River Basin Simulation Using *RIBASIM* in Sabarmati River Basin - A Case Study

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ABSTRACT

Water is one of the most important natural resources and is a key element in the socio-economic development of a country. The demand of water is continuously increasing due to population growth and development in industrial and agriculture sector. Ever increasing demand and finite availability of resources is bound to increase the gap between demand and supply. For overcoming such a situation, it is very important to efficiently plan and manage available water resources. Water resources development has been so far project oriented with main emphasis in providing irrigation to agriculture land. Most developmental decisions today are multi-objective in nature involving economic, social and environmental dimensions. The present paper is an attempt to create awareness to river basin scale simulation program and application thereof.

INTRODUCTION

River resources have been developed and managed for centuries to control the supplies of water in order to meet community and regional demands for water quantity, quality, and reliability in time and space. In recent years challenges in water sector, viz., growing population and economic development and enhancement in life style of the people have caused an intensification of water use resulting in scarcity of available finite water resources. This has raised critical issues in the efficient allocation, distribution and management of water resources. Due to intensified activities, inter-sectoral conflicts in river basin resource allocation have developed for water quantity and quality in space and time. As many uses are physically linked through the basin hydrology, the management of water resources can be made efficient using basin-wise approach. These addresses the integrated water related planning of a particular region in view of its physical interactions and distribution of impacts in river basin, as the river basin forms a natural area unit. In view of above, the need for an integrated water supply management has become well established. This involves traditional water supply management techniques to locate, develop and exploit existing and new sources of water in a cost-effective way. Simultaneously demand management is also required which is concerned with the way water is used and aims to establish and promote desirable levels and patterns of use. The planning for such an increased scope requires an integration of disciplines, implementation of measures with impacts in different sectors and effective coordination between water users and planners at all levels for effective implementation. River basin planning aims at such integration and provides useful planning at regional and basin level.

PROPOSED MODEL

Planning at river basin level requires to consider a complex/large set of `components and their interrelationship. Mathematical modeling has become a widely used tool to handle such complexity for which simulation and optimization techniques are employed. However, simulation models are advocated for water resources planning because of their versatility to handle the complex situations compared to optimization models that require many approximations for application in such situations. *RIBASIM* developed by Delft Hydraulics is a model package for simulating the behavior of a river basin under various hydrological conditions. The main *RIBASIM* user interface is presented as a flow diagram of blocks representing the tasks to be carried out and their order to complete the simulation process. The interface guides the user through the analysis from data entry to simulation *RIBASIM* enables a schematization of the river basin to be prepared interactively from a map. The map is to be produced by any other G.I.S. package and imported as a map layer, which is as a background to the schematisation. This schematization is the core of the model and consists of a network of nodes and links. The node-link network configuration reflects the spatial relationship between the elements of the water resources system. Main elements of the schematisation can be grouped into four groups as described below:

- Infrastructure (surface and groundwater reservoirs, rivers, lakes, canals, pumping stations, pipelines), both natural and man-made.
- Water users (public water supply including domestic, municipal & industrial supplies, agriculture, hydropower, aquaculture, navigation, nature, recreation), or in more general terms water related activities.

- Management of the water resources system (reservoir operation rules, allocation Methods).
- Hydrology (river flows, runoff, precipitation, evaporation) and geo-hydrology (groundwater flows, seepage).

For supply, discharge, and the water using activities are connected to the network in nodes and also natural supply to the network is concentrated in the nodes. The transport of water in the network and consequently between users takes place in links. No other interactions other than via nodes are permitted. The transport of water via links is controlled by the operation rules as specified by the user for the system. The time aspect is brought in by the time series of discharges (inflows), rainfall etc. and also in the form of time series for the water demands by the users (consumers).

