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INTEGRATED WATER RESOURCES MANAGEMENT IN KHALIFAN RIVER BASIN

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I hereby declare that all information in this document has been obtained, presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I had fully cited and referenced all material and results that are not original to this work.

Arkhawan Jawhar Sharef SHAREF

ABSTRACT

INTEGRATED WATER RESOURCE MANAGEMENTFOR IN KHALIFAN RIVER BASIN

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PhD in Civil Engineering

Supervisor: Prof. Dr. Mehmet KARPUZCU

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This study comprises the application of integrated water resources management (IWRM) in Khalifan River Basin (KRB), north of Erbil province. The overarching goal of this study is to establish 15 years evaluating and analysis plan for Khalifan river basin. The interactions of water users competition have been identified in the basin. In the meantime, some action plans and strategies for the solution have been addressed. The thesis also highlights the top management issues addressing the obstacles to the implementation of integrated water resources management. The water evaluation and planning system (WEAP) model applied to the basin to determine the optimum KRB planning system and the optimum operating policy of the plan. The study compared five scenarios, (reference, high population growth, flow requirement, dam added and water saving). The comparisons show that April to September water demand is high, due to agriculture season. Maximum water demand is 3 million cubic meters, which occurs in August on the other hand the proposed dam only supplied 2 million cubic meters. In addition, for domestic water demand maximum is 0.4733 million cubic meters and the minimum is 0.36978 million cubic meters, and almost has the same level of water demand for each month. Accordingly, the government should start to complete the Gali Ble Dam with a reservoir capacity of 2 million cubic meters. The deficient water demand in the water saving scenario results for both sectors agriculture and domestic start from 1 million cubic meter during the year 2020 and arise to 3.26 million cubic meter in the year 2032.

Keywords: Khalifan River, IWRM, Water Pollution, WEAP Model.

ÖZET

KHALIFAN NEHIR HAVZASINDA ENTEGRE SU KAYNAKLARI YÖNETİMİ (IWRM)

SHAREF, Arkhawan Jawhar Sharef

Doktora, İnşaat Mühendisliği Bölümü

Danışman: Prof. Dr. Mehmet KARPUZCU

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Tezin amacı, Erbil ilinin kuzeyindeki Khalifan Nehir Havzasında (KRB) entegre su kaynakları yönetimi (IWRM) uygulamasını içermektedir. Bu çalışmanın temel amacı, KRB için 15 yıllık değerlendirme ve analiz planlaması oluşturmaktır. Havzada rekabet eden su kullanıcılarının etkileşimleri belirleyici olmuştur. Bu arada, çözüm için bazı eylem planları ve stratejileri ele alındı. Tez ayrıca, Khalifan Nehir Havzası için entegre su kaynakları uygulanmasının önündeki engellere değinen üst yönetim konularını da vurgulamaktadır. Su değerlendirme ve planlama sistemi (WEAP) modeli, optimum KRB planlama sistemini ve planın optimum işletme politikasını belirlemek için havzaya uygulanmıştır. Çalışmada beş senaryo karşılaştırılmıştır (referans, yüksek nüfus artışı, akış gereksinimi, baraj katkılı ve su tasarrufu. Karşılaştırmalar nisan-eylül aylarında su talebinin tarım sezonu nedeniyle yüksek olduğunu göstermistir. Gerçekleşen maksimum su talebi Ağustos ayında 3 milyon metreküp olup, önerilen baraj ise sadece 2 milyon metrekübü tedarik etmiştir. Ayrıca, yurtiçi su talebi maksimum 0,4733 milyon metreküp, minimum 0,36978 milyon metreküp olup neredeyse her ay aynı su talebi oluşmaktadır. Buna göre, hükümetin Gali Ble Barajını 2 milyon metreküp rezervuar kapasitesiyle tamamlaması gerekmektedir. Su tasarrufu senaryosundaki su ihtiyacının yetersiz olması, hem tarım hem de yurt içi 2020 yılında 1 milyon metreküpten başlayarak 2032 yılında 3.26 milyon metreküp seviyesine çıkmaktadır.

Anahtar Kelimeler: Khalifan Nehri, IWRM, Su kirliliği, WEAP model

To my family and my husband.

And to Lasy, and Paku.

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ABBREVIATIONS

Agr	Agriculture
APHA	American Public Health Association
Ave	Average
BCM	Billion Cubic Meter
BOD	Biological Oxygen Demand
Ca	Calcium
CBC	Coliform Bacterial Count
CM	Cubic Meter
CO_2	Carbon Dioxide
CROPWAT	Crop Water Modeling
CWR	Crop Water Requirement
D	Director
DAE	Directorate of Agriculture, Erbil
DEM	Digital Elevation Model
Dem	Demand
DI pipe	Ductile Iron Pipe
DIE	Directorate of Irrigation, Erbil
DN	Diameter Nominal.
DO	Dissolved Oxygen
Dom	Domestic
DP	Dynamic Program
DSM	Digital Surface Model
DTM	Digital Terrain Model
EC	Electrical Conductivity
EIA	Environment Impact Assessment
ET_0	Net Evaporation – Transpiration
EU	European Union
EWR	Environment Water Requirement

FAO	Food and Agriculture Organization
GD	General Directorate
GI pipe	Galvanized Iron Pipe
GIS	Geographic Information System
GNP	Gross National Income
Gov	Government
GWP	Ground Water Program
Ha	Hectare
HCO_3	Bicarbonates
Hm^3	hectometer
ID	Iraqi Dinar
Irr	Irrigation
IWL	International Water Law
IWRM	Integrated Water Resource Management
KR	Khalifan River
KRB	Khalifan River Basin
Max	Maximum
MCM	Million Cubic Meter
MENA	Medial East North Africa
Min	Minimum
MOA and WR	Ministry of Agriculture and Water Resource
MOM and T	Ministry of Municipality and Truism
MOP	Ministry of Planning
NLP	Non-Linear Program
Ntu	Unit of Turbidity
PCBs	Pesticides and Polychlorinated Biphenyls
PE Pipe	Polyethylene pipe
PH	Acidity or Basicity
PVC	Polyvinyl chloride Pipe
RBA	River Basin Area
RBM	River Basin Management
RBMP	River Basin Management Plan
SB	Sub Basin

SDP	Stochastic Dynamic Programming
SDR	Scenario Dam reservoir Add
SEA	Strategic Environment Assessment
SEF	Scenario Environment Flow
SEI	Stockholm Environment Institute
SFR	Scenario Flow Requirement
Spr	Spring
SR	Scenario Reference
St	Station
Sum	Summer
TDS	Total Dissolved Solids in water
Tem	Temperature
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNESCO	United Nations Educational Scientific and Cultural Organization
UNICEF	United Nation International Children's Emergency Fund
UTM	Universal Transverse Mercator
WCD	Water Conference Directive
WD	Water Demand
WEAP	Water Evaluation Analyze Planning
WFD	Water Framework Directive
WHO	World Health Organization
WR	Water Requirement

CHAPTER 1
INTRODUCTION

1.1 Overview

According to the statistics of the Ministry of Planning in the region, Erbil Province, which is the capital of the region, shows a substantial increase in population and Khalifan is one of the sub-district located in the mountain area. Years revealed that there would be approximately extra sixteen thousand people in the next 15 years in Khalifan river basin, Erbil province. This increase in population leads to an increase in water demand as well as food preparation. Based on the Erbil statistics, the water demand will be around double in the next 15 years (MOM and T, 2016). Therefore, the new strategic plan for Khalifan River Basin (KRB) is essential.

Table 1.1 Population growth ratios per five years (MOM and T, 2016)

Year	Growth Ratio per 5 Years	% Growth Ratio Per/Year	KRB Population
2010	0.173	3.46	22183
2015	0.173	3.46	26021
2020	0.167	3.34	30522
2025	0.162	3.24	35619
2030	0.161	3.22	41390
2032	0.161	3.22	**48054**

Iraq rebuilding and its economic and demographic growth, especially in Erbil, will result in increasing pressures on the water resources. Guaranteeing a sufficient supply of water quality to meet the needs of the different uses, in a context of overall sustainable development, must become a significant aim for local authorities.

The pilot area selected is the foremost importance for Khalifan River Basin as the potential for economic growth in this area is real irrigated agriculture, industries but also tourism and recreation will grow in the coming years. Some tasks have been point out regarding the current balance between resources and needs, regarding the institutional and legal aspects and regarding the data management, groundwater level decrease, no wastewater disposal, lack of surface water storage. Take into consideration, a set of KRB development action plans needed for the next 15 years to predict the future problems of the Khalifan Basin. However, KRB's water resources are exposing to some risks and threats, in particular:

1. A fast growing of population means fast growing of demands and caused by urbanization, economic development and in particular the planned extension of irrigating areas.
2. Lack of availability of groundwater, resulting in overuse in particular around Khalifansubdistrict;
3. Increased water uses in the basin, resulting in reduced water flow rate.
4. The expected influence of climate change on drier and worst weather
5. Increasing wastewater flow into the river without treatments causes damage to the river ecosystem

A standard definition for integrated water resources management (IWRM) from the Global partnership (2000) is a “process which promotes the coordinated development and management of water, land and related resources to maximise economic and social welfare equitably without compromising the sustainability of the vital ecosystem.” Also is defining as a “process that strives to balance regional economic growth while achieving wise environmental stewardship” (Linkov, 2014).

Water resources management and planning became the most critical natural resources worldwide. Within the developing nation, the world faced water scarcity for either drinking or another purpose, flood, water pollution and disease (Lins et al., 2011). Thus, integrated water resources management (IWRM) is necessary for a better future. Integrated water resources management is an action to articulate and implement common vision management, planning strategies for the sustainable development and use of water, taking into account both natural processes, and human and ecological water uses (Rahaman, 2005).

Demand for water resources in the developing country and the Middle East is part of growing fast over the past three-decade result from increasing population, urbanisation, industry, irrigation and another purpose. During the twentieth century, the world population perceived rapid growth. It reported more than 15% of the world's population has no access to potable water (Bruschweiler, 2003).Moreover, the amount of water used for irrigation purposes across the world estimated to be 75% (Harrington et al., 2009).

Water shortage in the last decade, became a big issue and most importantly quality of water because only 0.3 percent of water in the globe was used for human consumption,1.1 billion people have a problem in accessing sufficient drinking water, and 2.4 billion people have a problem in the accessing sanitation services. Water diseases annually kill more than 5 million people. The main factor behind this global phenomenon is a limitation in water supply especially in dry regions such as Africa and parts from Asia due to climate changes (John et al., 2012).

Extensive assessment of the human activities impact upon the natural system is changing the way of earth resources management. Speedily water resources have already widely exploited across much of the earth, population growth and climate change. Now a day, in most of the planet there is significant discussion about future management of water resources, also the emphasis upon water trading and pricing. Human is living with the legacy of past activities, particularly those dealing with high-cost engineering infrastructure. However, the foundation provides substantial social and economic benefit to other side effects the environment, which acts water resources as well (Winz et al., 2009).

The industrial wastewater in most of the developing countries has been waste due to the lack of waste treatment. Water basin (or reservoir) plays a major role in life. It became a critical issue in the history of human development. People were trying to settle and establish communities near irrigate areas with a sufficient supply of water. The surfaces and groundwater resources, its quantities and qualities have strongly linked within the basin (Medema et al., 2000). The continued development of human (population growth, increased economic activity, and improved standards of living) has imposed a higher pressure on the water basins, in which many of them are over-utilized (Jaspers, 2003).

Water resources face threatened by globalization; environmental pollution is one of the critical issues over the last few decades. Water and food all threatened by global pollution. In addition, animal, human wastes and erosion of fertilized agricultural land and industrialization are the primary sources of pollution. Furthermore, soil sediment in water leads to degrading water such as an increase in turbidity, changing the color of the water as well as makes the water less attractable for fishing (Puertas et al., 2014).

Water is a source of life and essential natural resources. However, approximately 98 percent of water is seawater and is unusable for drinking due to the high concentration of salt. About two percentages of the earth's water use for drinking as fresh water, but 1.6 portions blocked in polar ice and glaciers. In addition, 0.36 rates had been finding underground in wells and aquifers. Thus, 0.036 of the earth's total water resource is available in the lakeandtheriver. World Health Organization WHO/UNICEF survey that in 45 developing countries, woman and children are taking as a primary responsibility for water collection in the vast majority 76 percentages of households. Furthermore, what remains from freshwater resources is gradually becoming polluted and unusable due to human growth and industrial activities. Increasing pollution of freshwater systems by establishing thousands of industrial sector and natural chemical compounds are the keys to the environmental problem facing humanity over the world (Reddy et al., 2012).

Providing safe drinking water supply is one of the major conditions for a healthy life, but also water disease still is a major cause of death in many parts of the world especially in developing countries, particularly in children. Drinking water is taking either from surface water such as rivers and reservoirs or from groundwater. All water contains natural contaminants, especially inorganic contaminates that rise from the geological division through water flow and to changing extend anthropogenic pollution by both microorganisms and chemicals. Generally, surface water is more facing pollution than groundwater. There are many sources causing water pollution; each one is more important than others are. In addition, the flow rate from industrial sites and wastewater treatment works are point sources, and as such are more readily identifiable and controlled runoff from agricultural land and hard surfaces such as roads cannot control easily (Fawell and Nieuwenhuijsen, 2003).

Water is everywhere, without a watery life will end. The water in an area, moving and moving from one country to another and from one location to another, makes planning and managing water a complex and challenging task in the best of circumstances. Water may exist in most places so that the availability, quantity and quality should controlled by using it.

The problems of water in the world are neither similar nor fixed over time, and vary from one region to another, even in one country, from season to season from year to year. The solution to water resources depends not only on the availability of water. There are various influences, including water management, efficiency and the capacity of the institutes it administers. As well as the prevailing social and political conditions are affecting on planning processes, and administrative procedures, taking into account the appropriateness of implementing the foundations of legal frameworks with the availability of funds, social conditions and the environment in the country. As for the level of technology available, national, regional and international perspectives, such as political conferences, transparency, corruption, education and current research on water management is critical (Biswas, 2004).

Challenges faced many countries in their struggle for social development, and economic are progressively related to water. Lack of water, quality decline, and flood impact are among that problem which needs to take action and attention to it. Integrated water resources management is a process that can help countries deal with cost effect and sustainable way. The freshwater resources are under pressure.

Growth in population, increased economic development and facing conflicts over freshwater resources are factors in decreasing freshwater. Moreover, lack of poverty lessoning program, economic marginalization also force people living in risky poverty to damage soil and forestry resources, which has a negative result on water resources. In addition, the lack of pollution control measures the future destroys water resources (Agarwal et al., 2000).

Growing in population, urbanisation, agriculture intensive development, industrialization, and environmental supplies increase in water demand and land as well. In addition, renovation of the forest and agricultural land to commercial and residential uses is causing too rapid transformation in agriculture product, social structure, ownership of property and land market in the urban and rural border. In addition, many negative sides of the unbalanced environment such as water quality shortage, flood, and drought, decreasing groundwater, land subsiding, erosion, and sediment, as well as seawater intrusion, are more probable generated from manufactured objects. Moreover, another negative impact of water pollution and conveyed disease are continuously risking human health (Das et al., 2005).

Integrated water resources management now became the dominant paradigm for water management in most developing countries. The integrated water resources management paradigm desires the government to involve stakeholders in each level of water management. Engaging stakeholders to maintain and to restore the natural stream flow regime of the river is key to building sustainable water resources management (Fulazzaky, 2014).

Integrated water resources management is a process, which stimulates the development and management of water, land and other related resources to increase the level of economy and social welfare reasonably without compromising the sustainability of vital ecosystems. IWRM is involving the collection and managing natural water resources information, getting considerate of the connection that occurs in the uses of the resources, together with implementing policy rule, practices and administrative framework, which enables resources to be, used (Das et al., 2005).

The growing awareness that complete water resources management needed due to, freshwater resources are limited. Freshwater nowadays became more and more polluted. Unfitting water for human consumption and sustain the ecosystem, limited fresh water has divided among competing needs and society demand. Many areas, especially in developing countries, cant access to sufficient and safe freshwater resources, its realized that there is increasing in crop production and achieving security for food through more intelligent use of rainfall through improved soil and water conservation and harvesting system, a construction such as dams and dykes to control water (Liu and Savenije, 2008).

Therefore, engineering, economic, social, legal aspect and ecological should be considered. In addition, quantitative and qualitative aspect, demand and supply water need to find as well.

Moreover, management cycle like planning, monitoring, operation, and maintenance needs to be regular. For changing its water management in any country towards a more holistic and integrated management system, it will need to review the water policy such as happened in many countries worldwide. A water policy will start with the definition of some fundamental principle and objective such as the need for sustainable developing and desired socio-economic development (Liu and Savenije, 2008).

Within change in social values, traditional water management style focused hardly on water supply development without considering social impact or ecosystem impact are no longer sufficient. With knowing that, water experts have wanted to implement the principle of integrated water resources management (IWRM) to report threats from ageing infrastructure, climate change, and population growth while balancing environmental, social and economic needs (Bateman et al., 2011).

Quantitative, description and correlation study was aimed to develop a better set of the way currently the integrated water management is applied and then to formulate and propose a better form. To get a picture of what institutions are involved in IWRM, whether all villages and farmers have the opportunity to be included in the management of water and decision-making. The study based on Khalifan water basin in Iraq.

1.2 River basin problems

In general, Iraq like other country water scarcity is increasing due to the rapid growth of population and development in the region, specifically with fresh water. The result of water shortage caused by many reasons such as, neighboring country's policies, those that share water resources with Iraq, climate changes and using water for hydropower (Heshmati and Khayyat, 2012).

Rapidly growing population and using water for lives and livelihood, agriculture that consumes most water, infrastructure and industry, and other factors have a direct effect on water quality, all those factors but not much treatment (Corcoran, 2010). Earth recognized as the blue earth, due to covering earth by water. Unfortunately, 98% of surface water is in the oceans, only two percent accounts for the fresh water supplies of the world. In added, 90% of this fresh water supply either is in the poles or remains under the ground.

In Iraq, agriculture productions, severely affected by the current drought conditions in the country. The Food and Agricultural Organization of the United Nations realized these facts and made many attempts to overcome this problem through the execution of many irrigation projects

Iraq has a limited source of water. Within the increasing population, it's important to consider the water using in a good way so can survive the shortage in water. A comprehensive strategy needed to conserve and develop our water resources. For build a plan, several factors should keep in mind. These include the availability of water, its quality, location, distribution and variation in its occurrence, climatic conditions, nature of the competing demands and socio-economic conditions. To deal with each of them, every effort made to optimize the use of water, to make a high level of continuous production possible. Our goal today is to increase agricultural output per unit of water volume per unit area of agricultural land, per unit time. At the same time, provision must take to protect the environment against point and non-point sources of pollution.

The present supply with potable water in the region based on tube wells drilled individually for each village and signed on springs; it is necessarily a mix of tube wells and springs. Springs are often temporary and are dry especially during summer, and none of the villages is entirely supplying by a strong spring alone.

Due to falling groundwater table and low yields of wells and springs, extracting adequate quantities represent a severe problem. As a result, the supply of potable water is intermittent in all and villages and quite a number supplied via water tankers especially in the dry summer month. Furthermore, storage capacity is insufficient in all of the towns and the distribution networks are old and worn out. Real losses are reportedly 25 % however; it assumed that these Figures are instead in a range of 50 % — problems with water quality not reported for any of the villages.

One fundamental problem of the existing water supply system in Khalifan is the seasonal and inadequate distribution of the water to the consumers. The reason for this lies partly in the lousy state of the components and non-structured management. Additionally, the existing network does not cover future expansion areas. Because of the insufficient number of personnel, equipment and the lack of funding, the operation and maintenance system cannot operate satisfactorily.

Critical problems in the KRB listed as below:

1. The farmers who own lands near the head of the canals, springs and the main river have water and take his needs, but those who hold farms at the tail ends or a high level of their lands face the problem with accessing water.
2. The irrigation methods planned not to fit the existing soils, slopes, and crops. Even though furrow irrigation is well adapted to gentle slopes, it is a common practice even on moderate and steep slopes. This practice will result in soil and nutrient losses through water erosion.
3. The degree of land preparation is not compatible with the applied irrigation method.
4. No mechanized irrigation system provided to control water excellently.
5. The main river subjected to point source pollution Khelakan, Alana, andKhalifan.

Mainly there are many sources of river pollution due to several human activities and described part of this pollution factors as shown below:

1. Direct disposal of human and animal waste, throw into the streams and rivers.
2. I am devoting spots of lands near the bank of the main river as yards for cattle.
3. The main sewer of the Khalifan sub-district disposes all the waste of this town into the main river, and there is high pollution at the point of the confluence.
4. Throw the heaping of manures from the villages adjacent to the bank of the existing river by the villagers.
5. Other waste inputs throw into the river flow such as asphalt factory waste available near the entrance of Khalifan sub-district.
6. There are soil erosion impacts from the side slope of the basin where its high steeps and open lands on the hilly and mountainous areas surrounding the main river and its cause to pollution.
7. Use poor quality of pesticides in the farmlands by the farmers.

1.3 Research objectives

KRB benefits from relatively abundant water resources. Winter precipitation in the mountains area combined with surface water inflow from Alana valley is by far not sufficient to cover the current water demand. Part of water demands in the area is supplying from Bekhal spring, where was located outside of Khalifan river basin. A favorable geological structure, with good karstic and intergranular aquifers covering large parts of the area and enable to ensures water availability in the more arid lowland areas.

However, the KRB water resources exposed to some risks and threats, in particular:

i. A fast-growing demand caused by urbanisation, economic development and in particular the planned extension of irrigated areas;
ii. Lack of regulation of groundwater use, resulting in overuse in particular around Khalifan and its villages;
iii. Increases in water use continuously in villages located in upper areas in the KRB, and this affects the amount of water use by the villages below the KRB

The objective of this study is to determine the optimal river basin is operating and planning rules, which is part of the general plan located in Iraq. The annual flow for the river used primarily for domestic uses, irrigation, industrial, tourism, environment, and all the other use. A reassessment of the existing operating and planning rules is therefore required as water demands are likely to have changed. Also, new techniques in the water resources system analysis are also available to determine the river basin operating local policies. The study aims to observe the difference in operating rules formulated several years ago and those that derived using updated water demands and more modern optimization techniques.

As mentioned early, the optimal decision defined as the best economic return from the following main objectives:

a) The interest in the local water supply is to provide maximum water with high reliability to meet the target water requirements.

b) Management water supply typically requires a very high level of reliability whereas supplying water for irrigation often involves acceptance of the greater risk of shortages and based more on maximizing net economic benefits.
c) Usually, during the shortage, priority will be given to supply of urban water given the primary socio-economic function; lost production in irrigation can relatively easily be replaced and compensated;
d) The interest in flood control is on minimizing flooding damages within the basin; this river is one of the tributaries of Rwandwz River, which is flow free, and Non-control River due to unavailability of dams on it.
e) The groundwater faced several problems due to maximum water withdrawal and reducing the recharge due to expanding the cities by development
f) Increase water pollution due to unavailability of the wastewater treatment plant and increasing water demand.

Therefore, the important of the study is to saving water resources for future generations, and the objectives are as below:

(i) Identification of the catchment area, sub-watersheds, and rainfall water flows to the streams and the main river, also, select mountain areas, hills and plain area using Arc Map
(ii) Find the water balance accounts and equations for Khalifan river basin.
(iii) Identify current and future water requirements for all sector users such as household, industrial and agriculture using the WEAP program.
(iv) Develop a model for future planning and management of water resources in the river basin. Implement the necessary strategic plan and reduce water scarcity as much as possible.
(v) Determination agricultural water needs, the area planted with crops, and forecast irrigation areas as well as the non-irrigation areas over the next 15 years up to 2032
(vi) Determine the optimal plan for all water users in the Khalifan river basin.

1.4 Research approaches

In this case, the questions will asked, "How much water can be reliably delivered month after month from the projects on within the watershed for all users of stated capacity through a long record that includes droughts? A perfectly parallel question can be asked for river basin devoted to water users, namely, "How do we operate this river basin of a stated capacity to provide the most significant amount of benefits' that can be delivered steadily month after month through a long record that includes drought(Campbell,2006). Since irrigation and tourism are two conflicting objectives, the multi-objective river basin operation problem reformulated as a single objective problem through the constraint method.

To cope with the mentioned risks and management challenges an integrated water resources management IWRM approach is required. The main aims of the study, which includes finding answers to the following questions regarding the KRB:

i. What are the main instructions and agreements related to the use of KRB as well as to river basin management?
ii. How these water demands are transfer to land use regarding government planning on a regional level now and in future?
iii. What are the most common water-use problems in the KRB?
iv. Is there any conventional system for water use in river basin management?
v. How does information announced and communicated to all villages within KRB, specifically on the sustainable planning of the river basin?
vi. What are the relationship and connections between the KRB and other watersheds surrounded?

CHAPTER 2
LITERATURE REVIEW

2.1 Background

For better-integrated water resources management, government, private sectors, and communities should involve making decisions to reduce the gap between them especially within communities farmers should participate due to essential positions in decision-making. Also the role of tourism and own effecting on water pollution.

This research concentrated on water scarcity and the potential conflicts over water in the Khalifan watershed. The primary goal was to identify the conflict zone with its past and present problems and offer suggestions for the future. The result of this study will be a better understanding of the way to handle the IWRM issues and better managing the water users and stakeholders in the region.

Based on the previous study, this chapter will discuss and highlight water scarcity issues. Generally, facing water scarcity and water management across the world are also considered. Moreover, the correlation between agriculture, forest, farmer, household, and tourist should know to understand how they effect on water resources.

Integrated water management may distinguish in three ways. First, it is limited to include numerous dimensions of water, such as external water and groundwater, and the amount of water quantity and quality. The reason for that is that water is an ecological system that consists of some dependent elements that need to manage with consideration to their interrelationships. However, looking from this view, integration issues related to water supply, wastewater disposal and treatment, and the quality of the water can bring about concerns. Secondly, integrated water management can indicate the water is one separate system; it is simultaneously as an element that interacts with other systems. In this regard, the interaction between the land, water, and environment in the context of river need to outline and recognized that changes in of the systems might result in consequences in the others. Therefore, concerns related to management issues at this point may include floodplain management, erosion control, and reduction of diffuse pollution and the preservation of wetlands and fish habitats.

The third and most important understanding of integrated water management refers to the interrelationship between water and social and economic development; which may indicate concerns that water is both an opportunity and a barrier against economic growth. Additionally, concerns regarding water usage for sustaining long-term growth need to resolve. In this sense, water use in producing hydroelectricity, in enabling transportation of goods and in serving as an input to manufacturing production (Heshmati and Khayyat, 2012).

The pressure on water resources highlights the hydrological, social, economic and ecological inter-dependencies in river, lake and aquifer basins. The interdependencies demands are integrated approaches to developing, manage water, and land resources. There is a dynamic relationship between basin stakeholders and central governments, who have to work together to ensure the viability of their decisions in meeting sustainable development goals (Biswas, 2004).

The watershed approach later evolved to balance institutional objectives at the Federal, state and local levels and to provide consensus building among multiple stakeholders to address the water resources challenges of society. Water issues touch all segments of society and all economic sectors. Population growth, rapid urbanisation and industrialization, the expansion of agriculture and tourism, and climate change all put water under increasing stress. Given this growing pressure, it is critical that this vital resource managed correctly (Poff et al., 2003).

Issues like increased population, growth in economic activity and improved living standards in arrangement with social inequity, economic sidelining and a shortage of poverty enhancement programs, all these put pressure on resources of the world's already limited freshwater. For a maintainable use of freshwater resources, integrated management often referred to as “integrated water management”, “integrated water resources management” or “integrated river basin management”, this has significantly promoted as the solution for the problem (UNESCO, 2006).

Conflicting objectives and the uncertainties associated with future hydrologic conditions, including possible impacts of climate change could causes more complicates the identification of optimal operating policies (Labadie et al., 2004).

IWRM should apply at the level of the catchment. The catchment is the smallest complete hydrological unit of analysis and management. Therefore, integrated catchment management turns to the practical operating method. Even though this method is visible, sound and finds wide acceptance, too narrow interpretations need to elude. Integrating water and environmental management is essential. This principle broadly and sturdily maintained. IWRM can be wire through the integration of Environmental Impact Assessments, water resources demonstrating and land use arrangement. It is for understood that a catchment or watershed method suggests that water should be managed alongside the management of inter-reliant natural resources, specifically soil, forests, air and biota (Basnyat et al., 2000).

Participation in a decision with stakeholders, including workers and the community involved and this will include new institutional arrangements. There must be an increased level of self-sufficiency, but this must ally with transparency and accountability for all decisions. Caution will take to guarantee that those contributing to any catchment management structure do represent a chosen group or sector of society. It is also vital to safeguard that representative deliver feedback to the communities they serve IWRM seeks to syndicate interests, priorities, and disciplines as a multi-stakeholder planning and management process for natural resources within the catchment ecosystem, centered on water. Driven bottom-up by local needs and preferences, and top-down by regulatory responsibilities, it must be adaptive, evolving dynamically with changing conditions.

Attention in social dimensions is entailing concentration to the use of social effect assessments, workplace indicators and other tools to make sure that the social aspect of maintainable water policy is applied, and will contain the elevation of reasonable access, the improved role of women, and the employment and income suggestions for change. Community stakeholders may not be familiar with the concept of water resource management, catchment management, corporate governance, and their role in these. Many, even in developed countries, do not even know what a catchment or watershed is. The water stakeholders must collaborate in designing and implementing strategic elements of capacity building as part of the evolving IWRM process (Heshmati and Khayyat, 2012).

Information obtainability, the ability use of water management to make procedure and forecast responses, this implies, firstly, adequate information on hydrological, biophysical, economic, social and environmental characteristics of a catchment, to permit knowledgeable policy selections to be made. Secondly, some capability to forecast the most immediate reactions of the catchment system to factors such as waste flow rates, diffuse pollution, changes in agricultural or other land use performs and the structure of water retentive structures. The latter centers on the competence of scientific models: Models should be as multifaceted as the problem necessitates and no more so. It known that foreseeing ecosystem response to perturbation with reasonable confidence is strictly taxing current scientific competences, motivating continuing research (Labadie, 2004).

The acknowledgement of water as an economic good is fundamental to accomplishing reasonable provision and sustainable usage. Water allocations enhanced by benefit, cost, and aim to make the most of water benefits to society per unit cost. For instance, low-value uses could be a move to higher value uses such as basic drinking water supplies, if water quality allows. Likewise, lower quality water assigned to agricultural or industrial use (Corcoran, 2010).

2.2 Wastewater management

Water supply and sanitation is a basic need for human right, and it is vital for dignity and health for the whole community. According to WHO reported in 2004 that the percentage of people served some forms improved water supply from 79 percentages 4.1 billion in 1990 and 82 percentage 4.9 billion in the year 2000. Moreover, over the same time, the proportion of the world’s population with access to excreta disposal facilities increased from 55 percentages 2.9 billion people served to 60 percentages 3.6 billion. Besides, they reported that at the beginning of 2000, 1.1 billion people of the world’s population were without accessing of improving water supply and 2.4 billion people lacked access to improve sanitation which most of them were live in Asia and Africa.

WHO and UNESCO estimate in 2015 that 2.4 billion people have lack access to improved sanitation- hole with a slab or other facilities intended to isolate human faces from the environment. Moreover, one billion of these people have no sanitation facility to use in daily life. Those problems can observe clearly in developing countries such as countries located in the south and Southeast Asia and Africa as well. Maybe this poor sanitation associated with infection and nutritional outcomes and these outcomes causes severe disease for global. Its accounted that 1.4 million death annually is by illness from the water. One billion people are at risk from soil-transmitted infection means five million lives of people lost in a health situation. Trachoma is a leadinginfectious cause of blindness in the world; it is responsible for visual damaging of 2.2 million people with 1.2 million forever blind. Globally, 142 million children are short in height (Swyngedouw and Castro, 2002).

The most significant risk for the people living in the urban area in developing countries is improved water supply and sanitation. Access to sanitation and water is an essential factor in defining community vulnerability to natural threats, especially recently world facing a global crisis. Lack of sanitation is not only impacting human health but also its effects on the ecosystem and communities activities including tourism. In addition, as water is a driver for economic development, the degradation of water will affect the direct and indirect financial impact on business and the public sector (Johannessen et al., 2014).

2.3 Sustainable water management in the Middle East

To the sustainable development of the county or any region, it needs the availability of resources and its efficiency. Water as resources is the most important source, and it's such a valuable source, depended. To use water as sources for development, it needs appropriate management. Water supply management is a multifaceted attitude; an important affecting this attitude is how to use potential resources. Waste reuse is one of the way solution for improving the management of water resources, especially in developing countries such as the Middle Eastern countries, because of these countries faced with water scarcity. Within that reuse of wastewater, still has a limitation. Policies are essential to wastewater reclamation in the Middle East due to fundamental, technology and cultural limitation in those countries (Moghaddam et al., 2017).

The Middle East as a semi-arid region is incompetent to change water quality and quantity. Some countries have a history of regional and international conflicts on the political and social issue. Two areas have the evolution of resources-based conflicts one is Jordan river basin from which Syria, Lebanon, Jordan and the Palestinian authority draw their water and Euphrates river basin which originates in Turkey, Syria, and Iraq. In both areas of economic development, political autonomy has regulated the supply and distribution of fresh and safe water over time. The Middle East is a striking example of the conflicts for vital resources due to geography and history shaped the region (Luterbacher and Spinz, 2001).

Countries such as Jordan is the fourth developing country regarding water supply, and its 9th rate in the highest population growth means Jordan needs 1.15 cubic meters annually, but in reality, 850 million cubic meters of renewable supply is available. Because of Jordan is an arid country, even small change in water levels it impacts on agriculture, industry, nutrition, and health as well. Moreover, due to seasonal rainfall and high in evaporation, Jordan has a shortage of water supply. This country takes water from different sources some from two different rivers Jordan and Yarmuk which are the main sources and some they took from groundwater which is not renewable aquifer and treated wastewater. As shown by the United Nations Development Program, one of the most effective matters for water stored. Mercy crops suggested supplying freshwater to a rural area. It focused on both improving water networks and building catchments for rain storage. Also transferring water from area to another area is a good challenge since water in Jordan is not distribute equally (Denny et al., 2008).

2.4 Water supply environmental value

With a frame of water function in the hydrological cycle, there is social economic and ecological value, and they are essential for sustainable development. Increase in population growth, change in climate, rapid urbanisation, land conversion, and pollution all have an impact on water supply. However, population density increase over the year and watersheds, aquifers has undergone that affect the vitality, quality, and quantity of water resources. The United Nations have reported that the world population growth will reach 9 billion people in 2050; at the same time, water supply is the same or less if not managed well. Additionally, rapid urban growth will stress the capacity of water and sewerage, due to the lives of more than half of the world population currently in the cities. Few regions in the world have rivers and aquifer that has not influenced by human activity.

Many areas have already faced crises related to the increasing influence of worldwide change drivers, particularly on resources of water. That its effect is aquifer reduction and water pollution, increase water stress and food security, access to fresh water and socio-economic vulnerability. Within that, the quantity and quality of clean water from the rivers, groundwater, soil moisture, lakes, and ice are under pressure from the world. Water pollution is a global problem, which affects the health of freshwater, and people who live on them for water. Many rivers no longer lead to the ocean; hundreds of meters are a decline in fossil groundwater sources (UNESCO, 2006).

2.4.1 Water pollution and treatment

Increasing in population, industrialization, urbanisation, energy intensive, daily life, loss of forest, lack in environmental awareness, lack in rule and regulation for the environment, untreated wastewater from industries and municipalities and using chemical fertilize instead of organic matter are all the causes of water pollution. The most massive pollution source is wastewater from the cities. Besides, infection from the flow rate of industrial and wastewater besides finding the way to surface water reservoirs or rivers are also infecting into the ground to pollute groundwater sources.

Polluted water has color, odor, taste, turbidity, organic matter content, harmful chemical content, toxic and heavy metal, pesticide, oily material, waste from the industrial product, radioactivity, high total dissolved solids, acid, alkalis, viruses, bacteria, worms, etc. Moreover, to avoid ill from water pollution to human and animal health and also agricultural, standard guideline like (world health organization) and (World Bank) are encouraged to plan for the flow rate of wastewater from industry and municipality, quality of drinking water, irrigation water and most important freshwater (Spellman, 2013).

Thesewage from houses, agriculture, forestry, industry, and infrastructure with continues growth in the community from the urban or rural area has the potential for causing water pollution. The estimation of the population will increase to 11 billion by 2050 that currently more people have impossible access to safe water. With the lake in wastewater management affecting the ecosystem and daily human life such as in drinking, washing, food production, sick and also mortality. Some cities like Jakarta with a population of nine million people, less than three percent of the 1.3 million cubic meters wastewater is generated each day, which reaches a treatment plant, is the capacity to process fifteen swimming pools worth. In addition, the source of water pollution comes from not managing water resources. The particulars exist on water effecting on water quality such as organic matter, nutrient, and metal (United Nations, 2011).

However, for better water resources management should be involved only urban but also rural area throughout of agriculture, fishery and forestry. Due to using the largest amount of water in agriculture, it is vital to take to consider the agriculture sector. Its estimated seventy percent of total global water is freshwater, and the majority is back to the system. It has determined that significant cause of water pollution in the water basin is through means of agriculture (Corcoran, 2010).

Many minerals affect water to pollute like lead, mercury, chromium, arsenic, nickel, barium, cobalt, vanadium, oil, and grease, pesticides, etc. are harmful and toxic and some used for human and animal health like Zinc, copper, iron, nitrates, potassium, etc. Furthermore, the wastes from industry and municipality use of the toxic element, pesticide, insecticide, and fungicides, the leak of soils, debris and rocks are the cause of water pollution.

2.4.2 Water flow and sedimentation

Environmental pollution became a critical issue over the last few decades. The water drinking along with the air breathe, and the food eaten all threatened by global pollution. The pollution reaches such a degree that becomes dangerous to public health, harmful for commercial and recreational uses and unhealthy for birds, animals and plant life. Generally, animal and man wastes and erosion of fertilized agricultural lands and light industrialization are the main sources of water pollution in the area under study. Water is one of the materials required to sustain life and suspected of being the source of many illnesses affecting humanity. The primary effect of soil erosion as a non-point source of pollution caused not by the influx of soil sediment itself into the water, but by the various other things (nitrogen fertilisers and other additives.), that carried along with it.

Soil sediment in water causes considerable damages to himself. It increases the turbidity, discoloring water, making it less attractable for fishing and swimming. It clogs canals and waterways and causes treatment of water more expensive. The disposal of human and animal wastes as point sources of pollution always created a dangerous problem. With the growth of urban areas, it becomes essential to require drainage or sewer systems that carry these wastes from the region. The standard repository is typically the nearby watercourse, but the rivers have the partial capability to hold excess materials without creating irritation.

Usually, the stream would cleanse itself in ten miles of flow. But as population density grows, the capacity of rivers and streams to assimilate the wastes cleanse the water is exceeded resulting in accumulation of residues in a deteriorating environment Production of a great variety of residues from established industries also constitutes another source of environmental pollution. During the past few decades, many chemicals formed for agricultural uses. Some of them used for weed control, others for pest control. Remains of these materials often passed to watercourses throughout periods of heavy rainfall and irrigation and therefore have a severe impaction environmental pollution.

The primary consideration of environmental water protection is to produce adequate supplies that are hygienically safe. The goal is to bring about finished waters that are free of colors, turbidity, taste, scent and damaging metal and provides water, which has low hardness ions total solids, non-corrosive, and non-scaling form. In addition, the farmers desire waters that do not create salinity, toxicity and permeability problems. In water resource evaluation, the quality of water is of nearly equal to quantity. The water available in the nature are not always pure; they may often contain at least small amounts of dissolved gases and solid. The arrangement of the aqueous solution is a purpose of the diversity of factors, for example, the original composition of the water, the partial pressure of the gas phase, the nature of mineral matter the links, and the pH and oxidation ability of the solution (Delipınar and Karpuzcu, 2017).

The chemical, physical, and bacterial features of water regulate that its practicality for the community, commercial, industrial, and domestic water provisions. The progress makes opportunities available for pollution of water and contemplation must give to the safety of superiority. Water with some physical and chemical distinctive may be appropriate for agricultural uses, but not beneficial as domestic water supplies. Therefore, the study of water quality is of significant value to define the significant mode of use. The review of water quality contains an explanation of the appearance of numerous constituents and the relation of these constituents with the aquifer (Poff et al., 2003).

2.5 Water resources management in Khalifan river basin

Generally, in Iraq water is a limiting source. Its active practice is elementary to the survival of the population growth. A comprehensive strategy needed to conserve and develop our water resources. Build water resources strategies are essential to take into account several factors. These include the availability of water, its quality, location, distribution and variation in its occurrence, climatic conditions, nature of the competing demands and socio-economic conditions.

In the process of dealing with each of these, effort must make to provide the best use of water, to make possible a high level of constant making. The goal today is to surge agricultural production per unit volume of water per unit area of cropland, per unit time. For the same reason, provision must be in use to keep the environment clean against point and non-point sources of pollution.

Population growth and periodic drought conditions have put pressure on available water resources; the effects made to conserve water in agricultural, municipal and industrial. Evapotranspiration is a critical factor for estimating irrigation water requirements. Rational evaluation of this factor is essential for planning, designing, operating and measuring levels in water resources projects particularly under extremely arid conditions, which prevail in many parts of the world (Heshmati and Khayyat, 2012).

Rasul and Askar (2010) studied integrated water resources management of the Alana valley by using WEAP and ArcGIS. They used historical data for a period 2006 – 2008 and estimated the average rainfall-runoff coefficient by the rational method for the sub-basins. The factor for the whole basin was 0.27. They also calculated the maximum annual flow for Alana River, which is upstream of KR as amount 69.8 million cubic meters, and yearly minimum flow for the dry year 41.4 million cubic meters. The researchers find out construction dam reservoir capacity with not less than 5 million cubic meter in the location of Gali Ble as a result upstream of Alana River for controlling shortage of water during dry seasons (Rasul and Askar, 2010)

In Erbil province, the agriculture productions profoundly are affecting by the present drought conditions. The Food and Agricultural Organization of the United Nations realized these facts and made many attempts to overcome this problem through the execution of many irrigation projects. Among these activities were drilling wells, lining irrigation canals, constructing dams and rehabilitation of watersheds, Water Resource and Irrigation Sub-sector North/ FAO prepared a plan to build several lined irrigation canals in Izup and Smaquly watersheds to distribute irrigation water efficiently and to organize irrigation schedule. They also made many other plans to rehabilitate other watersheds in the region. Among these efforts is the study of water management in Khalifan watershed.

2.6 River basin systems

The motivation for public administration is: to get equity and judge conflicts among water users, to maintain ownership on a strategic infrastructure, to ensure that certain water services viewed as public goods preserved, and to promote the development of water resources (Sharma et al., 2007).

Water resources systems managed efficiently while respecting all operational objectives and constraints. This type of management is complicated because of the varying requirements, uncertain flow, multi-purpose and multi-institutional characteristics of water supply. Dams, the subject of this thesis, optimal control of the river basin and can provide critical benefits such as irrigation and tourist uses (Kularathna et al., 2017).

The construction of dams and reservoirs also causes problems for people within the river basin, such as destroying agriculture lands, disruption of the ecosystem and damage to the environment.

For river basin operation problems, the main decision variables are water releases and demands. The allocation of river basin services among water uses requires that the river basin management model and model function as an economic objective. The optimization model will define the optimal river basin operation policy for the river basin system in the KRB.

The objective is to maximize the overall benefits obtained from the water supply, tourism, irrigation and flood control. The optimal river basin is operating policies and evaluation analysis planning simulated over the 2001-2016 period, which is the reasonable period with historical flow records.

CHAPTER 3

RESEARCH STUDY AREA

3.1 Background

Khalifansubdistrict is located in Iraq's Erbil province within the Soran District area. It is 80 kilometers northeast of the Erbil, between Northing (N36° 36′ 31.88″), Easting E (44° 24′ 28.39). Figure 3.1 shows the location and river basin.

Figure 3.1 The area map and location for Khalifan river basin

The majority of the populations are Muslims. Generally,Khalifan district is a mountain area with elevations from 650m to 2200m above sea level. The catchment area is approximately about 75000 hector. There are 63 villages in the KRB with a population about 28573 people, 72% of population gathered in Khalifan, the 10% of the rest distributed in 11 communities of sub-catchment and 18% in 20 communities of rain catchment (MOA and WR, 2016).

Table 3.1 shows some village survey done by the Ministry of Agriculture and water resources, it shows the area of the village, and area distributes to Forest, orchard, Pasture, and Residential.

Table 3.1 Field survey for some of the villages (MOA and WR, 2016)

Villages	Total area km^2	Arable km^2	Non-arable km^2	Orchard km^2	Forest km^2	Natural pasture km^2	Residential km^2
Malakan	13.75	3.25	1.625	3	2.25	3.6	0.025
Kandor	11.5	2.5	2.8	0.225	2.75	3.25	0.0075
Bardok	1.9	0.25	1.4	0.02	0.14	0.075	0.0075
Harutakon	7.25	1.5	2.75	0.61	1.125	1.25	0.015
Bnawi	18.28	2.8	7.6	2.5	2.8	2.5	0.005
Bla	19.57	2.25	12.6	0.15	2.75	1.8	0.0025
Gurgar	5.4	1.15	1.5	0.67	1.25	0.75	0.025
Khandol	3.6	1.4	0.56	0.18	0.87	0.43	0.005
Kanipisan	2.25	0.38	0.97	0.15	0.21	0.5	0.0075
Alana	14.15	3.75	7.3	0.25	1.5	1.25	0.025
Kani rash	3.47	0.9	2.5	0.0075	0.062	-	0.0025
Jolamerg	16.6	5.5	7.7	0.31	0.84	2.23	0.025
Tarina	4.14	0.75	2.10	0.057	0.45	0.75	0.025
Birokan	3.8	0.92	1.30	-	0.725	0.87	0.005
Dashtiloka	2.98	0.75	0.775	0.075	0.625	0.75	0.005
Total	128.66	28.067	53.71	8.22	18.43	20.02	0.187

3.2 Climate and precipitation

The climate of KRB generally characterised by warm, dry summers and cold winters. The transition periods in spring and autumn are very short. Rainfall concentrated during winter, which contributes 85% of the annual total November to April. A significant percentage of the yearly rainfall, therefore received as snow, except in the lowland areas where snowfall still occurs but is less critical. The lowland plains have a semiarid climate.

Khalifan district is a mountain area, located in the north of Iraq, where the climate is warm during mid-day but cool during the night and cold rich in precipitation and snow in winter. Rain and snow in the north of Iraq are changing from year to year; depending on the geographical and climate condition. The amount of precipitation has affectedthe water level in the river and spring as well (Heshmati and Khayyat, 2012).

Generally, the climate in Iraq is warm in summer and cold in winter with a fall of snow in the mountain area. The average temperature of KRB in winter is 1.6c and in summer is 27.8c. Usually, precipitation is starting from October until the end of April depending on climate change. Rainfall almost is between 600-1000 mm and snow 0.5-1 meter (MOA and WR, 2016).

The primary source of humidity of the region is Mediterranean cyclones that move eastwards during the winter. However, Arabian Sea cyclones from southerly directions can also cause abundant precipitation as they carry large amounts of moisture. In the summer, maximum temperatures in the lowland areas exceed 40°C and dust storms are a common phenomenon. Evaporation rates are high in summer due to a combination of high temperatures, the absence of clouds (high radiation) and low air humidity. Summer maximum day temperatures reach 42°C in Erbil (average of the months July and August) Relative humidity during the summer months ranges between 20 and 30% in the low lands and is less than 50% even at the highest meteorological stations (Abawi, and Hassan, 1990).

Table 3.2 shows monthly averages of reference evapotranspiration calculated using the FAO CROPWAT software (v8.0).

Table 3.2 Reference evapotranspiration (based on the Penman-Monteith equation)

Metrology station	**Altitude a.s.l.**	**Annual ET_0 (mm/y)**	**Month (average in the mm/day)**											
			J	F	M	A	M	J	J	A	S	O	N	D
Khalifan	720 m	1533	1.0	1.5	2.0	4.5	5.8	6.7	8.1	9.2	6.7	3.2	1.6	0.3

Alternative options such as subsurface storage and artificial groundwater recharge carefully considered to minimize water losses. Table3.3 compiled from original data provided by the various meteorological and agro-meteorological departments, offers critical data for four stations at a different altitude.

Table 3.3 Key data for the metrological station (MOM and T, 2016)

Month	J	F	M	A	M	J	J	A	S	O	N	D
Average evaporation mm	18	12	30	88	174	200	242.4	276	140	96	46	9
Average rainfall mm	238	156.5	185	145	75	5	3	0.5	13	82	152	145

Precipitation is generally increasing with elevation; the Table below shows rainfall in Khalifan.

Table 3.4 Monthly precipitation of Khalifan station (mm) (MOM and T, 2016)

Year	Monthly rainfall [mm]														
	J	F	M	A	M	J	J	A	S	O	N	D	Total annual rain	Highest monthly rain	Lowest monthly rain
2000	90	180	135	35	60	0	0	0	10	33	150	193	886	193	0
2001	93	185	122	30	49	0	0	0	12	17	119	204	830	204	0
2002	188	71	136	177	20	0	0	0	0	44	53	241	930	241	0
2003	141	200	193	63	8	1	0	0	0	43	91	112	851	200	0
2004	197	141	15	138	52	0	0	0	0	4	161	23	732	197	0
2005	112	162	93	43	49	2	0	0	0	9	35	71	576	162	0
2006	164	328	65	150	24	0	0	0	0	173	74	30	1008	328	0
2007	82	171	103	156	28	0	0	0	0	10	35	42	625	171	0
2008	51	126	121	8	1	0	0	0	17	40	35	100	499	126	0
2009	10	67	187	81	2	0	0	0	5	65	55	120	593	187	-
2010	193	76	141	182	30	0	0	0	0	49	58	246	975	246	-
2011	139	197	190	59	13	1	0	0	0	40	89	109	837	197	-
2012	205	141	65	120	65	0	0	0	0	35	182	45	858	205	-
2013	122	171	101	52	57	2	0	0	0	24	56	85	670	171	-
2014	151	215	208	95	45	1	0	0	0	48	93	115	971	215	-
2015	199	145	85	141	55	0	0	0	0	24	163	44	856	199	-
Mean	**134**	**161**	**123**	**96**	**35**	**0**	**0**	**0**	**3**	**41**	**91**	**111**	**794**	**203**	**0**
Min	10	67	15	8	1	0	0	0	0	4	35	23	499	126	0
Max	205	328	208	182	65	2	0	0	17	173	182	246	1008	328	0

The maximum annual precipitation as shown in Table 3.4 is 1008 mm during the year 2006 and the maximum monthly rainfall 328 mm as well as during February 2006.

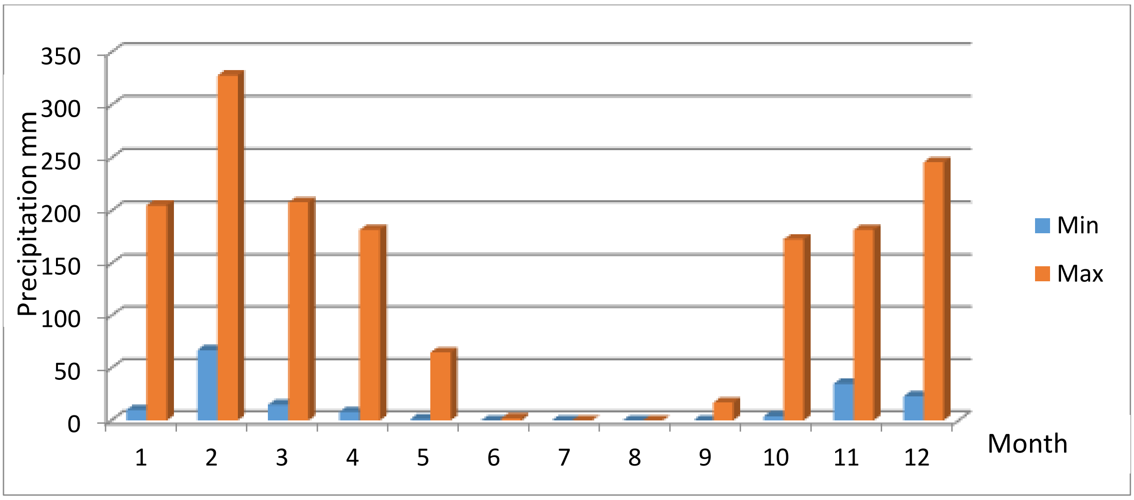


Figure 3.2 Khalifan precipitation chart (MOA and WR, 2016)

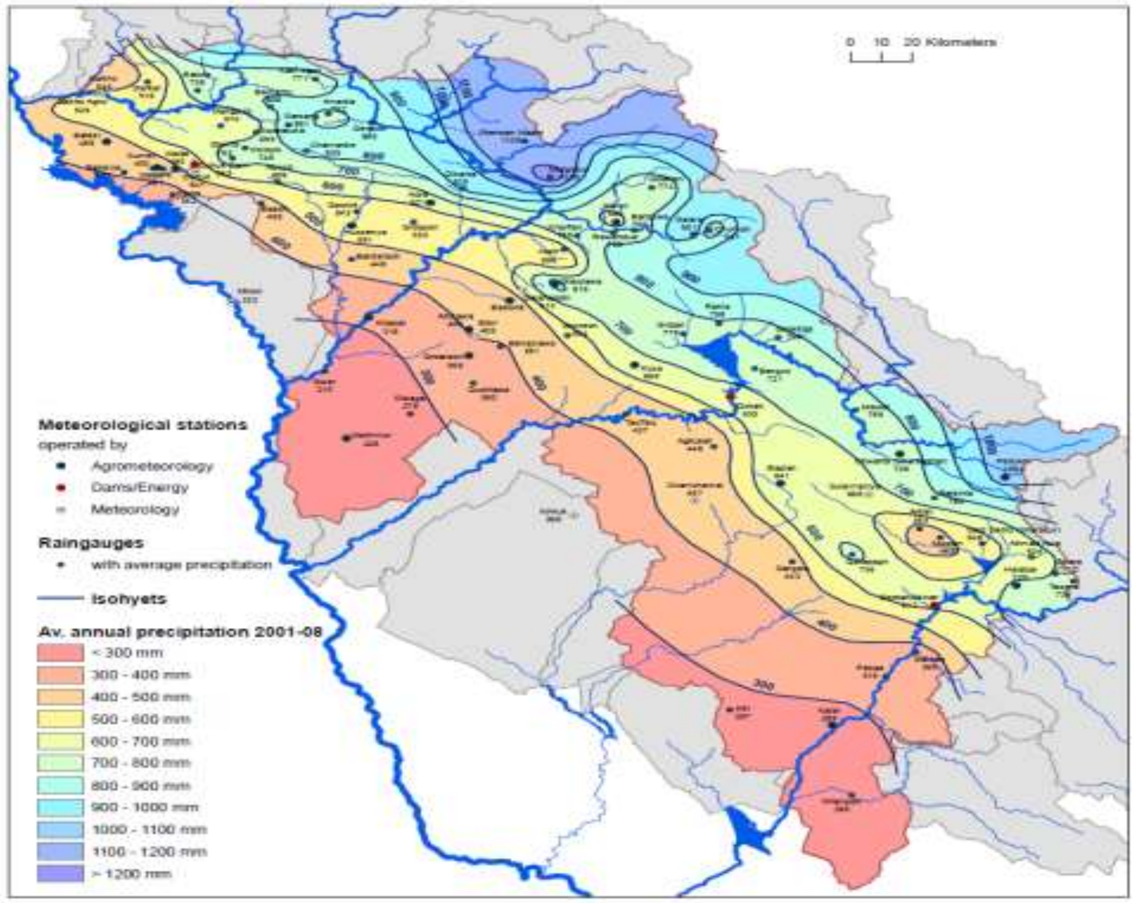


Figure 3.3 Contour line annual rainfall,reference period 2001- 2008

3.3 Socio-economic conditions

Nearly all the villages in this area destroyed during continuous wars in the past, but the regional government in collaboration with governmental and non-governmental agencies has reconstructed most of them. The whole area comprises 63 villages. The main occupation of the villagers is irrigation farming (farmers), with emphasis on goat sheep and cattle (MOA and WR, 2016).

Generally, the living standard is low. High illiteracy, malnutrition, and poor health are silent features of the area. The people lack the capital to conserve soil and water. Deep-rooted traditions and customs in land use observed. The people of the remote villages have the difficulty of transportation, especially during the winter season

3.4 Sources of water in the Khalifan river basin

The present water supply in Khalifan town based on three wells and two springs. In the far south of the city, there are three wells close together, which referred to in this report as “old wells”. Also, three wells drilled recently by the Food and Agriculture Organization FAO and located the southern boundary of the town. The water pumped from these wells to a reservoir situated about 800 m north. The old wells provide water to a relatively new concrete tank that lies a short distance north. The seventh well is located almost in the center directly adjacent to a specific reservoir (MOA and WR, 2016).

The springs Kani Rash and Kani Ble lie in the southeast with a distance of approximately 7 kilometers, respectively 10.8 kilometers from the town. Water flows by gravity to the corresponding reservoirs. The spring Kani Rash delivers water to a concrete tank in the center of the city. Water from the spring Kani Ble fills a water tank in the east approximately 900 m away from the town center. Also,kaniplnga, kanibnawsha, kanibaran located in malakan used for a different use.

Critical causes that faced the catchment area are:

1. The furrow irrigation method is not adequate for the lands which have considerable slope
2. The irrigation depth of water has no scientific basis. They irrigate their farms when they desire without using any instrument or doing some simple tests like forming soil balls when the press in hand or using the dark bluish green color of leaves as signs of water needs, Furthermore, they apply a high amount of water.

It will give rise to excessive nutrients leaching by runoff and deep percolated water.

1. Lack of cost provides for installation pump stations and soil conservation as well as for water supply networks
2. No irrigation enterprise like private, quasi-public or public type organized under specific laws and the regulations to distribute water among the farmers.
3. There is no law or regulation to put restrictions on people not to pollute the available water in the area under study.
4. Use small diameter pipes to convey water from the source to the villages in spite of water availability at the source. For instance, the pipeline, which expresses the water from Zhazhok to BleKhuaroo, has a diameter of 3 inches.

The problem above effect:

1) An extensive area of agricultural lands left without a supply of irrigation water, this case accepted for high-level lands at the lower Jolamerg, Ble Khuaru, Kandor, and Bandor.
2) The water of the main river became highly polluted, especially from the downstream of Zelakan up to the downstream of Khalifan.
3) Reduce yields per unit area due to an inadequate supply of irrigation water and nutrition losses through runoff water and deep percolated water.
4) Most of the villagers were unable to obtain a sufficient quantity of water for domestic uses
5) Intensive soil erosion from steep irrigated lands and the hilly area surrounding the bottom of the valley due to sparse vegetation cover.

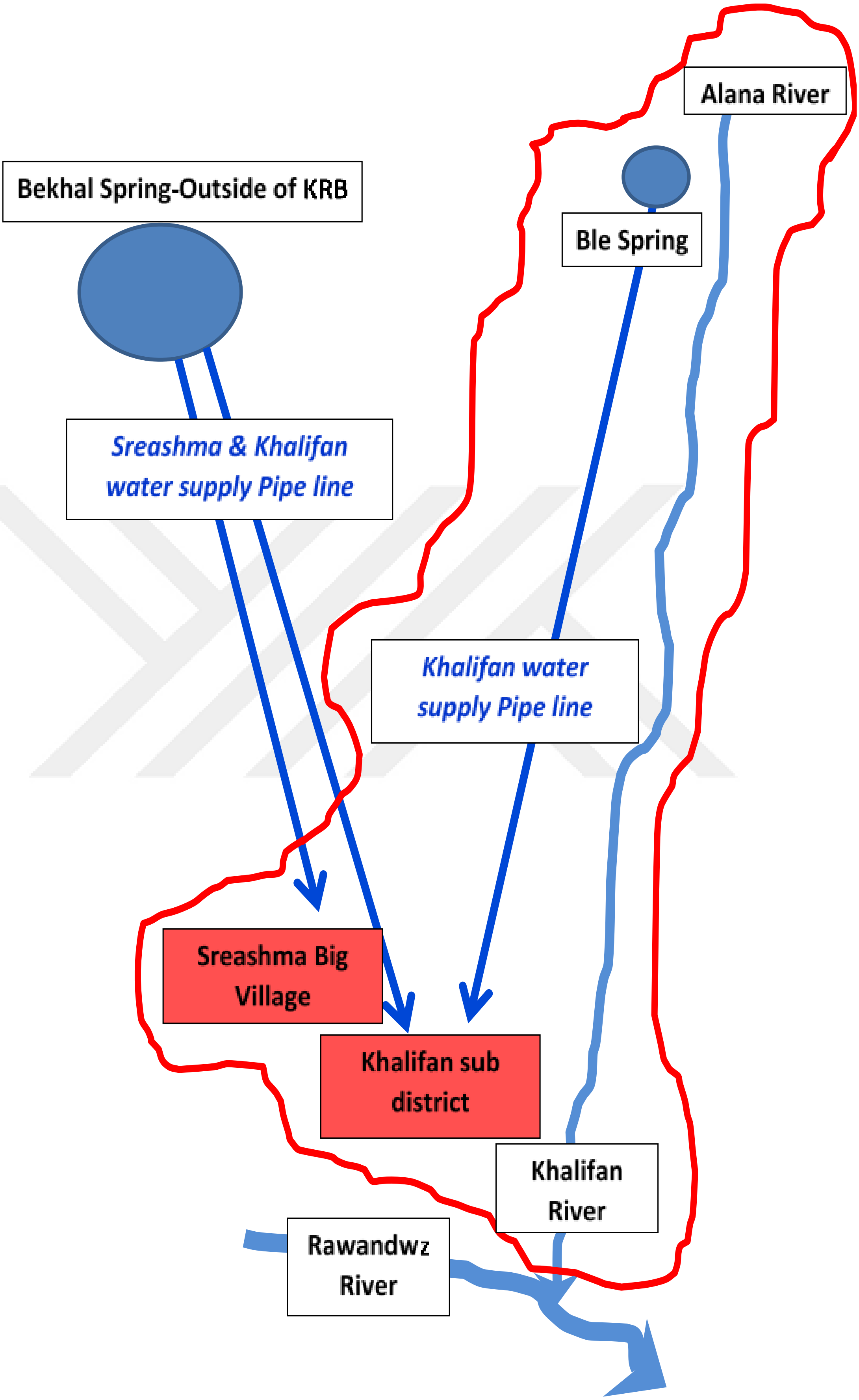


Figure 3.4 Water system and water supply in Khalifan river basin

3.5 Most popular tourism place

Gali Ali Beg Waterfallis located in Iraq, which lies in the mountainous northern part of the country in the Erbil province Region, north of Erbil Gali Ali Beg Waterfall 87kilometers far from Erbil. This waterfall is the host for many visitors and tourists across the country Figure 3.5.This valley lies between the Korek and Bradost Mountains.

