

Proposed river-linking project of India: a boon or bane to nature

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Abstract India is a vast country and is highly diversified in terms of natural resources and socio-economic setup. Moreover, its water resources are unevenly distributed in space and time. With increasing population and increasing aspiration for improved standard of living, there is an acute pressure on the demand and availability of water. Though the idea of interlinking of rivers is not a new concept in India, it had rather persisted long back as much as in other countries of ancient civilization. National Water Development Agency (NWDA) has given the real shape to the proposal of the interlinking of rivers of the country. In India the river-linking project in a sensible and scientific manner will not only allow the prevention of the colossal wastage of a vitally important natural resource, mitigate the flood and inundation by detaining flowing surface water of rainy seasons, but also ensure availability of water to drier areas; combating both flood and drought simultaneously. Moreover, this project will generate 34,000 MW of hydropower and irrigation of an additional 35 million hectares (135,135 square miles) of land. Though linking of rivers may initially appear to be a costly proposition in ecological, geological, hydrological and economical

terms, in the long run the net benefits coming from it will far outweigh these costs or losses. However, in the absence of any definite international legal framework, Bangladesh has raised objections against the project. This paper aims at looking at this long-term plan, the project proposal, its involvement and impact not only on the states of India, India as a whole, but also on its neighbouring nations which are linked with India through the waterways, and share the common climatic conditions and economic status.

Keywords River linking · Peninsular rivers · Himalayan rivers · Ganga Plain · Rainwater harvesting · India

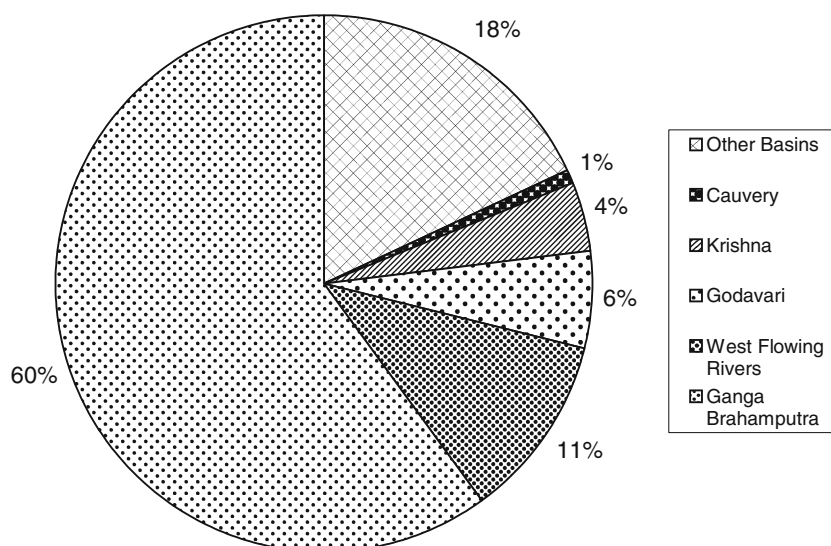
Introduction

The dense network of fluvial channels both active and abandoned, numerous types of stagnant water bodies such as lakes and ponds of varying dimensions characterizes Indian geomorphology. Their distribution is also varied in different parts of the country. The northern, north-central and eastern parts have mountainous topography and many glacially as well as ground water-fed rivers, that receive a major portion of SW monsoon, while the western India faces the water scarcity and peninsular part have mixed picture of water availability and scarcity. In India the distribution of rainfall is highly erratic and uneven over space and time. Out of the total annual precipitation, as much as 75% is received during the monsoon (June–September). A large variation in the availability of water in the different river basins of India is depicted in Fig. 1. The availability of per capita utilizable water based on 1991

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Fig. 1 Large variation in the availability of water in rivers of India (after, Patel 2004)



population varies as 182 m³ in Sabarmati, 18,400 m³ in Brahmaputra, 380 m³ in Cauvery 2,500 m³ in Mahanadi and 3,082 m³ in Narmada basins. The utilizable water available in terms of per hectare of cultivable area is 1,244 m³ in Sabarmati, 8,320 m³ in Mahanadi and 7,669 m³ in the Narmada basins (MOWR 1999). The uncertainty in the occurrence of rainfall marked by prolonged dry spells and fluctuations in seasonal and annual rainfall is a serious problem, which is being faced by India almost every year. The monsoon is the backbone of the country's economy. Some parts of the country receive more rain than the normal rainfall leading to heavy floods particularly in the Ganga and the Brahmaputra rivers affecting the states of Assam, West Bengal, eastern Uttar Pradesh, parts of Orissa and Bihar, while Rajasthan, Gujarat, Andhra Pradesh, Karnataka and Tamilnadu are the states experiencing the acute shortage of water almost every year. The worse form of the problem can be seen during summers when water availability even for drinking purposes becomes critical, not only in the drought-affected areas but also in the metropolitan cities like Delhi and the adjoining areas located in the fertile Ganga Plain where the water is not scarce at least till now, but ground water level has a continuously declining trend as a consequence of the over-drafting as compared to the recharge to groundwater. The pressure of large population makes the problem more critical. To fulfill the water demand and mitigate flood and drought, India has been planning a huge scheme encompassing the Himalayas and most of India, by linking all the major rivers through interlinking canal systems and numerous dams and barrages.

The scheme seeks to interlink the Himalayan and peninsular rivers through 30 interlinking canal systems,

of which 14 are in the Himalayan component and 16 are in the peninsular component (NWDA 1982; Shiva and Jalees 2003). The general perception regarding the proposed project is that it would greatly reduce the regional imbalance in the availability of water in the different river basins. Surplus floodwaters, which flow unutilized to sea, would be productively utilized for providing additional irrigation; domestic and industrial waste supply, hydropower generation, navigational facilities etc. This proposed project has raised a lot of controversies and debates since its formulation as such a water resources development strategy had many disadvantages and adverse impacts on the river ecosystem in countries like Russia, China, Kazakhstan, Israel and Turkey, which have taken up gigantic task of water diversions. The results are varied from country to country. Russia's ambitious project of diverting the waters of Amudariya and Syrdariya, which drained into Aral Sea, was proved to be a great success when the cotton production was top in the world. But the success soon became a bane as the cotton production declined slowly because of salt degradation by salinization (Kumar and Srinivasa Rao 2004). The climate became too hostile and hundreds of livelihood were displaced; the area became the sickest place on the earth due to pollutants blowing with winds from dry bed. One report by the World Bank says of Aral Sea, "the large-scale diversions created ecological and human disasters."

In Canada 16 interbasin water transfer schemes have been implemented for hydropower development. In the USA the longest and best known schemes implemented so far is the California State Water Project, which envisages transfer of water from the Sacramento river in North California to Southwards through a 715-

km-long aqueduct with a lift of about 1,000 m to meet domestic, industrial and irrigation demands (NWDA 1982). Similarly, in China, there are schemes existing from ancient time and recently, supplemented by modern construction techniques. Now China is also planning for a transfer of 45 BCM of water from the Yangtze River to the North China Plain.

