SIMULATION OF WATER RESOURCES OF TAHTALI-SEFERİHİSAR SUB-BASIN BASED ON WEAP MODEL

A Thesis Submitted to
the Graduate School of Engineering and Sciences of
İzmir Institute of Technology
in Partial Fulfillment of the Requirements for Degree of

MASTER OF SCIENCE

in Civil Engineering

by
Sait Mutlu KARAHAN

December 2021
İZMİR

To my family and my love…

ACKNOWLEDGMENTS

First of all, I would like to thank my supervisor Prof. Dr. Şebnem Elçi, for giving me an opportunity to work with her. I am really grateful for her support and her valuable time.

I am incredibly grateful to my family (Mrs. Birgül Karahan, Mr. Nuri Karahan, and Mrs. Tutku Ekiz) for their love and encouragement. Their presence gave me strength in every situation and at any moment.

This study would not be possible without the help of my fiancé, Gülşah Varol. She was always with me during the thesis. Thanks for supporting me with her love and being there for me in every difficult moment.

Lastly, I would like to thank my friend, Mr. Mehmet Akın, who always listened and supported me.

ABSTRACT

SIMULATION OF WATER RESOURCES OF TAHTALI-SEFERİHİSAR SUB-BASIN BASED ON WEAP MODEL

Water is a vital resource for humanity and nature, and the lack of water affects life in all areas. Today, problems such as the inability to protect the status of existing water resources and excessive water withdrawal cause the amount of water to decrease day by day. In addition, conditions such as urbanization and industrialization and the resulting population increase, deterioration of water quality due to chemicals used in agricultural activities, and climate change affect the availability of water resources negatively.

In this study, a basin-based water management study was carried out by applying the "Integrated Water Resources Management" approach to the Tahtalı-Seferihisar Sub-Basin located in Turkey, where it is expected to experience water stress in the future. The hydrological (precipitation, flow, evaporation) data of the water resources that are important for the basin and İzmir (Tahtalı, Seferihisar, Ürkmez, and Kavakdere Dams) were used to predict the availability of water resources in the future using the WEAP (Water Evaluation and Planning System) program, and several possible scenarios for water demands/supplies were analyzed. Under these situations, the water budget balances expected to occur 2050 have been estimated. Basically, seven different scenarios were created to transfer possible future possibilities to the program: Reference Scenario, Best Case Scenario, Worst Case Scenario, Report Consumption Scenario, Return Flow Scenario, Population Projection Scenario and Various Forecast Scenario. The water balances that can be obtained under different conditions in each scenario were calculated and compared with each other.

ÖZET

WEAP MODELİNE DAYALI TAHTALI-SEFERİHİSAR ALT HAVZASI'NIN SU KAYNAKLARININ SİMÜLASYONU

Su, insanlık ve doğa için vazgeçilmez bir kaynaktır ve suyun eksikliği her alanda hayatı etkilemektedir. Günümüzde, mevcut su kaynaklarının durumlarının korunamaması ve aşırı su çekimi gibi sorunların yaşanması, suyun miktar olarak gün geçtikçe azalmasına neden olmaktadır. Bunun yanı sıra, artan nüfus, gelişen endüstriyel faaliyetler, tarımsal aktivitelerde kullanılan kimyasallar, iklim değişikliği gibi koşullar da suyun kalitesini bozmakta ve kullanılabilirliğini azaltmaktadır.

Gelecekte su stresi durumunu yaşayacak olan ülkemiz için de Tahtalı-Seferihisar Alt Havzası kapsamında "Entegre Su Kaynakları Yönetimi" yaklaşımı uygulanarak havza bazlı bir su yönetimi çalışması gerçekleştirilmiştir. Bu çalışmada WEAP (Water Evaluation and Planning System) programı kullanılarak, havza ve İzmir için önemli olan su kaynaklarının (Tahtalı, Seferihisar, Ürkmez ve Kavakdere Barajları) hidrolojik (yağış, akış, buharlaşma gibi) verileri kullanılarak gelecekte gerçekleşebilecek ihtimallerin sonuçları irdelenmiş ve bu koşullar altında havzanın 2050 yılına kadar göstereceği su bütçe hesapları bulunmuştur. Olası gelecek ihtimallerin programa aktarılması için temel olarak yedi farklı senaryo oluşturulmuştur: Referans Senaryosu, İyimser Senaryo, Kötümser Senaryo, Rapor Tüketim Senaryosu, Geri Dönüş Akım Senaryosu, Nüfus Projeksiyonu Senaryosu ve Çeşitli Tahmin Senaryosu. Her bir senaryoda farklı durumlar altında elde edilebilecek su bilançoları hesaplanmış ve birbirleriyle karşılaştırılmıştır.

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

Figure **Page**

Figure	Page

Figure **Page**

Figure **Page**

Figure **Page**

Figure **Page**

LIST OF TABLES

Table **Page**

CHAPTER 1

INTRODUCTION

Water is an unrivalled and crucial resource for all living things. The presence and quantity of water are therefore essential. Civilizations that have lived throughout history have established their existence near water resources and used these resources according to the conditions of the period. As long as water resources continue to exist, people will be able to continue their agricultural, industrial, social and industrial activities.

Factors such as the rapidly increasing population, climate changes, growth in industrial activities, and expanded agricultural areas enlarged the need for water. The excessive use and pollution of water resources have gradually increased as a result of these factors. In addition, insufficient environmental awareness in people has caused pollution of groundwater and surface water resources. As a result, not only the amount of water is affected, but also the quality of the water too. These issues have increased the importance of water, which is a crucial source of life.

Pollution of water resources affects not only humans but also nature and the creatures in wildlife. Polluted water sources can cause dangerous health problems in humans as well as damage nature. For this purpose, necessary studies should be carried out to protect water resources from all kinds of pollutants and to transfer these resources to future generations in a healthy way.

Water has many benefits as well as some harms. It is known that excessive amounts of water can cause natural disasters such as landslides, floods, and tsunamis, and these damages can cause endanger human life. Heavy rainfalls, which have occurred due to global warming, have started to be seen today and caused humanity to observe natural disasters more frequently. In light of these problems, it is necessary to implement integrated water policies in order to control water resources and avoid their damages.

In today's world, countries spend most of their resources finding new water resources and building new water storage structures. The scarcity of water resources encourages these situations more. Water resources such as transboundary rivers, on the other hand, cause increased conflicts between countries.

The total amount of water on earth is 1.4 billion km3. Approximately 97.5% of this amount represents water in the oceans and other saltwater resources. The remaining 2.5% is from the water resources called freshwater, and approximately 68.7% of freshwater is in glaciers and ice caps at poles. 30% of the 2.5% freshwater is groundwater. The remaining one percent represents surface waters and other freshwater sources.

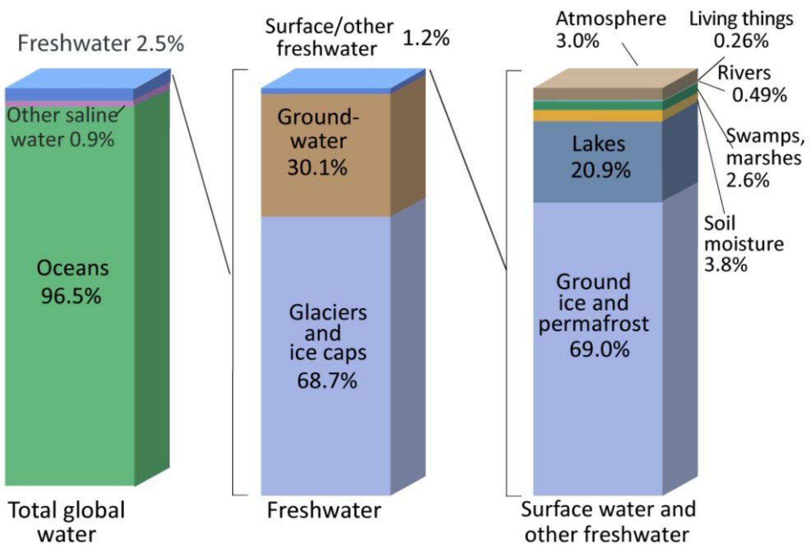

Figure 1.1. World’s freshwater resources
(Source: Shiklamonov, 1993)

For this reason, freshwater resources, which are limited and very valuable, are essential for humanity. It is necessary to determine how these resources will be in the future, what factors they will be affected by, and in which situation they will be in terms of both quality and quantity. The motivation of this thesis is to be able to determine the future state of the water resources in the Tahtalı-Seferihisar Sub-Basin, which includes the critical water resources of İzmir.

In the thesis, there are 7 Chapters: General Concepts and Literature Review, Study Site, Methodology, Numerical Modeling via WEAP Model, Creation of Scenarios, and Results and Findings.

A brief introduction of the water resources of Turkey and İzmir is given in Chapter 2. Then, the general concepts related to reservoir operation and hyrdrological processes are presented. Finally, literature review of the studies utilizing WEAP model was summarized at the end of the chapter.

Chapter 3 outlines the characteristics of Küçük Menderes Basin in general the characteristics of the Tahtalı-Seferihisar Sub-Basin, that is selected as study site, in specific. The water resources of the study site were presented and discussed in detail.

Chapter 4, not only provides information on the numerical model (WEAP) utilized in the study, but also presents the data used in the modelling approach. In the final part of the chapter the methodologies used for projection of population in the modeled area, for determination of volume - depth graphs of the dam reservoirs via QGIS and for forecasting of future flows with using AutoRegressive Integrated Moving Average (ARIMA) Method in R are presented.

Setting up of the model using WEAP program and the calibration and validation processes of the model are presented and discussed in Chapter 5.

