate prediction of BOD assimilation as above would also help in the implementation of pollution control programme for Ganga

TURBIDITY CAUSING MATTER (Organic and inorganic)

The rivers receive a large bulk of suspended load from surface run-offs and discharge from the domestic and industrial activities, the suspended matter of organic and inorganic materials both cause turbidity in water. The amount of inorganic turbidity (originating from surface runoffs) depends on the stream velocity. The organic turbidity which originate mainly from domestic and industrial wastes also contributes towards the BOD of the stream. The BOD removal and decrease in stream velocity are both therefore effective in the removal of turbidities in rivers.

Pavani et al (1972) found that the exocelluar polymers excreted by various species of bacteria in the endogenous growth phases are excellent coagulants. Every cycle of pollution deoxygenating – regeneration in stream would essentially involve in its last stages population of microorganisms in an endogenous growth phase due to depleted food resources and would thus accumulate significant quantities of exocellular polymers . pavani showed that these polymers are not easily biodegradable and would hence be sustained in the streams for long periods.

In a stream such as Ganga at the upstream of sewage out falls at urban centres, sufficient polymers are present from past pollution history to rapidly coagulate all the colloidal material and remove it through settling to the bed. A considerable reduction in BOD and thus turbidity also results due to coagulation of organic matter with exocellular polymers. This phenomenon was confirmed in a field test on Ganga where in two imhoff cones were taken with sewage diluted with distilled water in one and diluted with Ganga water presumably having excellular polymers, in another, in each case, the volume of settled sludge was observed against time , such teat runs were made with different dilutions, it was found that in each case much quicker and far greater settling occurred in the imhoff cone containing the dilution with Ganga water which itself had no seetlable matter in it. This occurred due to coagulation of suspended matter in sewage with exocellular polymers contained in the Ganga water. It was also observed that as the ratio of Ganga water to swage increased, the settling was even quicker and far greater showing as hypothesized that an increase in Ganga water to sewage ratio provided greater amount polymers to the same volume of sewage .

Since the actual dilutions of sewage discharged into Ganga was much greater than the test dilutions, a very significant bioflocculation is expected to take place resulting in a very considerable reduction in BOD and thus turbidity also soon after the sewage is mixed with Ganga river at the sewage outfalls. The floc formed during bioflocculation was found to settle at a rate of about 3 meters/day resulting in about 60% reduction in BOD in 30 to 60 minutes time.

COLIFORM GROUP OF ORGANISMS AND PATHOGENS

A large number of organism of the coliform group and pathogens are among the large number of microorganism that are discharged in the rivers through the domestic sewage outfalls at the urban centres along the rivers, these pose potential danger to the health of downstream consumers. The natural environment of the rivers is indifferent to coliform organisms and the pathogens, as a result, their number decrease with time. In Ganga and Yamuna the coliform organisms and pathogens also decrease in number due to dilution and their getting enmeshed in the settling floc formed during bioflocculation. In Ganga the coliform MPN at waste outfall points was found to decrees from more than 2400/100 ml to 23/100 at kanpur in winter, and from 240/100 ml to 9/100 ml at Varanasi during winter, in reasonably short times. The chances of pathogens surviving in Ganga are therfore presumed to be little. This is also evidenced by the fact that several users downstream of kanpur and varanasi have been consuming raw Ganga water, the Ganga therefore seems to have a high potential in reducing as well as decreasing the pathogens.

TOXIC MATERIALS

Toxicants find their way into rivers mainly from industrial and agricultural activities. The concentrations of toxicants are reduced in the rivers mainly by dilution with river discharge, infiltration of ground water, discharge from tributaries, snow melts etc, their concentrations has generally not been reported to be alarming except around the outfalls from industries discharging such materials.

CONCLUSIONS

The river polluted from mainly domestic, industrial, and agricultural activities, under go natural purification. The bulk of pollutants added in the form of organic matter, pathogens and toxicants etc. are reduced in concentrations during the process of natural purification. During a water quality survey of Ganga and Yamuna, several interesting phenomenon were observed which played significant role in the natural purification of these rivers, the rate of exocellular polymers, excreted during the endogenous growth phase of the various species of bacteria, is very considerably reducing the BOD and hence turbidity has been highlighted. The interaction of exocellular polymers present in the rivers with the colloidal matter present in sewage results in a very rapid and significant reduction of the BOD. The data analysis has shown that Ganga has the highest BOD rate constant value and the re-aeration rate constant value both of which are higher by an order of magnitude than the thus far reported values. The coliform organisms are also found to reduce significantly in very short times. The findings have been reasoned to suggest that Ganga is the most naturally- purified river.

Case Study VI

"River Laws in U.S.A.".

Interstate Water Controversies and Agreements

There are basically three methods of settling interstate water right controversies. They are . : (1) Direct legislation by the congress of the United States (2) Suits to United States Supreme Court, and (3) Compacts between and among the several states with approval of congress.

Besides being slow and time-consuming process, congress rarely if ever settles interstate water right disputes. The only past exception to this statement has been in the area of defining state boundaries.

Adjudication before the United States supreme court is usually under taken as a last resort. Initiation of adjudication proceedings in the federal court system generally indicates that communication between the litigating parties has completely broken down. The United States supreme court decides each case in accordance with what it deems to be equitable. Thus to the litigants, nothing is certain and each case is decided on its own individual merits.

The United States constitution, however, provides another way of settling interstate water disputes i.e. through use of interstate agreements or compacts. Article I, Section 10, Clause 3, of the constitution of the United States provides" that no state shall without the consent of congress enter into any agreement or compact with another state". Congressional assent is most probably the last stumbling block to the successful water compact. Many hours of pains taking studies and negotiations precedes the successful compact and are incorporated into final document. Congressional assent, although a lengthy procedure, is almost never refused. And as a result, the congressional check provided for by the constitution has not in any significant way adversely affected development of interstate agreements.

Once ratified, a compact can not be revoked unilaterally and the signatory parties thereto are prohibited by the constitution from passing any legislation impairing obligations incurred by the compact. This fact has prompted recent discussions among state water right advocates as to the desirability of including the United States as a party in the future interstate water agreements with the dual purpose of preventing future federal regulations from impairing the apportionment methods arrived at by the compacts entered into and as a means of achieving federal financial participation on compact projects.

Case Study VIII

"River Laws in Japan".

The river Law (1896) is the basic law governing the general uses of rivers from the view point of flood control. In addition, it stipulates the water rights for irrigation and other uses, the allocation of costs of rivers and supervision of river administration. As the result of increased use of water, the law was replaced in June 1964 by a new one modernizing the river administration system and treating each river system as an integrated whole.

The Aichi Irrigation Corporation Law No. 41 of 1955 established the Aichi Irrigation Corporation. This corporation has no capital of its own, but its operating costs are covered with loans from the state, the International Bank of Reconstruction and Development and other banking organs. The main functions of the corporation are as follows (Article 18).

To carry out the projects enumerated below in the areas designated by cabinet order (areas along the Kiso river system in Nagano Gifu, Shizuoka, and Aichi prefectures).

(a) construction, disuse or change of irrigation and drainage facilities necessary for conservation or utilization of farm lands.

(b) Development of uncultivated land which the state purchased under the Agricultural law (Law No. 229 of 1992) into paddy fields and other fields.

(c) Land reclamation by drainage or filling.

When the Corporation formulates the project enforcement plan and the facilities Administration Regulations, it must consult the prefectual governors concerned. The Corporation may collect the whole or a part of the cost of a project it carries out from the beneficiaries as dues.

Administration of Irrigation and Drainage Works

The development of irrigation and drainage is of public utility and therefore, its administration is closely tied in with the Government authorities in the form of approval of plans and execution of projects. The various subjects have been allotted to the Ministries according to their functional utility, who carry out their business through the national Government, prefectual Governments, and private organizations like the associations and co-operatives depending upon the size.

The ministry of conservation – River conservancy works involving flood control erosion control, river improvement, torrent control etc. are administered by this ministry. The multipurpose dams, whose main purpose is flood control, are constructed and controlled by construction ministry in accordance with the Multipurpose Dam Law, and the cost are allocated among the fields concerned by the economic planning agency. The construction ministry controls the class 'A' rivers of national importance, designated by the cabinet.

The economic planning agency deals with the comprehensive adjustment of funds among the various fields. The multipurpose projects are carried out only after mutual adjustment of opinions about the plans and allocation of costs.

With regard to water systems for which it is necessary to exploit the water resources from the national point of view, the Prime Minister designate them, and the national government agencies concerned work out water resources development basic plans for them in order to recur water supply for the areas needing large quantities of water for various purpose. On the lines of the basic plans, the national government, the local public bodies concerned, or the water resources development corporation, as the case may be, execute the water resources development projects.

The prefecture – operated works- the class – B rivers (designated by cabinet) which have an important connection with public interest, are administered by the prefectual governors. However the minister of construction may assign the responsibility for administering part of any class-A river to the prefectual governor concerned.

Case Study (VIII)

"Development of Water Resources in Ganga Brahmaputra Basin"

The water resources availability and utilization in 1974, 2000 and 2025 A. D. are estimated as below.

Table - 5 Water Resources of India

Water Resources	1974	Year 2000	2025
Availability (m ham)			
Surface water	180	183	185
Ground water	67	76	85
Utilization (M ham)			
Surface water			
Irrigation	24	42	51
Other uses	1	8	19
Groundwater			
Irrigation	11	21	26
Other uses	2	4	9

The total utilization in the year 2025 will reach 105 mham, which is more or less the limit of utilizable resources, without taking into account major inter-basin transfers and recycling. This quantum of utilization, however, requires creation of 35 mham of storage against 25 mham that we shall get when on going projects are completed. According to estimated demand the available water resources will suffice to meet it upto 2025 A.D. but after that year, if we are not able to contain the demand by population stabilization, conservation and more efficient use of water, we shall find water to be a sever constraint on further development.

Ganga-Brahmaputra-Meghna (GBM) Basin

The basin is located in Northern and Eastern part of the Indian subcontinent and spreads over five countries-India,. Nepal, Bhutan, Bangladesh and Tibet region of China (Fig. 2). GBM basin is the second largest international system in terms of runoff. It carries a peak flow of 1,41,000 m^3/s at its estuary and empties 120.1 mham of water into the Bay of Bengal every year. Almost 80% of the total flow is in the four monsoon months of June to September, with the minimum flow as low as 7,200 m^3/s in February. While the water availability per unit of land is one of the highest, land and water availability per capita is one of the lowest in the world. The basin area in different counties is as shown below.

Table - 6 Basin area (m.ha)

Country	Ganga	Brahmaputra	Barak/Meghna	Total
India	86.14	19.50	4.20	109.84
Bangladesh	4.60	4.70	3.60	12.90
Bhutan		4.50	-	4.50
Nepal	14.00	-	-	14.00
Tibet (China)	4.00	29.30	-	33.30
Total	108.74	58.00	7.80	174.54

Thus the basin area in India accounts for almost 1/3 rd of the total geographical area of the country. Further, India is the predominant riparian state accounting for 63% of the basin area. Neglecting Tibet region where there is very limited scope for utilization, the figure would be 77.7%. Within India 73.56 mha out of 109.84 are cultivable.

The basin Socio-economic indicators (190-91) for India, Bangladesh and Nepal are given in Table –3.

Table 7: Basin Socio-Economic Indicators (1990-1991).

	Bangladesh	India	Nepal
Population (million)	109.90	862.70	18.50
Population growth rate (percent)	2.03	1.80	2.10
Density (per sp. Km)	740.00	263.00	128.00
Crude birth rate (per 1000	31.60	27.50	29.60
Crude death rate (per 1000)	11.00	9.40	NA
Infant mortality rate (per 1000)	111.00	90.00	102.00
Total fertility rate (per woman)	4.23	4.00	5.60
Life expectancy (years)	51.80	59.10	52.20
Adult literacy (percent)	35.30	48.20	25.60
Adult literacy-female (percent)	22.00	39.00	13.00
Adult literacy-male (percent)	47.00	64.00	38.00
Females as percentage of males	94.00	93.00	95.00
Urbanization (percent)	16.00	27.00	10.00
Daily per capita calorie supply (% of requirements)	88.00	101.00	94.00
Population with access to health services (1987-90)	74.00	NA	NA
Population with access to safe water (1988-90)	78.00	75.00	37.00
Population with access to sanitation (1988-90)	12.00	13.00	6.00
Public expenditure on health (% GNP, 1988-90)	0.90	3.20	0.70
Per capita GNP (US$)	210.00	360.00	170.00
Human Development Index (HDI)	0.189	0.309	0.170
Ranking in HDI	147.00	134.00	152.00
Population below poverty line (percent, 1990)	86.50	48.00	60.70

Sources: UNDP, Human Development Report, 1992 and 1993: Statistical Yearbook of Bangladesh. 1992., The population of the Indian part of the basin (1991) was 405.40 million, which was 47% of the total population of the country. The population density for the basin as a whole comes: 0369 per sq. km. The poverty level in the basin is even worse than the deplorable level for the country as a whole. The H.D.I. for U.P. is an appalling 0.07 and that for Bihar 0.11 against 0.31 for India.