These are the examples, which suggest that it is quite hard to predict precisely whether the implementation of proposed river linking project (interbasin water transfer) is going to be a boon or bane to nature. The present work is based on the detailed study of the scheme for sharing of water by interlinking rivers throughout the world, their different advantages and disadvantages. This study would help for the assessment of pros and cons related to the proposed river-linking project of India.

Origin of the proposal

In July 1982, the Government of India formed the National Water Development Agency (NWDA); under the Ministry of Water Resources to carry out the water balance studies on a scientific and realistic basis for interbasin water transfer link schemes in order to give a concrete shape to the linking of the Himalayan and the peninsular rivers. The initial concept was designed and proposed by the Dr. K. L. Rao and later By Captain Dastur. The present form of the project is the revision and modifications of these early proposals, carried out by many scientists and officials. These proposals include the construction of storage reservoirs to store floodwaters and interlinking of river systems through extensive canal systems for optimum utilization of available water resources. NWDA, studied in detail the water balance study for different peninsular rivers such as Mahanadi and Godavari, Krishna, Pennar, Cauvery, Vaigai, West flowing rivers of Kerala, Karnataka, north of Bombay and south of Tapi etc. These studies indicate that while the Mahanadi and Godavari basins are water surplus, other basins in Peninsular India, such as Krishna, Pennar, Cauvery and Vaigai are water deficit. Under the proposed project, 16 probable links of the peninsular rivers and 14 probable links of the Himalayan rivers are proposed (NWDA 1982), which are represented in Figs. 2, 3 in detail.

Peninsular rivers link

The peninsular river project is more vital and crucial because in the peninsular part no river is glacially fed. The water budget strongly depends upon the rainfall

(both SW as well as NW monsoon) and ground water. The project has been divided into four major parts. (1) Interlinking of the Mahanadi–Godavari–Krishna–Cauvery Rivers and building storages at potential sites in these basins. This part involves major interlinking of the river systems where surpluses from the Mahanadi and the Godavari Rivers are intended to be transferred to the more interior parts of peninsula. (2) Interlinking of west-flowing rivers, originating on the Western Ghats, North of Bombay and South of Tapi. This part will be supplemented by the construction of storage basins. The scheme incorporates water supply by canal to the metropolitan areas of Mumbai; it also provides irrigation to the coastal areas in Maharashtra. (3) Interlinking of Ken–Chambal. The scheme provides for a water grid for Madhya Pradesh and Uttar Pradesh and interlinking canals backed by as much storage as possible. (4) Diversion of other west flowing rivers to the east. The plan includes the construction of an interlinking canal system backed up by adequate storage spaces to transfer water to meet the needs of drought-affected areas. The Peninsular development is expected to provide additional irrigation of about 13 million hectares and is expected to generate about 4,000 MW of power. The proposed probable links of Peninsular rivers are:

1. Mahanadi (Manibhadra)–Godavari (Dowlaiswar) link
2. Godavari (Polavaram)–Krishna (Vijayawada) link
3. Godavari (Inchamaplli)–Krishna (Nagarjunasagar) link
4. Godavari (Inchamapally Low Dam)–Krishna (Nagarjunasagar Tail Pond) link
5. Krishna (Nagarjunasagar)–Pennar (Somasila) link
6. Krishna (Srisaillam)–Pennar link
7. Krishna (Almatti)–Pennar link
8. Pennar (Somasila)–Cauvery (Grand Anicut) link
9. Cauvery (Kattalai)–Vaigai (Gundar) link
10. Parbati–Kalishindh–Chambal link
11. Damanganga–Pinjal link
12. Par-Tapi–Narmada link
13. Ken–Betwa link
14. Pamba–Achankovil–Vaippar link
15. Netravati–Hemavati link
16. Bedti–Varda link

Himalayan river link

The Himalayan river component holds the idea of transferring water from the eastern part that is the Ganga–Brahmaputra system to the westwards covering

Fig. 2 Sixteen probable links of the Peninsular Rivers under the proposed river-linking project of India (modified after, NWDA 1982)

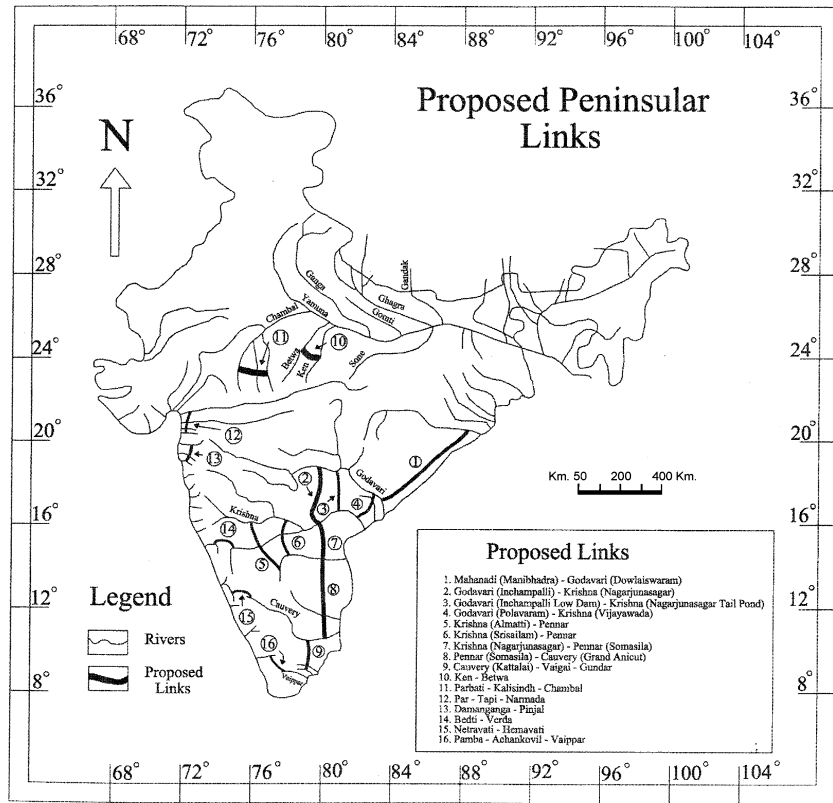
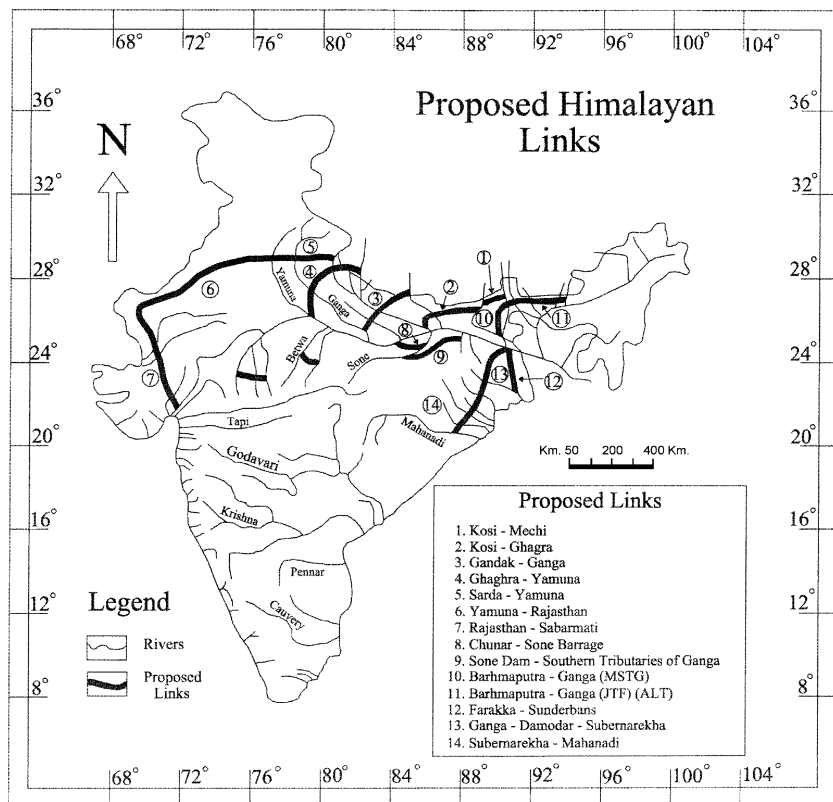