Different types of nodes as available in the current version 6.31 of *RIBASIM* model can be characterised as Layout nodes, Demand nodes or Control nodes and are tabulated below:

Table 1. Different types of nodes available in the *RIBASIM* model

Layout nodes	Demand nodes	Control nodes
Variable inflow node	Low flow node	Surface water reservoir node without hydro-power station
Fixed inflow node	Public water supply node	Surface water reservoir node With hydro-power station
Confluence node	Fixed irrigation node	Diversion node
Terminal or end node	Variable irrigation node	Groundwater reservoir node
Dummy or recording node	Advanced irrigation node	Pumping node
Run-of-river hydropower node	Brackish fish pond node	Link storage node
Water district node	Fish pond node	Surface water reservoir partition node
Bifurcation node	General district node	
	Groundwater district node	
	Loss flow node	

RIVER BASIN SIMULATION

Simulations are usually made over long (multiple years) time series to include the occurrence of dry and wet periods. The simulation time steps used are variable and are defined by the user. Time step may be ten daily, fortnightly or monthly. Within each time step, the water demand is determined, resulting in targets for water releases from reservoirs, aquifers, lakes, weirs and pumping stations. Then, the water is allocated to the users according to the release targets, water availability, operation rules and water allocation priorities.

SABARMATI RIVER BASIN

The basin

The river Sabarmati is one of the major West flowing rivers in Gujarat, which is situated on the Western coast of India. It originates in Arawalli Hills in Rajasthan at an elevation of 762 m above Mean Sea Level (MSL) at Latitude 24^0 40' N and Longitude 73^0 20' E, near popular shrine of Ambe Bhavani. The river joins the Gulf of Cambay at point Nevido after travelling about 323 km in Gujarat and in all 371 km from its origin.

The basin is bounded on the North and North-East by Aravallil hills, on the East by the ridge separating it from Mahi basin, on the South by the Gulf of Cambay and on the West by ridge separating it from the basins of minor streams draining into Rann of Kachchh and the Gulf of Cambay. The basin has a maximum length of 300 km. and maximum width of 105 km. It is triangular shaped with the main river as the base and the source of the river Watrak as the apex point.

The total catchment area of Sabarmati river basin is 21,674 sq. km, out of which 4,124 sq. km. lies in Rajasthan State and the remaining 17,550 sq. km in Gujarat State.The Sabarmati basin in Gujarat Region covers parts of the districts of Banaskantha, Sabarkantha, Mehsana, Gandhinagar, Ahmedabad and Kheda. Five major tributaries join the river Sabarmati during its course viz. Wakal, Sei, Harnav, Hathmati and Watrak.

Rainfall Pattern

The basin experiences south-west monsoon, which generally sets in over the southern part of the basin in the second week of June, and extends all over the basin in another week lasting up to the end of September. Validated HIS rainfall data for 92 stations related to Sabarmati basin were collected for concurrent period of 30 years (1970 to 1999) and it was observed that the average annual rainfall in the basin is about 770 mm. Nearly 95% of the average annual rainfall occurs during the monsoon period. The winter rains are rare and mild.

Evaporation

The basin falls under semi-arid region of western India. The rate of evaporation is maximum during April to June due to rise in temperature and increase in Wind speed. The average annual evaporation losses in the basin are generally assumed to be about 1500-2000 mm.

Water resources of the basin

Surface water resources

The surface water resources of the basin have been estimated from time to time by various agencies since 1949. The assessment of the 75% dependable yield is continuously made with addition of reliable data base. It is observed that the yield of basin is on falling trend. This is due to the frequent experience of drought in the basin, rapid industrialization within basin and poor response of the basin to generate runoff. The assessment of basin yield at 75% dependability during various periods is shown in Figure 1.