This basin was one of the foci of ancient civilization and prosperous by prevailing standards upto the 18th century, is today one of the poorest and least developed regions of the world.

The Water Resources for the portion of GBM falling in India is summarized in Table-6

Table – 8 Water Resources of GBM Basin

	Ganga	Brahmaputra	Barak/ Meghna	Total or average
Mean Annual Rainfall (cms/year)	120	212	450	
Total Annual Runoff, (mham)	52.3	53.7	4.84	110.84
Utilizable water Resources (mham) (a) Surface (b) Ground	 25.0 14.48	 2.4 2.4	 0.20 0.145	 27.60 17.396
Total utilizable Water resource Surface and ground, (m ham)	39.40 say 40	4.8	0.346	44.996 say 45.0
Present Estimated utilization (mham) (a) Surface (Data confidential but perhaps about 15 (mham) (b) Ground	4.5	0.05	0.005	4.555

The ultimate net irrigation potential in the basin is estimated as about 28 mha from surface water and 20 mha from ground water or a total of 48 mha out of a cultivable area of 73.56 mha. Out of the ground water irrigation potential, about 9 mah has been attained. Maximum development has taken place in U.P. followed by Bihar and West Bangal. There is little development in Assam and other North-Eastern states.

Surface irrigation is the GBM basin has a culturable command of about 30mha but annual irrigation may well be no more than 20 mha.

Though the basin is endowed with ample, water resources, the demand is growing rapidly due to growth of population and industrialization. As standards of living rise, more and more water is needed for domestic and industrial uses. It has been estimated that the available water resource in the basin if properly harnessed can meet demands upto the year 2025 A.D. there will still be surplus water in Brahmaputra basin, but its transfer to the rest of the GBM basin on the west is very expensive. After that it will be necessary to use more innovative technologies for water conservation and also recycling of used water. There is no doubt that given the will, such technologies will be forthcoming-many are available now. With drip irrigation 25% to 60% saving in water can be achieved, while increasing yields by 5 to 25%. Similarly complete recycling of domestic effluents has already been successfully achieved in U.S.A. These techniques and newer ones, are energy intensive. Fortunately the river system in GBM basin can prove abundant low cost energy.

Flood Management

A large portion of the GBM basin it susceptible to flood damage. Huge losses and hardship are imposed on the people, year after year. In some years the magnitude attains disastrous proportions flood management may be achieved, by structural as well as non-structural measures. Among structural measures the importance of storage cannot be denied. However, for economic feasibility, flood control storage has to form a part of comprehensive multipurpose water resources projects. On Ganga, Tehri and Kotibhel could have appreciable flood moderating effect. However, major storage sites in Ganga basin – on Sarda or Mahakali, Karnali, Gandak and Kosi are located in Nepal and involved international agreements.

The Brahmaputra Basin Master Plan drafted by Brahmaputra Board (1986) stipulates that the key to flood problem in the long run lies in the construction of large storage reservoirs. Potential sites indicated include dams on Dihang, Subansiri and Manas, which together envisage a storage capacity of over 7 mham. Tipaimukh Dam on R. Barak will have a storage of 1.6m ham. These storage if implemented will provide a very considerable capability of flood reduction.

Other structural measures that can be used are flood embankments and stream channel and drainage improvements. Non-structural measures include watershed management, flood forecasting and warning systems. Flood plain zoning and disaster management capability.

Water Resource Based Development Strategy for the Basin

The relative prosperity of GBM basin in the past was based on its agriculture wealth and skill of its craftsmen, particularly in textiles. Foreign travellers' accounts starting from Megasthenese to Ibn Batuta (14thcentury) and Bernier (about 1660) eloquently speak of the plentiful previsions and comfortable life available to the people of the area. It is cruel paradox that this regions rich in all the resources which make for agricultural abundance and prosperity is among the poorest in the world today.

In India situation with monsoonic climate, irrigation is the most crucial factor in Agricultural Productivity.

Case Study - IX

"Environmental Management in Water Resources Projects. Indian Experiences of Irrigation and Power Projects".

In some quarters a view has been expressed that environmental disruption is an inevitable price to be paid for economic progress. This view has been considered in various forums and there is a growing consensus today that, given certain preconditions, both economic development and environmental management can be pursued simultaneously. This is the point of view of the contemporary water resources mangers of India.

Water resources planners in India have for centuries been aware of most of the environmental issues being raised today. The main issues – the resettlement of displaced populations, waterlogging, deforestation, pisciculture, reservoir sedimentation, water quality and impact on climate-are considered here.

Resettlement

Resettlement of families displaced by water resources projects is undoubtedly a very delicate and sensitive issue. It is essentially a human problem. By and large people have a deep attachment to their land, tradition, culture and way of life and do not want to part with them. Early planners were well aware of such problems. Epigraphical report number 397 of 1909, as referred to in the publication irrigation in India Through the Ages (Central Board of Irrigation and power, 1951), mentions that whenever private lands were acquired for the construction of irrigation works, the owners were provided with the lands in compensation. Serious consideration was also given by the authorities to objections raised against the acquisition of any land for the construction of any particular work.

The problems of resettling and safeguarding the interests of displaced persons continue to be considered into the present day. In consequence resettlement policies have been enacted by various state governments from time to time. Liberal compensation, ex-gratia payments, loans, and various facilities are provided at new sites. After the enactment of the Forest Act (1980) by the Government of India, the policy was further modified to include cash compensation along with civic amenities at new sites.

Waterlogging

Agricultural land is said to be waterlogged when the soil pores. In the crop root zone become saturated with water. This is usually by a high subsoil watertable. Waterlogging can also result form excess soil moistures due to periodic flooding, overflow of runoff, seepage from canals, over-irrigation, artesian water and impeded subsurface drainage conditions. As a consequence, osmotic pressure in the root systems does not function properly, thereby affecting the growth and yield of crops. Such conditions may occur throughout the year or during only part of the year. Thus waterlogging may be of a temporary or a permanent nature.

Waterlogging is normally experienced during the initial phase of irrigation. This is mainly due to excessive seepage from canals and/or the absence of drainage during this initial period. It is, however, found that the seepage from the canals can be substantially reduced by fine sediment in the canal waters which is deposited and seals the pores along the periphery of the canal, thus producing a sort of self-sealing effect. During the initial phase of irrigation, the drainage is usually not provided. This is mainly because groundwater modelling techniques have not advanced to the extent that a prediction can be made of groundwater conditions and adequate drainage facilities provided in advance. It is, therefore, considered expedient to monitor groundwater conditions in the field for a certain length of time before implementing the drainage scheme.

A number of steps have been taken in various projects in India to reduce the adverse effect of watelogging. These include measures such as the conjunctive use of surface and groundwater, the lining of canals and filed channels, the levelling or irrigated lands and the adoption of a cropping pattern that takes into account the crop-water-soil relationship. The area of land that is waterlogged is generally small compared to the irrigated area. The percentage of waterlogged land in cultivable command areas observed in various projects has been found to vary form 1.5% to 10%.

Among the early works in Northern India where a waterlogging problem was faced were the Western Yaumna canal. The Western Yumuna canal was constructed towards the end of the 14th century. No checks were imposed on irrigation, and this combined with the faulty design of the canal, resulted in large tracts of the command area becoming waterlogged. Saline efflorescence made its appearance and there was an epidemic of malaria. The canal was remodelled in 1873, the old alignment was improved and drainage works were introduced. These measures resulted in significant improvements and the reclaiming o. f land, and the canal remains in service to this day. Similar problems were faced with the Eastern Yaumna canal, but they were rectified later by the construction of large drainage schemes.

Provision of drainage and anti-waterlogging measures in water resources projects has evidently been in the minds of Indian irrigation engineers since long ago. In the Northern India Drainage Act of 1880 provided for the drainage and improvement of any tract of land. Under the Bengal Embankment Act of 1882 the government was empowered to take over and maintain any water course which was necessary for the protection of drainage of neighbouring land, thereby making it a public water course.

Various reason adduced for the waterlogging are :

i) Seepage from unlined canals and from demaged portions of lined canals beds;

ii) Blockage of natural drainage due to the construction of a vast network of roads;

iii) Poor working of the existing surface drainage system;

iv) Very little utilization of groundwater for irrigation;

v) Internal flow of subsurface water from north-east to southwest; and

vi) Injudicious water management.

Deforestation

It is reported that that the forested area of India is shrinking at the rate of 150000 ha per year. Of this total, the area lost for agricultural purposes is 66%, while for river valley projects it is only 12%. This is partially offset by compensatory afforestation and improved method of biomass regeneration now being adopted. The Department of Environment of the Government of India has issued detailed guidelines for the diversion of forest land for non-forests uses. Some of the salient features are as follows:

i) Comprehensive afforestation is one of the: important conditions stipulated for approving proposals for diversion of forest land to non-forest uses. Steps proposed to compensate for the loss of forest area therefore have to be specified.

ii) The norms laid down for compensatory afforestation are that (a)where non-forest land is available, compensatory afforestation should be undertaken over the equivalent area of non-forest land, (b) where non forest land is not available, compensatory plantation should be undertaken in degraded forests over twice the extent of the area being diverted.

iii) Stipulations have been made for identifying the equivalent non-forest area or degraded forest land, the agency responsible for afforestation, the provision of funds, the monitoring mechanism, and the preparation of a detailed work schedule.

iv) Lands identified for compensatory afforestation are to be transferred to forest Department.

Pisciculture

The undertaking of water resources projects results in changes in water velocity, temperature and stream bed configuration which have significant impacts on water quality, which in turn may adversely affects the life cycles of fish in the new environment. The series of Damodar Valley Corporation(DVC) dams reduced the proportion of Indian shad in total catches from 60% to 5% due to the drying up of spawning areas. Similarly, following the construction of the dam at Pandoh across the Beas river, winter catches of brown trout downstream at Mandi in Himachal Pradesh and the regular winter fishery of snow trout further downstream were reported to be on the decline.

Reservoir sedimentation

Sedimentation problems started receiving close attention after 1940, when a programme of systematic surveys was adopted on the initiative of the Central Board of Irrigation and Power. A publication entitled Silting of Reservoirs was brought out in1953 describing the work done by Dr. A.N. Khosla, Ex-Chairman of the Central Water Commission, and expounding his views (Khosla, 1953). Using data available in India and from other countries such as the United States of America, China and parts of Africa, Dr. Khosla developed enveloping curves for annual sedimentation rates for major (larger than $2590km^2$) and minor catchments. Sedimentation rates were found to vary from 3.57 to 4.76 ham/100 km^2/yr and 12.85 to 3.57 ham/100km^2/yr for major and minor catchments respectively.

Reservoir sedimentation has been receiving considerable attention in India since a number of reservoir surveys showed a much higher degree of sedimentation than originally anticipated. It has therefore been considered necessary to take steps to plan future projects on a sound basis so that sedimentation of reservoirs will not reduce the benefits faster than envisaged. An in-depth study of the problem with remedial measures involving engineering structure, afforestation and soil conservation in plain areas of the catchment for each reservoir would clearly be of great value. Realizing this, the Government of India formed a Reservoir Sedimentation Committee in February 1978 to make in-depth studies of sedimentation process, sedimentation transport and deposition mechanics, to consider measurement techniques, sedimentation sources and yields, to review the actual reservoir sedimentation situation and draw up recommendations for future policies on various aspects of reservoir sedimentation. The recommendations and observations of the Committee include the following :

(i) A major drawdown of the Panchet Hill reservoir in Damodar Valley for two consecutive years revealed the flexible reservoir operations consistent with the requirements can enable maximum consolidation of deposited sediments, thus prolonging the useful life of a reservoir.

(ii) The high rate of sedimentation in downstream reservoirs emphasizes that in an integrated plan the construction of upstream reservoirs should not be unduly delayed.

(iii) There is a need for scientific and technical evaluation of soil conservative programmes, which should be carried out by project authorities in consultation with agricultural universities and other academic institutes such as the Indian Institute of Technology.

(iv) Under a watershed management programme, a planning and analysis cell and implementation organization is necessary for each state and at the centre. These should be multidisciplinary in nature.

(v) Comprehensive watershed management programmes provide multiple benefits at micro level resulting from small centres of intensive activity, generate larger income for the local people, greater employment opportunities and a more stable ecology. Therefore it is recommended that soil conservation programmes should be interwoven with comprehensive watershed management plans.

(vi) More attention needs to be paid to estimating silt inflow volumes in reservoirs at the project planning stage itself and to the provision of the requisite additional capacity for sedimentation. Periodic surveys of existing reservoirs should be carried out for estimation of sediment inflows.

Suspended load measurement in streams and rivers is carried out by various agencies in India. There is about 466 sites where silt observations are being undertaken with varying periods of data availability in various states.

