AN OPTIMUM APPROACH FOR THE UTILIZATION OF THE GREAT MAN-MADE RIVER WATER IN LIBYA

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ABSTRACT

The Great Man-Made River project is a water conveyance system being constructed to transport over 6 million cubic meters of water per day from the groundwater aquifers in South to the North of Libya. About 80% of this water will be utilized for agricultural irrigation. In this paper an optimization modelling approach is devised using the on-demand supply philosophy system of phase II of the project. The main objective of this modelling process is to minimize the required operational water storage, to reduce conveyance system over-stressing including well field operations, and most importantly to save water, as it is so precious. Results of several optimization scenarios are shown. The results indicate substantial cost saving on storage infrastructures, operation and maintenance, as well as overall water saving.

Key Words: Water Supply, Utilization, Optimization, Man-Made River

INTRODUCTION

Libya, which is located on the North coast of Africa, relies almost entirely on groundwater as its main water supply. For the last fifty years or so, extensive groundwater abstraction has taken place in the North and specifically in the Northwest of the country (the Jafara plain), where most of the agricultural activities take place and where most of the population resides. Prolonged periods of groundwater abstraction with minimal surface water recharge, in this region of the country, has created severe water imbalance, subsequently resulted in substantial seawater encroachment into the coastal ground aquifer system (Ghazali, et. al., [1]).

In looking for alternative water sources for the area affected by seawater intrusion, planners during the decade of the 1970's has set on a major proposed project to transport water from the south to the north of the country. The Great Man-Made River project (GMRP) as it is called, is to carry over 6 million cubic meters per day of water abstracted from the ground water aquifer systems of Sarir and Kufra in the south east and Murzag in the south west of the country. This water is planned to supplement water needs for the coastal areas in the north of the country for domestic and agriculture uses, with about 80% of the water to be allocated for agricultural irrigation. This conveyance system is considered at the time as the largest Man-Made project in the world undertaken to transport water.

In 1983, the project was initiated comprising of several phases, whereas Phase I and Phase II being the two major components of this project (Figure 1). Phase I of the project covers the eastern part of the country, as water will be conveyed from the Sarir and Tazarbo well fields to the coastal areas of Benghazi and Sirt. This phase's operational philosophy is based on continues average flow supply. This operational scheme required large storage reservoirs for operation, as of to date about 55 million cubic meters of storage facilities has been built or under construction.

Phase II of the project will convey water from the Jabal Al Hasouna well fields in the Southwest of the country to the Northwest region of the greater Tripoli area and the Jafara plain extending to the western mountain region (Al Jabal Al Gharbi). Unlike that of phase I, the design and operation philosophy of phase II are based on the supply on demand criterion within the system limits. This flexibility of operation allows for greater management of the water supply from the well fields to the end users.