The famous Gali Ali Bag waterfall is located in the river basin outlet, a popular tourist site and there are regular visits four seasons by Iraqi citizens from around the country to visit. The breathtaking scenery around the waterfalls has long since assured the site's popularity as a picnic spot, and the resort today, complete with a waterside souk and its host of terrace cafes and eateries, and offers a warm, authentic welcome. During the long summer months, tourists from all over Iraq found in these popular waterfalls – famous for their outstanding natural beauty. The dramatic mountain scenery in the second half of the three-hour drive makes the excursion well worth the effort and one of Erbil Lifestyle's favorite day trip destinations (MOM and T, 2016).

Figure 3.5 Gali Ali beg waterfall tourism area, summer 2017

It is 12 kilometers long with spectacular views, such as springs and waterfalls. Hailed as the highest waterfall in the Middle East, Gali Ali Beg, a dusty but beautiful three-hour drive from Erbil, is a mountain resort located on the intersection of two mountain ranges, the Korek chain in the north and the Bradost chain in the west and two rivers, the Rwandwz, Sidakan and the Khalifan.

Koreak Mountain in the mountain region has very volatile and extreme weather; the higher temperature is 33 centigrade and lower -13 centigrade with rainfall of 20-75mm and snowfall about 60-100 days. In the mountain, there is a cable car from its Bekhal Bottom station to Mount Korek within distance 3kilometers. In addition, there are 132 villas and several rides in this project, which called "The Korek Mountain Resort and Spa (MOM and T, 2016).

Figure 3.6 Korek mountain tourism areas

3.6 Main domestic water supply

There are different infrastructure to pump, convey and store water for agriculture and domestic uses. The projects include a 3-pump station to pump water from three deep, some private pumps owned by farmers, four concrete irrigation canals, head regulators, farm regulators, concrete basin and pipeline for various diameters.

Table 3.5 Domestic water supply exist (MOM and T, 2016)

Infrastructure type	Deep well pump	Head regular	Regulation valves	Concrete storage tank	Pipe lines km	Concrete Culvert box	pipeline supply water from Kani Rash	Concrete basin
number	3	4	50-60	7	12	1	1	2

3.6.1Transmission line and pumping station

The main transmission from the spring Kani Ble to the connected reservoir is from 2006, while the line from the spring Kani Rash is from 1994. The latter is indeed not in good condition. There is limited information concerning the situation and the characteristics of the pumps. To improve the management of the system and to strengthen the reliability of the supply, the set of pump replaced except the ones extracting water from the well Number one. The information obtained is incomplete regarding the exact lengths and connections of the wells to the reservoirs. Table below summarizes these assumptions and the results of the field survey (MOM and T, 2016).

Table 3.6 Existing transmission mains pipes Khalifan town (MOM and T, 2016)

Existing transmission mains			
Supply area	**Inch**	**Material**	**Pipe lengths m**
Transmission main, well no.1.1	6	DI	3,200
Transmission main, well no.1.2	6	DI	
Transmission main, well no.1.3	6	DI	
Transmission main, well no.2.1	4	PE	800
Transmission main, well no.2.1	4	PE	
Transmission main, well no.2.1	4	PE	
Transmission main, well no.3	6	PE	75
Transmission main, spring 1	150	DI	10,800
Transmission main, spring 2	225	PVC	7,200

3.6.2 Existing water storage structures

The town of Khalifan has five concrete water storages and two steel water tanks for collecting domestic water and water supply to the city, up to date the six of the water storages are in use, the last one under maintenance by the government due to seepage problems. The water tanks made of either concrete or steel. The total existing water storage volume is about 2380 m^3 (MOM and T, 2016). The altitude and characteristics of the water tanks and the associated water sources listed in Table3.7

Table 3.7 Existing water storage facilities–Khalifan town (MOM and T, 2016)

Existing water storage reservoir						
Name/no.	**Material**	**Type**	**Volume m^3**	**Altitude m.a.s.l**	**Condition**	**Location**
Reservoir no.1	concrete	ground	480	753	useable	Southwest
Reservoir no.2	concrete	ground	100	730	useable	Southeast
Reservoir no.3	steel	ground	64	670	requires rehabilitation	center–east side of the main road
Reservoir no.4	steel	ground	300	705	useable	center–west side of the main road
Reservoir no.5	concrete	ground	480	748	useable	southnearwell1-3
Reservoir no.6	concrete	ground	480	730	useable	South
Reservoir no.7	concrete	ground	480	730	useable	east outside the buildings
		total	2,380			

3.6.3 Existing water distribution system

The total length of the existing distribution system is approximately 26.5 kilometers. The age of the oldest pipes is 42 years, and detailed information on the condition of the water pipes couldn’t be obtained. Only the pipes ductile iron pipe DIwith diameter nominal DN 150 can be integrated into the future design. The diameters are ranging from 3 to 8 inch, and the predominant materials are PVC, DI, and PE (MOM and T, 2016).

The network has a branch typology with some loops in the living quarters, is not divided into zones and covers only the existing part of the buildings. It does not take to account the designed for the future development of the town. The water supply system of Khalifan does not avail of sufficient control and shut-off valves for adequate network control and management.

3.6.4 House connections

The consumers supplied on average with 1.5 hours daily for four days per week. Most of the houses in Khalifan have roof tanks to store water, as supply is in the term its tent. House connections generally made using iron ferrules, which are prone to leakage. Materials used are galvanized iron pipe GI and various types of plastic. In principle, all houses do have connections to the water system, but none metered.

3.7 Agriculture and soil conditions

The soil is one of the essential elements to obtain good production through agriculture. The soil in the mountain area is shallow, and it is the rockiest type, which cannot use for farming. Meanwhile, the deep soil layers of the land are changing from location to another area (Malczewski, 2004). In addition, in the valley and the plain area, which is useful for, agricultural are chestnut soil, dark brown soil, and black soil. It is some of the best soil for agricultural due to great depth, good texture and rich in organic. Also in semi- Mountain area and the mostly plain area covered with red clay and brown soil.

Khalifan is considering as a mountain area with having some lands for farming. The land soils are composed of loam clay sand, loam silt, and clay. Mixtures of soils characterize the soils that exist in the study area starting from Alana valley to Gali Ali Bag.

Some areas of the river basin have a steep slope where farming is difficult and expensive compared to good riverbeds on the banks of the river. The total length of Khalifan watershed is 36kilometerswithin difference in elevation is 1550m, and the average slope is 4.3%.In general, the slope of the sub-catchment area is steeper than that of the main catchment. This area contains lot of beautiful divisions and good recreational locations like Fall of Gali Ali. Khalifan river with two other rivers (Balak and Sedakan) combine a Rwandwz River and then flown into Greater Zab, which is one of the main branches of Tigris (MOM and T, 2016).

The main crops in Khalifan area are:

1. Field crop: Wheat, barley, chickpea and other legumes
2. Vegetable crops: Includes dry onion, sunflower, tomato, tobacco, potato, cucumber and other vegetables.
3. Fruit crops: Includes walnut, cherry, pomegranate, apricot, fig and grape.

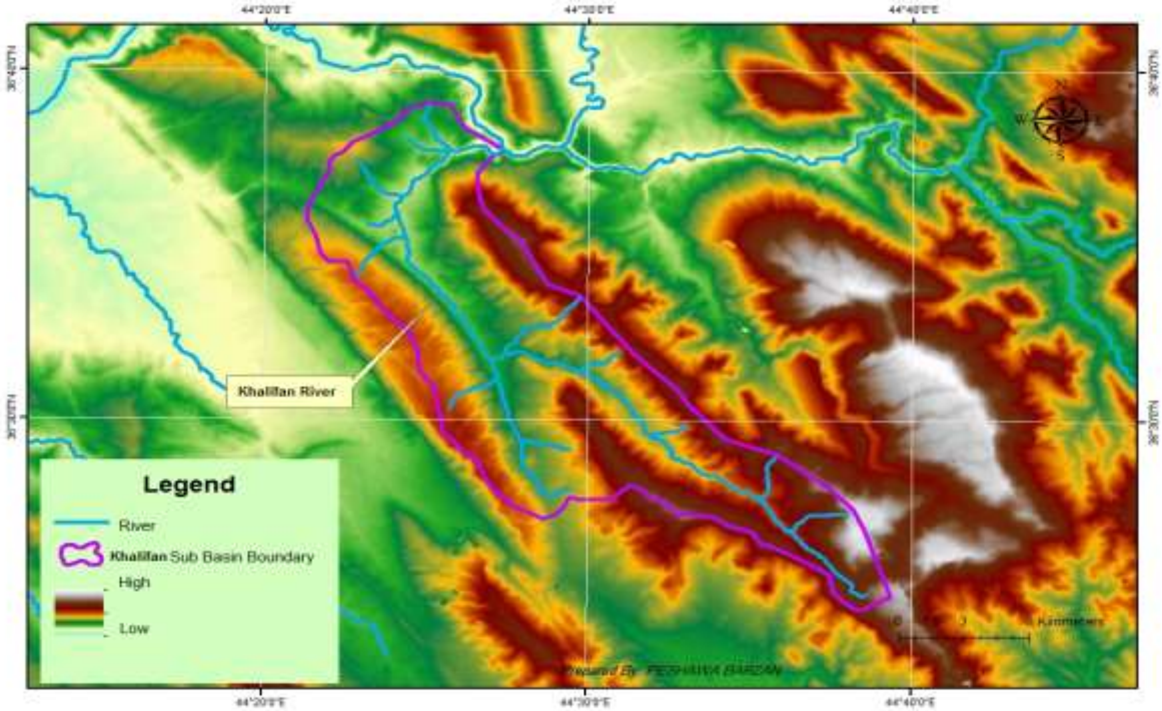


Figure 3.7 Map of boundary and elevations

There are two types of agriculture is produced either by rainfall or by irrigation project. Furthermore, all land belongs to a farmer means its privet agriculture and one important point is there is no security food within the area.

The total area irrigated 3100 ha, the year 2017and Catchment area around 75,000 ha

3.7.1 Seasonal distribution of precipitation

Climate data show that despite differences in annual rainfall in absolute numbers, the seasonal distribution of rainfall is very similar. Over-precipitation and therefore groundwater recharge and water generation from lowlands in October: from November to April, only 85% of the annual rainfall is concentrated in the half of the year from November to April, while the four summer months of June to September contribute less than 5%. The snowfall in KRB reaches the depth of three meters in the top of Korak Mountain (MOA and WR, 2016).

3.7.2 Climate change effect on water resources availability

Climate change is a global phenomenon that taken into consideration in the main planning because it influences the decision to design and adapt it to water management especially in KRB. The full discussion of this phenomenon, in particular, the reduction of the scope of regional projections for the analysis of local impacts in KRB, is beyond the scope of this study. However, the length of some available meteorological records allows analysis of whether any trends detected (MOA and WR, 2016).

Two related questions analyzed in this way:

1. Does precipitation decrease in general?
2. Is there a change in the seasonal pattern of water availability?

3.8 Quality of water and description of collecting water samples

During the research, this information system used mainly included four sectors; the first sector is agriculture and irrigation, other domestic water (drinking water and sanitation), third environment and heritage and the fourth is tourism sector. Water sampling carried within two different periods of fieldwork; first starting from 2/10/2017endedat15/10/2017 and second sample tested on 25 March 2018.

Compared with World Health Organization WHO 1996 guidelines, Table3.8 for drinking water for all parameters except for the waters of the main river, due to several leakages in the water network systems in the villages the quality of water delivery to the houses are below the water quality standards.

Generally, the fieldwork regarding taking water samples divided to two parts, the first one is taking water samples from the deferent sources and the second is to test the sample from the laboratory by the Directorate of Erbil water staffs

3.8.1 Laboratory water test works

This part of jobs includes several testing according to the requirement of WHO instructions as shown below:-

A- Physical measurement; water physical characters are included in its temperature, color, taste, and turbidity. Water samples of Khalifan watershed taken from different exploitation resources (deep wells, surface water, and springs). Generally, water samples were colorless, tasteless, low turbidity, and its temperature ranges from 17.6-20.6 centigrade. The physical characteristics of nearly all samples are within acceptable ranges when compared with WHO-1996 standard for drinking water.

While the chemical characteristics of the water samples interpreted are using the analysis results of Appendix A.

1- Color: The watercolour has two types: apparent colour due to suspended materials and true colour due to vegetables and organic extracts. Visual observations on the waters of the springs and water of the main river revealed that both types of colour are not detectable. Therefore it is expected that there is no reluctance of the water consumers to drink such waters, especially those of the springs.

2- Turbidity: The term turbid applied to waters containing suspended materials that interfere with the passage of light through it. Turbidity caused by a wide variety of suspended materials which range in size from colloidal to coarse dispersion, depending upon the degree of turbulence. Turbidity may be caused by grinding action of the glacier, farming and other operations that disturb the soils, washing of topsoil under the effect of the flood, domestic and industrial wastewaters, street washings and bacterial growth. The measurement of this physical property for water is important in the disinfecting, filterability and aesthetic (Davies and Smith, 2001).

The Environmental Protection Agency has placed a limit of 1 unit for turbidity as the maximum amount allowable in water supplies. From the results that tabulated in Appendix A and B, it is observed that the turbidity of the water of all the springs and the water samples taken from the main river at Ble Khuaru and onwards is below one unit. On the contrary, the turbidity of the water samples that received from the main stream at Gurgar, Alana, Khalifan, and Gali-Ali exceed one unit.

Table 3.8 The chemical analyses for drinking water, WHO

Parameters	WHO guidelines 1996	Source cause
Temperature C^0	12-25	Earth's temperature or chemical reaction
pH- value	6.5-8.5	Acids, PCO2 lower, bicarbonate increase the pH
Na (mg/l)	200	Dissolved from practically all rocks and soils, also found in I seawater, brines and wastewater
Ca (mg/l)	75	Dissolved from all rocks and soils, especially from limestone, dolomite, and gypsum.
K (mg/l)	125	Same as Ca, from sedimentary rocks.
HCO_3 (mg/l)	12	Sedimentary rocks. Wastes of man, livestock, and fertilizers.
CI (mg/l)	125-350	In most water, nearly all hardness is due to calcium and magnesium.
SO_4 (mg/l)	250	Dissolved from rocks and soils Present in wastewater, ancient brines, and seawater
CI (mg/l)	250	Dissolved from rocks and soils containing gypsum, iron ·sulfates, and other sulfur compounds.
NO_3 (mg/l)	50	Decaying organic, legume earth, wastewater nitrate, and fertilizers
TDS (mg/l)	500-1000	Dissolved from rocks and soils Includes organic matter.
Hardness (mg/l)	500	
Faecal Coliform colony/100ml	-	Waste and residues of living organisms
Total Coliform colony/100ml	50	Waste and residues of living organisms

B- Chemical measurement

1-Total dissolved solids (TDS) mg/I

Total dissolved solids considered for the water testing and when the results arehigh, sampling processes repeated for those wells, surface water, and springs, and tested for one or two times. Maximum TDS value was 322 ppm, and the minimum was 215 ppm. The homogeneity total dissolved solids index of (H.TDS) is:

H.TDS= minimum value of TDS/ maximum value of TDS *100=215/322 *100=66.77%

The low TDS homogeneity index values indicate a wide range of variation in the TDS values for the tested samples. Generally, TDS indicate a total sum of cautions and anions, in addition to the rare and secondary elements. The high TDS concentration values may be due to sulfate, which may be deposit as gypsum, which traps some of the water during evaporation processes (Davis and Dewiestn, 1966).

In addition, change in pH means changes in the TDS values. When pH is decreasing in wastewater due to bacteria activity, TDS will increase, due to the mobilization of calcium carbonate as the effluent moves through the vadose zone (Reddy et al., 2012).

Table 3.9 Water type and range of ppm

Type of water	T.D.S ppm
Freshwater	<1000 ppm
Moderately saline	1000-3000 ppm
Saline	>3000 ppm

It is a general indication of chemical water quality. All water samples of Khalifan watershed are of a current type because their values are less than 1000 ppm.

2-Electrical conductivity (EC)

Electrical conductivity or electricity conductance is the ability of water to conduct an electrical current. The conductance of water is a function of the concentration of various ions, type of ions present and temperature. Specific conductance readings usually adjusted to 25C so that variations in conductance are a function only of the concentration and types of dissolved constituents present (Davies and Smith, 2001). The maximum value of electrical conductivity was 0.503 ms/cm, and the minimum was 0.336 ms/cm micro Siemens per centimeter, and the mean value of electrical conductivity was 0.322 ms/cm inKhalifan watershed Appendix A and B.

The highest TDS, and EC values, also the lowest amounts of TDS and EC appears in the same water points, which indicates a direct relationship between TDS and EC values.

The results are in Appendix A, and B shows that the EC does not exceed 0.503 ds/m. These waters would present no salinity problem according to the revised FAO classification of irrigation water EC< 0.75 ms/cm. Applying the FAO criteria to the EC and SAR values reveals that for the lands irrigated with these waters there would be a slight permeability problem.

3-Total Hardness (TH)

The total hardness TH is necessary to be determined in order to know the suitability of water either for domestic or industrial. It use data basis for recommending the need for softening processes.

Total hardness mainly reflects, water contents of Ca, Mg ions, and expressed by its equivalent from calcium carbonate according to the following equation (Todd, 1980):

$$TH=2.497Ca+ 4.114Mg$$

Where TH, Ca and Mg express by ppm

The TH values of water samples calculated as shown in Appendix A and B. The Table below shows Total Hardness in different sources of water in Khalifan watershed.

Table 3.10 Water hardness in different sources

Source of water	Total Hardness TH (ppm)		
	Maximum value	Minimum value	Average value
Surface water	208	158	187.14
Deep well	220	210	213.33
Springs	218	170	185.77

The high values of TH in Khalifan watershed is mainly due to water contact with the calcareous top soil and the limestone formation below it. Mixing of wastewater and septic tank wastewater with the main surface waters is another reason. Hammer (1986) described hardness to be most common in water in area shaving extensive geological formations of limestone.

According to Todd (1980), the hardness in water derived from the solution of carbon dioxide released by bacterial action in the soil, in percolating waters. Low pH conditions develop and lead to the solution of insoluble carbonate salts in the soil and the limestone formation (in the Khalifan watershed, the pebbles are mainly of limestone types) to convert them in to soluble bicarbonates. Impurities in limestone, such as sulfates, chlorides, and silicates, became exposing other solvent action of water as the carbonates dissolved so that they also pass in to solution. The classifications of water type according to (TH) value are shown below (Sawer and McCarty, 1967; Todd, 1980).

Table 3.11 The standard of water total hardness

Hardness water class	Mg/l(ppm) as CaCO3
Soft	0-75
Moderately hard	75-150
Hard	150-300
Very hard	300 up

Waters of high (TH) values are not desirable, because the presence of divalent metallic captions, of which calcium and magnesium are the most abundant in water, react with soup to form precipitates, and with content, anions present in the water to create scale.

Therefore, because of their adverse action with soup, hard waters are unsatisfactory for household cleansing purposes; hence, water-softening processes for removal of hardness needed, for water samples of Khalifan watershed, all examples show that it is hard according to its TH values.

4-pH value

It is a way of expressing the hydrogen ion concentration, or more precisely the hydrogen ion concentration, its concluded from the above results that these waters are desirable as drinking water for livestock because the water pH does not exceed 9.5 (Reginato et al., 1973).

The pH value of water has an important influence on living organisms and any use of water, as well as it has as significant impact on biochemical processes occurring in surface water. According to WHO 1996 water quality standards for drinking water, the permissible pH values ranges 7.45-8.1. The maximum and minimum pH values for the water shown in Table 3.12.

Table3.12 Value of pH in different sources of water

Source of water	pH value		
	Maximum value	Minimum value	Average value
Surface water	8.1	7.66	7.88
Deep well	7.81	7.61	7.71
Springs	8.01	7.45	7.75

In the case study of KRB regarding pH for water type at sources and comparing the present results with the WHO, all water samples are potable.

C- Microbiological tests

1-Total bacterial count (TBC)

The following procedure followed to determine the total bacterial count: one ml of the water sample poured into a Petri dish (duplicate) then add the glucose extract agar as well as incubation at35C/48hrs. This count gives an idea about the quality of drinking water. Whenever the count of the total bacterial is high, there would be the possibility of water pollution. Also, the high numbers of the total bacterial count indicate the presence of a considerable amount of organic matter, which allows the growth of the high number of bacteria. Most of the standards for drinking water states that the total bacterial countshouldnotexceed50/ml of water samples (Davies and Smith, 2001).

Since the total number of bacteria in the river water exceeds these standards, they considered suitable for drinking and should be a treat before it used for drinking. The TBC ranged between 0-16 in water samples for Khalifan watershed.

2-Coliform bacterial count (CBC)

The bacterial coliform count found by pouring one ml of the water sample into a petri dish (duplicate) then violet red bile agar were poured and incubated at 35C foraperiodof24-48hrs. The presence of Coliform in drinking water may indicate faucal pollution and thus a potential hazard of exposure of the water consumer to other pathogenic enteric organisms. Most of the standards for drinking water state that the drinking water should not exceed 1/100 ml of water samples (Davies and Smith, 2001).

Since the CBC of all he water exceeds these standards considered unsuitable for drinking and treated before their use for drinking. The CBC ranged between (<2<16) in water samples for Khalifan watershed.

The result of the biological analysis showed that only the water of the river polluted according to CBC.

The second test takes on the period of 17.3.2018 to 25.3.2018. The difference between the two tests is specifying more detail about the situation of water resources in a different village and different location.

In Appendix C, the study picks seventeen tests, not only from water resources as an upstream but also from sewerage, a canal that uses for agriculture and basin for animals. Most tests from this Table took it from a different location as an upstream and downstream of the sources such as Alana, Khalifan, Berwkan, to get more information about what happening within passing water through the village.

a) As seen in the appendixes C, turbidity only for the animal basin in the baweyan village and sewerage is more than one, pH is in range of 6.5-8.5 according to WHO guideline for in all area. Electricity conductivity in some area is more than 0.75 such as both spring sources in Berwkan, sewerage of the village, and basin for the animal.

b) To find electric conductivity EC salinity and total dissolved solids used in the calculation. Electrical conductivity indicates water purity; less EC gives purer to the water. For example, filtered water is an insulator, but salt water EC is high. Electric conductivity affects by many factors some naturally like rain, geology and evaporation and some as a human impact like road salt, agriculture runoff. EC for fresh water is between 0.5-3 us, but tap water is in the range of 50 to 800us also for the fresh stream is 100 to 2000us.

According to the ranges above, spring sources in Berwkan is not clean water. Also in animal basin water and other sewerage, the electric conductivity is more than 800us means water is not purer.

- Another test is about total dissolved solids are less than 1000ppm means are fresh water.
- Hardness in the second test became more which are greater than 300ppm.
- Other cation and anion such as calcium and magnesium in some sources like both springs in between and sewerage are high.

CHAPTER 4
WATER ANDPOLLUTION INKHALIFAN RIVER BASIN

4.1 Introduction

Environmental pollution became a critical issue over the last few decades. Nowadays, drinking water, air and food are become threatened by global pollution. The pollution reaches such a degree that becomes critical to public health in which harmful for commercial and recreational uses and unhealthy for birds, animals and plant life.

Generally, animal and man wastes and erosion of fertilized agricultural lands and light industrialization are the main sources of water pollution in the area under study. Water is an important source to sustain life, and it became a source of illness for human due to infection. The primary effect of soil erosion as a non-point source of infection caused not by the influx of soil sediment itself into the water, but by the various other things (nitrogen fertilizers and other additives), that carried along with it. Soil sediment in water causes considerable damages on its own. It increases the turbidity, discoloring water, making it less attractable for fishing and swimming. It clogs canals and waterways and causes treatment of water more expensive (Reddy et al., 2012).

The disposal of human and animal wastes is the sources of pollution. Growing urban and increasing wastewater also became a serious problem. The common repository is usually close to the watercourse, but the rivers have limited ability to holder waste materials without creating irritation.

Usually, the stream would cleanse itself in ten miles of flow, but as population density grows the capacity of rivers and streams to assimilate the wastes cleanse the water exceeded resulting in accumulation of residues in a deteriorating environment. Production of a great variety of wastes from established industries also constitutes another source of environmental pollution.

Past few indicate shows, many chemicals material have been producing for agricultural purposes, used for weed control and, some for pest control. Remains materials are often carrier to waterways during heavy rainfall and irrigation and have effects upon environmental pollution.

The major consideration of environmental water protection is to produce adequate supplies that are hygienically safe. The goal is to create pure waters that are free of colors, turbidity, taste, odor and damaging metal and provides water, which has low hardness ions total solids, non-corrosive, and non-scaling form. In addition, the farmers desire waters that do not create salinity, toxicity and permeability problems. In water resource evaluation, the quality of water is of nearly equal importance to quantity. Natural waters usually are not pure due to containing at least small amounts of dissolved gases and solids. In addition, for municipal, industrial and domestic water supplies or any usage the characteristics should determine such as chemical, physical, and bacterial (Pirastuet al., 2013).

This study is initiating, and the objectives are:

1. Make a spatial identification of the potential and actual point and non-point sources of water pollution
2. Prepare a layout for sampling the area under study and taking water samples from many pre-selected locations
3. Assess the source of contamination, their effects, and the level of the problem.
4. Suggest some solutions to manage water pollution problem in the basin under study.
5. Compute the total water demand
6. Make a comparison between the water offer and demand calculate water balance to show whether there is a surplus of water or there is the problem of water shortage
7. Describing and assessing water management in the watershed

Propose some solutions or projects to modify water use efficiency or to reduce the hazard of water pollution in the area under study.

4.2 Khalifan water resources

The present water supply in Khalifan town is basing on three wells and two springs. In the far south of the city, there are three wells close together, which are referring to in this report as “old wells”. Also, three wells recently drilled by Food and Agriculture Organization FAO, located in the south of the town. The water is pumping from these wells to a reservoir that is situating about 800 m north. The old wells provide water to a relatively new water reservoir that lies a short distance north. The seventh well is located almost in the center directly adjacent to a reservoir (MOA and WR, 2016).

The springs Kani Rash and Kani Ble lie in the southeast with a distance of approximately 7 kilometers, respectively 10.8 kilometers from the town. Water flows by gravity to the corresponding reservoirs. The spring Kani Rash delivers water to a reservoir in the center of the city. Water from the spring Kani Ble fills a tank in the east approximately 900 m away from the town center. Also,kaniplnga, kanibnawsha, kanibaran located in malakan is using for different use as shown in Figure 4.1

Figure 4.1 Kaniplnga spring upstream of Alana village

Table 4.1 illustrates village populations, number of families and the sources of water surface water from the river, subsurface water from springs and groundwater from deep wells in KRB

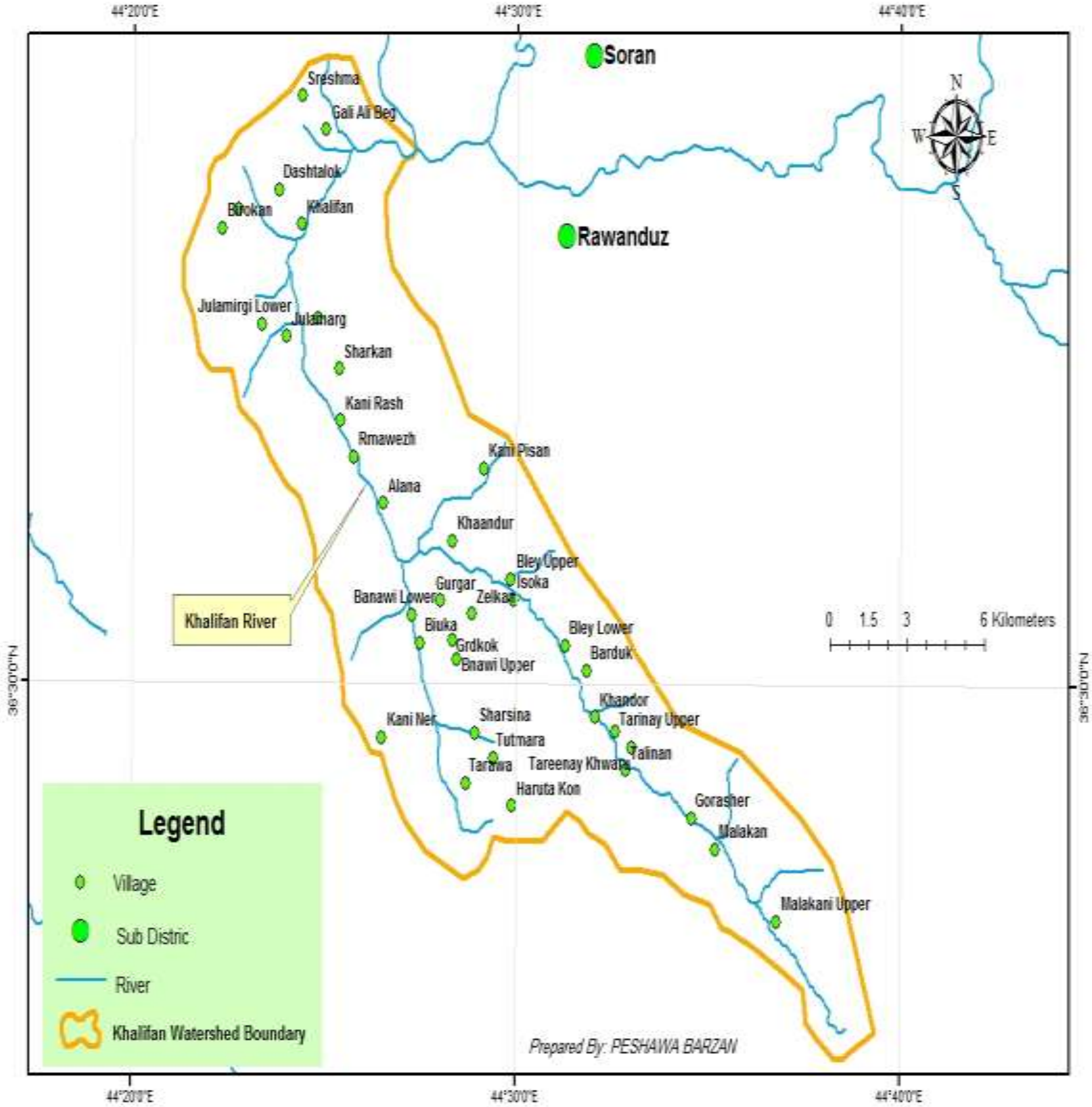


Figure 4.2 Water resources from malakan to Gali Ali Beg

The current supply of potable water in the basin depends on deep wells drilled individually in three separate areas as well as on the springs. The drinking water system is necessarily a combination of deep well water and springs. The capacity of some springs are small in amount, and it will be dry especially during the summer, so villages cannot be supplied with water regularly from small springs but through large springs located within the KRB and also through the Bekhal spring, which established outside of KRB. Due to drawdown groundwater levels, low yields from wells and springs, and the extraction of sufficient quantities is a severe problem. As a result, the supply of potable water is sporadic in all villages, so the leading network of Khalifan and

Srshemah as linked to Bekhal spring. In some drought periods, water is supply through water tanks, especially in the dry summer months. In addition, insufficient storage capacity in all villages and distribution networks is old and rundown. True losses reported to be 25%, but these Figures as summed to be within 50% (MOM and T, 2016).

Table 4.1 Villages population and existing water resources (MOA and WR, 2016)

Villages population and water resources year 2016			
No.	**Villages**	**Population**	**Water resources**
1	Alana	1301	River, deep well
2	Bardok	64	Spring
3	Blai upper	68	Spring
4	Blai lower	1288	Spring, water project
5	Bnawi	1262	Deep well, water project
6	Gorasher	116	Spring
7	Harwtakawn	90	Spring
8	Jolamerg	1431	Spring
9	Kandor	541	River
10	Malakan	1038	Spring, river
11	Malakanisaru	164	Spring
12	Rmawezh	1043	Deep well
13	Sharsina	869	Deep well
14	Isoka	129	Spring
15	Sharkan	515	Spring
16	Tarawa	90	Spring
17	Tarinanikhawarw	386	Spring
18	Tarinanisaru	902	Spring
19	Tutmara	386	River, deep well
20	Kani rash	109	Spring
21	Kani pisan	40	Spring
22	Beku	52	Spring
23	Zelakan	167	Spring
24	Grdok	321	Spring
25	Gurger	140	Spring
26	Kandor	128	Spring
27	Kanineri	32	Spring
28	Khalifan	15714	Spring,deepwell, reservoir
29	Berokan	144	Spring
30	Kulak	40	Spring
Total		**28.572**	**28572**

An accurate mapping of the town areas supplied by the sources and the reservoirs is not identifiable as the operation and maintenance system has serious shortcomings. Presently the town of Khalifan has 15714 inhabitants in 2016which are supplied with this amount of water, resulting in a per- capita production of 600 l/d including system losses. The per capita "consumption" will be considerably lower as the operation and maintenance personnel between 60 to 80 % estimate the percentage of losses. The amount of water extracted from the existing sources will be sufficient to cover the water demand in 2032. The Table below shows most villages around Khalifan water basin with water uses (MOP, 216)

There are eighteen irrigation projects in Khalifan river basin; the irrigation projects include an intake structure, concrete canal, earth canal lateral gates, underpass overpass and culverts, Table 4.2 shows irrigation projects, irrigated area and the water flow rate in each project

Table 4.2 Irrigation canal, irrigated area and flow rate source (MOA and WR, 2016)

No.	**Canal length (m)**	**Irrigated area(ha)**	**Canal flow rate (l/s)**	**No.**	**Canal length (m)**	**Irrigated area (ha)**	**Canal flow rate (l/s)**
1	3692	28.584	98.15	10	1616	6.900	30.05
2	3537	34.117	82.99	11	2950	72.622	130.73
3	2037	10.055	87.83	12	5051	67.613	109.17
4	1077	3.463	16.12	13	7174	89.476	188.08
5	1280	5.455	13.67	14	5243	10.842	170.06
6	1077	6.368	19.29	15	2216	31.262	75.7
7	1899	17.391	35.63	16	4123	52.096	130.46
8	1063	8.857	16.81	17	845	6.046	20.84
9	1563	8.187	20.92	18	2596	26.486	56.08
Total from project number 1 up to project number 18						**49482**	130258

Table 4.3 indicates of water sources river flow, surface water springs; ground water used by villagers for a different purpose Domestic, Animals, Agriculture, etc. with the average water flow rate cubic meter per second m^3/sec for each source.

The irrigation canal discharge and springs surface water flow are measuring by Directorate of irrigation staff, as well as the river flow are measuring by Alana concrete weir. (DOI Erbil, 2016)

Table 4.3 Flow rates of rivers, springs, canals and well (MOA and WR, 2016)

No	Some resources of water	Flow rate m^3/s	Uses	No	Some resources of water	Flow rate m^3/s	Uses
1	Mainspring of Malakan	0.277	Domestic and agriculture	11	Jolamerg deep well	0.007	Domestic
2	Mainspring of Ble Khuaru	0.649	Domestic and agriculture	12	Shersena deep well	0.005	Domestic
3	Sarukani spring	0.042	Domestic	13	Downstream of Kawreetung	0.0899	Domestic and agriculture
4	Binawila spring	0.054	Domestic and agriculture	14	Downstream of Zar Gally	1.357	Domestic and agriculture
5	Sartka spring	0.002	Domestic	15	Tarawa spring	0.0005	Domestic
6	Harwata spring	0.020	Domestic	16	Tutmara spring	0.0008	Domestic
7	Sharsena spring	0.001	Domestic	17	Girdkok spring	0.100	Domestic
8	Kani rash spring	0.020	Domestic	18	Baran spring	0.006	Domestic
9	Sharkan spring	0.050	Domestic	19	Bnawsha spring	0.005	Domestic
10	Jolamerg spring	0.005	Domestic	20	Plinga spring	0.277	Domestic and agriculture

As shown in the Table 4.4 maximum flow for the KR is 5.66 m^3/sec, in the February 2013 regarding 15 years, historical data from 2002 to 2015 and minimum was in September 2008, river measurement type manually by the current meter at the station after Gali Ali Bag waterfall, at the outlet of the basin to the Rwandwz River. The Rwandwz River joins with the Ble River in Bekhme village to become the Greater Zab

River. This river passes through mountain regions in the upper part of the river inside Iraq, crosses the Bekhme narrow and then flows to the Tigris.

Table4.4 Average monthly flow rate (MOA and WR, 2016)

	Average flow rate for KRB m^3/sec.											
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
2002	3.18	2.96	3.09	4.95	2.98	1.28	0.93	0.84	1.21	1.32	1.52	1.93
2003	3.36	3.19	3.33	5.15	3.19	1.04	0.83	0.79	1.11	1.27	1.70	2.72
2004	2.85	3.09	3.25	3.42	3.48	1.86	1.35	0.86	0.79	1.25	1.55	1.90
2005	3.04	3.75	3.28	2.67	2.53	1.76	1.46	1.31	0.82	1.13	1.25	1.30
2006	2.36	5.43	3.55	3.46	3.02	2.08	1.42	1.12	0.88	1.19	2.23	2.53
2007	3.19	4.32	2.38	3.93	3.31	1.91	1.29	0.88	0.69	0.64	0.60	1.19
2008	1.09	1.48	1.80	1.72	1.47	0.98	0.95	0.67	**0.44**	0.45	0.54	0.64
2009	1.18	1.34	2.08	2.87	2.26	1.41	1.07	0.79	0.53	0.49	0.81	1.13
2010	1.77	2.39	2.90	3.12	3.28	1.95	1.31	0.85	0.65	0.52	0.49	0.55
2011	0.99	1.90	2.56	4.38	4.06	2.28	1.37	0.99	0.71	0.63	0.78	0.75
2012	3.12	4.03	3.67	3.06	2.99	2.21	1.85	1.70	1.24	1.55	1.69	1.82
2013	2.57	**5.66**	4.42	3.85	3.51	2.47	1.82	1.43	1.30	1.69	2.73	2.99
2014	3.47	4.62	3.12	4.42	3.71	2.34	1.69	1.30	1.11	1.17	1.17	1.56
2015	1.43	1.74	2.34	2.21	1.95	1.43	1.43	1.11	0.85	0.91	1.05	1.17

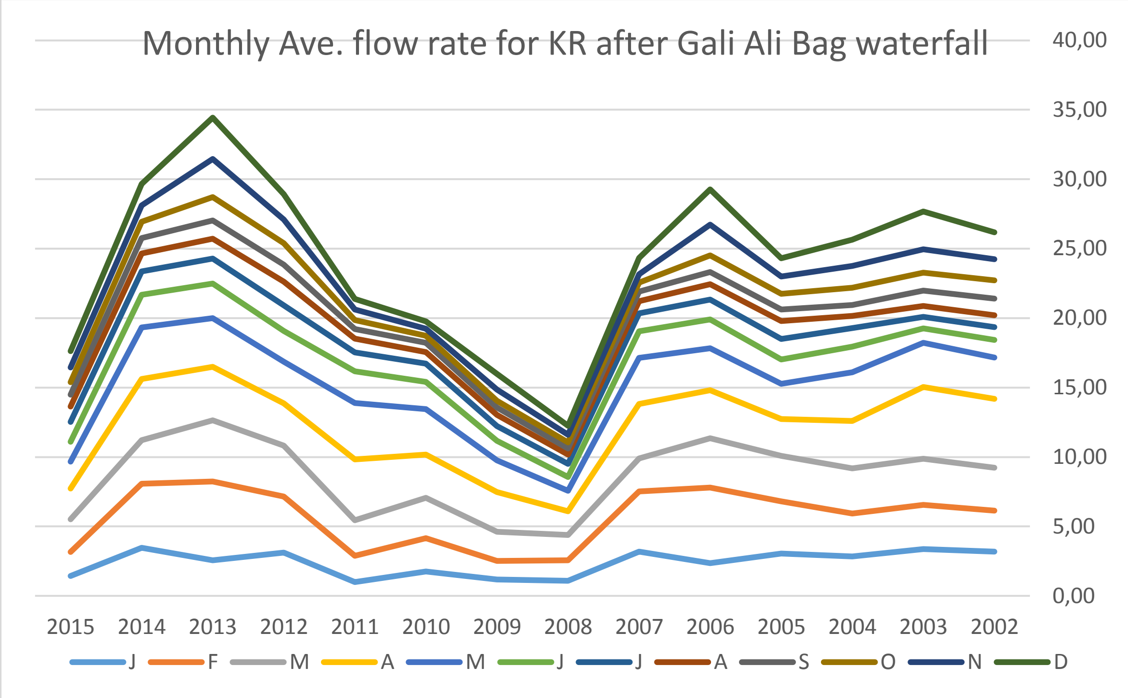


Figure 4.3 Average flow rates per month for Khalifan river basin

Bekhal spring is the biggest spring in the area located outside of Khalifan river basin, part of water supply shortage covered by extending two pipelines for supply water from this spring to Khalifan district and Sreashma big village, Table 4.5 illustrates historical data for 15 years from 2001 up to 2015 Bekhal spring monthly flow rate m^3/ sec. The maximum flow rate as shown was 12.94 m^3/Sec in February 2002.

Table 4.5 Monthly flow rate for Bekhal spring (MOA and WR, 2016)

Spring name: Bekhal **District: Rwandwz**
Method: Current meter

	Average flow rate (m^3/sec.)											
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
2001	2.55	2.84	5.25	9.83	10.45	4.99	3.85	2.67	1.12	0.06	0.99	3.50
2002	7.27	**12.94**	7.37	10.45	10.10	5.07	3.34	2.84	2.23	1.80	1.61	2.27
2003	3.22	3.54	4.25	8.33	9.45	4.91	4.16	3.22	2.85	2.33	2.87	3.21
2004	5.80	6.20	7.05	7.15	6.42	5.66	4.09	3.15	2.93	2.66	2.78	2.89
2005	7.08	7.60	8.28	8.55	6.23	5.19	3.96	3.01	2.83	2.61	2.41	2.66
2006	5.55	11.04	8.76	10.37	8.15	6.03	3.31	2.84	2.47	2.99	3.31	3.72
2007	4.78	6.03	5.35	8.15	7.10	5.27	3.05	2.75	2.25	2.07	2.15	2.78
2008	2.55	5.58	4.27	5.17	5.11	3.73	2.82	2.32	2.01	1.82	2.10	2.20
2009	2.83	4.80	4.94	6.31	7.36	5.11	3.22	2.52	2.21	1.99	2.57	2.63
2010	3.25	5.16	5.21	6.52	7.63	5.52	3.65	2.64	2.32	2.20	2.00	2.12
2011	2.46	4.52	4.84	7.09	7.47	5.68	3.82	2.86	2.55	2.35	2.44	2.35
2012	7.12	7.68	8.33	8.75	6.33	5.22	4.1	2.9	2.85	2.55	2.51	2.69
2013	5.5	10.9	8.56	10.12	8.05	6	3.22	2.64	2.44	2.87	3.21	3.62
2014	4.98	6.53	5.75	8.45	7.33	5.67	3.35	2.95	2.85	2.47	2.35	2.98
2015	2.59	5.59	4.31	5.22	5.21	3.84	2.91	2.44	2.11	1.92	2.33	2.25

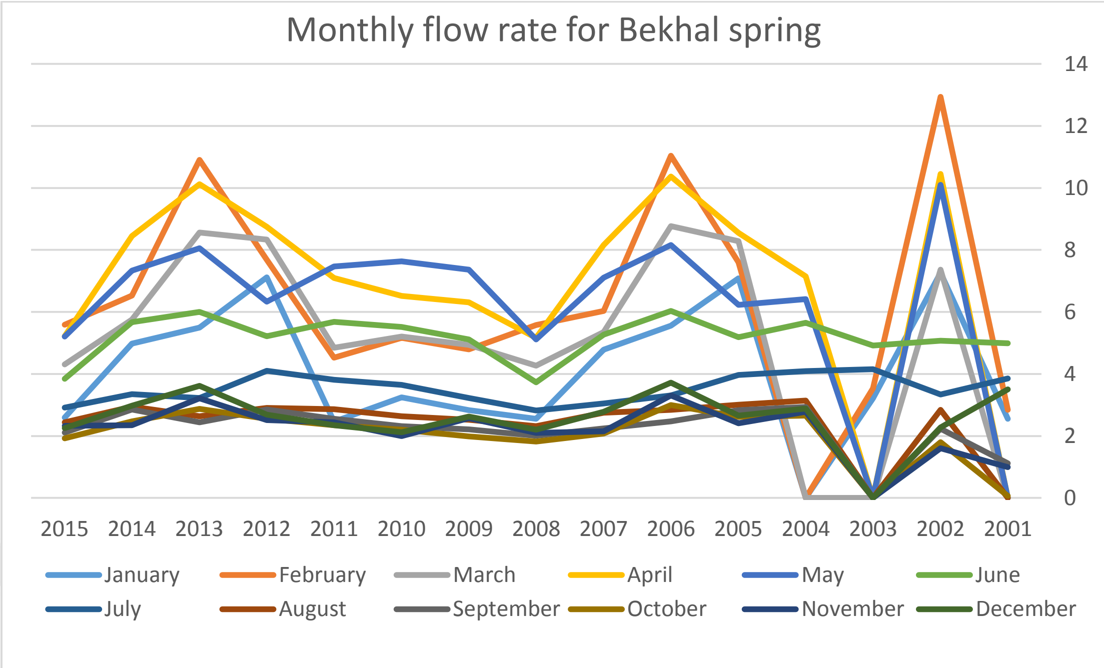


Figure 4.4 Bekhal spring average flow rate per month

4.3 Water quality

Depends on whether the water of the appropriate quality for a particular purpose based on acceptable quality standards or criteria for that use. Drinking water quality limits due to its full development for this purpose (Todd, 1980). The water in Khalifan River used for different purposes, so it is necessary to verify its suitability for different purposes.

4.3.1 Domestic water use

Drinking water defined as non-contaminating water that does not cause any problems or health problems when used prematurely .The appropriateness of water as a drinking water depends on several factors, such as basic and inorganic chemicals, biological characters and personalities of radioactivity. There are many standards like drinking water such as WHO (1996) standards. Water quality defined and standardized through indications of restricted concentrations of relevant components and other water characteristics about their health effects. Their values derived from the nature and intensity of the impact of the components related to the human being (Jermar, 1983).

4.3.2 Animal water use

Foster and Lawrence (1995), give the following upper limits of TDS concentration for livestock water. All water in the study area has sufficiently low TDS concentration for livestock uses. It is worthy of mentioning that these waters considered as desired drinking waters for livestock because the water pH does not exceed 9.5 (Reginato et al., 1987)

Table4.6 Animal water and food requirement (MOA and WR, 2016)

KRB Animal water and food requirements			
Poultry	2860 mg/l	Cattle (beef)	10100 mg/l
Cattle (dairy)	7150 mg/I	Sheep (adult)	12900 mg/I

4.3.3 Irrigation water use

Its mineral composition and its effects on both plants and soil affect the suitability of water for irrigation. The successful growth of the plants depends on the quality of the water for irrigation. The hydrochemical parameter of the water limited the irrigation water suitability, with other criteria such as the soil properties, irrigated crops, local climate and management of irrigation and drainage. Water quality constraints in irrigation examined using some empirical indices; the most critical index used in the classification of water for irrigation purposes is the sodium concentration index. The high sodium content influences the soil structure and texture especially it may reduce the permeability of soils, (Todd, 1980).

4.4 Type of water pollutions

Generally, in Iraq water is a limiting source. Its effectual use is basic to the survival of the growing population. A comprehensive strategy needed to conserve and develop our water resources. For build strategy, several factors kept in mind and took into account. These include the availability of water, its quality, location, distribution and variation in its occurrence, climatic conditions, nature of the competing demands and socio-economic conditions.

The objective of this study is to increase agricultural production per unit of water volume per unit area of agricultural land, per unit time. At the same time, measures taken to protect the environment from non-fixed and point sources of pollution. The objective of this study is to increase agricultural production per unit of water volume per unit area of agricultural land, per unit time.

The main sources of water for domestic and irrigation used are large springs like the spring of Malakan, Ble Khuaru, and Binawila. Besides the springs above, there are numerous scattered springs within the area under study, but most of them have a low flow rate. Moreover, there are three deep wells for domestic uses. The map Figure 4.5 shows the location of different sources of water

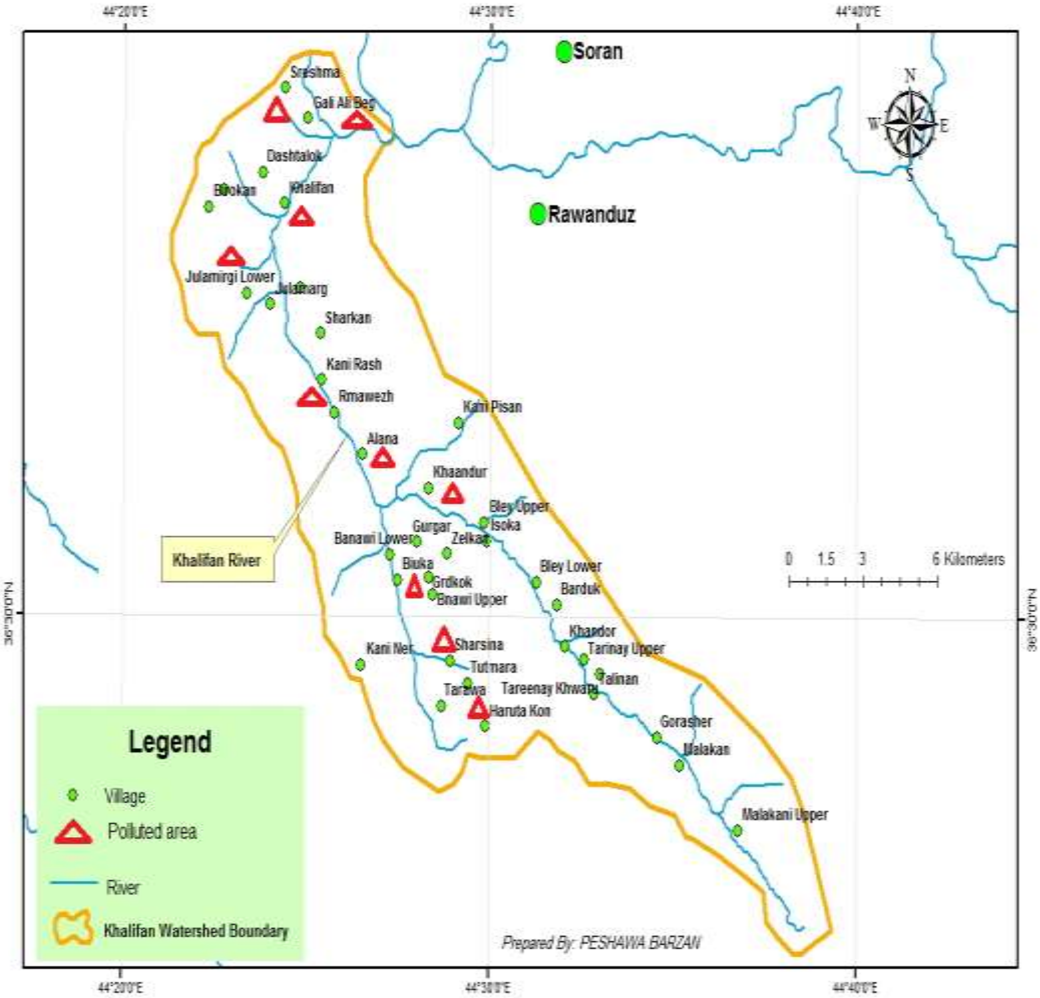


Figure 4.5 Water resources and pollution area

The Figure4.6shows general sources of pollution, which divided by point sources and non-point source. Point sources include feedlots, organic solids, nutrients, and bacteria. In addition, domestic waste, industry, municipality and organic chemical are a source of point pollution. Nonpoint pollution source including mining and logging, suspended solids, acid mine, drainage, waste oil, flow rate, runoff, urban storm, residential dust, silt from erosion, fertilizer and another microorganism.

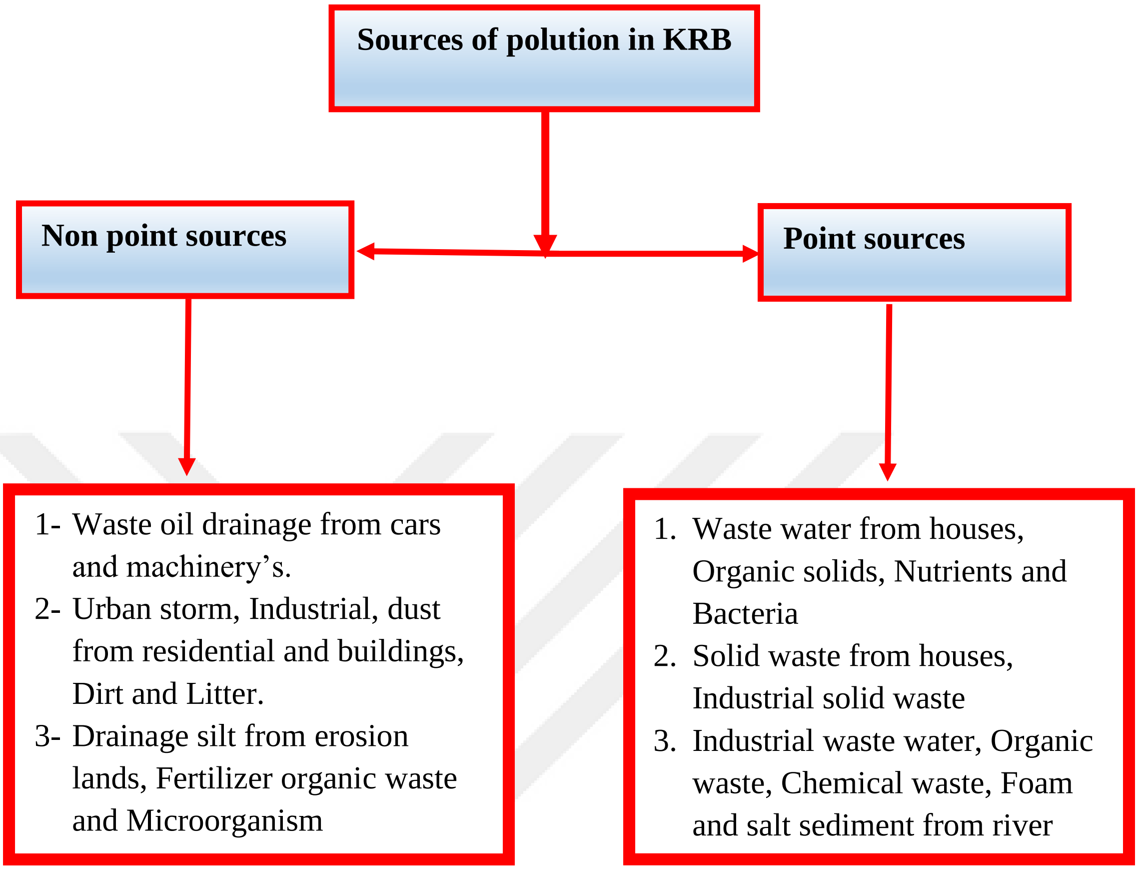


Figure 4.6 Main sources of pollution

4.4.1 Waste pollution from agriculture

Agriculture is one of the causes of pollution. Organic nutrients mostly come from rich plants, municipal wastewater treatment plants, and industry. It helps to cultivate natural groups of aquatic bacteria. The mineral degradation of organic matter will result in reduced dissolved oxygen, with obvious effects on other organisms that require oxygen. Two inorganic plant nutrients such as nitrogen and phosphorus from the main concern; this is mainly from came from wastewater reservoirs, basins, highly fertilized crops, and wastewater treatment plants, and this causes the growth of extreme vegetation that prevents waterways from sailing. The fall of the plants in autumn causes a decrease in dissolved oxygen, which may lead to the suffocation of fish and other organisms. Fortunately, the use of fertilizers per unit of land and the total amount used is very low in Erbil province and a less serious problem as a source of pollution (Wang et al., 2010).

Water sources in the region flow mainly from the region, but some start in other neighboring countries through rivers and streams and some from village wastewater. How water mostly contaminated in this area is through leakage from wastewater and rain networks when the air polluted. Urban traffic is high, but the density of cars is still relatively low and may not be a major source of air pollution. The number of vehicles is increasing rapidly and in the absence of good traffic and environmental policy may become a health and safety problem. In general, water considers being clean in Erbil governorate for agricultural purposes (MOA and WR, 2016).

Crops affected by contaminated water used for irrigation. Water contaminated with irrigation has many negative external effects. May reduce harvest or make crops polluted and impractical for human consumption. Besides, the seeds may not use again for cultivation because the soil will contaminate and will continue to have effects for several years to come. In August 1990, Iraq was forced to leave Kuwait and in mid-

February 1991, the Iraqi government set fire to its oil wells. Smoke covered the southern Kurdistan region. The effect of the rain, which contaminated with carbon, is on grain crops, but this is a special case and does not happen very much. Fortunately, the use of fertilizers per unit of land and the total amount used is very low in Kurdistan and a less serious problem as a source of pollution (Amahmid et al., 1999).

Water may hold pathogenic bacteria, viruses, primates, and parasites. Unprocessed or inadequately treated wastewater, animal waste, waste food after processing such as meat filling, and wild species refer to the major sources of infectious agents. Water-borne infective viruses are a particulardifficulty in developing countries with poorly developed sanitation and sanitation systems. Thus, inadequate sanitation and treatment plants pose a significant health hazard in the Erbil government.

There are no chemical plants in the Erbil region that cause pollute, and water sources in the area flow mainly outside the zone, but few of them originate in other neighboring countries through rivers and rivers. The way in which water mostly contaminated in this area is through leakage from wastewater and rain networks when the air polluted. Urban traffic is high, but the density of vehicles is still relatively low and may not be a major source of air pollution, although the number of vehicles is growing rapidly and in the absence of good traffic and environmental policy may become a problem for health and safety.

4.4.2 Domestic wastewater and solid waste

As an effect of the daily production and consumption actions of the population of various elements, large quantities of landfills left behind. Many organizations, households, parks, business zones, and marketplaces produce waste materials on a daily basis. There are municipal services concerned with the cleaning and treatment of waste. In the lake of suitable sanitation, the household waste materials pollute the area of housing environment. This pollution is gradually flowing into the air and ground. Thus, groundwater affected. Also, the existing of shallow wells close to the wastewater, lead to severe pollution. This waste and water management practice is certainly having significant negative effects on people's health and may cause epidemic diseases such as malaria, cholera and many other negative health effects. Limited prevalence of cholera observed in a few cases (Todd, 1980; Fetter, 1994).

Usually, within water resources, there is an issue of gender and is a vital part of water management especially a woman. A woman has an impact on water as providing, managing and protection. Therefore, a woman can name as providers, collector, and users of water in the family, in agriculture, and the living environment has a great knowledge of water. Their responsibilities can cover quality, reliability, limitations and storage methods. These vital key factors should be better replicate in an institutional arrangement for development, policies, programs and water resources management (Gasperi et al., 2008).

Many villages have limited water sources stored in open spaces, which used for different usages, these water storages used for both household consumption and animal managing. By using and sharing, the same sources human and the animal will convey many diseases between and among the two groups’ users. Usually, water needs to transported to home for consumption, cleaning, and washing water need for feeding animals, cleaning animal places and milk processing and other outputs.

Water access and it using differ from people who live in the urban area and rural area. In Iraq, water accessing to the places is limited to a few hours per day. That is because of limitation of water supply, insufficient infrastructure, inefficient use of water resources and limitation of electricity cause reduce water supply to the household (Eriksson et al.,2002).

There are many way cause pollution the water sources. The picture below shows a big basin with non-covering, for collecting water in Bawyan one of the villages located in the catchment area. This water comes from the well then to the basin then by pipe to the houses. Pipe made of plastic as seen in Figure 4.7 and Figure 4.8.

Figure 4.7 Household concrete water basins, Bawyan village

Figure 4.8 Plastic connection pipes from network to village houses

There's a strongrelationship between the villages and river flow in KRB especially for irrigation, weir structure constructed on the river for arise water and diverted to irrigation canals, for example, Alana irrigation project built in 1970 and maintained in

2000 by Food and Agriculture Organization FAO, Figure 4.9 shows Alana weir structure.

In some villages like Rmawezh, water comes from Alana River which made the weir structure in the river. As the Figure show after the water overflow the weir with water many debris and rubbish collecting in the structure, it did not clean continuously the water polluted. Rubbish and pollution will collect cross the canal as well as Figure 4.10 shows convey rubbish in the water canal.

Figure 4.9 Alana irrigation project, weir structure

Figure 4.10 Rubbish convey to the irrigation canal and to the houses water use

Figure below 4.11 indicates pumping water in the water canal to houses by a plastic pipe, which shows high pollution. Due to bad service, people convey water from the polluted canal to houses which using for daily life.

Figure 4.11 Pumping water and supply from the water canal to the houses use

The other reason people convey water to the tank by open basin, as seen in Figure 4.12. People in the village they face a different kind of problem some from shortage some from service and accessing water for using at home.