The importance of conservation measures in reducing reservoir siltation was well recognized even at the time the Central Water Commission was constituted in 1945. To reduce siltation rates and soil erosion, soil conservation programmes have been initiated as part of the Government's five-year plans. The importance of soil conservation in the proper development of land and water resources and their optimum utilization have been recognized, and 29.4 million ha were treated up to 1985 by various soil conservation measures at a total investment of Rs. 12000 million.

Water Quality

Water quality management has been a cause of concern due to the tremendous rate of industrialization and urbanization. Water quality monitoring was taken up by the Central Water Commission (CWC) in the early 1960s. Initially it was limited to determining the suitability of water for irrigation purposes. With the realization of the growing threat posed by pollution loads dumped into rivers, it was considered necessary to monitor pollution parameters also, which the CWC is now doing through a network of gauge and discharge sites. A special scheme was undertaken in 1978 on the Ganga river and its main tributaries to study various aspects of water quality, including pollution parameters. This study ended in 1985, and the work of river quality monitoring on the Ganga is now a continuing actively. A status report entitled Water Quality Studies-Ganga system was released (Central Water Commission, 1987). This report gives a summary of work done by the CWC on the Ganga. At present the CWC is engaged in water quality modeling studies for the Ganga in association with the Thames Water Authority of the UK.

The Central Board for the Prevention and Control of Water Pollution(CBPCWP), a national body on pollution control, was formed in 1973 to promote basin wide pollution in view of the interstate nature of India's major rivers. An understanding of the nature and extent of pollution together with control and coordination among the states through which a river flows is necessary for the implementation of pollution abatement schemes The CBPCWP collects information district by district and collects it across the basin. The information involved includes data on intensity of cultivation, pattern and intensity of irrigation, use of fertilizers and pesticides, pollution potential from rural and urban settlement, industrial pollution loads, location and origin of points of discharge of pollution, etc. in the system. The CBPCWP is being helped by State Pollution Boards which collect the requisite information within state boundaries while the CBPCWP itself collects information in the Union Territories. The Government of India has recently taken steps to protect and improve the human environment by enacting the Environment (Protection) Act, 1986. This empowers Central Government or any authorized agency or authority (constituted under the Act) to take all measures deemed necessary, including prosecution, for the protection and improvement of the quality of the environment (which includes water, air and land and the interrelationship which exists among and between water, air and land, and human beings, other living creatures, plants, micro-organisms and property and the prevention, control and abatement of environmental pollution).

Impact on Climate

Water resources development projects do have an impact on the climate in their vicinity. Investigations have shown that irrigation increases the moisture content in the surrounding air, leading to a slight increase in the humidity of the atmosphere. As far as temperature is concerned, irrigation cools the atmosphere for the simple reason that the hotter the air, the greater is the evaporation from irrigated ground. The impact on climate should be viewed in relation to the climatic regions of India. The major part of the country has an arid or semi-arid climate, and under such conditions a drop in temperature and increase in humidity have favourable effects. Studies conducted on Beas dam at Pong by Himachal Pradesh Krishi Viswa Vidyalaya, Palampur, in 1987, as part of a research project sponsored by the Department of Enviornment of the Government of India, showed that the maximum atmospheric temperature has become lower in the summer months (June-July) and has risen in the winter months. Likewise, the minimum temperature is higher almost throughout the year since the formation of the reservoir. Further, the variation between maximum and minimum temperature has been reduced. No appreciable effect on relative humidity was observed due to the formation of the reservoir.

INTEGRATION OF ENVIRONMENTAL ASPECTS IN PLANNING

Comprehensive guidelines were laid down for the preparation of project reports by a working group constituted by the then Department of Irrigation of the Government of India (Ministry of Irrigation, 1980). The working group, considering the importance of the environmental impact of water resources projects, emphasized the need to make a detailed analysis of the environmental aspects after collecting the requisite data from the relevant agencies. Aspects recommended for consideration in site selection included immediate and long-term impacts on human settlements, flora and fauna in the vicinity, impacts, on monuments and mineral resources, groundwater levels, etc. the working. Group considered the importance of soil conservation measures in the catchment of river valley projects and was of the view that they should be implemented as a Complement to river valley projects but should not form part of the project. Guidelines have also been laid down for considering the various public health aspects, sociocultural issues, weed problems, climatolgoical changes, groundwater levels, etc.

Though environmental clearance of projects has comparatively recently entered Indian thinking, most of the aspects mentioned were in fact considered by the early water resources planners. The Planning Commission at the centre decided in 1978 to stipulate prior clearance of all major river/valley projects form the Department of Environment. All the states concerned have to get the proposed river valley projects cleared before the commencement of construction, in case any submergence or deforestation of land is involved. Since 1972 all major reservoir projects have referred by the Central Water Commission (CWC) and/or Central Electricity Authority (CEA) to the Department of Environment (DOE) of the Government of India for clearance form the environmental angle. These organizations concurrently examine project proposals for their techno-economic suitability. The Department of Environment has established an Environmental Appraisal Committee (EAC), on which central departments are represented, to review the scrutiny carried out by the DOE of all the projects referred to it by CWC/CEA. Some of the coronary suggested safeguards are summarized as follows.

i) Necessary arrangements for the supply of fuel wood by the project authorities to the labour force during the construction period.

ii) Restoration of land in the construction area and prevention of soil erosion.

iii) Compensatory afforestation;

iv) Drawing up of a master plan for the resettlement of displaced persons;

v) Identification of the initially eroded areas in the catchment and undertaking of catchment treatment works at project cost in at least 2% of the catchment;

vi) A mechanism for the free covenant of fish upstream and downstream of the structure across the river;

vii) Preparation of reports on command area development.

viii) Covering of river banks with a 10 m width green belt;

ix) Provision of a drainage system in the irrigated areas;

x) Measures for the prevention of endemic health problems;

xi) Setting up of monitoring units for the implementation of the suggested safeguards;

xii) Alternatives in case of adverse effects on flora and fauna, etc.

CONCLUSIONS

Resistance and apathy towards water resources development projects have increased, as a result of a growing misunderstanding that environmental protection is the antithesis of development. This has been fostered by the use of alarmist language by certain supporters of environmental quality. Development in its correct meaning does not entail an outrage to nature nor any mortgage on the future and environmental protection should not preclude the exploitation of available resources.

Water resources development programmes need not necessarily be in conflict with environmental requirements. The large seasonal and annual variations observed in rainfall make the economy and planning highly dependent on the monsoon in a country such as India, where most of the rainfall is experienced in four months of the year. The dependence of agriculture on rainfall could render cultivation precarious and there have been very serious droughts at times in India, which have brought untold misery to the people in the past. This underlines the need to properly harness and utilize the rivers of India by means of major, medium and minor irrigation schemes so as to assure water availability for agriculture. In fact, in a tropical climate the very presence of water is not only pleasing to the eye but also a source of life for the flora and fauna of the area. Water resources development projects must be planned in such a manner that they do not cause significant environmental damage but on the contrary help to strengthen and reinforce the life-supporting natural systems of the area. Where, however, environment damage is inescapable, it should be made to correct imbalances in nature and not aggravate them. It should be realized that degradation of the environment may occur not only as a result of inappropriate development but also due to the lack of development.

Case Study – X

"Sustainable Management of Water Resources".

Growing Anthropogenic Pressures on Water Resources

The satisfactory part of the demographic situation is the fact that we had more frequent famines in 1901 than during the eighties inside of the over 3 fold increase in population since then. On the other hand, such growth has also led to increasing pressures on the basic life support system of land, water flora, fauna and the atmospheres. Forests have dwindled and hardly constitute 19 percent of the geographic area now. Hardly 4 percent of the land area is under pastures and grazing areas, although we have nearly 20 percent of the world's farm animal population.

It is in context of the above social and demographic background we should consider the next phase in the management of our water resources.

Development of Water Resources: Progress and Policies

Agriculture consumes nearly 70 percent of the water resources. During the last 10 years efforts in irrigation have been stepped up. According to the data of the Union Planning Commission, there is still consideable scope for tapping surface and ground water. The unexploited irrigation potential is particularly high in eastern India. There is increasing interest in water harvesting and watershed management techniques. The pattern or rainfall distribution affords opportunities for saving and sharing water.

While on the one hand there is increased investment in the irrigation sector, there is on the other hand a growing concern both about returns from an investment made in this sector and about the environmental and sustainability aspects of water management.

Another kind of problem has been highlighted in a study carried out by the operations Research Group of Baroda in the Command areas of twelve major irrigation projects in India. The study involved an assessment of the current levels of utilization of potential created and the water management practices prevalent in these projects. The study revealed under utilization of irrigation potential in all the projects. Also, the study revealed that in most of the projects the crop diversification as envisaged in the original project formulation has not materialized. The study also emphasized the need for appropriate and scientific water management policies in these projects to derive maximum benefit from the potential created (India 2021, 1989).

Ternds in Recent Research on Irrigation and Water Management

The term 'Irrigation Management' has now largely superseded 'water management and the need to include cultural, socioeconomic and political implication of irrigation practice in the design of irrigation projects is widely recognized. There has been a shift from the construction of new irrigation schemes to the rehabilitation of existing ones. The Trend towards small farmer managed schemes continues, as large projects are considered to be less economically viable, environmentally hazardous, difficult to mange and very slow to complete. Canal irrigation project in Asia have been especially disappointing. Irrigation is much well developed in Africa than in Asia.

Water Users' Associations, which can use irrigation water efficiently and ensure the maintenance of schemes, are much favoured. Farmers' participation is design as well as the management of projects is now encouraged and their training needs are studied. Lack of central management however, can lead to decreased efficiency.

A survey by the International Commission or Irrigation and Drainage has shown the rapid expansion of micro irrigation techniques (trickle and microsprinkler irrigation). These versatile techniques offer considerable saving in water, energy and labour. Although mainly developed in the USA, their use is increasing in other countries.

Computer techniques, expert system and models are available for irrigation planning and design, scheduling, management and control. Sensor has been devised to aid irrigation scheduling and international standards for equipment have been proposed. The design of wind, water, solar and animal-powered pumps is being developed in many countries, although labour intensive hand pumping is thought to be more economical for rural population. A World Bank survey concluded that the best linings for irrigation canals were constructed from unreinforced concrete. Studies on irrigation water include the improvement of its distribution and conveyance; the use of treated waste; Drainage needs should be considered in irrigation design, particularly in areas treated by waterlogging.

There is now growing awareness of the environmental constraints on irrigation development. Irrigation performs better in reduced tillage systems and it can itself include erosion. Irrigation can also cause enhancement of soil salinity and the redistribution of salts in the soil. Other sources of contamination include the agrochemical used in irrigation farming, although current evidence does not support reduction in the use of nitrogen fertilizers in developing countries. Health risks from the use of waste water in irrigation systems are being monitored in many countries and the effects of irrigation on the spread of such diseases as malaria and schistomsomiasis are being assessed.

As irrigation develops, there is an urgent need to identify new sources of ground water. The conjunctive use of surface and ground water sources is being developed in many countries.

New Paradigm of Water Resources Management

Past experience both within our country and outside indicates that for meeting the challenges ahead we need a new paradigm of water resource management with the following three interacting components.

a) Ecological sustainability in both quantitative and qualitative dimension.

b) Equity based economic efficiency.

c) Participating management

The requirements for converting such a conceptual paradigm into field are (1) research and education, (2) organization and management (3) public policy and political will, (4) peoples' participation and (5) conflict resolution.

1. Research and Education

Strategic, applied, anticipatory and participatory research approaches are essential to deal with the various aspects of integrated water resources management.

The present rate of growth of irrigation from ground water may result in the use of more than 85 percent of the utilizable resources for irrigation by 2005. Therefore suggested revised mandate for the Central Ground Water Board is "Develop and disseminate technologies, and monitor and implement national polices for the scientific and sustainable development and management of India's ground water resources, including their exploration, assessment, conservation, augmentation, protection from pollution, and distribution based on principles of economic and ecological efficiency and equity."

Institute for Ground Water Research, Training and Management is needed. Important responsibilities of which will be (i) organization of all India Coordinated

Projects in selected areas (ii) initiating anticipatory research studies on the potential impact of global climatic changes on ground water recharge and availability.

The failure to implement conjunctive use of ground and surface water in a scientific manner is reducing the return in production and income terms from the available water resources. Since water is likely to be key limiting factor in the years to come, it is important that production and productivity figures are expressed both in terms of land area and water utilization.

Training should be increasingly participatory, with farmers also participating as trainers. Educated youth after training can perform extension functions and serve as "Water Masters", entirely under the control of the watershed or irrigation command area community.

2. **Organization and Management**

There is ample evidence now to suggest that unless concurrent attention is given to all aspects of water management starting from its source to its end use on the farm water use efficiency cannot be improved. Several institutional devices like command Area Authority have been tried but these invariably have not met with the desired success largely due to the inadequate attention paid to participatory management on the one hand and to on farm management of water, on the other.

