TRANSBASIN TRANSFER OF RIVER WATERS IN PUNJAB FOR OPTIMISING BENEFITS

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ABSTRACT

To utilise the waters of the rivers Sutlej, Beas and Ravi flowing through Punjab, and which come to the exclusive share of India, as per the Indus Waters Treaty-1960 between the Governments of India and Pakistan, a number of projects have been planned, constructed or are under construction on these rivers. These projects have helped in gainfully diverting the waters of river Beas in Sutlej and of river Ravi to Beas, in addition to providing multi-purpose benefits. The projects have brought an agricultural and industrial revolution to the states of Punjab, Haryana and the desert areas of Rajasthan and transformed them into granaries of India. The paper briefly describes the various projects and their salient features. The impacts of the projects on the economy, environment, health, tourism and recreation etc. have been highlighted. Since these projects have enabled the diversion of surplus waters of one river to another, studies for integrated operation and management of waters of these rivers have been carried out for deriving optimum benefits. The paper also describes the real time integrated operation techniques, factors necessitating their adoption, and computer models used for integrated operation of the Bhakra Beas system of reservoirs. It is recommended that for effective utilization of the available waters, and implementation of the real time integrated operation techniques, an automatic data collection and transmission system be installed.

INTRODUCTION

India is bestowed with abundant water resources, but their spatial and temporal distribution is quite uneven. About 80% of the annual runoff in Himalayan rivers and 90% in Peninsular rivers occurs during the four monsoon months from June to September. Due to this, floods and droughts are occurring almost every year causing extensive loss to the economy and suffering to people. A number of reservoirs have, therefore, been planned and constructed for the conservation of excess water during the monsoon period, its utilization during the lean period, and to derive multipurpose benefits. Average annual runoff of various river systems in India has been estimated at 188 million hectare metre (Mham). Only 69 Mham can be put to use, even if all the available storage is developed.

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The remaining water would flow unutilised to the sea due to temporal variations of rainfall.

The Sutlej, Beas and Ravi rivers in the Indus basin constitute a major source of water for irrigation to Punjab, Haryana and Rajasthan. A number of projects on these rivers have been planned and constructed for the optimal development of water resources to transfer the excess water from one river to another, and to derive multi-purpose benefits. These projects have contributed significantly in meeting irrigation, municipal and industrial demands and the generation of hydel power, in addition to mitigating the flood menace.

Optimal utilization of the waters of the three rivers came to the exclusive share of India as per the Indus Waters Treaty (1960) concluded between the Governments of India and Pakistan. Bhakra and Nangal dams were constructed on the river Sutlej. Pong and Pandoh dams, and the Beas-Sutlej link on the river Beas, and the Ranjit Sagar dam is under construction on the river Ravi. The construction of these dams and diversion structures has not only helped in the conservation of excess monsoon flows, but also created an agricultural and industrial revolution in the states of Punjab, Haryana and Rajasthan. Even the far flung desert districts of Rajasthan, like Bikaner, Jaisalmer and Ganganagar have been transformed into green and fertile lands. The excess waters of river Ravi are being diverted to river Beas and those of river Beas to river Sutlej, through the Beas-Sutlej link. This not only avoids water going to waste but also increases irrigation & hydro potential. Drinking water requirements of big cities like Delhi & Chandigarh are being augmented by the waters of Bhakra reservoir.

The Bhakra-Beas reservoir system is one of the largest multi-purpose, multi-reservoir systems in India. It utilises the waters of the three rivers in an integrated manner. Operation of reservoirs is complicated in the case of multi-purpose uses where joint use of storage for meeting competing and conflicting demands is required. Advancements in the field of System Engineering and the modern computer facilities now available, could be effectively utilised for integrated planning and management of water resources of the basin.

Real time hydro-meteorological data collection and inflow forecast procedures have been implemented in some projects. This provides real time flood forecasts into the reservoirs. However, the technique of real time integrated operation of reservoirs, using computer simulation as an aid for making operation decisions, has not been attempted in India. To develop the computer based techniques of real time integrated operation, a case study of Bhakra-Beas system has been carried out by the Central Water Commission with the assistance of USAID. As a part of this study, real time stream flow forecast and reservoir operation models, along with other associated programs for data storage, inflow forecast etc., were developed. The study used the HEC series of software packages, under the guidance of two expatriate consultants.