Fig. 3 Fourteen probable links of the Himalayan Rivers under the proposed river-linking project of India (modified after, NWDA 1982)



the parts of southern Uttar Pradesh, Haryana, Punjab and Rajasthan and finally proceeding towards south meeting the peninsular component. It includes the construction of large storage tanks on main tributaries of the Ganga and the Brahmaputra in India and Nepal. It calls for interlinking canal systems to transfer surplus flows of the eastern tributaries of the Ganga to the West. It also proposes to link the main Brahmaputra and its tributaries with the Ganga, and the Ganga with Mahanadi. Dasgupta (2004) has proposed that this component would provide an additional irrigation of about 22 million hectares and would raise the ultimate irrigation potential from 113 million hectares to 148–150 million hectares facilitating the generation of about 30,000 MW of hydropower, besides providing flood control in the Ganga–Brahmaputra basin. It would also provide the necessary discharge for augmentation of flows at Farakka required inter alia to flush Kolkata Port and the inland navigation facilities across the country. The proposed Himalayan river links are:

1. Kosi–Mechi link
2. Kosi–Ghaghra link
3. Gandak–Ganga link
4. Ghaghra–Yamuna link
5. Sarda–Yamuna link
6. Yamuna–Rajasthan link
7. Rajasthan–Sabarmati link
8. Chunar–Sone Barrage link
9. Sone Dam–Southern Tributaries of Ganga link
10. Brahmaputra–Ganga link (Manas–Sankosh Tista–Ganga)
11. Brahmaputra–Ganga link (Jogighopa Tista–Farakka)
12. Farakka–Sunderbans link
13. Ganga–Damodar–Subernarekha link
14. Subernarekha–Mahanadi link

The annual volume of water transfer from the peninsular rivers is represented in Table 1 and shown in

Fig. 4. While Table 2 represents the surface water resource potential in the river basins of India.

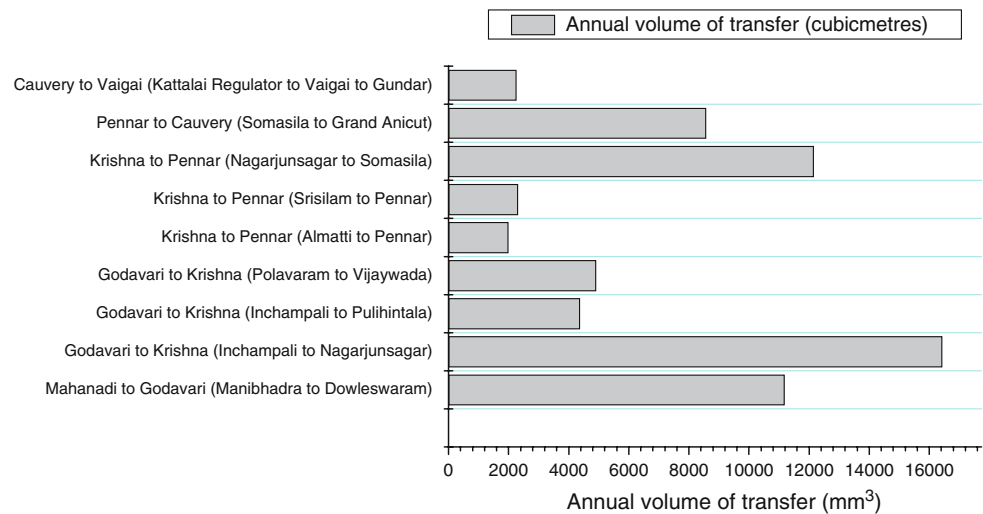
Water resources and hydrological issues

India has a vivid scenario of water resources. The country has a highly seasonal pattern of rainfall, with 50% of precipitation falling in just 15 days and over 90% of river flows occurring in just 4 months. The Indian mainland is drained by 15 major (drainage basin area > 20,000 km²), 45 medium (2,000–20,000 km²), and over 120 minor rivers (< 2,000 km²) rivers, besides numerous ephemeral streams (Sharma and McCornick 2006). There are several worries over the surplus basin identified for the river-linking project. The very fact regarding the issue is the amount of the surplus water, which occurred only during monsoon while the rest of the year they also suffer more evaporation than precipitation thereby receding the water budget. The adequate rainfall during monsoon months serves the need for the period of nonprecipitation and sustaining the growth of crops. It is worthwhile to mention that the Indian subcontinent is tilted towards east and most of the rivers in the northern part of the country as well as in peninsular part flow with general trends towards east and southeast, sinking their load in the Bay of Bengal. To supply water in the western part by linking these rivers will need the extra effort for working against the general slope. Besides these issues, one major threat is the serious contamination of river water bodies in many ways if they are connected with each other through canals and water grids. If it happens the resulting scenario will be beyond imagination. Moreover, a great part of population resides in the villages and rivers are the main source of serving their drinking and daily household needs as well as flushing out the human and animal wastes that are not adequately managed and treated. Most of the Indian rivers are seriously suffering from widespread fecal and

Table 1 Annual volume of water transfer from peninsular rivers (source: MOWR 1999)

Name of link	From river	To river	Annual volume of transfer (mm ³)
Manibhadra to Dowleswaram	Mahanadi	Godavari	11,176 (6,500)
Inchampali to Nagarjunasagar	Godavari	Krishna	16,426 (14,200)
Inchampalli to Pulichintala	Godavari	Krishna	4,371
Polavaram to Vijayawada	Godavari	Krishna	4,903 (3,305)
Almatti to Pennar	Krishna	Pennar	1,980
Srisaillam to Pennar	Krishna	Pennar	2,310 (2,095)
Nagarjunasagar to Somasila	Krishna	Pennar	12,146 (8,648)
Somasila to Grand Anicut	Pennar	Cauvery	8,565 (3,855)
Kattalai Regulator to Vaigai to Gundar	Cauvery	Vaigai	2,252