El-Ashry Gibbons (1986) have dealt with the problems of managing water in western United states both at the state and inter-state level. They have suggested a moving away from the historical reliance on expensive supply-side projects and subsidized water, towards better management and reallocation of existing supplies within water markets.

Lngram and Oggins (1990) have shown that the diverse values of water have to be reconciled in a sustainable management policy. These values are:

Water as a source of sustenance;

Water as an instrument of agriculture;

Water as a community good;

Water as a means of transportation;

Water as an industrial commodity;

Water as a clean and pure resource;

Water as beauty;

Water as a destructive force to be controlled;

Water as fuel for urban development; and

Water as a place for recreation and wildlife habitat.

We have similar problems in promoting harmony among competing demands for water. For efficient management it is clear that we should evolve at the block and village level a scientific land and water use policy. Land use can be broadly groped into the following three categories:

a) Conservation area, e.g., national parks, protected areas;
b) Restoration area. e.g, waste lands; and
c) Sustainable intensification areas, where given efficient water management and adequate soil health care, it will be possible to improve continuously biological productivity with out ecological harm.

Another area of management which needs multi-disciplinary attention is the conjunctive use of two or more of the following sources of water:

a) Rain water;
b) River water
c) Ground water;
d) Sea water; and
e) Sewage water and effluents from breweries and other industries.

In many cases, agriculture will have to be coupled with aquaculture. Fish farming with effluents and sewage water are often feasible and profitable.

3. Public Policy and Political Will

In the ultimate analysis, pubic policies have a dominant role in determining the long-term fate of water resources. Ground water can be contaminated and over-exploited, soil eroded, wildlife poisoned and reservoir filled with sediment, if no depreciation allowance is applied for the degradation of these assets. Faeth et.al. (1991) have shown that current agricultural accounting practices can mask a decline in weather as an increases in income i.e., "living off your capital". For agriculture and other economic sectors that are fundamentally dependent upon the health of the natural resource base, the accounting of natural resources capital is important, if that capital is used in a sustainable manner. Sevndsen (1991) has proposed three broad areas for study of sustainability in irrigated agriculture.

First the sustainability of past rates of growth in production of productivity needs assessment.

Secondly, there is need to examine the matrix of institutions and incentives that control irrigation systems.

Thirdly the interaction of irrigation with the physical resources base, need monitoring-otherwise problems of waterlogging, salinisation and reservoir siltation will recur.

There are numerous examples to show that without appropriate policy and institutional adjustments, no technical or engineering fix will succeed. Resolving critical water resource management issues requires basin-wide, comprehensive solutions encompassing actions on the political, economic, social and environmental fronts. A Water Management Plan to be meaningful must be part of a broader regional economic development plan that takes into consideration agriculture manufacturing, ecological and health related needs.

Issues such as water duties, water markets and water banking and the development of ground water sanctuaries need careful considerations. In the state of

California in USA, the purchase of water from some users by a water agency and its resale to other users through a Water Banking Mechanism has reduced waste of agricultural water. In our country, water markets and "Water lords" are increasing. There is need for a system of management of such development which will ensure that their is no long term ecological harm.

4. People's Participation

Anna University scientists have demonstrated the crucial importance of participatory management in improving water use efficiency. It is clear that equity in water sharing is essential for generation of cooperation in water harvesting and saving in rainfed areas. Watershed management will be effective only if the watershed community feels fully involved in the process of management. Irrigation water, if properly used, can generate more jobs for landless labor families (Dharm Narian and Syamal Roy 1980). Hence economic access to food improves when water is used to produce not only more food but also more jobs.

5. Conflict Resolution

Conflicts of various kinds-local regional, national and international are likely to grow in the coming years. Such conflicts will have their roots both in economic and ecological factors. We need a pro-active analysis of such situations and not just post-mortem reactions. It is best that long before such conflict assume serious social and political dimensions, they are anticipated and satisfactorily resolved. It would if the Universities and Research institution with the requisite experts establish on a Water Basin basis, a center for the study of water-related conflicts and trade offs. Such centers can also help in drawing up rational plans for inter-basin sharing of waters.

Water management strategies and conflict resolution should place of the costs and benefits of supply and demand management on an equal footing.

CONCLUSION

Both sustainable food and livelihood security will depend on how well we manage water resources. The scope for better management is great. This will however, need not only technological which are economically and ecologically sound, but also public policies which place a premium on sustainable public welfare and people's participation in the conservation and management of water resources.

Case study XI

"Conservation in A newly created national park in A Tropical Rain forest Region. The Gulung Mulu National Park, Sarawak Malesia".

In contrast to planning projects, the primary aim of Gulung Mulu National Park is conservation of natural rain forest environments.

Back Ground

The creation of such a national park in an area almost completely undisturbed by man was seen as a matter of urgency by Sarwak Government with deforestation for both timber and agriculture proceeding at an ever increasing pace. The tropical rain forest environment is still one which the scientists know comparatively little about and until it is more fully understood optimal strategies for economic development of tropical low land areas for forestry or agriculture can not be formulated.

Water Pollution and Other Problems

The increase in number of people in the park area and the establishment of permanent site of human occupation will inevitably result in some problems of rubbish and sewerage disposal.

Mulu National Park is an undisturbed area considered by the Sarawak government as being more valuable for scientific research.

Several planning themes emerge from the review of the major river basins. problems in Mulu first and foremost is the clear need for strict and effective conservation policies if the very sensitive ecosystem and geomorphic systems of the park are to be preserved.

A need for time zoning of access to the park. Access by river in the park is difficult both at times of low and high flow and overland routes are most difficult during the wettest months. Visitors may therefore be 'naturally' restricted at these times of difficult access.

Case Study – XII

"Salmon in the River Basin".

The fundamental fact that the river is the lowest point in any cross-section of valley results in both every natural condition – and every actin of the man in the valley impacting on the water in the river. Water carries with it all the characteristics of the ground over which, or through, it flows, picking up chemical components, flow conditions, organic material, particulate matter and even Folsam and Jetsam.

There is still a great deal of work to do in improving our "Industrial rivers" but because their condition has been such an insult to us all, appropriate legislation is in place to tackle the problem.

Salmon – the anadromous life cycle of the salmon creates an enormous range of requirements on a river system. The spawning area must have clean gravel and well oxygenated water which is largely free from sediment and does not become too acidic. The nursery areas for the Juvenile fish must also have good quality water with an adequate flow over gravel and cobbly where plants and invertebrates can grow, where fish can establish their territory and find shelter and protection with bank side cover. During the process of smelting and migration to the sea, the young salmon are delicate little animals and require easy downstream access. The returning adults must have protection and shelter so that they can ascend many kilometers of river to reach spawning areas perhaps 500 m above the sea level.

Major Impacts

The Salmon Advisory Committee has written two reports (Anon, 1993 a and 1993 b) outlining the factors, which affect natural smelt, production and migration within rivers. These factors are reviewed below:-

Afforestation: Afforestation and associated ditching can adversely affect the hydrological characteristics of the smaller streams in a catchment, increasing the flow at times of spate causing erosion and sediment transport, and reducing the flow at times of drought resulting in dry stream beds with no fish life. There will be reduced flow yields from the ground once the trees start to grow

Acidification: Salmond egg do not hatch if the pH falls below 4.5 and the percentage which successfully hatch at pH 5.0 is low. In addition, acidic water leaches chemicals which are toxic, particularly to newly – hatched and very young fish.

Fertilizers: One of the major constituents of fertilizers used for agriculture, nitrogen is likely to be washed into the river system in significant quantities and in some cases phosphorus may be a problem. It is suggested that there is a link between agricultural fertilizer and the growth of algae on the bed of the river.

Pesticides: Many of the pesticides used in agriculture, horticulture and silviculture have been screened to reduce the likelihood of damage to non-target organisms. The change from the organo-chloride-pesticides has been helpful in limiting the damage and there is E.C. directive which limit the concentrations of pesticides in order to protect fish and aquatic life.

Agriculture: Slurry has a BOD of 30,000 mg l^{-1} and silage effluent a BOD of 80,000 mg l^{-1}; thus any spillage is likely to be disastrous. Improved handling and farm yard care is reducing the number of pollution incident.

River regulation and dams: There is a range of problems for Salmon, which are associated with river regulation, dams and barrages. These include impediments to migration, flooding of spawning and nursery areas, alternation to the natural flows an modification to water quality.

Water abstraction: There are few catchment which are immune to water abstraction and very few which do not suffer from in a reduction on flow which is likely to be particularly noticeable at times of low flow when abstraction also has the potential to decrease dilution of effluents in addition, the flow of water into intakes may draw fish against screens.

River and riparian management: There are a number of factors related to riparian management which adversely affect salmon. Such factors include upland drainage which may benefit grazing but deplete low flows, enlargement of the river channel for flood channel for flood prevention, overgrazing and physical damage to river banks by sheep and cattle.

Gravel extraction : The commercial extraction of river gravel can impact on Salmon by the removal of spawning gravel, by channel degradation and by the release of fine sediments when the gravel is worked. Further more the removal of gravel from one point in a river is likely to accelerate the process of gravel transport from the river bed upstream, to the detriment of plant, insect and fish life.

Waste disposal: - The control which is placed on the quality and quantity of effluents from industry of all types and from domestic sewage works, is fairly strict water overflows with inert suspended solids, and from chemical processes. In many cases even in very low concentrations of effluent may be toxic to fish.

Fish Farming:- The intensive production of trout and salmon smolts in fresh water has expanded substantially in recent years and fish farming is now a major producer of food. But with intensive farming goes, the problem of disease, of solid waste feed, and of escape, all of which impact on wild stocks. The control of disease uses chemicals which may be harmful to small fish, solid and liquid waste lead to eutrophication and escapes may be adversely affecting the genetic characteristic of wild fish.

Water quality:- The quality of water is which salmon migrate is the most important single factor which demonstrates mans impact on our rivers, waste from industry, domestic sources and fish farms, hot-water from power stations, plant nutrient from agriculture, silts, sludges, and sediments, oils and toxic substances all are likely to cveate conditions which are unacceptable to fish. In England there was a decline between 1980 and 1990 of some 1100 km of river and canals which were classified as good and a comparable decline of 65 km of estuary. In Scotland (Anon, 1990) there has been over the same period an improvement of approximately 1000 Km of rivers of good quality.

Remediation:

Fisheries cannot be looked at on their own, nor can land-use or flood prevention; they must each be integrated so that all users of water are contributing to effective management.

Taking the factors of man's impact on turn.;

- New techniques of forestry ploughing can prevent severe alterations to the hydrology. Use intensive planting with open areas and deciduous trees near river banks provide favorable buffer zones.
- Reduction of sulphate and nitrous emissions will help to reduce the acidity in rain, wide buffer zones on the edge of all streams will reduce the acidity in the water. In extreme cases dumping lime stone in the water course will help to neutralize some of the acidity.
- The reduction of pressure on farmers for higher production will reduce the amount of fertilizer being put into land.
- The progression of controls and the increased Knowledge of the effect of pesticides is reducing their impact particularly is fish life, but there are unknowns about the effect of pesticides on invertebrates other than those for which they are intended.

- Better control and better management of slurry and silage storage is leading to fewer incidents of spillage.
- A better under standing now exists about appropriate compensation flows and the times when the majority of fish move upstream so that improved operating rules can be developed. Also knowledge of the behaviour of salmon at fish ladders has improved so that they can be more effective.
- An approach to abstraction which takes account of both environment and water user's needs, and the establishment of a limit of abstraction at flows where a prescribed minimums flow is set, both help to create more favorable conditions for salmon.
- While upland drainage is no longer being extended and some drained area are reverting to a more natural condition there is still extensive hill grazing which prevents regeneration of moorland and river banks. But these are problems which can readily be overcome.
- The effect of gravel extraction can be minimized if it is confined to areas away from the bed of a river and worked with proper control of stilling ponds.
- The improvement in Industrial river show what can be done to overcome the impact of waste disposal on salmons and continuing steps to wards improved treatment processes and better waste management will carry this improvement further.
- The challenge of upgrading the water quality in our rivers in one of the over riding impact on the catchment.

Case Study XIII

"The Thames / Potomac Seminars – A Model for River Basin Planning for Developing Countries"

Clean up of Thames and its tributary rivers is taking place under flexible standards, established by the Thames water authority based on the existing conditions of the stream segment and its anticipated uses. Industry is told what level of pollution control it must meet (but not told how it must meet them). Thus a pulp and paper plant wastes deplete dissolved oxygen could alleviate the problem by aeration of the receiving waters. In the Thames basin, responsibility for the major functions of water supply and waste disposal along with those of navigation, flood control, land drainage, recreation and fisheries all come under one river basin authority. These powerful structures were set up by national legislation in 1974 after long range projections had indicated that there was simply no way that anticipated demands for water supply or waste dispersal could be meet under the then existing decentralized system where in the Thames basin alone, 2000 separately managed waste disposal and water supply facilities existed, since 1974 these fully untargeted water authorities have controlled all water related activities funding these from fees collected from users of the various services provided.

