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RIVER BASIN MANAGEMENT USING ADVANCE GEOSPATIAL AND SIMULATION TOOLS

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ABSTRACT

The National Water Policy -2002[1] has recommended establishment of appropriate river basin organizations for the planned development and management of water resources in all river basins in the country. The policy has further emphasized the need for setting up of special multi-disciplinary units for optimum utilization of water resources. Any step in this direction would need a strong and reliable computer based information system. The River Basin Management Information System will be the back bone for any decision making process. This paper discusses about the importance and need for development of well organized information system for all river basins in the country using advance geospatial tools. The paper includes various components of the basin Management Information System (MIS) as well as the use of river basin simulation techniques for integrated management of the entire water infrastructure for meeting various water demands duly taking care of quantity as well as quality issues including socio-economic and environmental aspects by developing reliable Decision Support System (DSS) for efficient management of the river basins.

Key words: geospatial tools, integrated management, basin simulation, MIS, DSS

1.0 INTRODUCTION

Water resources systems are generally characterized for their complexity, long service life, high cost & duration of implementation as well as huge socio-economic impact. In the event of failure, the negation of benefits as well as the hazards created can have catastrophic effects. Hence the planning, development and operation of these systems are carried out with utmost care, in an integrated manner and using every available technology. With increasing stress on water resources, the earlier concept of management by a single project basis is becoming increasingly obsolete and irrelevant. Water management on the basis of administrative unit is technically, politically and institutionally has been increasingly difficult. Hence hydrological units could be most appropriate for managing water resources. Hence the planning, development and operation of the systems on river basin scale are accepted world over. Geospatial tools which include Geographic Information System (GIS), Global Positioning System (GPS) with inputs from Satellite Remote Sensing (SRS) along with use of modern communication and simulation tools, has been instrumental in development of “Management Information Systems” (MIS) and “Decision Support Systems” (DSS) which are useful to provide periodic, systematic, & value added information that helps in decision making on complex subjects like water resources management.

2.0 NATURAL RESOURCE MANAGEMENT

Natural resource management deals with the management of land, water, with a focus on how management affects the quality of life for both present and future generations. It brings together land use planning, water management, and the future sustainability of agriculture, tourism, fisheries etc. Natural resource management specifically focuses on a scientific and technical understanding of resources and the life-supporting capacity of those resources. There are various methodologies developed to assist natural resource management. Geographic Information Systems (GIS) is a powerful analytical tool as it is capable of overlaying datasets to identify links. A process of managing natural resources in a systematic way, which includes multiple aspects of natural resource, is depicted at Fig.1. It basically starts with collection, compilation and analysis of all relevant data for developing an information system. The information system (MIS) thus developed is used for initiating various actions in the form of planning, development and finally management of the resource (DSS). In case any these steps are missed, consequent leads to non optimum use of the resource.

