Effect of Bekhma Reservoir System on the Water Management Plan for Selected Area in Greater Zab River Basin

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Abstract- **A previous study had reported a detailed to develop a water resource management model using WEAP platform for selected area in Greater Zab River Basin (GZRB). Thomas-Feiring method which was able to reproduce the statistical characteristics of the flow had been used to generate 25 series with 26 years length each, to project the future flow in GZRB i.e (2015-2040). The evaluation of the management plan involved the study of some different external changes in order to accomplish this goal. Three different scenarios of stream flows have been proposed. These are: 1- using the same current average monthly flow, i.e. the average discharges recorded at Bekhma reservoir site as an input to the model, 2- When the flow is likely to be reduced to one-half of its average and, finally, 3- When the flow is farther reduced to one-third of its average. The current paper is concerning of studying the effects of Bekhma Dam when it introduced to the GZRB water resources system to cope with future difficulties associated with water shortages that might be emerged in the near future. Clearly, the addition of Bekhma Reservoir System (BRS) and alteration of the strategy of operating it according to the stream flow conditions is seen the right course of action in order to decrease the unmet demands. The improvement of the performance of the system is reflected in terms of improving the reliabilities and the reduction of the unmet demands, especially in agriculture sector. Additionally, the hydropower generation goal which represents the main objective of BRS was achieved in sense that the system was able to generate average annual amount of power estimated to be around 4.9 Million MWH under normal conditions of flow which is in coincidences with the designed capability of BRS in generating power . However, it was able to generate fair amount of power under other states of flow.**

Keywords: WEAP Model; Simulation,; Reservoir Operation

I. INTRODUCTION

(Allah says): "*We made from water everything live*". The ancient civilizations associated with aquatic sites had been named watery civilizations like the Mesopotamia and the Nile Valley. Though Iraq has a great rivers Euphrates and the Tigris, but it still complains a severe shortage of water to meet its needs. One reason for that is it has no rigid plan to manage its water resources. The Greater Zab River which is the largest tributary of Tigris River is not an exception and it is also suffering a lack of a clear plan to managing its water. Reference [1], highlighted the scale of the problem which Iraq is going to experience in the future. For instance, he concluded that Iraq is going to receive around one-third of Euphrates river average discharges in 2040. It is clearly seen that the same conclusion can be drawn for the rest of Iraqi rivers and of course the Greater Zab river is one of them.

In the unpublished M.Sc. thesis [2], which is reported a study aimed to fix a management plan for Greater Zab River Basin (GZRB), specifically, the catchment area bounded by the site of Bekhma reservoir and the discharge measuring station at Eski Kilik. The management plan has been evaluated by WEAP model which allows the users to notify the impacts of many different future strategies and ways before achieving them. However, the proposed plan for GZRB was facing several challenging viz.; **i.** The mismatch between supply and demand, **ii.** The uncertainty and the stochastic nature in both supply and demand, **iii.** The allocation problem of the limited supply of water among multi users having multi objective, **iv.** Drought periods experienced in the region. Additionally, the intension of Turkey to developing its water resources system, as the Greater Zab River is flowing from Turkey. Since it is not accurate and possible to predict completely what will happen if water demands and sources are going to evolve in future, so it was considered appropriate to work on using a scenario analysis approach for this study [3]. A set of realistic scenarios could be built in order to account for the uncertainty in the evolution of the water supply and demands. In fact three scenarios have been proposed to accomplish the study. These are: Scenario-1; testing the current situation of meeting the demand under natural condition of flow, Scenario-2; testing the reliability of meeting the demand when the flow reduced to half of its average values, and Scenario-3; testing the reliability of meeting the demand when the flow reduced to one third of its average values.

Returning to the management plan suggested above, the study was not including Bekhma Reservoir System (BRS) to the selected study area. The inclusion of BRS and its effects on the plan is the subject of the present paper. Consequently, this study is discussing the effects of BRS reservoir on the sustainable supply for civil, agriculture and hydropower requirements in the selected area of GZRB.

I. Bekhma Reservoir System

There is a reservoir under construction across Greater Zab River called Bekhma, with 62 km distance far to the north west of Erbil city. It is located upstream of Eski-Kilik gaging station that also lies across GZR (with coordinates 36.7008° N, 44.2711° E). The building of dam has a major purpose of producing hydroelectricity among other purposes. The capability of BRS is to generate 1526 MW (around 5 Million MWH/month) from the power plant.