Chapter 6, presents the implementation of different scenarios (Reference Scenario, Report Consumption Scenario, Best Case Scenario, Worst Case Scenario, Return Flow Scenario, and Population Extrapolatin Scenario) to the study site.

Finally, discussion of the results of different scenarios is given in Chapter 7.

CHAPTER 2

GENERAL CONCEPTS AND LITERATURE REVIEW

2.1. Turkey's Water Potential

According to Turkey's hydrometeorological data obtained between 1951-2000, the average precipitation height is 643 mm. The amount of water, corresponding to approximately 55 percent ($274x10^9$ m^3) of the falling rainfall, returns to the atmosphere through evaporation and transpiration. 14% ($69x10^9$ m^3) of the falling rainfall feeds subsurface waters and groundwaters. The remaining amount of approximately 31% ($158x10^9$ m^3) of water is poured into the seas or lakes in closed basins by means of rivers joining the flow. $28x10^9$ m^3 of $69x10^9$ m^3 water that feeds subsurface waters and groundwater is added to surface water via springs. Thus, the total annual flow is equal to (158 + 28) $x10^9$ m^3 = $186x10^9$ m^3. In addition, there is ~ $7x10^9$ m^3/year water coming from neighboring countries. Thus, the gross surface water potential of our country reaches $193x10^9$ m^3. The total renewable water potential of the country is calculated as $234x10^9$ m^3/year, including $41x10^9$ m^3, which feeds groundwater resources (Republic of Turkey Ministry of Development 2014).

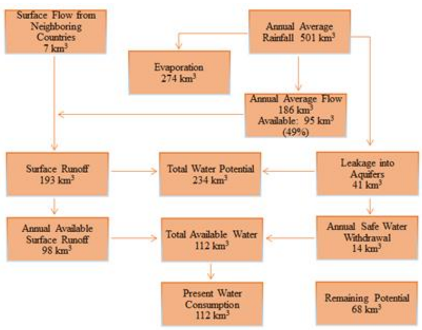

Figure 2.1. Water Potential of Turkey

Within the framework of technical and economic conditions, the potential of surface water that can be consumed is $95x10^9$ m^3 from domestic rivers and $3x10^9$ m^3 from neighboring countries, with an annual average of $98x10^9$ m^3. The same situation was calculated for groundwater resources as $14x10^9$ m^3 (~ 34% of the total) (Republic of Turkey Ministry of Development 2014). The total consumable of surface and groundwater is $112x10^9$ m^3 per year. Although Turkey's water potential is given as close to $112x10^9$ m^3 in many sources, in a project carried out by the Ministry of Forestry and Water Affairs, General Directorate of Water Management, the water potential is estimated to be $108.5x10^9$ m^3 (Republic of Turkey, Ministry of Agriculture and Forestry 2016).

Falkenmark has developed an indicator to measure water stress, and it is called the Falkenmark index, which is based on the measurement of per capita water availability in the country or region under consideration Table 2.1.

Table 2.1. Falkenmark Index (1989)

Category	Usable water amount per capita per year (m^3)
Absolute Scarcity	<500
Scarcity	500-1000
Stress	1000-1700
No Stress	>1700

The usable water potential per capita in Turkey was 4,000 m^3 in 1960. It is predicted that the water potential, which decreased to 1600 m^3 in 2000, will decrease to 1120 m^3 in 2030, taking into account the population growth (Republic of Turkey, Ministry of Agriculture and Forestry 2009)

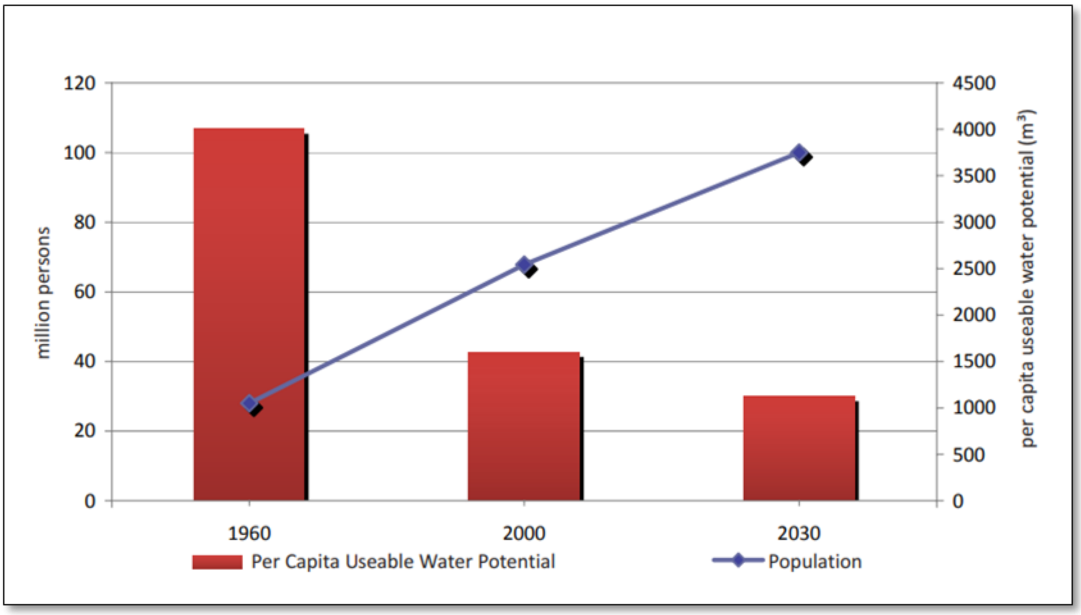

Figure 2.2. Turkey's per capita water potential

(Source: Republic of Turkey, Ministry of Agriculture and Forestry, 2009)

As can be seen in Table 2.1. and Figure 2.2, Turkey is not a water-rich country. In addition, the estimates made for 2030 are obtained with the assumption that the used water resources are preserved and carried into the future. For this reason, it is inevitable to experience water scarcity in the future unless necessary precautions are taken to protect water resources.

When using water resources, the aim should be to achieve maximum benefit because these resources are limited. For this reason, to use water resources efficiently, the systems that use water should adopt the optimum operating operations and consider the most profit that can be obtained.

Food needs, together with rapid population growth in Turkey have increased. This situation brought about the expansion in agricultural areas. Increasing agricultural areas means more use of water. In addition, the need for drinking and utility water, water used for electricity generation and industrial water demand have intensified with rapid industrialization. In order to meet the demands on the use of water resources on a sectoral basis, it has made the integrated management of these resources more important (Coşgun 2017). Water utilization rates in Turkey on a sectoral basis can be seen in Table 2.2.

Table 2.2. Sectoral Water Use Ratio in the World and Turkey
(Source: Republic of Turkey Ministry of Development 2014)

Sector Name	World (%) Year 2006	Turkey Early 2012 (billion m^3/year)	Turkey (%) Year 2012	Turkey 2023 (billion m^3/year)	Turkey (%) Year 2023
Irrigation	69	32	73	72	64
Domestic Water	12	7	16	18	16
Industry	19	5	11	22	20
Total	100	44	100	112	100

As a result, water use and management of water resources in every sector are essential regardless of scale. For this reason, a good water policy should be followed and implemented by making plans in line with this policy to make the best use of water.

2.2. Hydrological Watersheds in Turkey

According to the National Watershed Management Strategy, which was enacted in 2014, published in the Official Gazette, rivers in Turkey are divided: 25 main water basins, 1848 sub-basins, and 14608 micro-watersheds (Repuclic of Turkey, Ministry of Agriculture and Forestry 2017).

The average annual flow rate of 25 basins in Turkey is around 186 billion m^3. The ecological, social, demographic conditions of the basins and the use of the basin resources may differ depending on the region where they are located and the horizontal and vertical distribution of the basin areas. According to the data of State Hydraulic Works, approximately one-third of the average annual flow belongs to the Euphrates-Tigris Basin located in the east of Turkey. Euphrates-Tigris basin constitutes about 28 percent of Turkey's water potential, and it is also the largest basin in the country. Eastern Black Sea, Eastern Mediterranean, and Antalya Basins follow the Euphrates-Tigris Basin as the average annual flow. Kızılırmak and Sakarya Basins follow the Euphrates-Tigris Basin as the area size. Burdur Lake Basin and Akarçay Basin are the basins with the lowest water potential. General information about the 25 hydrological watersheds formed by Turkey's topographic structure is given in Table 3 (Republic of Turkey, Ministry of Agriculture and Forestry 2014).

The area of precipitation of Küçük Menderes Basin, which includes the Tahtalı-Seferihisar Sub Basin, which is the study area, is 6907 square kilometers, and the average annual flow is 1.19 km^3.