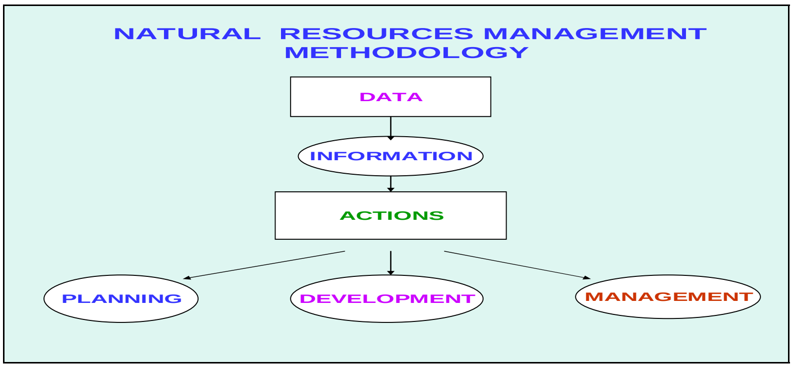
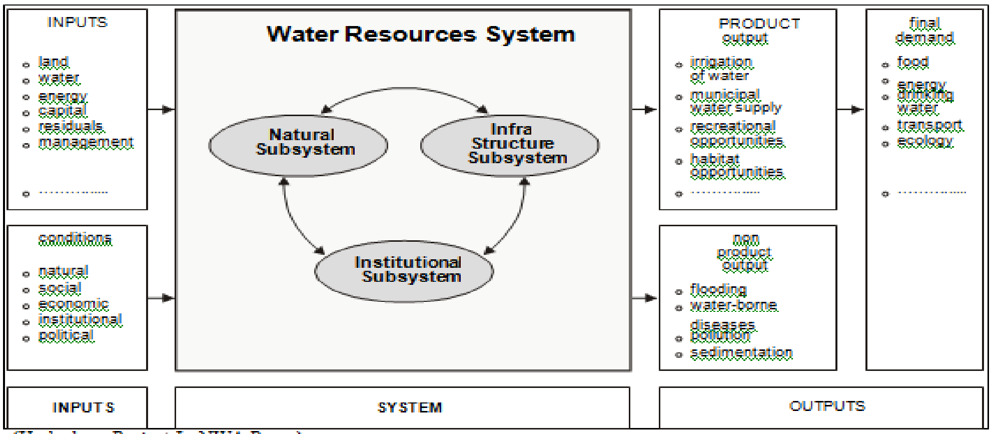


Fig.1: Natural resources Management Methodology

2.1 River Basin Management System

The basic features /components of the water resources system (Fig.2) [2] include the Natural Resources System (NRS) i.e. the system of rivers, lakes, groundwater aquifers including its functions for the ecosystem) ,the Socio Economic System (SES) (i.e. the water using and water related human activities) and the Administrative and Institutional System (AIS) (i.e. administration, legislation and regulation including depts. responsible for the management) to carry out subsistence functions, commercial functions, environmental and ecological functions.



(Hydrology Project-I –NWA Pune)
Fig.2: Water Resources Management System

The system uses natural as well as other resources as input & the outputs are food, fibre, energy and other services beneficial for the life in the basin. The effective management of the basin can be achieved when MIS is developed for all these three components using geospatial tools and DSS is developed using simulation tools for their intra and inter relationships.

3.0 MIS DEVELOPMENT

For management of such complex system, MIS based on modern advance geospatial and tools are suggested as a state of the art. Remote sensing capabilities allow faster and precise study of real time extractable parameters on a regional scale whereas, GIS combines layers of information about a place to give better understanding of that place.[3] It brings together all relevant information as the thematic details generated on a common platform as attribute tables and provide for the analytical capabilities. Such processes also lead to information generation on geo-environmental impacts and changes.

3.1 Basin Features

The basin geography, geology, hydrology & demography form the base for MIS. Average annual rainfall, runoff, evaporation etc. with temporal & spatial variations, more or less fully developed zones with thrust on rapid urbanization, major cities/towns, total population with urban-rural ratio can form part of themes. Reservoirs, dams, command areas, as well as the rail and road network with reference to their lat-long positions can be included. Each of the attributes to have information table which can give information about meta data as well as the specific spatial & temporal data about the feature layer which can be analysed whenever required for specific queries. The land use map is prepared using classification of the digital image of the study basin can be included.

3.2 Hydrological Network

Adequate network for measurement of hydrological & meteorological parameters is essential in the basin. The parameters like rainfall, river flows, evaporation, temperatures, wind data, sunshine period etc including ground water parameters are collected & analysed at various places in the basin to ascertain spatial & temporal variations. The Hydrological Information System (HIS) developed for surface as well as ground water forms the part of the MIS. River basin has major storage projects which are used for irrigation, municipal and industrial water supply, power generation and other purposes form part of the MIS. The MIS includes the information about all salient features of the dams & reservoirs. The reservoirs information includes their hydrological safety as well as water audit on various time scales right from their inception. The bench-marking parameters form the input to MIS. The aspects of sedimentation, evaporation, water quality, submergence etc also part of the MIS .The main canals serving a gross command area, its salient features, construction, renovation, lining, seepage, water logging areas, canal automation aspects etc are included in the MIS. Few of the layers generated for the sample basin are at Fig.3