Fortunately, WEAP program has the necessary tool to operate reservoir systems [2]. It can simulate the reservoir depending on some basis of operational rules, demand priority downstream the reservoir, hydropower generation, and evaporation. The reservoir storage in WEAP platform is divided into four pools or zones. These are; Flood Control Zone (S_f), Conservation Zone (S_c), Buffer Zone (S_b), and Inactive Zone (S_i). Both of the conservation and buffer zones, constitute the reservoir's active storage. WEAP ensures that the volume of water in the reservoir will not exceed the top of the conservation zone. i.e., the flood-control zone is kept vacant just in case that a flood wave might enters the reservoir.

II. Steps of BRS Operation in WEAP

The simulation of BRS operation starts with entering the initial storage of the first month of simulation, then the storage will be changed by the withdrawal and increment processes to the reservoir in that month to find the storage in the following month at the last day of first month according to followings:

Begin Month Storage $_{Res,\ m}$=Initial Storage $_{Res}$ for m=1;

Begin Month Storage $_{Res,\ m}$=End Month Storage $_{Res,\ m-1}$ for m>1

where **m** refers to time interval (month) and **Res** refers to reservoir.

Also the total storage refers to the total capacity of the reservoir and the initial storage is the initial amount of water that stored at the beginning of the first month of the current account year.

The storage in reservoir is entered within the administrative operation of the reservoir at any period of time of coming flow to the initial storage during that month minus the evaporation from the reservoir during the same period.

Storage for Operation of Res= Begin Month Storage $_{Res}$ + Upstream Inflow $_{Res}$ – Evaporation $_{Res}$

The amount of water that can be launched from the reservoir for the purposes of meeting the requirements downstream of the reservoir, i.e. hydroelectric power and flood control, is rely on the divisions of the reservoir or what is known (conservation and flood zones).

Storage Available For Release $_{Res}$ = Flood Control Zone Storage $_{Res}$+ Conservation Zone Storage $_{Res}$ + Buffer Coefficient $_{Res}$* Buffer Zone Storage $_{Res}$

Such that; **Outflow $_{Res}$ ≤ Storage Available For Release $_{Res}$**

Then storage at the end of the month is calculated as:

End Month Storage $_{Res}$ = Storage For Operation $_{Res}$ – Outflow $_{Res}$

The buffer coefficient can regulate the release of water when the water level is within the buffer zone in the reservoir. The buffer coefficient is a fraction of the water in the buffer zone which is available in each month for release. Thus, if the coefficient close to 1.0 this will rapidly empty the buffer zone while causes demand to be almost fully met. And if the coefficient is close to 0 this will preserve the water in the buffer zone and likely leaves demand unmet [4].

It must be mentioned that the representation of the system to be studied using WEAP model is specified by means of nodes. These nodes represent the minimum requirement of instream flow at a point on a river. The downstream requirement may include the environment, water quality, wildlife and fish, recreation, navigation, or other requirements.

The principle of priority is used for determining the allocations from the reservoir to the different demand sites such as supplies to catchments (for irrigation), filling the reservoir, generating hydropower, and for instream flow requirements. WEAP makes it easy to assign a certain priority to a certain requirement and can be changed with range from 1 to 99. Priority 1 means the highest priority and 99 is the lowest. It must be known that the reservoir filling priority defaults is 99, i.e., it will be filled after satisfying all other demands.

Some conditions are put to control the release and the demand of hydropower and agriculture to make the civil demand always met. The condition used for agricultural annual water use rate is:

If (PrevTSValue(Supply and Resources\River\greater zab\Reservoirs\Bekhmeh:Storage Volume[m^3])<Supply and Resources\River\greater zab\Reservoirs\Bekhmeh:Top of Buffer[Million m^3], 8000, 10000)

8000 MCM related to annual water use rate if storage volume in the reservoir is less than storage volume at top of buffer and 10000 MCM related to annual water use rate if storage volume in the reservoir is more than storage volume at top of buffer. But for energy demand is:

If (PrevTSValue (Storage Volume [m^3]) <Top of Buffer [Million m^3], 100000, 200000)

Where 100000 (MWH) is the target monthly hydropower production requirement when storage volume in the reservoir is less than storage volume at top of buffer. While 200000 (MWH) is the target monthly hydropower production requirement when storage volume in the reservoir is more than storage volume at top of buffer. And the condition that used to restrict the release from the reservoir is started at the level of top of buffer is;

If (PrevTSValue (Storage Volume [m^3]) <Key Assumption/Guide Curve [Million m^3], Key Assumption/Guide Curve [Million m^3], 6000)

where: **PrevTSValue (Storage Volume):** Calculated storage volume from previous time step. **Key Assumption/Guide Curve:** Guide curve is the monthly time series of water demand of Civil and Agriculture plus the dead storage, and 6000 MCM: storage volume at top of buffer if the PrevTSValue (Storage Volume> Key Assumption/Guide Curve.