Figure 4.12 Concrete water basins for domestic water use

Increasing water storage reduces part of the problem but causes the decline of the quality of water stored in the house. Monitoring all steps of water storage and separating the storage of potable and non-potable water takes a large part of women's time. The shortage of valuing and promoting mechanisms has led to the waste and inefficiency of water resources and the incapability of municipalities to advance in the required organization.

Many families are heating drinking water to avoid the risk of various diseases. The heating process, moreover to the advantage of killing different bacteria, has some defects also. Which include: the fact is to heat water need to gas and electricity. These are rare energy sources, and the cost is a limiting factor of the healed amount. In addition, some viruses undisposed of by heating water and heating harm the quality of water content (Wright et al., 2004).

The water for human use is often proportional to the amount of drinking, cooking, washing and cleaning with the size of families. The rapid increase in the population will increase the demand for water supplied from existing and new water sources. Household wastewater contains important chemical elements in the form of shampoo residues, various cosmetics and hair colors. Thus, the gender aspect of household pollutants can easily create. The flow rate of chemical elements from homes and their mixtures causes severe water pollution and is a major environmental external factor. The separation between them is expensive, and failure to clean them leads to serious diseases, low production potential, and burden for families, especially for women in captivity (Swyngedouw et al., 2002).

4.4.3 Impact of animal waste

Animal waste considers as one of the sourcesof pollution that affects water quality and will influence human life. However, most people combine animal waste problems with agriculture. Previous studies have shown that animals, water birds, and other wildlife waste can cause major water pollution problems. Animal waste can hold some hazard material those effects on water quality such as nutrients, pathogens, natural toxic substances, and ammonia. When the animal settles in a lake or any waterway, it declines, uses oxygen and releases its cause's polluted load (Tamminga, 2003).

Moreover, in the summer months when the water is going to be warm, the mixture of low levels of oxygen and ammonia can easy kill fish and other organisms because nutrients cause the extreme growth of aquatic grass and algae. When the water is cloudy and smelly, or when the surface of the water is cover by thick vegetation, which causes the area, becomes unattractive or impractical for swimming, boating or hunting. In addition, pathogenic bacteria and viruses correlated with animal waste can make water unsafe for human use.

Pollution comes from a place of the animal as Figure 4.13 shows in the Sharkan village they put on the main road, which from the downriver it comes

Figure 4.13 Villages animal barn

4.5 Water requirements

Population growth and periodic drought conditions have put pressure on available water resources. Effects made to conserve water in agricultural, municipal and industrial settings. Evapotranspiration is a key factor for estimating irrigation water requirements. Rational evaluation of this factor is essential for planning, designing, operating and measuring levels in water resources projects particularly under extremely arid conditions, which prevail in many parts otherworld (Swyngedouw et al., 2002).

In Erbil province, the agricultural production was highly affected by the present drought conditions. The Food and Agricultural Organization of the United Nations realized these facts and made many attempts to overcome this problem through the execution of many irrigation projects. Among these activities were drilling wells, lining irrigation canals, constructing dams and rehabilitation of watersheds, water resource and irrigation sub-sector FAO northern office -Iraq prepared a plan to construct several lined irrigation canals in Khalifan watersheds to distribute irrigation water efficiently and to organize irrigation scheduling, they also made many other plans to rehabilitate other watersheds in the region. Among these efforts is the study of water management in Khalifan watershed. One of the preliminary requirements of this project is the study of the water demands of crops see Table4.7 and for Population and livestock see Table4.8. Crop water demand estimated from reference crop evapotranspiration and crop coefficient values. In addition, for this reason, the study needs to identify the actual and potential water uses in the basin. Quantify, every month the water demand for all water use and Infrastructures used with the technical specification.

According to the FAO report, most of the villages in the upper part of the basin face the problem of drought. That is true for the lower Talina, Ble Zhoru, Ble Khuaru, Bardok, and Bandor. The water of Malakan spring fails to reach the above villages. Therefore, most of the existing canals in these villages are empty. At Ble Khuaru there is plenty of water, but nearly all the agricultural lands have a high level, and there are no pumping systems to lift water to these high lands.

On the contrary, there is plenty of water for irrigation at most of the villages of Alana basin. Accordingly, the lands intensively cultivated. Some communities also face the problem of water shortage in this valley, such as the upper part of Binawy and the lower Jolamerg.

To restore water availability, many families dig wells in the area. Water disposal from the well requires technical solutions and investments that may be outside the family budget. Lack of electricity or lack of power leads to the use of manual solutions those need human resources. Consequently, these restrictions have implications for the additional hardship of women. Their involvement in agriculture with less education and technical tools makes women spend more time and face greater difficulties in plantation and plant management (MOA and WR, 2016).

The dominant crops are:

1. Walnut products as a fruit tree in the Malakan village.

2. Cherry, pomegranate and grapevine as fruit crops have a priority in the Khalifan basin mainly.
3. Wheat and chickpea as the dominant field winter crops grown in the area under study.
4. Onion is the dominant early summer vegetable crop.
5. Tomato, Tobacco, and sunflower are late summer crops.
6. Poplar is the dominant riverbank forest tree.

The main source of water for different uses is:

a) The mainspring of Malakan
b) The mainspring of Ble Khuaru
c) The springs of Binawila and Sarno Kani
d) Numerous scattered springs of low flow rate, those distributed along both sides of the main river.
e) Three deep wells with a total flow rate of 19.3 l/ s.
f) There are some springs with a low flow rate in villages far from the main course, such as the spring of Sartka, Harwata, Tarawa etc.

The total flow rate of the above springs estimated to be about 1.38 m^3/ sec at mid. of June. That without measuring of low flow rate springs, which flows directly into the main river. The overall maximum duty of the eighteen existing canals is about 0.113Mm^3/day (1302.58) l/s during the hottest months of the summer season, but the maximum water demand for non-agricultural uses amounts to 690 m^3/day (7.99 l/s). It is out of comprising the domestic water requirement of Khalifan town because the main source of water for such use is drilling wells and a buried spring. Water lifting to uplands by pumping is very limited. Installation stations are required at Ble Khuaru and the lower Jolamerg to feed the highlands. Generally, the irrigation efficiency in the area under study is low due:

- ✓ The high rate of deep percolation because most of the soils especially those adjacent to the main river are medium to coarse textured and with a high permeability value.
- ✓ Most of the irrigated lands have gentle to moderate slope. Accordingly,a high rate of water loss due to runoff expected.

- ✓ There are many obstacles against water flow in the main river such as plant debris, direct planting of poplar at the lowest and, the banks of the main stream. Thus, high seepage rate expected.
- ✓ There is considerable water loss due to seepage from the existing earth canals, so the lining of these canals is required. That is to save water for an additional area of 75 hectares.

Installation of gage stations at the intake of Malakan spring, upstream of Zelakan and downstream of Alana and Khalifan is required to collect information on the amount of water, which enters and leaves the area under study continuously during the year.

Since most of the existing lands have a considerable slope, conservation practices such as fanning on contouring, terracing and gully plugging are required. Around each village, there are considerable areas of arable and fertile lands without cultivation. These lands require reclamation such as land leveling and rock picking. The water demand for all uses other than agriculture use ranges from 7.99 l/sec.(MOA and WR, 2016).

Water demand increased when the rice included as a summer crop, and uplands irrigated by pumping and some rocky and sloppy lands a reclaimed.

Table 4.7 Monthly crop water requirements (MOA and WR, 2016)

Crop type	**Crop name**	**Cropping period**	**Month (mm)**												**Total**
			J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	
Winter field crop	**Wheat**	1/11-1/6	8.83	18.73	45.54	64.88	79.50						24.57	9.52	251.57
	Barley	1/11-15/5	8.05	17.59	43.55	59.98	30.55						24.57	9.35	193.64
	Chickpea	20/3-1/7			8.01	45.9	185.24	196.22	22.31						457.68
Sumer field	**Other legume**	1/11-15/5	9.99	18.9	45.53	51.4	30.4						25.51	12.14	193.87
	Sunflower spring	¼-10/8				31.21	141.75	232.62	227.48	31.22					665.63
	Sunflower summer	25/6-1/11						12.81	106.91	257.1	199.77	78.37			654.96
Crops	**Rice**	1/4-15/10				52.4	161.08	232.63	295.72	315.08	191.1	98.85			1346.86
	maize	1/5-20/7					74.09	212.4	156.15						442.64
Summer vegetable	**Tobacco**	1/7-15/9							134.21	274.75	61.73				470.69
	Potato	15/4-15/9				12.24	78.92	206.34	261.58	264.66	56.98				880.72
	Tomato	10/5-15/10					39.27	105.19	245.68	302.47	185.89	31.89			910.39
	Tomato	1/7-1/11							100.09	249.54	208.48	90.22			648.33
Late summer	**Dry onion**	25-3/23/7			4.22	35.5	153.02	212.4	135.02						540.16
	Cucumber	1/5-20/8					57.99	137.56	204.73	115.62					515.9
Permanent	**Vegetables**	1-12	6.31	11.18	27.73	45.9	120.81	157.79	181.98	196.61	130.3	76.88	32.47	11.15	999.11
Fruit crop	**Deciduous**	3- 12			19.79	45.9	153.02	202.29	227.48	239.46	156.36	93.36	32.47		1170.13
Rainfall in mm/month			131	122	108	44						15	90	108	742

The agricultural sector considers as second largest regarding water uses. The sector uses water for drinking, animal husbandry, and irrigation. The area was mainly an agriculture community. The rule of Iraq in the 1970s and 1980s led to the systematic damage of rural life and accelerated the process of urbanisation. Therefore, there is change within agriculture area and demography.

The industrial sector in Iraq is small and in its early stage, but it is the third largest group that uses water in different production processes. The expansion of the industry has been one of the imports issues for Iraq whose activity enhanced by the Investment Law and various incentive policies. The main users of water resources associated with industrial processes are cement users, drinking water, construction and food processing. The construction industry may be the largest group. There is hardly any manufacturing industry in the region, domestic production of materials for construction and agriculture produced locally.

The latter category of consumers, classified as municipalities and other services such as hotels and restaurants, are major consumers of water. Water used in this category to preserve nature, for reasons of water security, recreation, and tourism as well as for the production of electricity. The first types of uses linked to public environmental investment. There are comprehensive public and private investment programs to build infrastructure, which is necessary to develop the tourism industry. Capacity exists but services not used efficiently, the reason may be lack of experience, advertising, and, ineffective regulation, excessive investment in the unknown area, security issues, and transportation costs are expensive. However, hydroelectric power production is a major water user.

Water has a direct impact on human life. Each from male and female has a different view and uses of water resources. Men most use water for irrigation in agriculture, in the industry and construction, while women often employed in households for drinking, cooking, cleaning, and washing. Quantity and quality requirements vary by gender and often complementary to one another (Nadhir et al., 2007).

Women vary according to rural and urban living situations and water use. One of the main tasks of women in rural areas is to find suitable water sources, this becomes even more important when the spring comes to an end and with the onset of the summer season, and water availability greatly reduced. Women's research intensifies water resources and takes time.Table4.8shows the number of households and animal water user.

Table 4.8 Populations, animals and water consumption (MOA and WR, 2016)

River basin	Item	No.	Average water requirement / day	Annual WR m^3
KRB	Population	28573	360 (l/capita/day)	3650200
	Cattle	1803	30 (l/animal/day)	19745.04
	Sheep and goat	45080	10 (l/animal/day)	164542
	Horses	1288	35 (l/animal/day)	16454.2
	Poultry	10948	0.5 (l/bird/day)	19980.1
Total Annual Water Requirement m^3				3870921

4.6 Water losses impact

The present supply of potable water in the region is relying on the tube wells that drilled individually for each village and signed on springs. Generally, it consists of a mix of tube wells and springs. Springs are often temporary and are dry especially during summer, and none of the villages is entirely supplies by a strong spring alone.

Due to falling ground water table and low yields of wells and springs, extracting adequate quantities represent a serious problem. As a result, the supply of potable water is intermittent in all and villages and quite a number supplied via water tankers especially in the dry summer month.

Furthermore, storage capacity is insufficient in all of the villages and the distribution networks are old and worn out. Real losses are reportedly 25 % however; it assumed that these Figures are rather in a range of 50 %, problems with water quality reported for any of the villages (MOA and WR, 2016).

The network will need expansion to cover the areas of future development. The exist pipes older than 20 years and those, which do not meet the hydraulic requirements, will replace.

It noted that the conceptual design of the regional scheme for Khalifan would cover the bulk distribution of water from the intake (three tube wells) to the individual storage reservoirs only and will not cover the distribution systems within the villages.

Visual inspection of soil condition suggests a solid layer of gravel and sand and a reasonable amount of groundwater and infiltrated river water can expect. Water extracted through the two wells and pumped into a ground tank for the storage of raw water. In case it found that the turbidity of the water is too high, the consultant has included a closed pressure sand filter for treatment in the cost estimation. From the pressure filters water will be conveyed to a second compartment in the ground tank, chlorinated and pumped to individual ground tanks and elevated tanks in each of the villages.

The distribution system divided into the Kuna Sikhur in the Southern side of the Rwandwz River supplying three villages, Kuna Sikhur, Bawrakan, and Goraz, and the Hanara in the northern side, providing the remaining seven communities. In addition, approximately 60 % of the water pumped to the Hanara side.

4.7 Water balance

4.7.1 Introduction

Water balance is a key factor to help manage integrated water and predict where and when water shortages may occur. It used in the process of irrigating agricultural areas, flow assessment and calculation of surface water quantity (e.g. through the Rain Off model), combating the risk of flooding and combating pollution of rivers. Moreover, it used in the design of the wastewater system and the heavy water drainage system, which may be horizontal (using pipes, sinks, trenches) or vertical (drainage by wells). To estimate drainage requirements, the use of hydrogeological water balance and groundwater model may be essential (Ponce and Shetty, 1995).

A general water balance equation is $P=R+E+\Delta S$

Where: P is precipitation, E is evapotranspiration, R is stream flow, Delta S is the change in storage (in soil or the bedrock/groundwater)

The above equation used for knowing the principles of maintaining the mass in a closed system, where the amount of water entering the system through sedimentation, and must transferee to any evaporation or, surface runoff above the surface of the soil. Then finally reach the channel and leave it in the form of drainage, in soil and ground pores in the form of groundwater through infiltration. This equation requires calculations within the one basin where the beginning of the basin and knowing the end of the basin as well, so this should take into consideration.

Expanded water stocks in agricultural hydrology discussed in particular for prior knowledge and planning of river basin cultivation of agricultural varieties according to these necessary information's.

The illustration can give water balance using the water balance method within the river basin, which paints the levels of precipitation and steam often on the scale of the monthly calculations. Many water balance models have been developed and worked for a variety of purposes and knowledge of the direction and stages of rainwater movement within the river basin. The monthly water balance models have studied since the 1940s (Ponce and Shetty, 1995).

The concept of integrated water management within river basins is to achieve better water balance calculations within a single river basin or watershed for calculating. The amount of water available from rain and snow, surface water (springs) and groundwater, which use for all sectors such as agriculture and domestic uses, industry and tourism. That provides a clearer understanding of all components of the water balance of a particular river basin.

4.7.2 The water balance

Watershed balance in catchment basins is a process in which rain separated into its components. For the entire system, which consists of surface water and groundwater, P precipitation separated into four components as seen in Figure 4.14

Evaporation E, Evapotranspiration ET, Surface water runoff Q, and Groundwater flow G, appearing eventually as base flow.

Such that

$$P = E + ET + Q + G \qquad \text{(Eq. 1)}$$

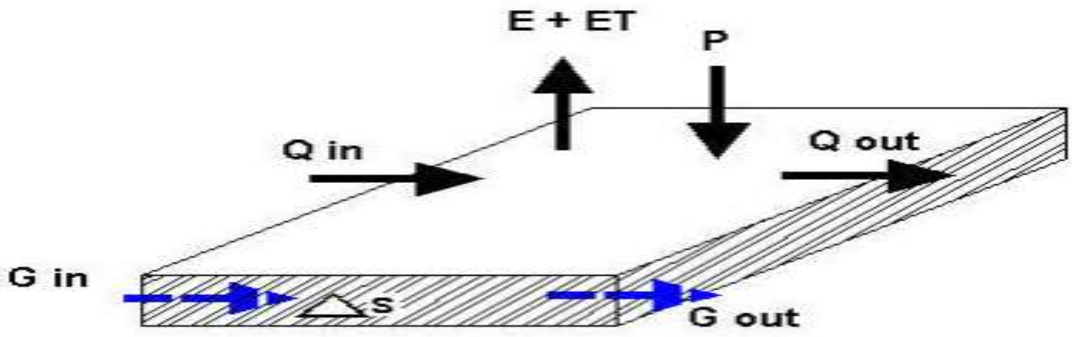


Figure 4.14 Components of precipitation water balance (Ponce and Shetty, 1995)

Deep-water filtration within the soil layers is the amount of flow and movement of groundwater that does not appear as a primary source, the flow of the G base, and completely avoids surface water. According to the most of studies and resources, the amount of water filtration within the layers of the soil and to the depth of the groundwater is usually less than 1.5% of rainfall; therefore, it neglected and not calculated on a practical basis (Ponce and Shetty, 1995).

For a water balance that excludes groundwater, precipitation separates into four components Figure4.15. For the water balance that excludes groundwater, precipitation separated into four basic components

Such that

$$P = E + T + Q + I \qquad \text{(Eq. 2)}$$

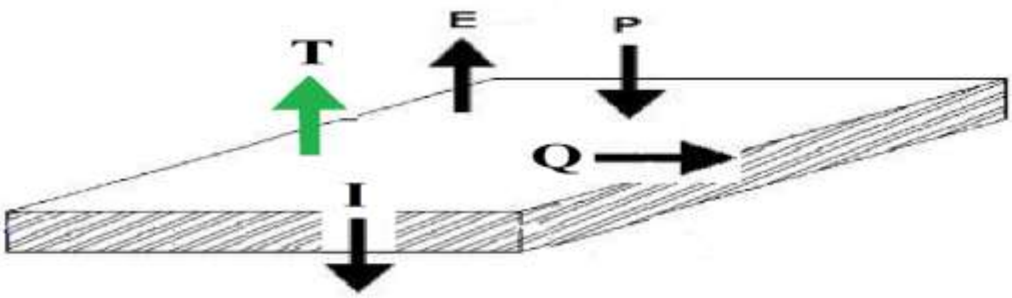


Figure 4.15 Precipitation and water balance, (Ponce and Shetty, 1995)

A source of complexity in a water balance using Eq. 2 is the unknown rate of infiltration (Ponce and Shetty, 1995).

Infiltration may take one of several paths:

1. Return as evaporation E from lakes, ponds and swamps,
2. Return as evapotranspiration T through vegetation, or
3. Reach the groundwater Table and eventually infiltrate as base flow to join the surface waters Q.

According to pre-studies, this double counting has suffered from conventional water balance models. It is very difficult to predict and calculate the portion of water that converted into E, T or Q depend on the prevailing climate, infiltration divided between [total evaporation] and evapotranspiration and the Q part that arises in the base flow. However, split, and rain-to-parts calculations are difficult in humid climates and arid climates, often infiltrating into ET; on the contrary, in wet climates, infiltration often goes into the primary flow, i.e. runoff Q(Ponce and Shetty, 1995).

The solved of the problem is equation. 2, this equation assumes that infiltration is a basin independent of E or T or Q, whereas it is not. L'vovich (1979), who proposed a linked set of water balance equations to replace Eq. 2, solved this impasse.

CHAPTER 5

METHODOLOGY

5.1 Introduction

The present study is working on a qualitative and quantitative method. Regarding the qualitative method, the study will have questioners for different level from the household, farmer, and tourist to get a solution to have better water resource management. The first section is about collecting data, and the second is using the program to run data. After collecting primary and secondary data from the field and project location, one of optimizations methods new software Geo-Information System GIS and Water Evaluation Analysis Planning WEAP software will be using to define out my objectives. Then simulate the result, rather compared with the resulting outcome from other models which will be studied and prepared by another student, the outcome result will prefer to use software methods, that may be helpful to get a quick result and with reasonable accuracy.

Water evaluation analysis planning system WEAP is a micro tool use for integrated water resources planning, easy to use and suggest a comprehensive approach to water resources management. Many countries are working and developing the model; the Stockholm environmental institute was the first country who provided primary support, and United State Army Corps of Engineers provided funding for more developing this model. As a model developed since 1990, many studies have been benefiting from different sides such as agriculture system, municipality system, and single catchment or trans-boundary river system (Boxall et al., 2007).

WEAP model used in watershed planning projects, water distribution, river flow guidance, tank routing, demand analysis, hydrological analysis, watersheds, water balance, water quality, sediment analysis and public watersheds. Furthermore, some models are better in the spatial water quality analysis, supply and demand management in watersheds like Mike Basin and Molino, and some are a good analysis for projects where the river and reservoir routing like REPASIM (Mugatsia, 2010).

Water assessment and planning WEAP models seek to bridge the gap among water management, watershed hydrology, and supplies. It can effectively manage water resources are suitable, easy to use; reasonable and readily available to the wider water resource community. This model used in Ghana to simulate the effect of small depots in the Upper Volta region. The model was also practical for the Olifants watersheds in South Africa, which have been very successful in conducting a quick analysis of current and future water demands. In addition, the model used in different watersheds around the world has successfully used.

5.2 Methods and field works

For preparing classical research, set of questions will be a necessity and significant which very important for complementary of research as well as to come out a good recommendation for management of the river basin and structures, therefore, the below questions will ask:

1. What are the relationships between all users in the dry season and wet season?
2. What is the best way for an approach to arrangement and regulation of distribution release (output flow) between all users during the time within the river?
3. What is the amount of water shortage in the current situation?
4. What is the priority of the water users during the dry season?

Also for completing the study, it will be necessary to collect information about the study such as below;

- Design for data water users, the number of users, the maximum and minimum flow rate from each sub-basins and relationship, flow rate and different water users, and water system planning for the river, etc.
- Historical inflow data collect.
- Maximum and minimum runoff curves.
- Calculate for agricultural requirements, domestic requirements, recreation requirements and hydrological requirement.

- Measure the maximum and minimum flow, and the flow rate of Gali Ali Bag waterfall that is located before and after the irrigation project site in the river basin.
- Collect data on water users and water supply in the basin, the KRB population and the agricultural area with crop water requirements, etc.
- Find the best sites for constructing different water projects (water treatment project, dams, water supply projects, irrigation projects, environmental projects, etc.)

In addition, water supply for domestic uses comes from surface water (underground pipe, springs, and rivers) and groundwater. Historically, all water uses have met in three seasons (winter, spring, and autumn) and it is unmet in the summer season, although groundwater is the 20 % Percentage of water supply sources, especially household and agricultural uses, as well as water used in the industrial sector. Priority shall be for water used to meet domestic and industrial demand and then for agriculture.

Also, environmental problems have marked mostly by scientific warnings, public interest, political agendas, and media attention. Policy issues remain a problem when it comes to water. Most of the available water used for agricultural purposes, which is more than 80 percent (Gray, 1997).

Industrial water demand in Erbil province and Iraq government is on the rise. Also, water use in Erbil governorate industry generally from groundwater and is high due to a combination of factors including obsolete process technology, poor recycling and reuse practices and inadequate wastewater treatment. There is low and insufficient awareness about the problem and needs for wastewater treatment by industry. The efficiency of utilization in all the industrial uses of water should optimize, and recognition of water as a scarce resource fostered. The water resources kept from change and should be able to use by making greatest degree retention, taking away pollution and unimportant losses.

Two different periods of fieldworks included in the study; first starting from 2/10/2017endedat15/10/2017 and second was starting from 17/3/2018 up to25/3/ 2018.

From first sampling data collected from three deep wells, seven surface water, and thirteen springs for full chemical and biological analysis Polythene bottles of 1, 2litersused for chemical sampling. The water of the inventory water point from which the sample taken washed the bottles. A drop of toluene was added to the samples to prevent bacterial growth. Glass bottles of0.5 Liters used for biological sampling. The pH, electrical conductivity, and temperature of the samples recorded at the site using Potable pH-EC-meter with a thermometer are studied. Then the samples sent to the laboratories.

All collected samples analyzed in the laboratories of the Water and Wastewater Directorate. The systems that used for water analysis were the standard methods of water analysis as specified by the American Public Health Association (APHA) (1989) and other references.

The second test took at the period of 17/3/2018 to 25/3/2018. The difference between the two tests is specifying more detail about the situation of water resources in a different village and different location.

5.2.1 Agriculture water data use by model

The estimated current annual amount of water for each water use sectors in KRB summarized in Table 5.1. These estimates made by the both of ministries Agriculture and Water Resources and Municipality and Tourism based on the activities data for the year of 2016. Table5.1 shows the total unit irrigated area by the study river basin and the portion of the water used

Table5.1 The agriculture land and water demand from 2010-2032.

Year	**Land extend ratio per 5 years**	**Agriculture water demand m^3 /ha/ Year**	**Irrigation land ha**	**Annual total agriculture water requirement million cubic meter**
2010	0.178	3500	3100	10.850
2015	**0.173**	**3500**	**3652**	**12.781**
2020	0.167	3400	4284	14.564
2025	0.162	3350	4999	16.746
2030	0.161	3300	5809	19.169
2032	0.0644 per 2 Year	3250	6744	**21.918**

The agriculture land in KRB was around 3100 ha in the year 2010 and, these are estimated to be under irrigation in the KRB, using about 0.006 m^3 /sec. /ha and 10 hours in a day. Water flow for 57days (April, four days- May, eight days- June, ten days- July,15 days-August,12 days-September, eight days) irrigation in a year which calculated as 3500 m^3/ha/ year (DAE, 2016).

Saving the food basket in the river basin in 2018 and during 2032 is one of the main objectives of the study. Crop water requirements CROPWAT used to calculate water quantities, and irrigation method such as water saving technology (drip irrigation system and sprinkler irrigation system) open channel and pipelines, time and duration of irrigation, development of irrigation schedules under different conditions and water supply scheme of land. (Kuo et al., 2006)

Data preparation rain, crop type, soil type and crop pattern necessary to operating the CROPWAT module. The result will be three calculations CWR, irrigation timetable, and scheme types, the water balance method used in the calculation of crop Tables in CROPWAT, The incoming and outgoing water flows from the soil profile monitored

Table 5.2 Crop water requirement

Total crop water requirement in mm/month											
O	N	D	J	F	M	A	M	J	J	A	S
1710	534	0	0	0	255	952	3625	6863	8247	6388	3523

Population and rising socio-economic growth resulting in higher per-capita water demand in the domestic sector, and more intensive use of water in other sectors, including amenity and agriculture uses to drive the river basin’s water demand. In particular, the strategic plan for agriculture, this proposes more than double the irrigated area within 15 years.

Table 5.3 Crop type and duration planting

a) Winter crops

Average irrigation in (month)mm														
Crop name	**Cropping period**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**Annual requirement**
Wheat	1/11-15/6	83	72	0	0	0	0	8	38	0	0	0	0	201
Barley	1/11-01/6	83	66	0	0	0	0	0	0	0	0	0	0	149
Sunflower	1/11-15/5	69	59	0	0	0	0	16	51	0	0	0	0	195
Trefoil	1/10-20/5	117	14	0	0	0	0	9	114	0	0	0	83	337
Flax	1/11-25/5	56	53	0	0	0	0	28	56	0	0	0	0	193
Potatoes	16/8-15/12	138	57	0	0	0	0	0	0	0	0	153	139	487
Bean(seed)	16/10-30/4	57	25	0	0	0	0	50	0	0	0	0	139	271
Legumes	15/10-15/4	57	17	0	0	0	0	16	0	0	0	0	56	146
sugar beet	15/10-15/6	72	20	0	0	0	0	37	192	126	0	0	83	530
Vegetables	1/5-1/12	67	25	0	0	0	0	9	11	0	0	25	85	222
Onion	16/10-20/5	47	17	0	0	0	0	43	57	0	0	0	42	206
Cabbage	1/9-20/3	81	22	0	0	0	0	0	0	0	0	42	128	273

b) Summer Crops

Average irrigation in (month)mm														
Crop name	**Cropping period**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**Annual requirement**
Cotton	11/4-15/9	0	0	0	0	0	0	66	104	307	393	306	61	1237
Sesame	11/4-25/8	0	0	0	0	0	0	39	92	236	357	264	40	1028
Soybean	25/8-11/4	0	0	0	0	0	0	39	110	288	357	186	0	980
Corn(sp.)	16/3-15/7	0	0	0	0	0	39	0	190	281	99	0	0	609
Corn (su.)	11/7-30/10	125	0	0	0	0	0	0	0	83	128	236	267	839
Grain	15/4-20/8	0	0	0	0	0	0	39	88	294	372	143	0	936
Sunflower	1/4-15/8	0	0	0	0	0	0	39	115	281	382	96	0	913
Peanut	4/6-20/9	0	0	0	0	0	0	43	126	254	368	299	88	1178
Mung Bean	5/6-20/9	0	0	0	0	0	0	0	39	75	332	328	89	863
Haricot Beam	10/4-31/8	0	0	0	0	0	0	0	64	113	286	160	0	623
Rice	1/5-20/9	0	0	0	0	0	0	0	390	340	506	432	180	1848
Tobacco	11/4-30/9	0	0	0	0	0	0	39	126	290	104	310	160	1029
Watermelon	11/4-25/8	0	0	0	0	0	0	39	115	278	344	210	0	986
Sugar Beat	1/4-10/9	0	0	0	0	0	0	80	129	307	394	350	64	1324
Potatoes	16/3-10/7	76	0	0	0	0	39	12	186	288	76	0	0	677
Corn(fodder)	16/4-15/9	0	0	0	0	0	0	39	97	275	828	319	240	1798
Grain(fodder)	1/4-30/9	0	0	0	0	0	0	39	135	313	328	285	214	1314
Vegetables	1/3-1/10	44	0	0	0	0	19	34	124	276	226	188	117	1028
Tardy	21/4-31/10	81	0	0	0	0	0	59	107	278	344	310	192	1371
early Tomato	11/3-20/7	0	0	0	0	0	39	36	175	346	100	0	0	696
Egg plant	5/4-30/9	0	0	0	0	0	0	45	142	307	364	299	122	1279
Okra	28/3-10/10	21	0	0	0	0	39	1	149	317	393	303	147	1370
Green paper	21/4-25/10	68	0	0	0	0	0	39	96	274	356	292	174	1299

c) Permanent crops

Average irrigation in (month)mm															
	Crop name	**Cropping period**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**Annual requirement**
Permanent	Grapes	15/3-5/11	81	1	0	0	0	80	0	53	283	321	249	147	1215
	Fruits	1/1-1/12	133	36	0	0	0	0	9	154	283	321	303	226	1465
	Jet	1/1-1/12	154	50	0	0	0	0	0	0	70	168	300	240	982
	Average Req.		**1710**	**534**	**0**	**0**	**0**	**255**	**952**	**3625**	**6863**	**8247**	**6388**	**3523**	

5.2.2 Domestic water supply data use by model

The sources of water supply for household uses are surface water aquifers, springs, and rivers and groundwater. Historically, all water uses have converged in three seasons' winter, spring, and autumn and have not met in the summer season, although groundwater is below 5% supply for domestic use of water, agriculture and industrial water supply (MOM and T, 2016).

Table 5.4 Population growth and domestic water requirement (2010-2032)

Year	Growth ratio per 5 years	KRB population	Indoor water demand m^3 /cap/day	Outdoor WR demand m^3/cap/day	Total WR demand m^3 /cap/day	Domestic Water requirement million cubic meter /year
2010	0.178	22183	0.35	0.11	0.46	3.72
2015	0.173	26021	0.35	0.11	0.46	4.37
2020	0.167	30522	0.3	0.1	0.4	4.46
2025	0.162	35619	0.25	0.1	0.35	4.55
2030	0.161	41390	0.22	0.1	0.32	4.83
2032	**0.064 per 2 years**	48054	0.2	0.1	0.3	**5.26**

A large part of domestic water supplied through municipal surface water, although demand also met by surface water pumping stations, some through groundwater through the pipeline system as well as through water tankers. Collected agricultural water uses green gardens, orchards, vegetables, seeds, animal fodder or cattle, estimated the amount of each irrigated activity and the average annual activity rate in units m^3 per hectare. When all these water sectors use combined with the year 2016, sub-watersheds and surrounding villages use about 4.37 million cubic meter of water per year for domestic water use.

5.2.3 Environment and tourism water use data by model

Environmental problems marked mostly by scientific warnings, public interest, political agendas, and media attention. Policy issues remain a problem when it comes to water.

In addition, water efficiency levels are relatively low in the region, usually between 37% and 53% (MOA and WR, 2016)

Environmental flow requirements generally focused on the ecosystem parts and specific times of the year likely to be at risk in KRB. Most water use in watersheds may take place in the summer and may have an impact on species that have special requirements in these months (spawning, fish migration, sluggish vegetation, habitat availability.) At other times of the year, on ecological processes in the river or wetlands in these scenarios, the study will focus on determining the expected interest rates EWRs for the summer period, in particular, and monthly EWRs for each month.

The minimum flow rate for KR during dry year August 2001 was 0.66 m^3/sec, at the location where after Gali Ali Bag waterfall manually. Therefore, the study assumed minimum inflow as an environmental flow requirement up to the year start construction Ble reservoir on KR and it is estimated to be two m^3/sec in the year 2035 due to the water unmet water requirements (MOA and WR, 2016).

At the same time, the environment flow required to Gali Ali Bag waterfall started at0.66 m^3/sec but after constructing, the reservoir will arise to 2 m^3/sec and rise to more in the year 2032. The annual environment flow required totally in 2032 estimated by 63.072million cubic meters as shown in Table5.5

Table 5.5 Annual environment flow Gali Ali Bag waterfall location.

Year	**Annual environment flow**	
	m^3/sec.	million cubic meter
2010	0.66	20.814
2015	0.66	20.814
2020	1	31.536
2025	1.5	47.304
2030	2	63.072
2032	2	63.072

5.2.4 Animalwater use data by model

Due to the availability of large farmers in the KRB and most of the villager have second job breeding animals and livestock in addition to agriculture; therefore, calculation animal water requirement will be part of water demand, Table 5.6, 5.7and 5.8shows animal water requirement in KRB

Table 5.6 Annual animal water requirement in 2010 (MOA and WR, 2016)

Item	**No.**	**Average water requirement / day**		**Annual water requirement m^3**
Cattle	1803	30	(L/animal/day)	19742.85
Sheep and goat	45080	10	(L/animal/day)	164542
Horses	1288	35	(L/animal/day)	16454.2
Poultry	10948	0.5	(L/bird/day)	1998.01
Total annual water requirement m^3				202737.06

Table5.7 Annual animal water requirement (MOA and WR, 2016)

Statues of animal availability and water requirement from the year 2010 up to 2032		
Year	**Total annual water requirement million m^3**	**Agriculture land extend ratio per 5 years**
2010	0.203	0.178
2015	0.239	0.173
2020	0.280	0.167
2025	0.327	0.162
2030	0.380	0.161
2032	**0.441**	**0.065**

The annual animal water requirement for the next 15 years is 0.441 million meters cubic for a different type of animals.

Table 5.8 Prediction of animal availability

	Estimation of animal numbers up to 2032					
Animal type	2010	2015	2020	2025	2030	2032
Sheep and goat	45080	52879	61710	72015	83610	89044
Horses	1288	1511	1763	2049	2379	2533
Poultry	10948	12842	14987	17414	20218	21532

In Table 5.9, 5.10 and Figure 5.1, shows water consumption in each from domestic, agriculture and animal. Indicates domestic water use is 23 percentages while agriculture takes much more water with an amount of 75 percent. Besides, agriculture in the catchment area is a source of living, but it is not the only source because people have an animal as well and most importantly, it is a tourist area. However, there is much-losing water in the agriculture sector. In Khalifan river basin according to the ministry of agriculture, water consumption for a domestic estimate by 360 liters per capita per day, due to spending much amount of water in indoor and outdoor. However, water use for domestic is high according to the developing countries, reason back to no pricing water as a value and not exist any law for the water system.

Table 5.9 Water consumption annually

Water consumption of million cubic meter			
Year	agriculture	domestic	animal
2010	14.564	4.46	0.28
2015	12.781	4.37	0.239
2020	14.564	4.46	0.28
2025	16.746	4.55	0.327
2030	19.169	4.83	0.38
2032	**21.918**	**5.26**	**0.441**

Table 5.10 Water consumption per day

River basin	**Item**	**Average water requirement/ day**
KRB	Population	360 (l/capita/day)
	Cattle	30 (l/animal/day)
	Sheep and goat	10 (l/animal/day)
	Horses	35 (l/animal/day)
	Poultry	0.5 (l/bird/day)

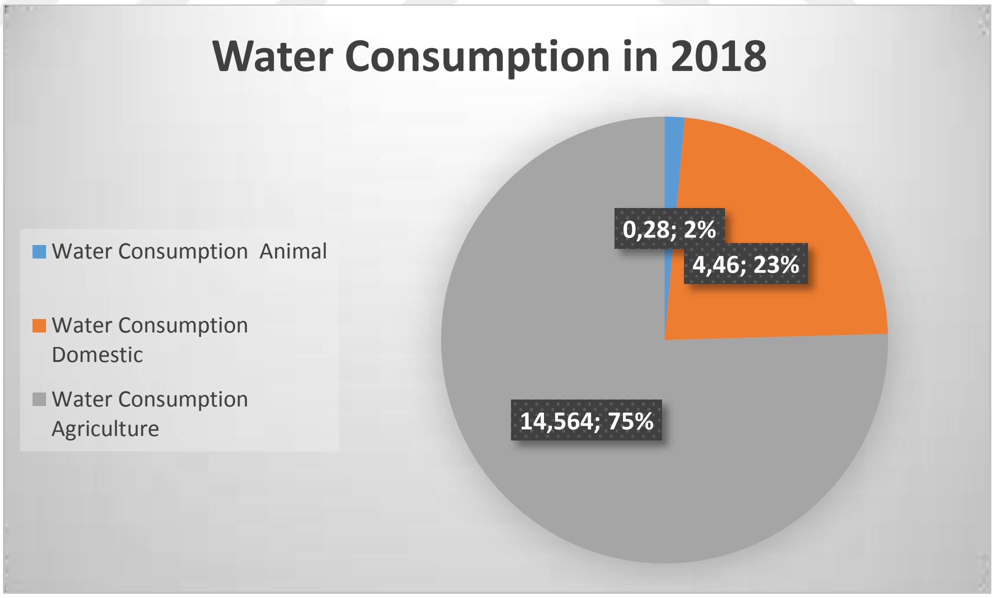


Figure 5.1 Water consumption for all sectors

Generally, the municipality sector comprises the quantity of water uses in cities, town, domestic and public service. Also in some cities, it includes water using in market gardening and for watering vegetable garden and domestic garden plans. Usually, the quantities of water use in the public sector depend on population and the service provided, such as pipe networks for supply and sewerage. Also, much depend on climate change. In many big cities especially in the developed countries such as Europe and North America, water use is 300-600 liters per day per second and within years increasing to 500-1000 liters per day (Wright et al., 2004). In on the other hand, in developing agriculture countries like Asia, Africa and Latin America public water withdrawing is 50-100 liters per day. Besides, in certain individual countries water fresh not more than 10-40 liters per day per person. For agriculture water use in northern Europe is between 300-5000 m^3/ha while in southern and eastern Europe is 7000-11000 m^3/ha. Also, returnable of water to intake is about 20-30 %. In the USA water use for irrigation sector is 8000-10000 m^3/ha and returnable water is about 40-50% of water intake. Moreover, in countries such as Asia, Africa, Central and South America, due to unlimited variation in climate change, crop composition and technics for watering, the water withdraw range from 5000-6000 m^3/ha to 15000-17000 m^3/ha and some region of Africa is about 20000-25000 m^3/ha (Shiklomanov,1998). According to (Ward and McKague,2007) beef cattle water requirement is in range of 15-54 liters per day and, for a horse is 16-60 liters per day while in Iraq for cattle is 10-30 liters per day and, for hours is 35 liters per day.

5.3 Overview of the geographical information system

Geographical information system (GIS) is a system network of hardware, software, data, people, organization and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth (SebtandDelavar, 2008).

Thus, geographical information systems are computer technologies for organizing spatially related data. The GIS is often defining not for what it is but for what; it can do (Clarke, 1997). This functional definition is very revealing about GIS use because it shows the set of capabilities that a GIS expected to have. These grouped into data capture, data storage, data management, data retrieval, data analysis, and data display.

One of the most beneficial GIS applications in planning and management is mapping and analyzing land suitability. The land-use suitability analysis is widely proposed to determine the most suitable spatial pattern for future land use according to the identification of requirements, partialities or forecasts of certain activities. The analysis of the suitability of GIS-based land use has been applying to a wide range of situations, including ecological methods for determining the appropriateness of habitats of animal and plant species, geological importance, land suitability for agricultural activities, landscape assessment and planning, a site for public and private sector facilities and regional planning. This study focuses on the analysis of land use suitability as applied to urban and environmental planning and management rather than agricultural applications (Malczewski, 2004).

Digital Elevation Models DEMs, are raster geographic digital datasets of elevations in x, y, z coordinates. The terrain elevations for ground locations sampled arrays of regularly spaced elevation values referenced horizontally either to a Universal Transverse Mercator UTM projection or to a geographic coordinate system. The grid cells are spaced at regular intervals along south to north profiles that ordered from west to east. There is no standard practice of the terms digital elevation model DEM, a digital terrain model DTM and digital surface model DSM in the literature.

Pre-treatment has applied to the Digital Elevation Model DEM, which has a larger coverage area than the study area to determine river basin boundaries as a precondition for hydrological treatment. All steps in the Pre-treatment list performed in sequential, top-down order. Hydrology tools, which are spatial analysis tools, used to describe the physical components of the surface in the Arc GIS system for this treatment. The functions of the hydrology tool in the sequence are; load DEM, fill the sinks, determine the flow direction, calculate the flow accumulation, determine the tracking, determine the watershed boundaries and establish the flow networks (Ismail, 2013).

5.3.1 Installing Arc Map software

After installation software, the step takes as summery

a) Open Arc Map and creating a new, blank map document and add the DEM for Khalifan watershed where prepared by GIS expert to the general map.
b) Set the DEM grid as the Input surface raster, and create a flow direction grid, by using the Flow Direction tool. In GIS for every 3x3-cellneighborhood, the grid processor finds the lowest neighboring cell from the center

c) Create flow accumulation grid, the new flow accumulation raster added to Khalifan map document and cells with higher flow accumulation values should locate in lower elevation, such as valleys or drainage channels where water flows while it is following the landscape.

d) Finally, create outlet point for the catchment area and delineate the watershed then Click OK to run the tool (Basnyat et al., 2000). Upon completion, a new watershed raster added to the map document as shown in Figure 5.2 and Table 5.11

Digital Elevation Models DEMs: are raster geographic digital datasets of elevations in x, y, z coordinates.

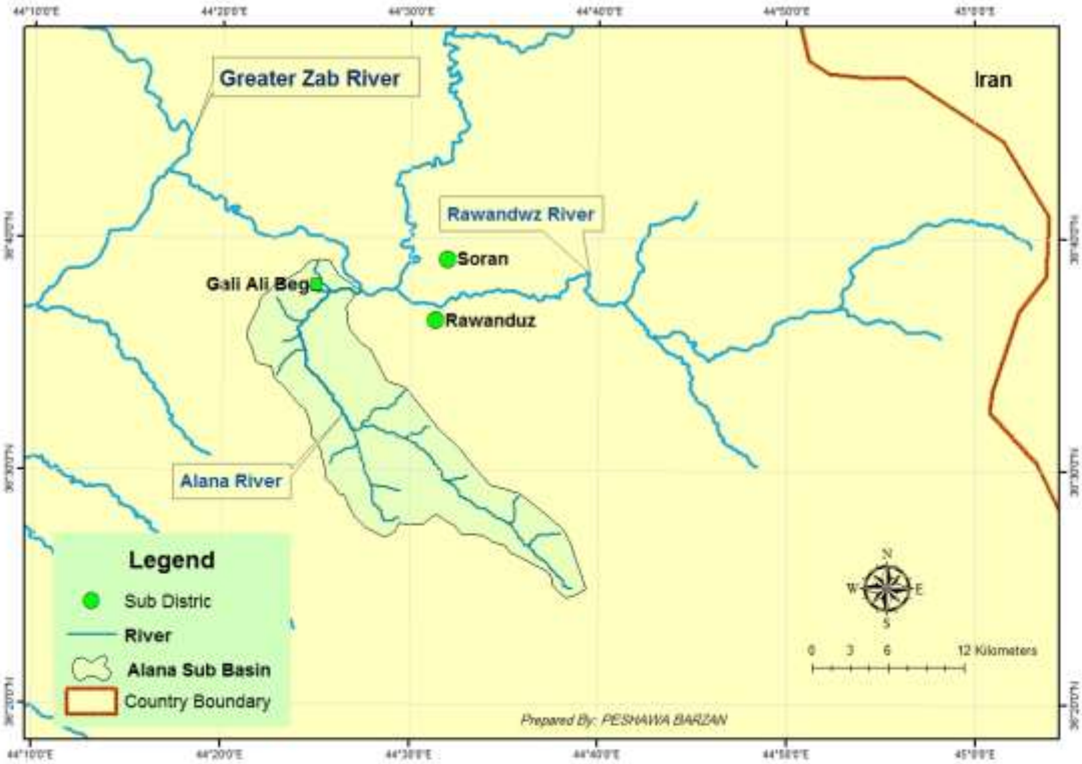


Figure 5.2 Raster geographic digital datasets in geo-reference

Table 5.11 Description of functions in hydrology tools (Basnyat et al., 2000)

Functions	Description
Flow direction	Create a network of flow direction from each cell to its steep gradient neighbor.
Flow accumulation	Create a raster of accumulated flow to each cell by accumulating the weight for all cells that flow into each downslope cell.
Stream shape	Converts a grid representing a linear raster network to a shape file
Snap pour point	Snaps selected pour points to the cell of highest flow accumulation within a specified neighborhood.
Watershed	Determines the contributing area above a set of cells in a grid

5.4 Program data analysis model

During research,the Water Evaluation Analysis Planning WEAP model used for analysis and evaluate water resource planning and management. This system developed by the Stockholm environment institute to the evaluation of planning and management about water resources. WEAP model can use in both municipal issue and agricultural policy system as well also can title a wide range of issues like water conservation, water demand, reservoir operation, ecosystem requirements and cost-benefit analyses (Arranz and McCartney, 2007).

The objective of this study is to propose a synthetic view of water resources uses in Khalifan watershed by gathering existing data and studies and feeding a simplified water evaluation and planning model.

WEAP consists of five main views: Schematic, Data, Results, Scenario Explorer and Notes. These five views presented below.

5.5 Database organization model

In general, WEAP Models include five schematic steps data, result, overview and note. In the schematic, the view contains GIS-based tools for easy configuration of the system. Objects (e.g., demand nodes, reservoirs) created and positioned within the system by dragging and dropping items from a menu. Arc View or other standard GIS vector or raster files added as background layers. We can quickly access data and results for any node by clicking on the object of interest (SEI, 2005).

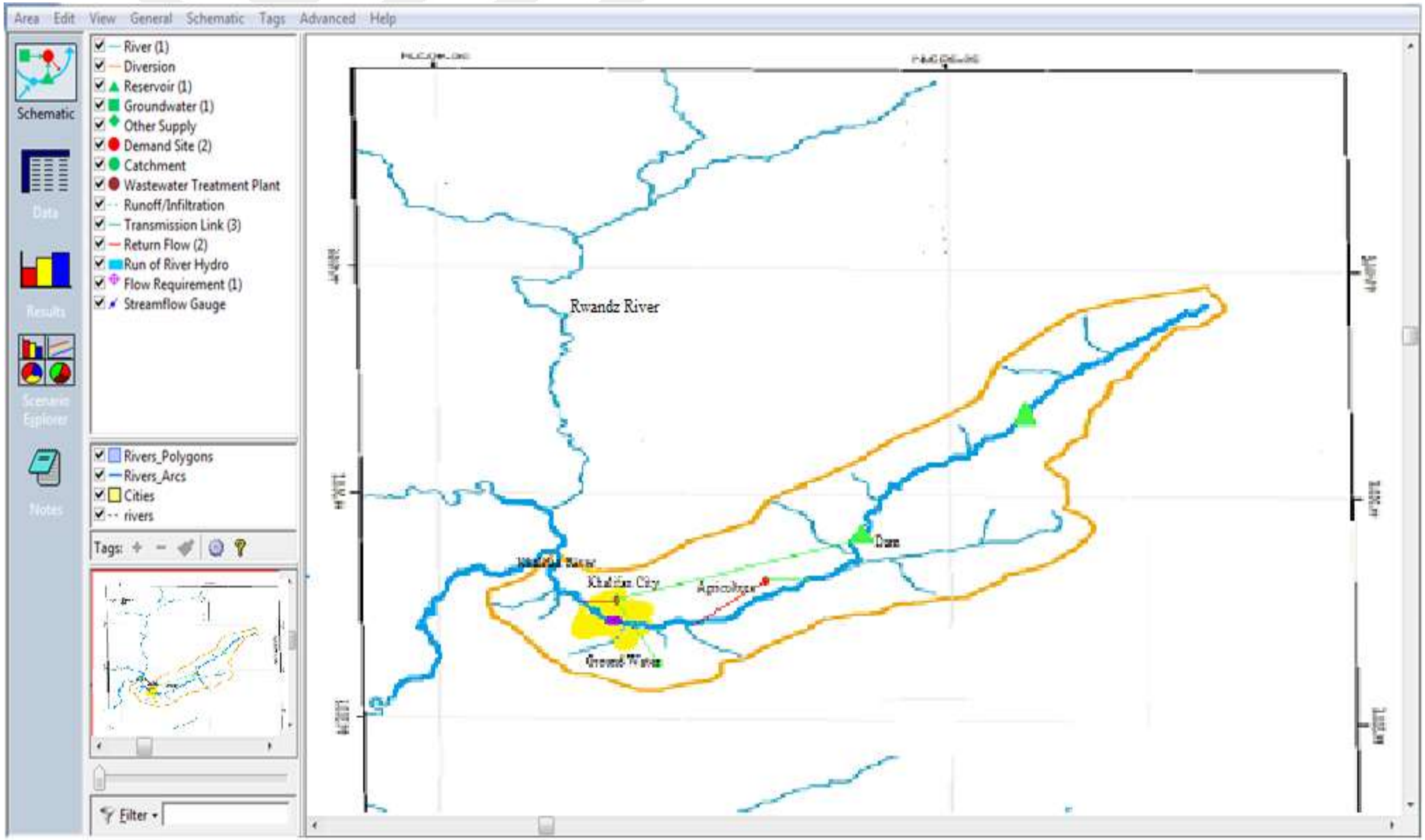


Figure 5.3 Map of Khalifan river basin in model program

The modeling software incorporates multiple dimensions critical to water resources management, including surface water and groundwater hydrology, water quality, water demands, population growth, reuse, system losses, and consumption. WEAP represents water supply and demand centers spatially because its focus is the flow of water from the river to the users. The organization of WEAP schematic map in Figure 5.3 shows, how the water flow and demand site, as well as the main features of the Khalifan River water system, have aggregated and represented in WEAP as so-called supply and demand nodes, transmission links between these nodes and water allocation rules demand and supply priorities–not shown.

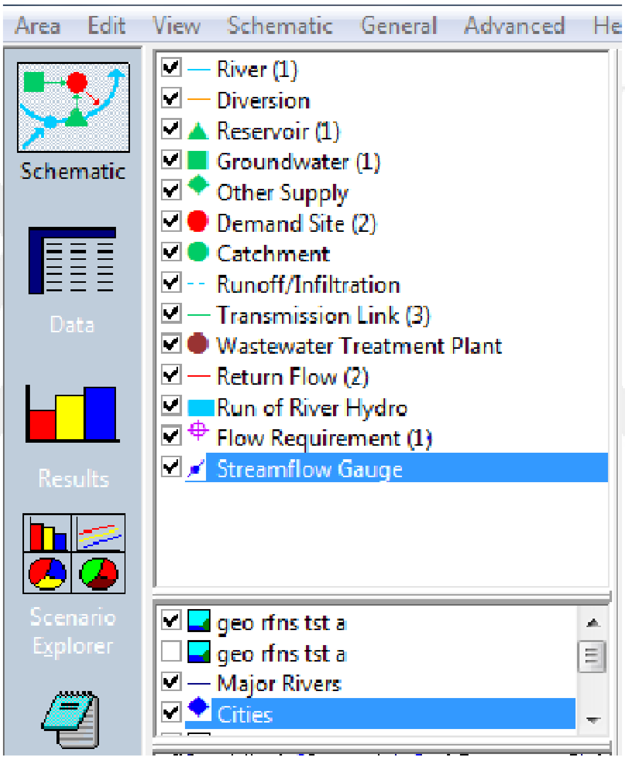


Figure 5.4 The model structure

Optimization models widely used in basic science and engineering. In general, the models reflect the basic features of the system and include the purposes of the model as realistic details. For example, when we drop a plane at the design stage, Wind tunnel using the aircraft model rather than the real plane during the examination of the antenna dynamic structure Experiments are performed. In agriculture, all plant and plant properties examined while optimization studies carried out, plant models are changing in a laboratory environment. Optimization needs for all resources such as labor, time, capital, processes, raw materials, capacity, equipment, etc. also, maximization, profitmaximizing, capacity utilization optimization and efficiency as a technology that provides access it will be by some model (Delipınar and Karpuzcu, 2017)

Optimization models mathematical programming formulated regarding value determination for a set of decision variables, which will increase or decrease objective function subject to limitations. Most optimization models rely on a type of mathematical programming technique: objective and objective limitations of mathematical expressions as a function of decision variables. Typical functions of river flow maximise or can be the minimum quantitative measure of an object such as economic benefits and cost, water availability and reliability and hydropower generation.

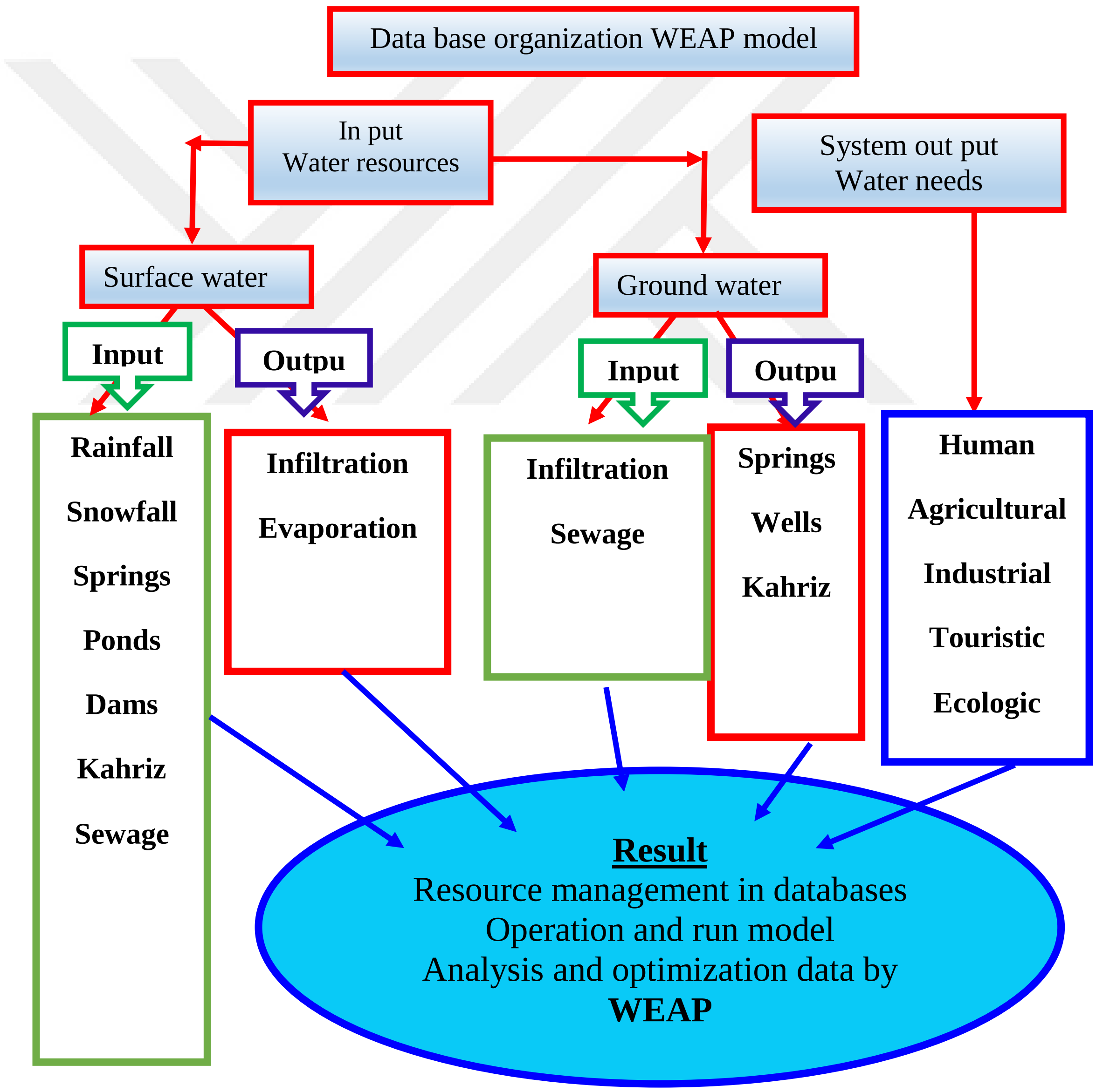


Figure 5.5 Modeldatabase organizations

INPUT in the area – OUTPUT from the area = available water in the area. The model compares:

1. The surfaces water aspect (hydrologic aspect).
2. Groundwater aspect (hydrogeological aspect).
3. The total water needs aspect (human demand aspect).
4. The river flow required (Environment river flow)

According to the field data collections and the references from both the ministries of agriculture and municipality reports the input data to the model as bellow

Generally, the database and organization for WEAP model divided by two-part the first part is input and the second part is output as shown in Figure 5.5, page 99.

The second part is current and features water needs for all users; the human water needs are the water requirements for domestic water use which including indoor and outdoor water uses, service, and all water house uses calculated by Directorate of water in Erbil by 350 I/c/day in general (DOWE, 2017).

The agriculture water needs to be calculating by CROPWAT, for the agriculture land in KRB water use 3500 m3/hectare (MOA and WR, 2017). The industrial water needs up to date is zero due to unavailable of factories in the KRB, but for the feature, calculated 100 m^3/day. Touristic and ecological water needed to calculate as a minimum river flow at Gali Ali Bag waterfall, which is 0.66 m^3 /sec (DOIE, 2017).

The first part is the water resources available in KRB and includes all types of surface and groundwater in the study basin of the watershed. Groundwater-fed through infiltrating of surface water and sewage. That concerning groundwater gains, but there is also a loss for groundwater present through the springs, flowing directly to the land surface and using deep wells where water pumped from groundwater and used by the residents of the KRB.

Regarding to the surface water available are comes from rainfall around 1200 mm/year, the average depth of snowfall around 1 m, there are three main springs and 9 small spring in the area, the average water flow around 1m^3 /sec, as well as the dam, proposed to construction in the KRB with reservoir capacity 2 million cubic meter.

Decision variables might be targets and release rates. Constraints typically include physical characteristics of the river flow system, such as maximum and minimum storage, maximum and minimum releases, and regulatory or policy requirements minimum instream flows, restrictions on allocations etc., and mass balances (Darper, 2001).

The method used to improve the use of water available within the Khalifan River Basin in the swap process is to identify barter curves among all users' agricultural, family and recreational, taking into account the prioritisation, and priority given to household uses

The data is a collection of information about the study collected from the site and then entered into the program with different assumptions using a mathematical relationship as well as data can be introduced by Excel also.

The result of running the Web program after entering all the information, a set of models for the future planning of water management discovered within the KRB, as well as the overview in this section; key indicators are readily available on the model to find a different strategic plan for future management.

Practically, Water Evaluation and Planning WEAP system, used in the study for analysis and is an integrated modeling system that can cover water resource stocks and flows connected with extraction processing, production, and consumption, including groundwater pumping, surface water, and the water supply. Moreover, the following steps are how WEAP works.

1) Set up the WEAP model: free download the software from internet Stockholm Environment Institute SEI website, its one-year free for educational staff. By filling the special form and then developing the water system model in WEAP required a comprehensive estimate of the water supply/demand characteristics of the Khalifan watershed.
2) Create new are and named the river basin, the from the general icon in top toolbar fix the year and time steps which 2017 to 2032 in this study, as well as from schematic icon added raster layer which is the study is a map made by GIS including a geo-referenced map
3) Installation the geo-referenced map in the WEAP program then draw the river by drag the river icon from the WEAP,

4) Build the water resource model: The ground and surface water model included a representation of the water supply systems of Khalifan watershed, using WEAP's catchment objects.
5) Regulate the water resource model: After building the water resource model and calibrated according to predevelopment, steady-state conditions that maintained a level groundwater Table and quantities of surface water flow across the representative area, from the Khalifan watershed and the model used to explore current and future water use conditions.
6) The detailed of agricultural demand developed and production model. Making use of crop water requirement model CROPWAT, and developed a detailed model of the primary crops in production in the region (fodder, vegetables, and orchards). This model used to explore the water demand and the production of agricultural outputs under current and future climate conditions.
7) Calibrate the WEAP model: Once the water supply and demand models developed, they run for the historical period time to establish baseline conditions based on observed data about water supply and use. That has considered a calibration phase.
8) Develop Reference Scenario RS scenarios that reflect current conditions growth ratio 3.4%, that continues, but that consider changes in future climate. In addition, we have developed a future policy scenario that assumes a reduction in the forestry and fodder areas, and an increase in the land, under agricultural cultivation for higher valued crops such as, orchards and vegetables.
9) Develop a scenario flow requirement SFR, in this scenario; the environment flows calculated into account monthly river flow 0.66 m3/sec. Flow release to downstream Gali Ali Bag waterfall for tourism. This scenario the monthly water flow mandatory release to downstream by the general directorate of tourism in Erbil. That proposed as a minimum river flow during the dry season.
10) Develop of scenario dam reservoir add SDR. The Gali-Ble dam designed by the Ministry of Water Resource and final design report has used in this scenario. Gali-Ble dam storage capacity is1.8 million cubic meters at the elevation of 993 m, dam height is 27m, and freeboard is 2 m.