3.3 Ground Water

The information about the potential availability of the ground water, irrigation & public water supply demands, depth of ground water table, recharge potential, draft ,critical or over exploitation area as well as water quality form the fundamental inputs in the MIS. The MIS shows the location of various wells that come under the study area. They are mainly categorized as dug wells and bore wells. It will give the location, name, taluka, no. of watershed and its categorization, i.e. whether it comes under safe, semi-critical critical or over-exploited zones.

3.4 Irrigation

Irrigation is the replacement or supplementation of rainfall with water from another source in order to grow plants and crops. Intensive irrigation is provided to areas beyond the basin boundary. Both surface & ground water is used for irrigation. The cropping pattern, total cropped areas, canal distribution network, crop water requirements, methods of irrigation, water supplied, water users associations, water cess collected etc form part of the MIS. Assessing proper crop requirements, proper scheduling using MIS can save substantial quantity of water. Thus, the user managed institutions can be able to save their time, man power and water.The effects of over irrigation in the form of water logging, salinity in certain areas can be classified & marked in the MIS as a separate layer. The MIS includes the extent & location of these effects, remedial measures; their results over a period of time are the query analysis in the MIS. The drainage schemes location their effects over a period can form the part of the MIS.

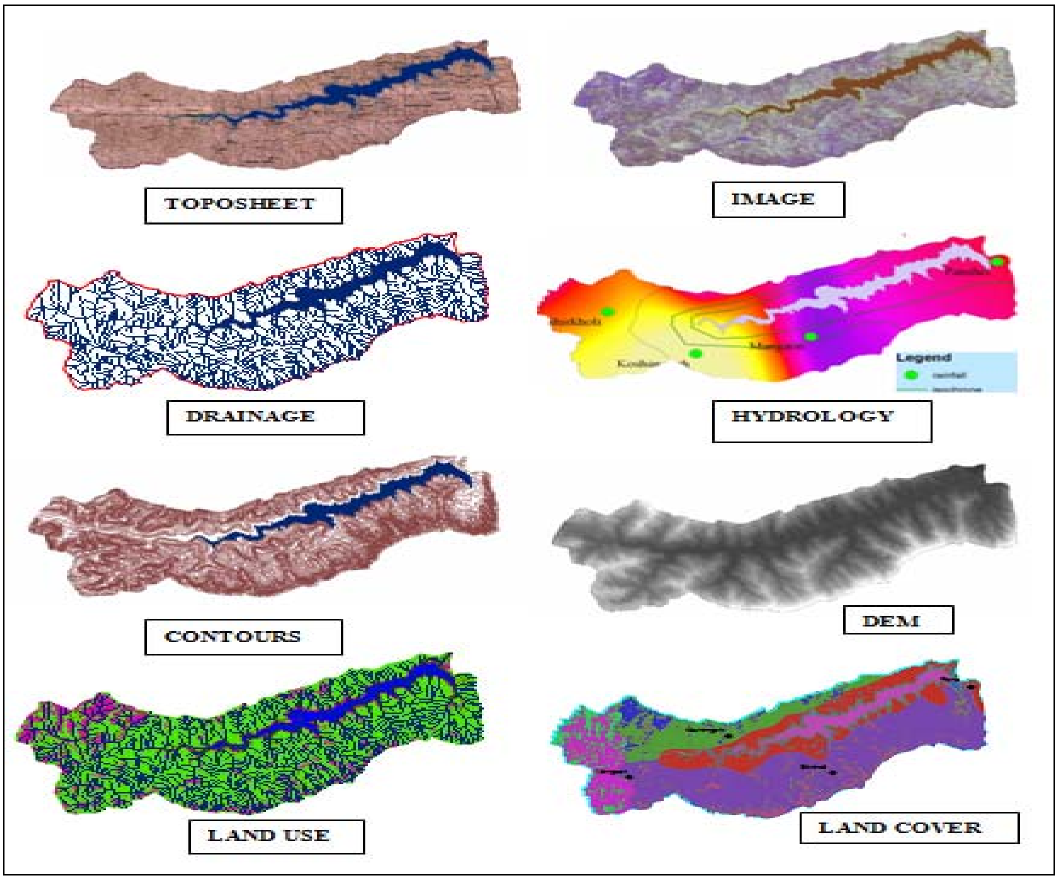


Fig.3: MIS layers for the sample basin

3.5 Domestic/ Industrial Water Supply

Because of rapid urbanization and higher standards of living, the demand in this sector has increased drastically during recent years. Low ground water level has resulted in drought conditions for villagers during summer season. Even the urban areas are facing acute shortage of water supply. Industrial demands are increasing rapidly because of high industrial growth in major cities. The storage, diversion, treatment & distribution network is part of the MIS. Its performance, water quality standards, spatial & temporal supply/deficit areas, including the industrial supply etc form the part of the MIS.

