GIS and Visualisation Capabilities for Interlinking of Indian Rivers

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INTRODUCTION

India is blessed with abundant water resources, which are unevenly distributed in space and time. When one part of the country is reeling under severe water scarcity, floods damage another part. India experiences extremes of climate within the 329 M ha of geographical area. Mean annual rainfall varies from 100 mm in western Rajasthan to over 11000 mm at Cherrapunji in Meghalaya (Indian Water Resources Society, 1994). Flood prone areas of 40 M ha and Drought prone areas of 51 M ha are being affected in India. Some rivers are perennially dry and some rivers discharge huge quantum of water to the sea every year. This necessitates the surplus and deficits to be redistributed for the betterment of the whole country through the massive task of Interlinking of rivers.

Interlinking of rivers involves multidisciplinary data on hydrological, environmental, agricultural, socio-economic and political aspects. Moreover, these data will be derived from various sources such as toposheets, remote sensing imagery, aerial photographs, paper maps and field data. For decision making on such complicated project issues, the related data and information should be stored at one place in digital form for easy retrieval, updation and analysis for effective planning and execution purposes. GIS, a powerful spatial technology, provides the scientific environment to store and analyse

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multidisciplinary data for solving such real world problems. GIS combines spatial database management, statistical analysis and cartographic modelling capabilities within computer hardware and software configuration. The objective of the paper is to explore the capabilities of GIS that will be very useful in solving the various issues of interlinking in order to expedite the process of interlinking.

NATIONAL PERSPECTIVE PLAN

Ministry of Water Resources and Central Water Commission formulated a National Perspective Plan (NPP) for Water Resources Development in 1980, which is undertaken by National Water Development Agency (NWDA). The NPP comprises of two components, Himalayan Rivers Development and Peninsular Rivers Development. There are 14 link canals in Himalayan component and 16 link canals in Peninsular component (Fig.1). Himalayan Rivers Development envisages construction of storage reservoirs on the principal tributaries of Ganga and the Brahmaputra Rivers in India, Nepal and Bhutan along with interlinking canal systems to transfer surplus flows of the eastern tributaries of the Ganga to the west apart from linking of the main Brahmaputra and its tributaries with Ganga and Ganga with Mahanadi. Peninsular Rivers component consists of diversion of surplus from Mahanadi to Godavari system and to a further transfer of the surplus from Godavari to Krishna, Krishna to Cauvery, and Cauvery to Vaigai Rivers. It also comprises of diversion of west flowing rivers towards eastern side and building storages at potential sites in these basins.

Figure 1 Components of Interlinking of Indian Rivers

The three stages of the above water resource project are:

(i) Preliminary Feasibility Stage
(ii) Feasibility Stage
(iii) Final Project Stage

NWDA has made a tremendous effort to formulate the detailed feasibility reports for various links of the project. If NWDA is assisted with the powerful spatial technology of GIS and Remote Sensing, it will definitely expedite the process of developing plans to solve the various issues and preparing the report accordingly.

FUNCTIONALITIES OF GIS

DIGITAL MAPPING

Digital mapping is the most elegant and compact method of displaying the spatial data. Graphical representation of natural resources, utilities and facilities smoothen the progress of decision-making. Maps that are difficult to make manually such as 3-D maps or stereoscopic maps can be created. Statistical analyses of attribute data can be performed and mapping can be done accordingly. Mapping of resources can be done at different scales (Small, Medium or Large), which depends on the level of study (National, Regional or Local). National level planning (Small Scale Mapping) is needed for sustainable water resources development of the Country, whereas local level planning (Large Scale Mapping) is needed for the benefit of the villages' enroute the river link.

OVERLAY ANALYSIS

Using the overlay technique, various thematic layers can be overlaid and specific information can be derived from it. For example, layer consisting of proposed canal of any particular stretch can be overlaid over the Land use map, of that region. From the resulting layer, one can get the information of land uses that are affected based on which the problems of deforestation, land acquisition, resettlement and impact on environment can be analysed. The strategies can be framed to solve the above issues within the stipulated time and proceed with the works. Drought prone area can be identified and planning of alignment can be made so as to benefit the deficit areas.

INTERPOLATION

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Spatial variation of any water related aspect such as rainfall, surface water, etc could be interpolated using GIS. Various interpolation techniques used are Natural neighbourhood, krigging, etc. which are provided by GIS. For instance, spatial variation of seasonal rainfall can be interpolated over a region to get an overview of rainfall deficit and excess regions. Figure 2 shows rainfall distribution map of Palar basin.