BASIN DESCRIPTION

The Bhakra – Beas reservoir system is one of the largest multipurpose and multi-reservoir river valley systems in India. The rivers and major tributaries in the system have perennial runoff due to snowmelt in the summer months & rainfall during monsoon and winter seasons. The rivers have interstate implications and water sharing aspects. Inter-basin transfer of water from one river basin to another, and the integrated operation of various multipurpose reservoirs having competing and conflicting demands, is necessary to mitigate floods and to authorise optimum benefits for irrigation and power.

The river Sutlej has a catchment area of 2,04,258 Sq.Km. of which 54,000 Sq. km. is in Tibet. It rises at an elevation of 4750 m above MSL from Rakas Lake, near Mansarovar lake in Tibet (China). The total length of the river from its source to the India-Pakistan border is 1078 Kms. The upper part of the catchment is permanently snow-covered. The river Beas rises from the southern face of Rohtang pass at an elevation of 4063 m above MSL. It drains an area of 20,303 Sq.Km., of which about 780 sq. Km. is under permanent snow. The total length of the river is 460 Kms and is wholly in India. The river Ravi has a catchment area of 14,042 sq. km. It is entirely in India, and rises near the Rohtang Pass. It drains the southern slopes of the Dhauladhar. From its source to the Indo-Pakistan border (about 2.6 Kms from Amritsar) the river has a length of about 370 Kms.

PROJECT DESCRIPTION

A number of projects have been planned or are under construction/ constructed for the integrated development of these waters. The Bhakra-Nangal projects and the Ropar and Harike head-works have been constructed on river Sutlej. The Bhakra-Nangal projects comprise the Bhakra dam, the Nangal dam, the Nangal Hydel channel with Ganguwal and Kotla power stations and the Anandpur Sahib power channel and its two power houses. The Beas projects comprise the Pandoh dam, Beas-Sutlej Link (BSL) channel and the Beas dam at Pong. The excess waters of river Beas are gainfully diverted from Pandoh dam through BSL to Bhakra reservoir. This not only helps the waters of river Beas from going waste and causing flooding downstream but also in generating power at Dehar, Bhakra-Dam and Bhakra Canal Power houses in addition to supplementing the water supplies of Bhakra reservoir. The Ranjit Sagar dam on the river Ravi is nearing completion. Surplus Ravi waters are diverted to Beas from Madhopur headworks through the Madhopur –Beas link. The Ropar and Harike headworks are constructed on river Sutlej and a network of canals from these headworks provides irrigation to Punjab, Haryana and Rajasthan. (See map, Figure-1). The various projects are briefly described below and their salient features given in Table-1.