3.6 Hydropower

Hydropower is one of the renewable resources of all the power sources, being the most efficient, reliable and economical. Assessment of hydropower potential, detailed surveys, hydel information like capacity, discharge, head power generation maintenance & operation of the project forms the part of MIS

3.7 Flood & Drought Prone Areas

This layer in MIS identifies the areas, flood frequency etc. The remedial measures, their effects / performance also can form the part of the MIS. Possible solutions of mitigation of the flood damage can be arrived upon query analysis. There are certain portions which are drought prone. This layer in MIS identifies the areas, types of droughts etc. The remedial measures, their effects / performance also can form the part of the MIS. Possible solutions of mitigation of the droughts can be arrived upon query analysis.

3.8 Environmental Issues

The data pertaining to the water quality (Surface and Ground), population in towns and villages, forest areas, soil conservation measures, afforestation measures, lean water flows etc. in various sub basins of the river system included in MIS. Important monuments, roads, bridges and their details can also be collected and maintained. This information will be very useful in carrying out Environmental Impact Assessment (EIA) studies. Satellite imageries are to be used extensively for quick data collection and updating.

Generic MIS can include several other aspects of the river basin, like navigation, recreation, aquaculture etc whereas the specific MIS can include the detail specific characteristics of interest. Some of the sample themes like command area, major projects, public water supply schemes, ground water wells etc along with attributes are depicted in Fig.4