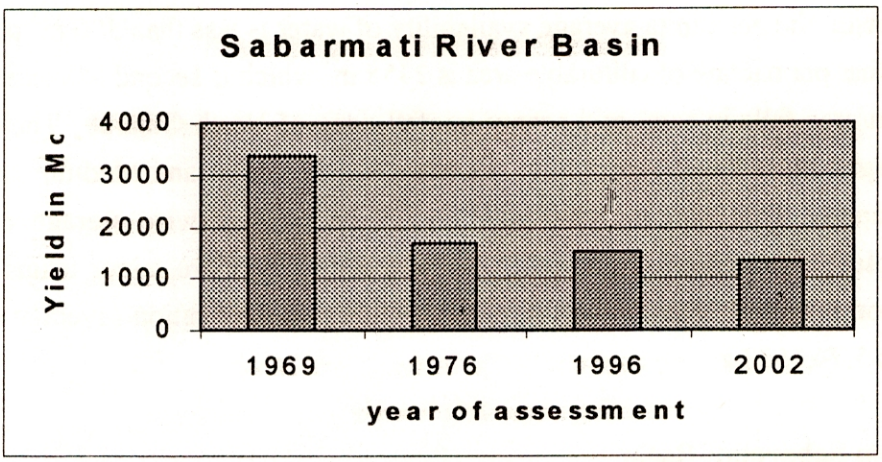

Figure 1. Assessment of yield of Sabarmati basin at 75% dependability

Ground Water Resources

The Sabarmati basin geologically comprises of rocks of Archaean age in northern and north eastern parts, while alluvial formations cover the central and Southern parts of the basin, the Archean rocks are mainly granites quartzite's, schists, phyllites and gneisses, while alluvial formations consists of alternating bands of sand and clays. The alluvial formations are mainly unconsolidated formations. In small area in Himatnagar formations are also comprising of sandstones and shales. The Archean rocks are the oldest rock formations, which form the basement of all younger semi-consolidated and unconsolidated formations. The main source of ground water in the basin is natural recharge from rainfall. The other source of recharge is the return flows from irrigation. The ground water potential figures are periodically being updated and as per the assessment made in the year 1997 the total annual ground water recharge 2570.37 Mm^3.

The basin consists of thick alluvial deposits consisting of clay and sand useful for ground water conservation. But the frequent droughts and water scarce years have made the people to rely more on this resource and thereby resulting in excessive exploitation of this resource. In some areas of the basin it has become nearly ground water mining. This has resulted in excessive salinity of ground water. Thus ground water plays a significant role in the basin.

Water Resources Development in basin including current import & export

Water Resources Development in basin

Any situation of water availability less than 1000 m^3 per capita per annum is considered a water stress condition by the international agencies and the situation of the water availability less than 500 m^3 per capita per annum is considered a primary constraint to life. In case of Sabarmati basin, the per capita average availability of water is less than 300 m^3 per capita per annum and that per hactare of culturable area is 2455 m^3 which is second lowest in India.

The basin area falls in semi arid scanty rainfall zone of North Gujarat. The economy of the area is agriculture based. At present the basin has 11 Major and Medium surface water reservoirs tapping irrigation potential of 1,66,507 ha. Project wise storage capacity and irrigation potential are given in Table 2. Over and above there are minor irrigation projects with irrigation potential of 24269 ha. Average ground water irrigation (average of 1994-97) works out to 5,74,151 ha.

Exports from Sabarmati Basin

Irrigation sector

It is worth to mention here that though Sabarmati basin is already a water scarce basin, it exports water to the adjoining basin as part area of Dharoi command and part area of Fatewadi (Wasna barrage) command falls outside the drainage boundary of the basin.

Domestic & municipal requirements

It is well known that the Mahesana district is having a declining trend for ground water levels which has resulted in problems related to excessive flouride contents. There fore to overcome this, water is being supplied from Dharoi reservoir to some villages and also a group water supply scheme named Danta –Vadgam- Palanpur is functioning. Thus the basin exports water for irrigated agriculture as well as domestic purposes.

Table 2. Project wise storage capacity and irrigation potential in Sabarmati Basin

S. N.	Existing Projects	Tributary	Storage [Mm^3]	Potential Annual Irrigation [Ha]	Remarks
1	Dharoi	Sabarmati	823.12	66796	including Tank Bed Cultivation, reverse canal & RBMB , LBMC
2	Watrak	Watrak	176.98	16874	LBMC, RBMC
3	Hathmati	Hathmati	152.83	27691	inclusive of zone A, B, C, & D
4	Meshwa	Meshwo	74.85	6880	
5	Guhai	Guhai	62.34	5831	
6	Mazam	Mazam	43.86	5259	
7	Harnav-II	Harnav	21.67	3440	inclusive of Harnav-I
8	Waidy	Suron [Watrak]	13.60	1336	LBMC, RBMC
9	Wasna Barrage	Sabarmati	5.34	33600	
10	Karol		6.00		supply to Hathmati zone D
11	Limla		8.35		supply to Hathmati zone D
		TOTAL	1388.94	166507	

Import to Sabarmati river basin

Irrigation sector

Simultaneously, import of water is being done from adjoining Mahi basin to irrigate the command area of Raska weir (supplement to the free catchment contribution),Shedhi branch of Narmada command and the command of Mahi Right Bank Main Canal falling within Sabarmati basin. The irrigation potentials of these projects are as given in table 3.