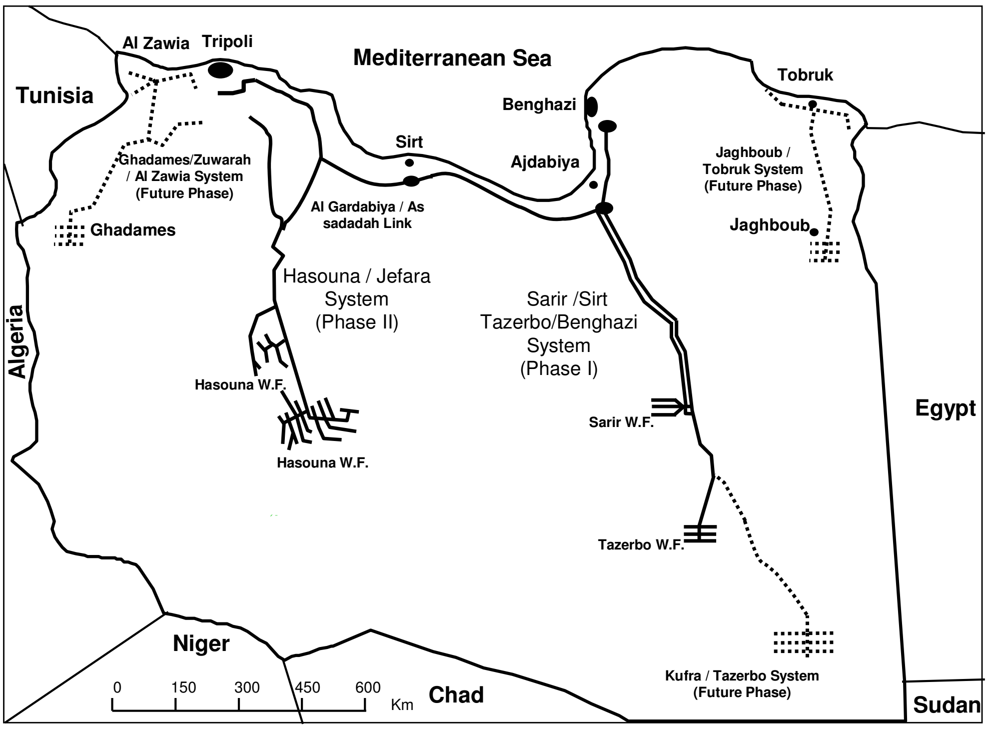

Figure 1. The Great Man Made River Project

The water use plan, which was drawn up for utilization of phase II water supply for agricultural irrigation, is based on using peak system flow-rate supply continuously to fulfil average water demand of the projects. This operation plan by the users results in an inflexible operation system; making the on demand operation philosophy of Phase II system idol and stressing the system continuously to its upper limit. Moreover, this plan would further require substantial operational storage facilities.

In this paper an optimization modelling approach is developed using the on–demand supply philosophy of phase II system and the water requirements of individual agricultural projects. The main objectives of this modelling process is to minimize the required operational storage, to ovoid over stressing of the conveyance system including well field operations, and most importantly to save water as it is so precious. This dynamic modeling approach utilizes several parameters that affect the overall water requirements for individual projects. The results of several optimization scenarios are shown which include cost saving on infrastructure, operation and maintenance and overall water saving

PHASE II PROJECT SYSTEM

System Description

Phase II of the GMRP serves the western Libyan region (Figure 2). The system consists of the well fields of the East and Northeast Jabal Al Hasouna, the water collection system from the well fields to the Al Hasouna header tank. The well field area extends over 4000 square kilometres with total of 440 operating wells and 44 stand by wells.

The water is conveyed to Ash Shwaref flow control station from the main header tank at Al Hasouna. Two branches are developed from Ash Shwaref flow control station; Eastern and Central branches as they are denoted (Figure 2). The Eastern branch connecting the coastal cities of Misurata, Khomos, and Tripoli and further extending to the Northern Sahal Jafara plain. This branch is provided with a connection to Phase I at a Seddada for future flow supply to Phase II from Phase I. The central branch extends through Ben Walid to Tarhuna and to the Tarhuna Regulating Tank. Further it continues to the Southern Sahal Jafara Plain climbing up to the Jabal Gharbi region (Western Mountain range) and feeding the mountain towns up to the town of Reehabat.

Phase II main conveyance system consists of over 1200 Km of pipeline length. The pipeline material is mainly Pre-stressed concrete cylinder pipes (PCCP) of 2.4 to 4.0 m diameters.