Table 2.3. General Information About River Basins in Turkey
(Source: Republic of Turkey, Ministry of Agriculture and Forestry, 2014)

River Basin Name	**Rainfall Area**		**Average Annual Rainfall**		**Average Annual Yield**
	(km^2)	**%**	**(km^2)**	**%**	**($1/s/km^2$)**
(1) Meriç-Ergene Basin	14,560	1.9	1.33	0.7	2.9
(2) Marmara Basin	24,100	3.1	8.33	4.5	11
(3) Susurluk Basin	22,399	2.9	5.43	2.9	7.2
(4) Kuzey Ege Basin	10,003	1.3	2.09	1.1	7.4
(5) Gediz Basin	18,000	2.3	1.95	1.1	3.6
(6) Küçük Menderes Basin	6,907	0.9	1.19	0.6	5.3
(7) Büyük Menderes Basin	24,976	3.2	3.03	1.6	3.9
(8) Batı Akdeniz Basin	20,953	2.7	8.93	4.8	12.4
(9) Antalya Basin	19,577	2.5	11.06	5.9	24.2
(10) Burdur Lake Basin	6,374	0.8	0.5	0.3	1.8
(11) Akarçay Basin	7,605	1	0.49	0.3	1.9
(12) Sakarya Basin	58,160	7.5	6.4	3.4	3.6
(13) Batı Karadeniz Basin	29,598	3.8	9.93	5.3	10.6
(14) Yeşilırmak Basin	36,114	4.6	5.8	3.1	5.1
(15) Kızılırmak Basin	78,180	10	6.48	3.5	2.6
(16) Konya Closed Basin	53,850	6.9	4.52	2.4	2.5
(17) Doğu Akdeniz Basin	22,048	2.8	11.07	6	15.6
(18) Seyhan Basin	20,450	2.6	8.01	4.3	12.3
(19) Asi Basin	7,796	1	1.17	0.6	3.4
(20) Ceyhan Basin	21,982	2.8	7.18	3.9	10.7
(21) Fırat-Dicle Basin	184,918	23.7	52.94	28.5	8.3
(22) Doğu Karadeniz Basin	24,077	3.1	14.9	8	19.5
(23) Çoruh Basin	19,872	2.6	6.3	3.4	10.1
(24) Aras Basin	27,548	3.5	4.63	2.5	5.3
(25) Van Lake Basin	19,405	2.5	2.39	1.3	5
TOTAL	**779,452**	**100**	**186.05**	**100**	

2.3. İzmir’s Water Potential

İzmir province is the third-largest city in Turkey and is the largest city in the Aegean Region. For this reason, groundwater and surface water resources that provide water to İzmir are of great importance. Drinking, irrigation, and utility water of the province are obtained from groundwater resources (deep-wells) and surface water resources (dam, lakes, and ponds).

2.3.1. Surface Water Resources

2.3.1.1. Rivers

Rivers are the leading source of surface water, and Küçük Menderes, Gediz, and Bakırçay Rivers passing through the borders of İzmir province are of great significance for the province. These rivers and their tributaries are critical not only for İzmir but also for the surrounding provinces.

Name of the River	Total Length (km)	Length within Province Boundaries (km)	Average Flow (m^3/s)	Instant Maximum Flow in Year (m^3/s)	River's Tributaries	Purpose of Usage
Gediz	401	198	19.3	104 (24.02.2012)	Nif	Agriculture-Energy-Drinking Water
Küçük Menderes	175	175	6.66	66.80 (27.01.2012)	Fetrek, Birgi, Kiraz, Çavuş Creek, Tasavra Stream, Pirinççi Stream, Eğridere Rahmanlar, Ilıcadere, Uladı Stream and Aktaş Stream, Zeytinova	Agriculture-Energy-Drinking Water
Bakırçay	129	69	11.14	141 (15.02.2012)	Geyikli, Galinos (Bergama) Stream, Ilyadere, Ilıca, Karadere, Kırkgeçit, Kocadere	Agriculture-Energy-Drinking Water

Figure 2.3. Rivers of İzmir Province
(Source: Republic of Turkey, İzmir Governorship Provincial Directorate of Environment and Urbanization, 2020)

2.3.1.2. Natural Lakes, Dams, and Ponds

There are natural lakes, ponds, dams, and rivers in the category of surface water resources within the provincial borders. The largest natural lake in the province is Gölcük Lake, located in Ödemiş district. In addition to natural lakes, there are 13 dam lakes within the borders of the region. The State Hydraulic Works (DSI) and the Special Provincial Administration (IOI) have many ponds that have been constructed and are in use.

Table 2.4. Dams, Natural Lakes, and Ponds of İzmir Province
(Source: Republic of Turkey, İzmir Governorship Provincial Directorate of Environment and Urbanization, 2020)

Dams	Natural Lakes	Ponds*	Ponds in use (State Hydraulic Works)	
Alaçatı Kutlu Aktaş	Barutçu	Aliağa Hacıömerli	Foça Arpaçay	Yenişakran
Balçova	Belevi	Balabandere	Aliağa Çıtak	Kiraz Çatak
Beydağ	Gebekirse	Dokuz Eylül	Ataköy	Tire Eskioba
Çaltıkoru	Karagöl	Sandıdere	Bergama Çamavlu	Dikili Çandarlı
Güzelhisar	Gölcük	Ulamış Kavakçayı	Bergama Yukarıkırıklar	Menderes Özdere
Kavakdere		Göçbeyli	Kemalpaşa Bağyurdu	Kemalpaşa Savanda
Kestel		Dikili Deliktaş	Kiraz Halililer	Gümüldür
Seferihisar		Karaburun Parlak	Menemen Emiralem	Bozköy
Tahtalı		Seferihisar Payamlı	Menemen Süleymanlı	Bornova Karaçam**
Ürkmez		Dikili Yahşibey	Tire Yenişehir	
Yortanlı		Urla Birgi ve Kocagöl	Torbalı Arslanlar	
Burgaz		Bayındır Arıkbaşı	Torbalı Karakızlar	
Bademli		Yuntdağı Hacılar	Mordoğan	
		Menderes Yeniköy	Dikili Harputlu	

Note: *Ponds built by the Special Provincial Administration

**Ponds whose construction has been completed but not yet put into operation

The water supplied from the surface water sources (especially from dams) to 11 districts of the old metropolis of İzmir Province (Konak, Karşıyaka, Çiğli, Bayraklı, Bornova, Buca, Gaziemir, Karabağlar, Balçova, Narlıdere, Güzelbahçe) is passed through a treatment process and given to the city as drinking and usable water. In Table 2.5, the capacities of the facilities that treat the drinking water provided to İzmir and the amount of water they treated in 2019 are given.

Table 2.5. Drinking-Water Treatment Plants of İzmir Province
(Source: İzmir Water and Sewerage Administration General Directorate, 2019)

Water Resource Name	Treatment Plant Name	Capacity (l/s)	Water Production in 2019 (m3/year)
Tahtalı Dam	Tahtalı Drinking Water Treatment Plant	6000	86.177.800
Gördes Dam	Sarıkız Drinking Water Treatment Plant	1500	4.350.218
Balçova Dam	Balçova Drinking Water Treatment Plant	800	6.364.600
Ürkmez Dam	Ürkmez Drinking Water Treatment Plant	109	1.400.348
Güzelhisar Dam	Aliağa Drinking Water Treatment Plant	70	1.496.013
Kutlu Aktaş Dam	Çeşme Drinking Water Treatment Plant	300	6.190.229
Suçıktı, and Pıtrak	Ödemiş Drinking Water Treatment Plant	215	3.100.582
TOTAL			109.079.790

2.3.2. Groundwater Resources

Groundwater resources have a large share among provincial water resources. When the resources that provide water to the city center of İzmir are examined, it has been revealed that 58.8% of them are provided from groundwater resources in 2019 (İzmir Water and Sewerage Administration General Directorate 2019).

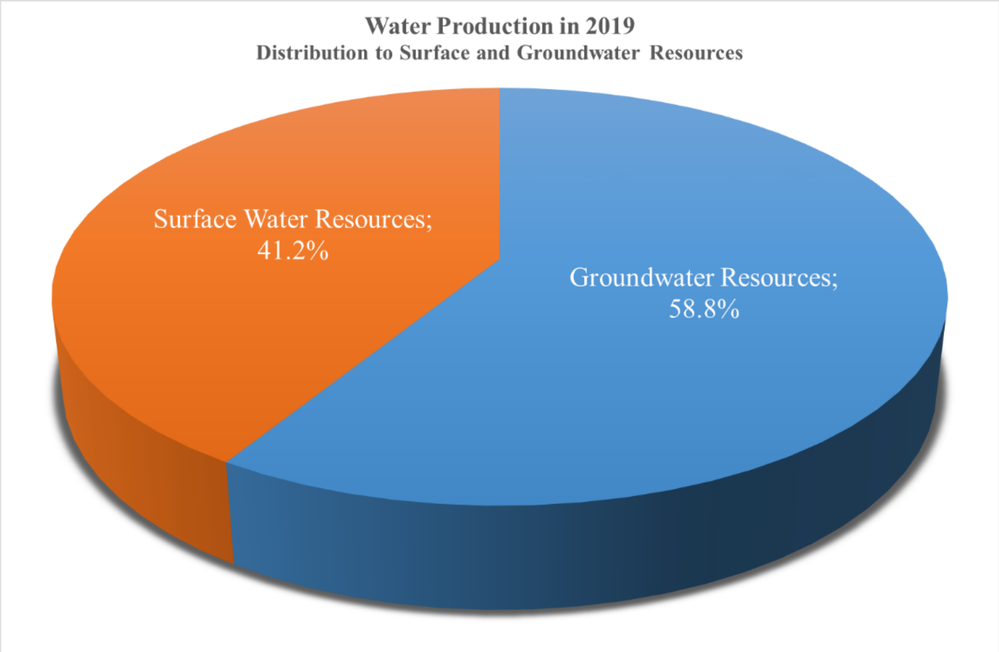

Figure 2.4. Distribution of İzmir Province Water Production in 2019 by Surface and Groundwater Resources

Table 2.6. Groundwater potential of İzmir province
(Source: İzmir Water and Sewerage Administration General Directorate, 2019)

Name of the deep-wells	hm^3/year
Sarıkız deep-wells	45
Göksu deep-wells	63
Menemen, and Çavuşköy deep-wells	25
Halkapınar deep-wells	45
Pınarbaşı deep-wells	2
Buca, and Sarnıç deep-wells	1

The values in Table 2.6 are the potential quota values determined by the State Hydraulic Works for each deep-well on an annual basis.

Sarıkız deep-wells have 38 wells with the last drilled wells, 30 of these wells are active in today. Göksu deep-wells, which were gradually opened between 1970-1974, was added to the additional wells drilled in 1995, lastly have 22 wells in total. Today, it still works actively in these 22 wells. The water produced in Sarıkız and Göksu deep-wells is combined in the Çullu Raw Water Tank, then transferred to the clean water tank after passing through the arsenic treatment plant, and pumped to the province of İzmir by means of the Yahşelli Pumping Station.