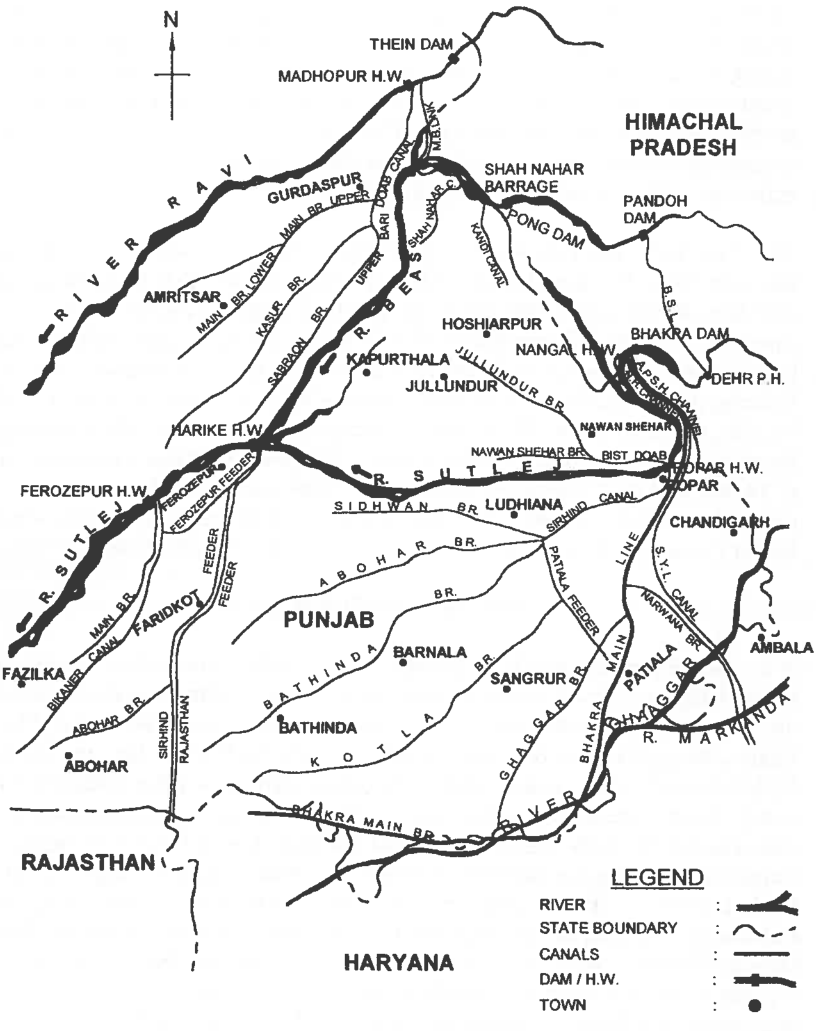

Figure 1. WATER RESOURCE PROJECTS ON PUNJAB RIVERS

Table-1 **SALIENT FEATURES**

	BHAKRA DAM	NANGAL DAM	PONG DAM	PANDOH DAM	R. SAGAR DAM
Year of Completion	1963	1954	1974	1977	Under Constn.
Type of Dam	Concrete Gravity	Concrete Barrage	Earth Cr.-c-gravel	Earth-c-rock fill	Earth Core cum gravel
Height-(M)	225.55	29	132.59	76.2	160
Cost (Crores)	218.24	27.04	325.88	449.17	3000
Storage Cap. Mm^3					
Initial Gr. Storage	9621	25.22	8570	41	3280
Present Gross Storage	8314	-	8040	-	-
Initial Live Storage	7191	-	7290	18.56	2344
Present Live Storage	6500	-	6392	-	-
Installed Cap. (MW)					
Left Bank	108	154	6x60`	6x165	4x150
Right Bank	132	-	-	-	-
Design Head (m)	122	28.35	72	360	-
BENEFITS					
Annual Generation of Elec. (Million Units)	7000	1000	1800	3600	1509
Value of Power Gener-Rated @ Rs.2/- per Unit (Crores)	1400	200	360	600	302
Water Supply (Mm^3)	16034	12334	-	-	-
New Area Irrigated Lakh Acres)	65	40	8	- -	0.32 3.16
Area under improved Irrigation (Lakh acres)	22	-	-	-	-
Town Electrified	128	-	-	-	-
Villages Electrified	13000	-	-	-	-
Cost of Annl. Produce (Crores)	465	350	100	-	140

In addition benefits due to fisheries, milk production, development of major industries, tourism, improved communication, employment generation, relief from floods, increase in the rate of literacy, health & standard of living et

Bhakra Dam : The Bhakra multipurpose dam, a concrete gravity structure of 225.85 m height, is constructed across river Sutlej at the Bhakra gorge. The reservoir created by the dam, known as Gobind Sagar, has a storage capacity of 9621 MCM and a water spread of 168.35 sq. Km. The catchment area is 56,980 sq. km. The over-flow spillway and river outlets can discharge 11,326 cumecs of flood waters. There are two power houses at Bhakra, one on the left and the other on the right bank with initial installed capacities of 5x90 MW and 5x108 MW respectively. The turbines have now been renovated and the installed capacities increased to 5x120 MW & 5x132 MW respectively.

Nangal Dam & Nangal Hydel Channel: The Nangal dam situated about 13 Km down stream of the Bhakra dam has 26 bays of 9.14 m each. The pond created by the dam acts as a balancing reservoir to smooth out the diurnal variation in releases. It is designed to pass a flood of 9910 cumecs (3.5 lakh cusecs). Just upstream of the Nangal dam, two hydel channels, namely Nangal Hydel Channel and Anandpur Hydel channel, take off from the left bank of Sutlej. The Nangal Hydel channel diverts water for power generation at Ganguwal and Kotla Power Houses, by utilising the natural falls available along the channel. The Ganguwal power house is located 16 Km. from Nangal, and the Kotla power house at 10 Km downstream of Ganguwal. These two power houses together have an installed capacity of 77 MW . The water released after power generation is utilised for irrigation in Punjab, Haryana and Rajasthan through the Bhakra Main canal. The Anandpur Sahib Hydel Channel has two power houses of 67 MW each.