U.K. officials were particularly curious about public involvement in the Potomac basin, especially the degree to which those other than water specialists. Are or should be a part of water resources planning and management decisions. To address this issue, the seminars were deigned so that they included representatives of all the various groups who influence water policy and its implementation; national, state regional and elected officials; Government officials from each of those levels, scientists, engineers economists, and educators from universities research institutions Industry and consulting firms; as well as community leaders and environmental activists, To assure that the point of view of the public was involved, throughout the Washington seminar volunteers from local and national citizens groups were requested to assist in each portion of seminar. In London, at the specific request of the British organisers, some members of the U.S. team of experts were not water specialists but citizens active in advisory bodies of water related agencies; and the entire final day of that seminar was dedicated to discussion of the interface between water management and their various public.

But the greatest concern in both the rivers is their uper estuaries which are the sites of both national capitals. Strict standards and goals for entire nation with an intent to eliminate the discharge of all pollutants Federal laws are framed in U.S.A.

In the late 1950's the 113 – kilometre tidal estuary of the Thames was virtually lifeless. No dissolved oxygen existed in the 48 – kilometre stretch of the river adjacent to and below London and only eels who could lift there heads out of the water to breathe, were able to survive. Waterfowl had left the area, stenches rose frequently from decaying algae, storm water runoff, and inadequately treated sewage. A clean up effort initiated at that time has made the Thames estuary what many consider to be cleanest industrial estuary in the world. By 1974 over 90 species of fish had returned to the upper estuary, wildfowl were back, recreation was flourishing and high priced redevelopment was appearing along the banks of the river. The challenge now was to maintain the improvements.

In the U.S. the same plant would have to remove the waste before discharge. The US is trying to eliminate discharge of manmade pollutants into water bodies. The UK has concentrated on alleviating the problems caused by discharge and is only eliminating sources if funding permits.

In depth discussion of these three major topics (water supply, pollution abatement, and public involvement) and related issues, Legislative and Government mechanisms which exist for water supply, water quality and public involvement.

In each of these discussions, representatives of each nation were forced to re-examine what they were trying to accomplish why, whether or not they were trying to accomplish, why whether or not they were succeeding, and what secondary effects were being triggered.

The paper gives stress to formation of strong integrated river authority, public involvement and strict standards and goals, for river management. The study has a relevance with management of the Ganga.

CHAPTER – 5

PRESENT STATUS OF THE GANGES WATER FOR WATER USE AND QUALITY

5.1 GENERAL

The drainage area of the Ganga basin in India is 0.86 million square kilometres. Total population as per 1991 census has been estimated as 356.8 million which is 42 percent of the country as a whole. Average density of population is 414 person per square kilometre as against 267 for the country. As per 1991 census, the basin had 111 urban centres with population more than one lakh, which includes 7 larger cities (Calcutta 109.2 lakh, Delhi 84.3 lakh, Kanpur 21.1 lakh, Jaipur 16.1 lakh, Lucknow 16.4 lakh, Varanasi 10.3 lakh, and Patna 11 lakh).

5.2 WATER RESOURCES DEVELOPMENT STATUS OF THE GANGA BASIN

Surface water resource potential of the Ganga and its tributaries has been assessed at 525 billion cubic metre (BCM). Out of which 250 (BCM) is considered to be utilizable. Based on 1991 census, per capita availability is 1471 cubic metre. Though the Ganga basin is bestowed with abundant water resources, its occurrence / availability both in quality and quantity is not uniformly distributed either spatially or temporarily. More than 75% of the rainfall occurs in monsoon months of June to September. As a result, large areas are subjected to floods on one hand and droughts on the other. Storage potntial of the Ganga basin in India is identified as 84.46 B.C.M. Till 1995 a total of 37.87 B.C.M. of storage was completed. Schemes with storage of 17.06 B.C.M. are under construction and worth 29.56 B.C.M. of storage are in the pipe line. Total replenishable ground water resource of the Ganga basin is estimated at 171.0 B.C.M. out of which 24% is presently utilized.

Net sown area is around 44 million hectares (M.ha) and net irrigated area 23.41 M.ha (53.14%). Important large storage constructed in the basin include Gandhi Sagar, Jawahar Sagar and Rana Pratap Sagar Cascade on the Chambal, Matatila on Betwa, Sarda Sagar on Sarda, Ramganga on Ram Ganga, Obra and Rihand on Rihand, Mayurakshi on the Marurakhi and Damodar valley corporation system of reservoirs on Damodar. Some other projects under construction are Rajghat on Betwa, Tehri on Bhagirathi, Bansagar on Sone and Lakhwar – Vyasi on Yamuna Kishau and Renuka in the Yamuna basin Auranga, Amanat in the Sone basin, Punasi on the Punasi river and upper Kansabati on theKansabati are some of the projects. A few projects are also being negotiated with government of Nepal.

5.3 PROBLEMS

Vast cultivable area of 60 M.ha needs water. This cannot be assured during Rabi season. Majority of good storage sites are in Nepal, which contribute down stream of Varanasi. Lean season flows in the basin without adequate storage backup are not sufficient to meet the minimum flow requirements for meeting various demands including ecological demands. Besides, monsoon flows in the basin is so high that the Ganga and its tributaries remain in spate almost every year. Almost all storage site crucial for flood abatement are in Nepal.

In the upper Ganga reach upto Allahabad in the non-monsoon season flow is already insufficient to meet the requirements for drinking water supply, agricultural and industrial uses. Increased pressure of urban population concentrated in numerous towns and cities, which are developed on the banks of the Ganga, and its tributaries are further aggravating the problems associated with its quality apart from causing its scarcity. Quantum of its flow associated with its quality is the dimension, which is the key issue in the present context of management of diminishing and deteriorating water resources. Impact on river water quality resulting from discharges of wastewater into the river mainly depends upon the degree of treatment offered and quantum of fresh water flow particularly during lean season. In case of untreated wastewater and industrial effluents any amount of dilution may not improve its quality to the required level. Even in the most optimistic programme for treatment of waste water prior to this discharge into a river, certain minimum flow of fresh water in recipient river would be required for dilution in order to maintain the desired water quality. The instream uses in the river, such as religious mass bathing, regular bathing and washing also require adequate flow to be maintained so that the pollution of the river caused by such uses can be kept within the acceptable limits. River supports a chain of life, which has to be conserved.

The numerous cities thriving on the water resources of the Ganga in turn generate and discharge huge quantities of waste water, a large portion of which eventually reaches the river through natural drainage system. The numerous industrial complexes, which sprang up along the river also brought with them the curse of the technological age by creating an imbalance in ecology due to the pollution loads they dump into the river. Over the years the Ganga and its tributaries were no longer merely source of water for survival and growth. They became the channels of transport of industrial effluents and the drains for the waste water of the cities. It is estimated that some 900 million litres of sewage is dumped into the Ganges every day. Three fourths of the pollution in the Ganga is from untreated municipal sewage. In particular the middle reach of the basin between Kanpur and Baxur is the most urbanized and industrialized as also the most polluted segment of the basin. Municipal and industrial wastes in dangerous concentration and proportions perennially find entry into the water courses of the region and pose real threat.

The Central Board for prevention and control of water pollution had estimated that the total urban organic pollution load in the Ganga basin is of the order of 2.5 million kg BOD per day. The pollution thus forced on the river by human interference was a serious health hazard to the dense population of the basin. It is in recognition of the magnitude of this problem and realizing the importance of water quality as a cardinal element of river management that the government of India started the planning and execution of a time bound programme to prevent the pollution of the river Ganga.

5.4 MINIMUM FLOW RATE REQUIRED

An interdisciplinary group was set up in 1989 to study and workout quantum of flows needed at critical locations on the Ganga for maintaining river water quality after meeting the present and future domestic, irrigation, water front and industrial requirements. The group observed that minimum water required to meet all domestic, irrigation, industrial requirements including maintaining 10 cumecs for water front for bathing and other rituals at Ghats and requirements for pollution abatement of a BOD level of 30 mg/l would need 232.06 cumecs at Kanpur, the most critical location on the Ganga. The group found that apart from various measures, to achieve a minimum flow of 10 cumecs after meeting all requirements, storage worth 3790 Mm^3 would be necessary.

5.5 WATER QUALITY CONTROL STRATEGY

In the Ganges during summers the flow basically arises from snow melts, while in winters, the flow mostly comprises of springs and base flows. There are a large number of urban settlements, industrial complexes and agricultural activities all along the river, as a result of which, this river constantly receive substantial amounts of various types of waste matter which impair the quality of their waters and thus affecting their various significant beneficial uses such as drinking with or without treatment, bathing, agriculture fish culture, industrial etc.

The dominant parameters for determining the suitability for the considered beneficial uses are as follows :

Beneficial Use	Significant Parameters
Drinking without treatment, bathing swimming etc.	Turbidity, BOD, Do nitrogen – amonia coliform MPN etc.
Drinking after conventional treatment, public water supplies	Turbidity, BOD, Do chlorides, Coliform etc.
Agricultural etc.	TDS, chlorides, Boron Sodium ration etc.
Industrial etc.	Hardness, Turbidity TDS etc.
Fish culture, wild life boating, recreational etc.	Temperature, DO, BOD chlorides etc.
~~Fish culture, wild life, boating, recreational etc.~~	~~Temperature, DO, BOD chlorides etc.~~

Table 9 Observations along Ganga (Summer)

Point		Temperature °C	DLP cm	DO mg/l	BOD mg/l	Conductivity m mhos/cm	Chlorides mg/l	Hardness as $CaCO_3$ mg/l	Coliform MPN no/100 ml
Rishikesh	u/s	18	16	8.0	4.4	130	4	58	100
	d/s	18	16	8.0	6.7	100	4	56	2400
Haridwar	u/s	18	18	8.0	8.0	150	3	56	2400
	d/s	20	17	8.0	7.2	155	2	68	1600
Narora	u/s	30	24	7.5	4.2	180	4	84	130
	d/s	29	28	7.4	7.2	147	5	76	63
Kannauj	u/s	28	39	6.0	4.6	301	7	140	240
	d/s	29	22	5.9	7.0	315	7	136	130
Kanpur	u/s	27	19	7.5	10.0	287	8	108	35
	d/s	29	18	6.0	27.0	293	9	120	2400
Allahabad	u/s	31	31	6.5	6.0	406	16	134	350
	d/s	30	35	6.5	6.8	406	24	138	2400
Varanasi	u/s	27	73	6.4	4.0	494	34	154	49
	d/s	31	78	5.8	10.0	515	34	158	2400

Table.10 Water Quality Indices for Ganga (Summer)

Point		Beneficial Uses					Overall WQI
		Drinking without treatment, bathing	Public water supplies	Atriculture	Industrial	Fish Culture	
		1	2	3	4	5	
Rishikesh	d/s	51	64	95	51	89	70
	d/s	34	46	96	52	85	63
Haridwar	u/s	30	44	96	54	81	61
	d/s	34	47	96	52	80	62
Narora	u/s	55	68	94	57	72	69
	d/s	52	64	94	61	66	67
Kannauj	u/s	56	69	89	61	71	69
	d/s	45	58	88	51	63	61
Kanpur	u/s	41	51	89	50	65	59
	d/s	11	20	86	49	23	38
Allahabad	u/s	50	62	82	56	66	63
	d/s	35	49	78	57	66	57
Varanasi	u/s	75	83	71	71	74	75
	d/s	33	47	70	72	53	55

Table 11 Classification of Ganga

Point		Beneficial Uses					Overall WQI
		Drinking without treatment, bathing	Public water supplies	Agriculture	Industrial	Fish Culture	
Rishikesh	u/s	III	III	I	III	II	II
	d/s	IV	III	I	III	II	III
Haridwar	u/s	IV	III	I	III	II	III
	d/s	IV	III	I	III	II	III
Narora	u/s	III	II	I	III	II	II
	d/s	III	III	I	III	II	II
Kannauj	u/s	III	II	II	III	II	II
	d/s	III	III	II	III	III	III
Kanpur	u/s	III	III	II	III	II	III
	d/s	IV	IV	II	III	IV	III
Allahabad	u/s	III	III	II	III	II	III
	d/s	III	III	II	III	II	III
Varanasi	u/s	II	II	II	II	II	II
	d/s	IV	III	II	II	III	III

The use of water quality index (WQI) is considered more appropriate than the different standards to designate the quality of the river water. This index is based on the sensitivity of different parameters.

The summer data on river Ganga from a water quality survey of the river is reproduced in Table 7 using these data in the WQI model the WQI values for each of the beneficial use listed are tabulated in Table 8 at the various points along Ganga. Depth of light penetration (DLP) and conductivity which respectively represent turbidity and total dissolved solids (TDS) have been used in place of turbidity and TDS respectively. While calculating the overall WQI 20 percent weightage was given to all the five uses.

