CHAPTER 1

INTRODUCTION

1.1 GENERAL

Of all the natural resources harnessed for economic development, none is more important than water, which directly or indirectly affects numerous human activities. Freshwater is a finite and vulnerable resource, essential to sustain life. In the last fifty years water demand in the world has trebled and is still increasing sharply every year as a result of population growth, increase in household income, and irrigation development. Approximately 70% of surface water and groundwater is claimed by irrigated agriculture to produce 40% of worldwide food needs (Brown 2001). Even though demand for water is increasing, rare are the countries in which its availability remains constant; more frequently the exploitation is well beyond the renewal rate of the resource. Degrading water quality further reduces the availability of freshwater suitable for domestic and agriculture use and increases the cost of treatment and reuse of water. Driven by these challenges, the last few years have seen a wide and growing interest towards the development of tools and techniques for integrated planning and management of these systems. While in the 1960’s the planning was based on the assumption that water was an infinite resource and the main concern was its allocation and distribution, now the approach must be oriented to sustainability and be more holistic.
The debate whether climatic change is a real problem or not, is still on, but the nature of that debate is beginning to change. Instead of arguing about the complex details of atmospheric science and modeling, increasing attention is being given to understand possible consequences for society and the kinds of responses that make sense despite the many remaining uncertainties. This is particularly true in the area of water resources, where many decisions depend explicitly on the assumptions we make about future climatic conditions. Long-term water planning choices, the design and construction of new water-supply infrastructure, agricultural planting patterns, urban water allocations and reservoir operating rules all depends on possible climate change. Many uncertainties remain about the timing, direction, and extent of these climatic changes, as well as about their societal implications. Indeed, the most important effect of climate change for water systems will greatly increase the overall uncertainty that managers face. These uncertainties greatly complicate rational water resource planning and have contributed to the ongoing debate over how to respond (Frederick et al 1997). But we cannot let these uncertainties paralyse us and stop rational and thoughtful actions from being taken. One of the possible methods is evaluating management and operational options under a broader range of climate scenarios than managers usually think.

While water management systems are often flexible, adaptation to new hydrologic conditions may result in substantial economic costs. Thus water agencies should consider re-examining engineering design assumptions, operating rules, system optimisation, and contingency planning for existing and planned water-management systems under a wider range of climatic conditions than traditionally used.

Also, successful management of water resources requires approaches that will need more and better quality information about the
current and potential future status of the water resources systems. Therefore, to meet the growing information needs of water management and water resources research, efficient modeling techniques are required that have high predictive power and are able to devise smart solutions. Models that are able to learn and generalise “knowledge” may be well suited to the problems of estimation, prediction, management and control in various aspects of water resources.

To solve the complex problems it is necessary to go beyond standard mathematical techniques. We need to complement the conventional analysis methods with a number of emerging methodologies and soft computing techniques such as Expert Systems, Artificial Intelligence, Data Mining approach, Neural Network, Fuzzy Logic, Genetic Algorithm, Probabilistic Reasoning, and Parallel Processing techniques. Soft computing differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty, and partial truth. Soft Computing is also tractable, robust, efficient and inexpensive. The main advantage of the recently developed soft computing techniques is that these techniques can be used to get solution in considerably less time and the model response also can be obtained fast thus reducing the cost. Moreover, these techniques can be used for modeling system on a real time basis. Another advantage of these soft computing techniques is that these are extremely effective in handling dynamic, non-linear and uncertain data.

Many such technologies that are already available can help the water managers to manage water resources to hedge against climate change and reduce stress on threatened natural resources.
1.2 ISSUES IN IRRIGATION PLANNING AND MANAGEMENT IN INDIA

Most of the problems pertaining to irrigation planning and management in Indian subcontinent are due to inadequate understanding of the irrigation system. The response of the system for a set of input is not known apriori. The heterogeneity of crops in the command area is not accounted properly. The irrigation requirements are also computed without considering the spatial variability of soils, crops and climate. Due to the above reason the following issues are there.

- The irrigation canal opening dates are usually based on availability of water at the beginning of the season. The rigid values of initial storage and absence of forecast information result in either conservative or over estimate of command area to be irrigated.
- The irrigation requirement is computed using duty method which has no reference to the stage of the crop.
- The traditional reservoir operation, based on rules of thumb, result in uneven inter-temporal allocation of water leading to failure of crops or over irrigation. In some cases, droughts are regular, making the situation catastrophic.

1.3 NEED FOR THE STUDY

Reservoirs provide dependable supply of water to meet a range of social, economic and environmental needs, like water for drinking, irrigation, power generation and waste assimilation, as well as the benefits of protection from flooding, sustained flows for navigation, habitat for fish harvesting and aesthetics. The single most effective method of water management is attained
through the development and operation of reservoirs. In developing countries like India, irrigation is the primary purpose for which most of the reservoirs are operated. The principle behind the management rule of irrigation reservoir is to accelerate the water use and supply water fully when water is sufficient, but to restrict the water use and supply water less than crop water requirement when water is scarce. But supplying the full irrigation requirement has been a traditional pattern of irrigation even in the drought season, which leads to great economic loss to nation.