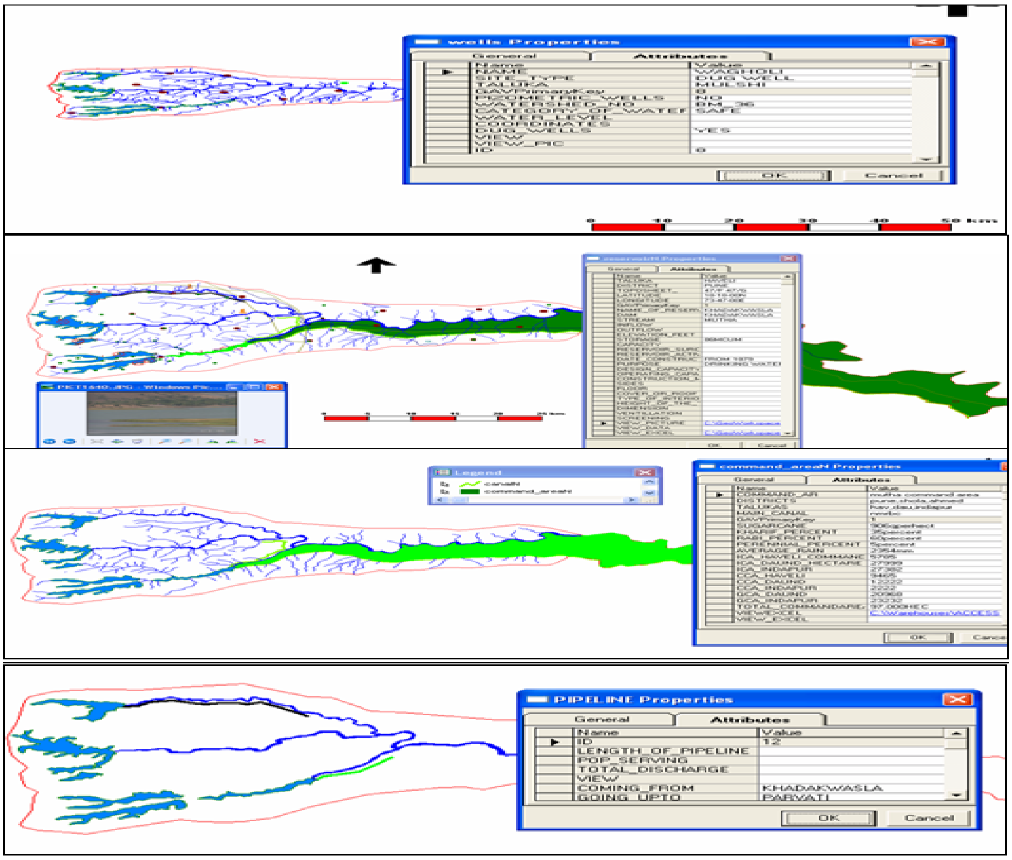


Fig.4: MIS Themes & Attributes for Sample Basin

4.0 DSS DEVELOPMENT

MIS thus developed serves as basic input for planning, development and management of water resources in a river basin in an integrated manner in relation to socio- economic, environmental and technical considerations, which is essential and desirable to obtain maximum benefits at minimum financial, environmental and social costs. The most important objective of a basin plan is to provide comprehensive and updated information on the present status, as well as development and /or management options for future after studying various strategies which is nothing but the Decision Support System (DSS). Water being a dynamic resource, the allocations from various sources through physical infrastructures such as reservoirs, canals, channels, pipelines, pumping etc. having specific physical attributes to multiple demands of competing as well as conflicting nature, having spatial or temporal variations, is a complex job. Development of DSS to achieve near optimum water allocations, a simulation approach can assist in realistic assessment of resources, demand / supply patterns, and effective operation of infrastructure leading to integrated water resources planning, development and management in optimal manner for future needs. The DSS thus developed enables:

- Accounting and budgeting of available water resources at the river basin level
- Planning, development & management of the water infrastructure
- Management of available water resources for various demands such as irrigation, domestic & industrial water supply, hydropower generation, flood/drought mitigation, navigation, aquaculture, recreation etc duly taking care of both quality as well as quantity aspects
- Environmental as well as socio-economic issues
- Integrated system operation and maintenance
- System monitoring and performance analysis

5.0 DSS COMPONENTS

The objective of basin simulation is to forecast the water scenario for future and to evolve a Decision Support System (DSS) to mitigate the impact of future demands to a maximum possible extent. The simulation considers base year and gives an overall idea about the future water scenario by carrying out simulation analysis using hydrological and other related long term data series adopting Integrated Water Resources Management (IWRM)[4] using the basin simulation software such as RIBASIM[5&6]. Following aspects are covered in the exercise.

5.1 Planning Aspects

The river basin simulation model provides an effective tool for better planning and management of water resources in the basin. The planning aspects cover:

- Situation profile problems, issues; policies and strategies; programs and projects (with accompanying budgets)
- Organization and management; monitoring and evaluation etc. duly taking care of the dynamics in planning such as changes in demand, economic developments, changes in production processes, population growth, land use developments, changes in supply due to natural developments (climate change) or human actions upstream, quantity / quality of inflows, technological options, societal changes regarding objectives and criteria (public opinion) etc..
- The other aspects include technical issues such as modifications of the water infrastructure including the operation rules etc., ecological measures to maintain functioning of the ecosystem ,economic incentives to use the water resources in a socially desired manner, regulation measures to restrict uncontrolled use of the water resources, institutional arrangements by specifying governmental dept. responsible for function of system and specifying the necessary interactions between public and private sectors involved.