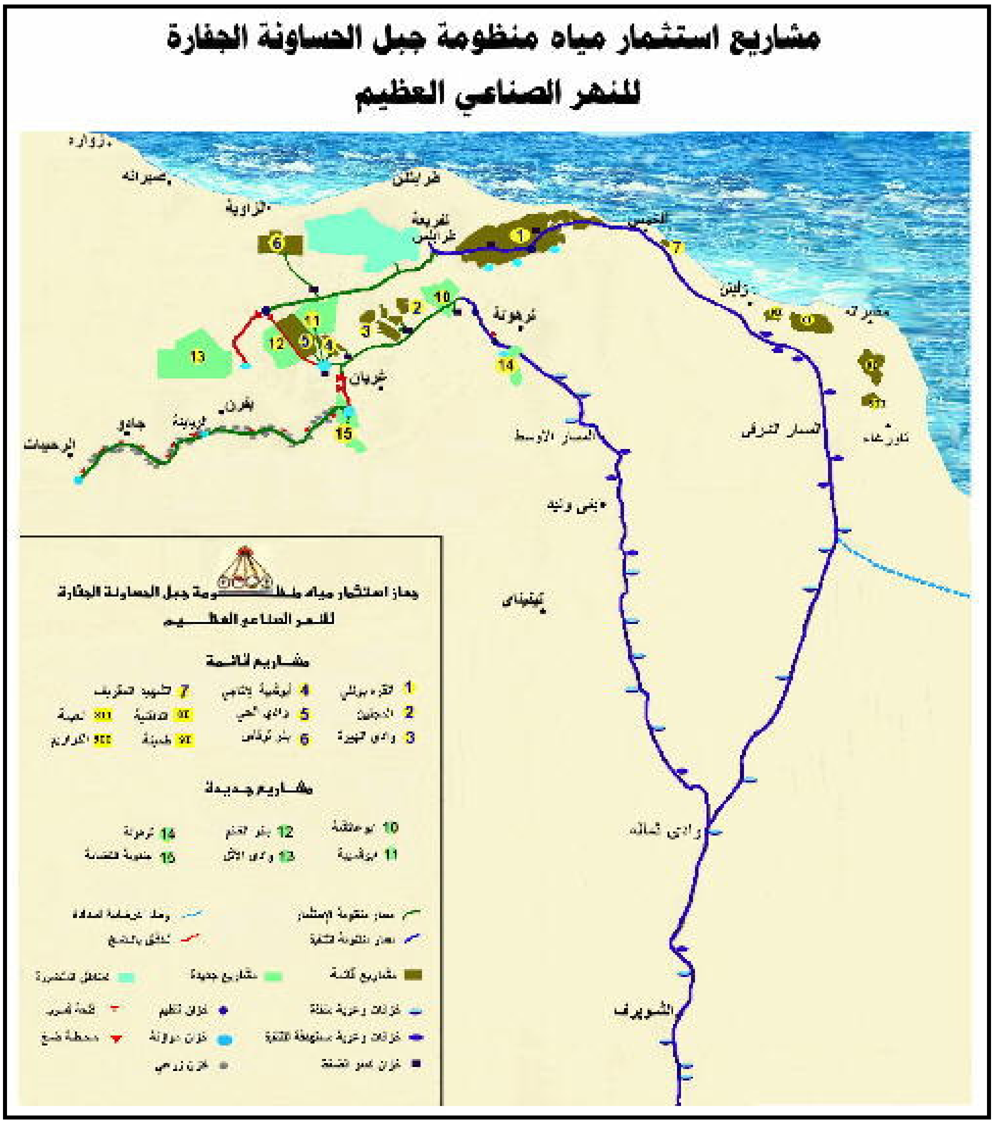

Figure 2. Phase II of the Great Man Made River Project

Design Flow rates

Each branch was assigned a design flow rate based on its hydraulic design capacity. The eastern branch is assigned a flow rate of 1.120 million cubic meters per day (MCMD) from Ash Shwaref flow control station on to the future link at Sedada where an expected extra 0.5 MCMD will be added from Phase I of the project via this link, making the total planned design flow rate value for the eastern branch of 1.620 MCMD.

The central branch of the project will carry a design flow of 0.880 MCMD from Al Shawerif flow control station. Due to hydraulic limitation on this rout from Ben Walid to Tarhona, this flow can only be exceeded by a small margin.

Operation and Control Philosophy

According to the Great Man Made River Authority plans , the phase II of the GMRP will be operated to satisfy the consumer planned water demands, while avoiding overstressing of the system. This operation will be implemented using the supervisory Control and Data Acquisition System (SCADA) (GMRP [2]).

The conveyance system comprises several small sized regulating tanks, that do not provide large storage capacities, and therefore, it must be operated as on demand system, providing quick changes based on consumer demands.

The phase II water supply is therefore designed to respond to a minimum of 3 day plan prepared by the consumer for water demand, provided that the total water demands are up to system capacity.

WATER UTILIZATION FOR IRRIGATION

According to drawn up plans, about 80% of the conveyed water would be utilized for agricultural irrigation. This will be implemented to provide an alternative water supply for the existing farming communities in the Sahal Jafara plain where the ground water aquifer has been over drafted with prolonged abstraction and diminutive recharge causing the aquifer to endure severe sea water encroachment. Further newly develop agricultural projects will also be supplied with this conveyed water.

Along the eastern branch eight agricultural projects are designated to receive water for irrigation and six projects are chosen to be supplied with water along the central branch rout according to utilization plans. Three other projects will supplied from the Rabta end reservoir. Each individual project is allocated water according to crop pattern strategy that require changing water demand rates on either monthly or bi-monthly bases. Figure 3 displays schematically utilization projects along both eastern and central branches and the their average daily water demand for irrigation based on total water budget per annum.

Figure 4 show actual water demand for an individual project (Abu Aisha project) along the central branch that is based on the crop pattern plan for such project. It is clear that demand varies monthly and fluctuates from a peak to a low value. Operationally, this either requires the water supply rates to follow that of demand or a provision of the so called operational storage to satisfy this seasonal variations.