Data processing, analysis, and interpretation essentially involved four steps.

1. Preparation of a dataset of monthly data for each station rain-gauge, gauging station, monitoring well, including validation and the correction of errors where possible;
2. Calculation of characteristic statistical values averages, minimum flows etc. for a common reference period, 2000 – 2016
3. Use geographic information system GIS and Arc GIS.
4. Calculate for water resources availability district by district.

5. 6 Model program data input

For data inputting, the water and agriculture systems model uses a host of data assumptions that influence water supply and demand. These data assumptions carefully assessed and incorporated into a working version of the water system model that adequately simulates historical conditions. After a review and vetting process by stakeholders of the current version of the model, a final version will develop that incorporates all feedback.

The Khalifan River Basin main water resources are:

1) Groundwater mainly available from natural springs or deep wells, depending on the regional area.
2) Local runoff typically collected using small dams/reservoirs
3) Main rivers and dams, those resources are originating upstream, and usually available at the borders of the districts.

The limits of accuracy are essentially due to the following factors:

i. High variability of the climate and hydrological regime in the basin, thus, a short time series of maximum 16 years for most stations cannot adequately capture the extremes, although the reference period of 2000 to 2016 does include two exceptionally dry years 2001 and 2008.
ii. Hydrogeological variability: Differences in the hydrogeological characteristics and the presence of karst phenomena cause major variations of unit flows and many other hydrological parameters; it is, therefore, difficult to provide reliable regional estimates.

iii. Data quality: The accuracy of the available data is limited; data collection and data processing practices do not yet fully meet international standards.
iv. The presence of trends: Climate change, irrigation projects upstream, reduced groundwater inflow due to increased abstraction and land use changes are all factors that may cause.

The representation of water supply and demand characteristics within the water system model was as “granular” as possible. While there was ample local data to construct a modestly granular water system model, there was not enough detailed data to develop a highly granular water system model. That has consequences for the level of detail that can analyses during the policy scenario analysis. That is, the water system model can analyses high-level (i.e., sectoral level) policy scenarios and offer first-order indications of alternative development pathways. However, the model cannot analyses the interactions between water supply/demand policies at lower levels of disaggregation e.g., level of enterprises, households, precincts (Jamieson and Fedra, 1996).

The water system model built in WEAP is fundamentally data-driven. Hence, there is a large amount of data, which needed to create the model. The data collection effort has benefitted from collaboration across relevant Erbil province institutions, which have granted access to necessary data. As of this writing, this process has satisfactorily completed. There were several different types of modeling assumptions, which incorporated into the water system model. Background for each of the major assumptions is providing in the subsections below regarding water supply, water demand, and wastewater treatment. The balance between water resources and demand cannot based on a single Figure, as the different types of resources groundwater, local runoff and river flow, have different characteristics regarding availability in space and time. Resources generated and available within the river basin; these resources are available in a decentralized way deep wells, subsurface water shallow wells, springs, and small runoff collecting reservoirs.

CHAPTER 6

RESULTS AND DISCUSSION

6.1 Overview of discussion

The low management of water resources by Erbil government caused several big problems regarding water resources such as problems in the construction of dams and reservoir and operation of rivers water flow. Therefore, every year Erbil has faced a big issue regarding the shortage of water and water losses in the agricultural field and tourism especially in Khalifan River Basin KRB.

Moreover, financial crises after 2014 play an important role in damaging the water resource and its projects in Erbil governorate generally and in KRB particularly. It means that the Khalifan River KR is working as a free flow river and working as an uncontrolled river. It is worth for the river to flow directly to the Rwandwz River instead of building a dam on the KR for multi purposes.

It stresses the limited access to drinking water in KRB. The Erbil Water Directorate well supplied, but the quality of the water distributed is poor. Sanitation services are practically non-existent. Besides the environmental challenges, the study highlights several institutional weaknesses: The poor performance of monitoring due to the lack of human resources, (including operation and maintenance), the related to the extremely low prices, insufficient funding for projects by the government, as well as lack of cooperation between water user sectors and insufficient awareness among beneficiaries.

During the research, uses of data and models as well as the organization to set management rules for future water resources development as well as strategy orientations for the next 15 years in KRB.

6.2 Modeling results:

The purpose of collecting data and information about KRB is running the WEAP model to develop different scenarios, which help to the better-integrated water resource. After receiving data as stated in chapter five, then installed GIS raster map for Khalifan river basin, inserted into the WEAP system program. In addition, the result gave five scenarios as shown in Figure 6.1.

Figure 6.1 shows the five scenarios there is water storage of about 80 million cubic meters for each month without a shortage. Also, the Figure indicates the maximum inflow to the area is 15 million cubic meter. In addition, from January to May and October to December, the flow of river water is good, but for three months June, July and September, the flow of river water to the area is low due to the summer season, no rainfall, and high temperature. In the supplyrequirement, the Figure shows the opposite of inflow to the basin, due to the usage of water for agriculture. The last part from Figure tells us about a shortageof water demand which is starting from May to September. Meanwhile, each scenario has a deficit in water demand most in inflow requirement due to flowing water to Gali Ali Beg that is required 0.66 million cubic meters for each second.

Figure6.1 Scenarios groundwater, inflow, supply req. and unmet water demand

As seen in the Table below unmet water demand for flow requirement scenario is 6.268 million cubic meter. For high population growth is 0.544 million cubic meters due to increase in population and more demand for water, cause a water shortage. While in the reference scenario, the unmet demand is 0.541 million cubic meters. Finally, in reservoir added there are 0.148 million cubic meters, due to constructing a dam within 2 million cubic meters.

In addition, Table 6.2 shows four scenarios with water supply requirement. Inflow requirement scenario for 2017 to 2032 is 236,127 million cubic meters, while in the scenario of high population growth is 246,136 million cubic meter. Also in scenario, reference mean current situation is 236,127 million cubic meters, and the reservoir added scenario is 236,127 million cubic mete

Table6.1 The scenarios with unmet demand

Area Edit View Favorites Advanced Help

Chart Table Map

Unmet Demand (Million Cubic Meter)

All Demand Sites (2) | All months (12) | All Scenarios | Annual Total | Monthly Average | No comparison

	January	February	March	April	May	June	July	August	September	October	November	December	Sum
Flow Requirement	0.000	0.000	0.000	0.148	0.391	0.555	1.272	2.101	1.801	0.000	0.000	0.000	6.268
Higher Population Growth	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.251	0.277	0.000	0.000	0.000	0.544
Reference	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.249	0.276	0.000	0.000	0.000	0.541
Reservoir Added	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.048	0.100	0.000	0.000	0.000	0.148

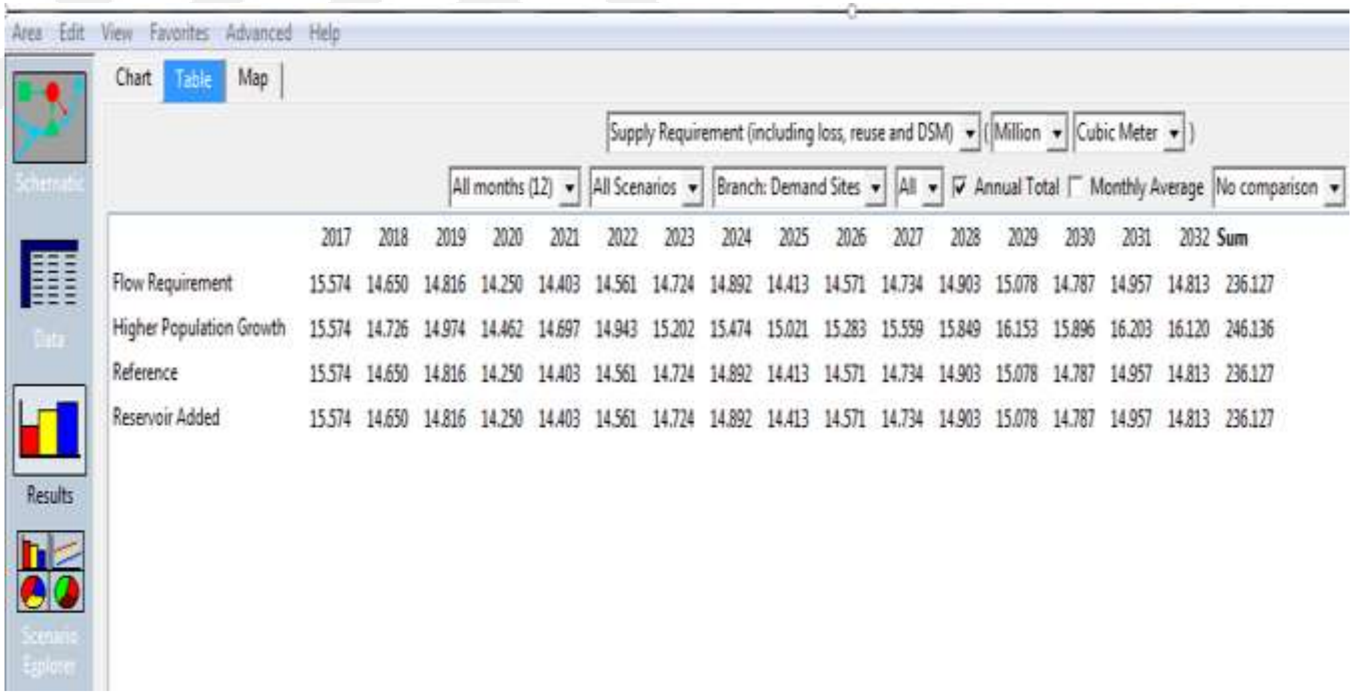
Schematic

Data

Results

Scenario Explorer

Table6.2 Thescenarios with supply requirement



	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**Sum**
Flow Requirement	15.574	14.650	14.816	14.250	14.403	14.561	14.724	14.892	14.413	14.571	14.734	14.903	15.078	14.787	14.957	14.813	236.127
Higher Population Growth	15.574	14.726	14.974	14.462	14.697	14.943	15.202	15.474	15.021	15.283	15.559	15.849	16.153	15.896	16.203	16.120	246.136
Reference	15.574	14.650	14.816	14.250	14.403	14.561	14.724	14.892	14.413	14.571	14.734	14.903	15.078	14.787	14.957	14.813	236.127
Reservoir Added	15.574	14.650	14.816	14.250	14.403	14.561	14.724	14.892	14.413	14.571	14.734	14.903	15.078	14.787	14.957	14.813	236.127

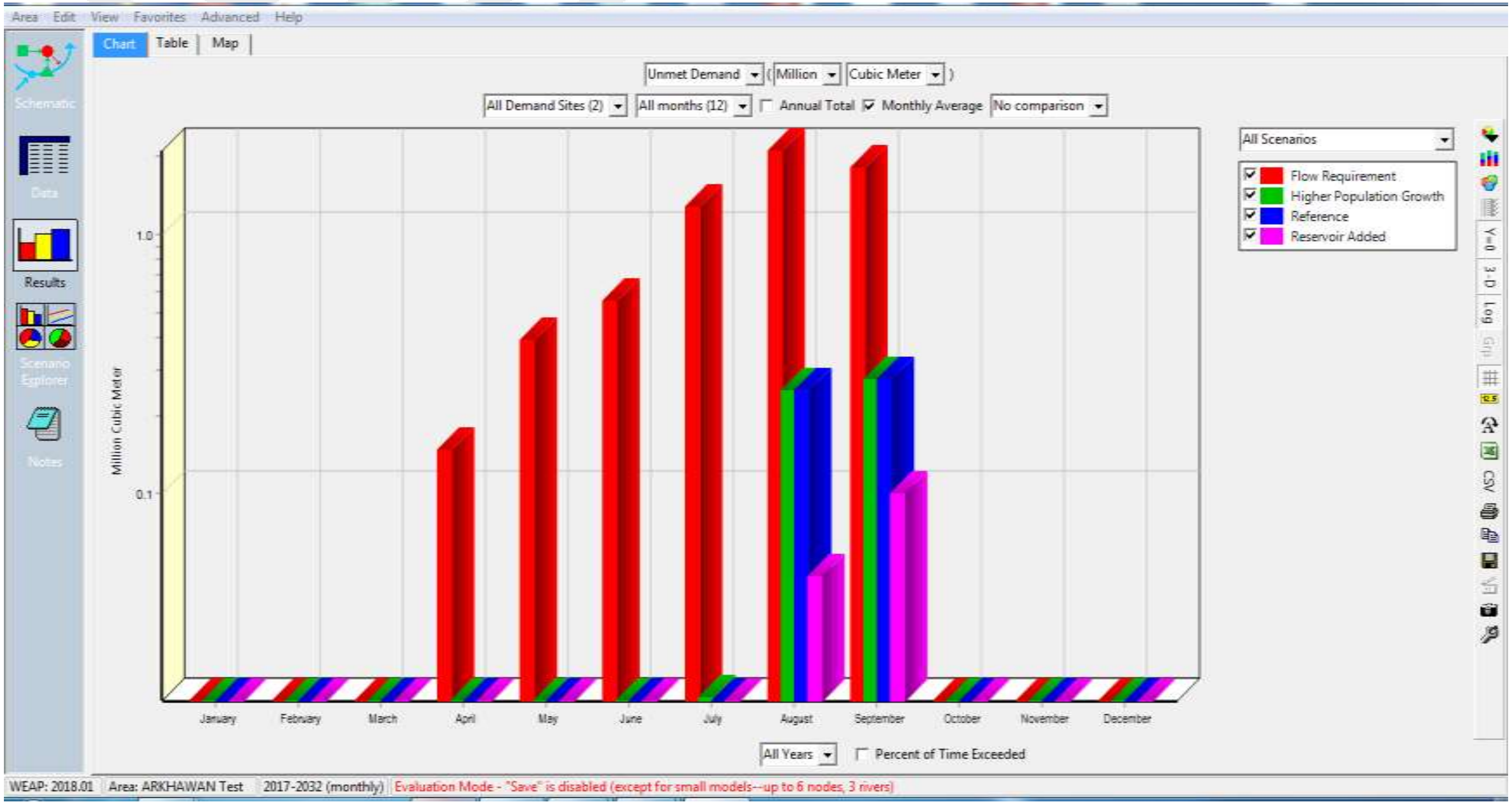


Figure 6.2 The scenarios with unmet demand

6.2.1 Scenario reference

In scenario reference real data is using and, it will be the base for another scenario. The annual population growth ratio calculated as a normal case 3.4% after insert all data required by software, ran model as a current situation which called scenario reference, the output result is the water supply cannot cover the demand for domestic water and agriculture as well. As shown in the Figure below:

In Figure 6.3 shows, supply delivered for the agriculture sector is 2.8 million cubic meters while for domestic is 3.2 million cubic meter due to the priority of domestic it should be first.

According to the Figure 6.4, in scenario reference there is maximum supply requirement 3, 42315 Million cubic meters in August and minimum is 0.36978 Million cubic meters in each from January to March and October to December due to raining season.

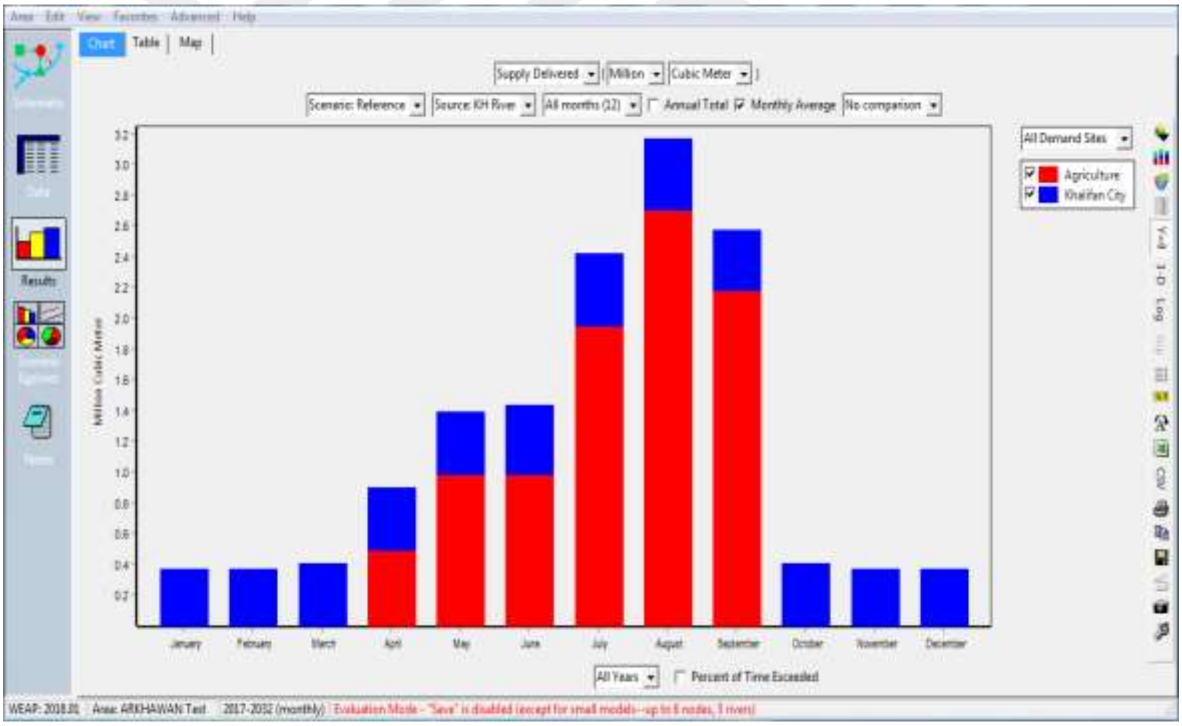
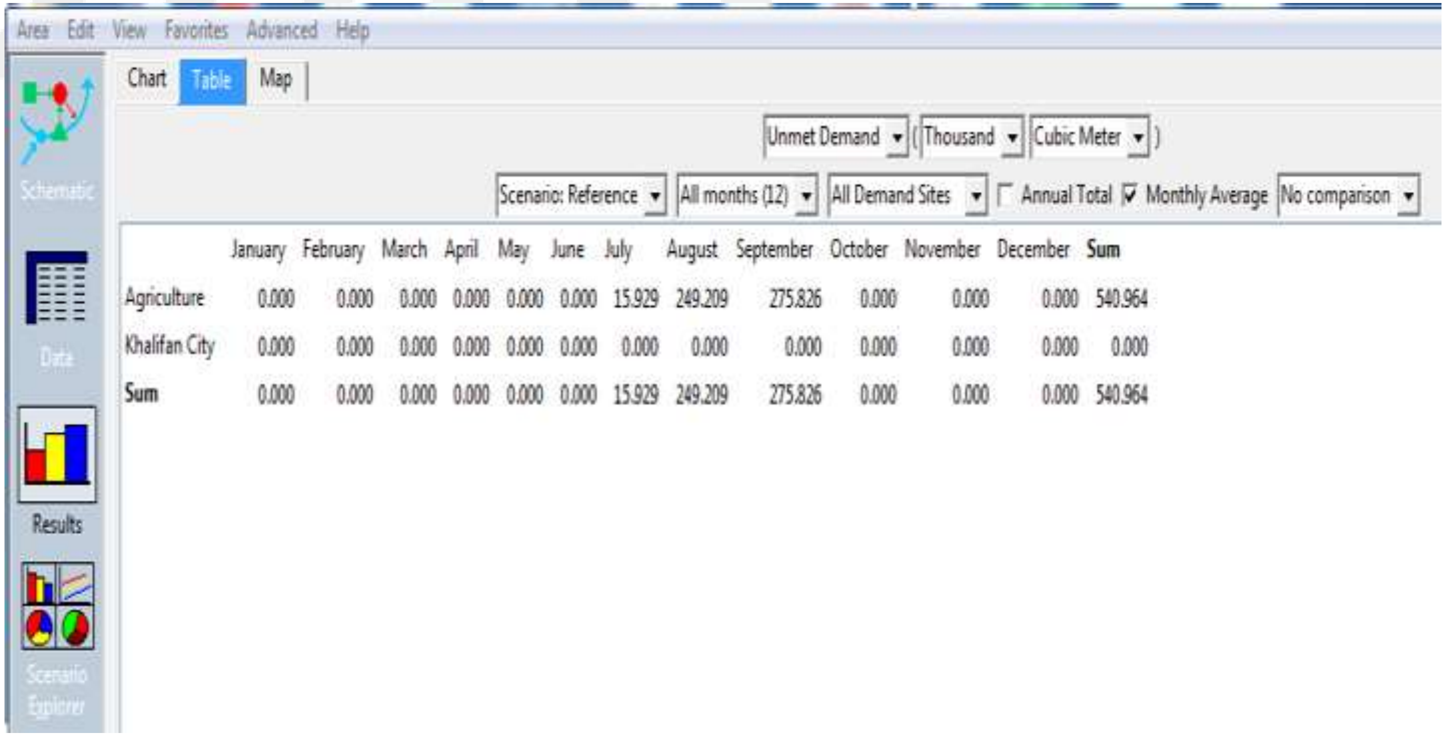


Figure 6.3 Scenarios reference with supply requirement

Figure 6.4 Scenarios reference with supply requirement

In table 6.3, the figure shows a water shortage in scenario reference. As seen, the water shortage is happening only in agriculture, which mean in scenario reference water is enough for domestic water but agriculture is not fitting. Moreover, in the agriculturesector, about 540,964 thousand-meter cubic is less than total demand. The study shows more detail for other Table and Figure in Appendix D.

Table6.3 Scenarios reference with unmet demand

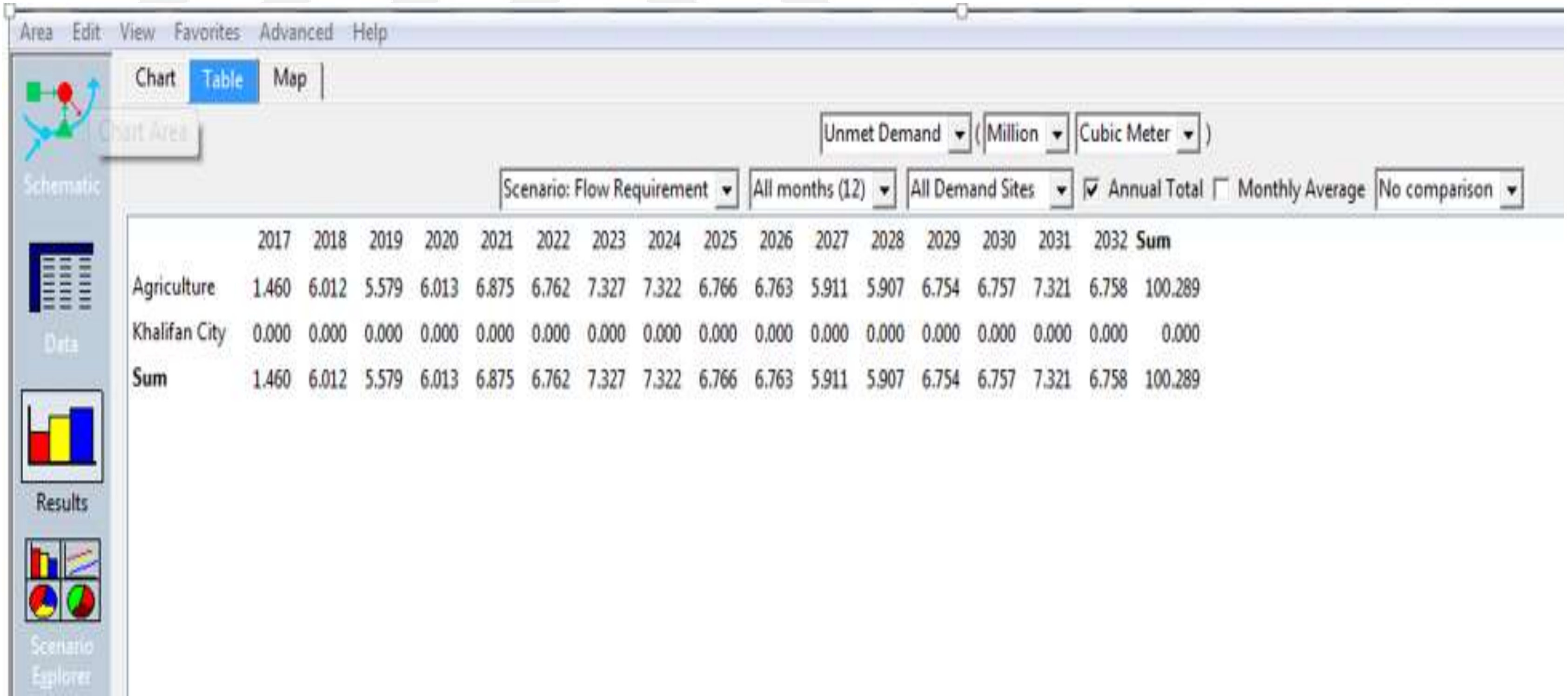


	January	February	March	April	May	June	July	August	September	October	November	December	Sum
Agriculture	0.000	0.000	0.000	0.000	0.000	0.000	15.929	249.209	275.826	0.000	0.000	0.000	540.964
Khalifan City	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	0.000	0.000	0.000	0.000	0.000	0.000	15.929	249.209	275.826	0.000	0.000	0.000	540.964

6.2.2 Scenario flow requirement

In the flow requirement Scenario, the study should consider that the minimum flow flowing to the Gali Fall is 0.66 meter cubic per second. The Table 6.4 and Figure 6.6 are shows that there is unmet demand. Meanwhile, water is enough for the domestic city, but there is a shortage of water for agriculture. For Khalifan city water demand is enough to all-purpose except agriculture has unmet water approximately is 100 million cubic meter.

Table 6.4 Flow requirement scenarios, unmet demand



	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**Sum**
Agriculture	1.460	6.012	5.579	6.013	6.875	6.762	7.327	7.322	6.766	6.763	5.911	5.907	6.754	6.757	7.321	6.758	100.289
Khalifan City	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	1.460	6.012	5.579	6.013	6.875	6.762	7.327	7.322	6.766	6.763	5.911	5.907	6.754	6.757	7.321	6.758	100.289

As seen in Figure 6.5, the water shortage is occurring in agriculture demand. Moreover, for domestic demand water is enough to fit all necessary fully but for agriculture water demand increase from 1.5 million cubic meters in 2017 to 7.3 million meters cubic in 2032.

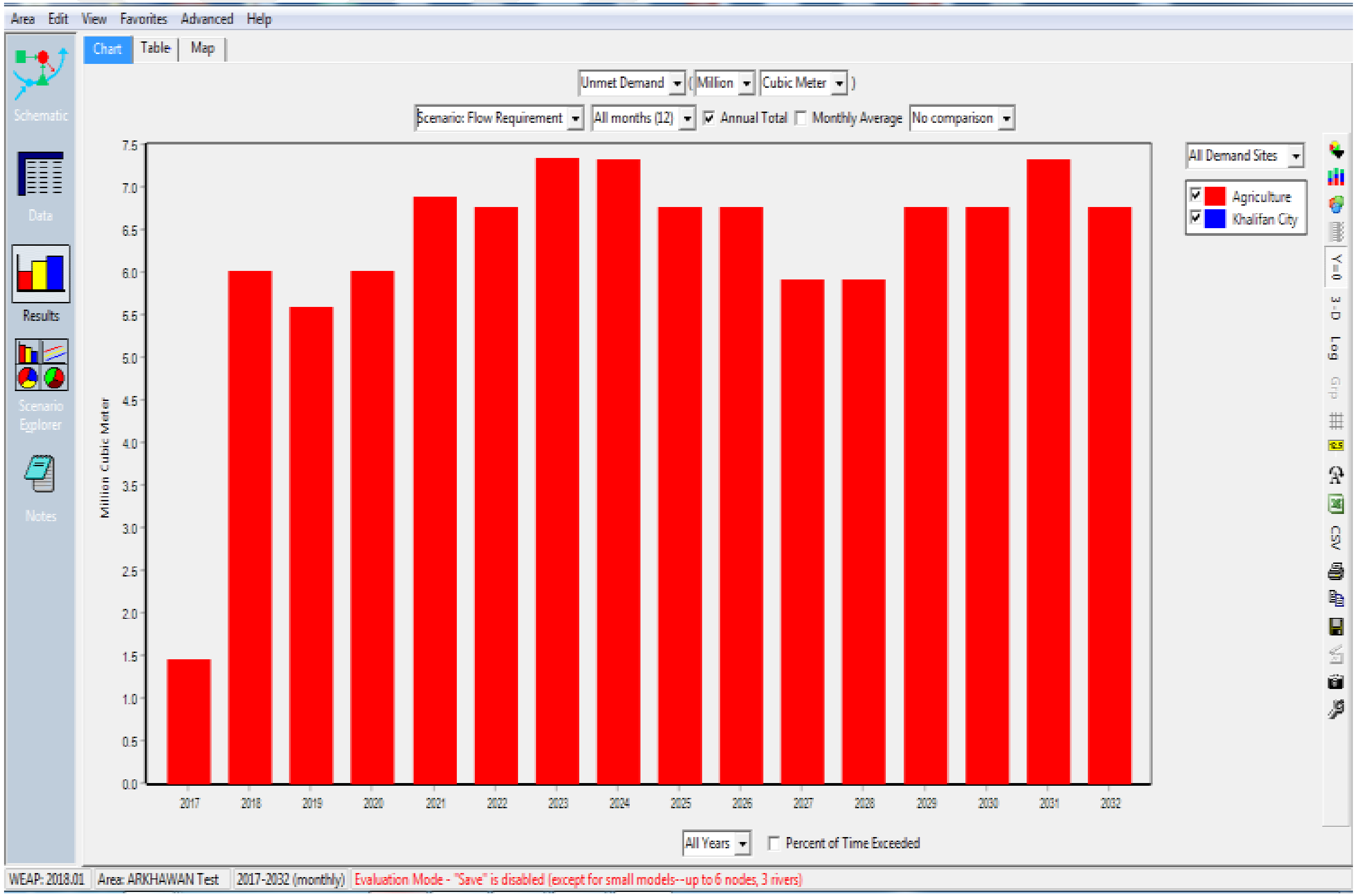


Figure 6.5 Flow requirement scenarios, yearly-unmet demand

The Figure 6.6 in flow requirement scenario, it shows monthly shortage demand. Also, demand water increase in April to September and other months is zero due to raining and snowing season. As seen the maximum water shortage is in September by the amount of 2.1 million cubic meters. Meanwhile, 2.1 million cubic meters of water reduced for agriculture, but for domestic, the demand is enough for daily life. For more detail, Tables and Figures see appendix E.

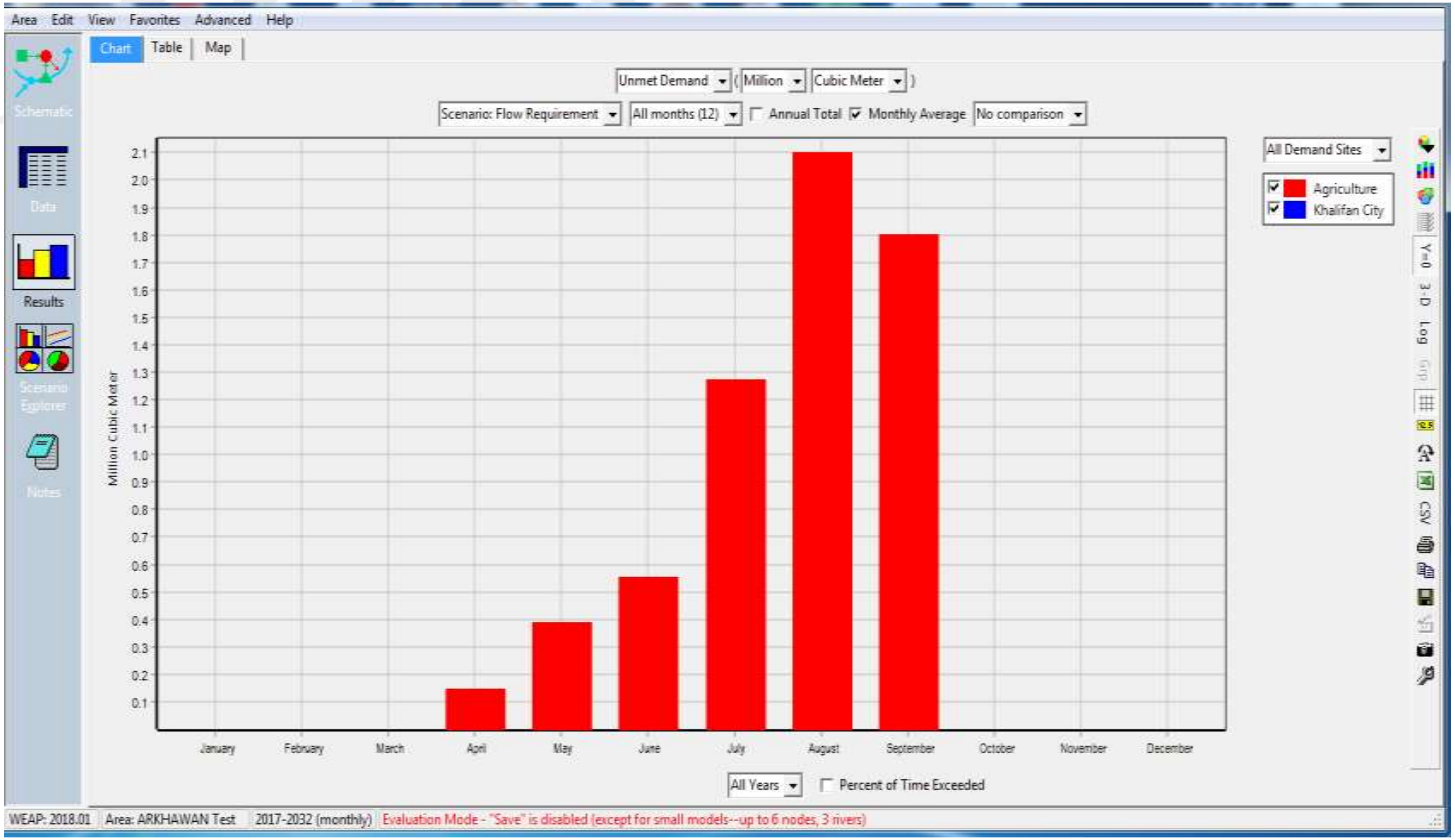


Figure 6.6 Flow requirement scenarios monthly-unmet demand

6.2.3 High population growth scenario

In this scenario, the rate of growth according to the ministry of planning is 3.4. After running the data, the result gave unmet demand. As seen in Table 6.5, the water demand is zero, but there is 8.707 million cubic meter shortage in the agriculture sector. Also, the water is not enough for supplying water in agriculture.

In high population growth scenario as shown in Figure6.8, there is water unmet for agriculture in each year 2017,2021, 2022, 2023, 2024 and 2031. According to Figure6.7 and 6.8, there is no water shortage for domestic demand in Khalifan watershed. The maximumdeficit will happen in 2023 and 2024. Therefore, the government proposes to construct a dam in 2025 to reduce that shortage which agriculture is facing in.

Also in the monthly flow requirement scenario, water shortage showed in July, August, and September. The maximum shortage is 275 thousand meters cubic, which happens in September, and the minimum shortage is 15 thousand meters cubic, which happens in July. In Appendix F, the study indicates more detail about this scenario.

Table 6.5 High population growth scenarios, unmet demand

Unmet Demand (Million Cubic Meter)

Scenario: Higher Population Growth | All months (12) | All Demand Sites | Annual Total | No comparison

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**Sum**
Agriculture	1.460	0.000	0.000	0.000	1.058	1.062	2.056	2.062	0.000	0.000	0.000	0.000	0.000	0.000	1.009	0.000	8.707
Khalifan City	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	1.460	0.000	0.000	0.000	1.058	1.062	2.056	2.062	0.000	0.000	0.000	0.000	0.000	0.000	1.009	0.000	8.707

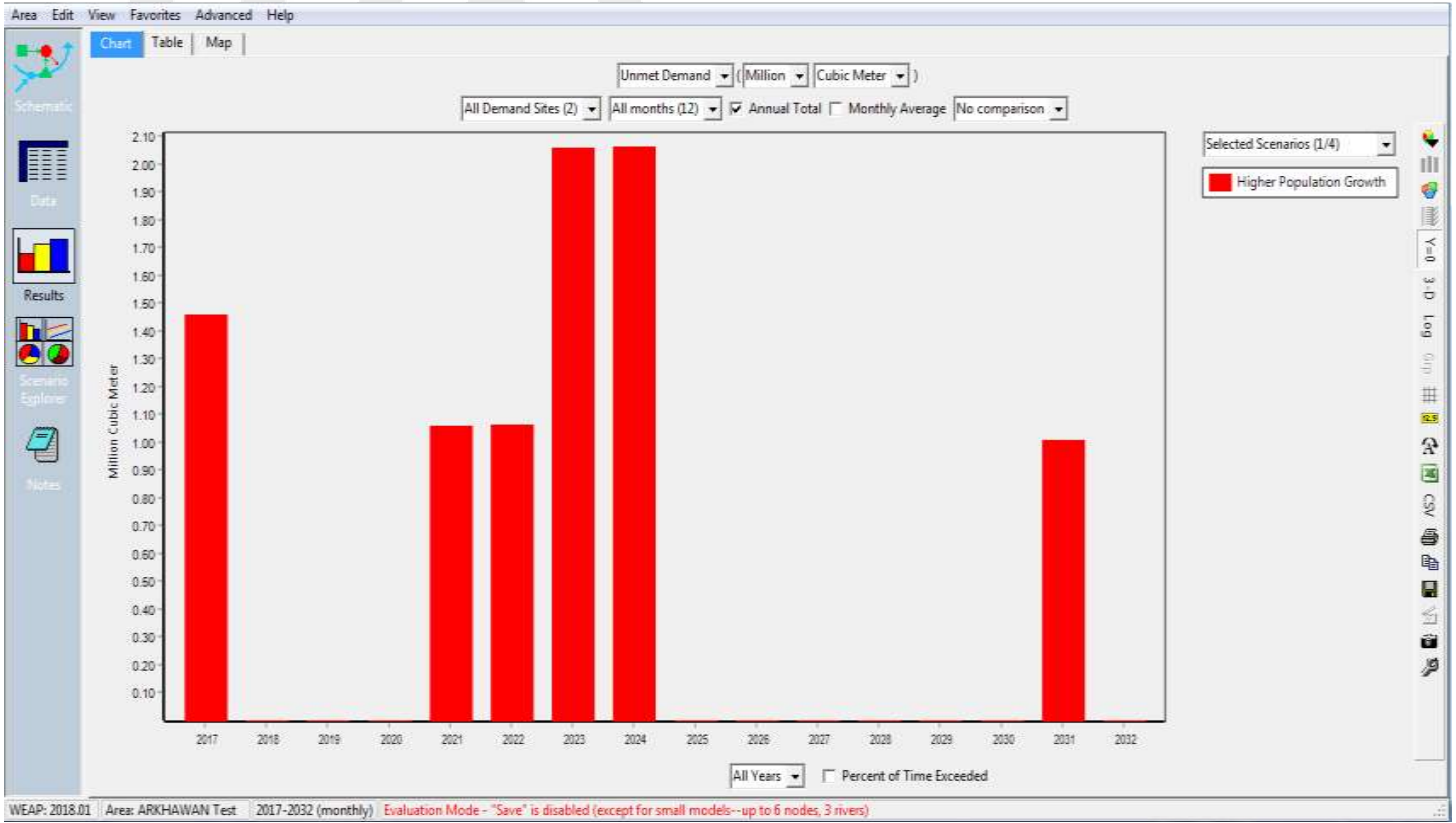


Figure 6.7 High population growth scenarios, unmet demand yearly

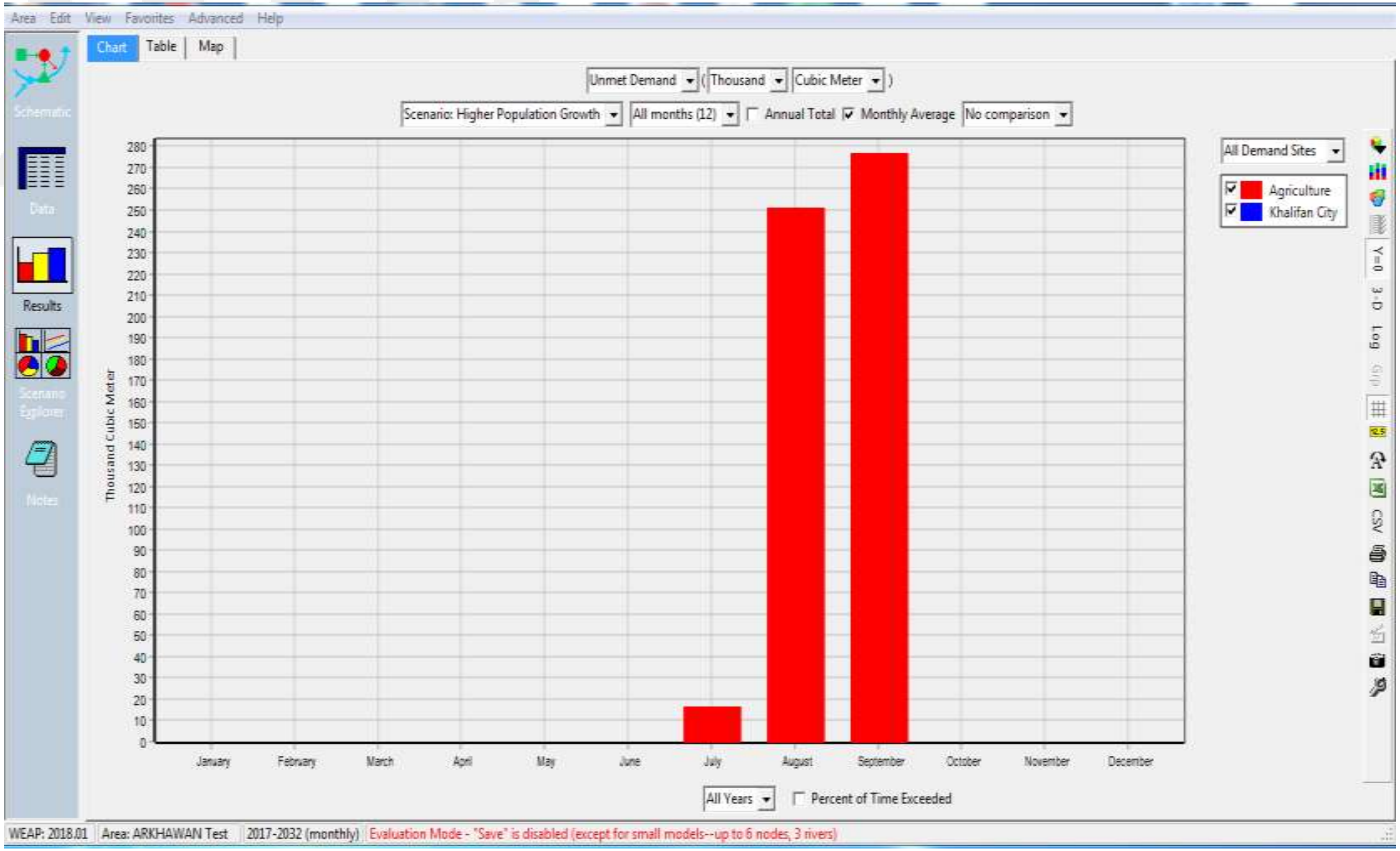


Figure 6.8 High population growth scenarios, unmet demand monthly

6.2.4 Scenario dam reservoir added

Gali-Ble dam designed by the Ministry of Water Resource, and the final design used in this scenario. Gali-Ble Dam store 1.8 million cubic meters at an elevation of 993 m, the height of the dam is 27m, freeboard is 2m. Table6.6 and Figure 6.9 shows (Elevation-Area-Storage).

Table 6.6 Elevation-area-storage for Ble dam reservoir

Elevation (m)	Area (m^2)	Storage (m^3)
961	0	0
965	1667	1689
971	18012	56652
977	47648	254160
981	71377	492888
987	115974	1059283
991	140519	1580169
993	151387	1875399

After designing the Ble dam for 2 million cubic meters, there is a shortageof water demand for agriculture in August and September. Moreover, the capacity of the dam which designed by the ministry of water resource is not enough for agriculture

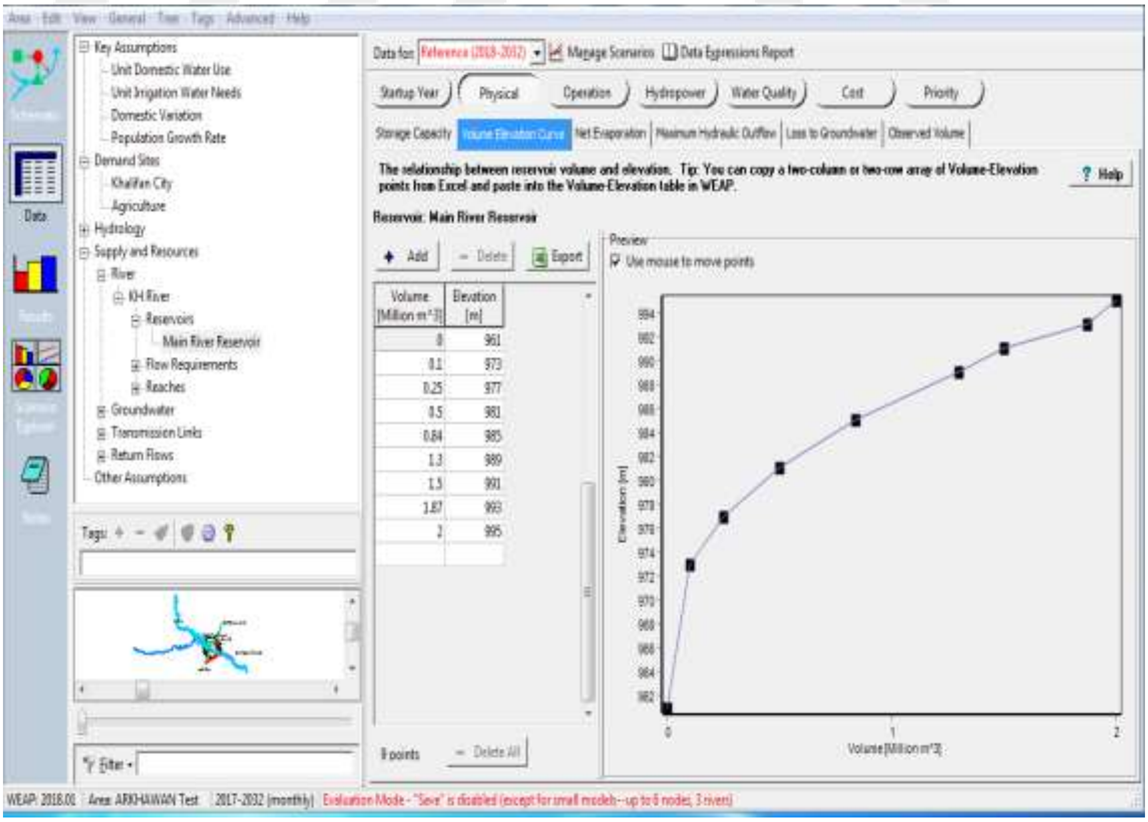


Figure 6.9 Elevation-area-storage for Ble dam

As seen in Figure 6.10 and Table 6.7, shows clearly water shortage in agriculture demand. In Table 6.7, there are water shortages in months that are August and September. A maximum shortage occurs in September by the amount of 100 thousand meters cubic due to no rain and uses water for agriculture. Moreover, beside the government proposed a dam with the capacity of around 2 million cubic meters with exist other sources such as river, springs and raining with snowing, there is a water shortage. However, the result shows that this capacity is not much enough for agriculture need may be adding to the 4 million meters cubic it will be better.

Table 6.7 Reservoir added scenario, unmet demand

Unmet Demand (Thousand Cubic Meter)

Scenario: Reservoir Added | All months (12) | All Demand Sites | Annual Total | Monthly Average | No comparison

	January	February	March	April	May	June	July	August	September	October	November	December	**Sum**
Agriculture	0.000	0.000	0.000	0.000	0.000	0.000	0.000	47.971	100.162	0.000	0.000	0.000	148.133
Khalifan City	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	47.971	100.162	0.000	0.000	0.000	148.133

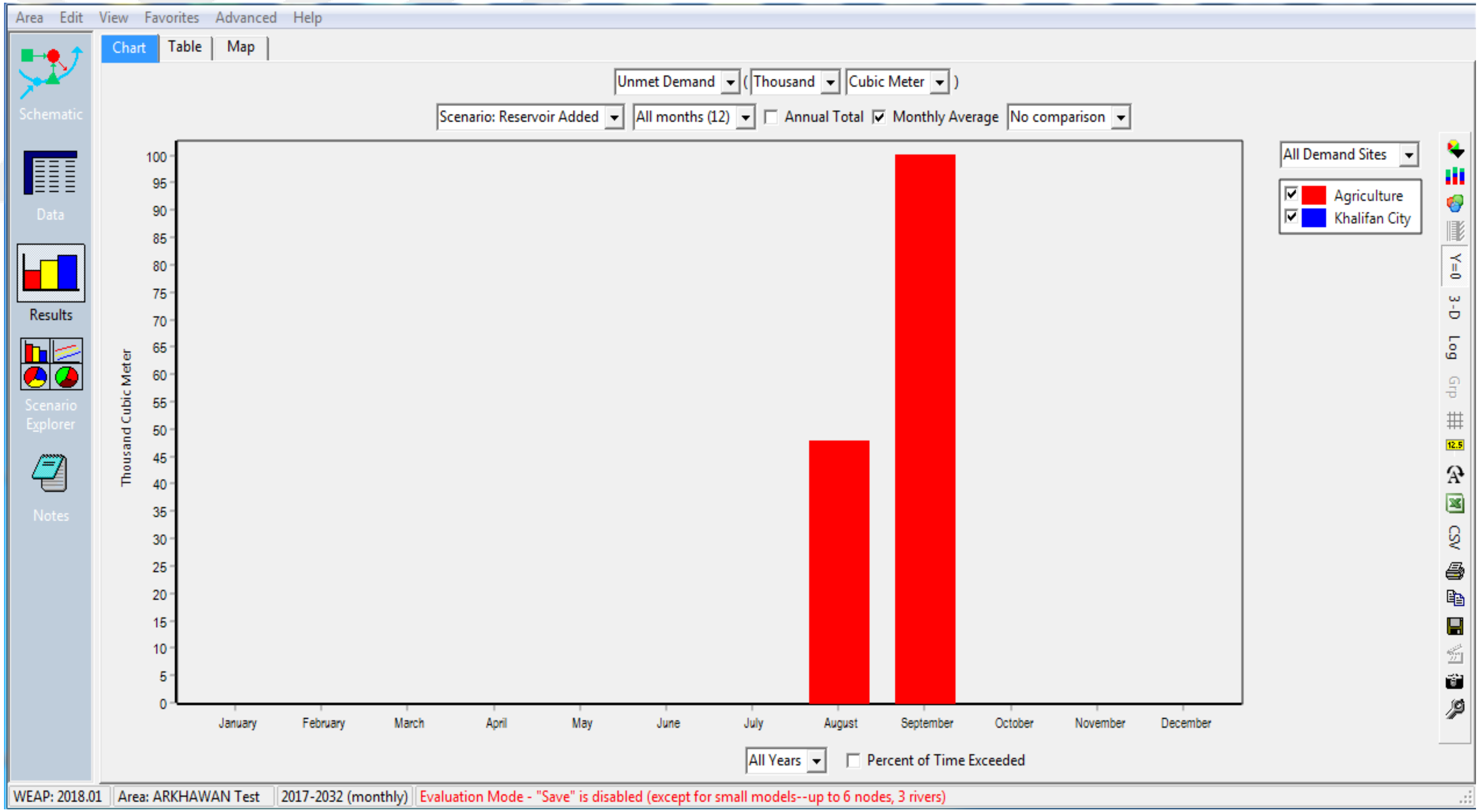


Figure 6.10 Reservoir added scenario, unmet demand monthly

In the Figure 6.11, there is water demand for agriculture, which is zero in January to March and from October to December zero due to the winter season and using less water for agriculture but starting from April to September, water demand is high due to agriculture season. Maximum water demand is 2.94984million cubic meters, which occurs in August, while the proposed dam only supplied 2 million meters cubic. Also, for domestic water demand maximum is 0.4733 million cubic meters and the minimum is 0.36978 million meters cubic, almost has the same level of water demand for each month. For more detail of the charts and Table, the study shows in appendix H.

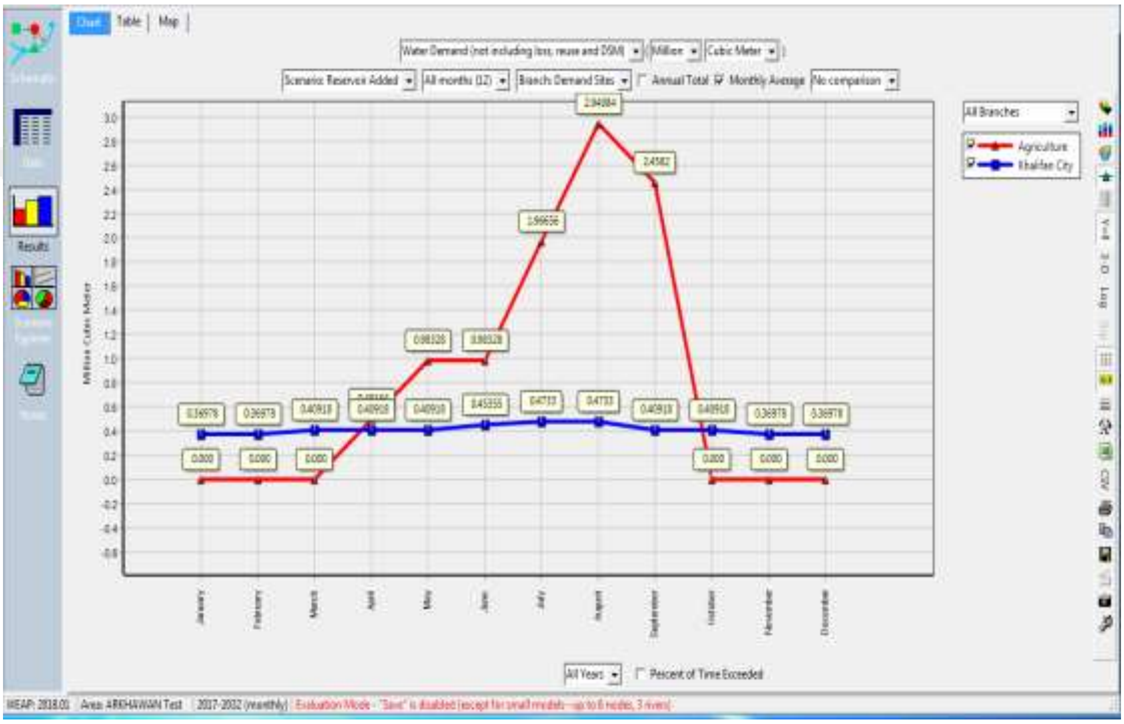


Figure 6.11 Reservoir added scenario, water demand monthly

6.2.5 Scenario water saving technology

In these scenarios, water evaluation analysis planning depends on reducing the water used by the agriculture sector using modern irrigation systems and use of advanced technology for the operating system as well as improving domestic water use networks by reducing the losses through different ways.

The purpose of saving and minimizing water usage is to reduce the cost of water used by water. Converting of old irrigation systems (open channels) to a modern irrigation system (sprinkler irrigation and drip irrigation) and installing a new irrigation system for farmers in the basin, and using farmers' guidance to cultivate minimal water consumption plants, and improved soil and tillage.

The decision to implement the irrigation rehabilitation project is often based on the economic aspect and reducing the amount of water used. However, there are indirect savings when added to the account can provide a complete picture of the return of real investment, as well as project expenses that must take into account.

1) Direct savings

The direct water saving amount through use of new irrigation system instead of irrigation by open canals, therefore the question will be answer during implement of water evaluation analysis planning

a) What is the reduction for water expected from a modern and more efficient irrigation system?
b) What is the amount of water available through replacing the irrigation system from open channels to sprinkler and drip irrigation systems where less water is required?

2) Indirect savings

The indirect of water saving include different types of water savings; the workers' savings is one of the indirect water saving.

a) By selecting the advanced irrigation system that automatically adjusts irrigation based on climatic conditions, this will remove the work required to reset the irrigation schedule manually and this cost, time and save the amount of water used.
b) Saving water through centralized control by the computer system, web browser and mobile device, you will spend many site visits to adjust or verify anything, large or small, which reduces the loss of water used.
c) There are saving water through maintenance of agriculture farmlands (weekly harvesting, edges, cut-off clearance, and seasonal enrichment) as well as by removing grasses where considered as a high-water consumption as part of conservation efforts and lead to saving water.

3) By crops type water savings

Provide plant type agriculture and plant cultivation is less water-resistant, drought-resistant and more economical (and is likely to see improvement in plant production) due to the use of a micro-irrigation system provided by a weather-based system. The total annual amount of water used by agriculture is 3500 cubic meter per hectare per year, but it is possible to reduce to 1842 cubic meter per hectare per year (MOA and WR, 2016).

6.2.5.1 Example for calculation of irrigation water supply

1- Direct saving of water supply amount for agriculture estimated by% 20
2- Indirect saving water supply for agriculture estimated by %10
3- Water supply saving by crop type estimated by % 5

Accordingly, the total water reduction ratio estimated by percentage 35 of the total amount of current water supply to the farmer lands by open irrigation canals.

$3500 - 3500 * 0.35 = 2275\ m^3 / ha$

It supposed to be use from the year 2020, as well as by the same reduction methods apply the system water reducing every five years 10 %. Therefore the agriculture water use in the year 2025 will reduce from 2275 m^3 / ha to 2047.5 m^3 / ha, and in the year 2030 will be 1842.75 m^3/ha as shown in Table 6.7.

The annual expansion of agriculture lands increased by 3.4%, according to the instruction of Directorate of agriculture in Khalifan district, and total agriculture lands in 2019 are 3100 ha (MOA and WR, 2016). Therefore, the whole agriculture land in the basin will be 4778 ha in the year 2032. Accordingly, the absolute annual water requirement estimate by 8.252 million cubic meters as shown in Table 6.7.

Table 6.7 Irrigation land and annual agriculture water requirements

Year	Annual land extend ratio years	Agriculture water demand m^3 /ha/ year	Irrigation land ha	Annual total agriculture water requirement million m^3
2019	0.034	3500	3100	10.850
Using scenario water saving technology				
2020	0.034	2275	3205	7.292
2021	0.034	2275	3314	7.540
2022	0.034	2275	3427	7.797
2023	0.034	2275	3544	8.062
2024	0.034	2275	3664	8.336
By the same reduction methods apply the system water reducing every five years by 10 %				
2025	0.034	2047.5	3789	7.757
2026	0.034	2047.5	3917	8.021
2027	0.034	2047.5	4051	8.021
2028	0.034	2047.5	4188	8.294
2029	0.034	2047.5	4331	8.294
By the same reduction methods apply the system water reducing every five years by 10 %				
2030	0.034	1842.75	4478	7.718
2031	0.034	1842.75	4630	7.981
2032	0.034	1842.75	4788	8.252

The agriculture land expansion per year interred to the model and as Figure 6.12.

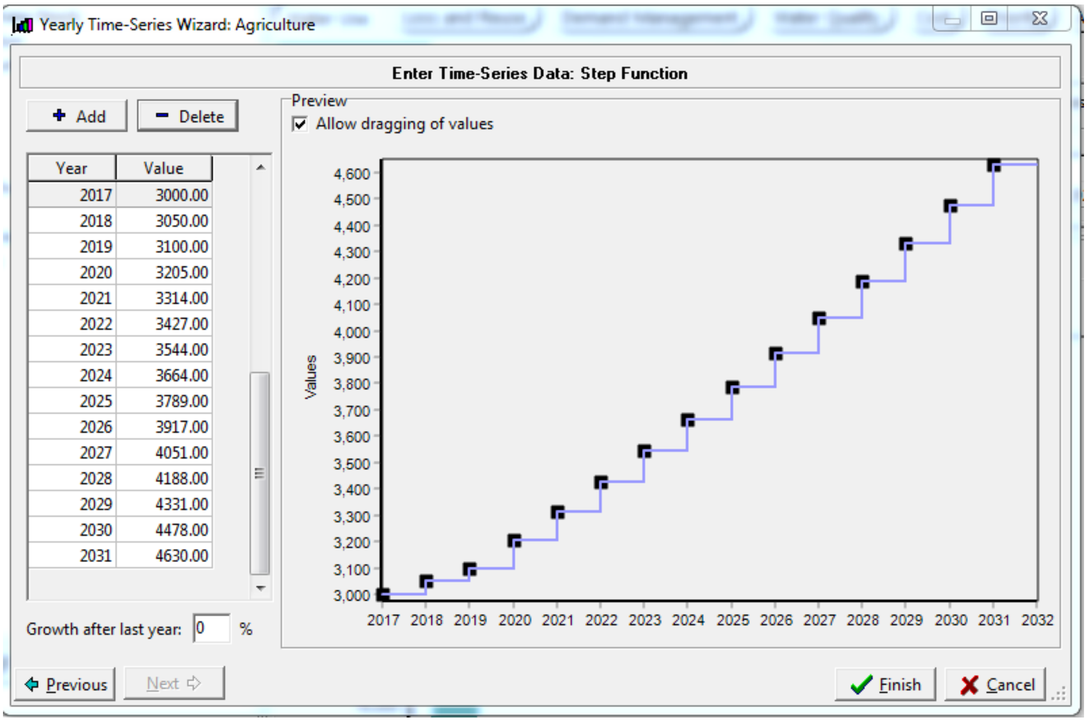


Figure 6.12 Yearly time series wizard agriculture

According to the model data entry, before the Figure 6.13 shows the unit irrigation water needs per year in the river basin.