Lower figure in the bracket shows the quantity of water reaching the recipient river

Fig. 4 The annual volume of water transfer from peninsular rivers**Table 2** Surface water resource potential in the river basins of India (source: MOWR 1999)

S. no.	Name of the river basin	Length (km)	Catchment area (km ²)	Average annual potential (km ³)	Estimated utilizable surface water (km ³)	Present use of surface water (km ³)
1	Indus (up to border)	1,114	321,289	73.305	46.000	40.00
2	a) Ganga	2,525	861,452	522.803	250.000	–
	b) Brahmaputra at Jogigupta	916	194,413	537.322	24.000	–
	c) Barak and other rivers flowing into Meghna like Gomti, etc.	–	4,1273	48.357	–	–
3	Godavari	1,465	312,812	111.348	76.300	38.00
4	Krishna	1,401	258,948	23.500	58.000	47.00
5	Cauvery	800	81,155	21.594	19.000	18.00
6	Pennar	597	55,213	6.741	6.741	5.00
7	East flowing rivers between Mahanadi and Pennar	–	–	22.520	13.110	–
8	East flowing rivers between Pennar and Kanyakumari	–	–	16.453	16.453	–
9	Mahanadi	851	141,589	66.879	49.990	17.00
10	Brahmani and Baitarni	799	30,033	30.044	18.297	N.A
11	Subernarekha	–	–	12.748	6.813	–
12	Sabarmati	371	21,674	3.355	1.925	1.80
13	Mahi	583	34,342	11.020	3.095	2.50
14	West flowing rivers of Kutch, Saurashtra including Luni	–	–	15.098	14.980	–
15	Narmada	1,312	98,796	46.039	–	–
16	Tapi	724	65,145	14.879	–	8.00
17	West flowing rivers from Tapi to Tadri	–	–	87.411	11.936	–
18	West flowing rivers from Tadri to Kanyakumari	–	–	113.532	24.273	–
19	Area of inland drainage in Rajasthan Desert	–	–	–	–	–
20	Minor river basins draining to Bangladesh and Burma	–	–	31.000	–	–
	Total			1,875.948	688.913	

organic matter contamination. If the rivers are linked with each other the condition will certainly worsen and the rivers that are now less contaminated with organic matter may suffer more. Moreover, the fecal contam-

ination seriously affects the use of water as a drinking water source or bathing, as well as the ecological health of the river. Several reports and researches are continuously alarming the increasing level of pollution in

the rivers and now most of the rivers in India have heavy metals and organic toxic pollutants. These pollutants enter into the river by diffused as well as point sources. In case the major rivers like the Ganga and Yamuna, highly polluted rivers that pass through large towns and cities, are linked up with the less polluted rivers, the entire country may suffer from severe river water pollution effects. We are discussing here the various aspects and their intriguing relationship between themselves and to this project.

Hydrological aspects

The proposed river-linking project has many impacts on environment and neighboring countries like Bangladesh and Nepal. Bangladesh has already shown strong protest against this project. The impact on environment is directly related to the country's health because ultimately it is the welfare of human beings, which is interrelated with all the components of environment. Withdrawal or diversion of water in the upstream will directly affect the hydrosphere which being linked with the lithosphere and the atmosphere will imperatively cause tremendous effect in it. Biosphere being dependent on atmosphere, the lithosphere and hydrosphere will be affected as well.

The hydrosphere scenario will be directly affected due to a dramatic reduction in the quantity of water in the major rivers. This reduction in quantity will bring immense effect to other sectors related with hydrosphere. The affected sectors are discussed below.

Water supply

The picture of water supply of the whole country is going to change by transferring the 'surplus water' to 'water deficit areas'. The concept of 'surplus water' is itself faulty, as a reduction of surplus/flood water will affect the surface water supply in terms of quantity and quality as well. India has an average annual flow of 1,869 billion cubic meters (bcm) of which 1,122 bcm is useable, distributed seasonally during the monsoon period (Environment News Service 2003). In India per capita availability of water has reduced from 6008 CuM to 2266 CuM since 1947 to 1997 (Bandyopadhyay 2004). To bridge the gap between continuously increasing demands and supply of freshwater, this surplus water is proposed to be utilized. Though the above picture appears to be quite beautiful but at the same time the other side of the plan may cause increase in the cost of water finally raising the costs of living. Reduction in the quantity of surface water will also cause reduction in ground water, i.e., lowering of

ground water in one area, hampering the irrigation, and in other areas causing the problem of water logging again affecting the crop yields. So either cost of production will be high or productivity will be reduced. Farmers will be directly suffered. They will either change their profession or will migrate elsewhere. Generally, migration takes places to the cities or urban areas. If these migrated people cannot be provided with any sort of job then social crime will increase and law and order situation will deteriorate. Furthermore, rapid migration will bring tremendous pressure on the service sectors of urban areas. Though there are no doubts that the estimated grid of approximately 40,000 km link ways is quite fanciful for alleviating the water scarcity, in the absence of any detailed feasible and impact studies the benefits are also suspicious.

Salinity

Majority of the rivers of the Ganga Plain and Northeast India originates from the Himalayan mountain ranges where there is generally high precipitation. Usually, in the mountains the concentration of total dissolved solid is low and most of the rivers flow through arid or semi-arid regions of the Ganga Plain. In such situations especially in their lower reaches the concentration of salts through evaporation rises steadily with distance downstream. If the proposal of interlinking of rivers is considered for implementation and the part of the flow is diverted for other rivers or canals for irrigation, the salt concentration could be escalated by evapotranspiration and it will increase the dryland salinity. Increase in dryland salinity especially in the Ganga Plain could affect the water quality, natural ecosystems and biodiversity. Moreover, the decrease in the flow of the rivers falling into the sea could cause saline water intrusion in rivers. Under such circumstances there could be increase in the salinity intrusion in the Ganga Plain, Peninsular regions of India, in south-center and north-east region of Bangladesh. Further the huge freshwater influx from the rivers in the Bay of Bengal lowers the salinity of sea surface thereby maintaining the monsoon circulation (Rajamani et al. 2006). Impoundment of large water may also affect this coupled relation between salinity and monsoon.

Geological aspects

Lithological constrains

It deals with the rock materials of earth surface particularly the soil and the landforms. As we know that soil is the final product of weathering of the rock

materials as a consequence of interactions among climate, plants, microbes animals. Pedogenesis reflects the nature of source material, its climatic, topographic and biological factors of an area. Water is again in turn the main factor behind all these parameters. Therefore, any imbalance in the hydrological cycle imparts negative impact on climate, plants, animals and microbes present in its basin.

The majority of the portion of the Northwest India is facing the problem of inland salinity. The prevailing arid to semiarid climatic conditions in these areas are enhancing the calcrete formation within the soil and thereby escalating the inland salinity leading to dying of entire vegetation cover. It is expected that the interlinking of rivers in these areas will prevent the escalation of inland salinity and vegetation cover.