Table 3. Irrigation Potentials of Projects in Sabarmati Basin

Sr. No	Project	Irrigation potential in ha.
1	Raska (including 1200 ha transferred from Kharicut system)	11524
2	Shedhi Branch (Mahi command)	48638
3	Mahi Right Bank Main Canal	212993

The taluka benefited by these projects are Thasra, Dascroi, Mahemdabad, Matar,, Nadiad, Anand, Borsad, Khambhat & Petlad. All these taluka are located in the lower part of Sabarmati basin.

Domestic & municipal requirements

Since water supply from Dharoi reservoir to Ahmedabad has been stopped, as an alternative arrangement, water from Mahi basin is being given and also for some group water supply scheme viz. Kapadvanj, Matar & Khambhat are based on water imports from Mahi basin. The current total water import from Mahi basin is about 2157 Mm^3 for all sectors mentioned above.

Overall Demands

The population of the basin is 11.44 million souls (year 2001). The basin is having about 20 Industrial estates developed by Gujarat Industrial Development Corporation and also many private industries. There are two thermal power stations in the basin viz. Ahmedabad Electricity Company (in Ahmedabad) and Gujarat Electricity Board (in Gandhinagar). Huge quantity of water is required for cooling purpose. Similarly water is required for cattle population of the basin and also the irrigated agriculture.

Configuration of the Sabarmati River Basin

The configuration of Sabarmati river basin consists of combination of layout nodes, demands and control nodes alongwith appropriate type of links. The configuration of the basin is shown in Figure 2.