The sustainable use of the limited water resources is constrained by insufficient knowledge of the resources, in terms of quantity and timing, and lack of management. In most cases resources are not managed and crisis management is employed at the last moment, when shortage is apparent. Hence it is important for water managers to know when to restrict water supply and how to manage during drought season in a sustainable manner. Also typical reservoir systems are usually subjected to thousands of constraints and variables including complexities due to uncertainty in the modeling parameters such as hydrological exogenous inflows and demand pattern. These uncertainties may result in significant impact on system predictions and related decision on system operation and management (Jenkins and Lund 2000). As a result, it is recognised that for an efficient real time operation of reservoir requires reliable prediction models integrated with decision support systems.

As a water resource system composed of reservoir storage approaches, the management of demand/operation of the system becomes especially important -particularly during drought and incipient drought. When drought strikes, water manager strive to reduce overall damages associated with an inability to meet normal demands to the greatest extent possible. Here drought means a time period during which ordinary demands cannot be
steadily met from stream flow and reservoir storage. Although there has been steady and systematic progress in both reservoir design and operation since the early 1960s, operation during and prior to a drought has received very little attention. As the most modern efforts have focused on the operation and design of multi-reservoir and multi-purpose systems, techniques for operation of the single reservoir dedicated only to water supply during drought or impending drought have not really improved significantly in recent years. In the general situation of actual or impending drought, water supply managers have been observed to prefer a number of smaller shortages to a few very large ones, suggesting that the damages are convex in the amount of a shortfall. Water managers utilize restrictions or rationing to reduce demand levels temporarily and to preserve storage for future use. If the water supply reservoir is entering a period of drought, a water manager needs specific quantitative values to signal the onset and extent of the restrictions that should be utilized.

It should be noted that the operating rule used in single reservoir water supply simulations, often called the standard operating policy (SOP) (Maass et al 1962), is only optimal if the objective is to reduce total shortfalls (Hashimoto et al 1982). The SOP is a rule suggested for use in simulation models and not for actual and real-time operation of a reservoir in a practical situation. This is because it does not provide a mechanism for reducing demand in small increments in the early stages of, or during indications of, impending drought. Realistic demand management/operating rules would suggest that, during periods of incipient drought, reductions be made in demand even when it can be fully delivered from storage and current inflow; the reductions prevent larger shortages and much larger damages in later periods of operation. The goal of the present work is the creation of demand management/operating rules that can sustain the operation of the reservoir
through a drought while avoiding severely damaging shortages. Such rules are needed because the damage function associated with shortfalls is apparently convex in the extent of the shortage.

1.4 RESEARCH MOTIVATION

A real world reservoir operation model plays an important role in sustainable development of the water resources management. The main challenges in developing the optimal or near optimal reservoir operating rules lie in dealing with uncertainty of the system variable. The system analysis techniques have been widely applied to model the reservoir operation over the past few decades. This is evident from the large number of operation models already developed for planning and operation of reservoirs (Yeh 1985, Labadie 2004, Wurbs 2005). Despite the considerable progress in the research relating to reservoir operation its application into practice is very slow. There exists a gap between theory and practice. Mujumdar (2002) explained the possible hurdles in narrowing such gap and emphasized the need of decision support systems in irrigation water management. Also, according to Ponnambalam et al (2002), for simplicity of operations and for fast actions, easy-to-use operating policies are necessary in the hands of operators. This constitutes the primary motivation for this research.

Rapid advances in computer technologies and learning algorithms which uncover the hidden relationships and patterns in data (soft computing like data-driven modeling) have the potential to revolutionise the water management. These techniques will serve as the foundation for providing estimates of the uncertainty in real time forecasts of future water systems behavior, and could potentially play a significant role in structuring integrated decision support model for providing better real time information for water management decisions. Without sacrificing accuracy, they might provide a potentially valuable method for reducing the cost of data collection and
modeling complex river basin system in support of water management needs (Solomatine 2002). Data-driven methods especially neural- networks have dozens of successful applications in water resources sector. Association rule mining approach is one of such methods, which discover relationships hidden in data and express them in natural language of decision rules. Relevant applications of this approach cover fields of medicine, engineering, banking and environment management, but very few in water resources management sector. Hence the purpose of the proposed research is to evaluate the possibility of the association rule mining approach as complementary or alternative to the traditional techniques used to solve complex water resources system problems.

Also, the detailed literature reveals that specific system level operating policy improves the system performance which can be implemented easily using latest methodologies. Thus the present study focuses on the improvement of the system performance of an existing reservoir for single purpose namely, irrigation, and development of a Decision Support Model (DSM) for optimal reservoir operation using the association rule mining which come under the category of data-driven modeling.

1.5 ORGANISATION OF THE THESIS

The general introduction and the importance of the present study have been presented in the preceding section. Chapter 2 gives a brief review of relevant literature. In Chapter 3 objectives and methodology are discussed. Chapter 4 provides a brief description of the system chosen for study. Chapter 5 deals with the development of model for getting optimum performance of the existing reservoir system. Chapter 6 deals with the evaluation of the parametric and non parametric monthly stream flow generation models. Chapter 7 presents the derivation of reservoir operation rules using association rule mining technique by the method of implicit
stochastic optimisation. Chapter 8 concerns with the building of decision support model for the reservoir operation utilizing the knowledge base resulting from the implicit stochastic optimisation. The summary and conclusions of the present study are presented in Chapter 9. The scope for future work is also mentioned.