5.2 Demand Analysis

Major consumptive as well as non consumptive demand analysis considered during simulation.

- Agriculture : present practices, location and area of irrigated agriculture, desired and potential developments, water use efficiency, etc.
- Hydropower: existing and planned reservoirs and power stations, operation and capacity
- Public water supply: location of centers of population and industrial activities, expected growth, alternative resources
- Recreation: nature and location, expected and desired development, water quality conditions
- Navigation: conditions of the water depth in (parts of) the open channel system
- Nature conservation: location of valuable and vulnerable areas and their dependency on water quality and quantity.

6.0 DSS DEVELOPMENT

As a case study, the software package is used for analyzing the behavior of sample river basin under various conditions. Using this comprehensive and flexible tool, the hydrological water inputs at various locations and the specific water-users in the basin have been linked so as to evaluate a variety of measures related to infrastructure, operational as well as the demand management. The results obtained in terms of spatial and temporal distribution of water quantity/ flow patterns in river reaches and reservoirs provide a basis for detailed analysis.

6.1 Basin Schematization

The sample basin is schematized which consists of a network of nodes connected by links, which represent the overall water inputs, infrastructure, uses and outflows for the basin. The nodes represent inflows, reservoirs, dams, weirs, pumps, hydro-power stations, bifurcations, intake structures, lakes, water users, losses, outflows etc. The links transport water between the different nodes. The network represents all the significant basin features for its water balance.

6.2 Data Entry & Calibration

The relevant attribute data with respect to each node and link is entered. For each time duration, the water demands, targets for water releases from reservoirs, aquifers, lakes, and weirs and pumping stations etc. are determined. Then the water is allocated to the users according to the release targets, water availability, operation rules and water allocation priorities. The model is then calibrated by comparing the model output results with the ground reality at various locations with respect to out flows; reservoir operation schedules etc by changing variable attribute parameters by trial and error. The calibrated model is used for conducting the simulation runs. The sample basin as schematized, calibrated & operated for DSS[7] is depicted in Fig.5

