Some issues on interlinking of rivers in India†

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Inter-basin water transfer (IBWT) is one of the options to remedy spatial mismatch in water availability and demand. To overcome this mismatch in India, a massive scheme consisting of nearly 44 links has been proposed to interlink the major rivers. Feasibility reports of most of the links have been completed and preparation of a detailed project report about the Ken–Betwa link is in progress. The entire programme will involve a huge volume of data analysis and design. In this article, attention is focused on issues pertaining to hydrologic data, analysis and regulation of the system.

Keywords: Himalayan rivers, inter-basin water transfer, interlinking of rivers, surplus water transfer, water balance.

HUMAN settlements and industries are not always near water sources and/or the available water may be inadequate to meet all demands at a place. Figure 1 gives a diagrammatic visualization of the spatial variability of water availability in different river basins of the country. Clearly, water transfer is one of the options to overcome the problems arising due to mismatch between requirement and availability. In a way, all water development projects involve transfer of water over long or short distances. While discussing interlinking of rivers (ILR), we are concerned with human-induced transfer of water from a (surplus) basin to a distant (deficit) basin. ILR or Inter-basin water transfer (IBWT) is one of the options to remedy spatial mismatch in water availability and demand. IBWT usually involves transportation of surplus water from a basin to another which is water-deficient. If the surplus and deficient basins are not near each other, which may quite often be the case, this will involve transfer of water over large distances, sometimes of the order of thousands of kilometres.

Under certain conditions, IBWT is a rational and sometimes indispensable measure. Diversion of water by IBWT increases the resilience of the water resources systems and reduces the risk of water shortage. The most common purpose of IBWT projects is to meet the water demand of agricultural areas or mega cities, or both. Special attributes of IBWT are[1]:

(i) Large volume of water is transferred.
(ii) Water is transferred over long distances.
(iii) Infrastructure is costly, there is the possibility of extensive environmental and ecological detrimental consequences, and
(iv) It has significant influence on the economy of the receiving area.

†The views and opinions expressed in the article are of the authors and may not necessarily reflect those of the organization to which they belong.

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Canals or aqueducts are commonly used to carry water from one basin to another; tunnels and pipelines are used to negotiate ridges. Geographical Information System (GIS) is being increasingly used these days to finalize the route of the transfer link. Many IBWT projects involve pumping of water in some stretches when a mountain is to be crossed or water is to be supplied at a higher elevation. The running cost of a system with pumping is significantly higher. Additional maintenance problems arise if sediment-laden water is to be pumped.

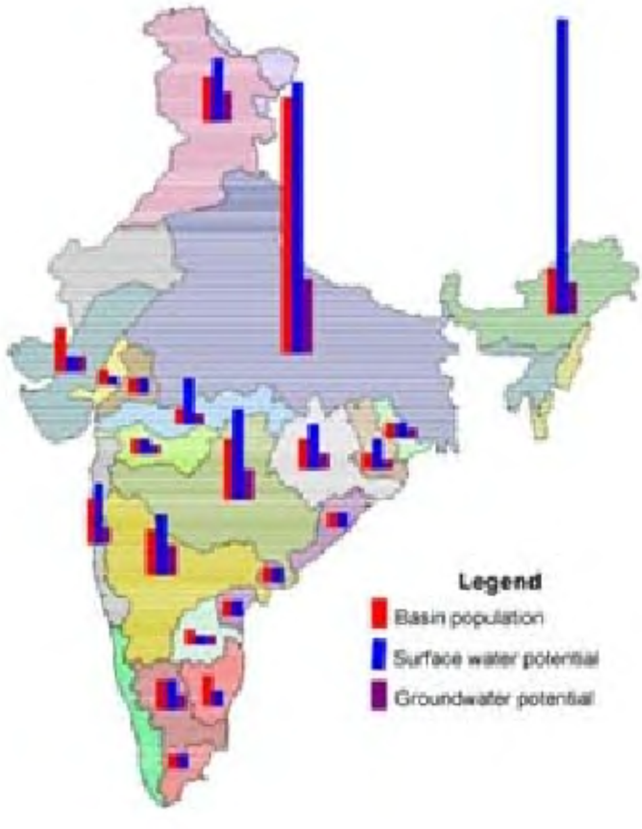

Figure 1. Spatial variation in water availability and population in India.