Since the water need of İzmir province became unmet in the 1970s, as a result of the groundwater development efforts, the Emergency Drinking Water Project was developed, and 14 wells were drilled in the Menemen district. Today, 30 wells are actively working in that region.

Halkapınar deep-wells, which has been providing water since 1897, has a total of 25 wells, 19 of which are actively in operation. The water produced from the deep-wells is collected in the water tank in Halkapınar and treated at the Halkapınar Arsenic Treatment Plant, then the treated water is pumped to the city.

Today, 2 of the 3 wells drilled in the Pınarbaşı region of Bornova District are actively producing water. The water produced from 3 deep wells in Buca District is transferred to the Buca water network. The water produced in 4 deep-wells in the Sarnıç region of Gaziemir, one of the districts of İzmir, is used regionally (İzmir Water and Sewerage Administration General Directorate).

The groundwater resources in Table 2.6 are the resources that provide water to 11 districts of the old metropolis city of İzmir (Konak, Karşıyaka, Çiğli, Bayraklı, Bornova, Buca, Gaziemir, Karabağlar, Balçova, Narlıdere, Güzelbahçe). The water needs of other districts and regions are met by dams and local water wells.

The water obtained from groundwater resources is given to the city after arsenic treatment. In Table 2.7, the names of the arsenic drinking water treatment plants of the groundwater resources that provide drinking water to İzmir, the capacities of these plants, and the amount of water produced in the arsenic treatment plants in 2019 are given.

Table 2.7. İzmir Province Arsenic Treatment Plants
(Source: Republic of Turkey, İzmir Governorship Provincial Directorate of Environment and Urbanization, 2020)

Well Area/Location	Arsenic Treatment Plant Name	Capacity (m^3/day)	Water Production in 2019 (m^3/year)
Sarıkız and Göksu Deep-wells	Çullu Arsenic Drinking Water Treatment Plant	3000	82.161.527
Menemen and Çavuşköy Deep-wells	Menemen Arsenic Drinking Water Treatment Plant	600	17.647.206
Halkapınar Deep-wells	Halkapınar Arsenic Drinking Water Treatment Plant	1000	33.399.482
Menemen K5 Wells	Menemen K5 Arsenic Drinking Water Treatment Plant	250	3.134.758
TOTAL			136.342.973

2.4. General Concepts

2.4.1. Parts and Purposes of Dams

The irregularity of the flow regimes of streams and the distribution of people's water use over time is often unsuitable. For this reason, water must be stored in order to ensure its use when needed. To do this, it is necessary to store the water when it is efficient in terms of flow in order to use the water when the stream flows are insufficient. Therefore, water storage structures should be built, and recently it has been constructed too many dams in Turkey.

The parts that make up the dam can be considered in five sections in general. The first of these parts is the **Body** part. The body forms the main part of the dam, closes the valley mouth, and acts as an impermeable barrier for water. The part where water is stored behind the impermeable barrier is called the **Reservoir**. The structures that allow the water collected in the reservoir to be drawn off are called **Water Intake**. The **Outlet Facilities** withdraw the water in the reservoir section to meet downstreams' water demands or prevent the floodwaters from coming with high flow rates from damaging the dam body. Sluiceway, bottom outlets, diversion tunnels are examples of outlet facilities. The last part is **Other Facilities**; this section includes such as hydroelectric power plants, roads, lodging, offices, etc. (Yanmaz 2018).

The reservoir area is also called the dam lake. The reservoir basically consists of 3 parts. The first of these is called **dead storage capacity**. Dead storage capacity is the volume reserved for the storage of suspended materials or sediments carried by the streamflow in a way that does not damage the structure. The second is called **active storage capacity**. Water in this volume range is used for purposes such as drinking water, irrigation, and energy. The last part is the **flood storage capacity**, and it is the volume reserved for the floodwaters coming to the reservoir area not to damage the structure.

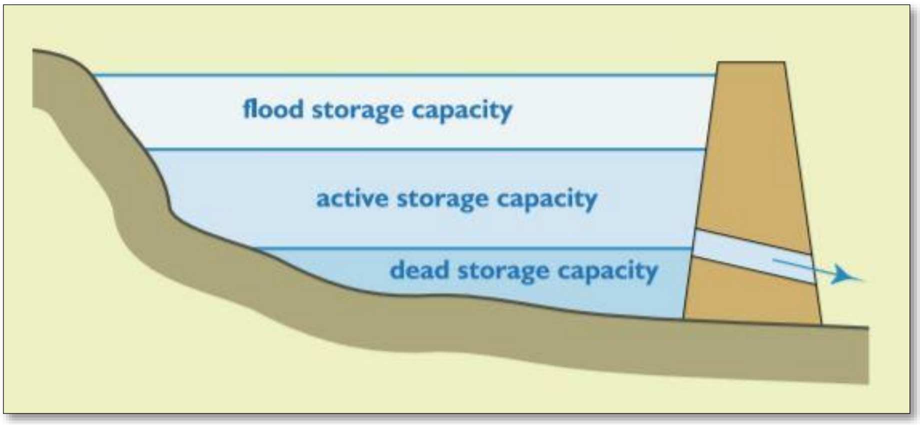

Figure 2.5. Zones of storage in a reservoir
(Source: Loucks ve Beek, 2017)

Dams store water for many purposes. Examples of these purposes include: providing drinking water, industrial water supply, flood control, groundwater feeding, sediment control, hydroelectric power generation, irrigation water for agricultural lands, pollution abatement, etc. (Yanmaz 2018).

In Turkey, water storage is provided for various purposes, but dams in the country are predominantly built for irrigation water purposes.

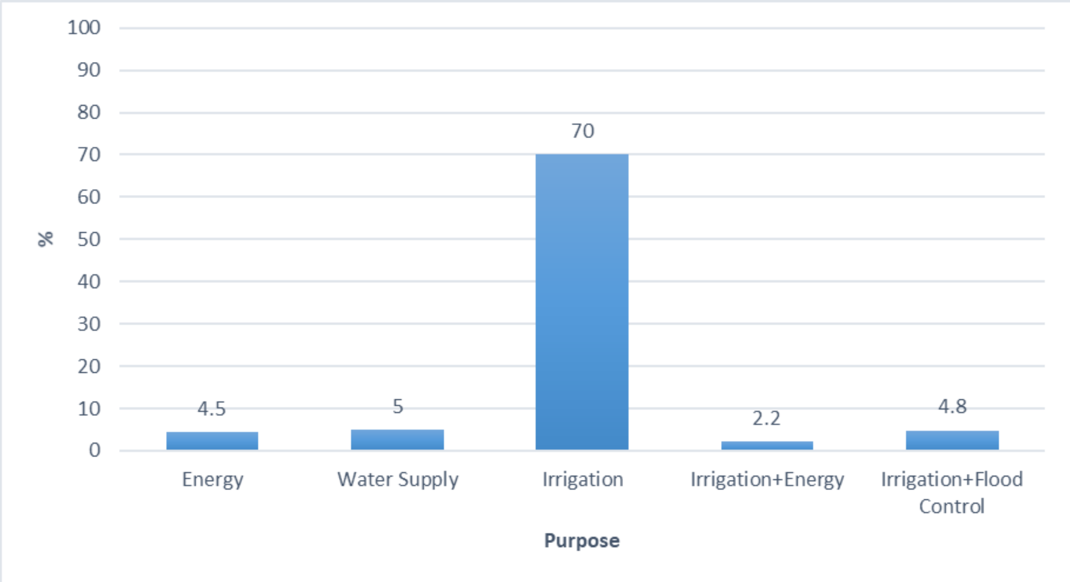

Figure 2.6. Percent distribution of dams in Tukey
(Source: Yanmaz, 2018)

2.4.2. Reservoir Volume Determination Methods

Active storage capacity and flood control capacity, which constitute the reservoir capacity, may vary annually. This situation can be simply answered as follows: during periods of no flood probability, the volume reserved for the flood storage capacity is not required (Loucks ve Beek 2017). Specific methods for determining these capacities are:

- Mass Curve Analysis
- Sequent-Peak Analysis
- Operation Study
- Other Methods

2.4.2.1. Mass Curve (Ripple Diagram) Analysis

Mass curve analysis, also known as the Ripple diagram method, is one of the most used methods to determine reservoir capacity.

- In order to determine the reservoir capacity in this method, the critical period must be determined firstly, that is, the period when inflow is less than demand.

- Flows to the reservoir (supply) are summed monthly and plotted cumulatively (ΣS) against time.
- Likewise, demand flows withdrawn from the reservoir are summed monthly and plotted cumulatively against time.
- Then, tangents are drawn to the peaks and troughs formed by the cumulative supply curve, which are parallel to the cumulative demand line.
- The vertical differences between the drawn tangents correspond to reservoir volume values. The largest of these volume values numerically give the reservoir volume.

The slope of the mass curve at any time interval corresponds to the supply value in that time interval. Likewise, the slope of the demand curve represents the demand value corresponding to that time. The mass curve example is given in Figure 2.7 is valid for 100% regulation (Usul 2017).