The classification of Ganga for the various individual uses and also the overall use as given in Table 9 has been done on the basis of the following range of WQI.

WQI	Range of WQI	Classification of each use
100	Greater than 90	I Excellent
80	Between 65 and 89	II Good
50	Between 35 and 64	III Satisfactory
20	Between 11 and 34	IV Poor
1	Between 10	V Unacceptable.

From a look at Fig. it is clearly inferred that the water quality level needs elevation. Therefore, appropriate treatment of the waste water that are discharged into the river at the upstream of the stated stations.

5.6 GANGA ACTION PLAN

Ganga Action Plan Phase – I

The Ministry of Environment and Forests (MOE & F) is the nodal agency in the administration structure of the Central Government for planning promotion co-ordination and overseeing the implementation of various environmental programmes on the Ganga. The Ganga Action Plan (GAP) was initiated in 1985 with cent percent grant-in-aid. Pollution abatement works for the river Ganga had been taken up in 25 class I towns (population over 1 lakh) along the main river Ganga under the three basin states of U.P., Bihar and West Bengal. The main objective of the GAP Phase I were :

(a) Reduction of pollution load on the river and improving the water quality as a result thereof, and

(b) Establishment of domestic / municipal waste water treatment system with emphasis on resource recovery to make such systems self-sustainable as far as possible.

The Ganga Action Plan besides aiming at de-polluting the river Ganga was to serve as a model to demonstrate the methodology of improving the water quality of the other polluted rivers and water bodies of the country to their designated best use class. A multi pronged approach was adopted to achieve the objective of the GAP, which comprised.

a) Interception, diversion, and treatment of urban waste water.

b) Monitoring of gross polluting industries located on the Ganga and taking necessary steps to reduce water pollution by such units.

c) Modernization of solid waste management and provision of low cost sanitation schemes with a view to maximizing the water pollution from such non point sources as run-off from urban solid waste dumps and areas along the river used for open defecation

d) Construction of electric Crematoria and wood efficient funeral platforms to prevent disposal of half burnt bodies in the river.

e) Providing scientific inputs to improve the biological quality of the river and identify appropriate technologies in terms of both off-site and on-site treatment of waste.

f) Maximising resource recovery from sewage treatment by way of bio-power generation, sale of sludge and use of treated effluent for agriculture and pisciculture.

g) Generating awareness through participation programmes for involving public for keeping the river clean.

A total of 261 projects have been sanctioned under the GAP Phase I for the abatement of pollution of the river from the 25 Class I towns. Against the cost of the schemes, on completion estimated at Rs. 462 crores a sum of Rs. 451.40 crores has been spent. The GAP Phase I envisaged tapping of 873 million litres per day (mld) of domestic / municipal waste out of the total 1340 mld generated in the aforesaid 25 class I towns. A total of 258 schemes have been completed so far, which account for the diversion of about 835 mld of wastewater. The remaining few schemes are in advanced stages of completion.

Similarly for industrial pollution, 119 industries were identified as grossly polluting the Ganga (main stem) (UP – 83, Bihar – 3, West Bengal – 33) upto end of September 1999, 50 units were complying with effluent standards (U.P.-18, Bihar-2 and West Bengal – 30). A total of 8 units were closed down (U.P. – 4, Bihar – 1, and West Bengal – 3).

Bharat Heavy Electricals Ltd., IIT, Kanpur, CPCB Central Pollution Control Board zonal Office and Patna University are monitoring water quality of the Ganga regularly at 27 stations, Rishikesh in Uttar Pradesh, to Uluberia in West Bengal. It is reported that the results of the schemes constructed under Phase I, the water quality of the Ganges has shown improvement in respect of Biological oxygen demand (BOD) which is

Table No. 12

Summer Average (March to June) D.O. & B.O.D. in mg/l at Various Locations on the Ganga

Station Name	Distance in Km.	Dissolved Oxygen (D.O.)		Biological Oxygen Demand (B.O.D.)	
		1986	1999	1986	1999
Rishikesh	0	8.1	0	1.7	1.0
Hardwar (D/S)	30	8.1	8.6	1.8	1.2
Garmutkeshwar	175	7.8	7.9	2.2	1.4
Kanauj U/S	430	7.2	7.1	5.5	5.3
Kanauj D/S	433	NA	8.8	NA	4.8
Kanpur U/S	530	7.2	6.8	7.2	4.6
Kanpur D/S	548	6.7	7.5	8.6	6.5
Allahabad U/S	733	6.4	8.8	11.4	1.8
Allahabad D/S	743	6.6	7.9	15.5	3.2
Varanasi U/S	908	5.6	8.2	10.1	2.2
Varanasi D/S	916	5.9	8.4	10.6	3.7
Patna U/S	1188	8.4	7.7	2.0	1.9
Patna D/S	198	8.1	7.8	2.2	2.4
Rajmahal	1508	7.8	7.5	1.8	1.5
Palta	2050	NA	NA	NA	NA
Uluberia	2500	NA	NA	NA	NA

Source: Annual Report 1999-2000 of MOE&F

a major polluter. The summer average values of the two important river water quality parameters viz., dissolved oxygen (D.O.) and (B.O.D.) are given in Table No. ----

The pollution abatement measures undertaken under the GAP Phase I would not be fully effective unless similar works are taken upon the other towns of the Ganga main stem and its tributaries. The Central Ganga Authority (CGA), at its 6th meeting held in February 1991 had recognized and accepted the need to undertake similar works on the tributaries of the Ganga and other grossly polluted stretches of the major rivers in the country. It was thus proposed to extend the GAP model for abatement of pollution of other rivers in two steps (a) Ganga Action Plan (GAP) II and (b) National River Action Plan (NRAP). The GAP phase II comprised the following :

(a) Essential pollution abatement works in the 25 class I towns, which could not be taken up in GAP phase – I of GAP due to resource constraints.

(b) Pollution abatement works in the grossly polluted stretches along class II and class III towns on the main river Ganga.

National River Action Plan

The GAP phase II was merged in the National River Actin Plan (NRAP) in 1996. The expanded NRAP covers 141 towns along 22 interstate rivers in 14 states and the total cost of the schemes under the NRAP is Rs. 2013.4 crore. Central share is 1776.18 crores and state share is 237.78 crores. The centre funds the plan on 100% funding pattern and only operation and maintenance is the responsibility of the state government. Sub plan concepts of NRAP in the Ganga basin are :

Ganga Action Plan Phase II (Main Stem)

Pollution abatement works are being taken up in towns (U.P. – 10, Bihar – 11, West Bengal – 8). A total of 35 schemes are sanctioned in 1999 so far and about 618 mld of sewage is target to be intercepted, diverted and treated. The plan includes substantial out lays for schemes in Allahabad, Kanpur and Varanasi . Out of the project outlay of Rs. 443 crore, the total expenditure incurred is Rs. 15.54 crore. Schemes are aimed for completion during IX Five Year Plan.

Ganga Action Plan – Supreme Court Towns (GAP-II – SC)

Under this action plan, pollution abatement works are being taken up in 30 towns (UP – 12, Bihar -3 and West Bengal – 15). About 162 mld of sewage is targeted to be intercepted, diverted and treated. Out of the total project outlay of 209.9 crore, the expenditure is Rs. 24.3 crore. Slow progress is due to problem of land availability.

5.7 Work of CWC in the Ganga Basin

Central Water Commission has an established network of hydrological observation stations for reliable assessment of the water resources of the Ganga basin. In addition to observation of river flows, Central Water Commission is also engaged in the water quality monitoring as an essential component of the integrated hydrological investigation and accordingly water quality observations are being carried out at 122 key locations distributed all over the Ganga basin and its tributaries.

In the Ganga Action Plan Phase I, CWC monitored 15 stations in the main stream of the Ganga out of 27 stations earmarked by Ganga Action Plan. CWC collected the samples as per procedure and used 16 parameters, out of 22 identified to be monitored under the Ganga Action Plan.

CWC also imparted training to various Research Institutions / Universities and State Pollution Control Boards regarding the systematic collection of samples. CWC is also interacting with various organizations by sending status reports, water quality year books and ten daily water quality bulletins of all basins as part of its activities. CWC is regularly publishing water quality status report and water quality year books.

CHAPTER – 6

REQUIREMENT FOR MANAGEMENT OF THE GANGES WATER

6.1 GENERAL

Right from the Hardwar upto the hooghly we find that quantity of flow is less in the river than the requirement. This is because the river basin has to support much more population than it can, and also the response to the river is not positive.

At Hardwar during the winter total canal diverson is insufficient to irrigate the whole command similarly during monsoon carrying capacity of the upper Ganga Canal is not adequate to irrigate paddy. Due to this inadequacy upper Ganga Canal, Madhya Ganga land and lower Ganga Canal are interlinked. A balancing supply from the Ramganga reservoir subtiutes the water demand.

There are various intake points below and upstream of Narora barrage where river water is abstracted for various uses. They are namely for lift irrigation, drinking purpose, industrial use, sanitary purpose etc. But there are no big barrage down stream to divert water for irrigation purpose. Even then water is found short for diluting domestic, industrial effluent, municipal use, navigation etc., on the other side quality of water is also deteriorating. Once there was a time when the river earned respect due to its water quality.

6.2 QUANTITY

Basic problem in the Ganga basin is that in relation to the relatively large annual flow in the basin, the available storage reservoirs and all the foreseeable ones in the basin in India are not enough to enable an optimum use of the total flows, unlike other basins in the country. For instance in Narmada or Tapi, the live storage capacity of all the schemes could conserve more than half of annual flows while the corresponding figure for Ganga is less than one sixth, which coupled with "vast cultivable area of 60 m-ha creates problems in development particularly during Rabi season. Majority of the good storage sites are in Nepal, which contribute downstream of Varanasi. Lean season flows in the basin without adequate storage backup are not sufficient to meet the minimum flow requirements for meeting various demands including ecological demands. Besides, monsoon flows in the basin are so high that the Ganga and its tributaries remain in spate almost every year.

6.3. FUTURE STRATEGIES

Inspite of India having a long tradition of managing water, increasing demands due to agricultural development and population and industrial growth have posed new challenges. Diminishing quantity and deteriorating quality has aggravated the already serious situation. Water storage in the basin will become even more pervasive by 2025 and stress overall human and economic development. Appropriate management of the precious resource is crucial for protection of public health and further economic development of the Co-basin states in particular and the country in general.

Strategies to be adopted for future development of this resource will have to recognise that every water use generates waste water that deteriorates its quality and reduce its quantity for further reuse. Therefore, waste water treatment and reuse has to be stressed for sustainable development. It must be recognised that every drop used has to be intercepted, diverted and treated before it is re-cycled into the rivers or used else where say for irrigation/pisciculture.

Growing population, rapid urbanisation growing industrial and other demands for maintaining ecology of the region has put tremendous pressure on the available water. All technologies to harness this resource are to be explored and exploited. Scientific rainwater harvesting, watershed management, even revival of traditional wisdom of water storage and conservation practices may also be simultaneously required. Increasing efficiency of canal irrigation, promoting, active community participation in the water management process, the empowerment of users and their association, especially farmers Co-operatives by way of decentralization of water management activities are crucial for sustainable long term development. Future development activities would depend on, how effectively can development process is aimed at rationalizing the availability of water for different uses.

Contamination of surface and groundwater resulting in water quality deterioration is further affecting the net availability of water for consumptive uses. Reallocation of demand pattern for various purposes are also likely to cause water deficiencies in certain areas in future. Policies on scientific management of groundwater with surface – water without excessive expatiation and without further deteriorating GW quality are to be formulated. These factors and growing concerns about social, economic, institutional and other external concerns refrain that the limited water resources has to be harnessed and managed properly in future.

Maintenance of minimum flow in the entire reach of the Ganga is not possible unless additional storage are created for multi-purpose development. [illegible] ment. Additional storages, which are only fractionally developed so far in the Ganga basin, are also necessary in the upper reaches for growing water supply, hydropower development and flood abatement. Recent water crisis call for integrated land and water use strategies as well. Advanced technical techniques are required for creating additional storage in upper Ganga Yamuna and other tributaries. For implementing these may include innovative water management techniques.

6.4 QUALITY

Water is a prime natural resource and is a basic human need. Scarcity and quality of water both pose problems.

Wastewater is a misplaced resource and can be reused to advantage through proper management. Reuse implies utilization of water that has been previously used for another purpose, and recycle implies reuse of water more than once for the same purpose. Utilization of water resources in India is classified depending on nature of use into three main categories domestic, agriculture and industry. An estimated total water use in the country is 4074 million m^3/per day for the year 2000-2001, the figures of distribution among these categories are 2.1%, 88% and 2.4% respectively.