Pandoh Dam & Beas Sutlej Link : The Pandoh Dam is an earth rockfill diversion dam of 76 m height on the river Beas at Pandoh, 21 Km. upstream of Mandi town in H.P.on Mandi-Kulu road. In addition to generation of power, the project helps in meeting the irrigation requirements of Punjab, Haryana and Rajasthan. A chute spillway with a flip bucket for maximum designed outflow of 9939 cumecs (3,51,000 cusecs) has been provided on the left abutment. The spillway has 5 bays having radial gates of 13 m x 12m to regulate the flow of water. The Beas-Sutlej Link (BSL) envisages diversion of 4716 million cubic meters of Beas waters into the Sutlej for generation of power at Dehar Power house, and utilising a head of 320 m, producing additional power in Bhakra-Nangal reservoir system, and then utilising this water for irrigation. A tunnel of 7.62m in diameter and 13.1 Km in length, and capable of carrying 254.85 cumecs (9000 cusecs), has been constructed between the Pandoh and Baggi control works. The BSL comprises the diversion dam at Pandoh, the Pandoh-Baggi diversion tunnel, the Baggi control works, Sundernagar Hydel channel, the Sundernagar Balancing Reservoir, the Sundernagar-Sutlej tunnel and the power house at Dehar. The designed head and installed capacity of Dehar power house are 320 m and 6X165 MW respectively.

Beas Dam at Pong : Beas Dam at Pong is an earth core gravel shell dam of 132.59 m height across river Beas at Pong in H.P., about 25 Km from Mukerian. This is the highest earth fill dam so far constructed in India. It has a gross storage capacity of 8570 MCM of water, of which 7290 MCM constitute the live storage. Five concrete tunnels of 9.14 m in diameter and 5 Km in length constructed for river diversion during construction stage, are being used as penstocks & to control irrigation releases. After serving their function as diversion tunnels, two of these tunnels have been converted into outlets for controlled irrigation releases and three are used as penstocks. An ogee shaped chute spillway having 14.48 m x 12.34 m with six number radial gates has been provided on the left abutment of the dam. The spillway accommodates a design flood of 33,555 cumecs (11,85,000 cusecs) with a maximum discharge of 12,375 cumecs (4,37,000 cusecs). The installed capacity of Pong power plant is 6x60 MW.

Ranjit Sagar Dam: The project envisages the construction of a 160 m high earth core cum gravel shell type dam and a concrete spillway involving 24 million cubic meters of rock excavation and four diversion/irrigation and power tunnels of 12 m diameter each. The gross storage capacity is 3280 MCM , of which 2344 MCM is live storage. As per the Indus Waters Treaty(1960), India is entitled to utilise all the waters of rivers Ravi, Beas and Sutlej. Presently, lot of water of river Ravi is going to Pakistan. After the completion of the project, it would not only provide irrigation to 348,000 hectares in addition to generation of 600 MW of hydro-power, but the project would also help in utilising the waters passing into.

IMPACT OF THE PROJECTS

Prior to the construction of the Bhakra-Beas projects, the Punjab State was facing famine, drought and floods year after year. Though the alluvial plains of the Indus Basin are fertile, people are subjected to periodical calamities of crop failure, loss of livestock, starvation & human lives. The farmers were at the mercy of weather. Most of the villages were not electrified and industrial development couldn't take place. After the construction of the Bhakra Beas projects, a vast network of canals now exists in Punjab, Haryana & Rajasthan to support irrigation. The plains of the Punjab have become the granaries of India. Waters of Bhakra are even reaching the desert districts of Rajasthan, such as Bikaner & Jaisalamer, where one had to travel miles in search of water. Most of the major towns of Punjab, Haryana & Western Rajasthan, along with Delhi & Chandigarh, depend on water supplies from these projects. People of Punjab have now forgotten about floods due to the mighty Sutlej and Beas rivers. They have in turn encroached upon river banks. Industrial and overall economic development of the area has taken place due to the availability of assured water, electricity and infrastructural facilities. Some of the effects of the projects are briefly described below:-