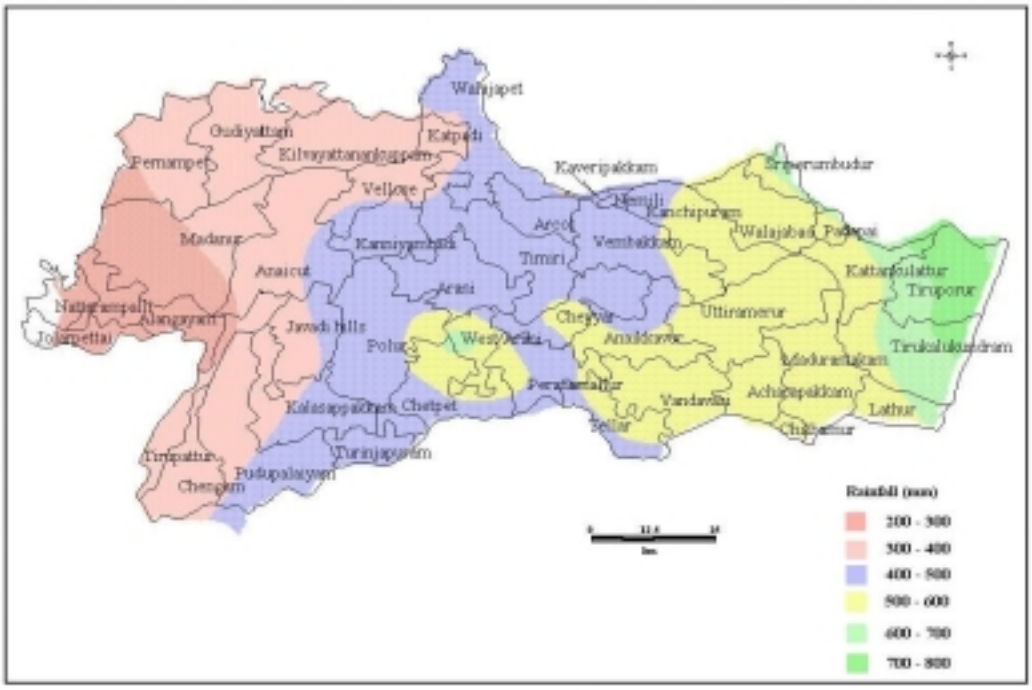

Figure 2. Spatial Distribution of Northeast Monsoon Rainfall in Palar basin

DIGITAL ELEVATION MODEL (DEM)

It is a quantitative model of part of earth's surface in the digital form. One of the most sophisticated GIS capabilities which is very much useful in hydrologic modelling is digital representation of topography of the catchment. Techniques used in the computer descriptions of topography are called Digital Elevation Models (DEM). Three principal methods for structuring a network of elevation data are square-grid networks, contour – based networks and Triangular irrerugular networks. They can be used to automate the delineation of drainage pattern, stream networks, and water sheds.

Digital Elevation Model of the region through which the canal passes can be created. This will help the engineers to study the three-dimensional topography of the region through which the canal passes. Automatic calculation of earthwork quantities for cutting and filling can be done. The fundamental requirement for canal alignment is topography of the region. The topography can be studied in detail if digital elevation model is constructed for the project areas using GIS software. Three dimensional view of the topography can be prepared using GIS which will be very useful for planning the canal alignment and construction of various hydraulic and irrigation structures enroute of the canal alignment. Planning shall be made so as to use the existing reservoirs and anicuts to the maximum extent. Moreover, the project involves construction of various irrigation and hydraulic structures along the canal. Tunnels, Canal alignment and cross drainage works. Figure 3 shows the digital elevation model of Cauvery – Vaigai – Gundar Link.

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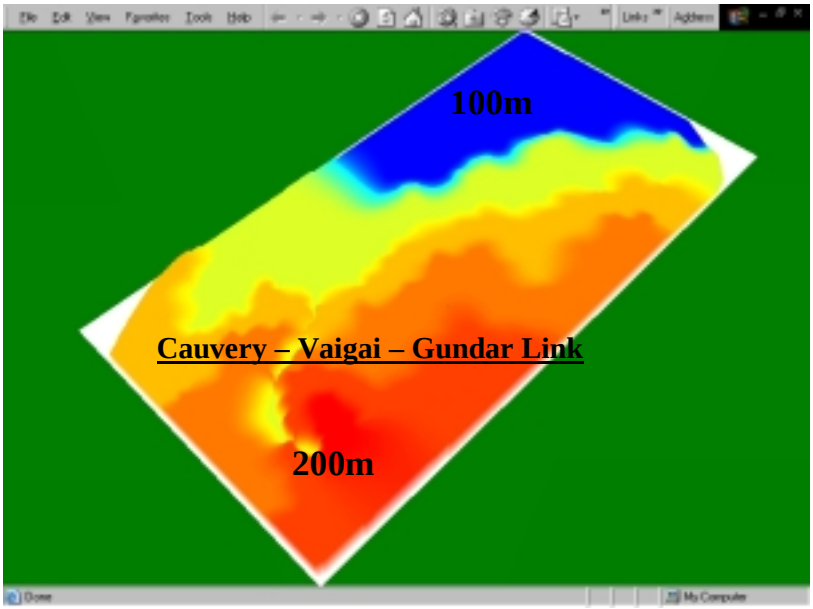