Cox[2] suggested the following five criteria to justify or reject IBWT projects:

(1) The area of delivery must face a substantial deficit in meeting present or projected future water demands after due consideration has been given to alternative water-supply sources and reasonable measures for reducing water demand have been attempted.
(2) The future development of the area of origin must not be substantially constrained by water scarcity; however, consideration to transfer that constrains future development of an area of origin may be appropriate if the area of delivery compensates the area of origin for productivity losses.
(3) A comprehensive environmental impact assessment must indicate that there is a reasonable degree of certainty that it will not substantially degrade environmental quality within the area of origin or area of delivery. However, water transfer may be justified where compensation to offset environmental injury is provided.
(4) A comprehensive assessment of socio-cultural impacts must indicate a reasonable degree of certainty that water transfer will not cause substantial socio-cultural disruption in the area of origin or area of water delivery. However, transfer of water may be justified where compensation to offset potential socio-cultural losses is provided.
(5) The net benefits from transfer must be shared equitably between the area of transfer origin and the area of water delivery.

The present article discusses several hydrological and associated issues that are of critical importance in the context of IBWT, with particular reference to India. Before discussing these, a brief historical and current perspective of the topic is provided.

Historical perspective

Although IBWT as a means to alleviate water deficit has drawn the attention of Indian planners since independence, two grand schemes that were proposed in the 1970s evoked widespread interest and enthusiasm. These were the Ganga–Cauvery Canal proposal of Rao[3], and the Garland canal system proposed by Dastur[4]. Rao's proposal required large amounts of power (5 to 7 MkW) for lifting the water and had no flood-control benefits[5]. Dastur was an engineer and pilot, who after an aerial survey of the land realized that 'we have more wealth in our water than Arabia has in oil' and proposed 'The Great Water Garlands' as a 'scheme for conservation of water and generating hydro-electric power by connecting all the rivers of India'. However, when this proposal was examined in detail, it was found to be technically unsound and the cost was prohibitive. Both these proposals were, therefore, not given further serious consideration although they continued to catch popular attention.

Notwithstanding the fact that these schemes did not materialize, the ideas of the proponents formed the stepping stone for more concrete and technically sound proposals that emerged later. The Government of India decided to set up a National Water Development Agency (NWDA) about a quarter century ago. After a detailed study of the earlier proposals, topography, river network, water availability and demands, NWDA formulated a National Perspective Plan (NPP) for water resources development. The distinctive feature of the NPP is that the transfer of water is essentially by gravity and only in small reaches by lifts (not exceeding 120 m). This plan comprised of two components: (i) Himalayan Rivers Development and (ii) Peninsular Rivers Development. A map of the proposed scheme of ILR is shown in Figure 2.

Himalayan rivers development component

The Himalayan component envisages construction of storage reservoirs on the main Ganga and Brahmaputra rivers and their principal tributaries in India and Nepal, so as to conserve monsoon flows for irrigation and hydropower generation, besides flood control. Links will transfer surplus flows of the Kosi, Gandak and Ghagra to the west. In addition, the Brahmaputra–Ganga link will augment dry-weather flow of the Ganga. Surplus flows that will become available on account of interlinking of the Ganga and the Yamuna are proposed to be transferred to the drought-prone areas of Haryana, Rajasthan and Gujarat. With this proposal about 14 m ha-m of additional water would be available from these river systems for irrigating an estimated 22 m ha in the Ganga–Brahmaputra basin, apart from Haryana, Punjab, Rajasthan and Gujarat. It would also provide 1120 cumec to Calcutta Port and would provide navigation facility across the country. It will also provide flood moderation in the Ganga–Brahmaputra system. Fourteen links are proposed in the Himalayan component.

Peninsular rivers development component

The main component of Peninsular Rivers Development is popularly known as the 'Southern water grid', which is envisaged to link Mahanadi, Godavari, Krishna, Pennar and Cauvery rivers. The scheme was prima facie found to be technically feasible and economically viable[5]. The link system is conceived on the basis of 'substitution and exchange' to avoid unnecessary lifts. Substitution envisages that the surplus water is delivered at the downstream use points in the basins facing water deficit, substituting for the existing committed releases from the upstream location in the deficit basin. In exchange, whole or part quan-

Figure 2. Proposed inter-basin water transfer links in India (Source: NWDA website – http://www.nwda.gov.in).

tum of the water will be drawn from the upper reservoir to cover the needy upland areas, wherever feasible.