It is estimated that 31% of rural population and 77% of urban population in India have access to potable water supply surface water is the dominant source of organized urban water supply. In rural areas ground water is the basic source. Only 63% of the metropolitan population is provided with sewage collection and treatment system. Less than 5% of the total waste water generated from the municipalities is collected and only 2% is treated. Thus 98% is discharged into the environment untreated.

This indiscriminate discharge of large quantity of untreated sewage into the surface water has deteriorated all the rivers in the country and the Ganges in particular.

The preservation and restoration of river water quality in India started with the launch of much published Ganga Action Plan in 1985. An important part of GAP was collection and treatment of domestic wastewater discharged from urban centres located on the banks of Ganga. GAP phase I has created an infrastructure for diverting 730 million litres per days (MLD) AND TREATING 540 MILLION LITRES PER DAY OF MUNICIPAL SEWAGE. The second phase of GAP aims in collection and treatment of domestic wastewater from 95 towns. Water quality status after implementation of GAPI is illustrated in the table attached.

Often construction of conventional sewage treatment plant requires huge capital cost. The Indian municipalities and public health departments are short of funds, thereby leaving most of the domestic wastewater untreated. The viable option is to adopt cost effective/low cost sewage treatment scheme. Sewage farming is one such option, which utilizes partially treated sewage for irrigation to grow crops and vegetables.

6.5 INDUSTRIAL CATEGORY

Industrial growth in India took place after the liberalization of Indian economy in 1991. To focus on Indus-trial pollution the Government of India has identified 19 critically polluted areas in the country and 17 industrial sub sectors which are polluting, viz. cement, thermal power plant distributaries, sugar, fertilizer, integrated iron and steel, oil refineries, pulp and paper, petrochemicals, pesticides, tanneries, basic drugs, and pharmaceuticals, dye and dye intermediates, caustic soda, zinc smelter, copper smelter and aluminum smelter. Many are installing pollution control schemes.

Since November 1991, World Bank with Ministry of Environment and Forests, Government of India is providing Finance for Pollution Control Project to individual Industrial units for pollution prevention and control. The funds are distributed by Industrial Development Bank of India (IDBI) and the Industrial Credit and Investment Corporation of India Limited (ICICI). Response from industry is positive. Government of India has recently negotiated second line under Industrial pollution prevention project where similar funds would again be available. In the case of new units, the cost of pollution control is internalized with the entire project cost and is financed within the overall financing package of the entire project. In general, this cost is less than 5% of the total capital cost of the project except for specific industry sub-sector where the cost may be as high as 10%.

Energy from Waste

Realizing the potential and importance of treatment of wastes and the resultant recovery of energy from these waste, the Government of India has launched in June, 1995 a National Program of Energy Recovery from Urban, Municipal and Industrial wastes with a view to promoting the adoption of proper technologies as a means of improving waste management practices in the country with the goals and objective of (i) creation of conducive condition and environment with fiscal and financial incentives to help promote, develop, demonstrate, disseminate and utilize wastes for recovery of energy, (ii) improving the waste management practices through the adoption of technologies for conversion of wastes into energy and (iii) promoting the setting-up of projects utilizing wastes from urban, municipal and industrial sectors.

Effective enforcement of environmental legislation, increased public awareness and change in industry's perception of its social responsibility have resulted in significant increase in compliance to the various provisions of environmental legislation in the large and medium scale industries.

Status and requirements of the wastewater treatment and reuse for select industries in the basin is briefly given below:

Pulp and Paper Industry

The water requirement of the paper mills in India is in the range of 250-440 m^3/tonne of product and the requirement depends on the quality of paper made and extent of recycle. Combined wastewater generation from large mills range between 167 to 281 m^3/tonne of product. No significant variation in wastewater generation is observed. It is found that lignin – bearing coloured wastewater accounts for about 30 percent of the total effluent discharged.

A study on wastewater recycle in the paper industry has revealed that wastewater recycle varies between 8 and 48 percent with an average recycle of 21.4 percent which facilitates reduction in fresh water requirement to the extent of 7 to 44 percent. The Indian pulp and paper industry is adopting recycling of wastewater either without treatment or after suitable treatment. It is also observed that there is growing recycle awareness in the industry.

Tanneries

Tanneries are concentrated in clusters, mostly in West Bengal and Uttar Pradesh. Kanpur is such a cluster. Approximately 39 – 40 litres of water is used for processing one kg of raw hide into finished leather. Most of the tanneries are located near river banks.

In India more than 80% tanneries adopt chrome tanning process 60% of the applied chromium is taken by the leather and remaining is discharged in wastewater.

Research organizations like NEERI, CLRI, and IIT, Kanpur have developed technologies for reduction in chromium salt utilization for chrome tanning and for recovery of chromium from wastewater.

Oil Refineries

The crude oil refining is the oldest industry in the country. The water consumption and wastewater generation in the oil refineries is governed by the type of cooling system adopted, viz., once through or re-circulation. The rate of water consumption and wastewater generation is much higher in the refinery adopting once through cooling system. It may be noted that in refineries having once through cooling system, due to the amount of water being used, a huge amount of valuable hydrocarbon is lost along with wastewater. These refineries have only primary oil separation facilities, which recover limited oil and discharge the further recoverable oil along with the effluent. The concentration of other pollutants in the wastewater depends upon the sulfide and phenol content of the crude oil processed.

The wastewater treatment system for oil refineries in India comprises three principal stages of treatment.

- Primary oil separation
- Secondary oil separation including sulfide removal, and
- Biological treatment for removal of phenols, residual sulfides and BOD.

.The survey of oil refineries in India reveals that about 85 percent of the total oil present in the raw wastewater are recovered in the primary oil separation unit and about 7 percent in secondary oil separation unit. The remaining 8 percent are lost and disposed alongwith finally treated wastewater. The percentage although is small the quantity of waste oil is large due to huge quantity of wastewater. A study was also conducted to establish relationship between cost of wastewater treatment and oil recovered in a refinery. It is observed that total cost of treatment of refinery wastewater including biological treatment is lower than the cost of oil that can be recovered from the plant.

Data on performance evaluation of waste water treatment plants have revealed that there is a great scope for improving the efficiencies of secondary oil separation units by at least 50 percent (thus increasing the overall efficiency of the oil removal from 92 percent to 96 percent). This would mean that oil concentration of the influent to the biological treatment unit can be brought down to 20 mg / L or less. For increasing the oil removal efficiency in the primary oil separation unit, it is recommended to provide continuous oil skimming and sludge scrapping arrangements in gravity oil separators.

Sugar Industry

Sugar is the second largest agro – based industry in the country waste water from Indian Sugar factories generates from two effluent streams namely, process house effluent, and cooling water and excess condensate. The quantities of these streams are equal. The cooling water and excess condensate do not contribute any pollution load and therefore the two streams are segregated and treatment units are installed for process house effluents only. The prevailing method of treatment for process house effluents is primary treatment followed by biological treatment.

The annual burden on sugar factory for constructing the effluent treatment plant and maintaining it is less than one percent of annual turnover of factories to achieve the Minimal National Standards (MINAS).

Chlor – Alkali Industries

Mercury pollution is associated with the chlor-alkali industry. To reduce the mercury –bearing wastewater some units have completely segregated the drains, The quantity of mercury bearing effluent generated ranged between 0.14-36m^3 per tonne of caustic soda produced in case of complete segregation of flow. The unit operation/process used for treatment of mercury-bearing wastewater in India are amalgamation, sodium sulfide-precipitation, polysulphide treatment, sand filtration, activated carbon bed filtration hydrozine treatment and ion exchange resin. A detailed investigation on existing treatment schemes of mercury-bearing wastewater was conducted to identify most suitable scheme. It is observed that combination of pretreatment followed by ion exchange process in continuation with sand filtration and activated carbon filtration presents the best suitable technology.

Small scale industries

Bulk of the industrial pollution in India results from small-scale industries. The concept of combined effluent. Treatment plant for small-scale industries is emerging in India due to large investment involved in constructions and operating the individual effluent treatment plants. The main objective of the (CETP) is therefore, to reduce the treatment cost borne by an individual unit to a minimum while protecting the water environment to maximum. The wastewater can be treated economically in (CETP) to produce process grade water. This water can be reused and recycled in the industry.

The small scale industries are classified according to their water consumption and pollution potential as under:

- High water consuming industries textile, pulp and paper
- Medium water consuming industries chemical, dyes, pharmaceuticals, leather
- Low water consuming industries paints and varnishes, rubber
- Dry industries table packing.

6.6 AGRICULTURAL CATEGORY:

India is an agricultural country. Majority of the Indian population lives in rural areas and agriculture is their main occupation. According to an estimate 88% of the Indian water usage is consumed by agriculture sector. As per the live stock census of 1992 the country has 204.5 million cattle, this is one of the largest live stock population in the world. The rate of chemical fertilizer consumption has increased rapidly as the emphasis in on increase in food grain production. The compound growth rate in agricultural production during 1950 to 1996 is 2.67 percent per annum as against the compound growth rate of nitrogenous fertilizer consumption at 11%. Contrary to the belief, agriculture sector is a major source of water pollution. The major factor of importance are reduction in wetland area, monoculture crop production, extensive use of commercial fertilizers and pesticides, irrigation, and intensified animal husbandry. Irrigation, which consumes maximum quantity of water, is known to cause water quality problems such as salinization, alkalization erosion of irrigated land.

There is a tendency in farmers to apply more fertilizers than the optimal rate in order to reduce a risk of being short of nutrients in good weather years. Excess chemical fertilizers and pesticides are washed off and reach the surface water or ground water. A survey has shown alarming increase of nitrates in ground waters of north India.

Live stockbreeding and animal husbandry is another source of water pollution from agriculture sector. The major pollution sources from animal husbandry are cattle slurry (dirty water which contains washing from the farm yard and milking parlour) silage effluent (fermented grass used as cattle feed) and animal faeces and urine, gives the BOD from animal husbandry sources. It is seen that BOD of animal sources is approximately 100 times higher than raw domestic sewage.

6.7 TOWARDS PRAGMATIC SOLUTION

To affect and change the burgeoning problem of water and waste water treatment in India, pragmatic solution to these problems at the macro level (policy level) as well as at the grass root level in terms of the implementation needs to be made following are some of the possible solutions to tackle this problem

- Adoption of low cost wastewater treatment systems for treatment of wastewater from small towns and cities. These technologies include water hyacinth pond, oxidation ponds and application of wastewater for irrigation and constructed wetlands. These technologies require less capital and operation and maintenance cost but require large area of land, which is available in plenty in the vicinity of smaller towns. Valuable by-products can also be recovered from these treatment schemes for example methane, fertilizer and water for irrigation from hyacinth pond. It is reported that domestic wastewater (3650×10^6 m^3) can contribute 219 x

10^3 tonne of nitrogen, 73 x 10^3 tonne of phosphate, 146x 10^3 tonne of potash and 1460 x 10^3 tonne of organic matter with an economic value of Rs 2000 million per annum.

- By imparting environmental education to the urban population by making them aware about the problems and consequences of discharging untreated wastewater into the environment and their duties towards social hygiene.
- Providing financial support to the municipalities for wastewater management either from state/central government or from financial organizations at reasonable terms
- Reducing the bureaucratic delays by simplifying the process of decision making.
- Providing suitable training to the treatment plant operators to efficiently run the treatment plant.
- Common effluent treatment plants provide a viable option for a cluster of small units. Which are not capable of setting up the treatment units individually on their own financial incentives in the form of grant should be made available for constructing CEPTS.
- The need to encourage adoption of cleaner technologies (CT) for industrial production is required. government of India is taking steps in this direction by setting up an Indian centre for promotion of cleaner technologies (ICPC) with a large number of agencies operating as a network with access of data base within as well as outside the country. The ICPC, after becoming operational shortly, will be able to serve the industry for waste management purpose in the following ways.
    - Recovering wastes
    - Treatment and disposal of wastes
    - Waste exchange to identify users for potential recyclable wastes.
- It is necessary to underline the fact that mere availability of technology is no guarantee that waste management would be undertaken in a proper manner. Skilled manpower and management package is equally important

inputs for successful completion of waste management programme. Considering the quantum of waste to be handled in the public sector, it is imperative that the constitutional mechanism is suitably strengthened and also made accountable for successfully and timely completing the assigned task. This aspect however; has not received the requisite attention and needs to be vigorously pursued along with the promotion of Research and Development effort in such areas as biotechnology intervention for waste management.

- Another approach would be to move from CEPT (combined effluent treatment plant) to jointly treat domestic sewage from surrounding community. This will not only solve the problem of community waste treatment but will also improve the treatability of industrial wastewater.
- There are at present several fiscal incentives for installation of pollution control equipment and for shifting industries from congested areas. However economic instruments should be amended to encourage the sift from curative to preventive measures, internalize the costs of pollution and conserve resources, particularly water. One possible suggestion is effluent charge based on the nature and volume of releases to the environment. The charge will be based on the cost of treatment and the flow discharged, thus putting thrust on optimal release of wastewater.
- At present the disincentives include penalties and fines for non-compliance under the various acts as well as water cess. All of these disincentives are extremely low in relation to cost compliance. The water cess, also comes nowhere close to cost of pollution prevention / control for compliance. This can be over come by increasing the amounts on penalties and fine.
- In addition to the above, some market instruments could also be employed. One such instrument is the Eco-mark labeling systems. This system through public awareness would provide market forces to encourage environment friendly production process.