Figure 3 DEM in a VRML Browser

VISUALISATION *(VIRTUAL GIS)*

"If I can see it, I can understand it" – Albert Einstein

Visualisation is a form of communication, which is universal and which has the ability to form an abstraction of the real world into graphical representation. Once a project proposal is developed, it is necessary to communicate the effects of proposed changes to other agencies and public review groups to facilitate decision-making. Some of the changes in the environment can be modelled and visualised using GIS. Visualisation provides additional insights to results, which would otherwise be displayed as text or numbers. The virtual GIS are making a revolution in 3D analysis. Multimedia technologies are enhancing the use of GIS as decision making tool. It is possible to visualise the landscape of project site in a virtual manner. This is very economical and less frightening than a ride in an aeroplane. The natural existing system can be virtually viewed in the desktop.

Using GIS and Virtual Reality Modelling Language (VRML), one can view the entire link as if the walkthrough of entire stretch. The required information about the project can be seen in advance. Visualisation technique combined with GIS will really be a boon for planners. Impacts during the droughts such as the depletion of ground water level, greater accumulation of silt leading to rising of river bed and saline intrusion in the coastal areas and impacts due floods such as inundation problems can be modelled and visualised in the computer system. As visualisation will project various benefits to the people with visual impact, it will greatly enhance the process of getting National political consensus.

The contours of regions through which the link canal passes will be digitised along with river and other physical features using MapInfo GIS software. A fly through the model of above contours can be developed using Virtual GIS module "PAVAN" of MapInfo that can be viewed using VRML browser. Third dimension of terrain and other geographic features can be visualised to get the real picture of the topography. By simulating the project in the system using virtual GIS, degradation of land if any can be evaluated and necessary measures can be taken to prevent the degradation. There will be a change in the regime of rivers due to abstraction and addition in the river. This aspect can be modelled and critically assessed and their impacts due to change in the quantum of water in rivers can be studied using Virtual GIS.

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NETWORK ANALYSIS

The other more specialised spatial analysis functions provided by GIS are the network routines. These routines were basically developed for transportation planning and allocation analyses. Shortest route and least cost path analysis are common examples of network functions. Canal alignment can be finalised using this technique. Optimum and shortest possible options can be determined before execution. Using the network routines, it is possible to make an analysis of the movement of the resources from one location to another. Inputs to routine are the river network configuration, source of river (u/s end), outlet of the river and constraints upon the movement of resources across the network. Transport of water through a system of link canals can be modelled by network functions. Alignments of canal, Reservoir projects and water use for command area and domestic purpose en route of the canal. Visibility analysis can be made using Network analysis capabilities of GIS.

GIS TO SOLVE THE ISSUES OF INTERLINKING

Technical Issues

Drinking water supply to towns and villages enroute

It is worthwhile to plan for domestic water supply to towns and villages enroute. Water supply network can be planned in GIS environment to carry out route tracing and resources allocation. People may come forward to get the consensus of concerned socio-political authorities, as they get water.

Water allocation for irrigation

Optimum usage of water for irrigation has to be facilitated by distribution channels up to the agricultural field from the link canals. This involves planning of field channel network so as to divert the water from the main link canal. Quantity of water can be metered and monitored**.** The above aspect can be very well planned using network analysis capability of GIS.

Command area development

Command area development involves suggesting cropping pattern to suite the region, providing proper drainage system, soil conservation, and water harvesting and credit system for the farmers and related activities. This also involves evaluation of present cropping pattern, irrigation facilities and related aspects of the command area. The spatial analysis capabilities of GIS will offer excellent facilities towards the planning of the command area along with the link canals.

Hydropower development

The possibility of exploration of hydropower has to be taken into account, since it will be difficult after interlinking the rivers. Economically exploitable hydro potential assessed by Central Electricity Authority is 84,040 MW. But, electricity developed so far is only 21.5%, leaving about 78.5% yet to be harnessed. The east flowing and west flowing rivers of southern peninsular regions offer excellent scope for hydropower development. Using GIS capabilities, the task of site selection for Hydel power plant can be made. The combined use of overlay technique and DEM will be very much useful for planning of power plants along the route of link canals.