The peninsular component of the interlinking system has 13 major water storage/diversion structures situated in four basins. These structures serve different purposes, viz. domestic water supply, irrigation and power generation. Three non-storage structures, viz. Dowlaiswaram barrage, Prakasam barrage, and Grand Anicut and storage node (Narayanpur) cater only to irrigation, while six storage nodes, viz. Inchampalli, Almatti, Nagarjunasagar, Pulichintala, Krishnarajasagar and Mettur serve both irrigation and power needs. One storage node, viz. Somasila is operated to meet domestic and irrigation needs and two storage nodes, viz. Polavaram and Srisailam are multipurpose projects serving domestic, irrigation and hydropower demands.

Highlights of the scheme

When the NPP is implemented completely, it would give additional irrigation benefits of 25 m ha from surface water and about 10 m ha by higher use of groundwater. Note that this will be over the ultimate irrigation potential of India, assessed at 140 m ha. The additional capacity to generate hydropower will be to the tune of 34,000 MW. Besides, the country would also get large benefits from domestic water supply, flood control, drought mitigation, navigation, fisheries, development of infrastructure, control of pollution and improvement of environment.

The major advantages of this proposal to interlink rivers are the following:

- This scheme will simultaneously address two critical problems of water management in India – floods and droughts. The construction of new storage projects will, to a large extent, help in the attainment of these twin objectives.
- Many cities will get additional water to meet the domestic needs.
- It will provide assured irrigation to additional 35 m ha area (about 25% of the ultimate irrigation potential of the country).
- There will be generation of additional electricity to the tune of 34,000 MW.

- The rivers and canals can be used to transport goods and traffic at lesser cost and in an environment-friendly manner.

All of the above will help the country achieve a higher GDP growth and improve the environment. The total outlay for the scheme has been estimated at Rs 560,000 crore. Note that this is an approximate estimation. When detailed project reports are prepared and the actual costs of different projects are worked out, the final figure may be substantially different. It is pertinent to note that the GNP of India for 2007 was Rs 3,536,400 crore.

Issues to be addressed for successful implementation of ILR

When a big scheme like the ILR is taken up, a number of issues from various sectors are likely to crop up. These include social, political, economic, legal, engineering and environmental problems. The remaining part of this article will mainly highlight the issues from the last two categories with possible remedies.

Data-related aspects

Optimal design and management of ILR projects would require large quantity of data from different disciplines. Here, our attention is focused on water-related data.

Hydrometeorological data: One of the major objectives of ILR projects is to divert surplus water from water-surplus basins to water-scarce basins. This will require construction of reservoirs for storage of excess water for a certain period and to regulate it, and canals are to be constructed to divert the water from one reservoir to another or to the places of need.

The planning of the ILR project would start with computing periodic (monthly) water balance and water availability in all the basins to be interlinked. These analyses requires time series of rainfall, stream flow and groundwater data of sufficient length (at least 30 years). Note that the discharge measured at the gauging stations may not be the representative stream flow under natural conditions, if some water development project(s) are utilizing a part of the available water in the basin upstream of the gauging sites. The periodic water utilization of such projects should be accounted for, while estimating the water availabilities. But frequently data of monthly water utilization of the upstream projects are not available. In that situation, these can be estimated from the data of the command area and cropping pattern of the projects, and normal monthly rainfall and evaporation in the command area of the projects.

Design flood is one of the key parameters for design and construction of dams. It is the maximum flood that a structure can pass without causing any damage to it. The design flood for a structure is estimated using different approaches depending on its size, storage capacity and catchment area. For small and medium projects, floods of specific return period, estimated by frequency analysis, are designated as the design flood. For large projects, the design flood hydrograph is computed using the unit hydrograph (UH) principles. To apply frequency analysis method, the annual maximum discharge series of sufficient length is required. The design flood hydrograph method requires the UH for the catchment, the design hydrograph (rainfall intensity vs time) hydrological loss indices and baseflow contribution. The UH for a catchment is derived either by analysing the short duration (event based) rainfall run-off data or synthetically from basin parameters. The design hydrograph is estimated from the probable maximum precipitation and time distribution of rainfall in the catchment area. The hydrological loss indices and baseflow contribution are estimated from the rainfall run-off data.

The expected life of a reservoir is estimated on the basis of rate of siltation, which in turn is computed from the sediment content of the reservoir inflow. Hence, sediment data of the streams are also needed for design of reservoirs and catchment area treatment recommendations.