- By providing R and D encouragement, create instruments for R and D related to cleaner technologies of production and pollution control from SSI.

CHAPTER –7

DISCUSSIONS / CONCLUSIONS

7.1 SANCTITY

Ganges is the river worshiped by billions. This is the legendary river loved and admired. Its sanctity is above all its uses.

From the study of the "proceedings of the meeting held at Hardwar" Dated 18th April 1917 we can conclude the immense respect of the Ganges in people's hearts. The proceeding reads –

"………(i) In order to guarantee an interrupted flow of the Ganges through the Har-ki-pairi and past the other ghats of Hardwar, a katcha bund will be made at the head of channel no. 1 when necessary, a minimum supply of 1000 cusecs in that channel being guaranteed, except at periods when clearing of the shoaling in channel no. 1, is in progress, the irrigation branch undertaking that this work shall be carried through as expeditiously as possible in order to ensure a flow from this channel into the Har-ki-pairi

It further reads-

(iii) The head of the new supply channel will not be fitted with gates ……

(iv) A free opening will be left in the weir, which will go down to floor level. The opening will be so constructed that it will give according to the calculation of irrigation branch a minimum discharge of 400 cusecs at the cold weather low flow of river

(v) At the Mayapur Regulator a free opening, going down to upstream bed level will be made calculated to provide a permanent flow of 200 cusecs for the service of Kankhal ghats which after leaving Kankhal will ultimately flow into the Ganges.

Here the people's respect is equally reciprocated by the then British rulers.

7.2 QUALITY OF WATER

Ganges water has immense respect. People use to put this water in pot for long time and consume it or spray it as a charm. It is a matter of pain that in this so called developed age the water quality gets deteriorated right from Risikesh. Ample management is required in this respect Ganga action plan is a move in positive direction. This requires to be continued. Aim should be 'O' pollution in this great river system.

7.3 RIVER CORRIDOR

Various human activities are going on in river khadir due to such activities river is in pressure, also wet lands are being drained and cultivated wetlands are bio super market and they store and clean river water so they need to be protected. Also river corridor should be maintained all through and where possible in urban areas also. This will upgrade riverside view and quality of water by stripping of few pollutants.

7.4 STORAGE RESERVOIRS

As dealt previously that pollutant load is so much high with the river that additional storage reservoirs are required to flush out these pollutants. So this condition rules out any chance of further abstraction, without making ample storage.

As the Ganges basin is rich in groundwater, requirements such as irrigation drinking water are to be supplemented with ground water.

7.5 FISH CULTURE

Ganges has a good fish life. Every action detrimental to fish culture is there in the Ganges due to human interference. This needs a discouragement. The barrages etc constructed across the river have traditional fish ladders which do-not simulate river flow situation research and development is needed to have better fish ladders.

7.6 PLASTIC POLLUTION

Plastic carry bags thrown in the rubbish find their way to the river and create nuisance in this regard consensus and necessary rules and amendments are required to reverse the situation.

7.7 BIO-DIVERSITY

The rich and unique bio-diversity of the Himalayas needs conservation Himalayan forests have many endemic species. Floral and faunal surveys are to be conducted and gene banks, biosphere reserves and game parks and sanctuaries are to be established.

Forest felling aggravates erosion, certainly erosion does result in the loss of top soil. Diversion of forests, virgin forests in particular should be avoided as far as possible. Historically, felling has largely been for cultivation, including jumping and settlement, for construction, to provide fuel, for smelting weapons of war and for firewood and fodder. Forests are commonly fired to secure a flush crop of grass.

Deforestation causes floods by checking rivers with sediment and preventing infiltration and ground water storage. Forests have influence on the macroclimate in large catchments.

7.8 CROP CULTURE

In the Ganges basin it is found that crop growing has become mono culture, which is not a suitable end. A diversified cropping system can make crops more disease resistant. A mix of grain crops, horticulture, vegetable gardening and fodder would be ecologically sound. Water demand also gets staggered due to such practice.

7.9 CONJUNCTIVE USE

Canal (surface) water augmented with ground water can resolve the high pressure on the Ganges canals. Farmers have developed consumptive use of optimum way. By use of ground water dynamic equilibrium of water table can also be maintained. Conjunctive use of water for irrigation in Ganga Jamuna Doab is a real example of successful efforts of farmers.

7.10 AWARENESS

For effective management of water use it is necessary to make the users as well managers aware of the economic value of water and decrements occurring due to misuse. People should know the right way of utilizing their facilities and duties to environment. This will largely enhance the water balance and quality situation.

7.11 AREA DEVELOPMENT

Catchment area development helps in various ways in water management. Catchment development includes catchment area treatment, watershed management, soil conservation, slope stabilization, and compensatory afforestation or forest densification. It is better to adopt the entire basin and not just the project sub-catchment as the unit of development.

The Tehri dam for example is only one of the whole cascade of projects. The energy ministry has promised Rs 300 crores for greening the Himalayan and proposes to charge this to the energy cost of all future Himalayan hydel projects. Such funds could be apportioned among upper catchment authorities, which could then be required to implement EIAS and consequent environmental guarantees

One might, consider allocating, say, 10 percent of project revenue. Especially from energy for upper catchment development. It might also be desirable to set up basin or regional rehabilitation boards to plan integrated area development on a wider scale.

The immediate need for area development can be cited through a news in Hindustan Times October 30, 2000. It reads

'Apple orchards dying for lack of snow in Himalayas.' From a distance, the Central Himalayas looks as grand as ever. But come closer and you will see that it has received very little snow this year and the last, and its glaciers have receded.

Gomukh has gone back almost two kilometers. If you wait there and watch you will witness mountains of glacial ice breaking off and crashing into the waters at the mouth of the Ganga every now and then, making its source recede still further. Though there is world wide concern over global warming, our scientists seems to be worrying more about the meeting of the polar ice cap than the dwindling snow fall in the Himalayas at home ....".

7.12 RADIO ACTIVE POLLUTION

Other than the usual Biological, physical and chemical pollutants there are chances for radio active pollution in the Ganges it has a nuclear power generation plant on its bank at Narora.

Besides, the gravity of the problem is cited through a news in the Hindustan Times August 18, 2000.

"IT BP Team to Nanda Devi flagged off" "The high-altitude Nanda Devi sanctuary closed to people for two decades, may soon be opened. A 19 member Indo-Tibet Border police (ITBP) expedition to climb its 25,645-ft (7,817-m) peak was flagged off in Josi math.

This is the first expedition to be allowed here since 1981. Though four years ago an Army Engineer's team had been in the area on the hush-hush effort to locate a nuclear powered device installed with the help of American's to monitor communication in Tibet.

The device failed to function and was lost, causing concern about a possible radiation leak. Which could pollute the whole Ganga water system. Its small nuclear reactor has not been found yet ...."

7.13 GANGA TO BE NATIONAL RIVER

From the study of the laws in America and Japan we find that they have categorized their rivers on the basis of their importance to the people. In America the inter state river agreements are approved by congress. In Japan cabinet categorises class 'A' and other classes of rivers. Abstraction from class 'A' river can only be decided by the Prime Minister.

A Similar National Status is required to be given to the great river Ganga. Any decision concerned to the Ganges should be taken though mass opinion building and at the level of the highest of the Government.

7.14 MINIMUM STREAM FLOW AT POINTS OF CANALS OFF TAKE

As described in the previous paragraphs there are three major canals off take points from the river. There is a standing order of releasing 600 cusecs of water at Hardwar (400 cusecs from the barrage and 200 cusecs from Mayapur regulator). Similarly some releases are made at Madhya Ganga head works and Lower Ganga head works. These releases are not considered adequate for the river, to achieve an ecological balance these releases should be increased.

It is expected that after completion of Tehri dam there will be more water in the Ganges. This volume will be taken in at Hardwar (in upper Ganga canal) at Raolight (in Madhya Ganga canal) and at Narora in Lower Ganga canal. Besides. these some amount of water will flow downstream of Narora.

Through the study of literature "Study on probable Losses / Regeneration in River Ganga from Haridwar to Raolight while using river as a carrier of Tehri water to L.G.C. and M.G.C. during non-monsoons". It is described in that literature that.

"As per report of 1985; the water form Tehri reservoir will be utilized for intensification of Rabi and Sugarcane irrigation in the command area of L.G.C./ P.U.G.C ~~Area~~ Agra canal systems and for providing Rabi irrigation in M.G.C command.

With a view to ascertain the quantitative loss of water in river Ganga, seepage loss studies were carried out.

Also, the data regarding ground water table were collected for the period 1971 to 1973 to prepare water table contour maps and see if river is effluent or influent in its various reaches from Haridwar to Narora.

From the above study it was concluded that there is positive regeneration between Haridwar and Raolight and any significant loss could not be established.

Thus in near future it can be envisaged that after completion of Tehri dam there will be more water along the river to make the river ecologically better.

REFERENCE

1. "River training works in connection with the Ganges canal at Hardwar" By Mr. W. Ward Smith M.I.C.E (Executive Engineer, Northern Division, Ganges Canal)
2. "Sharing the Ganges: The politics and technology of River Management" – Bencrow
3. "Development of Inter State Rivers: Laws and practices in India"- N.D Gulhati president ICID
4. "River Basin Planning: Theory and practice" Edited by Suranjit. K. Saha and Christopher J. Barrow. Center for Development Studies, University College of Swansea; U.K.
5. "Climate and Development" Edited by Asit. K. Biswas, Natural Resources and the environment series volume-13
6. "Integrated River Basin Development". Edited by Celia Kirby, W.R. White (1994)
7. "Practices used in Training and control of major Himalyan River- A case study of training and Rehabilitation of River Ganga at Kanpur"-A Dissertation by M.D. Singh WRDTC, UOR, Roorkee.
8. "Modeling and control of River quality"-Rainoldi, (MC Graw hill publication)
9. "Water quality of District-Hardwar (U.P.)" publication No CS (AR) –10/98-99 NIH, Roorkee.
10. "Water quality and sediment modeling in surface waters" status report (SR-3) NIH, Roorkee.
11. "A Disquisition on the Heads of the Ganges and Jumna canals in Reply to strictures by Major-General Sir Arthur Cotton". By Col Sir P. T. Cautley.
12. "Sustainable management of water Resources- Implication for Food and Livelihood Security" M.S. Swaminathan
13. "Development of water Resources in Ganga - Brahamputra Basin"- Bharat Singh
14. "Irrigation and Drainage in the world"-Framji, Mahajan, ICIID publication
15. "Irrigation in the world"- Hitoshi Fukuda

16. "The problems of the Ganga ecosystem"- Z. Hasan IWRS Vol. 20, No-3, July 2000.

17. "Water and Wastewater: Treatment Recycle and Reuse"- S.N. Kaul (et al) Journal IAEM, Vol. 27, 79-90 (1999)

18. "Environmental Management in water Resources Projects: Indian Experience in Irrigation and power projects"- M.A. Chaitali. IWRS Vol. 11: NO 1: Jan 1991.

19. "River Gnaga from Haridwar to Rolighat while using River as a carrier of Tehri water to L.G. C and M.G. C. during Non-Monsoons" upper Ganga Modernization (World Bank) I and P Circle (W.B) Roorkee

20. "Ganga the most self-Purifying River" – D.S. Bhargava.

21. "Water Management in the 21st century" – Johan Hemessy IWRS Vol. 1-4,1994.

22. "Waste Water Management – Indian Scenario" – R. Suresh Kumar (et al) Journal IAEM Vol. 27, 109-116

23. "Water Resources Hand Book" – Larry W. Mays (MC Graw Hill).

24. "U.G.N.D Regulations" Appendix N.D. I – Proceedings of the Meeting Held at Hardwar in 1916,

25. "Upper Ganga Canal – past and present" S.P. Bhargava | S. K. Kumar.

26. "Pollution Control Strategy": D.S. Bhargava.

27. "The Role of Judiciary and Citizens in Environment Protection and Sustainable Development" – M.C. Mehta. IWRS Vol. 19 (5) No. 2 April 1999.

28. "Integrated River Basin Planning and Development some case studies" S.K. Sinha., "Water Resources Planning and Management" – Editor V.P. Singh and B. Kumar.

29. "Himalya Ganga Development and Cooperation for a Billion people" – B.G. Verghese.

30. "Encyclopedia of Religion and Ethics" – Edited by James Hastings Volume VI

31. "Water Resources planning and Management" - V.K. Sharma, Himalya publishing House.

32. National water policy (1987)