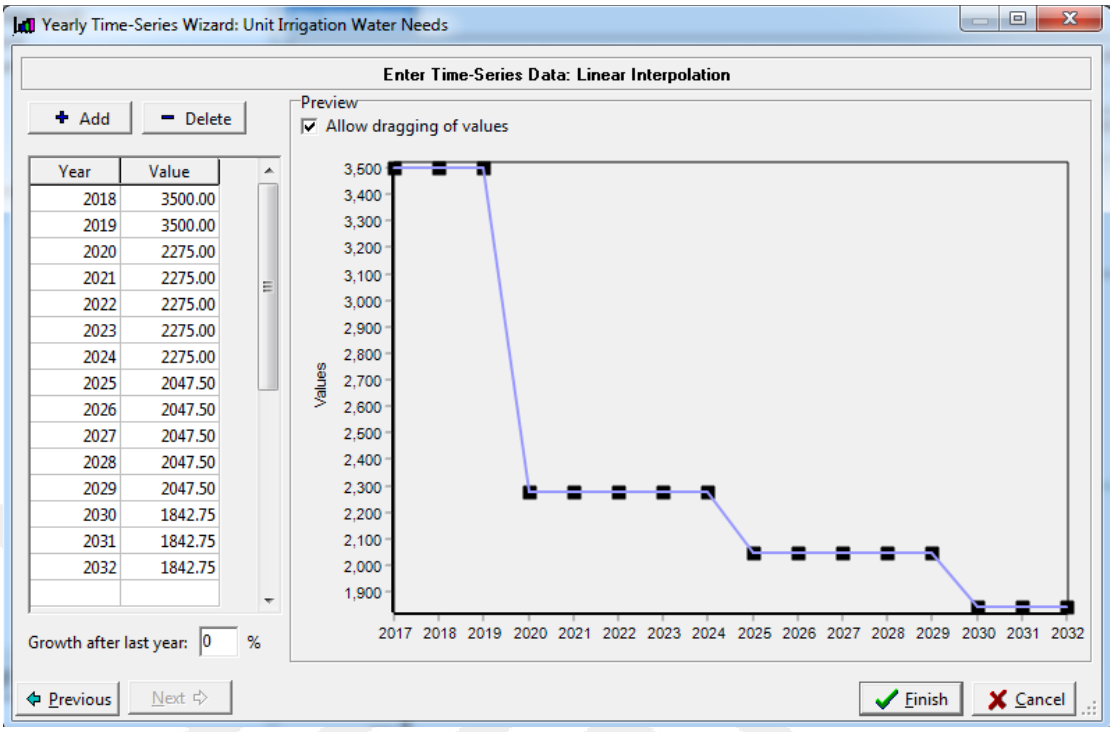


Figure 6.13 Yearly time- series wizard, unit irrigation water needs

6.2.5.2 Reducing domestic water use

Water uses by peoples, which requires the citizens, working for reducing it through several ways to save water. The critical way is water pricing when the water supply houses to be free without cost; it means that the value of the water unit is meager compared to the water supply project cost. Therefore leads to the use of large water quantities by the citizens, and thus the loss of a large amount of water through home connections to the main water network, as well as encouraging the illegal delivery of homes with the main water network and lead to a significant loss of water points. And therefore the inability to maintain and maintain water networks by the government and this leads to an increase in the amount of water supply per capita to more than 360 liters per person per day, and this amount is large compared to the amount of water used per capita in developed countries.

The domestic water use depends on the weather and air temperature, during the winter season, it is a minimum demand on the other hand during the summer season it is a maximum demand. Therefore, the domestic variation took to account and as the Figure 6.14.

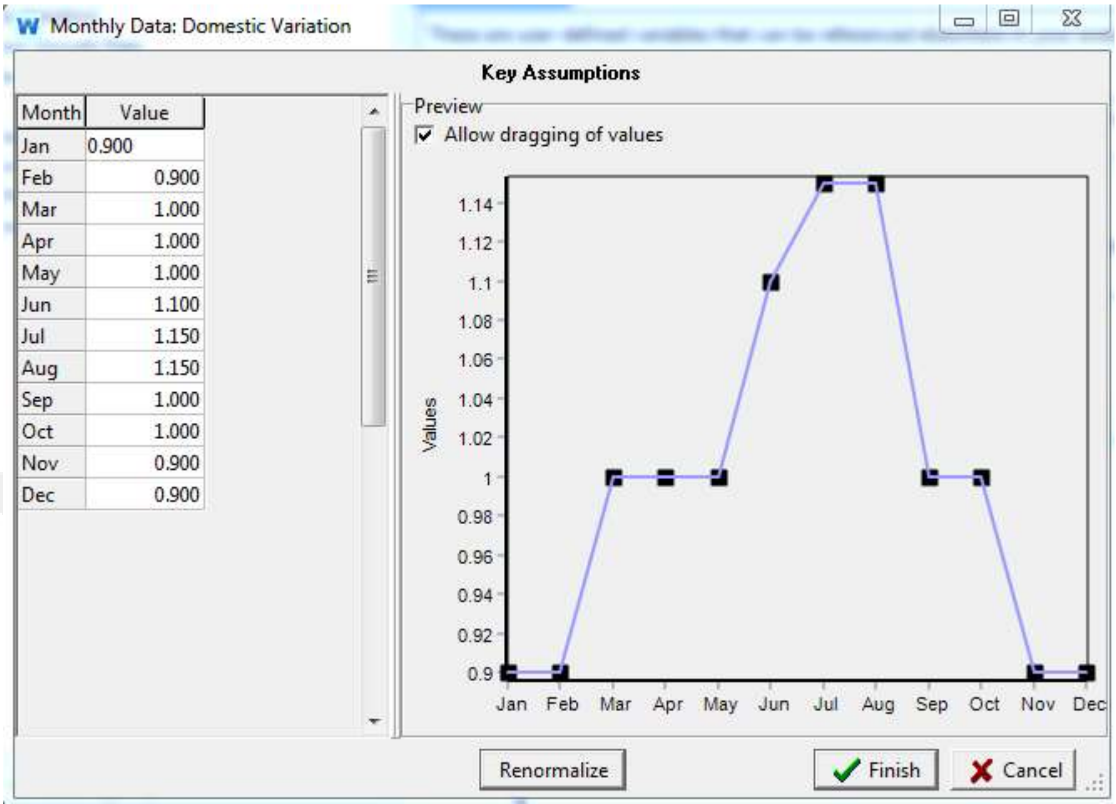


Figure 6.14 Household monthly data internal variation

The climate change influenced to the model and took to consider in the model through the relative inflow and as the Figure 6.15.

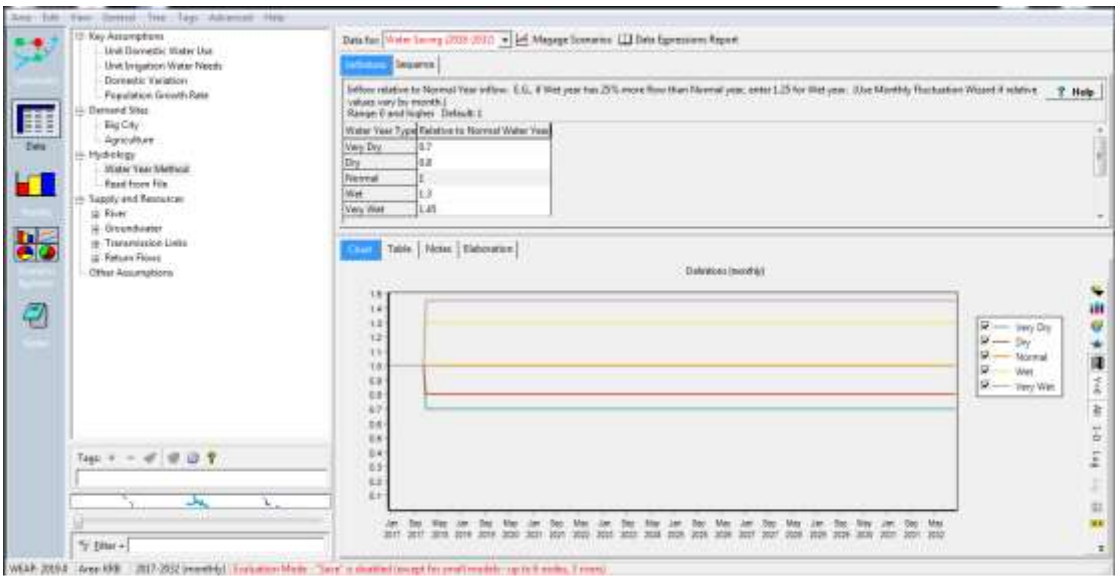


Figure 6.15 Climate change consideration during the model run period

6.5.2.3 Calculation for the reduce household water use

In this case, the water pricing leads to lower water uses per capita estimated by % 20. The maintenance of water supply projects from intake to the house connections also is part of reducing water losses method through several linkages in the system, take to the account of control continues to maintain of the system leads to lower the water supply liter per capita per day estimated by % 10. Another method for reducing water supply for domestic uses is through awareness of peoples, the increasing level of understanding the water supply cost and difficulties by peoples is essential and could be reduced the water supply by estimation ration around 5 %. The Total amount of water uses diminished by the above three methods estimated by (20 +10+5) %, which is equal to 35%, the amount of water supplied by the government to the cities around 360 l/c/d (MOM and T, 2016). Therefore reduced by 35% and the result are 234 l / c / d.

1- Through water price method reduce by % 20
2- Maintenance and losses, control in the water supply networks reduce by % 10
3- Trainings reduce by % 5

The total reduced ratio estimated by 35 percentage of the total amount of water supply.

360 – 360 * 0.35 = 234 l / c / d

and it is supposed to be used from the year 2020, as well as by the same reduction methods apply the system water reducing each 5 years 10 %, therefore water use by domestic in the year 2025 reduced from 234 l / c / d to 211 l / c / d and in the year 2030 will be 190 l / c / d.

The population growth is 3.4 % annually (MOP, 2016)

Table 6.8 Scenario of domestic water demand for water saving technology

Year	Annual growth ratio	KRB population	Water demand m^3 /cap/day	Annual unit domestic water use	Total demand m^3/cap/day	Domestic water requirement million m^3/year
2019	--	30091	0.360	131.4	11201	**4.09**
	Using scenario water saving technology					
2020	0.034	31114	0.234	85.41	7528	2.75
2021	0.034	32172	0.234	85.41	7784	2.84
2022	0.034	33266	0.234	85.41	8049	2.94
2023	0.034	34397	0.234	85.41	8323	3.04
2024	0.034	35566	0.234	85.41	8605	3.14
	By the same reduction methods apply the system water reducing everyfive years 10 %					
2025	0.034	38026	**0.211**	77.1	8023	2.93
2026	0.034	39319	0.211	77.1	8296	3.03
2027	0.034	40656	0.211	77.1	8578	3.13
2028	0.034	42038	0.211	77.1	8870	3.24
2029	0.034	43467	0.21	77.1	9128	3.33
	By the same reduction methods apply the system water reducing everyfive years 10 %					
2030	0.034	44945	0.19	69.35	8540	3.12
2031	0.034	46473	0.19	69.35	8830	3.22
2032	0.034	48053	0.19	69.35	9130	**3.33**

6.5.2.4 Result from model run

In this scenario, the rate of growth according to the ministry of planning is 3.4. After running data, as shown the Table 6.9 and Figure 6.16 the output results for monthly average demand sites are starting from 0.21 million cubic meter in January and increased to the maximum in August which is 3.84 million cubic meter .

Also according to the sum from average annual water demand the whole scenarios as seen in Table 6.9, the water saving scenario is less water demand compare to other scenarios which are 14.75 million cubic meter .

Table 6.9 Water demand, monthly average, and months

Water demand million cubic meter

Branch: Demand sites, monthly average, all, all months (12)

	J	F	M	A	M	J	J	A	S	O	N	D	Sum
Flow requirement	0.38	0.38	0.42	1.02	1.62	1.67	2.88	4.08	3.42	0.42	0.38	0.38	**17.05**
Higher population growth	0.42	0.42	0.46	1.12	1.79	1.84	3.18	4.51	3.77	0.46	0.42	0.42	**18.80**
Reservoir added	0.38	0.38	0.42	1.02	1.62	1.67	2.89	4.09	3.42	0.42	0.38	0.38	**17.07**
Water saving scenario	0.21	0.21	0.24	0.83	1.43	1.45	2.65	3.84	3.21	0.24	0.21	0.21	**14.75**

Also according to the result output, the average annual water demand for both sector agriculture and domestic is 18.8 million cubic meter for the high population growth scenario, therefore the comparison to the water saving scenario much more which is 14.75 million cubic meter.

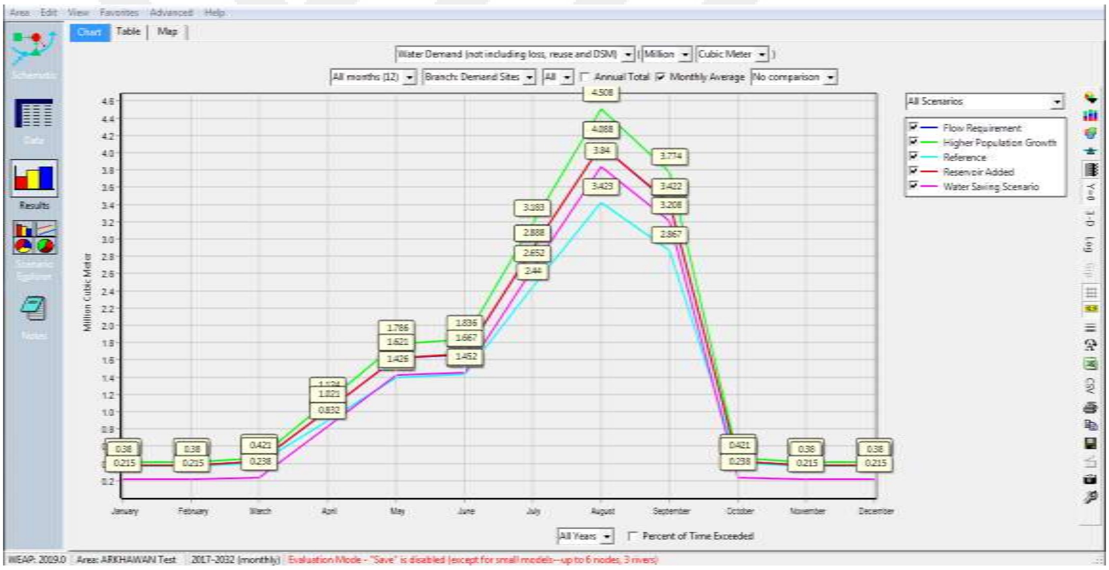


Figure 6.16 Water demand monthly

According to Table 6.10, the water-deficient for both sectors agriculture and domestic in water saving scenario result start from 1 million cubic meters during the year 2020 and arise to 3.26 million cubic meters in the year 2032. Therefore even the water saving technology cannot cover all basin demands, on the other hands by this scenario the government could be reducing the dam reservoir capacity from 4 million by two dams to 3.5 million cubic meter for cover hole basin demand up to the year 232 as seen in Table 6.10 and Figure 6.17.

Table 6.10 Water unmet demand monthly

	Unmet Demand (Million Cubic Meter)																
	Annual Total, All Demand Sites (2), All months (12)																
Scenario	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**Sum**
Flow Requirement	1.46	5.80	5.58	6.23	7.37	7.52	8.41	8.71	8.35	8.65	7.88	8.16	9.60	9.96	11.11	10.69	125.48
Higher Population Growth	1.46	0.00	0.00	0.00	1.43	1.64	3.17	3.51	1.13	1.52	0.15	0.41	2.59	3.05	5.09	4.03	29.18
Reservoir Added	1.46	0.00	0.00	0.00	0.00	0.00	0.61	0.70	0.00	0.08	0.00	0.00	0.65	0.74	2.60	0.98	7.81
Water Saving Scenario	1.46	1.34	0.99	1.09	1.21	1.34	1.48	1.63	1.78	1.94	2.11	2.29	2.49	2.73	2.99	3.26	30.13

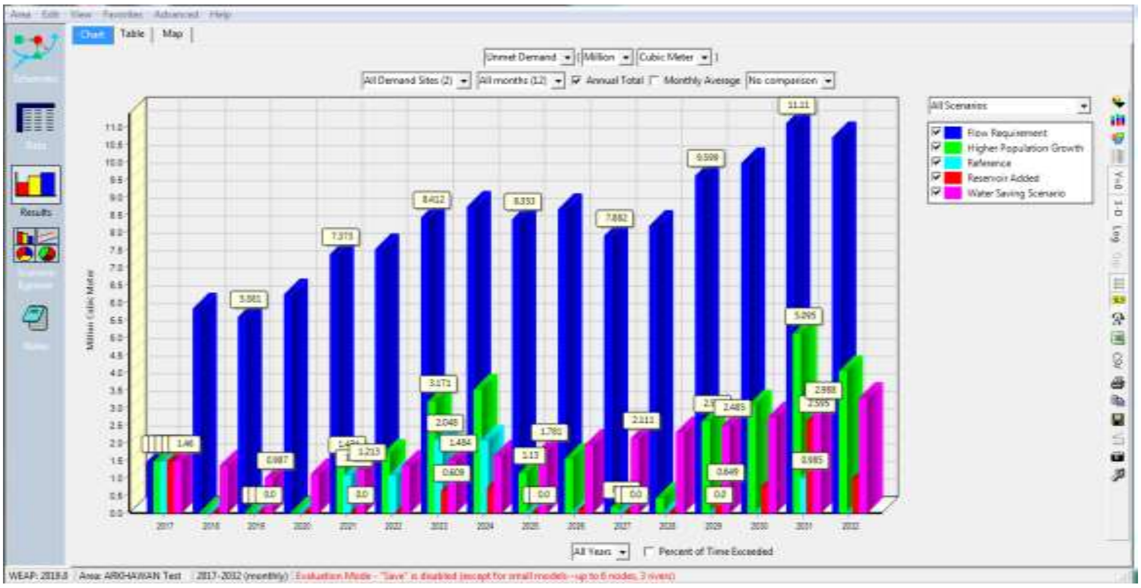


Figure 6.17 The unmet water demands, monthly average

CHAPTER 7

CONCLUSION AND RECOMMENDATION

7.1 Conclusions

According to the result, water demand annually in population growth scenario is 18 million cubic meters, which is, much more than another scenario due to high population growth rate and extends in agriculture land. On the other hand, in scenario water saving, the annual water demand is 14 million cubic meters, so the deference is 4 million cubic meters. However, total unmet water demand in flow requirement scenario, is about 125 million cubic meters accumulative for next 15 years. Meanwhile, unmet in scenario reference is much more than another scenario due to flowing water to Gali fall continuously and should be minimum 0.66 million cubic per second. Moreover, minimum water unmet in five scenario found in scenario dam added which is 7 million cubic meters.

In scenario reference, there is the most shortage of water because the scenario made based on the current situation, which is 2017. According to scenario reference, unmet demand is 6million cubic meters. In addition, in this scenario according to the model the study gave priority for domestic thus there is an only water shortage in the agriculture sector by the amount of 5 million cubic meters. However, in the scenario flow requirement, seen unmet demand for domestic is zero because the study gave priority to it. Thus in the agriculture sector, unmet demand is 100 million cubic meter. In addition, the result for unmet demand observes in 2023, 2024 and 2031 are 7million cubic meters. Moreover, in August water shortage for agriculture is 2 million cubic meters due to the summer season and more using water for agriculture.

According to the ministry of planning, the normal case 3.4 as a percentage of growth in population used by the study and the result shows that there is a shortage 8 million cubic meters only for agriculture. This amount came in the result of using water more for domestic rather than to another purpose. In addition, the area faced water shortage in the year of 2023 and 2024 because the dam has not yet constructed. In addition, the study observes water unmet more in summer season due to using water much more.

According to the design from the ministry of agriculture and water resources, dam capacity was 2 million cubic meter. Also, after running the model, the capacity was not enough to match water shortage especially in agriculture sector. Furthermore, the dam reservoir capacity should be more than 5 million cubic meters so the water supply will cover all the demands. After running fifth scenario (water saving scenario), the study found water saving by 3 million cubic meters. Moreover, in the dam added scenario the study shows a shortage in water demand for agriculture about 148thousand cubic meters annually. In addition, Ble dam is necessary to be constructing due to the tourism area and the dam using for collecting water in winter season and release it in dry season.

The water shortages in scenario reference are happening only in agriculture, which mean in scenario reference water is enough for domestic water but agriculture is not fitting. Moreover, in the agriculturesector, about 540 thousand cubic meters is less than total demand. More information detailed shown in the Figures Appendix D.

Figure 7.1 in decade the monthly water balance in the Khalifan river basin. In January, water inflow to the river is 198 thousand cubic meter while the output is 314 thousand cubic meter, due to raining season. Moreover, in the study observed that in winter and spring inflow is close to outflow because decreasing of water in, all site demand while in summer inflow is more than outflow. In addition, in August, inflow water is 1 million cubic meters but the outflow from the river is 487thousand cubic meter because the inflow is equal to the outflow plus demand. Meanwhile, in the summer season the water demands are very high that is causes to reducing the outflow from the river basin, which is using for tourism sector

Moreover, in Figure 7.2 indicate that maximum inflow in 2017 is 14 million cubic meters, but outflow is only 5 million cubic meters due to miss managing water resources and loss cause outflow less than other years. Within passing years, the Figure shows decrease in inflow for all demand and outflow almost is at the same level. Although, amount of water to be used some, amount of water available will decrease.

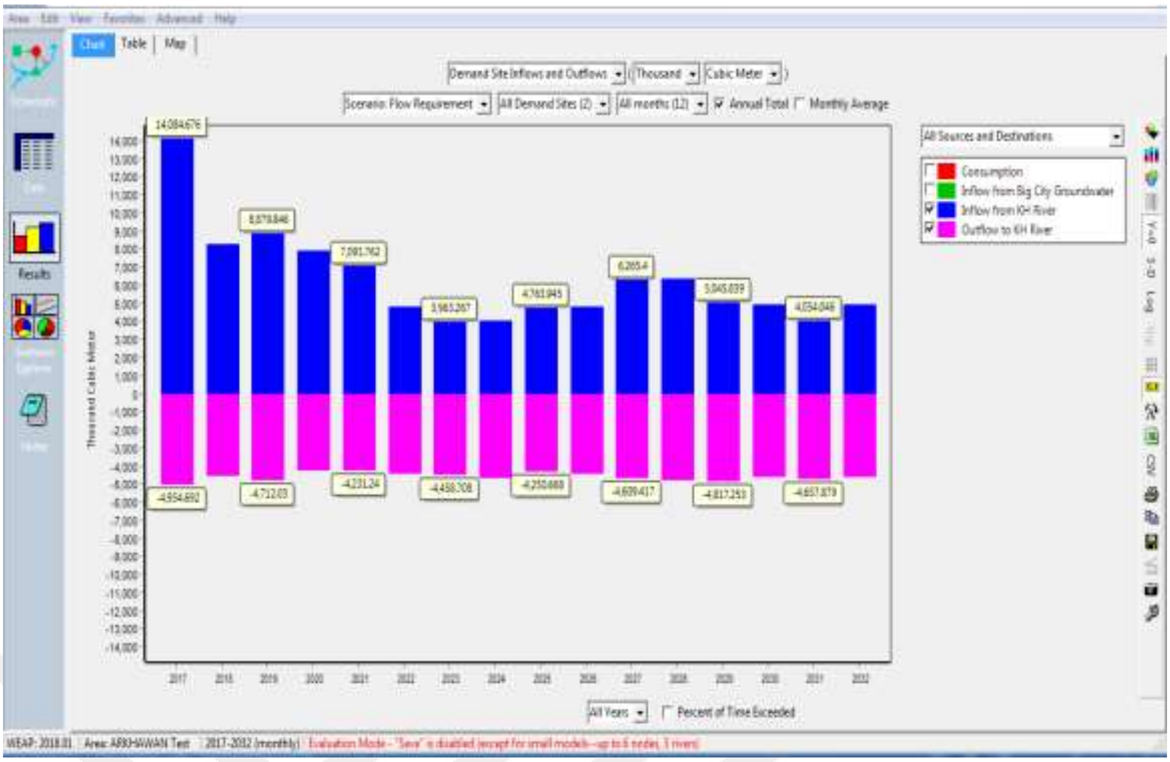


Figure 7.1 Annual river basin inflow and outflow

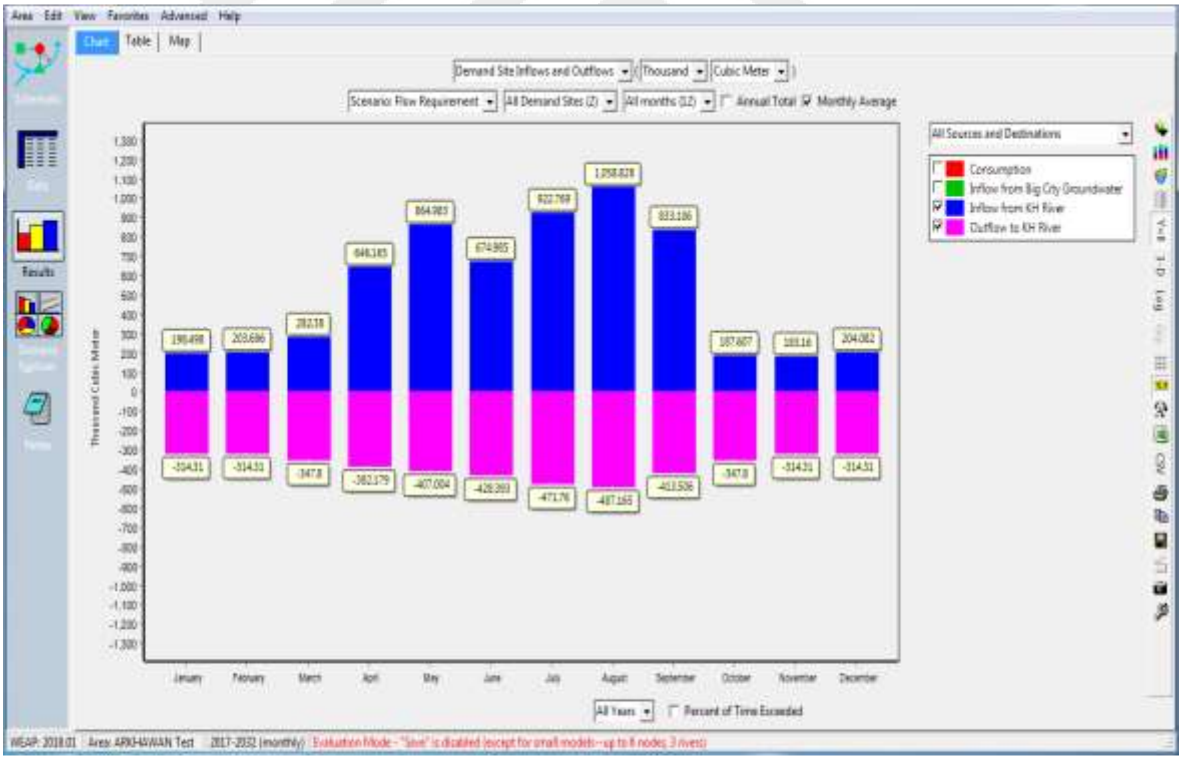


Figure 7.2 Monthly river basin inflow and outflow

Furthermore, the study concludes, in the winter season the maximum water supply about 0.46 million cubic meters in March, which cover all water the demands due to low water requirements, but in the summer season due to high water required which is about 4.5 million cubic meters in August, therefor the water availability cannot cover all demands. Thus, constructing the dam is necessary to integrated water resources management. The problem of drought is still standing in some villages, especially those that situated on high lands and those situated at long distances from the main river. Construction of a dam above Zelakan and Bla solves the problem of water shortage during the summer season as seen in Figure 7.3 and Figure 7.4.

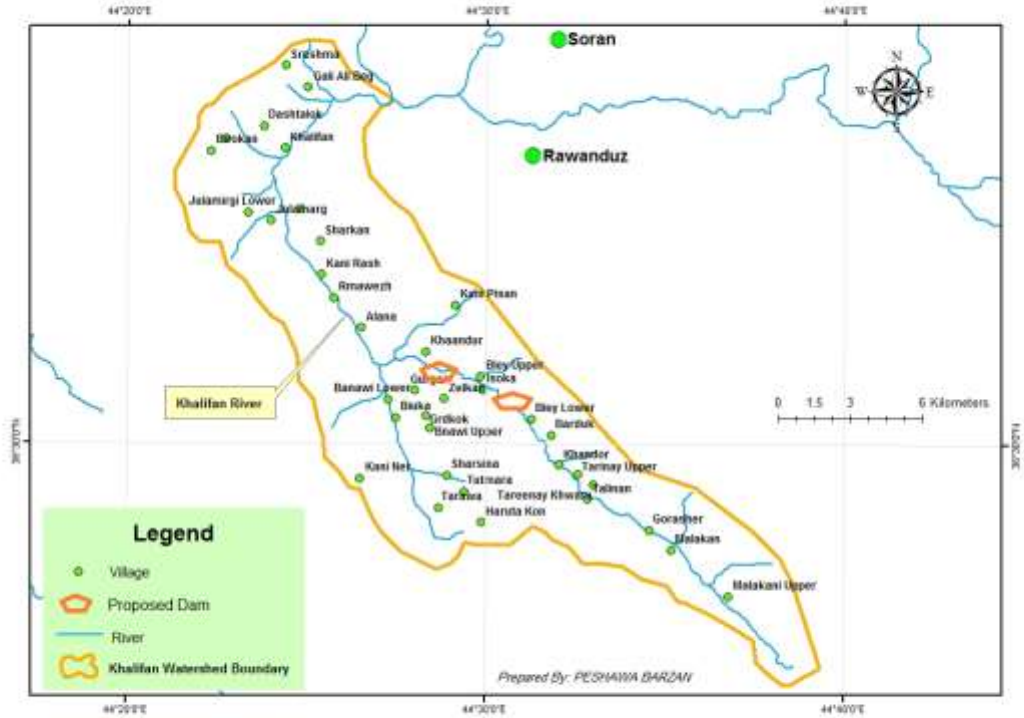


Figure 7.3 Exist planed and proposed dam

Figure7.4 Location of planned dams and recommended dams

Also according to scenario water saving the result output, the average annual water demand for both sector agriculture and domestic is 14 million cubic meters. On the other hand, the amount of the water in water saving scenario result was 4 million cubic meters less than the amount of water in high population growth scenario, which is 18 million cubic meters. This is, establishing the water saving scenario by the government is able to save annual amount 4 million cubic meters.

In addition, according to the laboratory result, on the top of the basin from the village of Ble to Malakan there is no water pollution in the main river, which is the number of E.coli is zero but after Ble village, the number of E.coli increased to16.

The study has shown that most of the villages in the upper part of the basin face the problem of drought regarding to the agriculture used on the other hands the water quality BOD 4.5 mg/l, which considered moderately clean under the standard range.

7.2 Recommendations

From the finding of the present research, some recommendations are listed follows:

1. In scenario dam added, due to unmet demand for the different users in future, the study recommend constructing of two dams on the upstream of Zelakan and Ble villages to store 4 million cubic meters water during the winter season and release it in dry season to control the water flow and continuing supply water to the users. While in scenario saving water, the study shows water saving by amount of 3 million cubic meters. The study recommends constructing at least one dam because in winter season the demand for agriculture closed to be zero while in summer season will be 3500 cubic meter / ha and the domestic water required is around 200 l/c/day, while in summer reach to 360 l/c/day is too high.
2. By setup system of water saving technology, the result is save amount of3 million cubic meters per year. This will be done by converting of old irrigation systems (open channels) to a modern irrigation system (sprinkler irrigation and drip irrigation) and installing a new irrigation system for farmers in the basin, and also using farmers' guidance to cultivate minimal water consumptions plants, and improved soil and tillage. By apply this steps the water saving estimated by 35% for both sectors agriculture and domestics

3. Currently, the T.H in the river closed to Khalifan city is 188 mg/l is too high and the BOD is 8.42 mg/l also is out of the standard quality therefore the study recommended to construct a wastewater treatment. The wastewater directly flow rated into the environment, either to rivers through surface gullies or to the aquifer. The two types of a wastewater network collecting both grey and black waters will lead to a wastewater treatment plant where the wastewater will treat. A storm water network is collecting runoff water generated by rainfall and discharging it, without treatment, to the natural channels and rivers.
4. Due to high erosion in Sreshma sub catchment's and sedimentation in to the out let of the river basin, the study recommends constructing network for storm water in the right bank of Khalifan. In addition, wastewater treatment network from the entrance of each villages to controlling the water qualities.
5. The water pricing is considering as an essential subject for the community. The government should make some suitable price for water using, so can save water for future and reduce some shortage in the area. The target is to reduce per capita demand from 365 l/d to 190 l/day. And it can save amount 3 million cubic meter in a year at the end of study plan 2032
6. Better coordination between the ministry of municipality and tourism and the governorates for implementation of the projects can lead the priorities to the wastewater project and irrigation projects in the basin.
7. Install of pump stations to lift water to the highlands of Ble Khuaru, Binawi, Sharkan and the lower Jolamerg to extend 120 ha agriculture lands.
8. Training courses to offer extensions to farmers about the scientific basis of the amount of applied water and time of irrigation are essential.
9. Reduce of evaporation through using of mulches. This will prevent direct exposure of the soil surface to direct sunlight and lower the soil profile temperature during the hot months of the summer season. Specially in the upper part of the basin which consist of high step sloops land
10. The lining of the 12 existing earth canals where irrigate the 500 ha of agriculture lands to reduce water losses due to seepage and save annul amount of water 0.613 million cubic meters.
11. Install of 12 gauge stations at different locations along the main river to collect information of the amount of water that enters and leaves the area under study continuously.

12. Clearance of the main river required by the villager during the study field trips and recommended with removing plant debris, growing plants and floating the arterials that offer resistance to the flow of water and will lead to a lower amount of water loss due to seepage.
13. The study found that the basin is faced many problems regarding to laws and regulations, there for the establish set of regulation required to reduce the hazard of pollution of the available sources of water, water rights and distribution of water among the farmers.
14. For better resources, management government should take some steps. Establishing a ministry of water resources was impressive in 2006. The water resource ministry worked for a short year, due to election and structure new government some ministries including the ministry of water resources cancelled and combined with the ministry of agriculture. Ministry of water resources had many departments in every cities and district. The main work in this ministry was about water project with working for professional staff. After combining water, resources became the second target for this ministry.
15. The point is the government should first establish the ministry of water resources in the north of Iraq as previously. Extend ministry such open departments including the production of researcher, reporter, website and statistics staff. Producing such department like researcher or reporter, government including communities can get information about water resources even they do not have high education. With this ministry, the government could inform farmer and communities about the state of water resources in the current situation in the north of Iraq.

REFERENCES

Abawi, S.A.and Hassan, M.S. (1990).Environmental engineering, water analysis, DarAlhikma, 296.

Agarwal, A., Delos Angeles, M. S., Bhatia, R., Chéret, I., Davila-Poblete, S., Falkenmark, M., and Rees, J. (2000).Integrated water resources management.Global Water Partnership.

Al-Ansari, N. (2013). Management of water resources in Iraq: perspectives and prognoses.*Engineering*. 5**(6),** 667-684.

Amahmid, O., Asmama, S., and Bouhoum, K. (1999).The effect of wastewater reuse in irrigation on the contamination level of food crops by Giardia cysts and Ascaris eggs.*International Journal of Food Microbiology*, 49(**1-2**), 19-26.

APHA, (1989).Standard methods for the examination of water and wastewater. Arner. Public Health Association. 17th edition. Ashington. 2005.

Asselman, N. E. (1999). Suspended sediment dynamics in a large drainage basin: the River Rhine. *Hydrological Processes*, 13**(10),** 1437-1450.

Basnyat, P., Teeter, L. D., Lockaby, B. G., and Flynn, K. M. (2000). The use of remote sensing and GIS in watershed level analyses of non-point source pollution problems. *Forest Ecology and Management*, 128(**1-2**), 65-73.

Bateman, B. O., McIntosh, B., Paige, S., Foster, E., and Mucken, A. (2011).Oregon's integrated water resources strategy.The Oregon Water Conference.

Biswas, A. K. (2004). Integrated water resources management: A reassessment: A water forum contribution. *Water International*, 29(**2**), 248-256.

Boxall, J. B., O'Hagan, A., Pooladsaz, S., Saul, A. J., and Unwin, D. M. (2007). Estimation of burst rates in water distribution mains. *In Proceedings of the Institution of Civil Engineers-Water Management* 2 (**160)**, 73-82.

Campbell, L. K. 2006. Civil society strategies on urban waterways: Stewardship, contention, and coalition building (Doctoral dissertation, Massachusetts Institute of Technology).Available at: file:///C:/Users/PC-DIYAR/Downloads/123897214-MIT.pdf Accessed 12. 9.2018

Corcoran D.B. (2010). Sick water. The central role of wastewater management in sustainable development: a rapid response assessment. UNEP/Earth print. Birkel and Trykkeri AS, Norway.

DAE. (2016). Agricultural land and product annual report. Directorate of Agriculture-Erbil. Unpublished Report.

Gupta, D. A., Singh Babel, M., Albert, X., and Mark, O. (2005).Water sector of Bangladesh in the context of integrated water resources management: A review. *International Journal of Water Resources Development*, 21(**2**), 385-398.

Davis S.N. and Dewiestn R.J.M., 1966.Hydrogeology.John Wiley and Sons.Inc.NewYork.463.

Delipınar, Ş and Karpuzcu, M. (2017).Policy, legislative and institutional assessments for integrated river basin management in Turkey. *Environmental Science and Policy*, 72, 20-29.

Denny, E., Donnelly, K., McKay, R., Ponte, G., and Uetake, T. (2008).Sustainable water strategies for Jordan. International Economic Development Program, Gerald R. Ford School of Public Policy, University of Michigan: Ann Arbor.

Derever J.F., (1982). The geochemistry of natural water. Prentice -Hall. Inc., N.J., U.S.A.

DES, U. (2013). World economic and social survey 2013: sustainable development challenges. United Nations, Department of Economic and Social Affairs, New York.

DIE. (2016). Water resource and irrigation annual report. Directorate of Irrigation-Erbil. Unpublished Report.

DME.(2016). Annual report- meteorology data record.Directorate of Meteorology-Erbil. Unpublished Report.

Draper, A. J. (2001). Implicit stochastic optimization with limited foresight for reservoir systems: University of California, Davis.

Eriksson, E., Auffarth, K., Henze, M., and Ledin, A. (2002).Characteristics of grey wastewater. *Urban Water*, *4*(**1**), 85-104.

Fawell, J., and Nieuwenhuijsen, M. J. (2003).Contaminants in drinking water environmental pollution and health. *British Medical Bulletin*, 68(**1**), 199-208.

Foster, S., and Lawrence, A. (1995). Groundwater quality concerns in Asian cities, UNEP-UNESCO scope groundwater pollution workshop. Beijing -China.

Fulazzaky, M. A. (2014). Challenges of integrated water resources management in Indonesia. *Water*, 6(**7**), 2000-2020.

Gasperi, J., Garnaud, S., Rocher, V., and Moilleron, R. (2008). Priority pollutants in wastewater and combined sewer overflow. *The Science of the Total Environment*, *407*(**1**), 263-272.

Gleick, P. H. (1993). Water and conflict: Freshwater resources and international security. *International Security*, *18*(**1**), 79-112.

Gray, N. F. (1997). Environmental impact and remediation of acid mine drainage: a management problem. *Environmental Geology*, 30(**1-2**), 62-71.

Grey, D., and Sadoff, C. W. (2007). Sink or swim? Water security for growth and development. *Water Policy*, *9***(6)**, 545-571.

Grischuk, T., Nestler W., Piechniezek, D., and Fisher, T. (1996) .Urban groundwater in Dresden, Germany, *Hydrology Jour*. (**4)**, 48-63.

Hammer, M.J. (1986) .Water and wastewater technology, 2ndedition, JohnWiley, and Sons. U.S.A., 536.

Harrington, J. F., Noy, D. J., Horseman, S. T., Birchall, D. J., and Chadwick, R. A. (2009). Laboratory study of gas and water flow in the Nordland Shale, Sleipner, North Sea.

Heshmati, A, and Khayyat, N. T. (2012). Socio-economic impacts of landmines in Southern Kurdistan. Cambridge Scholars Publishing.

Helmer, R., Hespanhol, I., and World Health Organization. (1997). Water pollution control: a guide to the use of water quality management principles.

Huang, W. C. and Yuan, L. C. (2004).A drought early warning system on real-time multi reservoir operations. *Water Resources Research*, 40(**6**).

Ismael P., J. (2013). Determining the hydrological characteristics of the greater Zab river basin by GIS, Unpublished MSc. Thesis, and University of Gaziantep.

Jain, S. K. and Singh, V.P. (2003). Water resources systems planning and management, Elsevier, Amsterdam-Boston

Jakeman, A. J, and Letcher, R. A. (2003). Integrated assessment and modelling: features, principles, and examples for catchment management. *Environmental Modelling and Software*, 18(**6**), 491-501.

Jamieson, D. G., and Fedra, K. (1996).The ‘Water Ware ’decision-support system for river-basin planning.3. Example applications.*Journal of Hydrology*, 177(**3-4**), 199-211.

Jaspers, F. G. (2003). Institutional arrangements for integrated river basin management. *Water Policy*, 5(**1**), 77-90.

John, Dore; Louis, Lebel; and Francois, Molles.(2012). A framework for analyzing transboundary water governance complexes illustrated in the Mekong Region. *Journal of Hydrology*. 466–467, 23–36

Karpuzcu, M., Gürol, M. D., and Bayar, S. (2009). Transboundary waters and Turkey. Gebze: Institute of Technology, Department of Environmental Engineering.

Khaleel, A, Ngah, Ossman, and T., I (2011). Distribution and spatial arrangement of the rural population in Shaqlawa district, Kurdistan region-Iraq. *Journal of Geography and Regional Planning*, 4(**16**), 785.

Kibaroglu, A., and Scheumann, W. (2013).Evolution of transboundary politics in the Euphrates-Tigris river system: New perspectives and political challenges. Global Governance: *A Review of Multilateralism and International Organizations*, 19**(2)**, 279-305.

Kumar, B, Sriwastava, S.P, and Seth, D.K. (2010). The Krishna water dısputes trıbunal wıth the decision. New Delhi, (**1**), 1-213.

Labadie, J. W. (2004). Optimal operation of multireservoir systems: a state-of-the-art review. *Journal of Water Resources Planning and Management*, 130(**2**), 93-111.

Lee, R., (1970). Theoretical estimates versus forest water yield. *Water Resources Research*, 6(**5**), 1327-1334.

Lehner, B., Verdin, K., and Jarvis, A. (2008). New global hydrography derived from space borne elevation data. *Transactions American Geophysical Union*, 89**(10)**, 93-94.

Linkov, I., Bridges, T., Creutzig, F., Decker, J., Fox-Lent, C., Kröger, W., and Nyer, R. (2014). Changing the resilience paradigm.*Nature Climate Change*, 4(**6**), and 407.

Lins, H. F., and Cohn, T. A. (2011). Stationarity: Wanted dead or alive. JAWRA *Journal of the American Water Resources Association*, 47(**3**), 475-480.

Liu, J., and Savenije, H. H. (2008).Food consumption patterns and their effect on water requirement in China.*Hydrology and Earth System Sciences Discussions*, 12(**3**), 887-898.

L'vovich, M. I., (1979). World water resources and their future. Original in Russian.English translation, American Geophysical Union, Washington, D.C.

Malczewski, J.(2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning*,62(**1**), 3-65.

Mant, J., and Janes, M. (2005).Restoration of rivers and floodplains. *Restoration Ecology: The New Frontier*, 141-157.

Giordano M, Drieschova A, Duncan JA, Sayama Y, Stefana L, and Wolf AT (2013). International environmental Agreements politics and economics. *A Review of the Evaluation and State of Transboundary Fresh Water*. *Journal of Springer* 2(**13**).

McCaffrey, S. (1998).The UN Convention on the Law of the Non-Navigational Uses of International Watercourses: prospects and pitfalls. *World Bank Technical Paper*, 17-28.

Ministry of Municipality and Tourism Water Balance and Management Report - **(1-2**) – March 2016 Unpublished Repot

MOA and WR. (2016). Water resource annual report. Ministry of Agriculture and Water Resource. Unpublished report.

MOA and WR. (2016). Water resource annual report. Ministry of Agriculture and Water Resource. Unpublished report.

Moghaddam, V. K., Changani, F., Mohammadi, A., Hadei, M., Ashabi, R., Majd, L. E., and Mahvi, A. H. (2017).Sustainable development of water resources based on wastewater reuse and upgrading of treatment plants: a review in the Middle East. *Desalination and Water Treatment*, 65, 463-473.

Molle, F., and Mollinga, P. (2003).Water poverty indicators: conceptual problems and policy issues. *Water Policy*, 5(**5-6**), 529-544.

MOM and T. (2016).Erbil governorate hydrology annual report. Ministry of Municipality and Tourism. Unpublished report

MOP. (2016). Statistics of Erbil governorate.Ministry of planning.Unpublished report.

Nadhir Al-Ansari, Ammar A. Ali, Sven Knutsson. (2007). Iraq Water Resources Planning: Perspectives and Prognoses, Jeddah Saudi Arabia Jan 26-27, 13 (**01**) Part XIII

Pirastu, R., Pasetto, R., Zona, A., Ancona, C., Iavarone, I., Martuzzi, M., and Comba, P. (2013).The health profile of populations living in contaminated sites: SENTIERI approach. *Journal of Environmental and Public Health*, 2013.

Poff, N. L., Allan, J. D., Palmer, M. A., Hart, D. D., Richter, B. D., Arthington, A. H., and Stanford, J. A. (2003). River flows and water wars: emerging science for environmental decision making. *Frontiers in Ecology and the Environment*, 1(**6**), 298-306.

Ponce, V. M. (1989). Engineering Hydrology: Principles and Practices. Pearson Education.

Ponce, V. M., and A. V. Shetty. (1995). A conceptual model of catchment water balance: 1. Formulation and calibration. *Journal of Hydrology*, 173(**1995**), 27-40.

Puertas, D. G. L., Woldearegay, K., Mehta, L., Beusekom, M., Agujetas, M., and Van Steenbergen, F. (2014). Roads for water: the unused potential. *Waterlines*, 33(**2**), 120-138.

Radosevich, G. E., and Olson, D. C. (1999).Existing and emerging basin arrangements in Asia: Mekong River Commission case study.In *Third Workshop on River Basin Institution Development* (**24**), 119.

Rahaman, M. M. (2009). Principles of transboundary water resources management and Gange's treaties: an analysis. *International Journal of Water Resources Development*, 25(**1**), 159-173

Rasul, H.A, and Askar, M. K. (2010).Integrated Water Resources Management for Alana Valley in Kurdistan Region-Iraq report.Available at: https://www.weap21.org/Downloads/IWRM_for_Alana_Valley.pdf Accessed 5.7. 2018

Reddy, M. V., Babu, K. S., Balaram, V., and Satyanarayanan, M. (2012). Assessment of the effects of municipal wastewater immersed idols and boating on the heavy metal and other elemental pollution of surface water of the eutrophic Hussainsagar Lake (Hyderabad, India). *Environmental Monitoring and Assessment*, 184(**4**), 1991-2000.

Reginato, R.J., S .N. Francis and J.B. Miller . (1973). Reducing seepage from stock tanks with uncomplicated sodium treated soils. Soil and Water Conservation. (Ed). The evaluation of materials for inducing off, *University of Ariz*., 1980. (**28**), 214-215.

Salman, S. M. (2007). The Helsinki Rules, the UN Watercourses Convention and the Berlin Rules: perspectives on international water law. *Water Resources Development*, *23*(**4**), 625-640.

Sinha, A., Nagel, C. L., Schmidt, W. P., Torondel, B., Boisson, S., Routray, P., and Clasen, T. F. (2017).Assessing patterns and determinants of latrine use in rural settings: a longitudinal study in Odisha, India. *International Journal of Hygiene and Environmental Health*, 220(**5**), 906-915.

Sissakian, V., Al-Ansari, N., and Knutsson, S. (2014). Karstification effect on the stability of Mosul Dam and its assessment, North Iraq.*Engineering*, 6(**2**), 84-92.

Snidvongs, A., Choowaew, S., and Chinvanno, S. (2003).Impact of climate change on water and wetland resources in Mekong river basin: *Directions for Preparedness and Action.Change*, 2**(2)**.

Solecki, R. S. (2005). The Bekhme Dam Project in Kurdistan Iraq: A Threat to the Archaeology of the Upper Zagros River Valley. *The International Journal of Kurdish Studies*, 19(**1/2**), 161.

Stevanovic, Z, and Iurkiewicz, A. (2009).Groundwater management in northern Iraq. *Hydrogeology Journal*, 17(**2**), 367-378.

Stockholm Environment Institute, SEI. (2005). WEAP: Water evaluation and planning system –user guide. Boston, USA.

Sullivan, C. (2002). Calculating a water poverty index. *World Development*, *30***(7)**, 1195-1210.

Swyngedouw, E., Kaika, M., and Castro, E. (2002).Urban water: a political ecology perspective.*Built Environment* (**1978**), 124-137.

Tamminga, S. (2003).Pollution due to nutrient losses and its control in European animal production.*Livestock Production Science*, *84*(**2**), 101-111.

Todd D.K. (1980). Groundwater hydrology.Second edition, John Wiley Sons, New York.535.

UN. (2011). United Nations population information network (Popin) UN Population Division, Department of Economic and Social Affairs, with support from the UN Population Fund (UNFPA). Available at: http://www.un.org/.Accessed 18.10. 2017

UNESCO. (2006). UNITED NATIONS World Water Development Report **2** Water a Shared Responsibility. Available at: http://www.unesco.org/water/wwap/. Accessed 2.2 2017

UN-Water Annual Report (2008) UN-Water.Available at: http://www.unwater.org/publications/un-water-annual-report-2008 .Accessed 19.1. 2017

Van Steenbergen, F. (2006).Promoting local management in groundwater. *Hydrogeology Journal*, 14(**3**), 380-391.

Wang, L., Min, M., Li, Y., Chen, P., Chen, Y., Liu, Y. and Ruan, R. (2010).Cultivation of green algae Chlorella sp. in different wastewaters from the municipal wastewater treatment plant. *Applied Biochemistry and Biotechnology*, *162*(4), 1174-1186.

White, I., and Howe, J. (2003).Policy and practice: Planning and the European Union water framework directive. *Journal of Environmental planning and Management*, *46*(**4**), 621-631.

World Health Organization, 1996.Guidelines for drinking water, recommendations, 2nd edition, (**l)**Geneva Switzerland.

Wilkinson, W.B. (1993). Groundwater problems in urban areas, proceedings of the international conference organised by the institution of civil engineers and held in London, Thomas Telford, and London.

Winz, I., Brierley, G., and Trowsdale, S. (2009). The use of system dynamics simulation in water resources management. *Water Resources management*, 23(**7**), 1301-1323.

Wolf, A. T. (1998). Conflict and cooperation along international waterways. *Water Policy, 1***(2)**, 251-265.

World Bank Group - International Development, Poverty, and Sustainability. Available at: http://www.worldbank.org/. Accessed 17.1.2018

Yates, D., Sieber, J., Purkey, D., and Huber-Lee, A. (2005). WEAP21—A demand-, Priority-, and preference-driven water planning model: part 1: model characteristics. *Water International*, *30*(**4**), 487-500.

Yeh, W. W. G. (1985). Reservoir management and operations models: A state-of-the-art review.*Water Resources Research,* 21(**12**), 1797-1818.

Zakaria, S., Al-Ansari, N., Mustafa, Y., Knutsson, S., Ahmed, P., and Ghafour, B. (2013).Rainwater Harvesting at Koysinjaq (Koya), Kurdistan Region, Iraq. *Journal of Earth Sciences and Geotechnical Engineering*, 3(**4**), 25-46.

Ziv, G., Baran, E., Nam, S., Rodríguez-Iturbe, I., and Levin, S. A. (2012).Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. *Proceedings of the National Academy of Sciences,* 109**(15)**, 5609-5614.)

APPENDIX

Appendix A Chemical analysis for water (October 2end, 2017)

No.	Location	Type	Temp. C	Turbidity	pH.	EC Ds/m	T.D.S mg/L	Calcium mg/L	Mg mg/L	T.H mg/L
1	Skarta	spring	19.6	0.66	7.62	0.369	237	30.5	24	175
2	Harwata	spring	19.4	0.437	7.71	0.401	257	34	27	197
3	Tarawa	spring	19.1	0.368	7.57	0.439	281	35	24	189
4	Tutmara	Spring	19.4	0.53	7.81	0.336	215	31	22	170
5	Sharsina	Spring	19.5	1.58	7.65	0.378	242	33	25	187
6	Kani sard	Spring	19.8	0.22	8.01	0.391	249	38	26	205
7	Malakan	Spring	19.6	0.35	7.85	0.395	253	33	24	184
8	L .Ble	Spring	17.6	0.33	7.94	0.386	247	31	28	194
9	Sharkan	Spring	19.9	0.272	7.45	0.406	259	34	20	173
10	Binawila	Spring	19.6	0.8	7.89	0.388	253	45	23	210
11	Sarukani	Spring	19.5	0.67	7.94	0.402	262	37	29	215
12	Jolamerg	Spring	19.6	0.484	7.52	0.404	258	39	22	191
13	Gridlock	Spring	19.1	1.24	7.88	0.385	246	41	28	218
14	Kandor	River	19.4	0.33	7.76	0.399	256	37	25	200
15	Ble Zhoru	River	19.1	0.81	7.78	0.431	276	35	20	175
16	Ble Zhoru	River	19.4	0.88	7.66	0.35	224	30	19	158
17	Gurgar	River	19.5	1.33	8.1	0.431	275	33	29	208
18	Alana	River	19.8	2.66	8.06	0.393	252	35	23	183
19	Khalifan	River	19.8	3.11	7.95	0.441	282	38	22	188
20	Gali Ali	River	20.1	5.49	7.88	0.503	322	42	22	198
21	Sreshma	Deep Well.	20.4	1.7	7.88	0.443	288	36	29	210
22	Jolamerg	Deep Well.	20.6	1.13	7.65	0.438	285	35	29	210

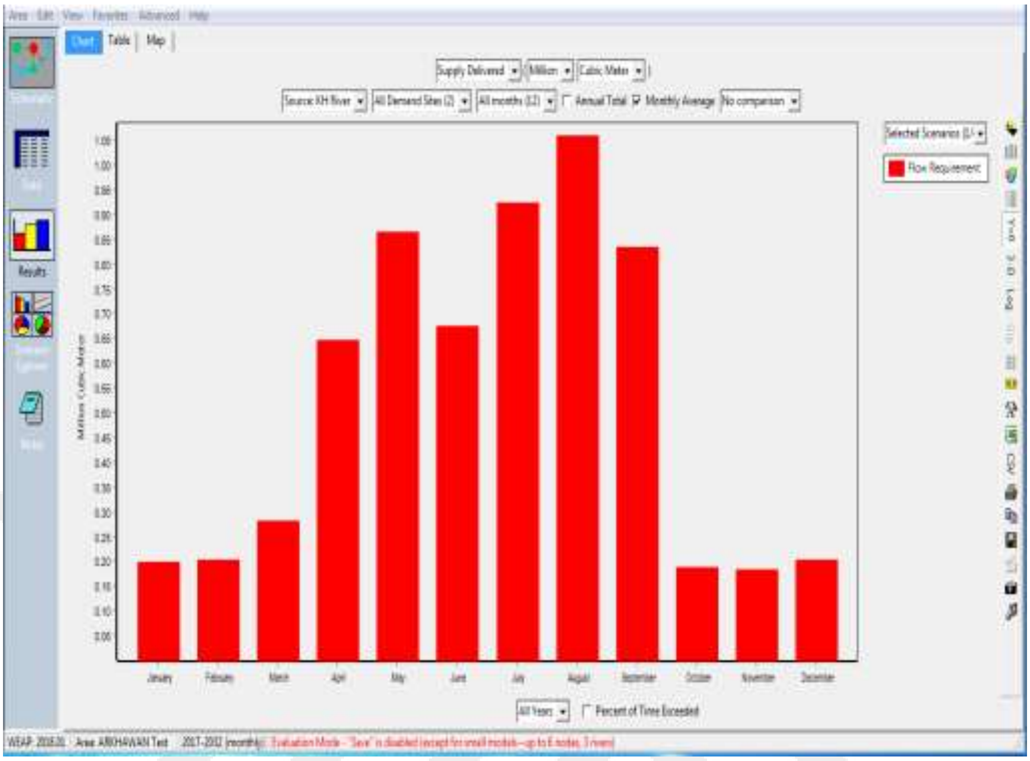
Appendix B Chemical analysis for water (October 2^{end}, 2017)

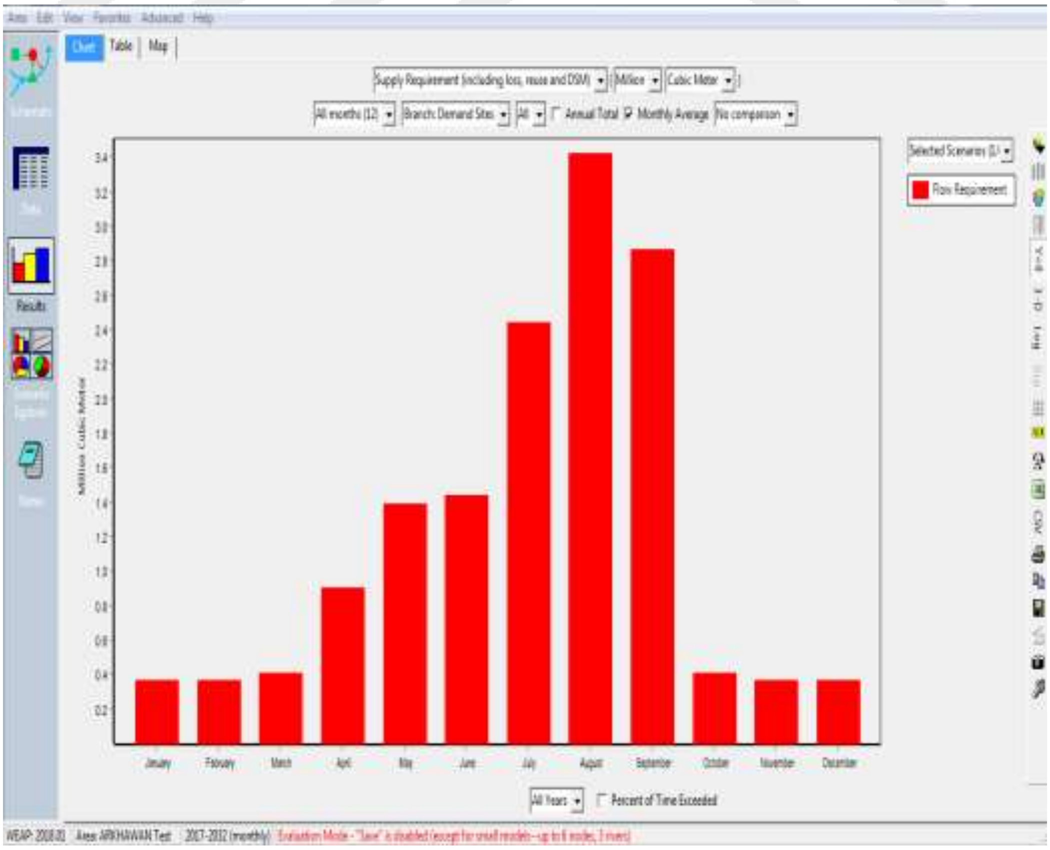
No.	Location	Type	Alkalinity mg/L	Chloride mg/L	Coliform No/100ml	E.coil No/100 ml	D.O mg o2/L	B.O.D mg/L
1	Skarta	spring	173	14	<2.2	0	6.13	.88
2	Harwata	spring	165	24.9	<2.2	0	7.11	1.21
3	Tarawa	spring	173	17.8	<2.2	0	6.35	1.36
4	Tutmara	Spring	188	10.65	<2.2	0	9.14	.95
5	Sharsina	Spring	191	14.2	<2.2	0	7.15	.56
6	Kani sard	Spring	189	14.5	<2.2	0	6.59	1.28
7	Malakan	Spring	192	17.8	<2.2	0	8.46	2.15
8	l. Ble	Spring	186	10.69	<2.2	0	7.67	2.84
9	Sharkan	Spring	179	17.75	<2.2	0	10.66	2.65
10	Binawila	Spring	177	17.6	<2.2	0	6. 87	1.06
11	Sarukani	Spring	187	13.4	<2.2	0	8.56	.85
12	Jolamerg	Spring	178	16.5	<2.2	0	8.16	2.35
13	Girdkok	Spring	196	14.2	<2.2	0	5.95	1.94
14	Kandor	River	177	21.3	5.1	2.2	4.12	3.45
15	Ble Zhoru	River	202	13.8	9.2	16	3.65	4.15
16	Ble Zhoru	River	153	17.8	<16	5.1	3.98	5.95
17	Gurgar	River	163	24.9	<16	16	3.21	6.15
18	Alana	River	164	21.3	<16	16	2.91	5.66
19	Khalifan	River	160	21	<16	16	2.9	8.42
20	Gali Ali	River	188	22	<16	16	1.65	9.65
21	Sreshma	Deep Well	214	10	<2.2	0	6.48	1.69
22	Jolamerg	Deep Well	194	12.8	<2.2	0	7.45	2.11
23	Sharsina	Deep Well	186	15.3	<2.2	0	9.35	1.54