Navigation

Many of the river links will also constitute National waterways. The Brahmaputra – Mahanadi link will be a major step in augmenting inland water transport. Inland waterways Authority of India has developed various important water ways such as Allahabad to Haldia, and Sadiya to Dhubri of Brahmaputra river. Techno- economic studies for waterways along the link canals can be planned for, before the execution of the project and necessary technical provisions can be made while executing the project. Network analysis capabilities of GIS can be explored for planning waterways with the link canals.

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Environmental Issues

Land submergence

The extent of land submergence due to the alignment of the canal and construction of reservoirs and hydraulic structures can be assessed before the initiation of project so that alternatives can be planned accordingly. The spatial assessment of submerged land can be analysed with the functionalities of GIS.

Forest Cover

Forest cover in India mostly lies in Mountainous regions. Forest areas that will be affected due to the alignment of the canal and construction of reservoirs and other hydraulic structures will be assessed. Deforestation can be avoided to maximum extent possible. Remote Sensing and GIS, in an integrated manner can be utilised for the above assessment. Ground truth verification is very difficult for forest cover assessment. The virtual GIS derived from contours and high-resolution satellite data will greatly assist for simulation of forest cover assessment as if in the real situation.

Ecology

Ecological aspects consist of studying the rare species located in the project area. The project canals, reservoirs and other irrigation structures may be planned accordingly so that the species are not affected to the maximum extent possible. GIS will support for the spatial analysis of the above feature. Areas of concern and modifications required in the project can be easily reviewed with the use of GIS database of the entire project.

Water logging and Soil Salinity

Soil salinity and water logging along the canal alignment has to be studied in detail so as to avoid those zones or to suggest remedial measures. Study of those spatial problems along with soil characteristics can be made using GIS. Lining of canals can be planned according to the zones. The problems zones can be identified mapped and planned accordingly.

Land Acquisition and Rehabilitation

Land acquisition and rehabilitation include payment of compensation for land, houses and properties acquired, allotment of agricultural land and house plots at new sites, free transport for shifting to new site, payment of ex-gratia, rehabilitation grant, subsistence allowance, development assistance, ration card issued at new R&R site and civil amenities provided at new site. Spatial database consisting of land and persons affected due to the project can developed in GIS environment. The spatial analysis capabilities of GIS will speedup the completion of entire process of Land acquisition and other aspects of Relief and Rehabilitation.

Socio-Economic Issues

At present 80% of the people live in rural India and most of them directly and indirectly depends on agro based activities. In most of the drought prone states, rural people live below poverty and under nourished. Due to water deficit most of the people particularly farmers and agricultural labourers are left with no means for their livelihood. This sort of acute scarcity will be reduced by irrigation from link canals. As irrigation facilities increases in the regions through which the link canals passes, the economic status of the rural people will be elevated. Particularly agriculture and related activities will fetch a good living condition to the rural people. The spatial socio-economic assessment with respect to various issues such as gender, social status of the people, cropping pattern, traditional practices with respect to occupation, and other related aspects at micro level can be made using GIS for the upliftment and development of the rural people of India.

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GIS BASED DECISION SUPPORT SYSTEM FOR INTERLINKING OF RIVERS

Decision Support System (DSS) can be developed using GIS to solve various issues Interlinking of Indian Rivers. The issues can be grouped into modules such as Technical, Environmental, Socio-economic, and Political. These modules consist of various alternative solutions made using the powerful functionalities of GIS. Figure 4 shows the Schematic representation of Decision Support System for Interlinking of Rivers. The developed DSS can provide strategic, tactical, and operational level information that will be useful for intelligent project planning. Various categories of people right from Farmers, Politicians, Water managers, Engineers and administrators can get the wide range of meaningful information from the developed DSS. When putting this system on a web, people can browse the entire project in their desktop and ascertain the benefits. The cost for creating such a system will come around only 1/1000th of the total cost of the interlinking project which is justifiable.