Economy

The Bhakra Nangal project was completed in the year 1963 at a cost of Rs.245.3 crores(US $53.3 millions), Pong dam was constructed at a cost of Rs.325.9 crores(US $70.8 millions) in 1974 and Pandoh dam at a cost of Rs.449.2 crores(US $97.6 millions) in 1977. Many direct and indirect benefits have accrued to the people of the area, some of which are described below:

The projects are generating 12.8 billion units of electricity every year on an average. Using conservative rate of power at Rs.2/- per unit, the annual value of power generated is Rs.2560 crores (US$ 556.5 millions). The projects are providing irrigation to 113 lakh acres of new land and have improved irrigation on 22 lakh existing acres. This has helped the country not only in meeting the food requirements but also providing surplus food production. The production of food grains and cash crops is estimated to be Rs. 200 billion every year. About 28,368 million cubic meters of water is being provided to meet drinking water requirements of major towns and a number of villages in the Punjab, Haryana and Western Rajasthan, including Delhi and Chandigarh. Milk production is valued at about Rs. 25 billion. There has been an increase in the development of fisheries in the Bhakra and Pong reservoirs, enabling the poor people of H.P. to earn their livelihood. Flood from rivers Sutlej and Beas in the Punjab plains were causing widespread loss of life, property, crops and land erosion, and these have been reduced. Better transport and communication facilities were created as part of the construction of these projects. Due to the availability of agricultural produce, water, power and other infrastructure facilities, industrial development in the region has increased. A lot of valuable temporary employment was generated for the construction of the projects. Additional and permanent employment opportunities have been created due to industrialisation and agriculture. A lot of indirect benefits have occurred due to increased the business activities, tourism, increase in rate of literacy and standard of living etc.

Environment

The projects have helped to improve the environment of the whole area. Prior to the construction of these projects, the Sutlej and Beas rivers were eroding vast tracts of lands during floods. Storage available in the Bhakra and Pong reservoirs is utilised effectively for controlling floods and thus avoiding flood losses and land erosion. Production of fodder has reduced pressure on grazing lands. Earlier people were cutting forests for fuel, making coal for winter heating, etc. With the availability of electricity and cooking gas, the forests in the catchment help in reducing soil erosion. Afforestation and soil conservation measures are implemented in the catchment areas of the projects to prevent soil erosion. Earlier the sediment brought by the rivers was deposited in the river bed due to reduced velocities, thereby increasing the bed levels & reducing the carrying capacity of the rivers. With the construction of reservoirs and soil conservation measures, the river beds in the plains are not raised & submergence of adjoining areas is avoided. Trees planted on the banks of canals and irrigation provide positive ecological effects. Earlier farmers were of the view that more irrigation water would give them more yield. This resulted in water logging and salinity problems in some areas. But the farmers are now educated in applying the required quantity of water.With proper drainage, the water logged areas have been reclaimed.

Health & Employment

The projects have helped in raising the standard of living and increased the rate of literacy. A considerable amount of employment has been generated through the construction of the projects, due to the increase in agricultural production and industrialisation. Most of the villages have been electrified. The water earlier going waste and causing widespread damage during floods is being stored and later utilised for multipurpose benefits. Efforts are made to make this water available for irrigation and drinking purposes. Milk production has increased due to the availability of fodder & water. Even in the far flung desert areas of Bikaner & Jaisalmer of Rajasthan, Bhakra waters have been made available. Per capita income in the states of Punjab and Haryana is about Rs. 19,000/- and Rs. 18,000/- respectively against the national average of Rs. 11,000/- . The projects have thus helped in providing food, clean water, electricity, employment, and thus improved the health of the people.

Tourism and Recreation

The Gobind Sagar Lake upstream of Bhakra dam, with a spread of 160 sq.km and a length of 90 kms, is a potential source of tourism. The lake is important to migratory birds from Siberia. A large variety of fish abound in the lake. Beautiful rose gardens, lawns at Bhakra, the natural views of the Shivalik hills, green forests, fresh air and calmness along the lake provide an ideal environment for tourism.