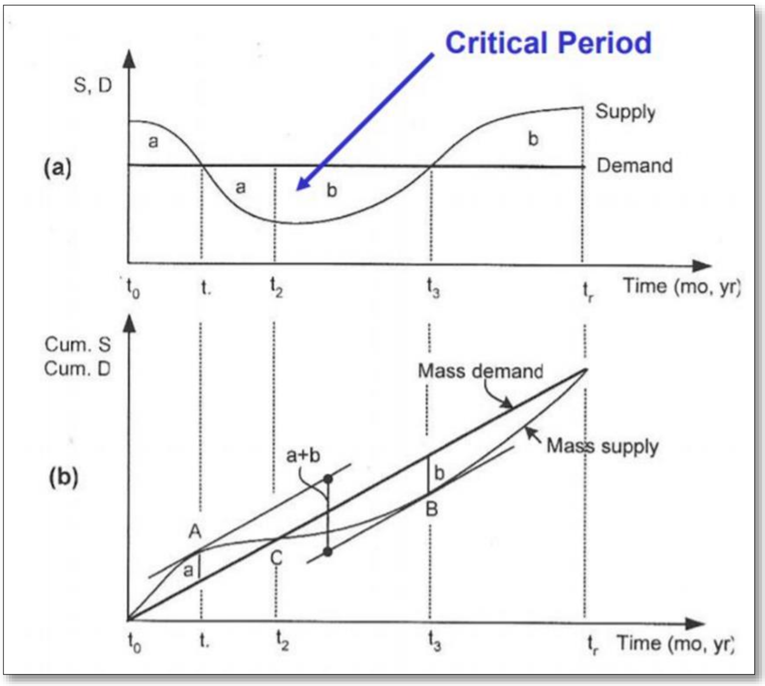

Figure 2.7. Mass Curve Analysis
(Source: Usul, 2017)

2.4.2.2. Sequent Peak Analysis

Mass curve analysis is easier to apply to short-term data. However, if the data is long-term, it is more reasonable to use Sequent Peak Analysis. Also, if the demand values show variable properties, it is more logical to use this method. The steps of this method are as follows:

- Inflows (S) and demands (withdrawals) (D) of the reservoir are calculated. After that, cumulative inflow values and cumulative demand values are obtained.
- Σ(S-D) graph is plotted by subtracting cumulative demand values from cumulative inflow values against time.
- Peak points and trough points are determined in the resulting graph, and the vertical distance between these points is calculated.
- This process is also performed for the other peak points on the graph. The value corresponding to the maximum vertical height indicates the reservoir capacity.

In this method, each peak value must pass the preceding peak value. Otherwise, that peak value is not taken into account to find the maximum volume.

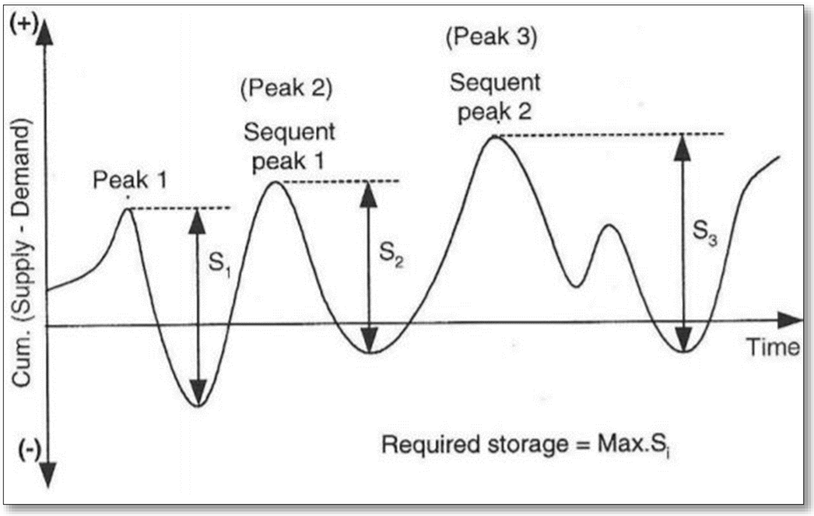

Figure 2.8. Graphical Solution of Sequent Peak Analysis

(Source: Usul, 2017)

The graphical solution of the sequent peak analysis can be time-consuming for the long time data interval. For this reason, the analytical solution of reservoir capacity can be performed.

$$V_t = D_t - S_t + V_{t-1} \qquad if\ D_t - S_t + V_{t-1} > 0$$
$$V_t = 0 \qquad otherwise \tag{2.1}$$

Here, V_t represents the reservoir capacity at the end of period t. V_{t-1} refers to the reservoir capacity at the end of the previous time period. The initial value of V_{t-1} is taken as 0. D_t represents the demand value of the reservoir during period t, and S_t represents the supply value during time period t. The largest value among the finding values found is used as the reservoir capacity.

2.4.2.3. Operation Study

Reservoir capacity is checked whether it is appropriate or not according to the calculated value by the operation study method. If the reservoir meets all demand values against seepage and evaporation situations, the reservoir capacity is suitable. The operation study is based on the continuity equation:

$$\frac{dV}{dt} = I - Q \tag{2.2}$$

Here, dV refers to the change in volume in the time interval dt. I and Q values represent instantaneous total inflow and outflow values, respectively. Operation study may differ depending on the purpose of the reservoir. The operation study would consider the critical period if it was built for water retention. The operation study is applied based on the wetland period if there is a flood prevention and delay purpose.

2.4.3. Precipitation

Precipitation is the release of all forms of water from the atmosphere to reach the ground surface. These precipitation forms of water are rain, snow, sleet, hail, and drizzle.

The difference between these forms is given in Table 2.8. Precipitation is a major input for river catchment areas. For this reason, it should be examined well.

Table 2.8. Classification of Precipitation Types according to UK Meteorological Office (Source: Davie, 2008)

Class	Definition
Rain	Liquid water droplets between 0.5 and 7 mm in diameter
Drizzle	Liquid water droplets less than 0.5 mm
Sleet	Combination of rain and snow
Snow	Ice crystals
Hail	Almost spherical balls of ice, 5 and 125 mm diameter

Some conditions must be fulfilled for precipitation to occur. These conditions can be collected under three main headings: cooling of the air, condensation, and growth of water/ice droplets. Cooling is essential for precipitation. Because the capacity of clouds to hold water vapor depends on temperature. When the air temperature decreases, the water vapor carrying capacity decreases accordingly. Cooling generally takes place according to the principle of rising the heated air. The pressure and temperature of the rising air decrease, and the decrease in temperature causes less water vapor to be retained in the air. This makes it easier for the water vapor to condense. This type of precipitation caused by rising air is called **convective precipitation**. The type of precipitation resulting from the rise of the air due to a topographic obstacle is called **orographic precipitation,** and these obstacles are usually mountains. The precipitation type that occurs as a result of the movement of air from high pressure to low pressure is called **cyclonic precipitation** (Davie 2008).

Condensation is called the transition of water vapor to a liquid state. Condensation takes place on hygroscopic particles called condensation nuclei. These particles are in micron size ($1\ \mu m = 1x10^{-6}$ m). Condensation nuclei are usually small dust particles, sea salts, smoke particles, sulfur three oxides, etc.

Condensation alone is not sufficient for precipitation to occur. It can create clouds and fog. But the water particles in the clouds are very small. These water particles must reach the size that they will fall on the earth. This situation occurs either by the presence of ice crystals on which water vapors can condense or by the merge of small droplets. For the merging water particles to form rainfall, their diameters must be between 500 and 4000 μm (Usul 2017).

2.4.3.1. Characteristics of Precipitation

Intensity: Intensity is the ratio of water height caused by precipitation to that time period. Generally, expressed as millimeters per hour (mm/h).

Depth: Depth of precipitation is the height of water created by precipitation in a horizontal plane in a certain time interval. In other words, it is integral of intensity with respect to duration time. It expresses in millimeters (mm).

Duration: It is the time interval during which precipitation occurs.

Frequency (f): It is the probability of precipitation occurring (f=1/T). T (period) is the mean time between these events.

Areal Extent: Areal extent is the average water height generated by rainfall in a particular area. In order to find the average precipitation, the following methods are generally used: Arithmetic Mean, Thiessen Polygons Method, and Isohyetal Method.

2.4.3.2. Measurement of Precipitation

Precipitation is expressed by the height of the water by accumulating at a certain time interval, where it falls. 1 millimeter of rainfall per square meter area is equal to 1 kg/m^2. Many different tools can measure precipitation. Funnel is the most classic one among them. It is simply dividing volume by the surface area. Other methods are Tipping Bucket, Weighing Pluviometer, Optic Pluviometer, etc. Nowadays, with the development of technology, precipitation can be measured directly by satellites.

2.4.4. Evaporation

Evaporation is simply the transition of water from the liquid phase to the gas phase. Evaporation has an important place among water resources because evaporation losses affect the reservoir capacities and the yield of the river's basin, etc. (Usul 2017).The effects of evaporation losses on water resources should be well calculated and included in future planning of water resources. Especially, evaporation in arid and semi-arid areas can cause significant losses.

Potential evaporation is the amount of evaporation accepted when the water resources are unlimited, and there is no limiting factor. **Actual evaporation** is the evaporation value obtained under natural conditions.

Evaporation can be divided into two groups as types. The first group is **direct evaporation**. Direct evaporation includes **open water surface evaporation**, **evaporation from the soil surface**, **interception evaporation,** and **sublimation of snow or ice**. Calculation of open water surface evaporation is vital for reservoir volumes of dams and for also lakes. Evaporation from the soil surface is the occurrence of evaporation over the soil moisture, and it occurs more on less permeable or impermeable soil layers. Interception evaporation is the evaporation of rainfall by holding it on surfaces such as leaves, plant branches, and forest floors. In other words, it is the evaporation that takes place on wet surfaces. Sublimation is the transition of snow or ice from a solid state to a directly gaseous state. Sublimation of snow or ice has a relatively low evaporation value compared to the amount of evaporation from the water surfaces. The second group is called **indirect evaporation**. This group includes **transpiration,** and it is the evaporation that occurs in plant stomata.

Evaporation can be measured using the evaporation pan and lysimeter instruments, as well as using methods such as the water balance equation, energy balance, or Penman method.