Sedimentation

Most of the rivers in India are characterized by their small bed slopes and shallow but very wide sections. After entering in the foothills they abruptly loose their gradient thereby reducing the flow velocity, erosive capacity and sediment-carrying capacity. As a result, the major rivers like the Ganga and Brahmaputra carrying enormous sediment budget deposit their sediment load on the riverbed and flood plains. This is the nature's blessing for this region forming the vast Indo-Gangetic alluvial plains. The sedimentation on the flood plain forms the natural soil, increases the fertility of the soil, and makes raising land. These sediments often carries undesirable nutrients, contaminants and hazardous chemicals which may have serious detrimental impacts upon other rivers connected. Moreover, it could affect the sustainable use of the fluvial environments (floodplains and fish spawning grounds).

The interlinking of rivers may cause large reduction in the sediment deposition, which could affect the natural land upgradation process on the flood plains for cultivation carried out by river. Moreover, it could retard the formation rate of emerging islands along the southern coast of Bangladesh.

River regime

There are large differences in river regimes of the Himalayan and the peninsular rivers and topography. Moreover, these areas are distinct in terms of geomorphology, geology, hydrology, climatic conditions and precipitation. All these factors show their combined effect on the river regimes. Most of the rivers in the Himalayas originate from the glaciers, the Himalayan Rivers and the groundwater-fed/perennial rivers

and their regimes are dependent on the pattern of water supply both from the snowmelt as well as the rainfall. The regimes of the Himalayan rivers is monsoonal as well as glacial while that of the groundwater fed perennial rivers of peninsular part are only monsoonal as they are controlled by rainfall alone. Therefore, many peninsular rivers have low volumes of discharge from January to June, which suddenly rises in August and September, when the rainfall is maximum. This ambiguity in the regimes is also responsible for the extreme floods and drought in the different parts of the country at the same time.

Geogenic problems

Many rivers in their course pass through different types of terrain having entirely different geology and have inherited some geogenic problems. One such example is the problem of arsenic in ground water and surface water affecting the parts of Kolkata and the adjoining districts, parts of Rajasthan and Andhra Pradesh, and fluoride contamination in the Rajasthan, Uttar Pradesh, Andhra Pradesh, Haryana and Karnataka. These two pollutants enter into the water resources of the area due to the geological constraints imposing serious threat to the health of humans and animals. Techniques so far implemented in these affected areas have not been successful to supply the pollutant-free water to the majority of the population. If these areas are connected with the water grid and canal it seems possible that the still localized problem will affect much greater part of the region.

Hydrogeological aspects

In India the geographical distribution, geological formations, ground water occurrence and groundwater quality show large variations throughout the country. Majority of the portions of North West India, the Ganga Plain and some portion of North East India belongs to unconsolidated formations, mostly composed of younger to older alluvium, sands, gravels and laterites. The recharge and storage of water underneath the surface are due to the rainfall and favorable hydrogeological conditions. The alluvium parts recharge more groundwater than other formations. From hydrogeological point of view, the entire Ganga Plain constitutes a very good to good groundwater-bearing zone. In such formations the groundwater occurs both in unconfined and confined conditions in the intergranular pore spaces. Generally, the gravel and sand constitute good quality aquifers in these areas. In case of the implementation of the river-linking project, these formations would

strongly support recharge, infiltration and percolation of water. This will stop or decrease the plunging of water table in these areas. Moreover, the recharge from surface water will improve the groundwater quality but the groundwater quality problems in the coastal and deltaic areas remain same due to the inward movement of marine water. There will be no impact on the saltwater intrusion problems along the coastal areas. It can be reduced only by preventing the over drafting of the groundwater

The majority of the portions of the Vindhyan basin, Cuddapah–Kurnool basin, Chhatisgarh basins and Western Rajasthan basins are composed of crystalline rocks. These formations belongs to Pre-Cambrian to Palaeozoic age and are generally composed of sandstones, limestones, shales, slates, quartzites and conglomerates. These types of formations are usually compact and have the cementation property with extremely low porosity and permeability. The groundwater recharge in these areas through interlinking of rivers will be minimum. It will totally depend upon the faults, joints, fractures, dikes and other secondary openings. Thus, it would be necessary to ensure the maximum utilization of river and surface water by making good canal network in these areas.

In India the large portion of the states of Maharashtra, Andhra Pradesh, Karnataka, Gujarat and Madhya Pradesh belongs to the Deccan trap. These traps composed of a series of horizontal basaltic fissures, which are highly weathered, fractured and jointed. These formations have extremely low or almost nil porosity and permeability. These formations do not support infiltration or percolation of water and usually the nature of aquifers is confined to unconfined. The impact of the proposed river-linking project on groundwater in these traps is largely depending upon the nature of traps (vesicular or zeolites or massive), the intensity of jointing/faulting and the degree of weathering. The proposed project might be proved worthwhile to these areas as a majority of the portion is facing drought-like condition due to low precipitation.

This is imperative that before the implementation of this project its impact on the hydrogeological provinces of India should be studied in detail. As India is highly distinct hydrogeologically, therefore the impact of this project would be distinct throughout the country.

Miscellaneous aspects

Impact on climate

Owing to its unique geography India is witnessing the extreme climate events almost every year: the floods,

droughts, cyclones, snow avalanches, etc. Moreover, the temperature range is also very wide of having over 45°C during May–June and as low as near 0°C during winters. The warming trend over India has been reported to be 0.57°C per 100 years (Rupkumar et al. 1994). Recent decades have experienced the unexpected pattern of rainfall; the eastern parts have suddenly become more and more wetter, (Singh and Sontake 2001) and the number of rainy days during monsoon has declined in the past decade. Apart from these the complex and coupled situations necessary for the onset of monsoon (ENSO, Bay of Bengal Salinity, and Differential heating of Tibetan Plateau) and receding glaciers of the country may greatly affect the future scenario of this project. Keeping this inconsistent scenario of rainfall in mind, it is important to look at the construction of large storage and checking the natural flow of the flowing water.

Impact on environment and ecology

Environmental deterioration is likely to occur by such a massive project. No detailed and feasible plans are seemed to be taken into account. Many environmentalists (in various magazines and press releases) are of opinion that the proposed canals and reservoirs would cut across the areas protected for wildlife. This will threaten tigers in western India, elephants in east and west, wild buffaloes in central India and destroy the habit of the Great Indian bustard. Similarly constructing the reservoirs of thousands of hectares will submerge the agricultural as well as the forestland. This is an additional indirect cost besides the deforestation due to the construction of engineering structures. The rich biodiversity of the country will be on the great risk by long continued construction program thereby affecting their natural habitat. Many species are already in the endangered stage and this interference will jeopardize them.

India's continuing search for irrigation water is expected to be further drying out the Sunderbans, the world's largest coastal forest, shared by India and Bangladesh. "The forest needs freshwater to survive" because the Farakka dam fresh water is not reaching there and the rivers are silting up rapidly (Mail and Guardian, 24, July 2003). The Farakka barrage was built across the Ganga 11 miles from the Bangladesh border in 1974. According to the Bangladesh Water Development Board (BWDB) the Farakka dam had reduced by half the water that once flowed via the Ganga into the Bangladesh and parts in the Bangladesh are turning into a desert, rivers have lost their navigability, and saltwater is intruding into farming

areas. The insufficient water in the common rivers is causing various problems, ultimately affecting the economy as well as the environment in Bangladesh. The general perception of the Bangladeshi water experts, social scientists and experts on geography is that if India builds a water grid line to shift from the northern region to southern region, it would be disastrous for Bangladesh and the country will be deprived of surface water drastically.