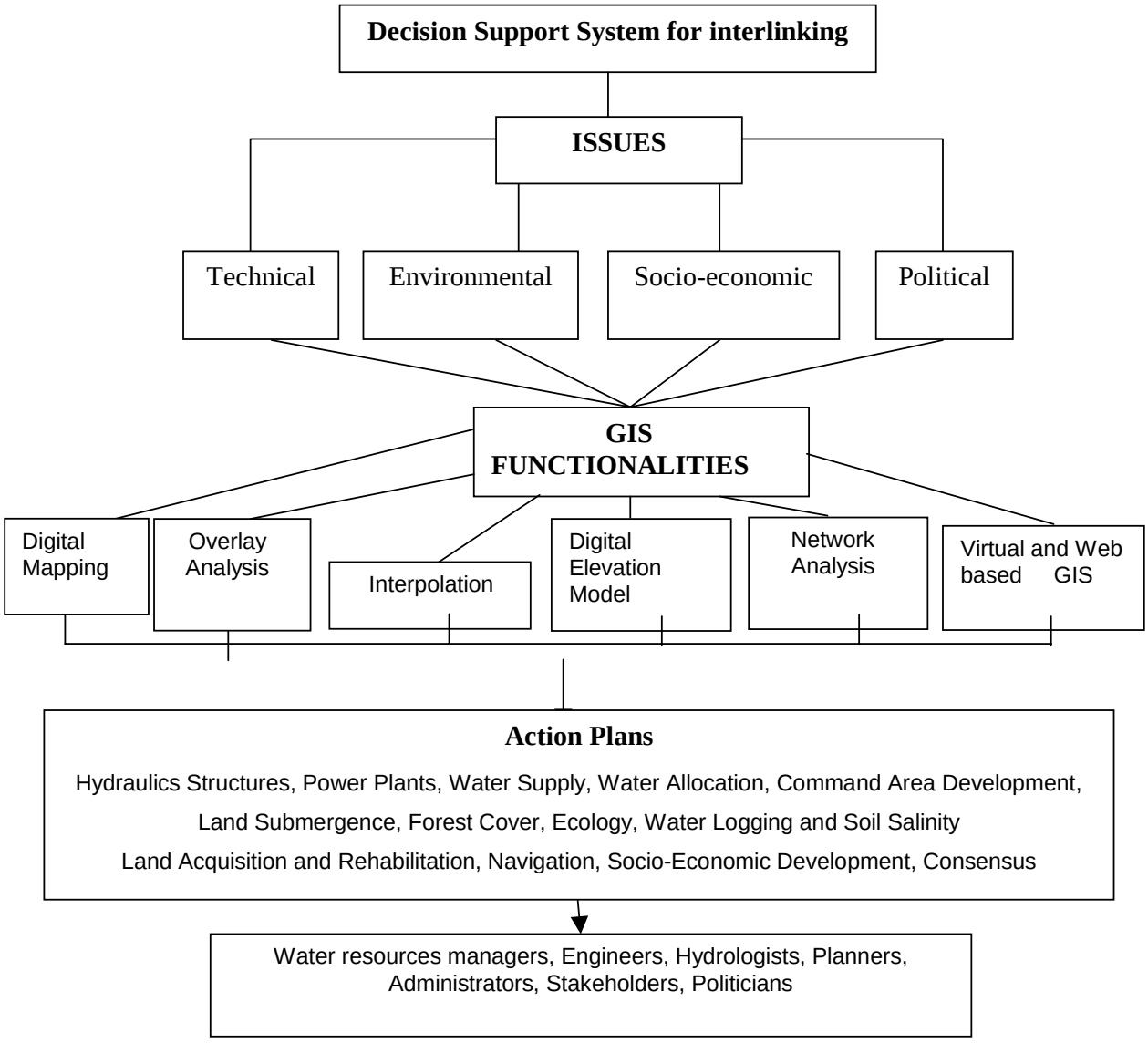

Figure 4 Decision Support System for Interlinking of Rivers

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CONCLUSION

As Floods and Droughts are inseparable hydrological components of our country, it is wise to use the available resource in a more distributed manner within the country. India is an agricultural country and its economy depends mostly on agriculture. But agriculture is gambled by monsoon. To utilise the resources to the maximum extent possible, interlinking of rivers is the only option. At this modern computer age, it is appropriate to use powerful methodology such as GIS combined with Remote Sensing and other softwares to make the planning of huge task of interlinking of rivers easier and effectively. Following are the conclusions of the present paper.

- GIS, a powerful spatial technology provides the scientific environment to store and analyse multidisciplinary data for solving such real world problems.
- The analytical capabilities of GIS that can be advantageously used for mapping, modelling, monitoring, and visualising the various aspects of interlinking.
- GIS can be effectively used for solving the various aspects related to technical, environmental, socio-economical and political issues of interlinking process.
- GIS based Decision Support System will definitely enhance the process of interlinking of rivers
- GIS combined with visualization techniques can be used as a media to create the public awareness and to get consensus among the states.

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