2.4.4.1. Evapotranspiration

Evaporation from the ground includes both evaporations from the soil or water surfaces and transpiration by plants, so they are called evapotranspiration (ET) as a combination of these. As with evaporation, evapotranspiration is divided into two as actual and potential. Potential evapotranspiration is calculated assuming sufficient surface moisture at all times without any restrictions. Actual evapotranspiration is calculated as limited by the moisture of the currently available soil surface. Evapotranspiration can be measured with evapotranspirometers or lysimeters. When calculating the evapotranspiration using these tools, the same soil type and vegetation are used with the evapotranspiration zone.

Many methods can be used to calculate evapotranspiration. However, two different methods are widely used when calculating evapotranspiration. The first of these is the Blaney-Criddle Method, and the second is the Penman-Monteith Method. In the Final Report of the Küçük Menderes Basin Master Plan, an essential resource used in this study, the Blaney-Criddle method was used to calculate the water needs of the products grown in the agricultural areas.

2.4.5. Infiltration

When the water comes to the ground surface by precipitation, it tries to penetrate rock or soil subsurface, and this process is called infiltration. The infiltrated water first increases the moisture content of the soil and then creates subsurface flow. The waters that do not participate in the subsurface flow leak into the groundwater storages by percolation. Infiltration capacity is expressed as the maximum rate of infiltration and surface runoff occurs due to the precipitation rate exceeding the infiltration rate. Infiltration has a vital place in the water cycle as it enables the formation of surface flows and feeds groundwater aquifers. Infiltration is commonly expressed in mm per day, and it is affected by many factors. Examples of these factors are precipitation, soil characteristic, soil moisture content, the ground slope, land cover, etc.

2.4.6. Groundwater

Among the world's total water potential, freshwater covers almost 2.5 percent, and groundwater constitutes approximately 30% of the freshwater resources. The rest of the freshwater is in the glaciers and ice caps. For this reason, groundwater resources are an important source of available fresh water for the world. Turkey’s average annual rainfall is 501 $km^{3,}$ and 8.2% of this amount (41 km^3) leaks underground. Most of the leaking water is discharged to the seas by feeding surface waters. Only 14 km^3 of the amount of water leaking into the ground is available and represents the safe amount of water that can be drawn from groundwater sources.

The usage rates and amounts of groundwater resources in the world are increasing day by day. The usage of the Turkey's groundwater sources is also growing in all areas (irrigation, drinking-utility, and industrial water) in Figure 2.9.

Groundwater and surface water are always in interaction because these two sources are often feeding each other, and the contamination or change in one of the two is observed by the other. Therefore, the relationship between surface water and groundwater should be carefully examined.

One of the major dangers for groundwater resources is excessive water withdrawal. Due to this situation, the balance in the basins may be disturbed, and the subsidence occurs in places. Also, excessive water withdrawal from wells in coastal areas generally results in salt intrusion situations. For this reason, the amount of water drawn from aquifers is of great importance, and the amount of water that can be withdrawn without causing problems is called a safe flow rate.

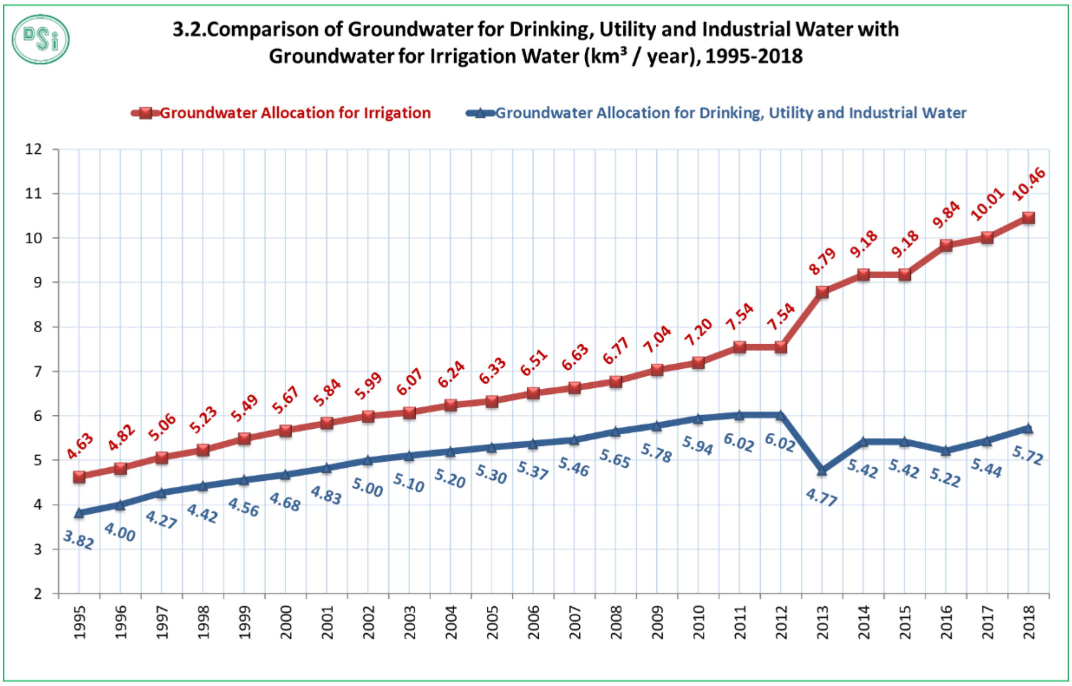

Figure 2.9. Sectoral allocation of groundwater usage in Turkey

(Source: State Hydraulics Works (DSI), 2019)

2.4.7. Flood and Drought Risk

Floods are common natural disasters in the world and are caused by the overflow of water that usually submerges dry land. Floods are generally caused by heavy rainfall, rapid snow melting, storms, or tsunamis that take place in coastal areas. The flood can lead to large-scale destruction and can damage personal property and public health infrastructure.

Among the flood types, three types are very common. The first of these three types are flash floods. Flash floods occur when the water level rises in rivers, streams, and canals as a result of heavy, rapid, and excessive precipitation. The second type of flood is river flooding. River flooding occurs as a result of continuous rain and snow melting, increasing the capacity of the river. The river, which has a higher flow than its capacity, spreads towards the flood bed by overcoming the embankments built to prevent floods. The maximum flow that the river can carry is called the peak flow rate. Peak flow is used in the design of structures such as bridges, culverts, and spillways planned to be built on the rivers. The flood volume plays a role in determining the capacities of the storage structures constructed for flood control. The last of these three types is coastal floods. Coastal flooding occurs as a result of sea flooding due to tropical cyclones and tsunamis. Extreme rains, whose frequency and intensity increase due to climate change, cause flood disasters to occur more frequently, and it is expected that people will face this disaster more in the future (World Health Organization (WHO)).

Drought can be defined as a long-term dry period in the natural climate cycle in its most general form, and it can happen anywhere in the world. Drought is not a situation that can be observed as quickly as other natural disasters (floods, hurricanes, etc.). Drought, which is a slow-onset disaster, is water scarcity caused by a lack of rainfall. It differs from each other with three distinct characteristics. These features are: intensity, duration is spatial distribution. Droughts are distinguished according to their meteorological, hydrological, agricultural, and socioeconomic types. Meteorological drought is a prolonged period when precipitation is less than other regular or average periods. Agricultural drought can be defined as scarcity of rainfall, the difference between actual and potential evapotranspiration, and lack of moisture in the soil. Hydrological drought is the impact on surface and groundwater resources as a result of precipitation deficiencies. Socioeconomic drought results from the inability to meet the supply of some economic goods. Today, with the increasing population, the demand for these goods is also increasing.

Drought affects both developed and developing countries, and its effects can be economic, social, and environmental. Drought has direct and indirect impacts on the economy. Examples of direct impacts on the economy are losses in the agricultural, industrial, transport, and energy sectors, etc. Its indirect impact on the economy is the tax losses that governments will experience due to increased unemployment and sector losses due to drought. Its environmental impact can cause damage to plants and animals in their natural habitats and increase forest fires and soil erosions. On the other hand, social impacts can be given as examples of public safety, health, inequalities in the distribution of water resources, and the conflicts this situation will cause among users. It is predicted that the climate changes and greenhouse effect was seen in the world in recent years will have significant effects on drought in the future.

2.5. Literature Review

In this part of the study, some of the studies in the literature related to water resources management through the Water Evaluation and Planning (WEAP) program will be summarized. Factors such as climate change, urbanization, industrialization, and population increase, many studies have been carried out to keep water resources under control and to plan and manage these resources for the next years.

Lévite, Sally, Cour, (2003), used WEAP to model the water resources of Steelport, which is the sub-basin of the Olifants River in South Africa and they discussed, the advantages and disadvantages of the program. They created various simulations and discussed the results of these simulations under adverse climatic conditions (dry, normal, wet years). The most important conclusion from the study is that the WEAP model can be used as a useful and fast tool and that it produces simple and understandable results among policymakers, stakeholders, and users thanks to its user-friendly structure and the results obtained are stimulating in raising public awareness and in terms of the use of water resources.

Huber-Lee, Yates, Purkey, Yu, Runkle, (2003) implemented the WEAP model tothe Sacramento Basin considering that the Sacramento River not only irrigates important agricultural areas, but also provides municipal and industrial water supply to the Southern California Coastal Plain, Los Angeles, and San Diego. Scenarios have been created on climate change, food security, environmental security issues. The year 2100 was chosen for the end year of the scenarios created. In the study, taking into account variables such as land use, land cover, population projections, climate change, was aimed to evaluate the future situation and distribution of these variables in California in the WEAP program. As a result, it has emerged that the unmet agricultural water need will increase with climate change, and the situation is inevitable. In the scenario where climate change is defined, the need for agricultural water, which could not be met, increased by 2.3 percent. Although the unmet agricultural water needs decreased compared to the business-as-usual scenario in the climate change adaptation scenario for food security, it generally increased by 1.7 percent. It has been shown that meeting the water demand of the aquatic ecosystem will also be problematic in the future. It has been found that the situation will worsen between 2070 and 2099 as the effects of climate change become more pronounced.