In accordance to utilization plans, the average required demand rates for all targeted projects nearly coincide with the available peak design flow rates of the system as it is shown for an individual project (Figure 4). This situation is imitated to all other projects on Phase II as shown on Figure 5 for the central branch. Consequently this leads to the need of operational storage to handle the required demand variations, making the required flow supply at almost a constant rate (at peak supply rate).

However, this makes the on demand philosophy of Phase II system almost irrelevant for such a scheme.

REQUIRED OPERATIONAL STORAGE

Based on the planned water utilization mentioned above and on the design flow supply rates of the Phase II, the required operational storage is quite significant.

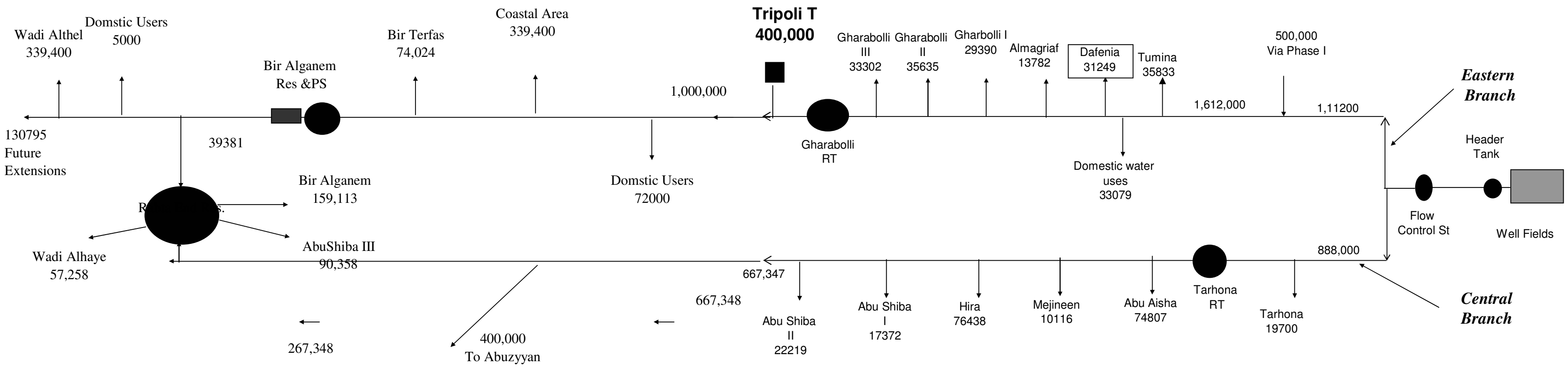

Figure 3. Schematic of Phase II Water Utilization (Average Flow m^3/day)