Restriction of flow and long-span storage of such enormous water would cause the problem of waterlogging. In the areas of average rainfall and shallow water table the waterlogging will result in a decline in the agriculture production. Since the most important agricultural belt of the country is the Ganga Plain, characterized by the silty-sandy topsoil over the water holding clayey soil, the waterlogging will result in food scarcity.

Impact on Nepal and Bangladesh

Bangladesh has raised major objections over the proposed river-linking project. Bangladesh, which is one of the densely populated countries of the world, has a predominantly agrarian economy and agriculture accounts for about 60% of the gross domestic products. Bangladesh government and the scientists think that 10–20% of reduction in the water flow to the country could dry out large areas. More than 85% of the people of Bangladesh live in rural areas and nearly 75% are engaged in agriculture, grow rice and depend upon the water that has flowed through India. Since the independence Bangladesh has a target to increase the food grain production and the agricultural investments are an important part of the overall development program (Rogers et al. 1989). The topography of the Bangladesh is extremely flat and in case India moves forward on the interlinking project then Bangladesh may have

to build a canal network system to irrigate large areas, at the moment, which are naturally fed by the Brahmaputra River. It could be a Herculean job and further it would cost a huge amount of money. Moreover, this project would dry out the Sundarbans, which is a world heritage site shared by India and Bangladesh.

Although Nepal government has not raised any major objection on the project, it would also have some implications for Nepal. The fact is that the Nepal government has still not taken any stand on the project. Both the Nepal and the Indian governments have started discussion over the construction of dams under the Himalayan component of the river-linking project. Moreover, both the countries have discussed on the Bagmati and Kamala storage dams. In case the project is considered for implementation, Nepal would have to bear 50% expenses of the same. Being a poor country with a population of 23 million (2001 census), political instability, high unemployment rate and inflation, it would be extremely difficult for Nepal to invest in such a large project.

Table 3 shows the average annual discharge of the nine large and medium rivers of Nepal, which is 5,675 cumecs. From 1949 to 1973 average annual discharge of the Ganga at Farakka was 12,105.4 cumecs, which means that the Nepalese rivers contribute a significant 47% of the annual average flow of the Ganga at Farakka. If one is to again compare the average flows of the three lean months (March, April and May) of the Nepal flows (1,442 cumecs) with that of the Farakka flows (1,917 cumecs), this gives an astounding 75% (Thapa and Pradhan 1995). The construction of dams on these rivers could extremely reduce the discharge of the Ganga, which would affect the discharge of all the tributaries of Ganga in marginal and central alluvial plain (the Ganga Plain). Further, it would highly affect the rabi crops and hydrological pattern in the entire Ganga alluvial plain.

Table 3 Average monthly and yearly flows in cubic meter per second of the four major rivers and five medium rivers of Nepal (source: Thapa and Pradhan 1995)

River name	Average years	Jan	Feb	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Average discharge (cumecs)
Mahakali		167	156	156	149	182	266	560	1,579	1,332	1,489	577	227	198	658
Karnali	1962–1986	370	335	335	348	445	702	1,520	3,290	4,370	3,020	1,320	632	446	1,410
Babai	1967–1985	19	15	15	13	10	15	56	222	241	232	95	36	23	82
West Rapti	1964–1985	28	23	23	18	14	15	93	298	388	355	147	57	33	123
Narayani	1963–1985	351	286	286	264	348	568	1,610	4,210	4,970	3,420	1,600	790	492	1,590
Bagmati	1965–1979	19	17	17	15	17	32	214	539	513	338	137	51	27	161
Kamala	1957–1969	7	5	5	4	3	8	46	130	160	102	45	17	11	45
Saptakoshi	1977–1985	364	315	315	318	424	705	1,660	4,110	4,340	3,460	1,460	795	501	1,550
Kankai	1972–1984	12	9	9	8	11	21	72	198	145	106	51	23	15	56
Total		1,170	1,005	988	988	1,272	2,066	5,271	12,997	15,127	11,033	4,855	2,401	1,548	5,675

Need and alternate solutions

The basic human requirement of water for drinking and keeping alive per person is just 2.5 l a day. India is not badly off when compared to many other parts of the world with respect to water availability. The average amount of rainfall received over the plains of India is 117 cm as against the global average of only 70 cm (Radhakrishna 2003). It means we are much benefited in terms of availability of water; the only important thing is to utilize it judiciously. There are a number of ideas have been given time to time by various workers, and still waiting for proper implementation. We are discussing here a few alternate solutions to mitigate the water crisis and merely their incorporation and implementation will improve the situation up to a significant level.

Rainwater harvesting

Rainwater harvesting is a freshwater augmentation technology and most popular terminology nowadays regarding the water resources management. It simply deals with the collection of falling rainwater and allows it to percolate beneath the ground to improve the storage capacity of aquifers and thereby recharging them. Though the idea is not very new rather it had been in practice since the ancient time as revealed by many ponds, ditches and ducts. The most obvious way to preserve as much rainwater as possible is to impound it where it falls. The technique has great potential for conserving water; as often the results are directly visible by enhancing the groundwater table in comparatively short time. In India it has gain the boost in the last decades only with the constant support of an NGO, Center for Science and Environment studies (CSE). In the last three to four decades the many fold increase in the population leading to land pressure has forced the dumping off the ponds and depressions and subsequent utilization of that land as residential or industrial purposes. Now the increasing awareness and need has motivated to adopt the rainwater-harvesting program, run by the support of both government as well as nongovernment sectors. By far the greatest potential for increased recharge lies in the installation of rainwater-harvesting systems in buildings of all kinds: public and private; residential and nonresidential; single storied and multistoried (see <http://www.rainwaterharvesting.org>). The roof top catchment technique is well suited for the urban areas, while the surface water catchments are more suitable in the rural areas. However, a strict policy is still needed to make it obligatory for the builders and the projects that with-

out having such proposal it should not be passed for construction.

Prevent water wastage

Nowadays it has become imperative that everyone should care about the use of water and prevent its wastage, the efforts should be carried out on domestic, irrigational and industrial levels. In urban areas mostly luxury hotels waste large amounts of drinking water in swimming pools. Most people are in regular practice to keep the tap water running while carrying out the daily household activities. As a result gallons of drinking water are wasted. There is an urgent need for an awareness program to reduce such colossal loss. A large amount of potable water is wasted following the old traditional way of irrigation. We can check this water by adopting modern available techniques, which are also economical like the use of drip irrigation and sprinklers. Radhakrisna (2003) have also advocated that the use of pop up and mini sprinklers can be run from a timer allowing irrigation in the early hours, when the air is still and cool reducing the evaporation losses. Likewise, the canal linking or water pipes will increase the water delivery as well as its efficiency in the canal system use for irrigation. Moreover, the water soil, moisture and other agricultural resources should be configured to modify the agricultural pattern, crop pattern and water-using pattern in farming, forestry and fishery. Farmers should be encouraged to grow crops with low water and high added value.