Haddad, Jayousi, Hantash, (2007), tested the usability of WEAP as a Decision Support Systems tool in Tulkarem district, Palestine. The field of work in West Bank's; covers 5 percent by area, 7 percent of the population, 10 percent of irrigated land, and 11 percent of water use in agricultural land. Eight different models were applied in the study, and results were generated for each model. Among the results of the models created, the results of the Data Quality, Knowledge Quality, and Water Quality models have turned out to be either unsatisfactory or not possible to be implemented in the program. Still, other results have shown that the WEAP model supports Decision Support Systems on the management of water resources in the study area.

Loon, Mathijssen, Droogers, (2007), worked on the Gediz Basin within the scope of the WatManSup project. The main reason for choosing the Gediz Basin is stated as the expected the expected water scarcity . Eight major irrigation and one wetland within the basin boundaries were transferred to WEAP as a point of demand. Although the primary water source in the region is the Gediz River and its tributaries, there also considered four reservoirs: Göl Marmara, Demirköprü, Afşar, and Buldan. Three different scenarios were created in the study. In the first of these scenarios, transmission losses are assumed to be zero. In the second scenario, the maximum volume value of the Demirköprü reservoir area was reduced due to siltation, and in the last scenario, the need for water was indirectly increased by increasing the agricultural area. The effects on the Gediz Basin were examined through these scenario studies.

Purkey, Joyce, Vicuna, Hanemann, Dale, Yates, Dracup, (2008), implemented the WEAP model to the Sacramento River Basin to find the effects of climate change on agricultural water consumption in the basin and the adaptation potential to climate change. Scenarios have been implemented with and without adaptation to climate change in the study. Two important conclusions were drawn from the study. The first of these is that WEAP provides an important advantage over water resources in the study on the effects and adaptations of climate change. Second, the results emerged that water management adaptation on a sectoral basis mitigates the impacts of climate change.

Mounir, Ma, Amadou, (2011), used to WEAP model to study on the Niger River Basin (in the Niger Republic). The study includes the analysis of the water needs of industrial cities such as Niamey and Tillabéry, as well as agricultural water needs and human needs. Three different scenarios have been created and in light of the results of these scenarios, it has been revealed that the establishment of a hydroelectric dam in the Niger River basin can control the flow values in the river and meet the sufficient water need with the water stored in dry periods. According to the results of the WEAP model, it has been brought out that if the resources in the Niger River are not optimized, future needs cannot be met.

Li, Zhao, Shi, Sha, Wang, Wang, (2015), carried out the WEAP program in modeling the water resources of the next years on Binhai New Area in China. They created three different scenarios within the scope of the study. In the first scenario, priority was given to the increasing water needs of the growing population due to urbanization. In the second scenario, taking into account the Gross Domestic Product (GDP), the water usage rates are distributed according to the GDP on a sectoral basis. In the last scenario, the water policy has been changed and implemented in the allocation of water resources. In line with these scenarios created, it was found that there will be water shortages in Binhai New Area in the coming years, and recommendations were made to meet the demands for future years.

Chinnasamy, Bharati, Bhattarai, Khadka, Dahal, Wahid, (2015), practiced the WEAP model in the transboundary Koshi River basin in Nepal. The study aims to predict water usage on a sectoral basis, determine whether the water infrastructure is sufficient today and in the future (increase in population, agriculture, and industrialization), and measure the amount of hydropower generation under these conditions. In the study, four different scenarios were created, one of which is the reference scenario. In the reference scenario, the annual water demand was 25,986 million cubic meters (MCM), and the unmet demand value was 660 MCM. In the Population growth scenario, the amount of water consumed annually increased by 16% compared to the reference scenario and reached 30,180 MCM, and unmet demand increased 39% to 920 MCM. In the Agricultural Growth scenario, the amount of water demanded annually increased to 28,922 MCM, and the unmet water demand reached 970 MCM. In the last scenario, Industrial growth, the highest water demand, and unmet demand were achieved. In this scenario, unmet demand increased by 52% to 1,003 MCM compared to the reference scenario. Along with the Water Resource Development (WRD) projects, 8,382 MCM water was stored and it was determined that it could satisfy the unmet demand values found for the four different scenarios prepared. With the implementation of the WRD projects, it has been shown that Nepal can produce 37 times the amount of electricity it receives from India, and even the electricity produced can be exported to neighboring countries.

Hao, Sun, Liu, Qian, (2015), used to WEAP model to water resources of Chifeng City is located in the northern part of China. As one of the effects of climate change, water resources in the study area have started to be insufficient. Therefore, different climate change scenarios and adaptation policies can be put forward against these scenarios in the study. The year 2009 has been chosen as the starting year for the scenarios, and for the scenarios created, 2040 has been chosen as the end year. In the study, the water resources of Chifeng City for the coming years were examined by using both WEAP and SWAT programs together. As a result of the scenarios produced, it has been shown that improvements in agricultural irrigation, less use of groundwater, and growing agricultural products that need less water, rather than creating new surface water resources in the region, will be successful in meeting the demands that cannot be met.

Psomas, Panagopoulos, Stefanidis, Mimikou, (2017), exercised the WEAP model to the Ali Efenti catchment area in the Pinios River Basin. The average annual precipitation value of the study area is higher than other sub-catchments and is fast in terms of groundwater recharge. However, due to the excessive amount of water withdrawn for irrigation in agricultural areas in summer, there is a seasonal shortage of water. The years 1995-2010 were selected as the baseline period, and the climatic data for these years were obtained from hydrometeorological stations. The periods of the scenarios created are between 2015-2030. Almost all of the unmet water demand (90-95%) is due to the agricultural sector. In line with the results obtained from the simulations, the future climate and socio-economic changes affect the water resources in the region in a very small amount. Restricting water withdrawal during the summer months, the experienced water stress decreased from 19.2% to 13.9%.

Hassan, Bano, Burian, Ansari, (2017), implemented the WEAP model to Lower Indus Basin located in Sindh, Pakistan. The starting date of the scenarios created was chosen as 2015, and the model was calibrated and validated for this year. The end year of the scenarios created was selected as 2050. If the growth rate in the city continues in this way, it is concluded that the water demand will increase by 2050. Sprinkler irrigation and lining canals projects, which are among the scenarios created for irrigation of agricultural land, increased the reliability of the system by 17% and 25%, respectively. However, a combination of these two methods should be used to meet future water needs.

Gao, Christensen, Li, (2017), Ordos, utilized the WEAP model to a typical arid/semi-arid area in northwest China, was chosen as the study area. The area covered by the region is 87,000 $km^{2,}$ and annual rainfall is 26,200 million m^3, while the yearly evaporation amount reaches 216,880 million m^3. The main purpose of the study is to test the effectiveness of the WEAP program in observing the impact of developments in an arid/semi-arid industrial area on local water resources within the limits of strategic environmental assessments. As a result of the study, the WEAP model was seen as a valuable tool for rapid testing of water use due to strategic environmental assessment.

Kou, Li, Lin, Kang, (2018), practised to WEAP to model the water resources of Xiamen City, scenarios were established between 2015-2050. This study is special because it is examined by dividing the city into five different regions, not as a single and whole piece. It has been revealed that the city's water needs and consumption will increase over the years. It is brought in the model that after 2030 if a new water source is not found or built, there will be a water shortage. The scenarios created showed that the structural water-saving scenario showed a water-saving potential of 6.97% and could delay water scarcity for three years. In the Technical Water-Saving scenario, which is another scenario, it has been shown that it has a water-saving capacity of 9.82% and postpones water scarcity for two years. In the double water-saving scenario, which is the combination of these two scenarios, it has been shown that there is a water-saving potential of 16.44% and delaying water scarcity by five years.

Amin, Iqbal, Asghar, Ribbe, (2018), implemented the WEAP model to the Upper Indus Basin, which is used as a study area, is located in the north of Pakistan, and the average maximum temperature in the region is 25.7 ^{o}C, the average minimum temperature is 4.4 ^{o}C. The basin receives annual precipitation between 2000-2500 mm. The model created was calibrated between 2006-2010, and validation was carried out for the years 2011-2014. The year 2050 was chosen for the end date of the scenarios created. The field of study was examined under climate change scenarios and different socio-economic scenarios, then it was found that the unmet water need in 2050 was 134 million cubic meters. It has been shown that with the construction and commissioning of the dams planned to be built by the Water and Power Development Authority, the unmet water need in the basin will decrease by 60%.

Ahmadaali, Barani, Qaderi, Hessari, (2018), worked the WEAP model to Lake Urmia Basin, where the lake was a drought-fighting, and that has been observed to have dropped by 40 cm each year over the past two decades. For this reason, Zarrinehrud and Siminehrud River basins in the Urmia Lake Basin have been examined in this study. The working period of the model created in WEAP was chosen between 2015-2040. In the study, three different future emission scenarios were created, and five different water management scenarios were discussed under each future emission scenario. Among the created models, the scenario (B1S4), assuming that the crop pattern has changed and the irrigation efficiency has increased, has been found to be the most successful. In this scenario, the highest environmental sustainability index value and the highest agricultural sustainability index values were obtained.