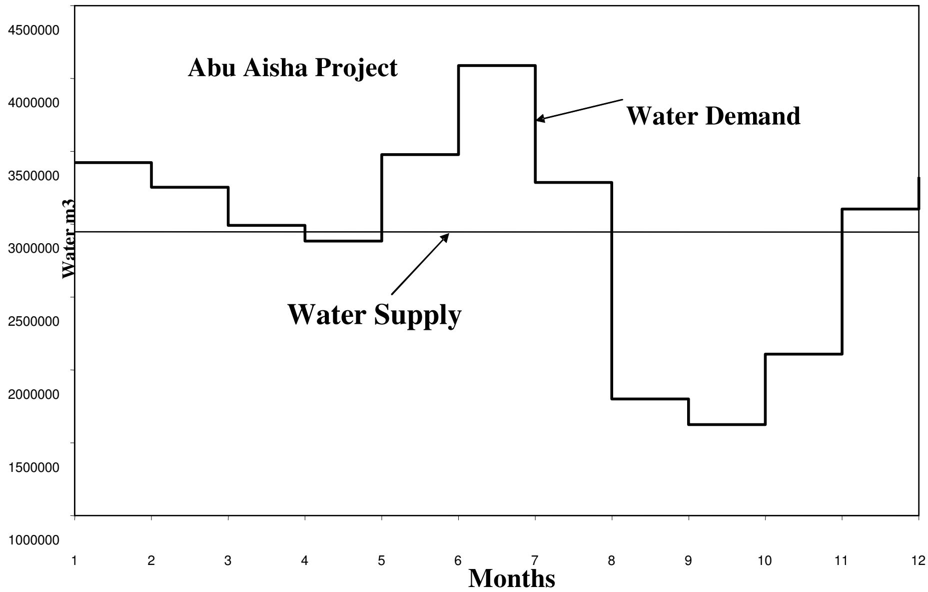

Figure 4. Abu Aisha Project - Water Demand and Supply

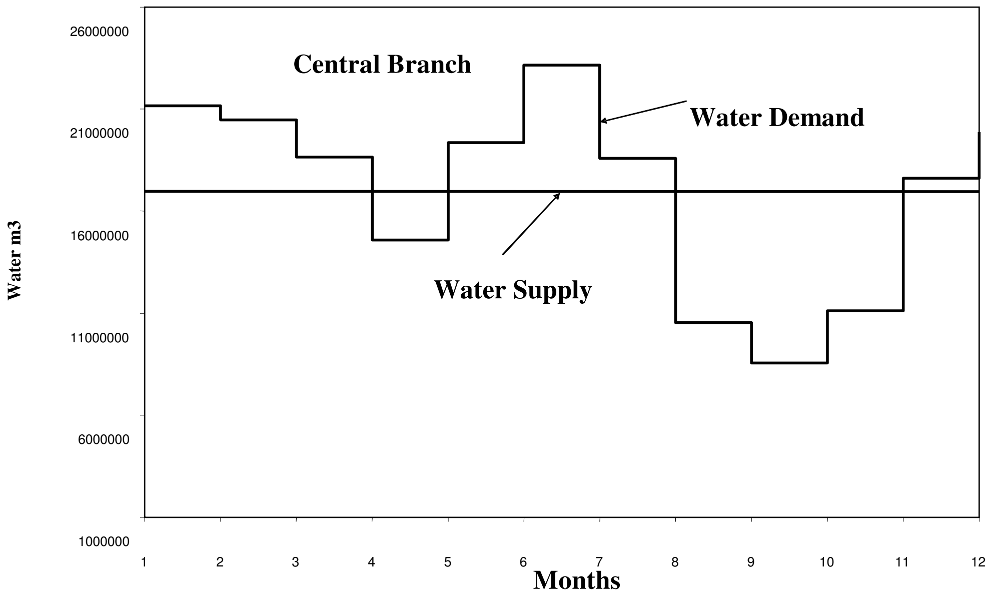

Figure 5. Central Branch Projects water Demand and Supply

Moreover the sophisticated operational procedures of phase II that includes on optimum conveyance system and the on demand response to user requirements are not in use since the planned demand requires almost constant flow at peak design flow rate value. To this end the required global storage for both branches are evaluated. This was performed based on individual project water demand schedule, turnout design flow rate, and total design flow of the system (system limits).

Central Branch

According to the planned water demand rates for the central branch projects sites including the three projects connected to the Rabta end reservoir, to the available supply rates along the pipeline, and to the individual turnout design capacity for each project, the minimum required operational storage for this branch is evaluated. A minimum operational storage of 22352120 m^3 is needed.

Eastern Branch

Similar to the procedure followed for the central branch, the minimum required operational storage for this branch is evaluated. A minimum operational storage of 33923515m^3 is required. Accordingly a total of 56275635 m^3 of operational storage is required. In terms of construction cost this correspond to over 500 million US Dollars.

OPTIMIZATION MODELLING APPROACH

Concept And Objectives

The basic concept of this study was to find the best way to benefit of the on demand operation philosophy of Phase II and the costs that was involved for the implantation of this philosophy. The optimization is realized first of all, by not operating the system at design peak flow rates continuously. Secondly, by getting the flow supply rates to follow the required demand variations, however this may not be achieved entirely. Finally, by making the peak to low demand flow rate ratio limited, i.e. limiting seasonal variation of flow rate demand for projects.

The objectives of the optimization process can be summarized in three particular points: first, to minimize the required operational storage for the utilization projects, secondly, to reduce conveyance system over-stressing including well field operations, and thirdly and most importantly to save water.

Dynamic Optimization Model

In order to achieve the objectives intended for the optimization in this study, a model is devised. The model is constructed using the Microsoft spread sheet data base software and all manipulations are performed using the micro programming techniques. Monthly water demand data for each utilization project , system design water supply rates, and project turnout flow limits are all used as input in the model for each branch of Phase II.

In this model all projects are linked to each other on the same branch in order to simulate the system physically and the effects of optimization are propagated both up and down streams of the conveyance system. Furthermore the model can handle any changes in basic input data including adding or removing project sites along the conveyance line. The optimization process is performed based on the water demand perturbation, mainly in reduction percentages, to a single project, chosen group of projects, or all projects along the conveyance line.