Appendix C Chemical test different water sources (Mar 17,2018)

No.	Location	Type	Turbidity	pH	EC/1000	T.D.S mg/L	Cl- mg/L	Alkalinity mg/L	Hardness(T.H) mg/L
1	Berwkan	Spring1	0.3	7.5	875	437.5	31	516	643
2	Berwkan	House	0.2	7.3	537	268.5	12	360	400
3	Berwkan	Spring2	0.2	7.2	882	441	19	480	641
4	Berwkan	sewerage	2.5	7.2	848	424	19	450	593
5	Bawyan	Water basin for animal	1.8	7.4	839	419.5	10	325	348
6	Bawyan	Water basin domestic	0.2	7.6	547	273.5	11	325	408
7	Bawyan	Well	0.6	7.4	428	214	10	326	394
8	Sharkan	Canal	0.4	7.6	549	274.5	10	362	307
9	Sharkan	Alana river	0.7	7.1	443	221.5	9	252	345
10	Rmawezh	weir structure	0.6	7.5	428	214	12	246	302
11	Alana	sewerage	0.5	7.4	290	145	13	290	440
12	Alana	intake structure	0.6	7.5	428	214	10	253	384
13	Ble	intake	0.5	7.5	453	226.5	11	290	313
14	Khalifan	Canal	0.3	7.6	464	232	10	260	384
15	Khalifan	weir structure	0.5	7.7	447	223.5	10	265	362
16	Khalifan	downstream	0.6	7.6	515	257.5	13	298	347
17	Gali Ali Beg	Downstream	0.9	7.6	475	237.5	14	313	344

Appendix D Run model output from scenario reference





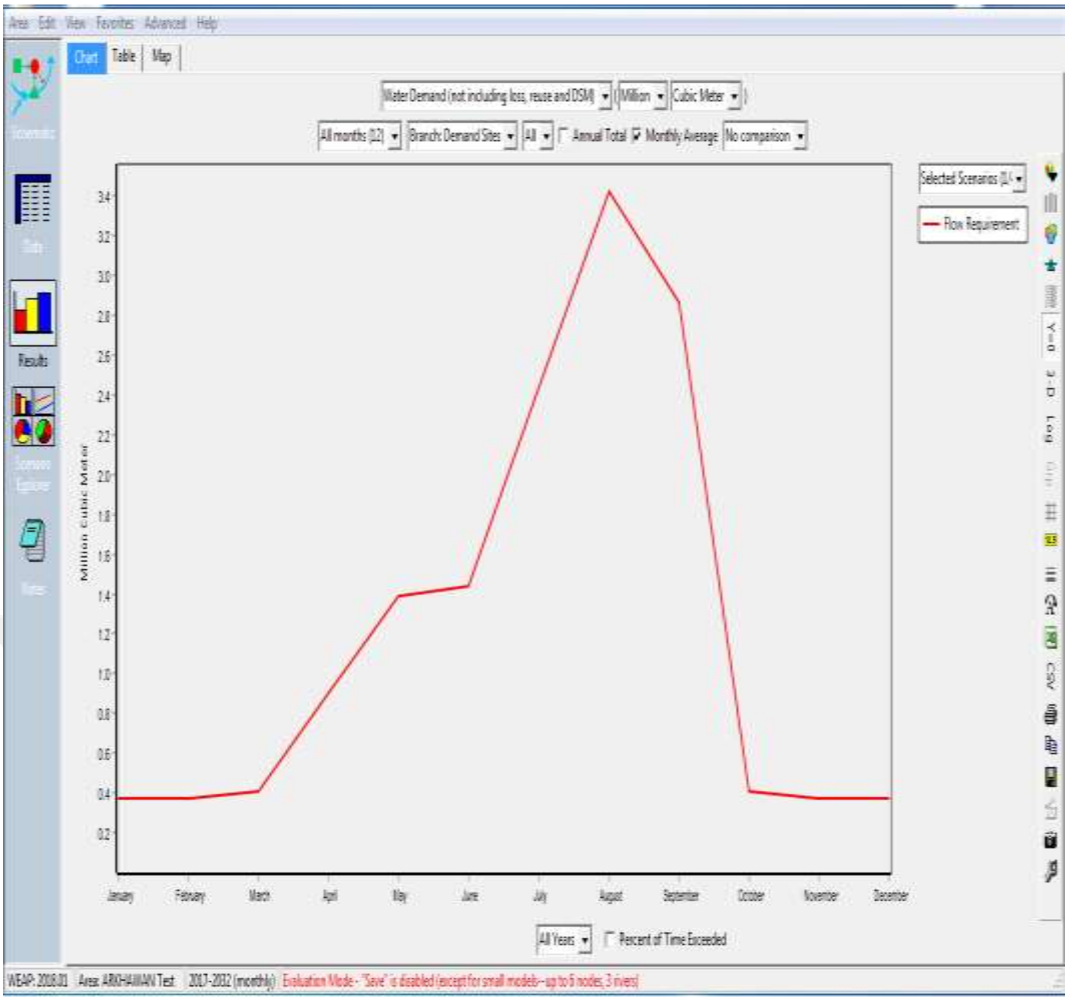


Chart
Table
Map
Water Demand (not including loss, reuse and DSM)
Million
Cubic Meter
All months (12)
Branch: Demand Sites
All
Annual Total
Monthly Average
No comparison
Selected Scenarios
Flow Requirement
Million Cubic Meter
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded
Results
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

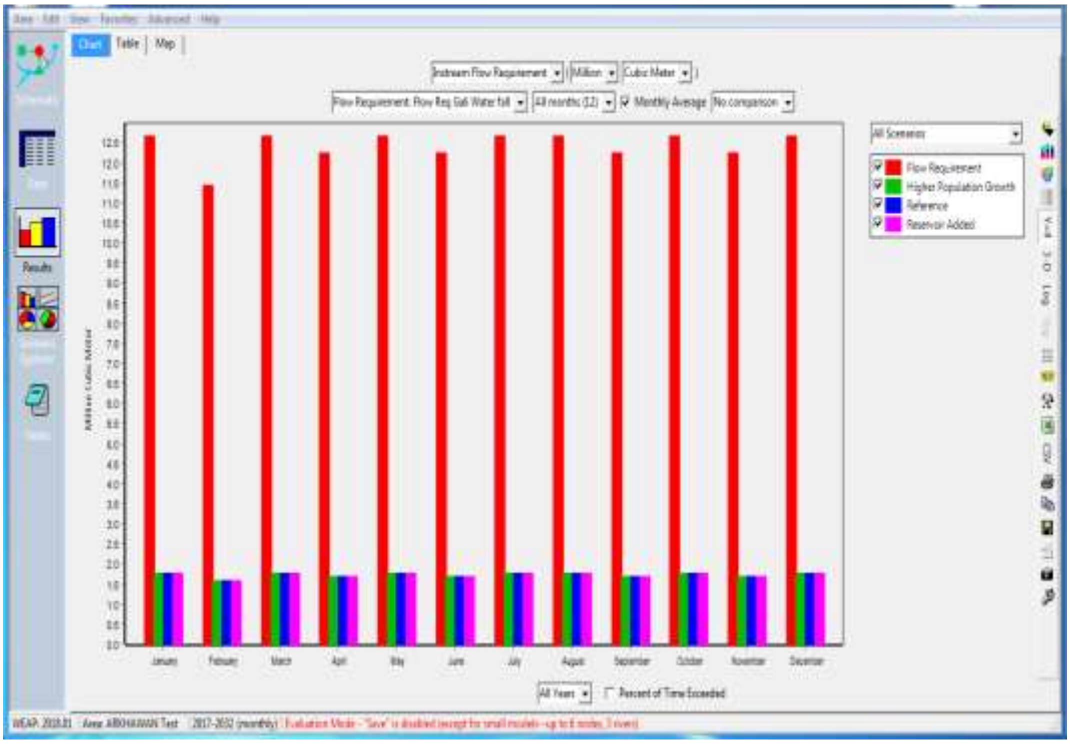
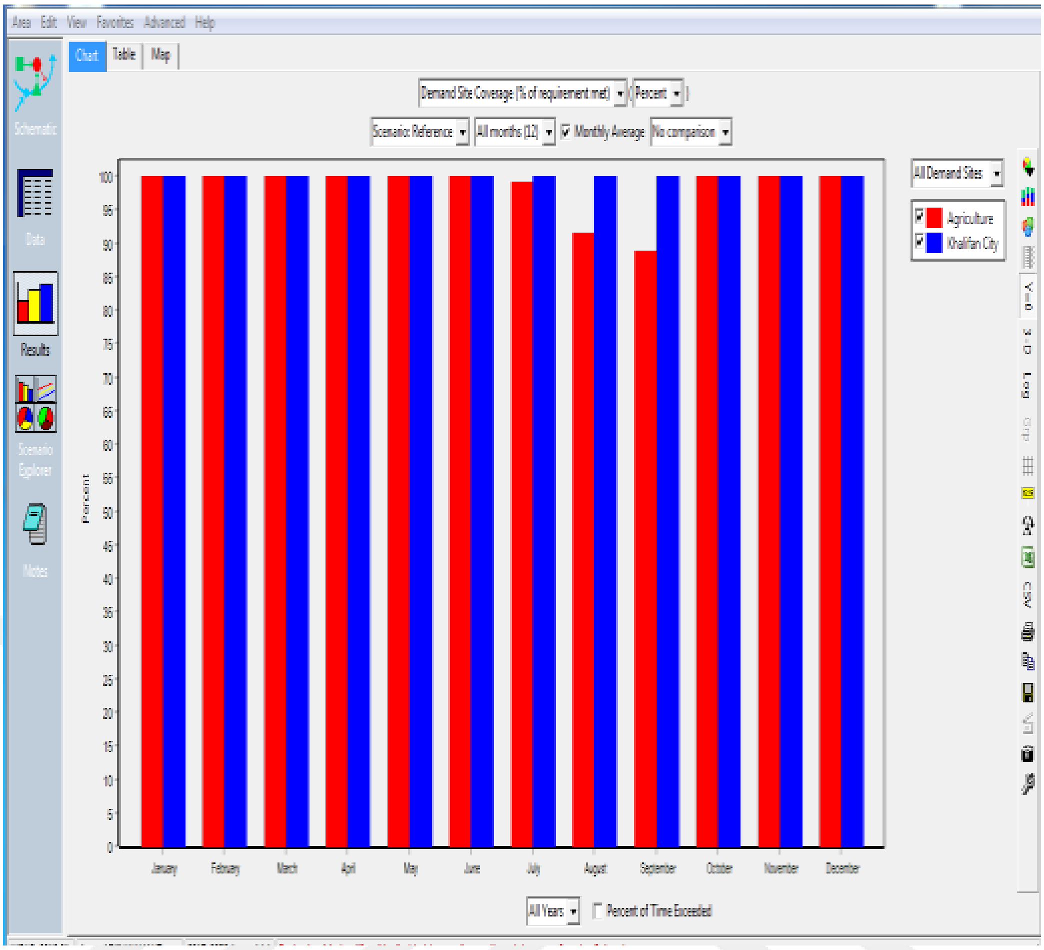


Chart
Table
Map
Instream Flow Requirement
Million
Cubic Meter
Monthly Average
No comparison
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
Million Cubic Meter
All Years
Percent of Time Exceeded
Results


Area Edit View Favorites Advanced Help
Chart Table Map
Demand Site Coverage (% of requirement met)
Percent
Scenario: Reference
All months (12)
Monthly Average
No comparison
All Demand Sites
Agriculture
Khalifan City
Percent
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded
Schematic
Data
Results
Scenario Explorer
Notes

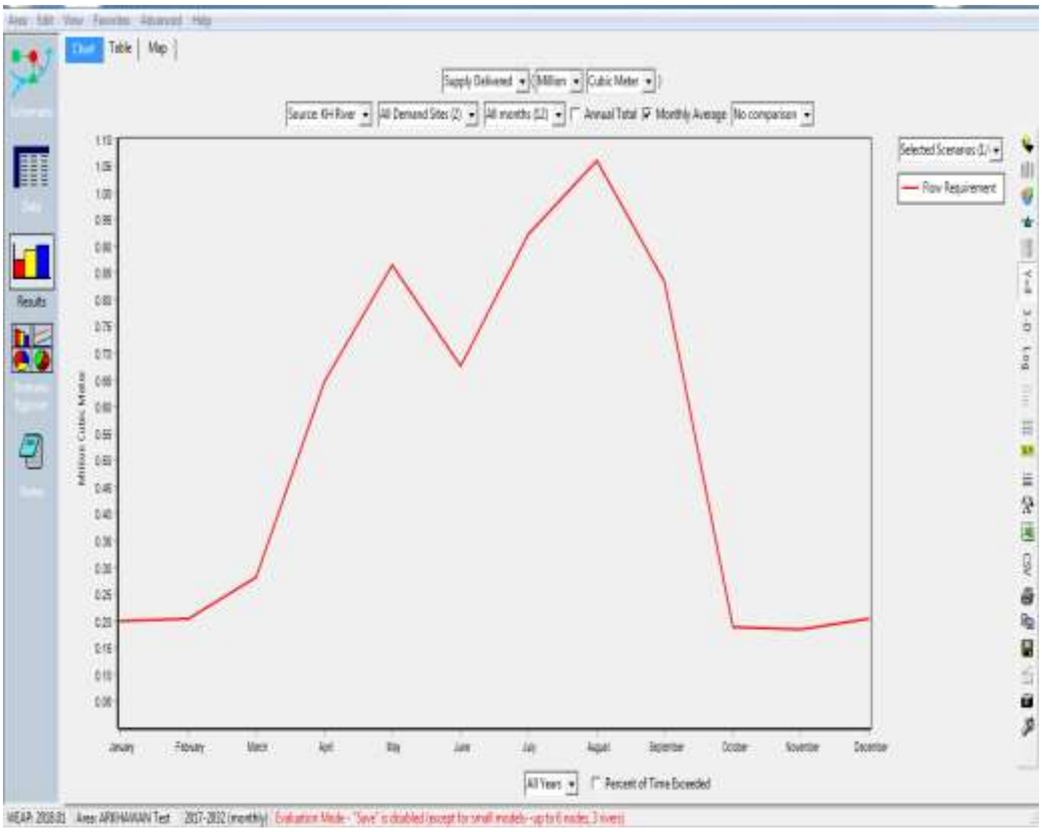
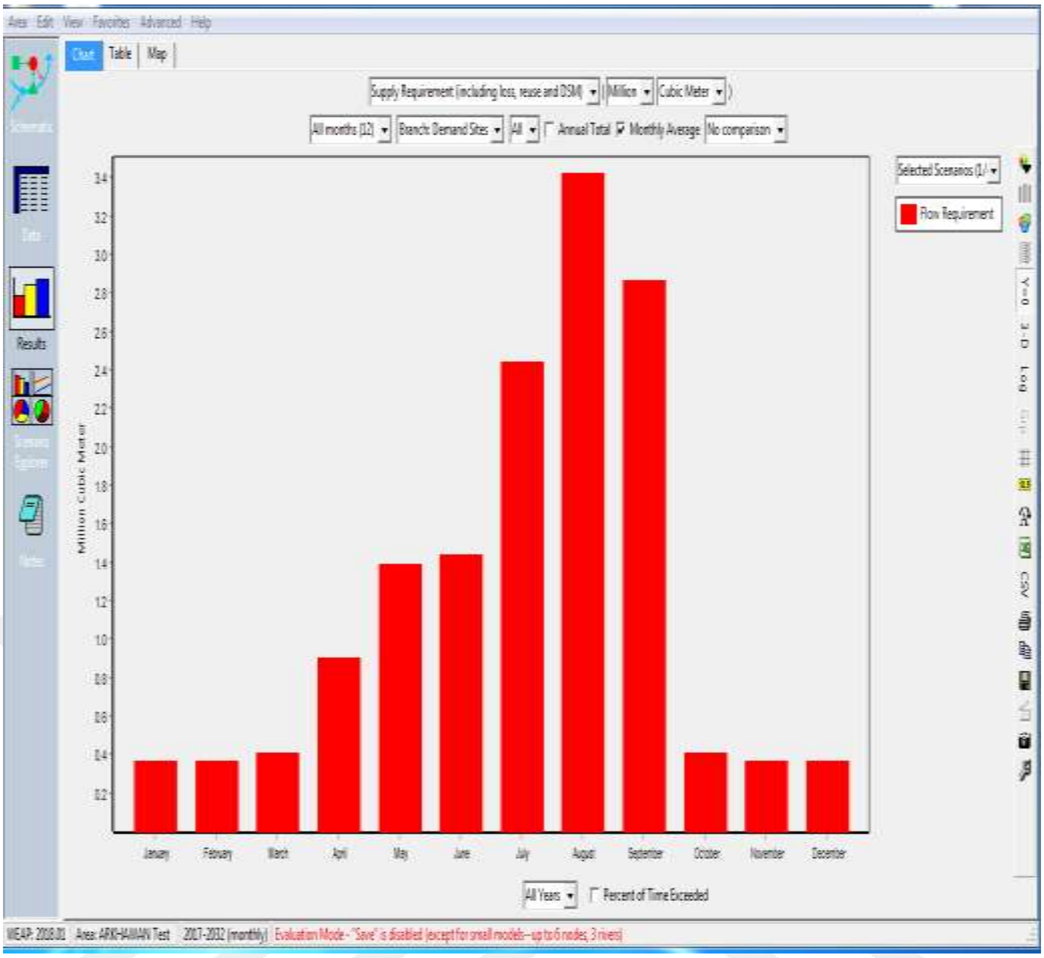
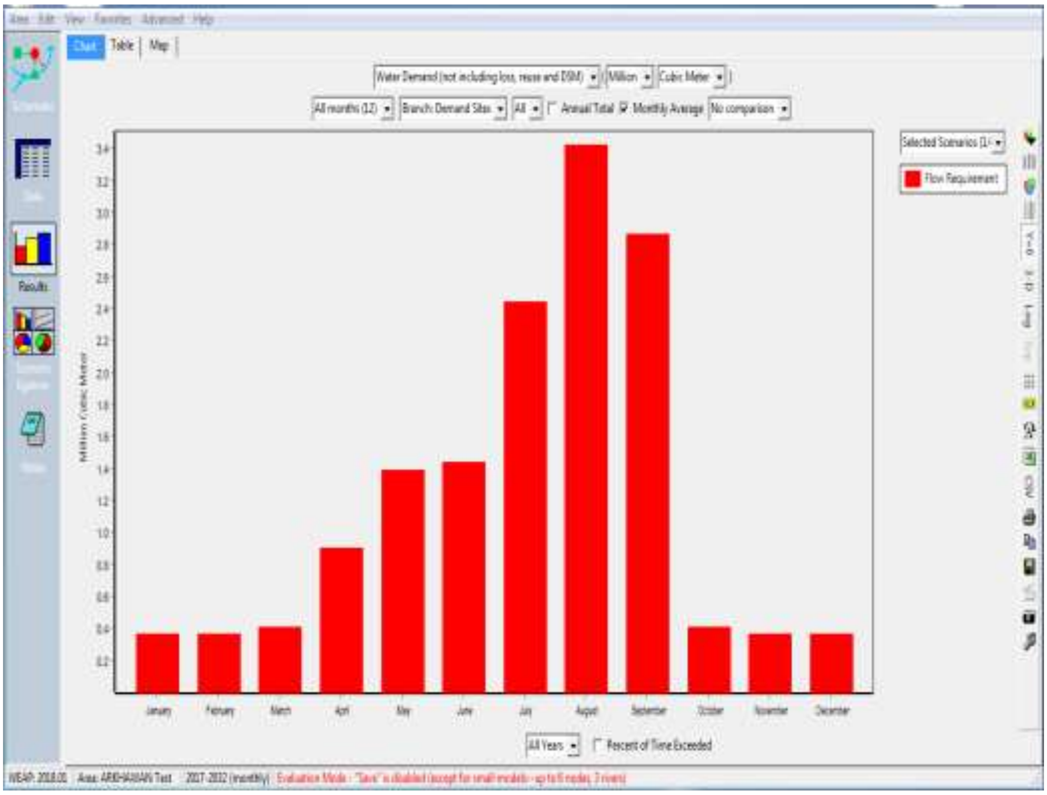


Chart Table Map
Supply Delivered
Million
Cubic Meter
All Demand Sites (2)
All months (12)
Annual Total
Monthly Average
No comparison
Flow Requirement
Million Cubic Meter
All Years
Percent of Time Exceeded
Results


Supply Requirement (including loss, reuse and DSM)
Million
Cubic Meter
Million Cubic Meter
Flow Requirement
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded


Water Demand (not including loss, reuse and DSM)
Million
Cubic Meter
Million Cubic Meter
Flow Requirement
All Years
Percent of Time Exceeded

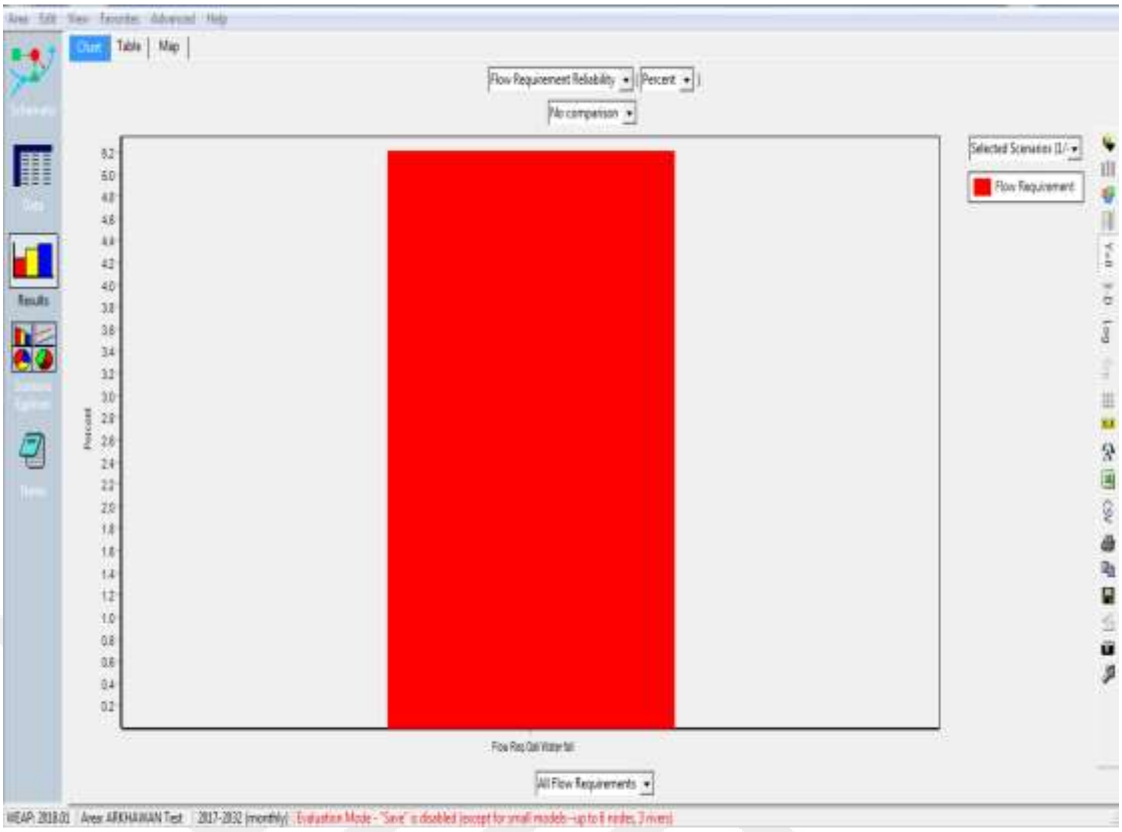


Chart
Table
Map
Flow Requirement Reliability
Percent
No comparison
Selected Scenarios
Flow Requirement
Percent
All Flow Requirements
WEAP: 2018.01
Area: ARKHAWAN Test
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

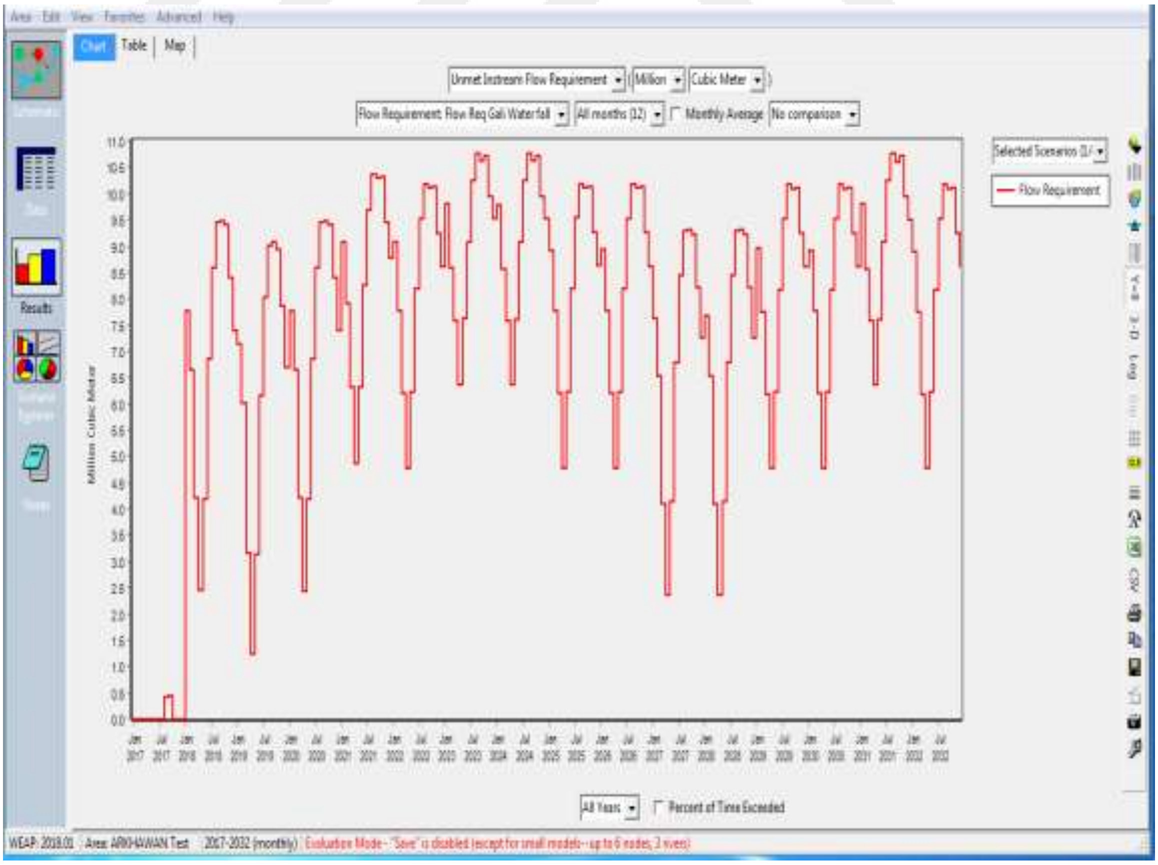


Chart
Table
Map
Unmet Instream Flow Requirement
Million
Cubic Meter
Flow Requirement: Flow Req Gali Waterfall
All months (12)
Monthly Average
No comparison
Selected Scenarios
Flow Requirement
Million Cubic Meter
All Years
Percent of Time Exceeded
WEAP: 2018.01
Area: ARKHAWAN Test
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

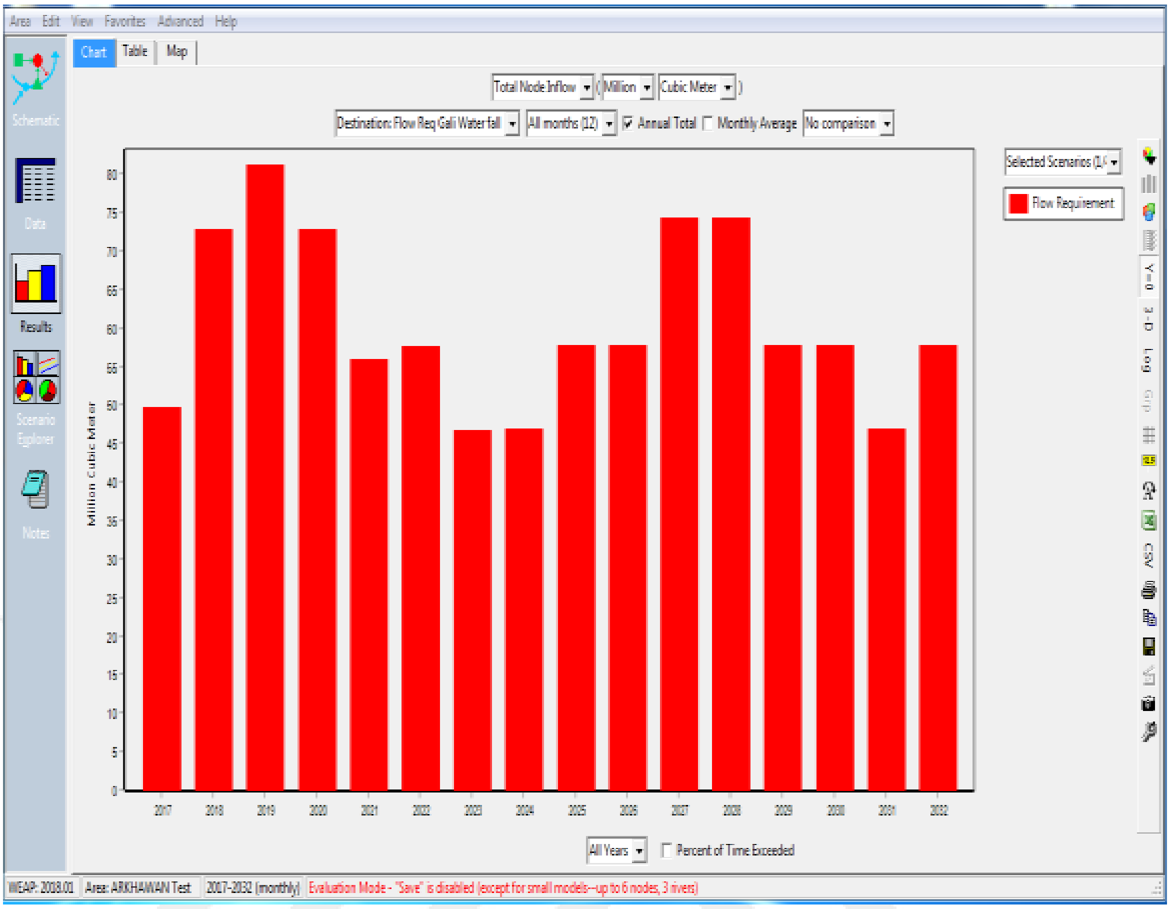


Chart
Table
Map
Total Node Inflow
Million
Cubic Meter
Destination: Flow Req Gali Water fall
All months (12)
Annual Total
Monthly Average
No comparison
Flow Requirement
Million Cubic Meter
All Years
Percent of Time Exceeded
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

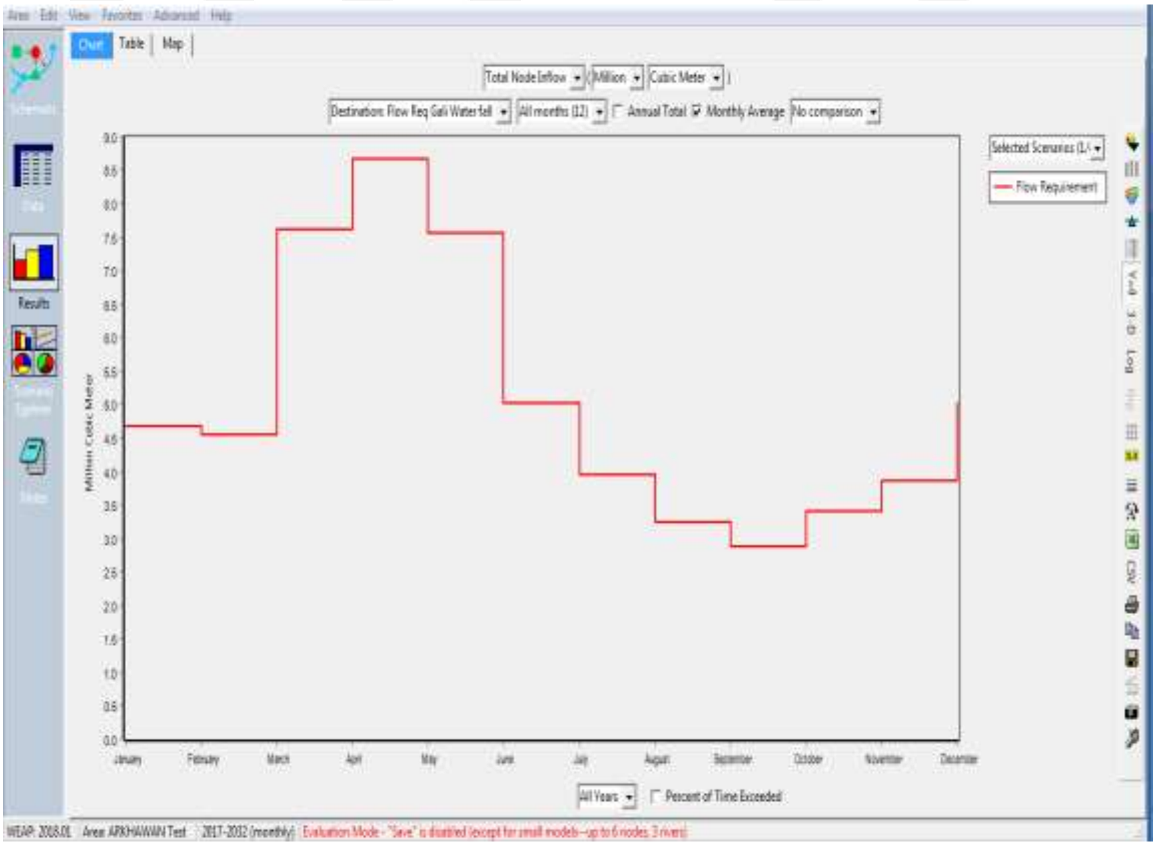


Chart
Table
Map
Total Node Inflow
Million
Cubic Meter
Destination: Flow Req Gali Water fall
All months (12)
Annual Total
Monthly Average
No comparison
Flow Requirement
Million Cubic Meter
All Years
Percent of Time Exceeded
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)

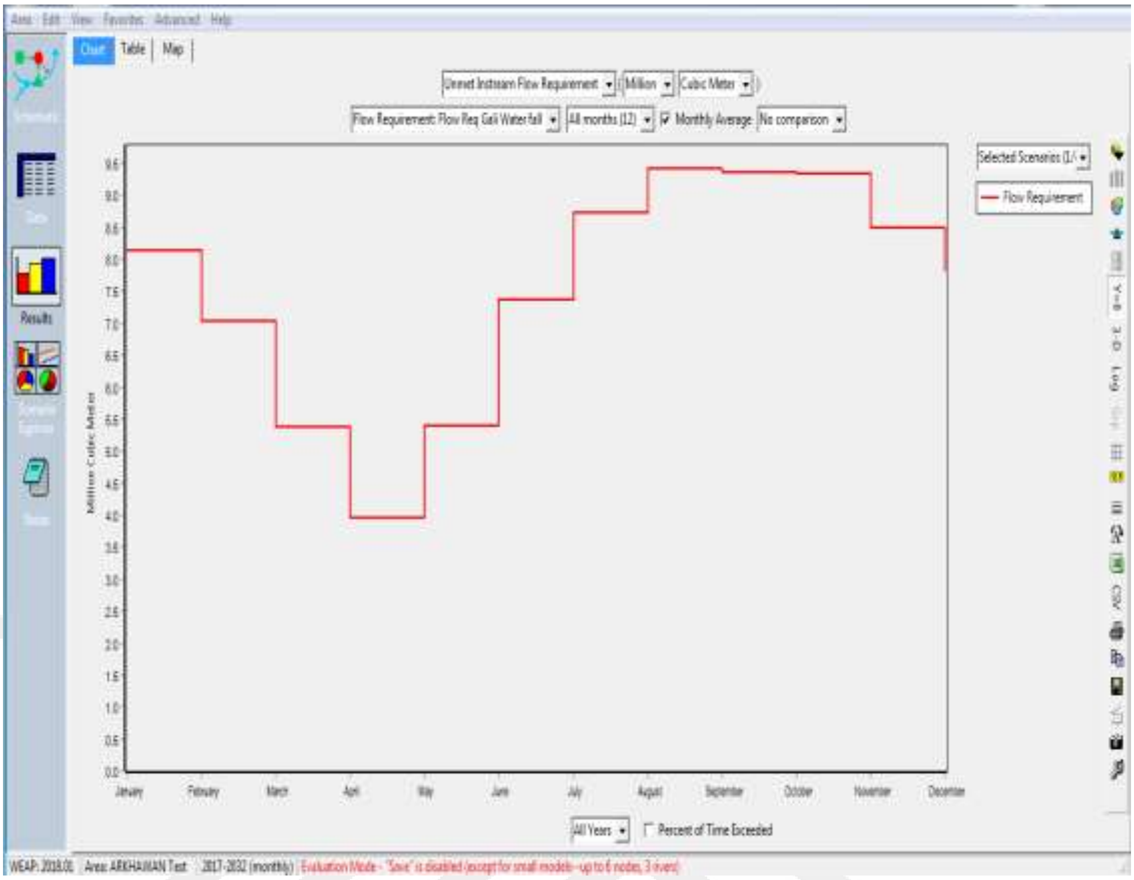


Chart
Table
Map
Unmet Instream Flow Requirement
Million
Cubic Meter
Flow Requirement: Flow Req Gali Water fall
All months (12)
Monthly Average
No comparison
Selected Scenarios
Flow Requirement
Million Cubic Meter
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded
Results
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

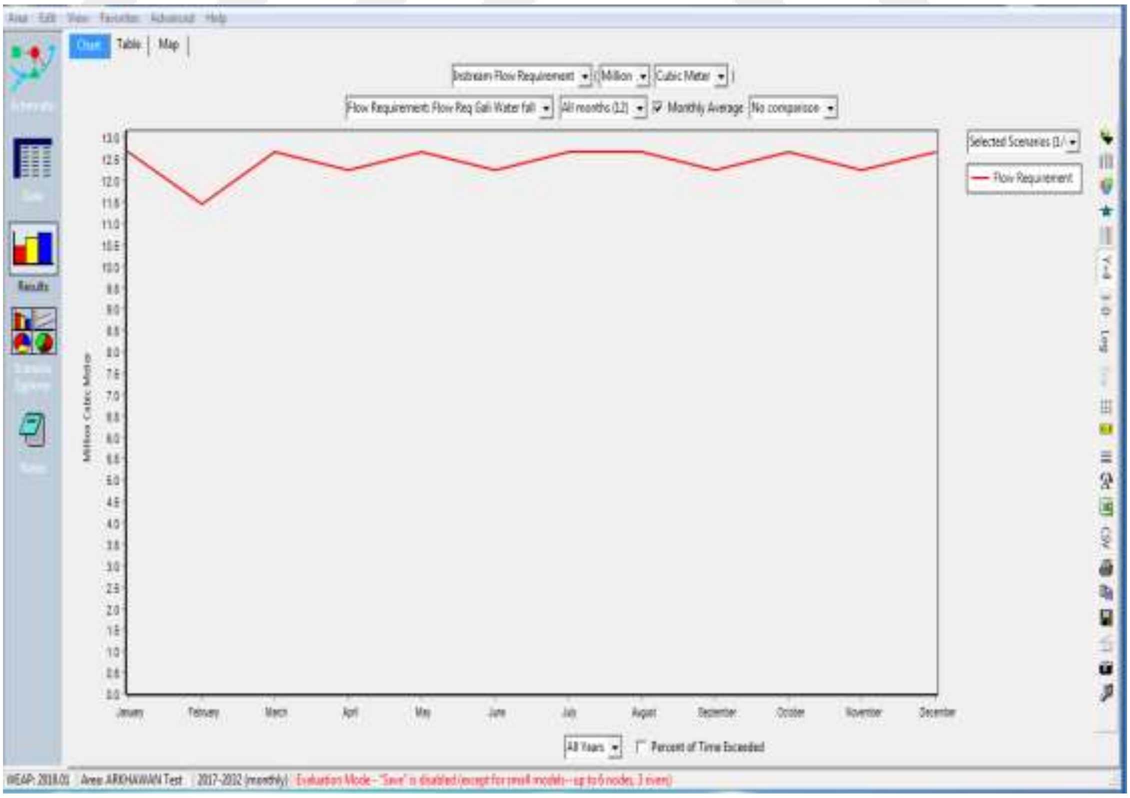
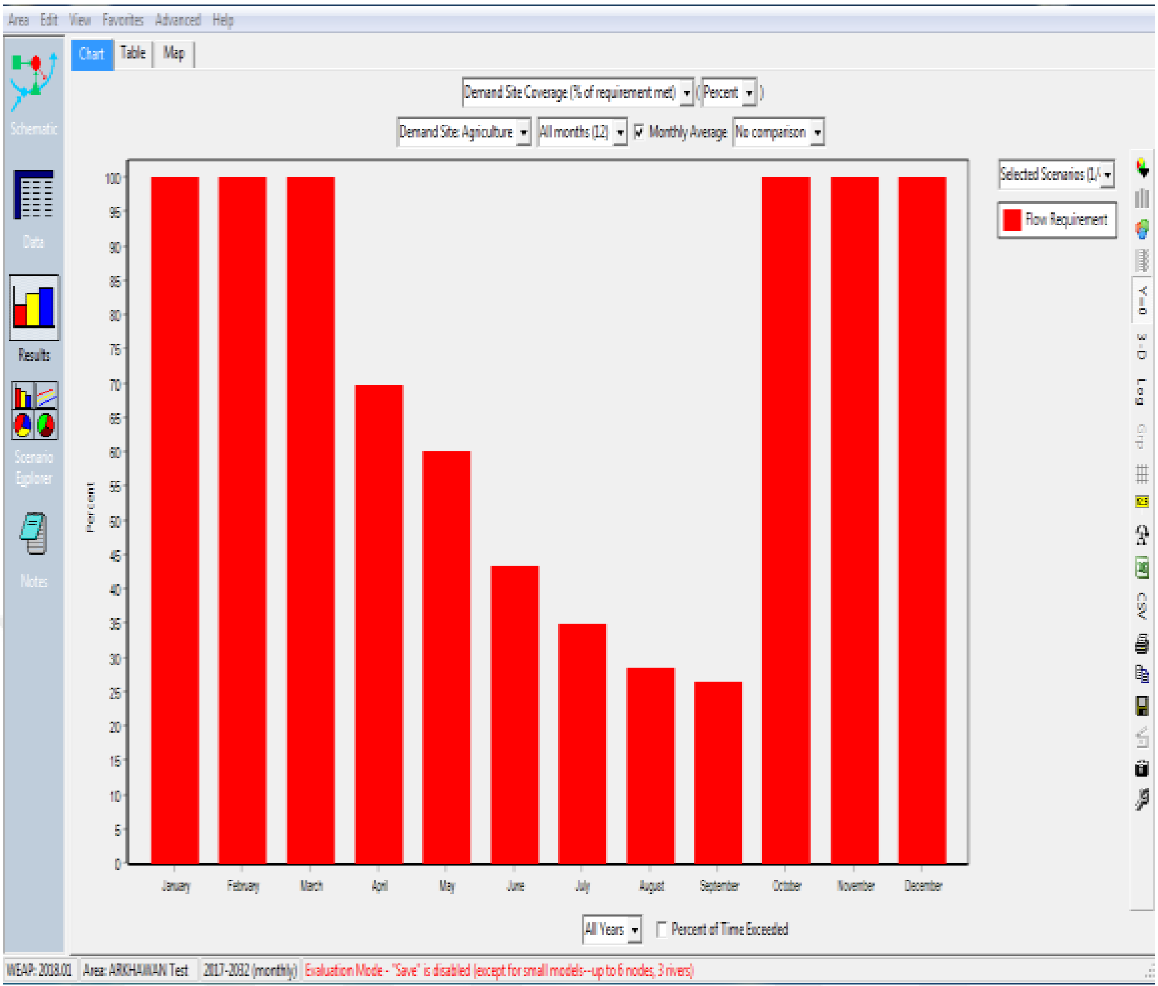
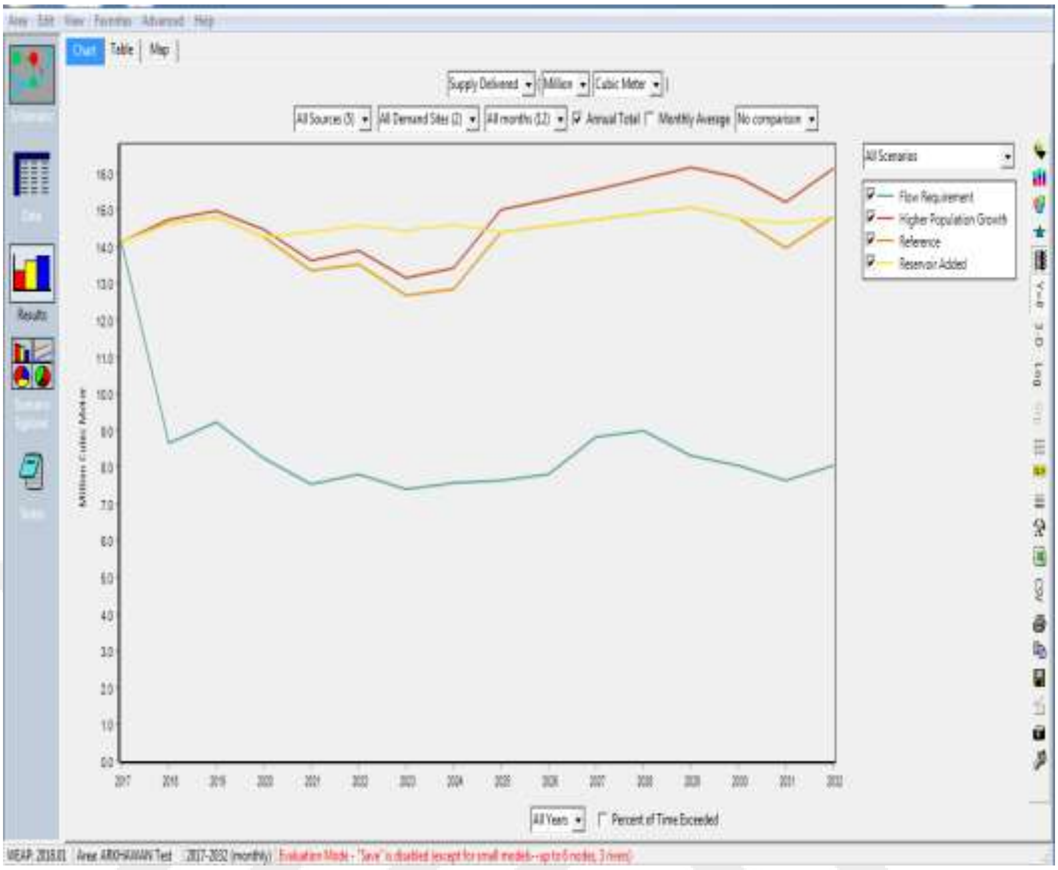


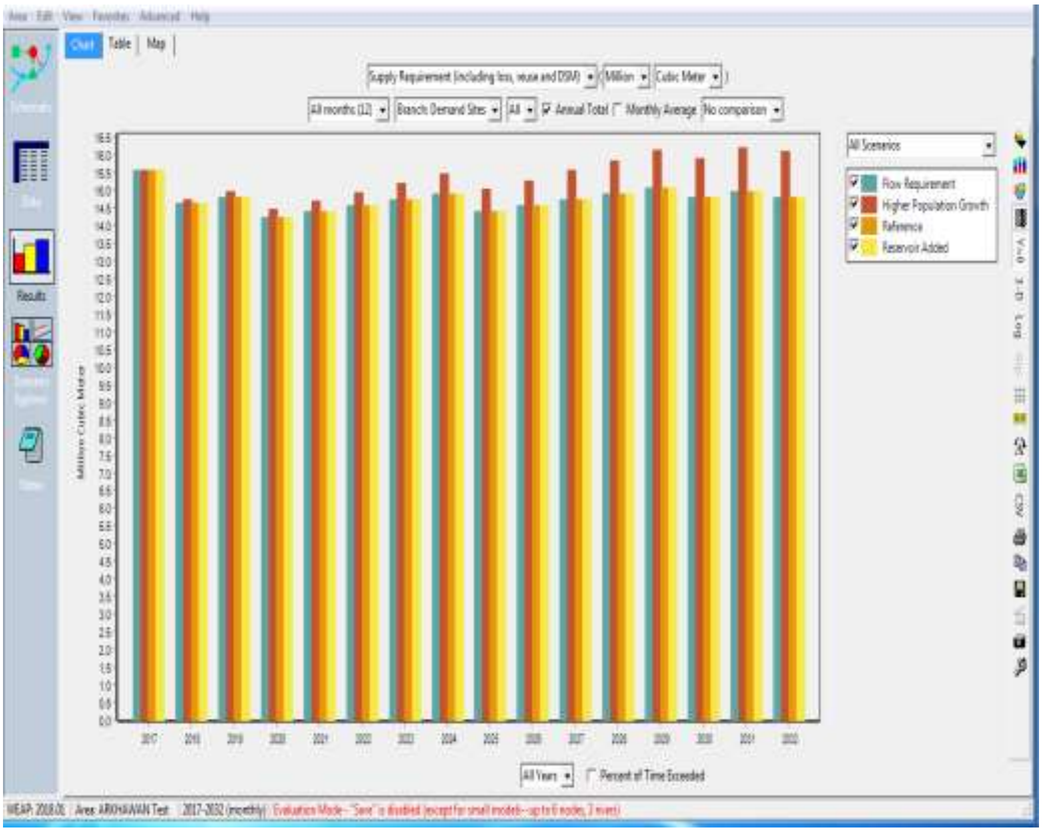
Chart
Table
Map
Instream Flow Requirement
Million
Cubic Meter
Flow Requirement: Flow Req Gali Water fall
All months (12)
Monthly Average
No comparison
Selected Scenarios
Flow Requirement
Million Cubic Meter
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded
Results
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

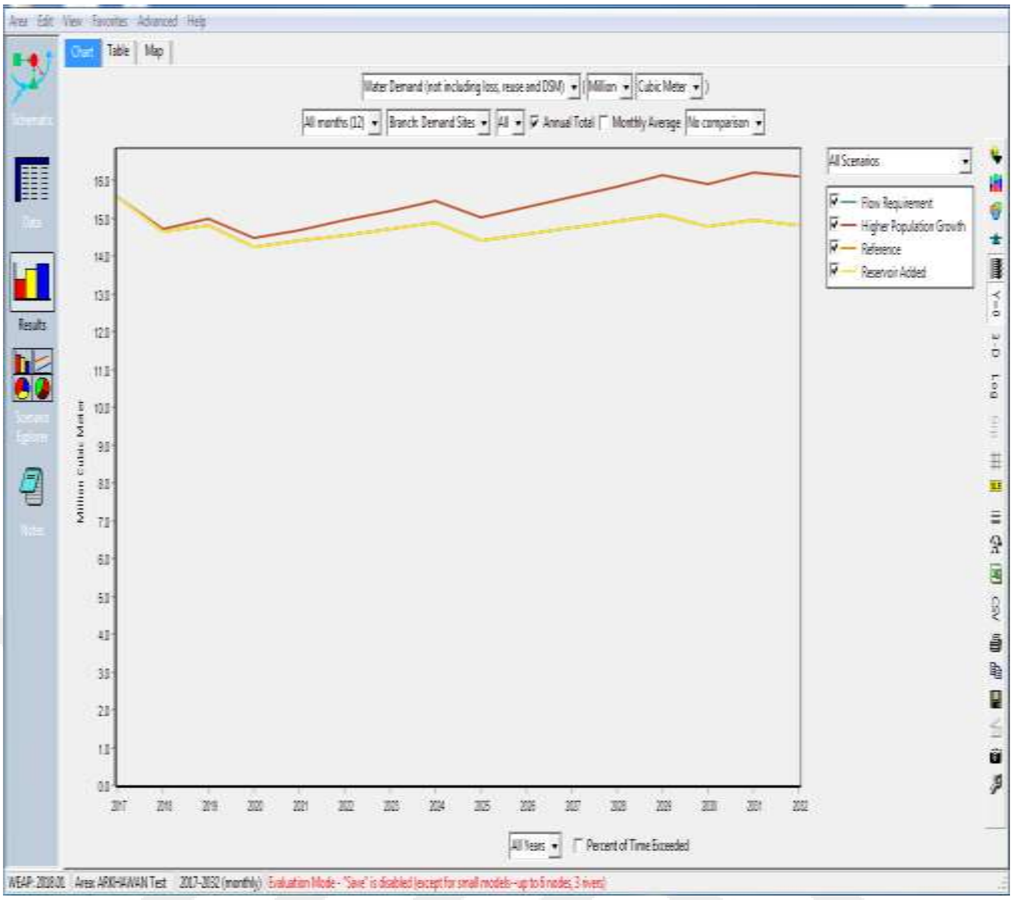


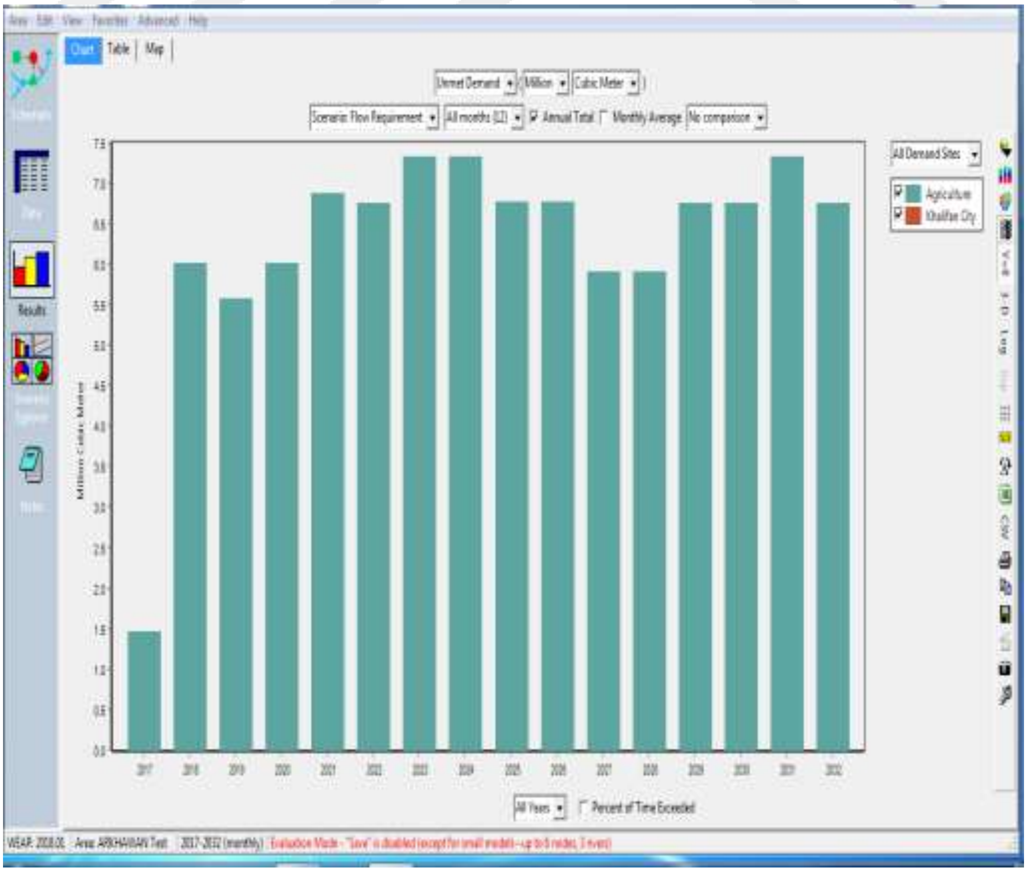
Area Edit View Favorites Advanced Help
Chart Table Map
Schematic
Data
Results
Scenario Explorer
Notes
Demand Site Coverage (% of requirement met)
Percent
Demand Site: Agriculture
All months (12)
Monthly Average
No comparison
Selected Scenarios
Flow Requirement
Percent
January February March April May June July August September October November December
All Years
Percent of Time Exceeded
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

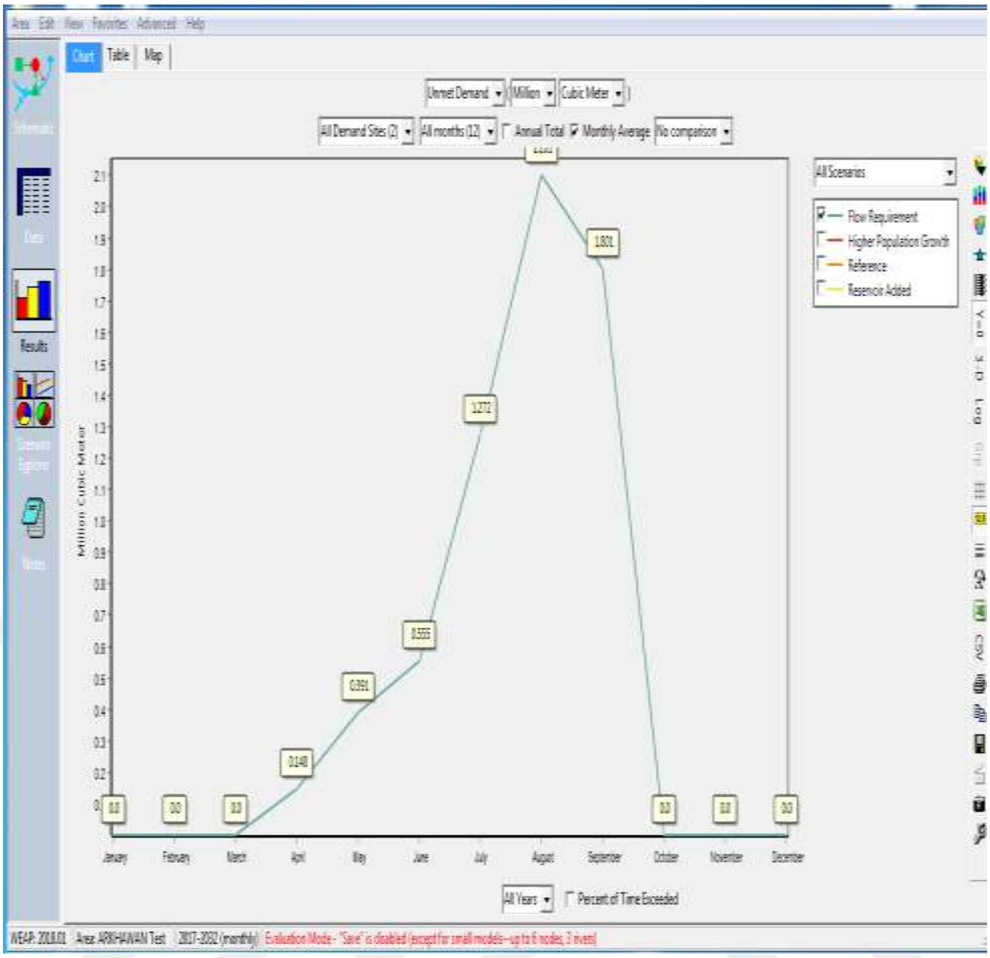
Appendix E Run model output from flow requirement scenario