The Kulu, Manali, Manikaran and Rohtang pass are already the most forward tourist locations in the Beas valley, which is known for its scenic beauty. The construction of the Pandoh Dam and the Beas-Sutlej link channel have created small lakes at Sundernagar and Pandoh, which are easily accessible. The curvaceous and serpentine 11.80 Km, Sundernagar Hydel Channel, with a road on its banks, provides an enjoyable drive in the picturesque Suketi valley. The awe inspiring spectacle of Beas waters ski-jumping from the bye-pass chute at Slapper on Dehar Power Plant (Head 360 m) is another star attraction. The islands in the Bhakra and Pong Lakes could be developed into amusement parks and botanical gardens. Floating restaurants and boat rides could be introduced along with rowing, canoeing and yatching . Proper publicity given to the tourist facilities will go a long way towards developing the tourism potential of these projects.

REAL TIME INTEGRATED OPERATION OF RESERVOIRS

The term 'Real Time Operation' is used to denote a mode of operation where reservoir release decisions are based on the condition of the system at that instant of time, combined with forecasts about the likely inputs over a specific time horizon. Decisions regarding releases are made relatively quickly and are based on short term information. Decisions depend on the initial reservoir storage, penalties for deviation from target storage, short term forecasts and the conditions downstream. More often, the definition of short term varies in accordance with the purpose of reservoir. If the reservoir is operated for irrigation, the short term can be a week or month. If the reservoir is operated for flood control, the short term may be daily or even hourly operation. The real time operation is especially suitable during floods, where the system response changes very fast and decisions have to be taken rather quickly and adjusted frequently.

Need For Computerised Operation

In India, the existing practice of reservoir operation is generally based on empirical methods. Operation personnel make decisions based on experience and judgement. Obviously, the present practice of reservoir operation has its own disadvantages & involves certain inherent risks. It may not be possible to judge accurately the consequences of an operation decision for multipurpose reservoirs. There is danger of conservative and non-optimal utilization. Since operation decisions are to be taken relatively quickly in real time operation, high speed computers help in carrying out detailed hydraulic and hydrological simulation of reservoir systems for various possible alternatives, thereby assisting the operation in-charge in selecting the best feasible alternative. Also the operation of reservoir systems is generally based on certain operation rules, developed from historical or synthetic flow series and taking into consideration the past demands. The real time operation models are developed to react to the current situation, considering the stochastic nature of flows into the reservoir system, & serve as a powerful tool for managers in making optimal operation decisions.

Components of Real Time Operation

Real time operation has great flexibility compared to the conventional methods of operation. It not only utilises the present set of available data for the system, but also takes into account meteorological and hydrological forecasts. For successful application of real time operation techniques, it is essential to have the following:

i) a suitable network for data collection and transmission
ii) Real time flow forecasting
iii) Real time reservoir operation

REAL TIME OPERATION OF BHAKRA-BEAS SYSTEM

Reservoir operation in the Bhakra-Beas system mainly constitutes controlled release of water downstream to various projects, depending upon the inflows, storage in the reservoirs, irrigation and power requirements and the condition of flooding downstream. The most crucial point in the operation of the system is the decision about releases, so as to ensure the filling of the reservoir by the end of the monsoon, and to derive optimum benefits from storage, while keeping in view the safety of the structures and multiple demands. For simulating integrated operation of the reservoirs, the following software packages developed by Hydrologic Engineering Centre (HEC) were found useful and have been adopted after carrying out necessary modifications to suit Indian conditions.

HEC Data Storage System (HECDSS)

In real time operation, the HECDSS is a key component. It holds the data base for the reservoir system, checks its consistency and provides inputs to application programs and also stores outputs from application programs, which in turn may act as input to other application programs. Thus, the interaction between various software is accommodated through DSS. The HEC application programs retrieve or store data in DSS by referring to a system of pathnames. The DSS software does not sequentially search for data, but uses the pathname to index its position within the file. This helps in rapid storage and retrieval of data regardless of size. Several utility programs are available in HECDSS for entry, management, mathematical computation, display of data, report generation, etc. A typical pathname referring to Sutlej river daily observed flow data for the month of June, 1990 might be as fellows: /SUTLEJ/RAMPUR / FLOW/01 JUN 1990/1 DAY/OBS/

Inflow Forecast Model (HEC1)

The surface runoff response of a river basin to precipitation could be effectively assessed by representing the basin as an interconnected system of hydrologic and hydraulic components, and simulation of the model so developed. The HEC1 models an aspect of the precipitation-runoff process of each component, within a portion of the basin, commonly referred as a sub-basin. Representation of components requires a set of parameters, which specify the particular characteristics of the component, and the mathematical relation, which describes the physical process. The result of the modeling process is the computation of stream flow hydrographs at desired locations, which can be routed and combined to obtain the inflow forecast. Caliberation and verification are obviously the essential parts of the modeling process. The HEC1 package has certain optimization techniques for the estimation of the parameters based on historical data of gauged sub-catchments.