Topography, soil and geological data: The interlinking canals should be designed to carry the required volume of water safely. The canals may be lined at some critical areas. Topography governs the slope of the canal and soil type affects the seepage through it. Hence, to design the canal sections and for proper layout detailed topographic, soil and geological data are required. Geophysical data are required for identifying suitable locations for dams and the design of their foundation.

The maximum water level of a reservoir is fixed by simulation and reservoir routing. This requires detailed topographical data (area–elevation–capacity curves) at the reservoir site, inflow to the reservoir, various demands downstream and losses such as evaporation and percolation from the reservoir. Analyses of geological data are required before construction of dams.

River cross-section and roughness data downstream of the dam are required for the hydraulic analysis of the river such as to compute the carrying capacity, sufficiency of embankment heights, morphological modelling, river routing, safe disposal of dam break flood, etc. These data at the upstream of the dam are also required to study the backwater effect of the dam.

Biological and biochemical data: The ILR projects should not have adverse effects on the environment. To preserve the ecological system of the rivers, some minimum flow in the rivers should be maintained. This requires extensive study of the existing flora and fauna in the river system. To estimate the minimum flow in the river, the lean period (non-monsoon) stream-flow data are required to be analysed.

In India, domestic and industrial effluents are frequently discharged into the streams without any treatment and this pollutes the water. Depending on the quantum of river flow, the pollution may get diluted while moving in the stream along with its water. To estimate the minimum environmental flow in the streams, data pertaining to the quality, quantity and entry point of the effluents, and quality of stream water upstream of the entry points are required.

Socio-economic data: The benefits of the ILR projects are aimed at the development of the society. The beneficiaries for the project are required to be identified. The benefits can be quantified only if the pre-project data are available. Socio-economic data on human population, livestock population, availability of human resource and economic conditions of the project area are required while designing and implementation of the ILR projects.

Problems in availability of data: Despite much advancement in information technology, databases containing requisite data are still lacking. River-flow data are the key to surface-water planning. In India, measured stream-flow data series of sufficient length is not available at many sites. For most regions, majority of the gauging stations were established in the 1960s. Subsequently, a number of stations were set up in the 1980s. Thus, in general, data for a period of 25 to 30 years are available at most of the sites. At a few sites, data series of 40 years is available. Clearly, the length of measured data series at most sites is not adequate to plan major projects. In the absence of measured data, either rainfall data are used to extend the flow series since long data series of measured rainfall are available in India, or synthetic data are generated and used in analysis. Although the synthetic data help in analysis, these are no substitute for the measured data.

Another difficulty lies in the determination of virgin flow, which is the sum of observed flow and the upstream water used. The water used in irrigation in the upstream water resources projects constitutes the upstream water use. These projects are classified as major, medium and minor based on their command area. Data like exact location of project, year of its commissioning and water withdrawal is generally available for major projects, may be available for medium projects, and in general is missing for minor projects. Further, information about medium and minor projects is usually not available at a central place. At times even district offices do not have these data and in some cases, the information is not available. There are instances where the working tables of even major projects are incomplete. Data on actual water use and its temporal variation (inter- and intra-annual) are rare to find. Thus, much time is spent in collecting data and even after that, one may have to assume certain critical values.

Assessment of water demands at a future date when these are likely to stabilize, say by 2050, and estimating water availability at that time is another component requiring extensive data. The important components of demand estimation are projection of population, industrial and agriculture growth. Population projections are made using past population records and future growth rates. The future population growth rates are also provided by international agencies like the United Nations. It is difficult to project the industrial growth and its water demand pattern. Information about planned water resources projects is generally available with water resources departments of the concerned state governments. But as stated above, only limited data are available. The water use of these future projects is determined using climatological approach, for which the reference evapotranspiration data are the main input. These data are available only at a few selected stations in India. There may be a case when there is no such station in the basin being analysed for surplus/deficit.

To save time and come up with correct answers, centralized databases containing all the required variables should be set up in all the states. It is pertinent to highlight that the issue of non-availability of data has been discussed in numerous conferences and meetings. It is now customary to include a recommendation concerning data problems as an outcome of any conference, and yet the problem remains unresolved.