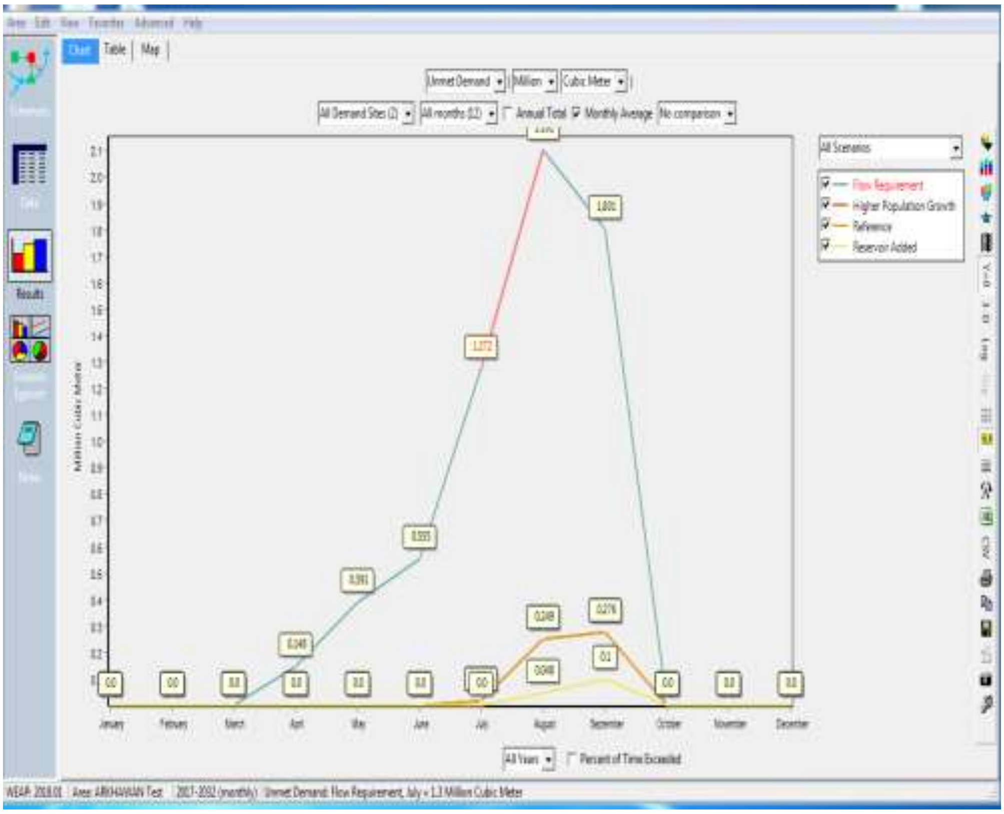


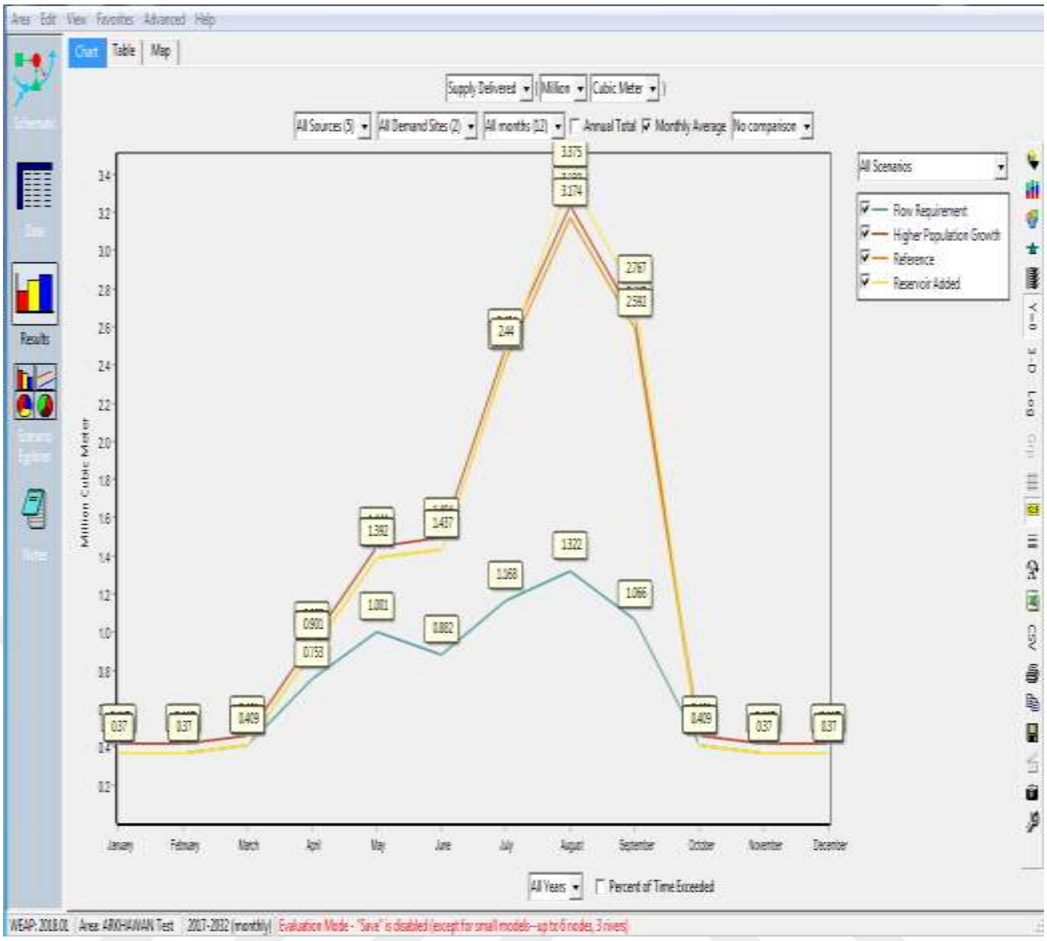


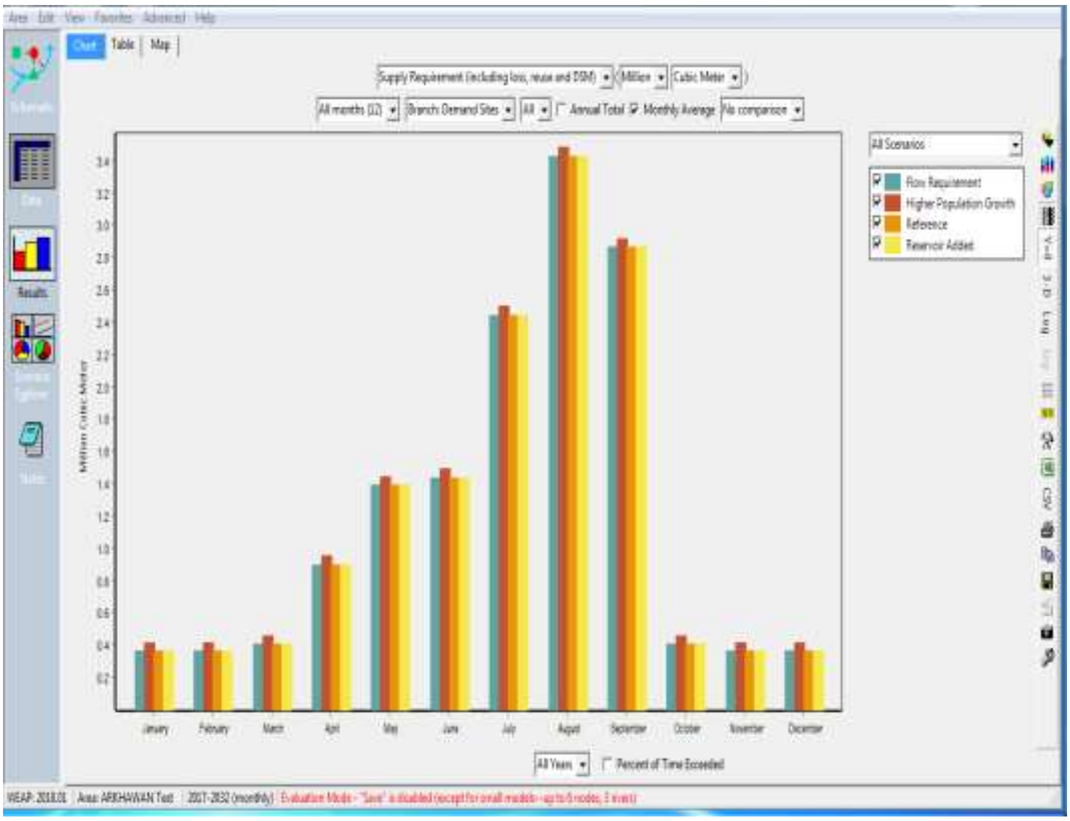

Water Demand (not including loss, reuse and DSM)
Million Cubic Meter
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added


Unmet Demand
Million Cubic Meter
All Demand Sites
Agriculture
Khalifan City






Supply Delivered
Million
Cubic Meter
Million Cubic Meter
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
January
February
March
April
May
June
July
August
September
October
November
December


Supply Requirement (including loss, reuse and DSM)
Million
Cubic Meter
Million Cubic Meter
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
January
February
March
April
May
June
July
August
September
October
November
December

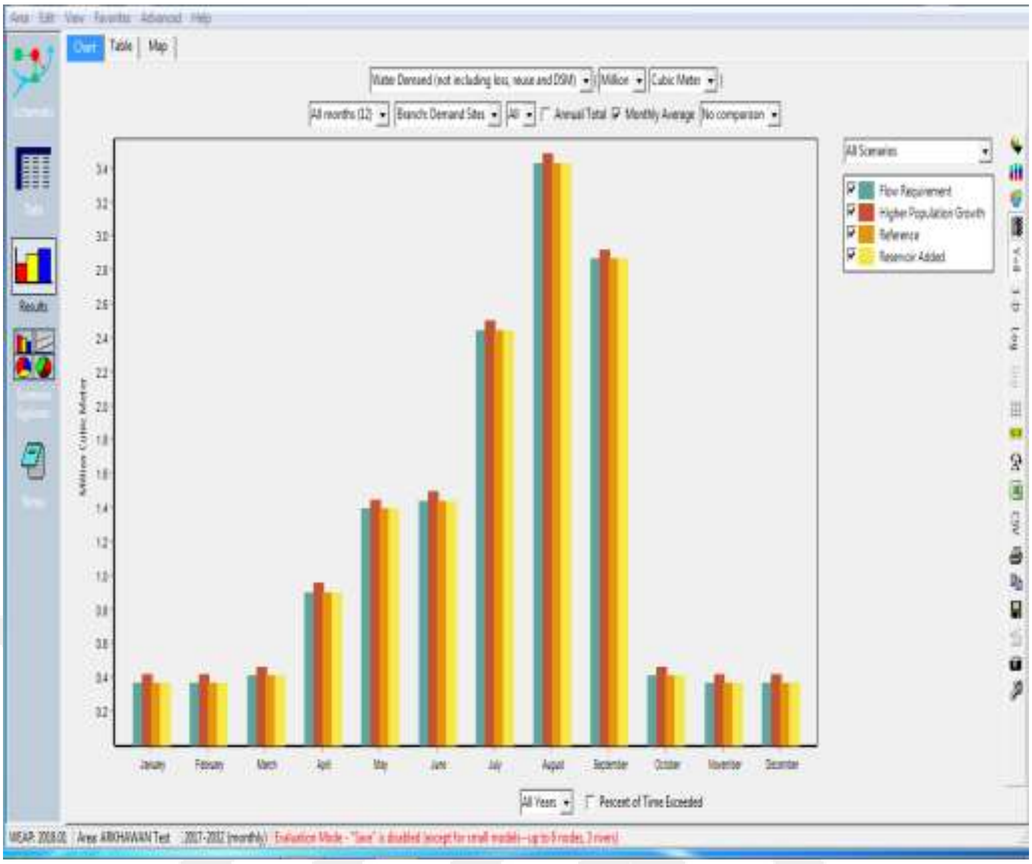


Chart
Table
Map
Results
Million Cubic Meter
January
February
March
April
May
June
July
August
September
October
November
December
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
All Years
Percent of Time Exceeded

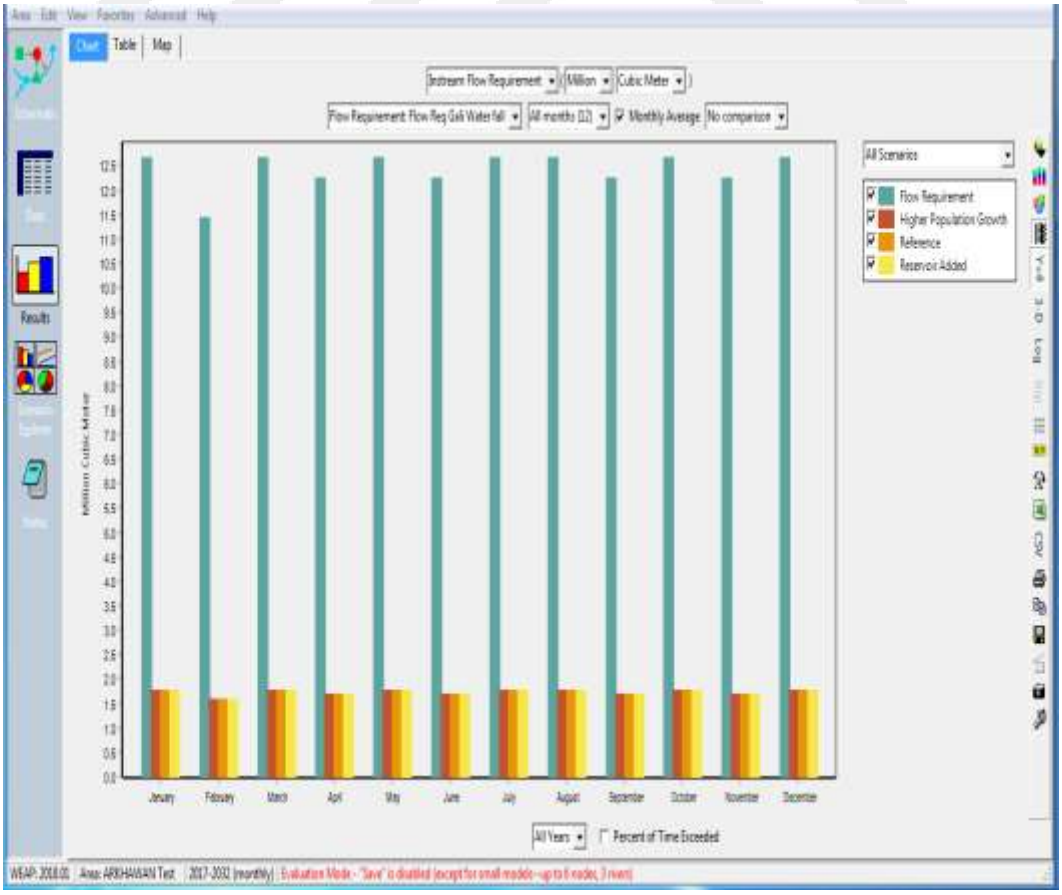


Chart
Table
Map
Instream Flow Requirement
Million
Cubic Meter
Monthly Average
No comparison
Results
Million Cubic Meter
January
February
March
April
May
June
July
August
September
October
November
December
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
All Years
Percent of Time Exceeded

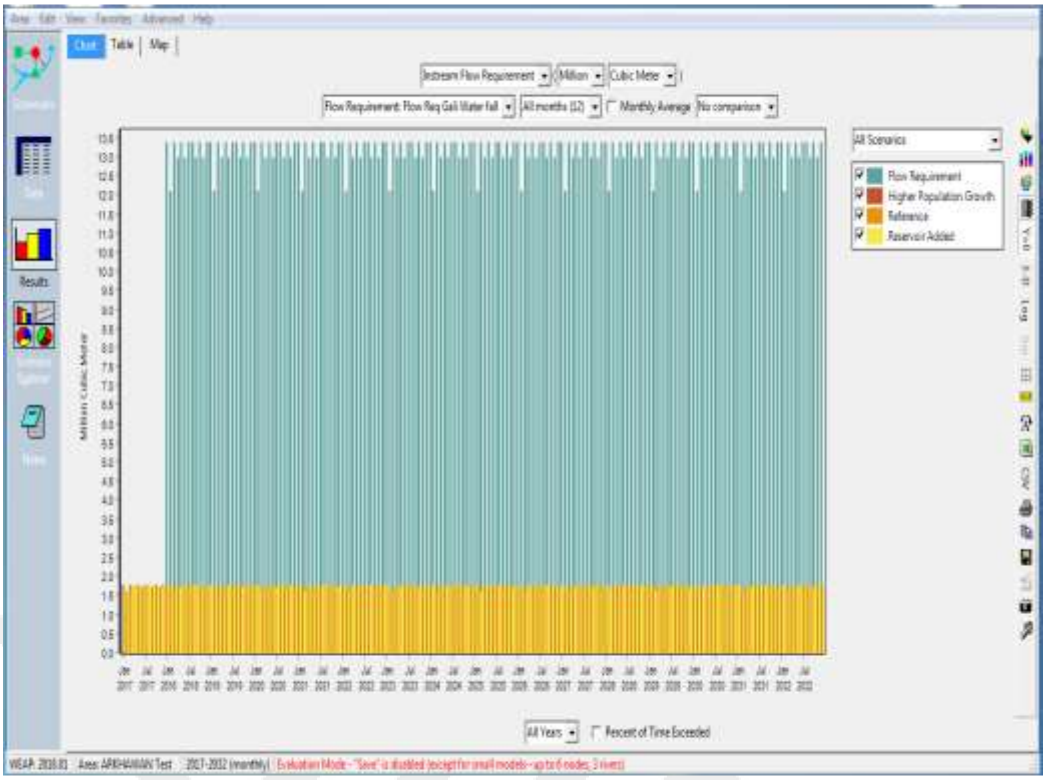


Chart
Table
Map
Instream Flow Requirement
Million
Cubic Meter
Monthly Average
No comparison
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
Million Cubic Meter
All Years
Percent of Time Exceeded

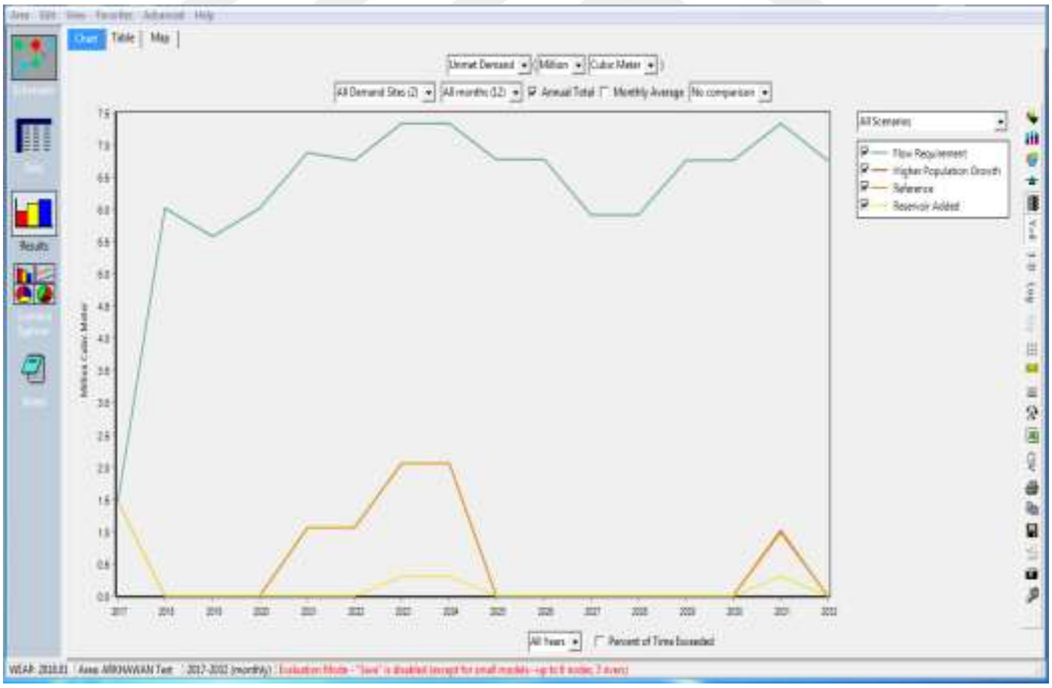
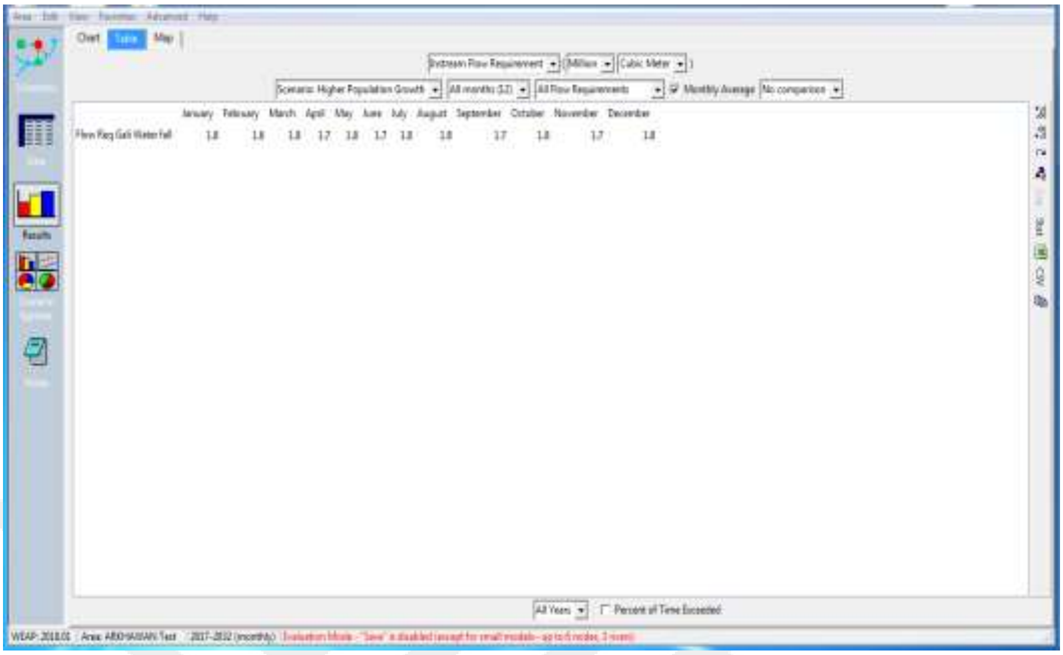
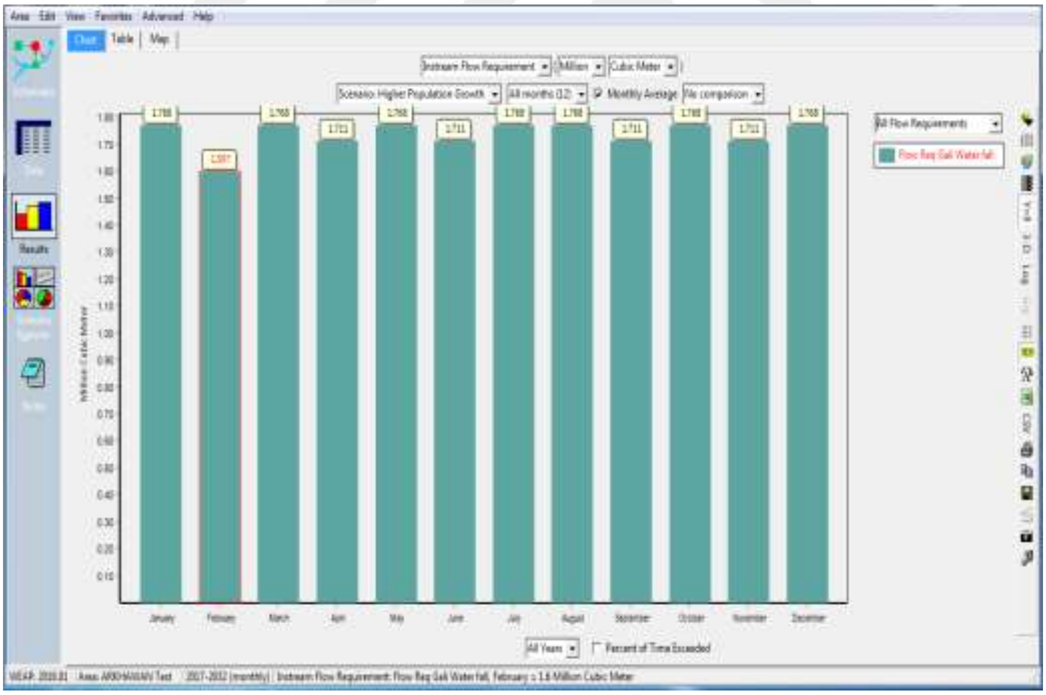
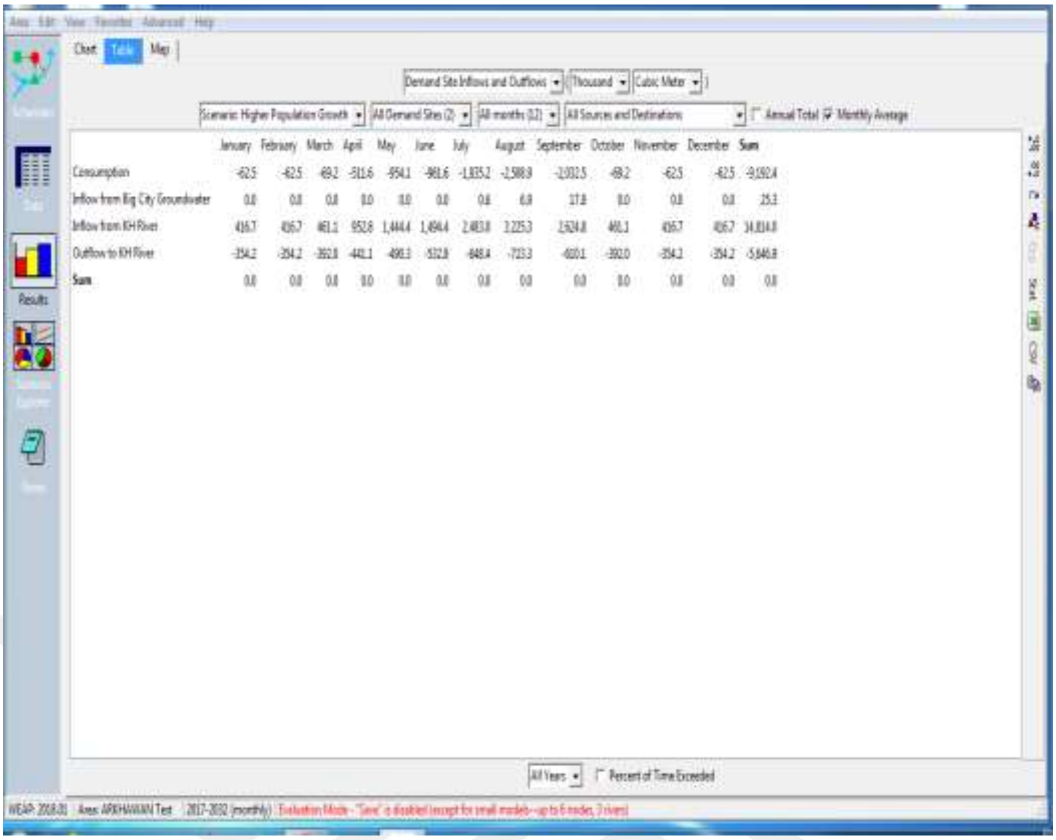


Chart
Table
Map
Unmet Demand
Million
Cubic Meter
Annual Total
Monthly Average
No comparison
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
Million Cubic Meter
All Years
Percent of Time Exceeded

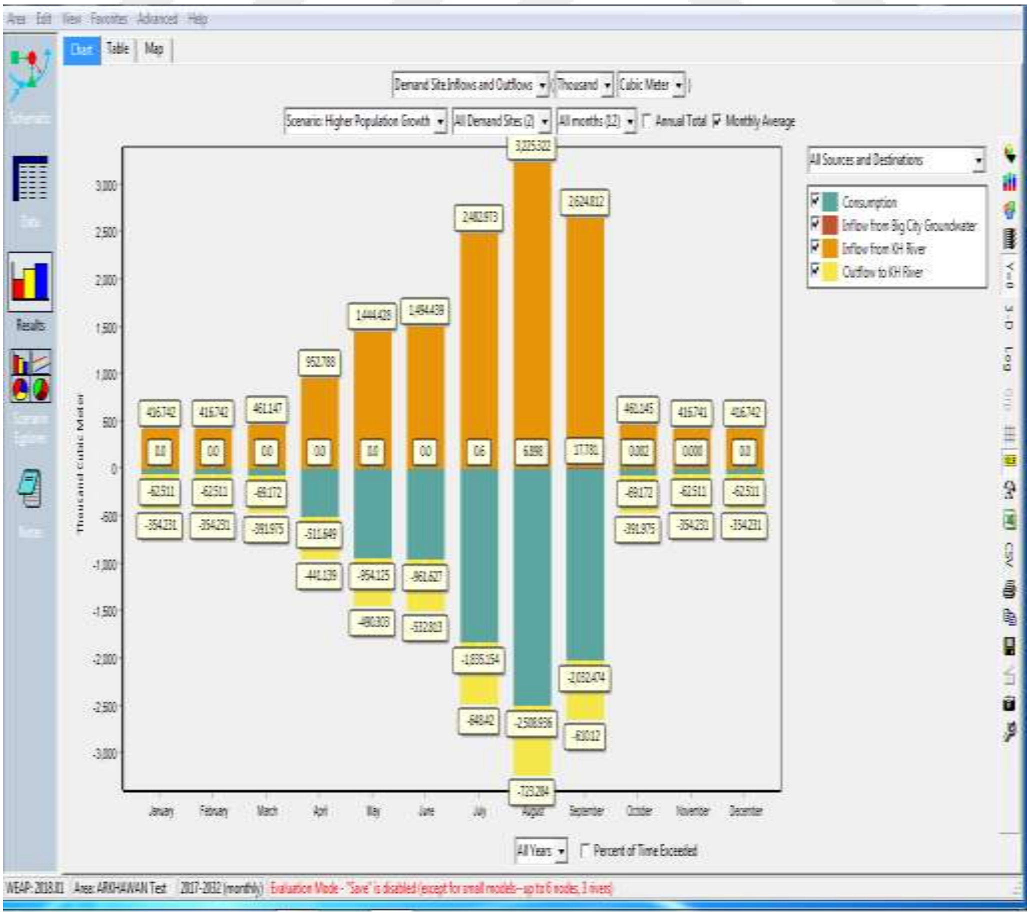
Appendix F Run model output from the high population growth scenario

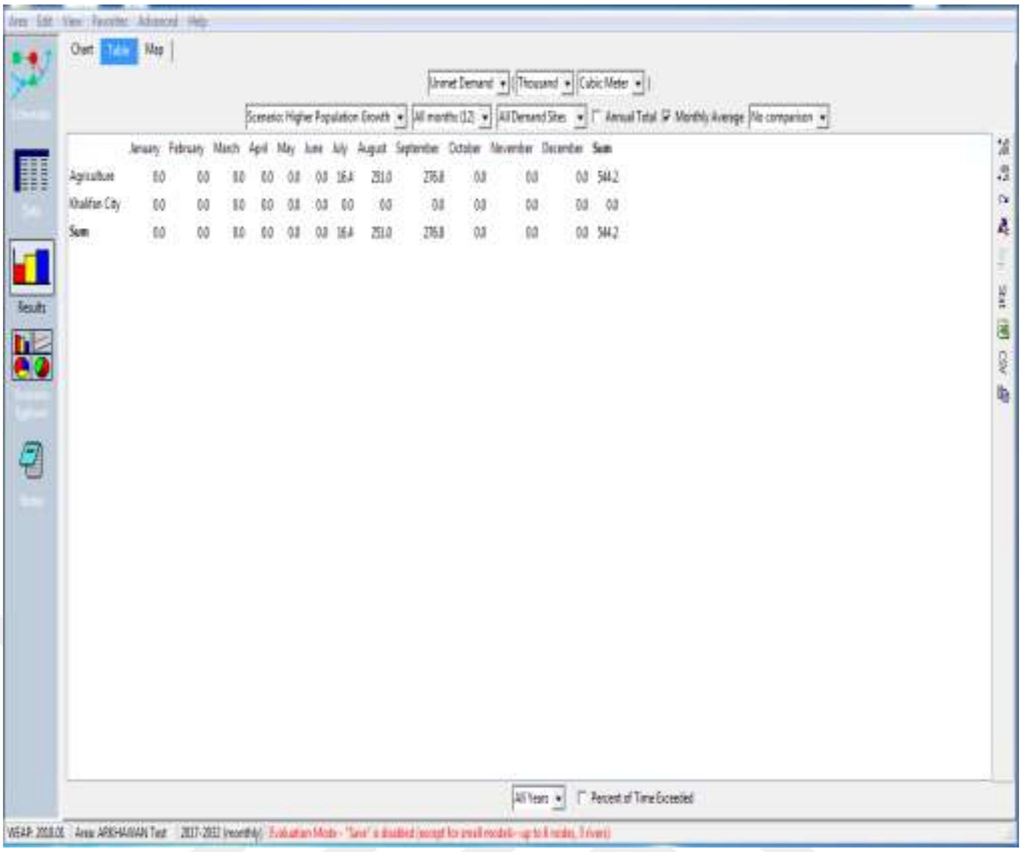




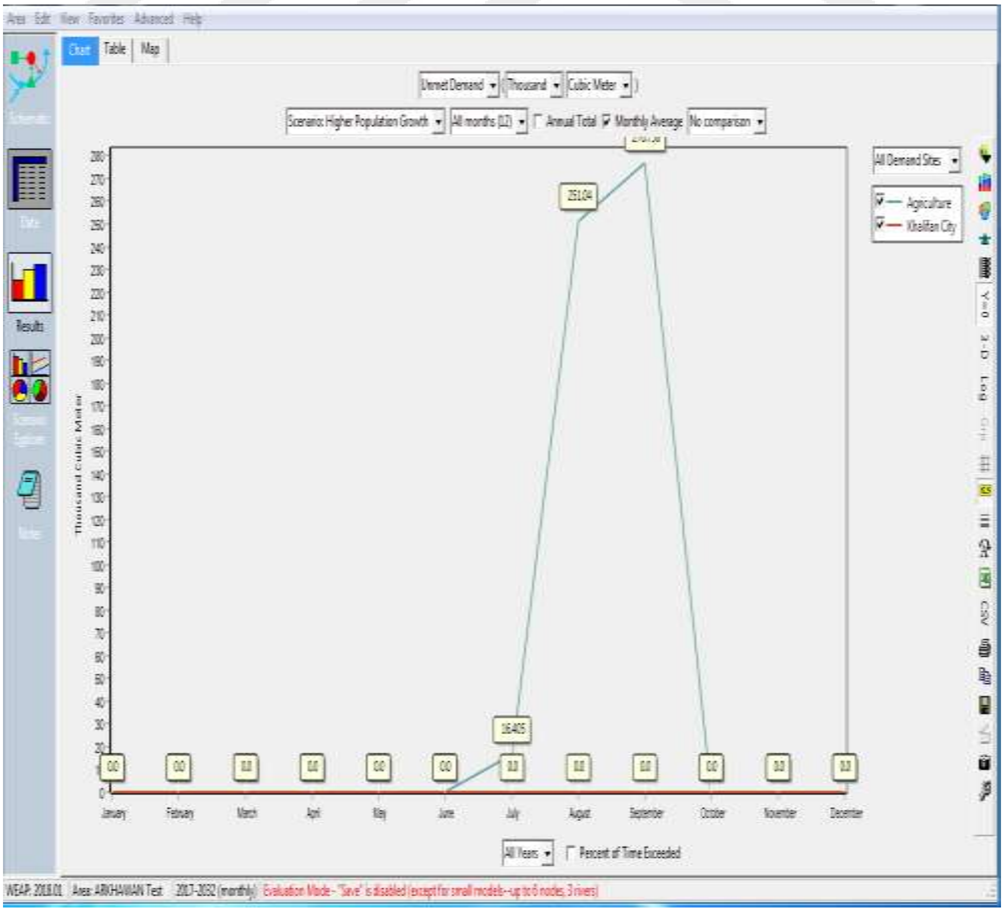


	January	February	March	April	May	June	July	August	September	October	November	December	Sum
Consumption	-62.5	-62.5	-69.2	-511.6	-954.1	-961.6	-1,835.2	-2,508.9	-2,032.5	-69.2	-62.5	-62.5	-9,192.4
Inflow from Big City Groundwater	0.0	0.0	0.0	0.0	0.0	0.0	0.6	6.9	17.8	0.0	0.0	0.0	25.3
Inflow from KH River	416.7	416.7	461.1	952.8	1,444.4	1,494.4	2,483.0	3,225.3	2,624.8	461.1	416.7	416.7	14,814.8
Outflow to KH River	-354.2	-354.2	-392.0	-441.1	-490.3	-532.8	-648.4	-723.3	-610.1	-392.0	-354.2	-354.2	-5,646.8
Sum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0





	January	February	March	April	May	June	July	August	September	October	November	December	Sum
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	16.4	251.0	276.8	0.0	0.0	0.0	544.2
Khalifan City	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sum	0.0	0.0	0.0	0.0	0.0	0.0	16.4	251.0	276.8	0.0	0.0	0.0	544.2



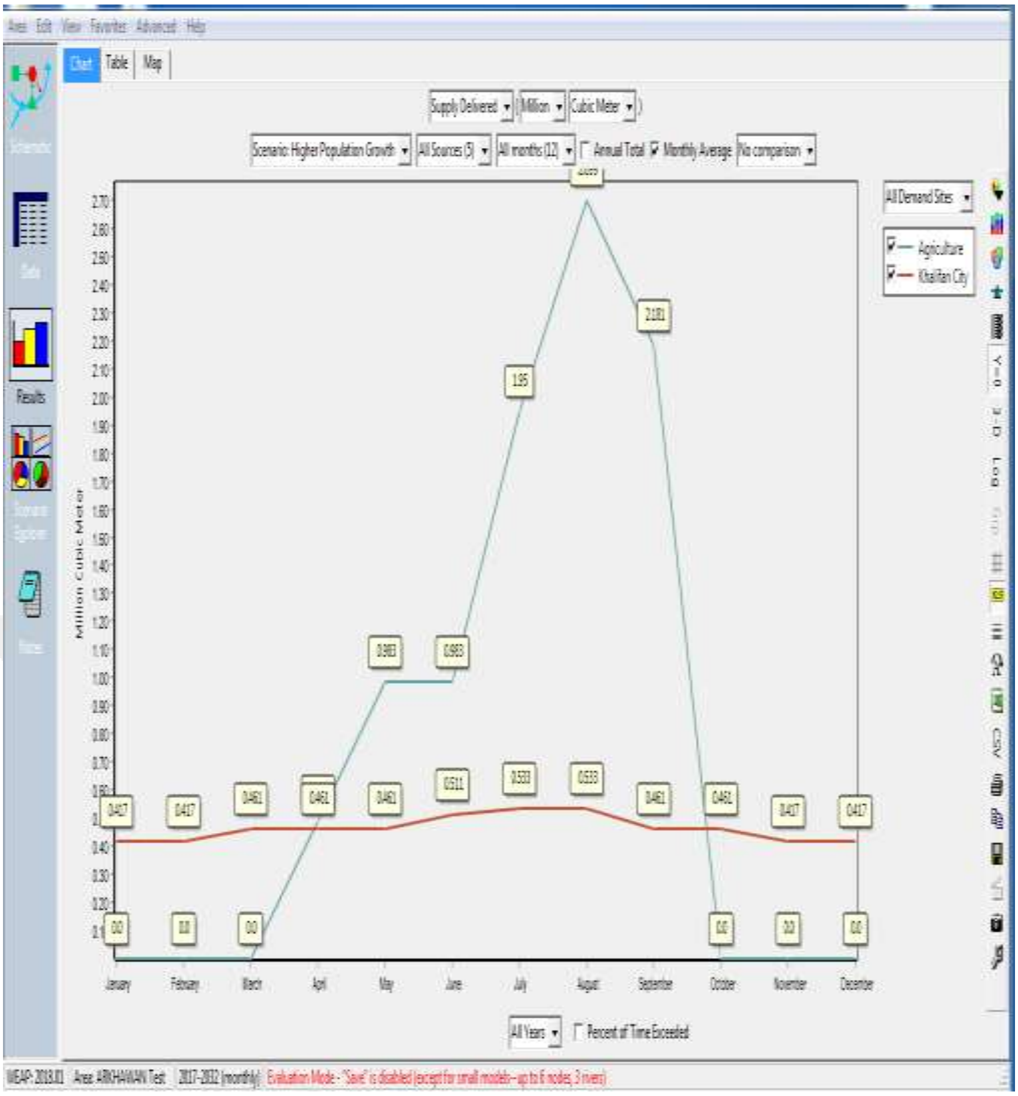


Chart
Table
Map
Supply Delivered
Million
Cubic Meter
Scenario: Higher Population Growth
All Sources (5)
All months (12)
Annual Total
Monthly Average
No comparison
All Demand Sites
Agriculture
Khalifan City
Million Cubic Meter
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded

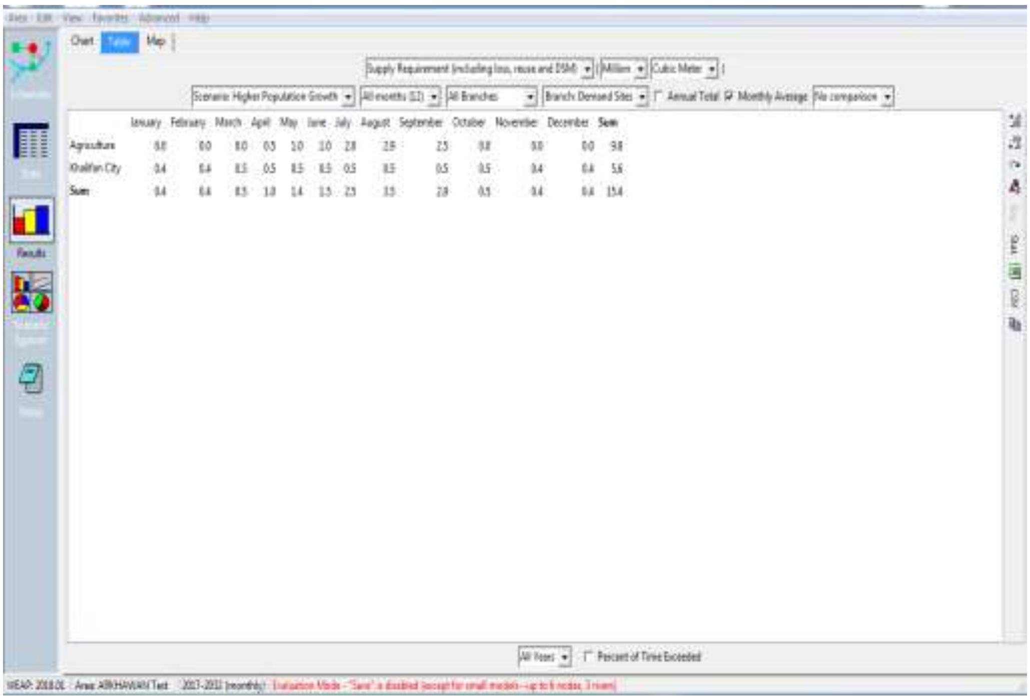
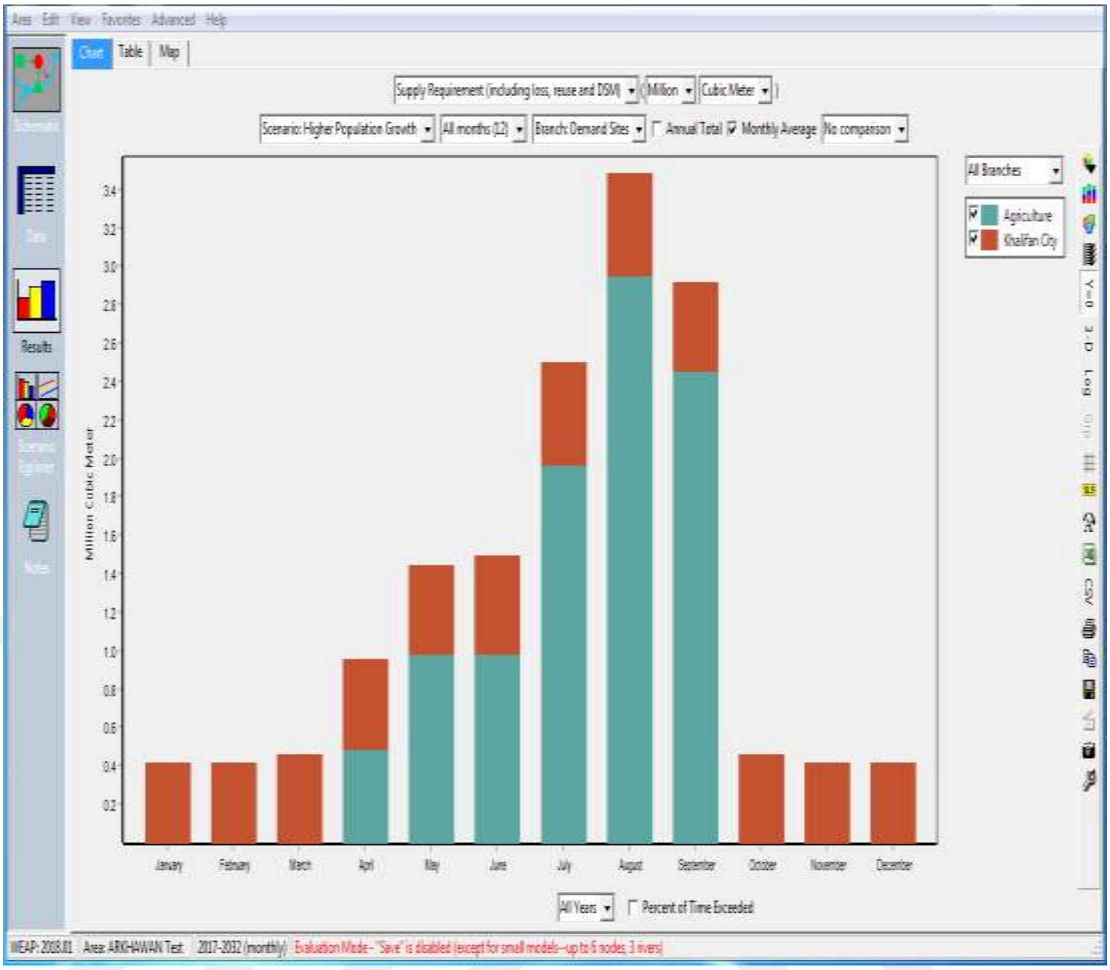
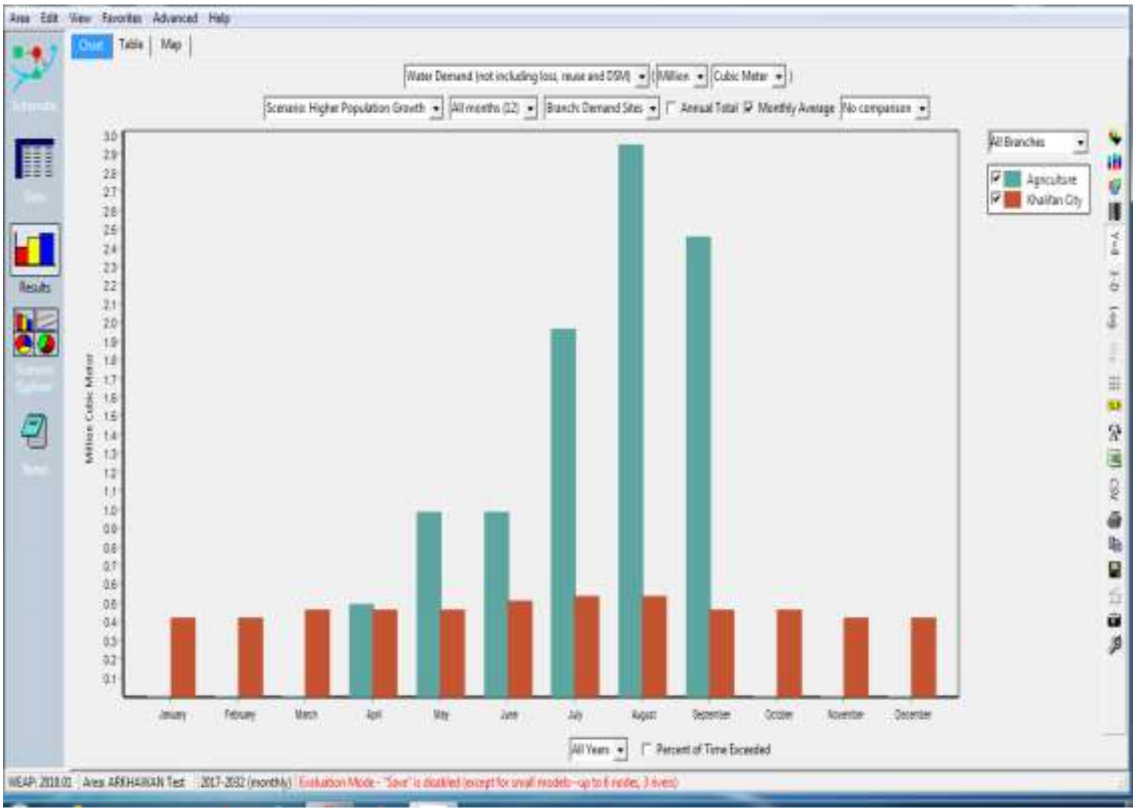
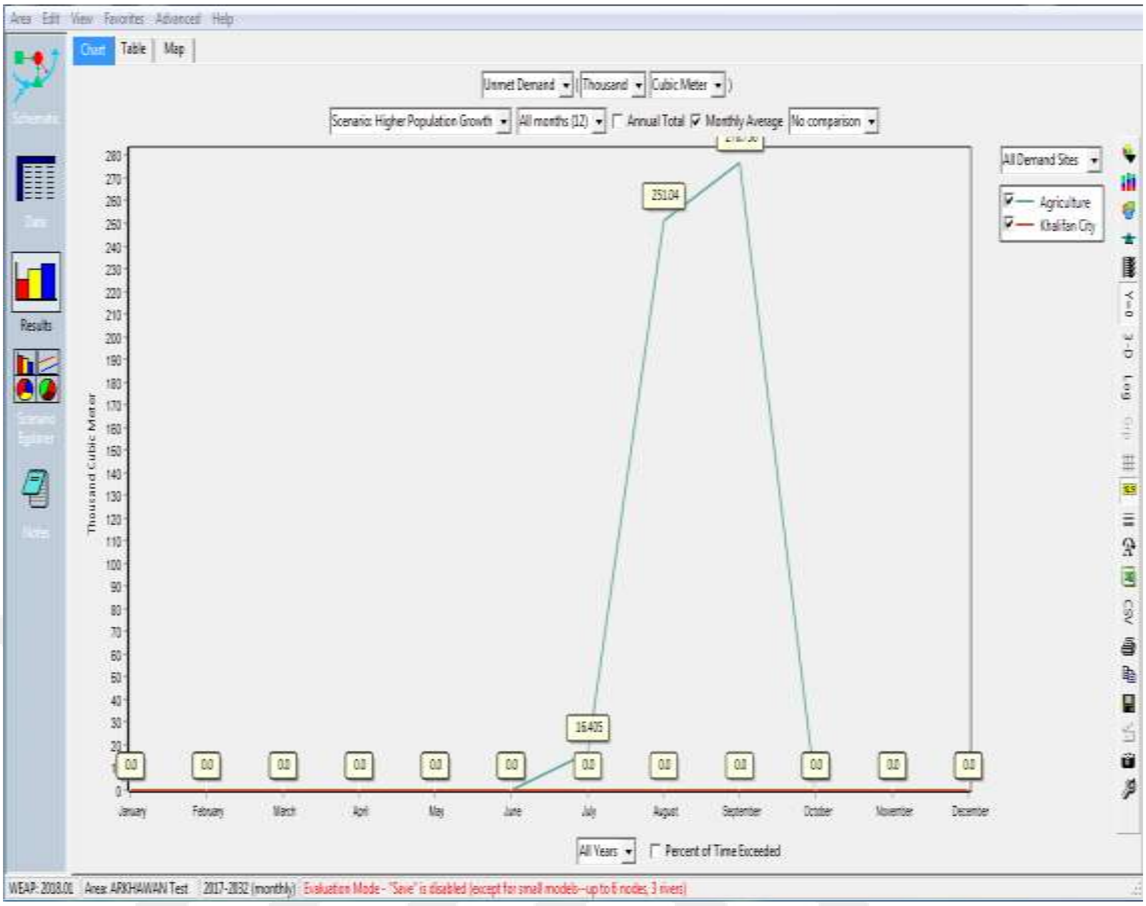
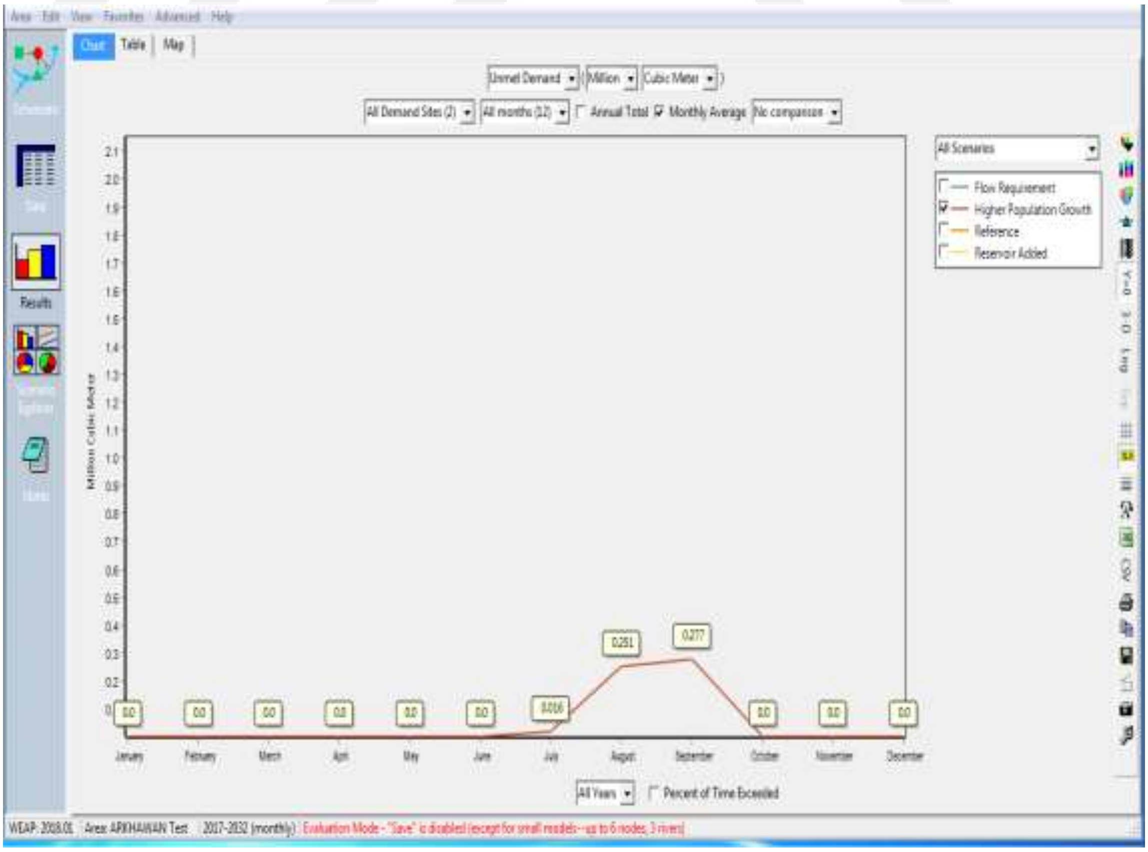


Chart
Table
Map
Supply Requirement (including loss, reuse and DSM)
Million
Cubic Meter
Scenario: Higher Population Growth
All months (12)
All Branches
Branch: Demand Sites
Annual Total
Monthly Average
No comparison
January February March April May June July August September October November December Sum
Agriculture
Khalifan City
Sum
All Years
Percent of Time Exceeded

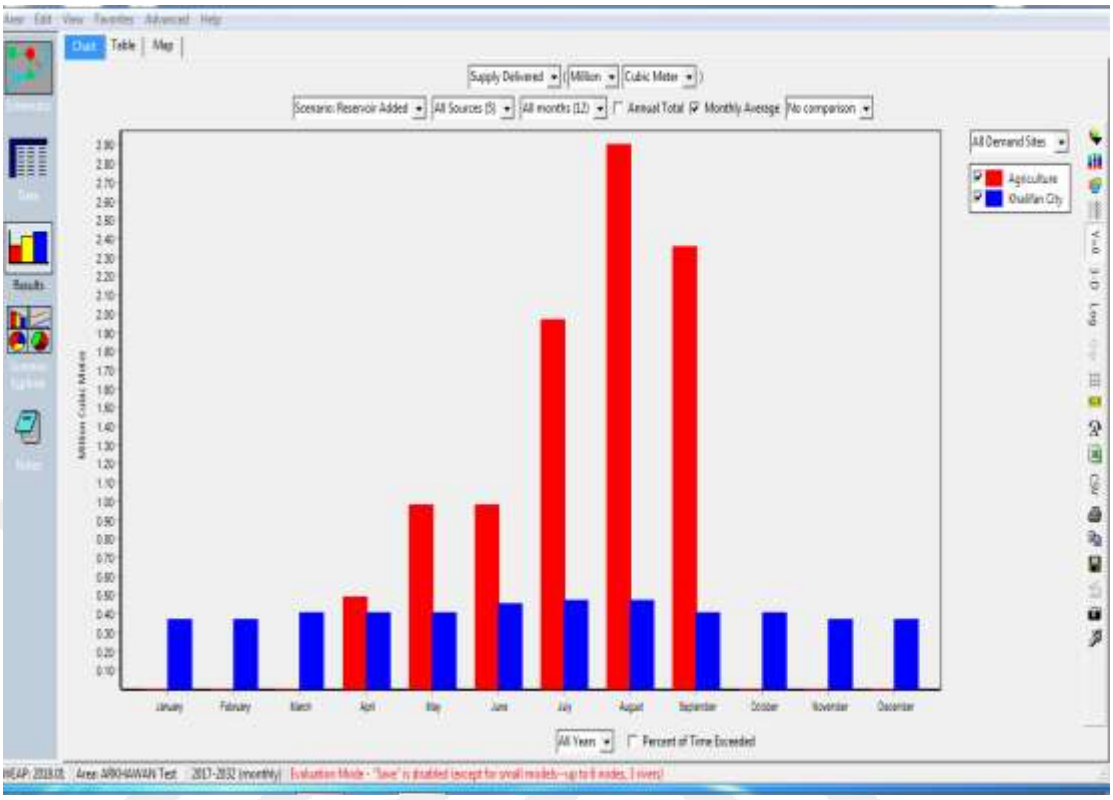

Supply Requirement (including loss, reuse and DSM)
Million
Cubic Meter
Scenario: Higher Population Growth
All months (12)
Branch: Demand Sites
Annual Total
Monthly Average
No comparison
All Branches
Agriculture
Khalifan City
Million Cubic Meter
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

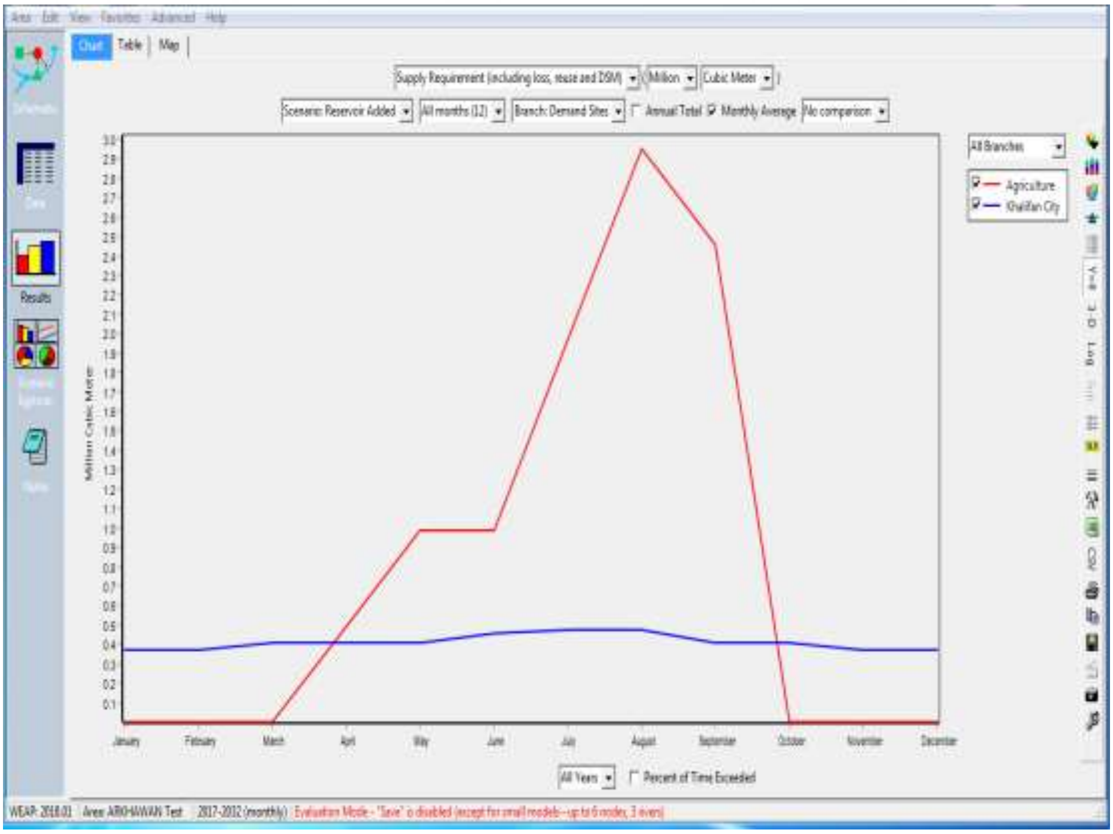

Water Demand (not including loss, reuse and DSM)
Million
Cubic Meter
Scenario: Higher Population Growth
All months (12)
Branch: Demand Sites
Annual Total
Monthly Average
No comparison
All Branches
Agriculture
Khalifan City
Million Cubic Meter
All Years
Percent of Time Exceeded
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

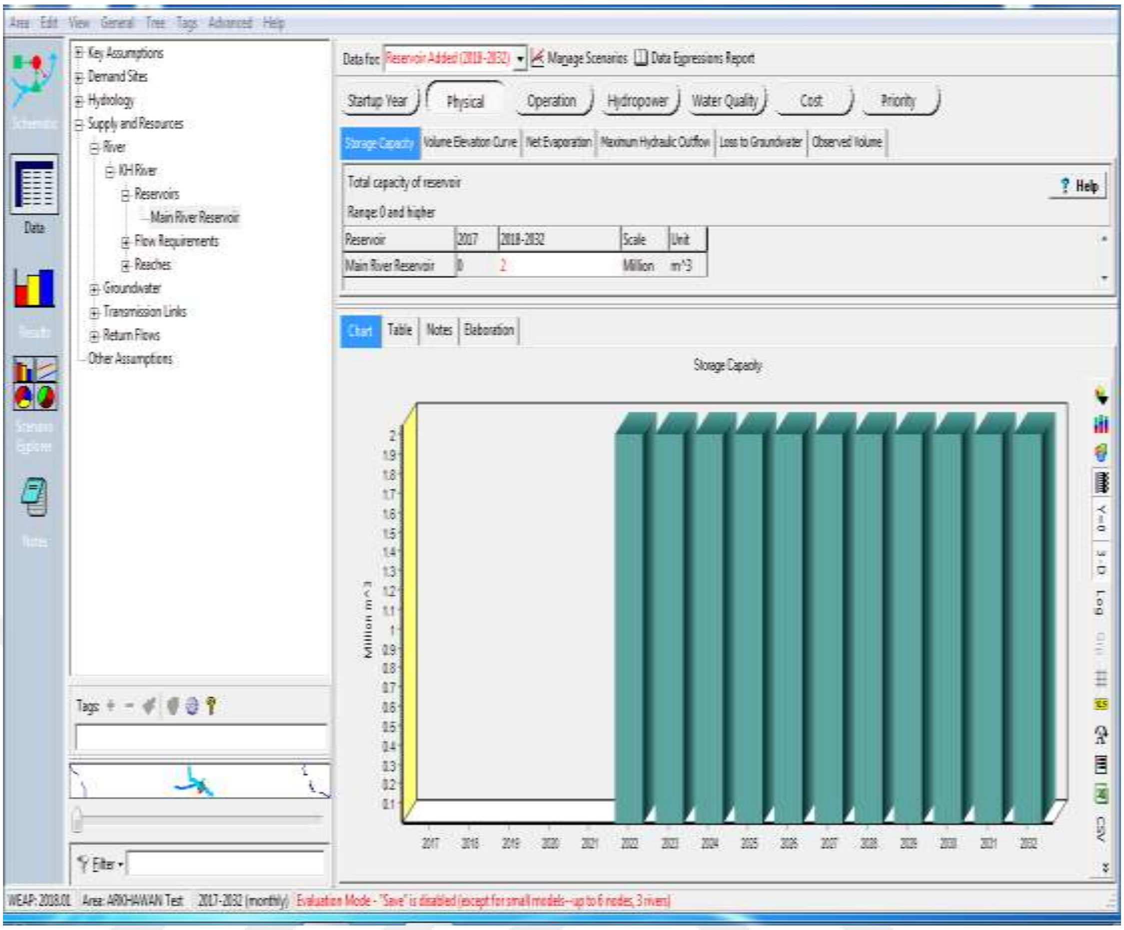

Unmet Demand
Thousand
Cubic Meter
Scenario: Higher Population Growth
All months (12)
Annual Total
Monthly Average
No comparison
All Demand Sites
Agriculture
Khalifan City
Thousand Cubic Meter
251.04
164.05
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)