The instream flow requirement downstream the reservoir is controlled using the condition below:

If (PrevTSValue (Supply and Resources\River\greater zab\Reservoirs\Bekhmeh: Storage Volume [m^3]) <Supply and Resources\River\greater zab\Reservoirs\Bekhmeh: Top of Buffer [Million m^3], 100, 321)

III. Results and Discussion

In order to accomplish the modelling process of GZRB and establishing a management plan, the Thomas-Feiring method was used to generate a total of 25 series of monthly flow of the Greater Zab river at Bekhma site [5], for the next 26 year, i.e. up to 2040. Thomas-Feiring method is known to be a good model for generating monthly inflows, in sense it is able to resemble several statistical parameters of the data used for generating extra data.

Three scenarios concerning flow states that may be changed due to the reasons mentioned above. These various scenarios were: 1- using the same current average monthly flow, i.e the average discharges recorded at Bekhma reservoir site as an input to the model, 2- When the flow is probably reduced to one-half of its average and 3- When the flow is farther reduced to one-third of its average. It is concluded that when scenario-1 was applied, all demands had been met for the specified requirements, i.e civil, and agricultural. However, when scenarios 2 and 3 were implemented, unmet demands start emerge especially that demand related to the agriculture. This study discusses the existence of BRS and trying to determine its effects using the same three scenarios given above. Figure (1) below depicts the civil unmet demand before adding the reservoir to the system, and after adding the reservoir. It illustrates the condition when the flow is normal according to scenario (1) where the reliability of meeting the civil demand does not change after adding the reservoir, so the civil demands are fully met throughout the next 26 years with and without BRS.

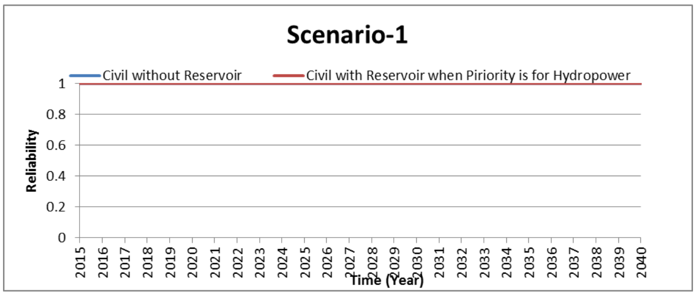

Figure 1. Reliabilities of meeting the demands for civil with and without considering BRS according to scenario-1.

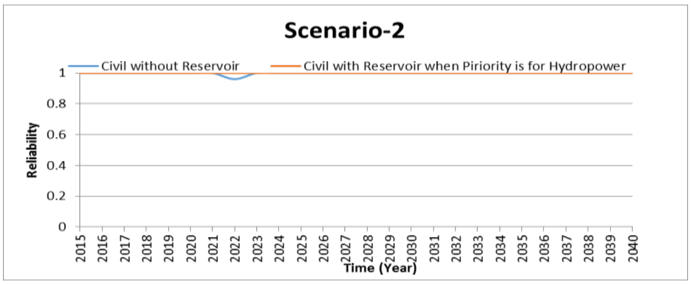

Figure 2. Reliabilities of meeting the demands for civil with and without considering BRS according to scenario 2.

While fig. (2) above discusses the situation according to scenario -2 when flow reduced to half its value.The figure found that the unmet demand appeared in year 2022 before adding the reservoir, while after adding the reservoir and control the release from the reservoir to cover the demand downstream and this problem is solved.

For the last scenario expected which is reducing the flow in the river to its one third values, fig. (3) shows that prior to the addition of the reservoir, many years of low reliability to meet the civil demand have been noticed, however, after the existence of the reservoir the reliabilities of supplying water have improved substantially.

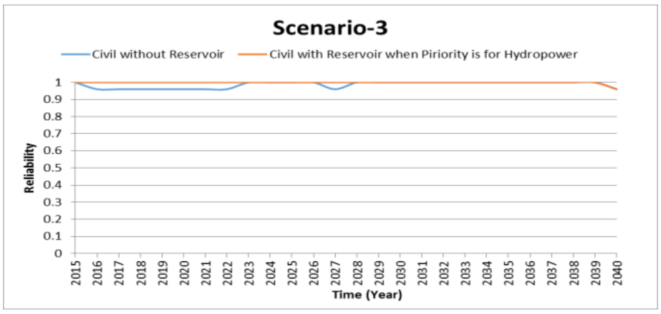

Figure 3. Reliabilities of meeting the demands for civil with and without considering BRS according to scenario-3.

The operation of Bekhma reservoir assured its capability to reduce the unmet demand even the flow in the river reduced to its one-third. Besides that the hydropower expected to be generated by Bekhma reservoir is about (3-5) Million MWH yearly when flow is in normal condition which is coincidences with the findings of other previous studies. Moreover, there are many situations emerged by including Bekhma reservoir to GZRB which can be considered as substantial improvements to the performance of the system from the perspective of meting different kinds of demands in the selected area of study within GZRB.