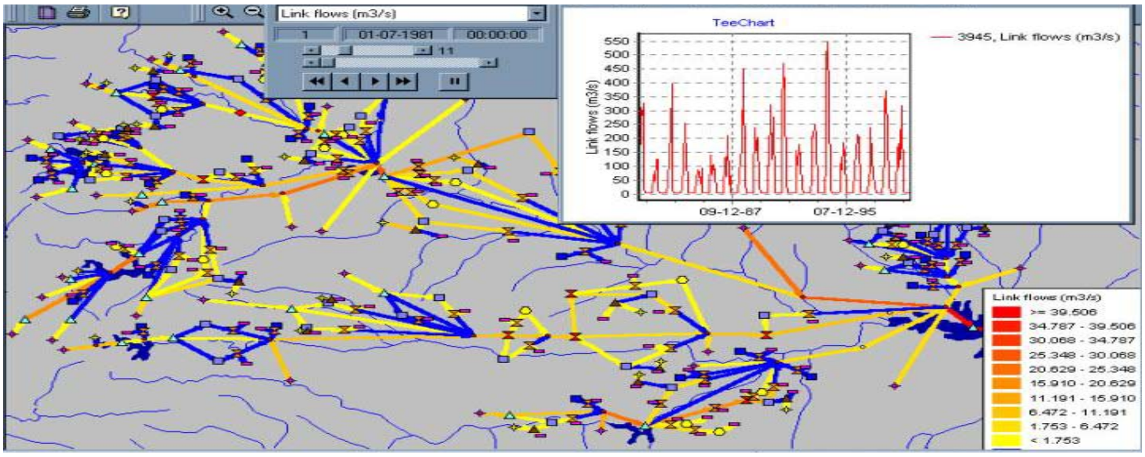


Fig.5: Schematized Flow Animation Simulation Model

6.3 Basin Simulation & DSS

Basin simulation for water allocation from various sources to various demands is made on monthly or ten daily basis over a period of about say twenty years so as to include the occurrence of sufficient dry and wet periods. The analysis is carried out for the present demand & supply scenario by appropriate management strategies such as reduce the demand and increase the supplies. For the future deficits scenarios for various uses certain measures as well as group of measures i.e. strategies are formulated. The quantitative impacts of these strategies on the projected demands are also analyzed. Sample results for DSS can be as per Fig.6. It can be seen from the sample results that the quantitative impact on the deficits can decide the efficacy of the strategy adopted. Hence it becomes easier for the decision maker to decide the priority actions as well as to select & adopt the development & management strategies from the various options available. [8]

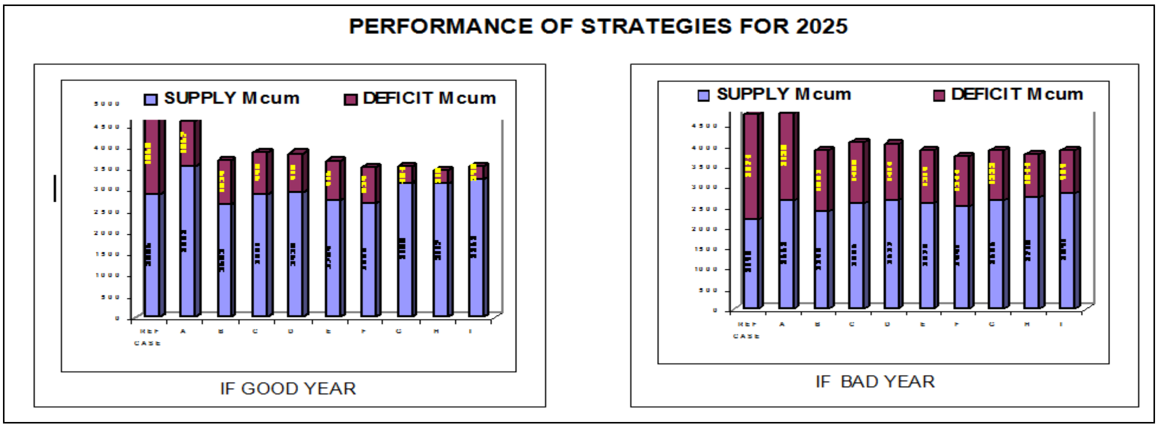


Fig.6: Sample DSS Results

7.0 CONCLUSION

The river basin management system has spatial & temporal dimensions since it is focused on a spatial unit, the hydrological catchments. This makes the use of geospatial tools in its integration with traditional water resources models. The MIS which provides reliable, accurate & value added information of entire river basins, encompassing various aspects of water resources availability, its spatial & temporal distribution etc. is far from trivial. For DSS development status, future scope, various consumptive & non-consumptive demands, their fulfillment status, future projections, socio-economic & environmental aspects etc. The initial development of generic software, data entry & callibration may take some time, but once established, the updating of the information is easier as most of the data will be obtained through remote sensing or from other database software. Moreover, in future we will be reaching a situation of water scarcity of such a magnitude that 'Water at any cost' is going to be the major guideline in deciding about future projects. The proposal of water transfer from one river basin to the other by way of inter linking of rivers is being implemented for which MIS/DSS is to play crucial role. Hence all efforts are necessary to combat the worst scenario and the beginning is to be made with establishing a reliable MIS/DSS which can lead to faster planning and optimum development & efficient management of our precious water resources in all river basins in the country.

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