The non-availability of the representative data of desired length and quality might lead to sub-optimal design and management. Due to inadequate or poor data, the assessment of available water may be on the wrong side or the projected demands may be far from the actual. The end results will be that full benefits may remain unrealized. Pooling all available data, observing/extending data series wherever possible, and using refined analytical tools can minimize the risk due to this eventuality. Ideally, data should be made available to all those who want to analyse them, so that the expertise available in the country can be best utilized. Working in secrecy, there is always a danger that the mistakes will propagate undetected and there is not much room for new ideas to flourish.

Methodology for water balance

While carrying water balance and estimating surpluses, groundwater availability in the basins is not accounted for generally. This is not scientifically correct. The National Commission for Integrated Water Resources Development Plan (NCIWRDP), 1999 is also of the view that groundwater should to be taken into consideration in water balance studies. In fact, the Cauvery basin was found to be water-deficit by the NWDA on ignoring groundwater, while NCIWRDP reported that when groundwater is considered, the basin will have surplus water.

Nowadays groundwater is extensively used to meet irrigation, domestic and industrial demands. Since surface water potential and groundwater potential are interdependent, computation of the former disregarding the latter is not the right approach. Therefore, the guidelines should be modified to include groundwater in water balance computations. This will align the guidelines with scientifically correct principles. Further, ownership rights of water are not clearly defined in India and this leads to different interpretations and inter-state disputes.

Skilled manpower needs

On account of the large size of the projects, skilled manpower needs for ILR will be extensive. Also, extensive field investigations will be required to prepare detailed reports for all projects. These will involve hydrological observations, topographical surveys, surveys of dam and reservoir areas, command area surveys, canal alignments, geologic and geotechnical investigations, construction material survey, socio-economic surveys in command areas and surveys related to EIA. All these activities need skilled technical manpower and some activities require specialists in their respective fields. With the advent of new technology (like total station) in surveying, the task of surveying is not that time-consuming, but to operate such sophisticated equipment and analyse the data requires skilled hands. Experts will also be needed for office and field studies such as hydrologic analysis and design, civil engineering design, geological and geotechnical investigations, environmental and ecological studies.

Any single organization such as the NWDA does not have experts with the range of background and experience needed for this work. Further, in view of the magnitude of work, adequate personnel are not found in any organization. Hence, much work will have to be outsourced. Supervision of the work being done by different organizations/consultants also requires different specialists. During construction, managers and supervisory staff will be needed to ensure quality and timely completion of the work. Moreover, many experienced staff are leaving government jobs these days. Thus, institutional strengthening and capacity building will have to be undertaken urgently.

Time and cost overruns

The estimated cost of the project is Rs 560,000 crore (Rs 365,000 crore for the Himalayan component and the remaining Rs 185,000 crore for the peninsular component). It is to be completed in a time-span of 10–15 years. There may be only a few water resources projects in India which have been completed recently, within the stipulated cost and time. There are chances that the ILR project will overrun the estimated cost and time. This may be classified as 'managerial risk'. A major lapse on this count may seriously undermine the benefits and may even jeopardize the viability of the scheme.

Raising of funds for the present estimated cost of the ILR project will be a problem and this will burden the economy of India. The cost escalation will further complicate the matter. After the construction of the project, money will be required for its operation and maintenance. These recurring costs are to be realized from the users, which is again a complex problem.

Environmental issues

There is likely to be opposition to the ILR scheme from environmentalists. Views have been expressed that the ILR may cause environmental impacts much different from those caused by general water resources development projects. However, this eventuality will arise only if the scheme is not properly designed, constructed and managed. If properly executed, this proposal has the potential to significantly improve the ecosystem in the receiving basins without degrading the same in the donor basins. However, the project should be undertaken with full recognition of the ecological damages that may be caused and that the benefits should far outweigh these costs[6].

Impact of climate change

Analysis of measured hydro-meteorological data suggests that the climate of the earth may be undergoing significant long-term changes. For a water planner, the changes may manifest in altered spatial and temporal patterns of precipitation, evapotranspiration and streamflow. Such changes, if at all they take place, might adversely influence the reliability of the project. Some of the components may fail to perform up to the mark and others may become redundant.

According to the Intergovernmental Panel on Climate Change[7], the major impacts of global warming in temperate Asia will be large northward shifts of subtropical crop areas. Large increases in surface run-off leading to soil erosion and degradation, frequent waterlogging in the South, and spring droughts in the North will ultimately affect agricultural productivity. The volume of run-off from glaciers in Central Asia may increase threefold by 2050.