Figures (4), (5) and (6) repeated the three above scenarios for agricultural supply reliabilities calculations. It is seen again that there is a considerable improvement in meeting the demand for agriculture when BRS is added to the system for all scenarios over the next 25 years. All these figures show reasonable improvement in both of the reliabilities of civil and agriculture supply after BRS has been added to GZRB.

As far as the priorities are of concern, the priority of supply water for power generation is dominated all the runs of the WEAP model as BRS is mainly introduced to generate power. So all the calculated reliabilities over the whole period of simulation are based on giving the priority to generate hydropower.

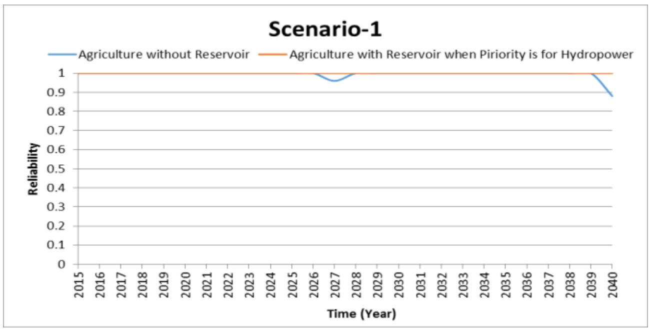

Figure 4. Reliabilities of meeting demands for agriculture with and without existing of BRS according to scenario 1.

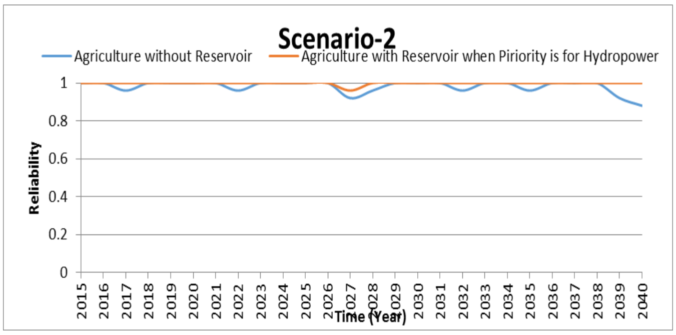

Figure 5. Reliabilities of meeting the demands for agriculture with and without considering BRS according to scenario 2.

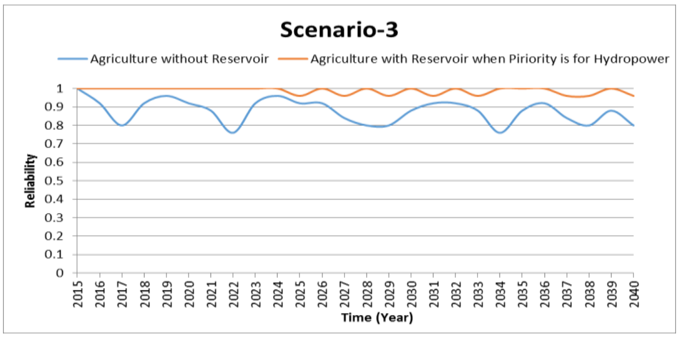

Figure 6. Reliabilities of meeting the demands for agriculture with and without considering BRS according to scenario 3.

For instant, and specifically for Scenario-3, another advantage has been emerged due to presence of BRS where there is a substantial gain in the hydroelectricity generated through the turbines. Table I lists the average annual generated power from Bekhma reservoir for the three proposed scenarios of inflows.

TABLE I. ANNUAL GENERATED POWER FROM BRS FOR THE THREE SCENARIOS OF INFLOWS.

Scenarios	Average Annual Generated Power (Million MWH)
Scenario-1	4.9
Scenario-2	2.1
Scenario-3	1.5

Scenario-1 results in 4.9 million MWH as average annual. This figure is coinciding with design criteria in which BRS should be able to generate around 5.0 million MWH per year during normal flow conditions. However, when inflow to BRS is reduced to one-half of its normal values (i.e. Scenario-2), the reduction in the generated power does not follow the same pattern of proportionality and only 43% of the average annual hydropower has been gained compared to the 50% of normal inflow reduction. The same conclusion can be drawn for Senario-3 where only 30% of the average annual hydropower been generated compared to only 33% of normal inflow entering BRS.

IV. CONCLUSIONS

The operation of Bekhma reservoir is assured its capability to reduce the unmet demand in GZRB even if the average flow in the Greater Zab river is reduced to one-third of its value. Moreover, the expected generated power by Bekhma reservoir is come to be around 5 Million MWH yearly when the flow is in its normal condition which is in agreement with the findings of previous researchers.

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