Controlling the excessive withdrawal of ground water

The continuously falling water table is posing a great risk of low yields of water. All over the country people are using the boreholes, and dug wells causing the overdrafting of water. The culmination of overdraft is complete depletion of groundwater reserve. Shallow wells go dry and springs and streams lose their water. This excessive withdrawal often causes the encroachment of the saline water in the coastal areas Therefore, a detailed and systematic study of the behavior of water table in the well fields its relation to rainfall, extraction and regulation is necessary to overcome and regulate this problem.

Recycling and reuse of wastewater

The natural water cycle or hydrological cycle is the best example of recycling and reuse of water for millions of years. Water used for bathing, washing and

toilets as well as that used by industries and power generation plants return to the hydrological system as wastewater and effluents. This water can be recycled and reused for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing and recharge of groundwater; further it will substantially reduce the volume of fresh water needed to meet the growing demand. More promising is the recycling of water in industrial and thermal power units. The potential contribution would be much more if large public and commercial building complexes are persuaded to install recycling plants for their wastewater in situ and to use the output for toilets, gardens and other nonpotable consumption.

Use of natural geomorphology for recharging ground water reservoirs

India is blessed with numerous and varied type of water bodies. Many of these features such as small channels, lakes and ponds have become abandoned, and remain dry during most part of the year, except during monsoon when they behave as active channels. The water flowing/captured in these abandoned water bodies has great potential for recharging. Only skills have to be developed for arresting rainwater where it falls and allowing it to recharge the groundwater reservoirs. Afforestation of catchment areas, contouring, leveling of land, creation of farm ponds and check dams across small streams and gully-plugging are measures aimed at arresting the flow of water on the surface and directing its infiltration and percolation (Radhakrishna 2003). There is no dearth of easily and economically feasible artificial groundwater recharge techniques. By the use of these techniques the recharge of groundwater reservoir is possible both in consolidated and unconsolidated formations. Furthermore, emphasis would be given on the formation of small watersheds, as it can be initiated at low cost.

Efficient management of floods

In Eastern India especially the parts of Assam, Bihar, West Bengal and Uttar Pradesh have experienced the extensive flooding almost every year during the monsoon periods. The Brahmaputra, Ganga, Rapti and Kosi are some of the major rivers responsible for flooding in these states. According to an estimation of the Planning Commission, about 50 million hectares of land is flood prone. The efficient control of the flood in these areas will solve the problem of water scarcity in the other areas. These can be achieved by constructing the diversion canals, check dams and storage reservoirs.

Encourage and educate the common man

The water conservation education is one of the most important lessons that should be taught from primary school level. Water conservation should not be just for the adults, it would be for the young people and children too. It is important that children become responsible adults, who can make logical decisions that will result in sustainable water supply for the future. However, to achieve this goal the first essential step is to involve the active participation of the common public and make them aware by launching large-scale public education and information campaigns. The second step as also suggested by CSE, is to introduce policies (operating primarily through appropriate pricing of water) to create strong incentives for users to adopt such practices/devices. The CSE and other NGOs are constantly promoting such programs and activities independently of government agencies, for several years. Some of the leading activists in this field are now a part of the National Water Harvesters' Network established under the auspices of the CSE. The members of the Network have made a sustained effort to spread awareness about the potential of rain water harvesting through media interactions, public lectures and organizing exhibitions in the city and outside.

River linking versus rainwater harvesting

So far we have discussed the various impacts and alternate solutions to combat the water scarcity. It is obvious and more likely that in future we do not have any other options but to depend on the large-scale desalination of seawater for our freshwater supply. Moreover, a world war over freshwater is also possible as the world's population is continuously increasing and the stock of freshwater resource is finite. In such circumstances the practice of rainwater harvesting routinely and efficiently, as a society, is a better option. As the river-linking project may be seen as the large-scale national and international efforts towards rational distribution and management of freshwater reserve; then the rainwater harvesting can be considered as a micro- or mesoscale societal efforts for the same goal because of the high degree of complimentary between the two.

No doubt river linking is a brilliant idea but the translation of the idea and thereafter its maintenance and management are economically and easily not feasible, as a developing country India could not bear the losses if this project does not perform as expected. Thus it is imperative to study the various aspects of this project thoroughly and suggest modification explaining

the reasons in order to minimize the probability of the any possible mishap.

India has enough water for its more than 1 billion population. According to the various gathered facts every Indian had an estimated (approx.) 2,400 m³ per year and as we have already pointed that the basic human requirement is of just 2.5 l a day. The average rainfall over the plains of India is 117 cm and this annual precipitation amounts to as much as 370 million hectares meters of water, which is adequate for our requirements. So the prime objective should be to harvest this water by community-based initiatives. For this CSE has recommended the creation of 1-ha plot in every village which can store up to a million liters of water. Moreover, the gross investments will be quite low as compared to river-linking project.

Thus instead of indulging in such a fanciful scheme and the disastrous consequences, it would be more sensible to encourage the traditional practice of conserving rainwater and give more emphasis on alternative solutions. Apart from the rainwater harvesting some of the other probable solutions suggested by various workers to the problem are prevention of water wastage, utilization of groundwater in deltas, recharging groundwater reservoirs, efficient management of monsoon water, enhancing the public awareness, etc.

Advantages and disadvantages

There are many projected advantages and disadvantages of this proposed river-linking project in different sectors which are going to play a major role in all the decisions related with this proposed project. Some of these are discussed here.

Agriculture sector

It is expected that the proposed interbasin water transfer will immensely increase the agricultural production. According to the task force on the interlinking of rivers 2004, the benefits in agricultural sector could be 25 million hectares of irrigation from surface water, 10 million hectares could escalate by the use of groundwater, totaling of 35 million hectares. After the implementation of the project most of the drought-prone areas would gain more sources of water either by canals or wells and the farmers could start tilling previously dry lands. But it is not necessary that increased irrigation means an increase in production because India was ranked poor in production as compared to the other countries despite 45,704,000 hectares of land under irrigation (Ministry of agriculture 2004). Thus it

is imperative to change the prevailing pattern of irrigation to increase the production and hence escalation in the budget.

Power sector

India has the capacity to generate around 84,000 MW of hydroelectric power but presently it is generating only 22,000 MW. It is expected that after the implementation of this project India will be in a position to generate around 34,000 MW of hydroelectric power through the dams proposed under the project; moreover, the hydropower is a renewable and green energy source, so it can be regenerated and reutilized. “The International Hydropower Association maintains that its use has saved a consumption of 22 billion tonnes of oil” (Dev Goel 2005). But still it is hard to predict precisely as interbasin transfer of water will itself require large quantity of power for lifting of water. In addition large number of people would be displaced due to the construction of large storage reservoirs and canals. Moreover, several thousand square kilometers of cultivated area and forestland would be submerged.