Catchment Rainfall Model (PRECIP)

One of the inputs for stream flow forecasting is the basin average rainfall, assessed from the real time rainfall data of the basin. Quite often, rainfall data from all the stations in the basin may not be available for estimation of inflow forecast, the due to practical problems, such as failure of the reporting station, delay in transmitting data, etc. Thus the station weights vary from time to time. The PRECIP program automatically calculates the basin average hyetographs from the rainfall data reported at any instant. PRECIP can retrieve data from a DSS file and write the calculated hyetograph into the DSS file.

Integrated Reservoir Simulation Model (HEC5)

HEC5 is a comprehensive computer program for simulating integrated operation of reservoir systems for conservation and flood control. The flood forecast obtained from the HEC1 model can be directly input as inflow for simulation through the HEC DSS model, thus saving input time and avoiding data input errors. The program can be used in a variety of ways for planning studies and for evaluating proper reservoir releases on integrated real time basis. It can simulate the operation of systems comprising up to 20 storage reservoirs and 40 control points, and can incorporate most of the operating objectives generally encountered. The priority among purposes can be changed to some extent by input specifications. The simulation can be performed in various time intervals such as an hour, day, week, or month. The basic input requirement consists of three types of data. i) physical data including storage-discharge capacity curves and linkages defining the system structures. ii) operational data including allocation of reservoir storage for various purposes, maximum and minimum channel capacities and, iii) hydrologic and time series data consisting of flow values.

Model Application

The HEC1 and HEC5 models developed for Bhakra Beas system could be used for real time integrated operation, by integrating the models through HECDSS and by continuous application of one model after another. For providing real time data inputs to the models, a network of wireless stations are presently available in the system. This system is transmitting rainfall and discharge data from various locations to the Headquarters at Nangal. However, for effective, quick and reliable real time data acquisition, it is essential that suitable DCPs be installed for automatic data collection at these stations. Transmission of data also needs to be made reliable and fast by adopting a suitable transmission media. For management of the real time data, PCs could be utilised

CONCLUSIONS AND RECOMMENDATIONS

Though India is bestowed with abundant water resources and ranks 5th in the world in water availability, it faces water scarcity during lean periods and floods & wastage of water to the sea during monsoon months. Storage of excess water during monsoon, and inter-basin transfer of water from surplus river basins to water deficient basins are therefore, of paramount importance in meeting the ever increasing demands and multipurpose benefits.

The Bhakra-Beas system of projects has helped to a great extent in the conservation and transfer of excess water from one basin to the other, in addition to deriving multi-purpose benefits. The projects have brought an era of overall development in the area and to the people, who were subjected to floods or droughts year after year. With the availability of assured irrigation, agricultural development has taken place and the whole area transformed into the granary of India. A lot of hydel power is being generated, which has helped in the industrial development. Per capita income, rate of literacy, & the standard of living have improved.

Since these projects are the lifeline of the region and constructed with huge investment, they must be managed and operated in the best possible way. For deriving optimum multi-purpose benefits, the advancements in the field of system engineering and the modern computer facilities available now, could be effectively utilised for integrated planing and management of the various river basins.
In view of the above, the following recommendations are made:

i) That computer models be used to help in making appropriate decisions for integrated operation of the various reservoirs.
ii) The present study has been carried out using the water control soft-wares developed by HEC. A number of models developed by other agencies are also available for implementing the procedure. It would be desirable to implement appropriate model after modifications to suit Indian conditions.
iii) The effectiveness of real time operation of a reservoir system mainly depends upon the data observation & transmission network in the basin. As far as possible, efforts are being made to install automatic data collection and transmission systems.
iv) In India, the technology of automatic observation & transmission of data is still in a primitive stage. There is an urgent need to assess the state of art available & train field officers on the subject.

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