The optimization modelling constraints are defined as:

- System flow rate limits
- Water budget balance
- Turnout design hydraulic limits.

Simulation Scenarios

Several optimization cases were simulated, however in this paper in particular, reduction in water demand Scenarios are presented.

Overall Reduction In Water Demand

In accordance to planned water utilization for the Phase II projects, the average yearly water demand per hectare is 6981 m^3/hectare/year for the total targeted area of 69237 hectares. The idea of reducing water demand may be employed by either reducing the targeted irrigated area or the average yearly water demand per hectare. However this could be also instigated by reducing the provisions made for irrigation efficiency and leachate water which comprise considerable portion of the total water required in the calculations of crop water demand.

Several model simulations were performed with reducing total water demand for irrigation. In all simulated cases considerable reduction in the required operational storage was achieved. Actual storage reduction depends on the nature of the simulated case; single project water demand reduction, multiple project water demand reduction, or all project water demand reduction. Moreover, the simulations resulted in water saved that in turn correspond to cut back in well field production by the same water saved rates.

Water demand reduction of 5%, 10%, and 15% for single, multiple, and all projects are simulated for the central branch projects. Table 1 shows the results of these simulations. Figure 6 shows the relationship between the percentage reduction in water demand for all projects along the central branch and that in required operational storage. The results indicate a maximum storage reduction of about 65 million m^3 or about 29% reduction in total storage, it also shows that over 30 million cubic meter of water is saved over the year.

CONCLUSIONS

In this study an optimization process is implemented for the utilization of the Phase II of the Great Man Made River water for irrigation. The irrigation water demand and supply system of planned agricultural projects on Phase II of the Great Man Made River project was analyzed based on the existing water demand conditions and required balancing storage was determined and found to be about 56275635 cubic meters which on one hand is expensive to construct, maintain, and operate and on the other hand does not utilize the supply on demand philosophy that operation of phase II conveyance system is built on.

Table 1. Model Simulation Scenarios Results for Central Branch

Case	Demand Reduction %	Required Storage m^3	Water Saved m^3/year
One Project Scenario (Abu Aisha)	5%	21486881	1768284
	10%	20861255	3536568
	15%	20662627	5304851
Two-Project Scenario (Abu Aisha, Mejineen)	5%	21348089	1962611
	10%	2058485	3925222
	15%	20485548	5887833
All Project Scenario	5%	16915938	10180265
	10%	15969640	20360530
	15%	15868691	30540795

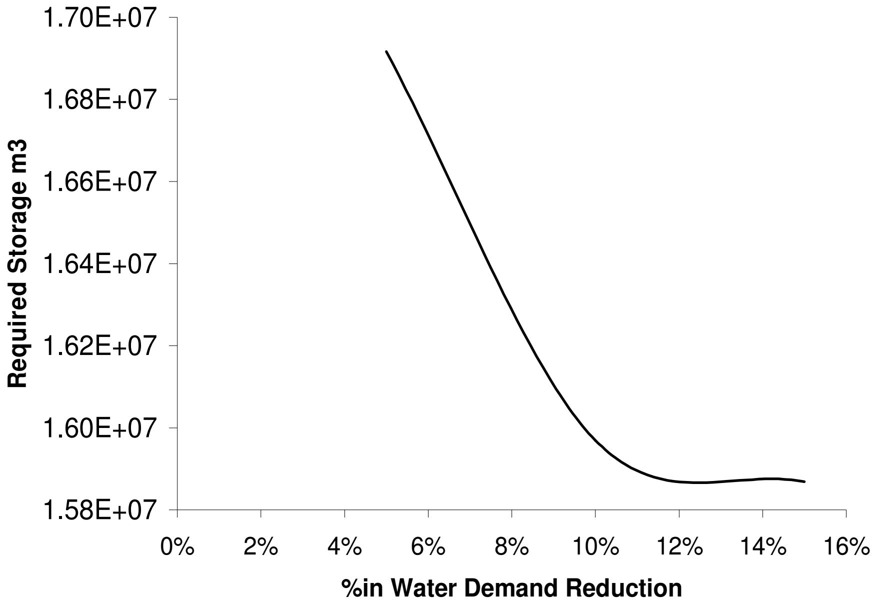

Figure 6. Required Storage Based on Water Demand Reduction

A dynamic optimization model is constructed to for this system and several simulation cases were performed in which entire water demand was reduced. Results of these optimization scenarios were presented and showed sizable reduction in operational storage and considerable water volume saved. This in turn results in cost saving in infrastructure operation and maintenance and water savings.

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