In monsoon Asia, the issue of sensitivity of physical and natural systems to the hydrological cycle is linked to major stresses caused by the projected climate change on agricultural production and increased exposure of social and economic systems to impacts of extreme events, including forest die-back and increased fire risk; typhoons and tropical storms; floods and landslides, and human disease impacts. These stresses on physical systems translate into key social vulnerabilities, particularly in combination with unsustainable utilization of resources. For example, the excessive withdrawal of groundwater has increased the rate of sea-water intrusion near many major coastal cities of Asia. The ecological security of mangroves and coral reefs may be put at risk by climate change. Sea-level rise could cause large-scale inundation along the coastline and recession of flat, sandy beaches of South and Southeast Asia. Monsoons in tropical Asia could become more variable if ENSO events become stronger and more frequent in a warmer atmosphere.

Decision-making mechanism

The principles on the basis of which the riparian states share water have been established over time internationally and in the various agreements between Indian states. But the transfer of river water from a surplus basin to a deficit one has no such agreed principles. If both the basins exist in the same state, there may not be any problem, but in case of inter-state water transfer, their mutual consent and agreement are needed. The agreements should be signed between the concerned states and be applicable on a long-term basis. The mechanism to enforce the agreement has to be worked out. Problems like scrapping of all water-sharing agreements by Punjab through the State Assembly should be kept in mind while framing such mechanisms.

The canals of the ILR projects are expected to cover two or more states. The requirement of the destination basins can be fulfilled only when water is available at the canal-initiating basins. This will require frequent exchange of demand and availability data among the states, which may complicate the operation of the project. It may be appropriate to have a central agency to monitor the demand and availability of water at different locations, simultaneously. The agency would decide the quantum and time of water transfer from one point to the other. The decision of the agency would be final. This, however, may require some legislation at the highest level.

It may not be correct to say that the State Governments oppose water transfer – what they may be opposing is free transfer of raw water. For instance, all the State Governments encourage the setting up of industries (even those that consume large quantities of water) to produce goods which may be shipped outside the state. Further, large amount of water is exported from many states (some of which may be facing water shortages) as virtual water[8] through agricultural products. One way to overcome this opposition by the states is that after allocating for the basic needs, water should be considered an economic goods and a raw material in the production process. As many inputs in the production process are transported all over the country, an acceptable mechanism for transport of water should be evolved.

Social and political opposition

Social opposition to the ILR projects may arise mainly when people assume that there will be loss of valuable resources, land and water. However, the people can be convinced that with assured and timely availability of water, more revenue can be generated from less land resources by increasing the cropping intensity. This would require massive mass awareness campaigns. People's participation should be ensured during all phases of the project, starting from the planning to the operation of the project. Water user associations may be created to make people's participation more effective. The operating agency should function by making direct interaction with these associations.

Law and order problems

Civil engineering works may be subjected to vandalism and terrorism. However, due to their large size and structural strength, it is difficult to inflict major damages to hydraulic structures. In India, canal water is often (illegally) diverted by farmers who feel deprived of their legitimate share. Besides, inter-state disputes concerning sharing of river water are not new to India. Recently, such disputes have generated considerable bitterness, even animosity among sections of the population of neighbouring states.

The ILR project includes construction of canals, many of which will pass through several states. These long-run canals are always at risk from vandalism. A canal breached deliberately by undesirable elements would interfere in the transfer of water and would spell disaster for the areas around the breach. If a particular area through which such a canal is passing (but water is not used for that area), faces water scarcity, there are more chances of such vandalism. There is also threat to the ILR infrastructure from terrorism. As such, there are no examples of a major terror strike on any water resource project, but there is a need to ponder over this issue and take necessary measures.

Summary

The inter-basin transfer project will be funded mainly by the Government of India, international agencies and market borrowings. Decidedly, it will be the most ambitious scheme in the history of India. Successful completion will rapidly wipe out many curses of poverty and denial. On the other hand, any serious delay or failure will lock large resources in non-productive investment and negate the benefits of growth in many sectors that the country has tasted recently.

Finally, ILR alone will not solve all water-related problems of the country. Concepts such as water conservation, optimal regulation of existing facilities, rainwater harvesting, watershed management, water reuse, etc. will continue to be highly relevant and this grand scheme will be an important supplement to these. A holistic view of the scenario is always important and necessary.

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