Drought and flood mitigation

Drought mitigation and flood control is one of the major objectives of the proposed project. The flood control is a process that promotes an integrated rather than fragmented approach to flood management. It will require the detail study of water quantity, water quality and the process of erosion and deposition. This proposal does not contain plans of such studies. Further studies on the land use changes on the various elements of the hydrological cycle should be taken into consideration. Flood control plans should be intertwined with the drought mitigation by transferring water from “surplus” to “deficit” areas. The objective of complete drought mitigation cannot be achieved as it will be hard to cover all the parts of drought prone areas. Thus the plan of complete mitigation of drought can only be achieved by the implementation of rainwater harvesting and artificial groundwater recharge schemes on a large scale.

Inland navigation

The proposal of inland navigation will definitely lessen the heavy traffic on the road, and save the fuel and also serve as a good source of revenue. However, if all the rivers and canals would be open for full commercialization the very fact of more pollution in the surface waters cannot be ignored owing to our life style.

Besides this problem another issue is that the heavy traffic on the rivers would impose a negative effect on our biodiversity specially on the reserve of freshwater fish. If we put these drawbacks aside for a while, the willing power of the government and officials to remove our major rivers pollution free is also questionable. For example the Ganga River Action Plan, came into existence in 1986, to clean up the river has completed its first phase only recently in a time span of about 20 years. Similarly the Yamuna Action Plan (the river Yamuna is the second major river after the Ganga, and also flows through the highly populous area like Delhi) implemented in 1993 has completed its first phase but the river water has become blacker and mass mortality of fish has now happened to be a common news. It is obvious that traffic in these mighty rivers will prove to be a disaster than the supposed benefits.

Operational and maintenance cost

According to the National Water Development Agency (NWDA) estimated budget for the entire project would be of US\$ 112 billion at 2002 prices. However, as in the case of other projects, it is supposed that the cost will go up to US\$ 200 billion, that too if the project would be completed within the given time limit, and any delay and extension in the project will surely further increase the cost. Besides these estimated expenditures, other indirect expenditures as the maintenance of dams, desilting reservoirs, relining canals and creating artificial drainage where needed will enhance the cost to a great extent. Moreover, that is when the irreparable loss to environment, ecology, biodiversity and social costs have not been taken into consideration. The estimated cost itself represents 20% of India's Gross Domestic Product, 2.5 times the annual tax collection; 2 times the foreign exchange reserves and equals the amount spent on irrigation in the last 44 years (The South Asian 2005). According to the Government's Economic Survey for 2001–2002, this amount is higher than the gross domestic savings, and also the total outstanding external debt of the country. It is not yet very clear that from where such enormous fund would be raised and ultimately it would be the people of India who will bear the burden and debts of this project for a very long time. Therefore, it is highly impracticable to complete such a huge project by 2020, when already so many projects are incomplete and pending.

Rehabilitation

The project of this magnitude will certainly displace millions of people. Thus there should be a concrete

rehabilitation policy, in which the displaced people should be provided the agricultural land and livelihoods. Further laboring people in the agricultural and nonagricultural sectors losing their livelihoods should be provided some compensation for at least 1 year of minimum agricultural wages. More importance should be given to the minimum displacement of persons and identify nondisplacing or least displacing alternatives as there is enormous land pressure and dearth of productive lands. Further the government should make a minimum interest or without interest loan policy for the displaced persons, which will facilitate them in regaining their old lifestyle and improve their living standards. We lack a proper rehabilitation policy as a result severe problem arises during the projects as in the case of Narmada dam the rehabilitation matter is a burning issue at present. After so many years of the project proposal and partial implementation, people are still fighting for their land and livelihoods (see <http://www.narmada.org> for a detailed report). Similarly in the case of Tehri dam, according to the PUCL bulletin report (2004), "the dam affects one town (Tehri), 37 villages fully and 88 villages partially. The urban families to be fully affected are 5,291. Partially affected rural families are 4,278. Rehabilitated rural families are 2,473. Rural families still to be rehabilitated are 2,539. It may be noted that families to be partially affected are not to be rehabilitated. They are to be compensated in cash for the land acquired from them. Those qualifying for the compensation are 4,278 persons, but only 214 persons have been compensated. It may be noted that the Tehri Dam will submerge 5,200-ha land". It has been estimated that large dams have displaced 21–56 million people over the past 50 years in India, 40% of them tribal people. Less than 50% of those displaced were rehabilitated. The submergence of land has been two to three times of that originally estimated in these projects.

Employment

Implementation of interlinking project will require huge manpower for the construction of dams/reservoirs, canals, tunnels, cross drainage structures, power houses, etc. These construction activities would enhance the demand of excessive construction material and equipments leading to massive industrialization in the related fields, resulting in enormous increase in employment opportunity. According to TILFR the employment in rural sector, labor force will give boom for generation of employment opportunities.

Conclusion

It is obvious that water is essential for sustaining the life on the planet earth and all kinds of socio-economic developmental activities. Rapidly developing countries like India, already suffering from the increasing population and shortage of all kind of natural resources including the water, need such a mammoth project to combat the water scarcity. The planning and management of water resources is optimal, and its economical and equitable use has become a matter of the utmost urgency. Many proposals put forward by many authorities and workers admit the view of such project and justify it as an approach towards the development. However, before implementing such a huge project many mini and microprojects incorporated therein need to be visualizing each and every dimension, as it is going to change the geography of the whole country. Many experts are of opinion that such a project is not feasible on many counts (Biyani and Gupta 2004). Korse (2004) has raised the point for the need of case-specific studies, citing the example of the Western Ghats, which is known for its unique flora and fauna, and the implementation of such construction-intensive projects will lead to biodiversity loss that would be beyond comprehension.

But the principle 21 of the UN Declaration on Human Environment (Rio Earth Summit 1992) proclaims that “states have the responsibility to show that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond the limits of their natural jurisdiction” (quoted in Jafar 1995). Therefore, the apprehensions of the neighboring need to be taken into account. The concept of ecological rights in riverine-riparian systems has to be better addressed in international water treaties and environmental laws (Korhonen 1996; Verghese et al. 1994). Changes in river basin hydrology and ecology based on anthropogenic gains and short-term political decisions in water politics have created significant ecological stress and socio-economic problems. ‘Sustainable development’, which has been the stated development goal of India, Nepal and Bangladesh for the last two decades, therefore, would clearly call upon greater cooperation between the countries involved in managing the watershed and sharing water, a greater respect for international laws and treaties that address the issues, and increase in political commitment to developing mutual trust and good faith (Crow and Singh 2000; Nishat 2001).

The advantages and disadvantages of the proposed project have been already discussed in detail. One of

the aspects is of national integration, as it will increase the interdependency between the citizens of the country. Proper balancing distribution of water in space and time will generate more food for the deprived people, more irrigation potential especially for marginalized subsistence farmers and a huge generation of employment. These are some projected benefits that cannot be achieved in an alternative way. Thus the economic feasibility, the social impact and the sustainability of the current solution and the alternatives need to be studied in detail.

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