Unmet Demand
Million
Cubic Meter
All Demand Sites (2)
All months (12)
Annual Total
Monthly Average
No comparison
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
Million Cubic Meter
0.251
0.277
0.016
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

Appendix G Run model output from the reservoir added scenario






Data for: Reservoir Added (2018-2032)
Manage Scenarios
Data Expressions Report
Startup Year
Physical
Operation
Hydropower
Water Quality
Cost
Priority
Storage Capacity
Volume Elevation Curve
Net Evaporation
Maximum Hydraulic Outflow
Loss to Groundwater
Observed Volume
Total capacity of reservoir
Range: 0 and higher
Reservoir
2017
2018-2032
Scale
Unit
Main River Reservoir
0
2
Million
m^3
Key Assumptions
Demand Sites
Hydrology
Supply and Resources
River
KH River
Reservoirs
Main River Reservoir
Flow Requirements
Reaches
Groundwater
Transmission Links
Return Flows
Other Assumptions
Chart
Table
Notes
Elaboration
Storage Capacity
Million m^3
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

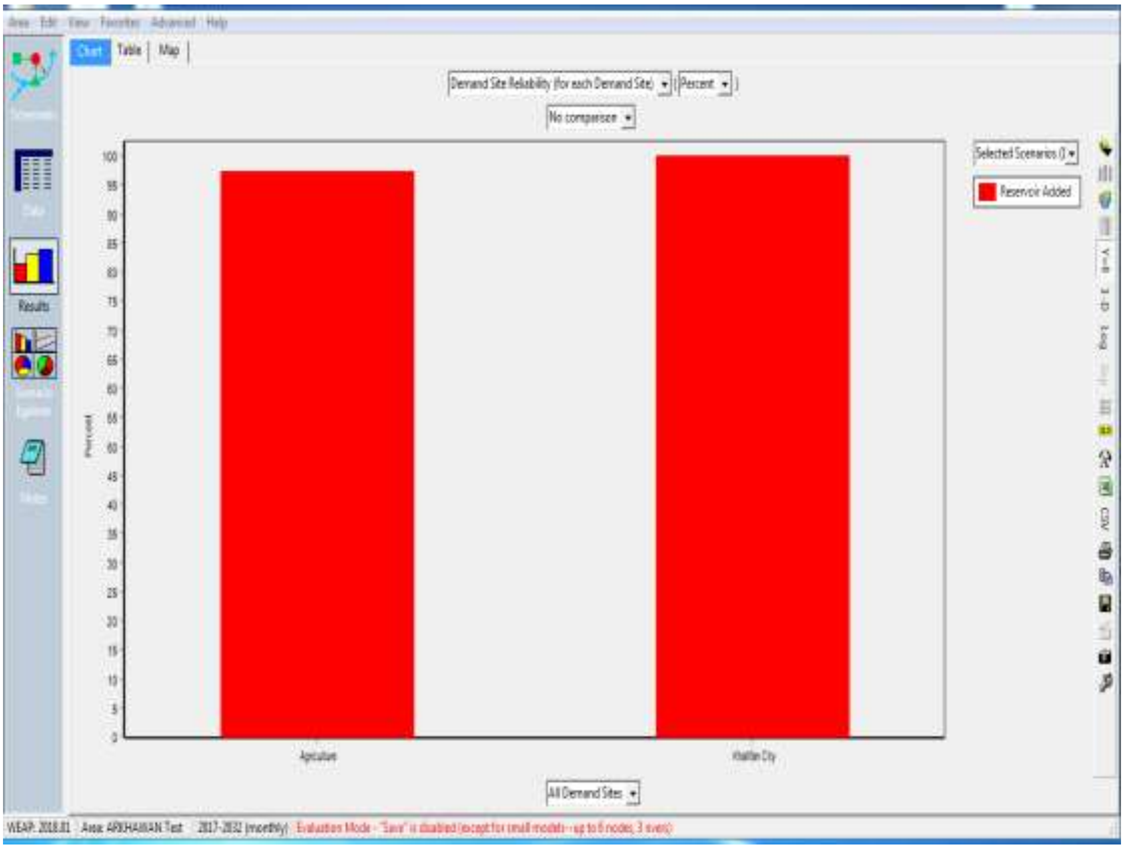


Chart
Table
Map
Demand Site Reliability (for each Demand Site)
Percent
No comparison
Selected Scenarios
Reservoir Added
Percent
Agriculture
All Demand Sites
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)

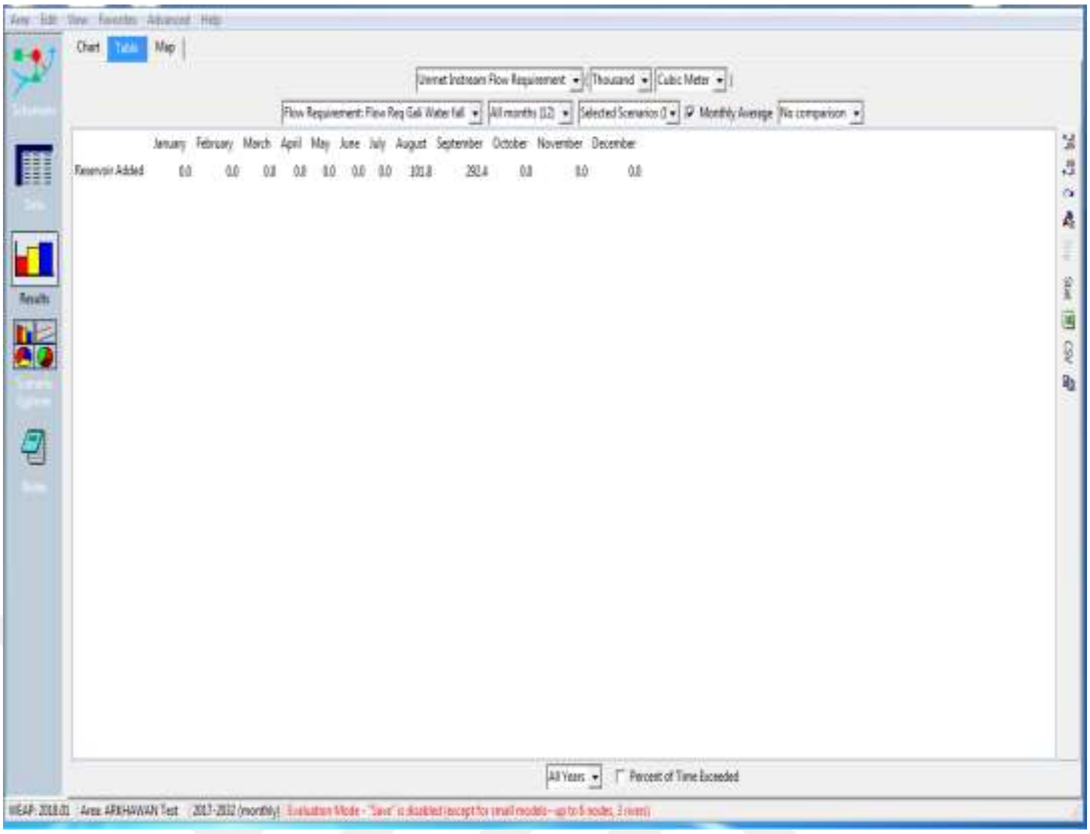


Chart
Table
Map
Unmet Instream Flow Requirement
Thousand
Cubic Meter
All months (12)
Monthly Average
No comparison
January February March April May June July August September October November December
Reservoir Added
All Years
Percent of Time Exceeded

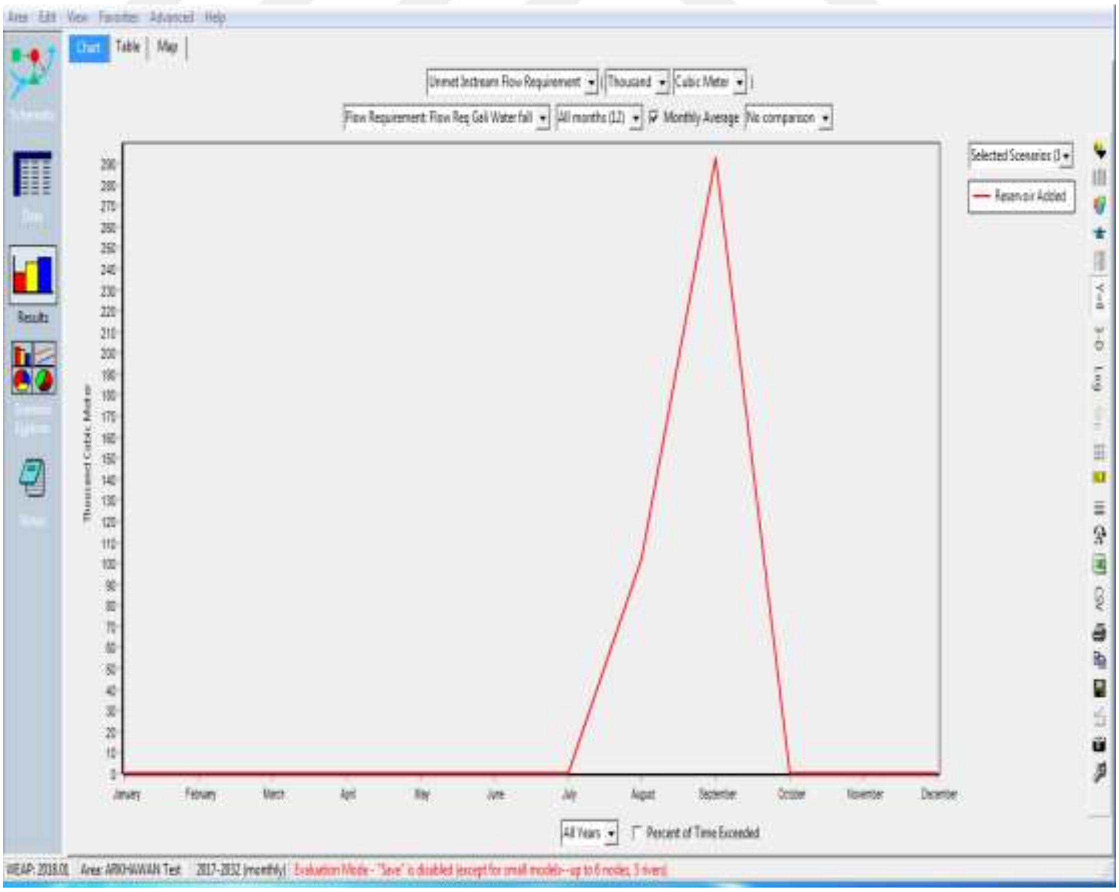


Chart
Table
Map
Unmet Instream Flow Requirement
Thousand
Cubic Meter
All months (12)
Monthly Average
No comparison
Reservoir Added
Thousand Cubic Meter
January February March April May June July August September October November December
All Years
Percent of Time Exceeded

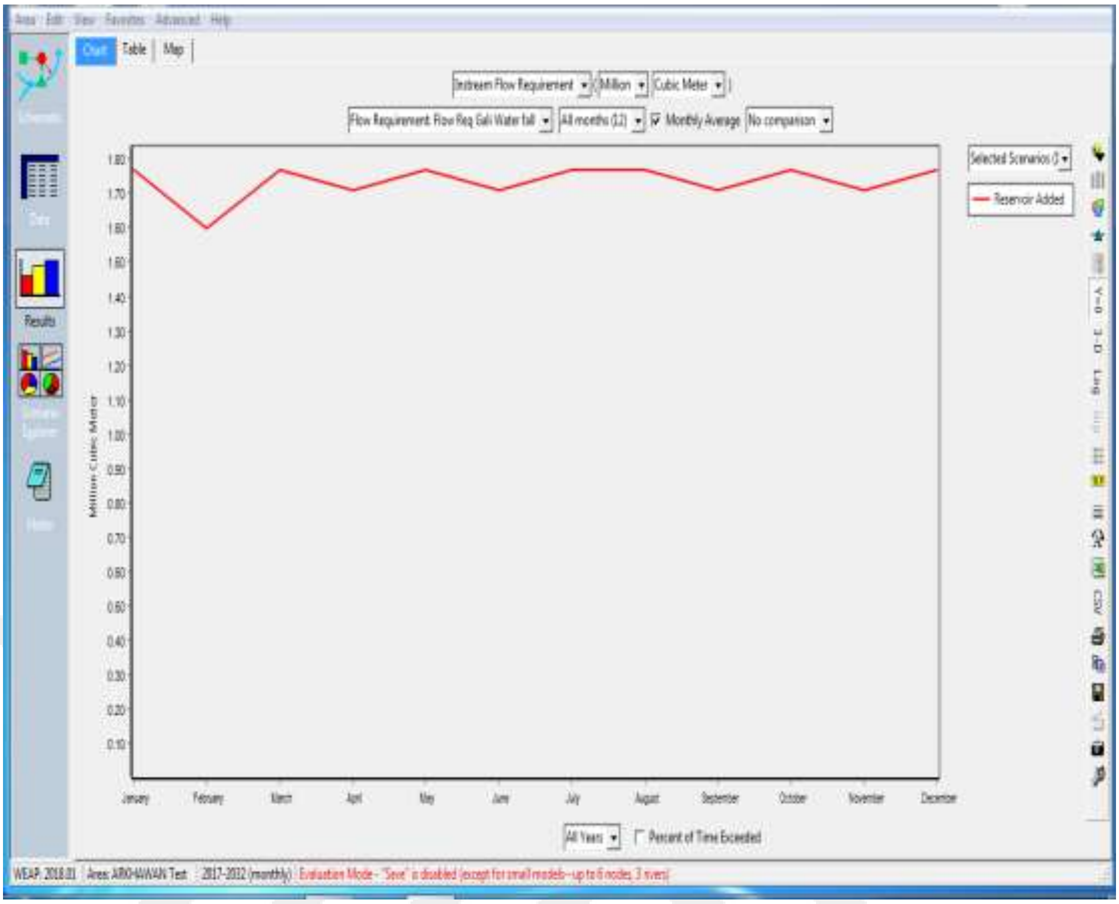


Chart
Table
Map
Instream Flow Requirement
Million
Cubic Meter
Flow Requirement: Flow Req Gali Water fall
All months (12)
Monthly Average
No comparison
Selected Scenarios
Reservoir Added
Million Cubic Meter
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

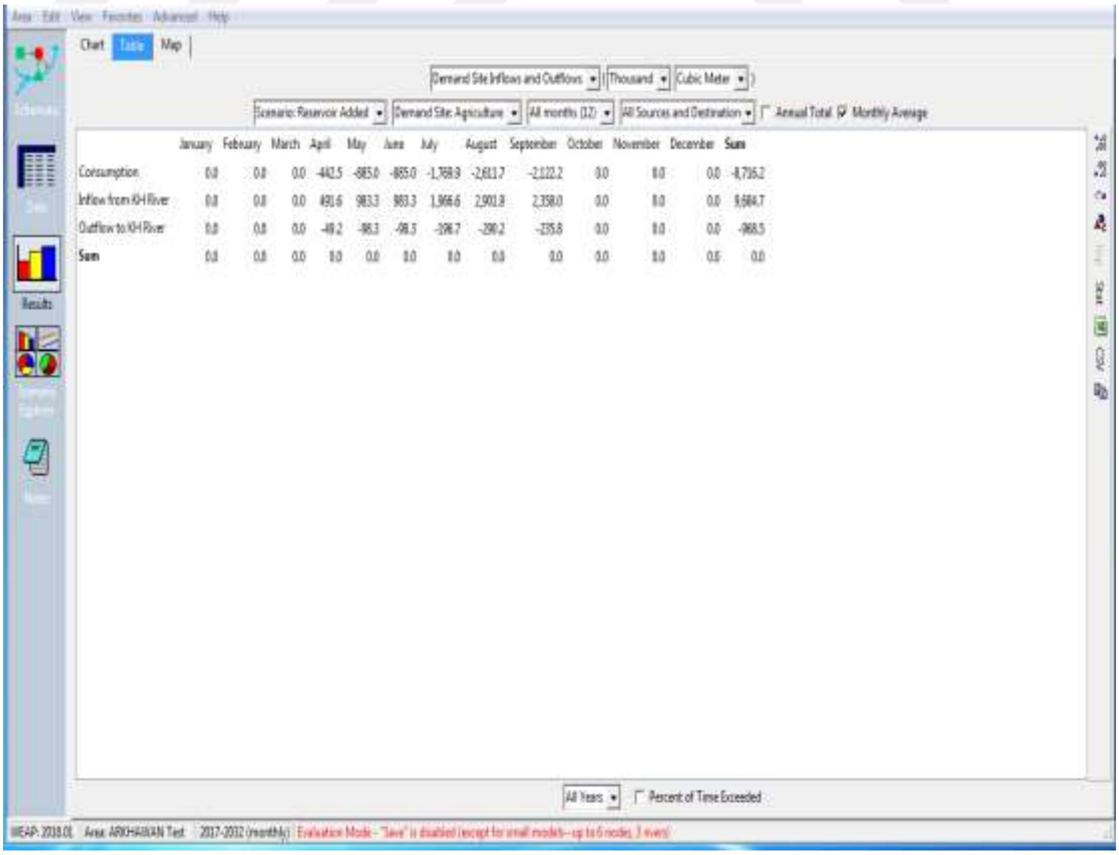
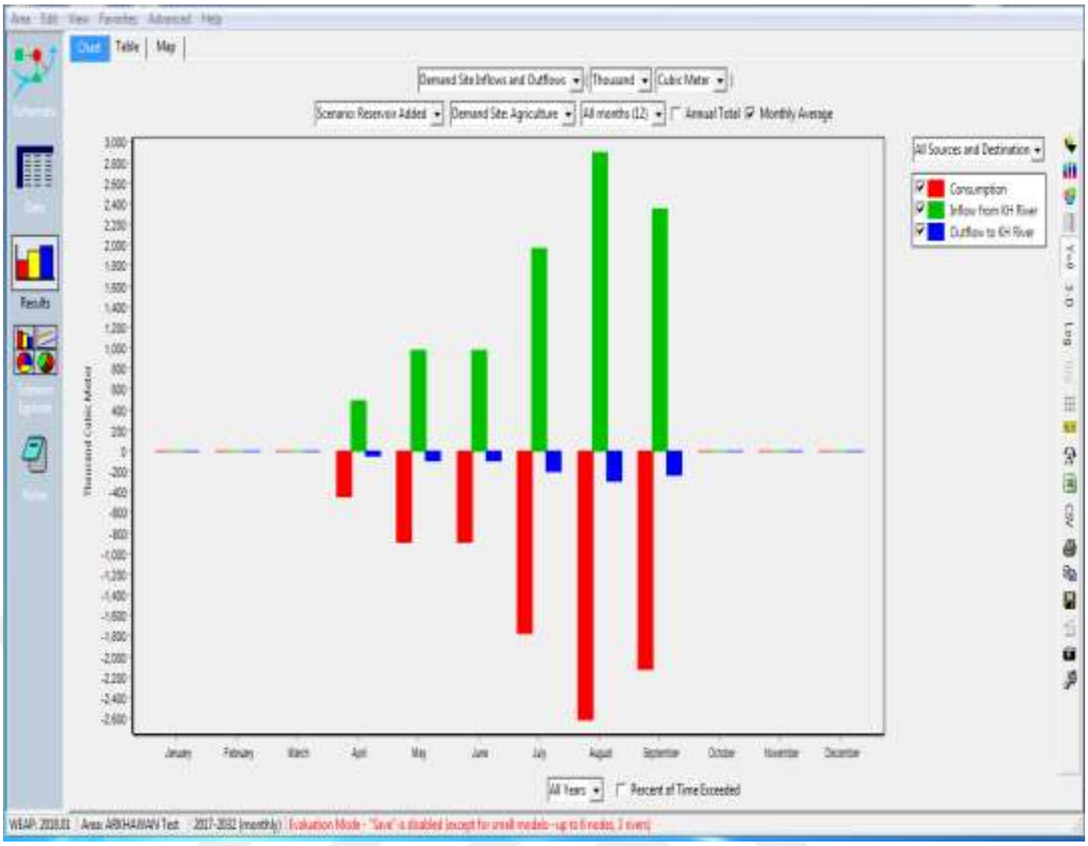
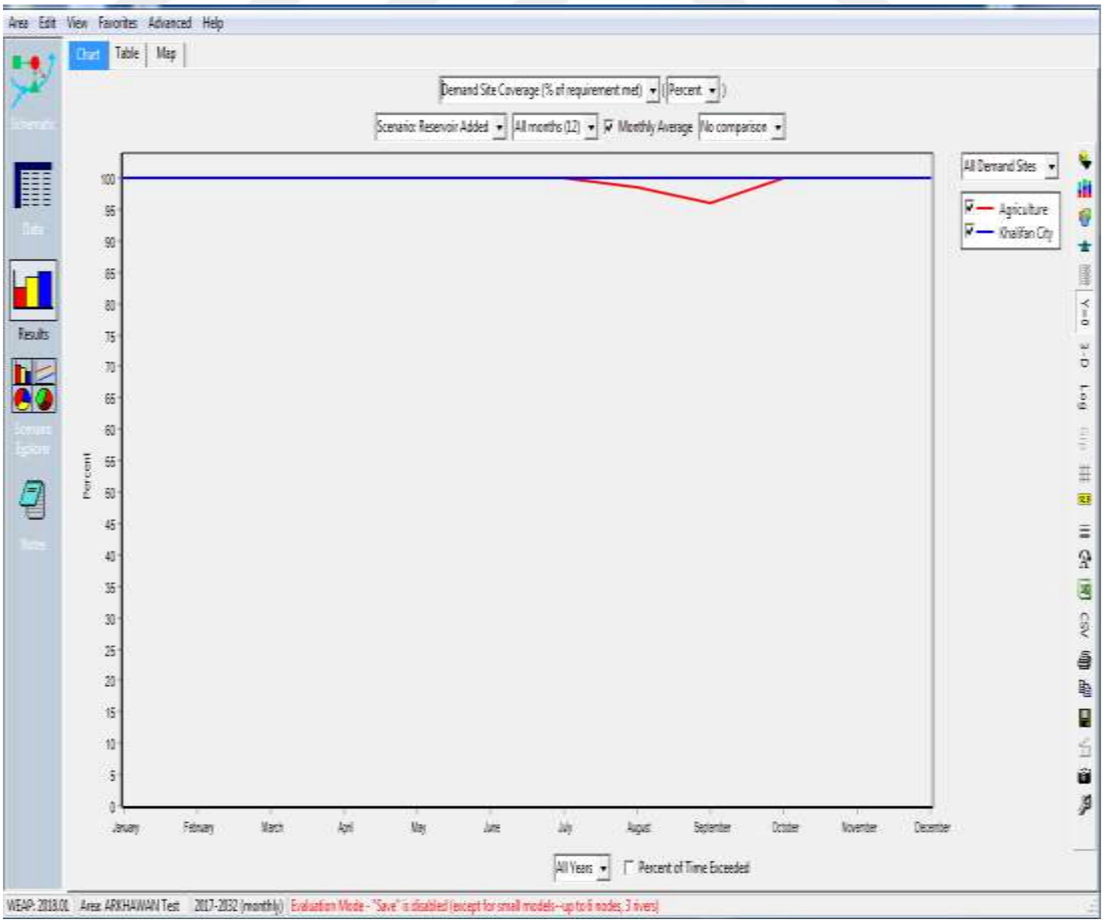


Chart
Table
Map
Demand Site Inflows and Outflows
Thousand
Cubic Meter
Scenario: Reservoir Added
Demand Site: Agriculture
All months (12)
All Sources and Destination
Annual Total
Monthly Average
January February March April May June July August September October November December Sum
Consumption 0.0 0.0 0.0 -442.5 -885.0 -885.0 -1,769.9 -2,611.7 -2,122.2 0.0 0.0 0.0 -8,716.2
Inflow from KH River 0.0 0.0 0.0 491.6 983.3 983.3 1,966.6 2,901.9 2,358.0 0.0 0.0 0.0 9,684.7
Outflow to KH River 0.0 0.0 0.0 -49.2 -98.3 -98.3 -196.7 -290.2 -235.8 0.0 0.0 0.0 -968.5
Sum 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
All Years
Percent of Time Exceeded
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)





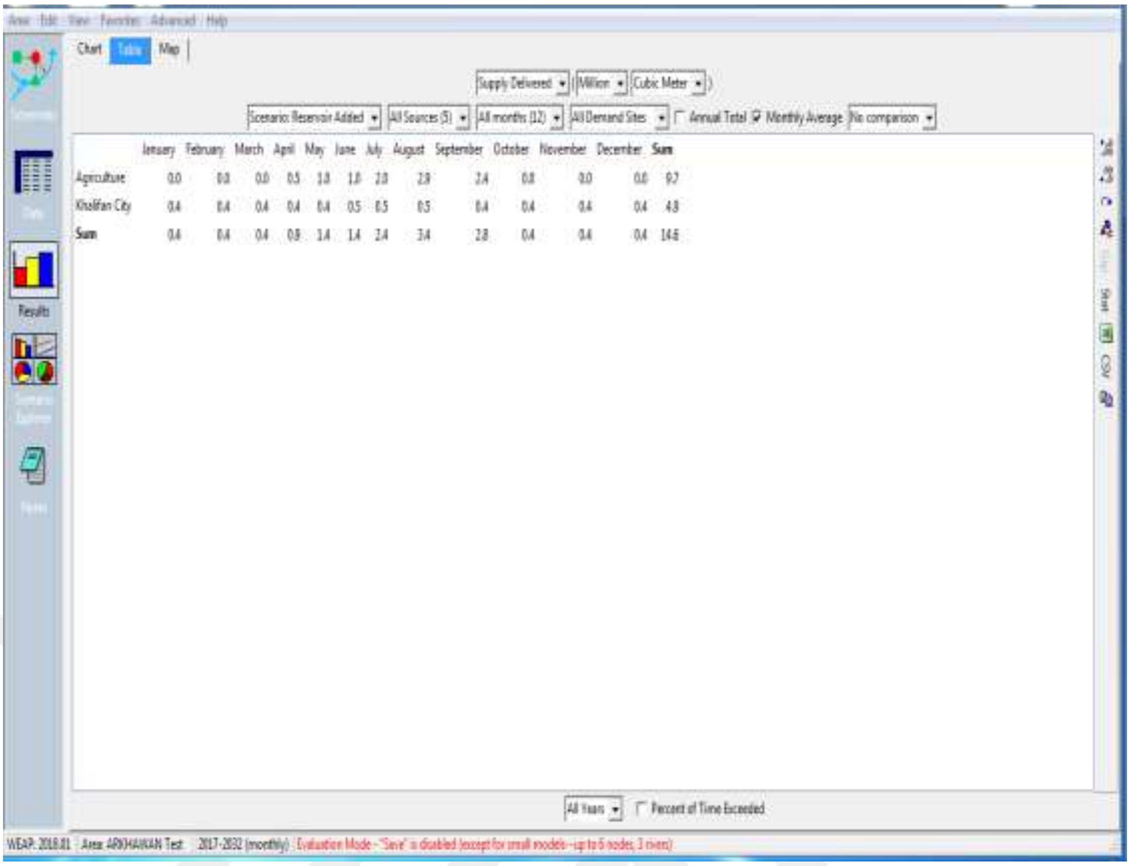
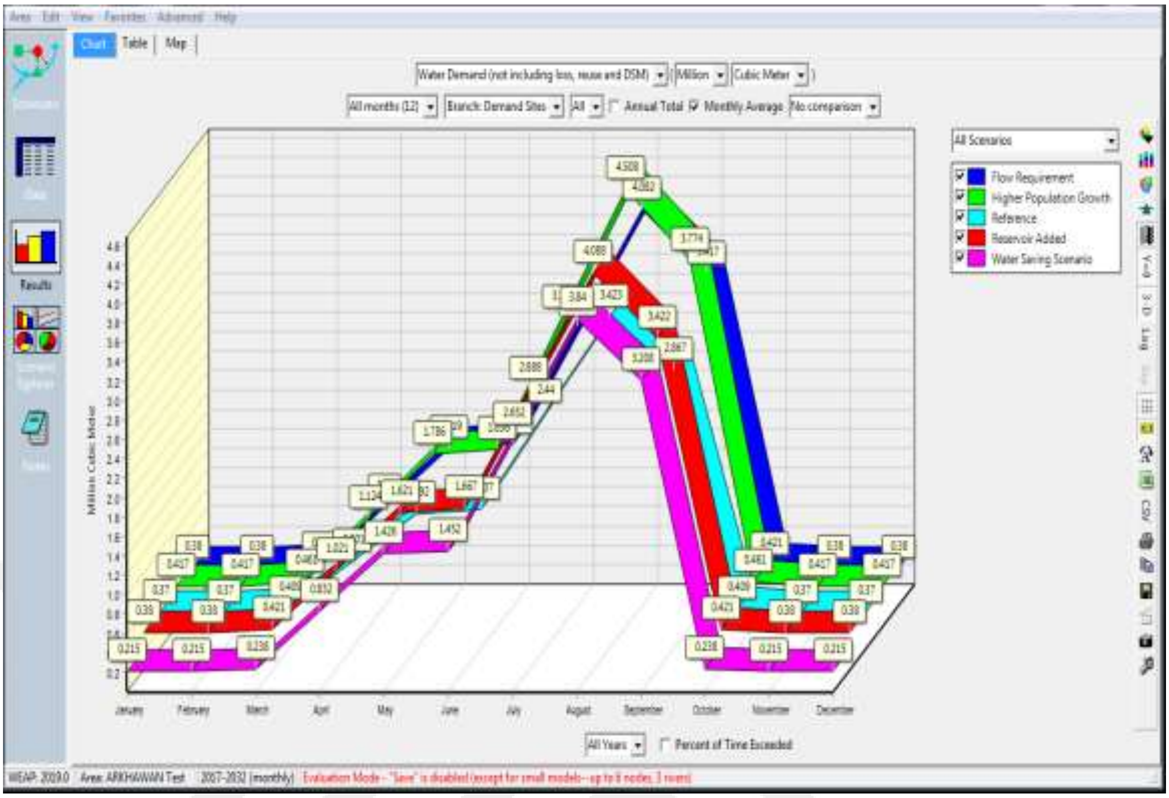
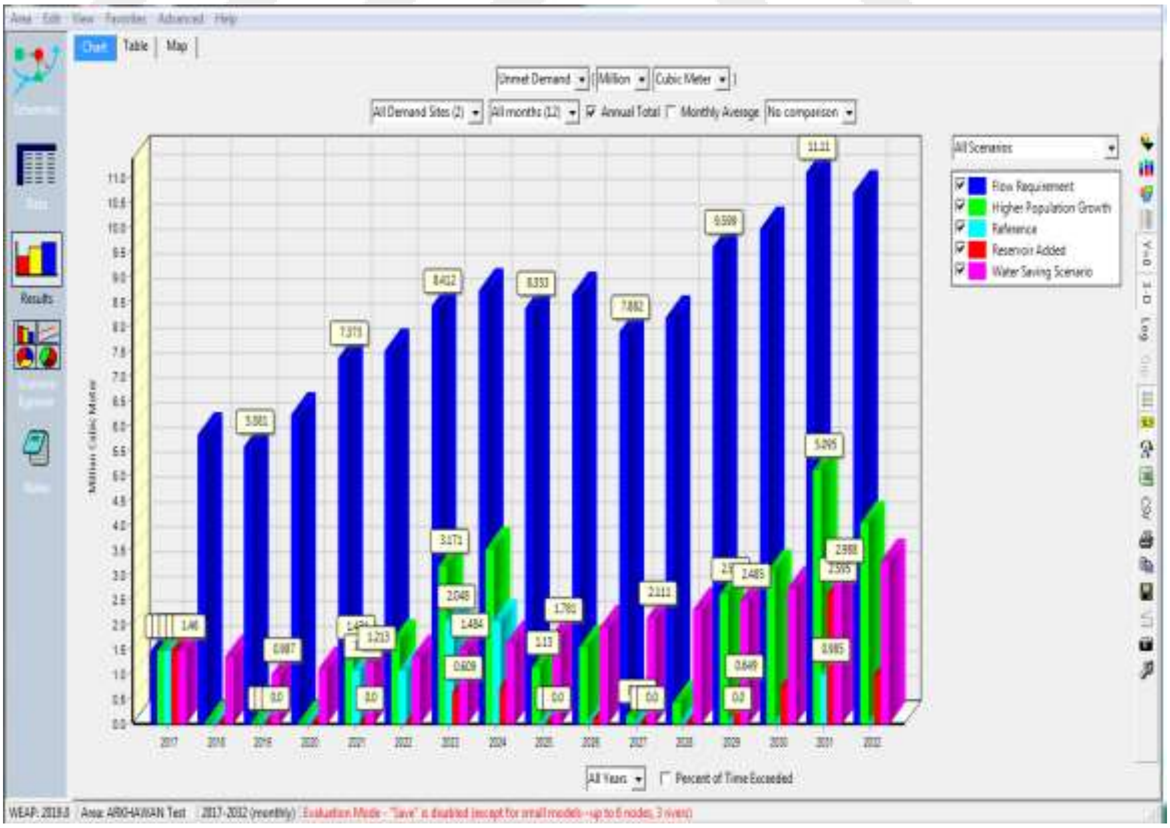
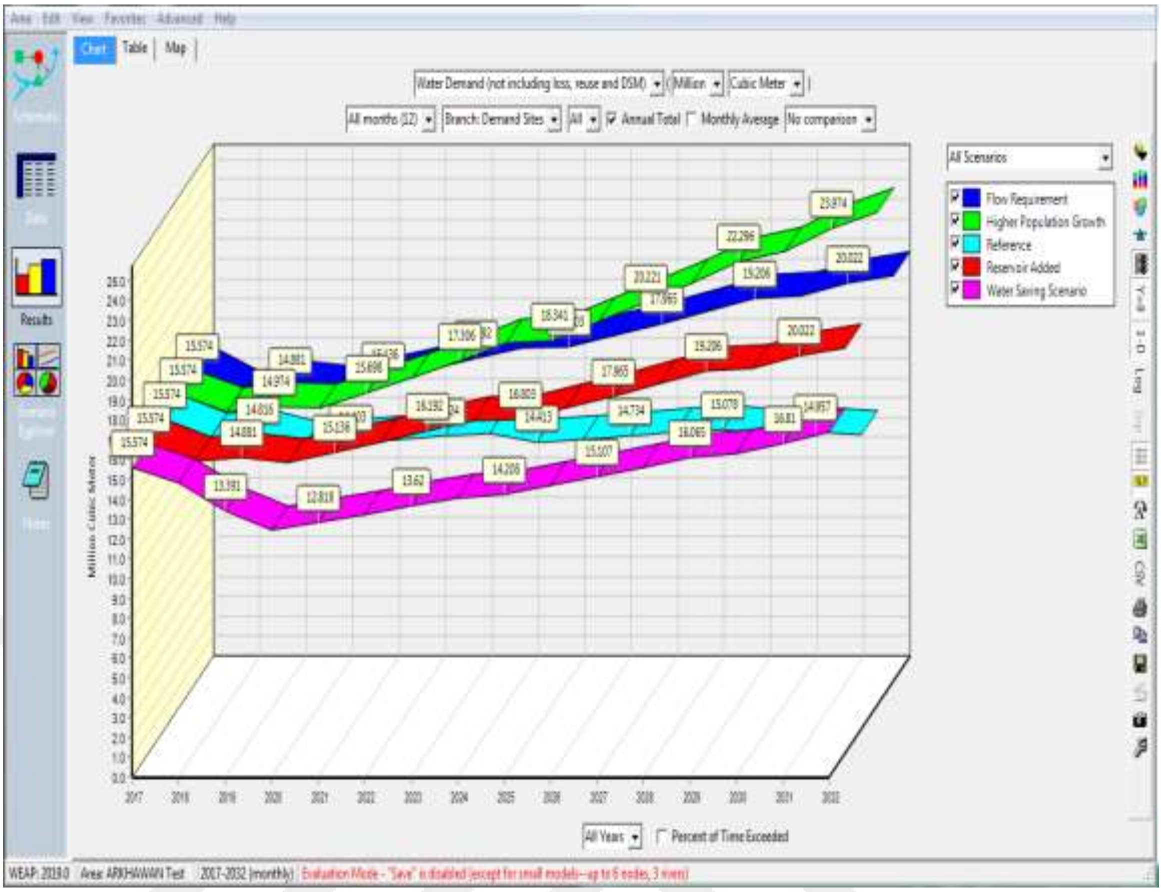


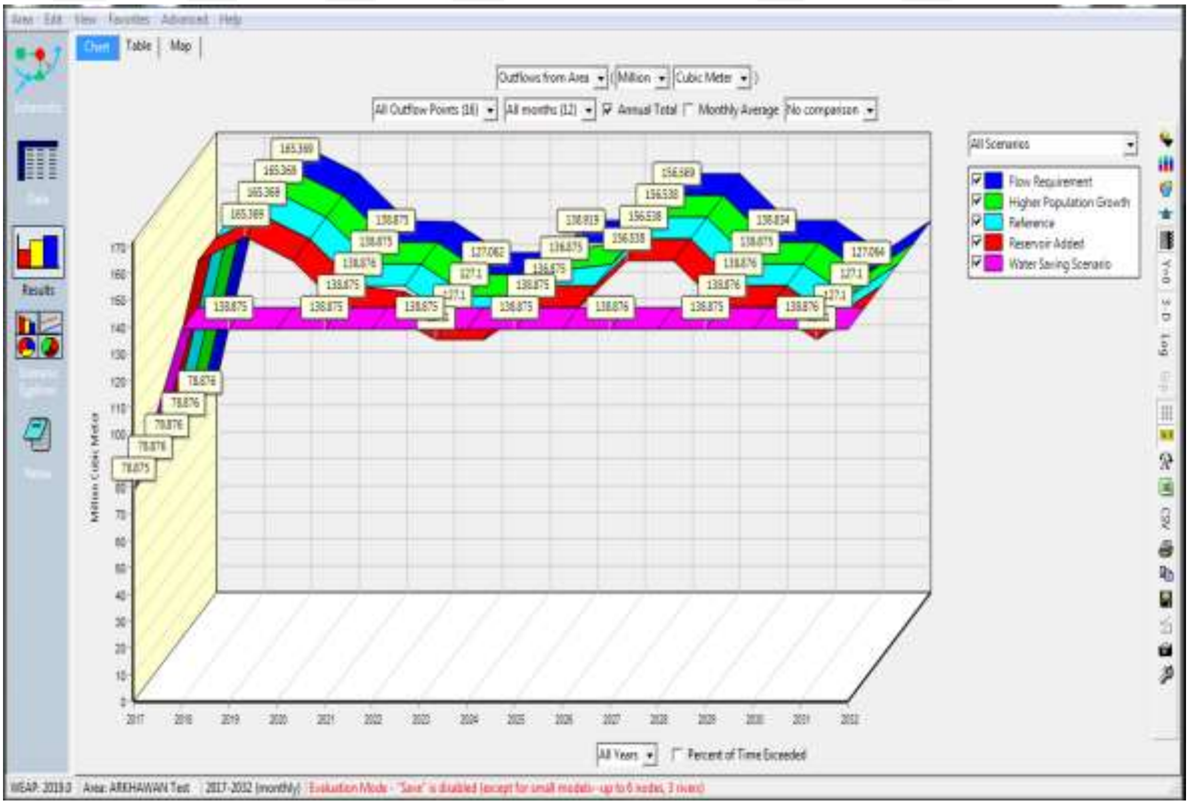
Chart
Table
Map
Supply Delivered
Million
Cubic Meter
Scenario: Reservoir Added
All Sources (5)
All months (12)
All Demand Sites
Annual Total
Monthly Average
No comparison
January February March April May June July August September October November December Sum
Agriculture 0.0 0.0 0.0 0.5 1.0 1.0 2.0 2.8 2.4 0.8 0.0 0.0 9.7
Khalifan City 0.4 0.4 0.4 0.4 0.4 0.5 0.5 0.5 0.4 0.4 0.4 0.4 4.8
Sum 0.4 0.4 0.4 0.8 1.4 1.4 2.4 3.4 2.8 0.4 0.4 0.4 14.6
Results
All Years
Percent of Time Exceeded
WEAP: 2018.01
Area: ARKHAWAN Test
2017-2032 (monthly)

Appendix H Run model output from the water saving scenario






Water Demand (not including loss, reuse and DSM)
Million
Cubic Meter
All months (12)
Branch: Demand Sites
Annual Total
Monthly Average
No comparison
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
Water Saving Scenario
Million Cubic Meter
All Years
Percent of Time Exceeded


Outflows from Area
Million
Cubic Meter
All Outflow Points (16)
All months (12)
Annual Total
Monthly Average
No comparison
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
Water Saving Scenario
Million Cubic Meter
All Years
Percent of Time Exceeded

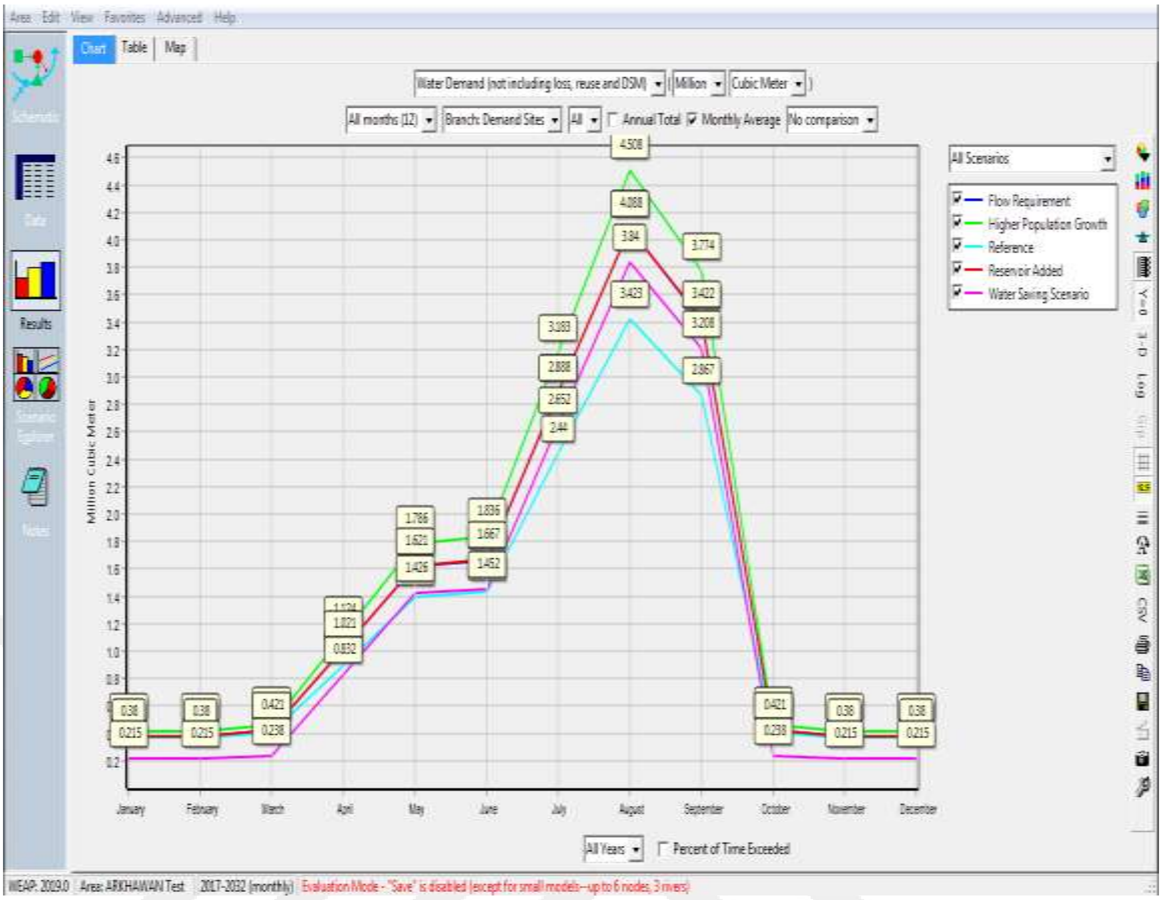


Chart
Table
Map
Water Demand (not including loss, reuse and DSM)
Million
Cubic Meter
All months (12)
Branch: Demand Sites
All
Annual Total
Monthly Average
No comparison
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
Water Saving Scenario
Million Cubic Meter
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded
Results
WEAP: 2019.0
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

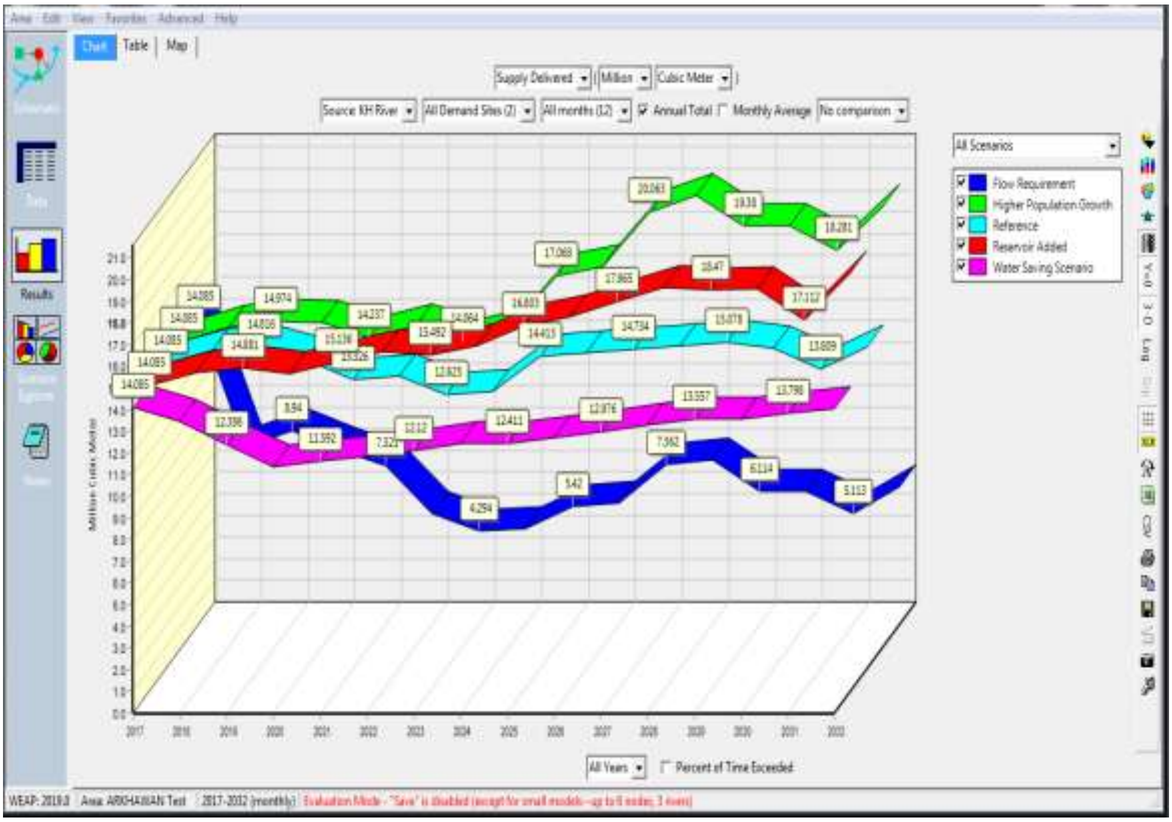


Chart
Table
Map
Supply Delivered
Million
Cubic Meter
Source: KH River
All Demand Sites (2)
All months (12)
Annual Total
Monthly Average
No comparison
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
Water Saving Scenario
Million Cubic Meter
All Years
Percent of Time Exceeded
Results
WEAP: 2019.0
Area: ARKHAWAN Test
2017-2032 (monthly)

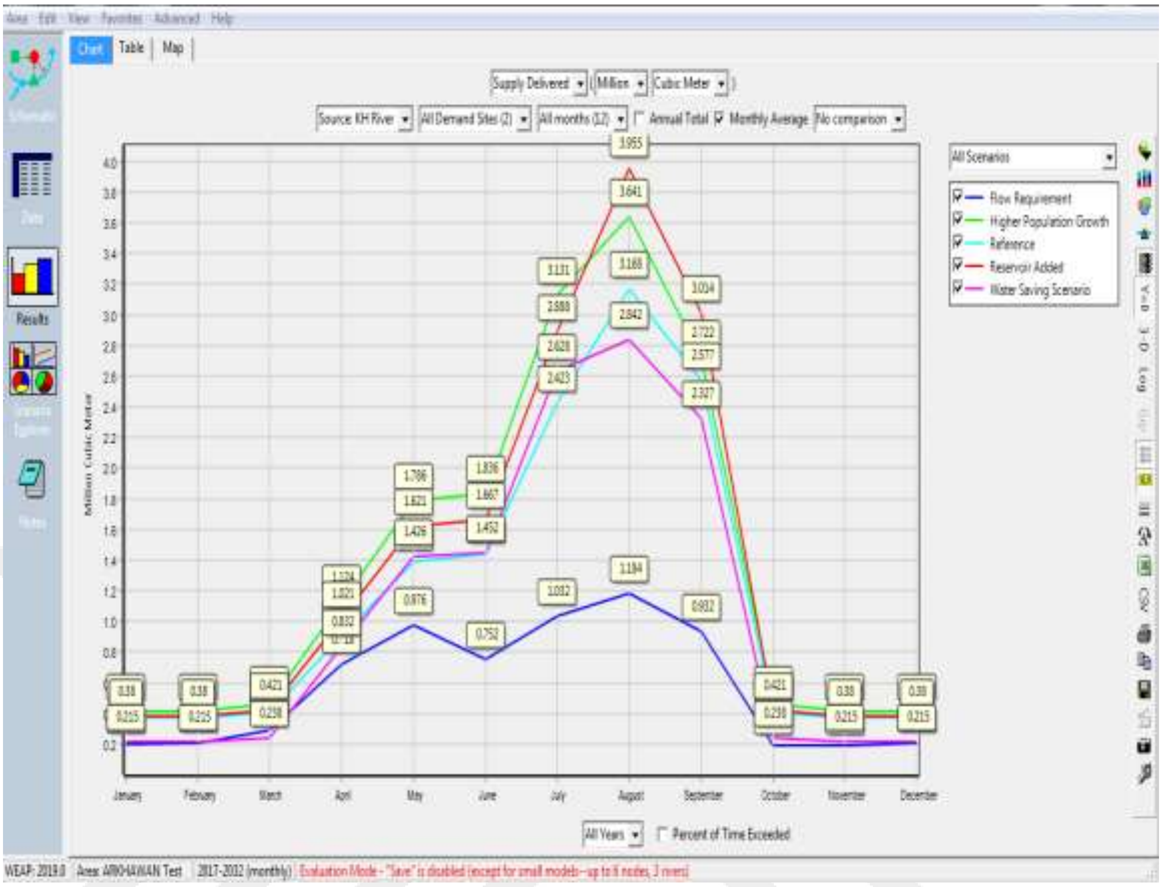
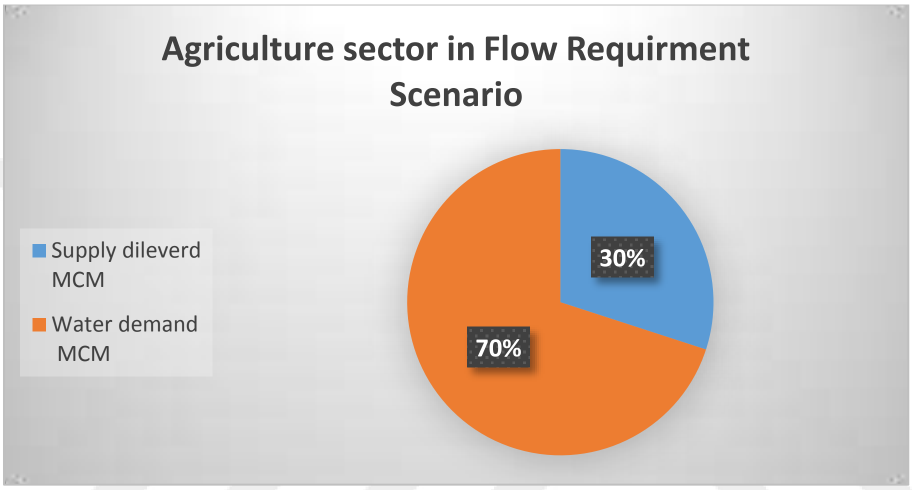


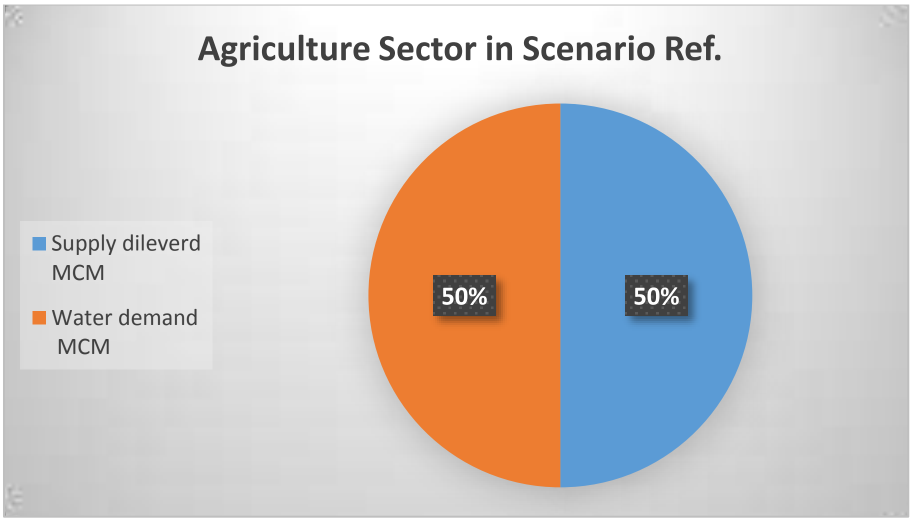
Chart
Table
Map
Supply Delivered
Million
Cubic Meter
Source: KH River
All Demand Sites (2)
All months (12)
Annual Total
Monthly Average
No comparison
All Scenarios
Flow Requirement
Higher Population Growth
Reference
Reservoir Added
Water Saving Scenario
Million Cubic Meter
Results
January
February
March
April
May
June
July
August
September
October
November
December
All Years
Percent of Time Exceeded
WEAP: 2019.0
Area: ARKHAWAN Test
2017-2032 (monthly)
Evaluation Mode - "Save" is disabled (except for small models--up to 6 nodes, 3 rivers)

Appendix I The water balance table data and figures.

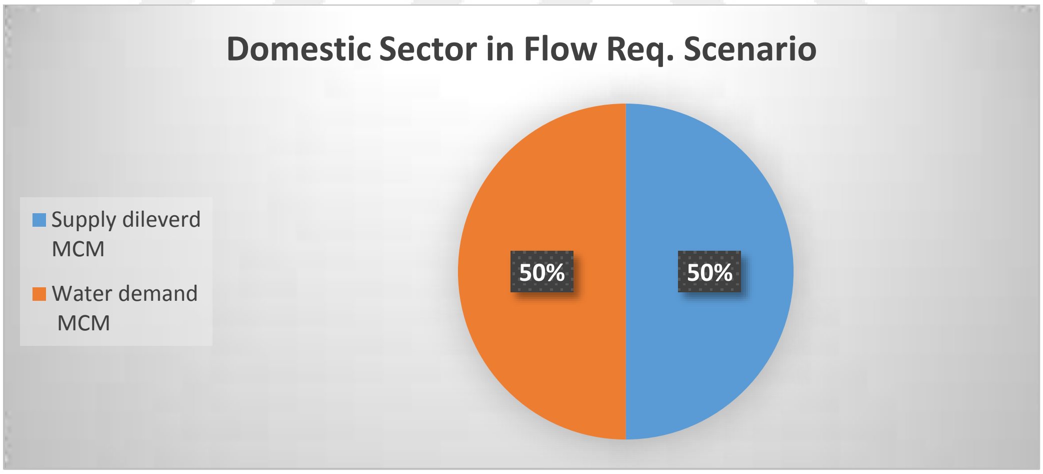
Flow Requirement Scenario				
Unmet demand	**Supply requirement MILLION CUBIC METER**	**Supply delivered MILLION CUBIC METER**	**Water demand MILLION CUBIC METER**	
5.6	9.8	4.2	9.8	**Agriculture**
0	5.1	5.1	5.1	**Domestic**



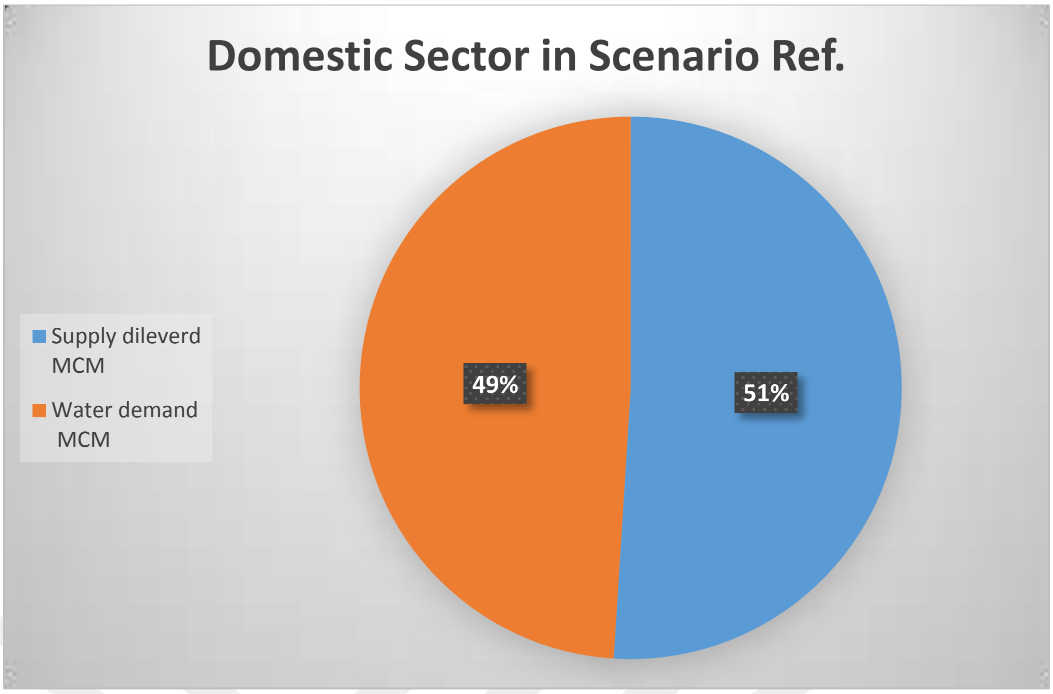
Scenario Reference (Base Case)				
Unmet demand	**Supply requirement MILLION CUBIC METER**	**Supply delivered MILLION CUBIC METER**	**Water demand MILLION CUBIC METER**	
0	9.8	9.8	9.8	**Agriculture**
0	5.1	5.1	4.9	**Domestic**



Unmet demand	Supply requirement MILLION CUBIC METER	Supply delivered MILLION CUBIC METER	Water demand MILLION CUBIC METER	
0	5.1	5.1	5.1	**Domestic**



Unmet demand	Supply requirement MILLION CUBIC METER	Supply delivered MILLION CUBIC METER	Water demand MILLION CUBIC METER	
0	5.1	5.1	4.9	**Domestic**



Dam added scenario				
Unmet demand	Supply requirement MILLION CUBIC METER	Supply delivered MILLION CUBIC METER	Water demand MILLION CUBIC METER	
0	9.8	9.8	9.8	**Agriculture**
0	5.1	5.1	5.1	**Domestic**

The high population growth scenario				
Unmet demand	Supply requirement MILLION CUBIC METER	Supply delivered MILLION CUBIC METER	Water demand MILLION CUBIC METER	
0	9.8	9.8	9.8	**Agriculture**
0	5.2	5.2	5.2	**Domestic**

Appendix J The site visited and fieldwork pictures.


Bawyan human water basin
2018 03 17


pumping water from
canal to house
2018 03 17


pumping water from canal
to houses in alana village
2018 03 17


Alana intake
structure
2018 03 17


Bawyan
spring2


sreshma waste water


rmawezh weir


2018 03