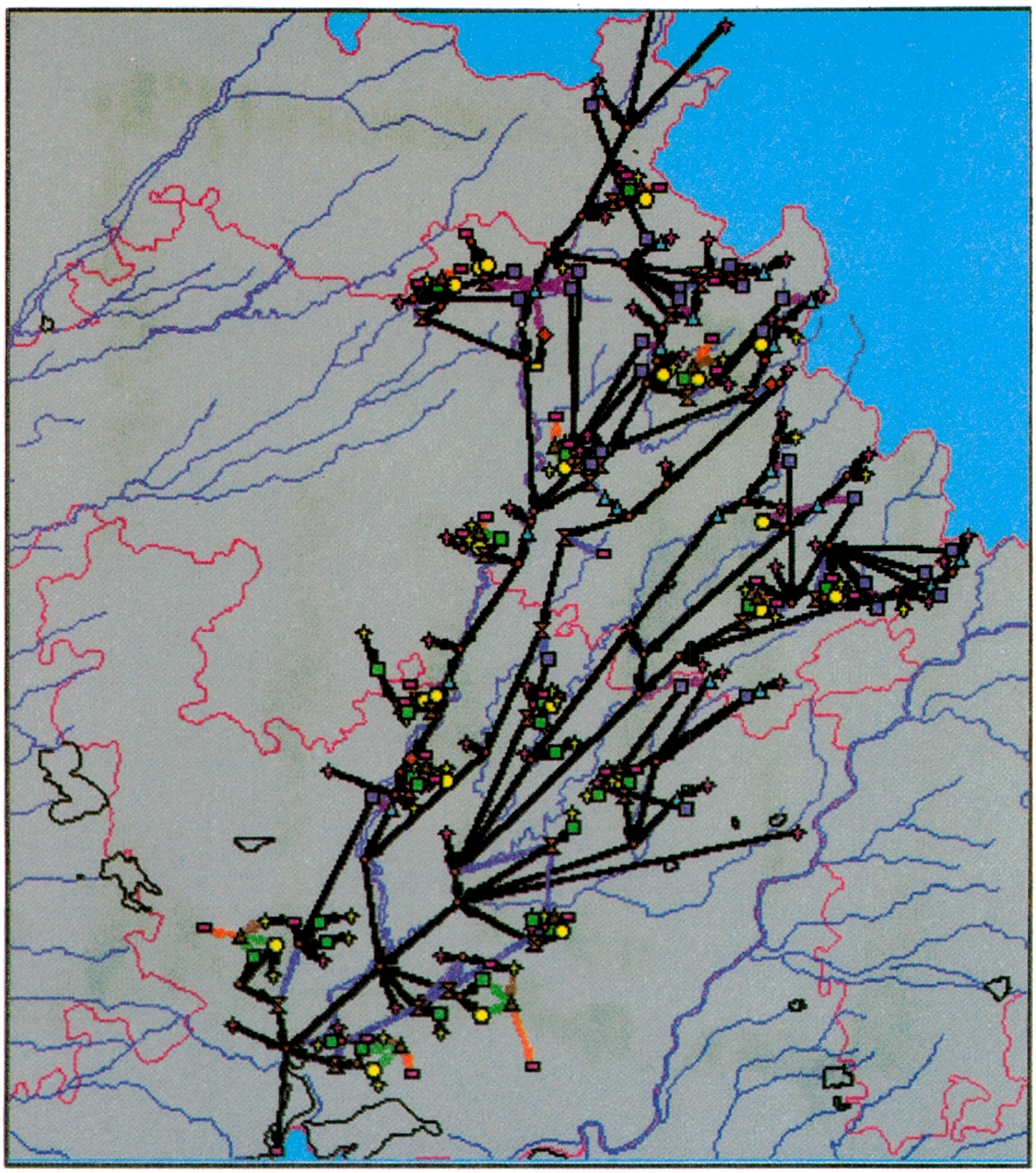

Figure 2. Configuration of the Sabarmati basin

SIMULATION CASES CONSIDERED

Simulation of the basin can be carried out for different hydrologic conditions termed as scenarios in 'RIBASIM' studies. This simulation per time step is carried out for the selected time period within the series entered. For Sabarmati basin, monthly data series for period 1980 to 2000 have been entered in the model and accordingly simulations are carried out. The first simulation runs are done for the base case depicting the present situation in the basin and results analysed. Normally, the studies are carried out for future planning, therefore, a second set of simulation run is made for the conditions depicting the autonomous development in the basin consisting of increase in demand due to various reasons like population growth. Industrial development and increase in irrigated area. The gap between demand and supply or areas where intervention is required can be identified for taking suitable measures. Thereafter, Likely measures are introduced in the simulation runs to know the impact on the system. Number of combination of measures can be considered and suitable simulations carried out to arrive at strategies for planning for the basin.

For Sabarmati basin studies, year 2001 has been considered as the year for base case and year 2025 has been considered as the year for reference case. The simulation results indicate that if the river flow composition downstream of confluence of Sabarmati river with Watrak tributary are segregated, Watrak shows major contribution indicating surplus water The reference case indicates increase in demand requiring inter basin transfer of water into Sabarmati basin. Therefore, the component of importing planned water from Sardar Sarovar Project was considered as a measure and basin was simulated. The demand and shortage position of the basi for all three cases is shown in figure 3.

Sabarmati river basin is a water scarce basin with all shorts of water related problems. The upper portion of the basin is water scarce and the lower portion downstream of Vautha is flat and there are problems related to flooding. Appropriate decisions and strategies are required to be formulated to meet the demands of this basin and the same can be studied further by introducing more measures.

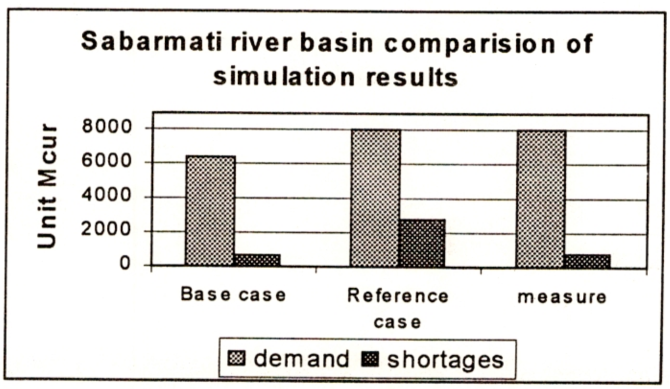

Figure 3. The demand and shortage position of the Sabarmati basin

CONCLUSION

Various cases for river basin simulation can be developed by using *RIBASIM* model as a tool and analysed. Combination of measures can be considered to arrive at strategies for planning at river basin level.*RIBASIM* can be one of the tools for decision support system (DSS).

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