Brown, Mahat, Ramirez, (2019), applied the WEAP model to the basins that are subdivisions of 18 water resource regions from the United States were selected as the study area. These basins consist of 204 four-digit hydrologic units. Of these 204 basins, 66 are discharged into the sea or the Great Lakes, nine are released either to Canada or Mexico, 12 are closed basins, meaning they don't discharge, and 117 basins discharge into another basin. The study aims to examine the scenarios suitable for the expected water shortage in many areas, such as possible adaptation projects, water withdrawal efficiency, demand reduction, improvement of reservoir capacities, etc.

Tena, Mwaanga, Nguvulu, (2019), used the WEAP to the Chongwe River Basin. The study used rainfall and streamflow data, which are the average of many years. In the basin, the annual average change in the storage capacity of the basin has been found to be 120.18 million m^3. It has also been shown that 22.55 million m^3 of water flows into the basin from the neighboring Kafue River basin. When the results of the created model are examined, it has brought out shown that the results obtained are at an acceptable level. As a result of the study, it was recommended to provide appropriate water resources management options for the basin.

Olabanji, Ndarana, Davis, Archer, (2020), performed the WEAP model to the Olifants River, the main tributary branch of the Limpopo River. The basin has an area of 54,475 km^2. Rainfall in the basin generally falls between October and April, and the annual average amount of precipitation varies between 500 mm and 800 mm. The amount of evaporation varies from region to region and the winters are relatively cold and the summers are very hot. The temperature ranges from -4 ^{o}C to 45 ^{o}C. Two different climate change scenarios have been implemented in the program. The data between 1996-2002 were used for the calibration of the model, and the data between 2003-2005 was used for the validation of the model. Nash-Sutcliffe Efficiency (NSE) and R^2 values found for the data obtained as a result of the model are at an acceptable level. It has been predicted that the unmet water demand will increase by 58% for the mid-century and 80% for the end century as a result of the increase in economic activities and the decrease in streamflow. The study has shown that the combination of management strategies created against climate change scenarios yields the best results.

CHAPTER 3

STUDY SITE

3.1. Küçük Menderes Basin

Küçük Menderes Basin is located between 38°41’05’’ and 37°24’08’’ north latitudes and 28°24’36’’ and 26°11’48’’ east longitudes. The basin area is approximately 696.49 ha and covers 0.9% of Turkey's surface area. Küçük Menderes Basin is located in western Turkey between Gediz and Büyük Menderes Basins. The basin includes the area that discharges its waters into the Aegean Sea together with the Küçük Menderes River and other streams.

Küçük Menderes Basin is surrounded by Karadağ, Çulha and Ayrık (Oyuk) Mountains from the east, Beydağ, Kümeli Mountain from the south to the west, and Bozdağ, Çallıbadağı, Mahmut Mountain and Kesme Mountains from the north to the west. In the west, the basin surrounded with the İzmir Bay and the Aegean Sea.

Küçük Menderes flood plain, which is smaller than the neighboring Gediz and Büyük Menderes Plains, is home to three important plains. The first of these is the Kiraz Plain, located at the northeastern end of the basin. The second one is Fetrek Plain located in Torbalı in the basin's northwest. Finally, it is the Selçuk Plain, which is formed where the Küçük Menderes River empties into the Aegean Sea.

The basin covers a large part of İzmir province and Kuşadası district of Aydın province. There are a total of 361 settlements in the Küçük Menderes Basin, including provinces, districts, neighborhoods, and villages. There are two metropolitan cities, 14 district centers, and 345 neighborhoods and villages within the borders of the basin.

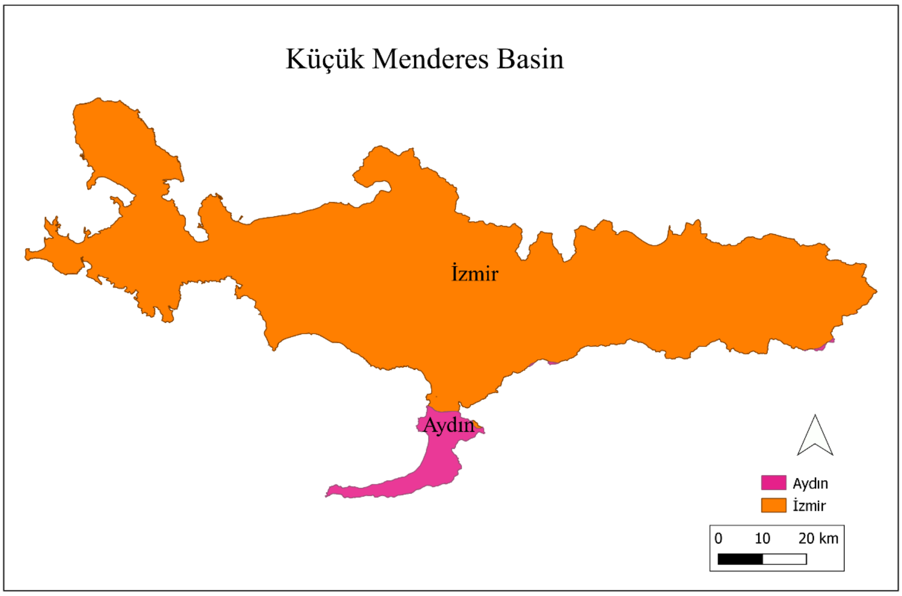

Figure 3.1. Küçük Menderes Basin

In the Küçük Menderes Basin, typical features of the Mediterranean climate are observed; in this type of climate, the summers are hot and dry, and the winters are warm and rainy. About half of the total annual precipitation in the basin falls in winter. In the coastal parts of the basin, snowfall and frost are rarely seen, but in high-altitude regions, winters are snowy and cold. The month with the least precipitation in the basin is August, and the month with the highest precipitation is December. The vegetation that develops due to the Mediterranean climate characteristics of the Küçük Menderes Basin consists of dwarf plants at low elevations and mixed-type tree communities and coniferous forests towards higher elevations.

When looking at the general land distribution of the basin, while settlement, tourism, industry, and mining activities are carried out in 3%, water surfaces constitute 2%. According to a study conducted in 2012, agricultural areas (38%) and forest-maquis areas (32%) constitute a significant part of the lands in the Küçük Menderes Basin. Küçük Menderes Basin has some of the most productive lands in Turkey and has a high agricultural potential in terms of both product quality and yield. 55% of agricultural lands are used as dry farming lands, and today irrigated farming areas (45%) are gradually expanding in the basin (Republic of Turkey Ministry of Forestry and Water Affairs, General Directorate of State Hydraulic Works, Department of Surveying, Planning and Allocations 2016).

When the total agricultural area is compared based on the districts entering the basin, it is seen that there are more areas in Ödemiş district compared to the others. Considering the agricultural activities in Bayındır, Beydağ, Kiraz, Ödemiş, Selçuk, Tire and Torbalı districts around Küçük Menderes River in the basin, it is seen that agriculture in this region is above the average of Turkey.

In the Küçük Menderes Basin, field areas take first place in terms of agricultural land use, followed by olive areas, vegetable areas, and planted areas. Corn, potato, wheat, barley, cotton, alfalfa, rapini, vetch, and tobacco production are in the foreground within the field areas. Among the vegetable fields, tomato, watermelon, pepper, cucumber, bean, okra, and green pea cultivation have important places. In the planted areas, fruit, vineyard, citrus, etc., take the first place.

İzmir province, which represents an important part of the Küçük Menderes Basin, is one of the three provinces where the industry is most developed in Turkey. Raw material resources, qualified workforce, transportation opportunities, proximity to domestic and foreign markets have been the driving force of the development of the industry in the basin. Today, industrial structuring has settled and developed along three main axes, namely Pınarbaşı-Işıkkent-Kemalpaşa, Çiğli-Aliağa and Karabağlar-Torbalı-Menderes, and continues in this direction.

3.1.1. Küçük Menderes River

The most important river of the Küçük Menderes Basin is the Küçük Menderes River, which gives its name to the basin. There are also many tributaries of the Küçük Menderes River. The important ones among these tributaries are: Fetrek Stream, Uladı Creek, Ilıca Stream, Değirmen Stream, Aktaş Stream, Rahmanlar Creek, Pirinçci Stream, Yuvalı Stream, Ceriközkaya Stream, Eğridere, Birgi Stream, Çevlik Creek and Keleş Creek.

The Küçük Menderes River travels approximately 129 km until it reaches the Aegean Sea. The Küçük Menderes River, fed by the streams flowing from Bozdağ, Karadağ, and Gediktepeler in the east of the basin and starting from the Kiraz Plain, first flows in the north-south direction, then proceeds in the east-west direction from the Beydağ district, crosses the Ödemiş Plain and flows to the east of Torbalı. From here, it again passes through Belevi in the north-south direction and reaches the Selçuk Plain, and after flowing in the east-west direction, it pours out in Pamucak, forming a delta in the Aegean Sea (Republic of Turkey Ministry of Forestry and Water Affairs, General Directorate of State Hydraulic Works, Department of Surveying, Planning and Allocations 2016).

Table 3.1. Some streams in the basin and their lengths

Stream Name	Length (m)
Küçük Menderes River	129.114
Çevlik Creek	12.043
Keleş Creek	11.557
Rahmanlar Creek	13.286
Uladı Creek	4.71
Değirmen Stream	10.261
Ilıca Stream	14.231
Fetrek Stream	13.783
Aktaş Stream	8.943

3.2. Sub-Basins of Küçük Menderes Basin

The General Directorate of State Hydraulic Works (DSI) has determined five different sub-basins in the Küçük Menderes Basin, taking into account features such as surface precipitation area, groundwater recharge area, geological, hydrogeological, and aquifer structures. These sub-basins;

1- Küçük Menderes Sub-Basin

2- Tahtalı-Seferihisar Sub-Basin

3- İzmir Bay Sub-Basin

4- Çeşme-Karaburun Sub-Basin

5- Kuşadası Sub-Basin

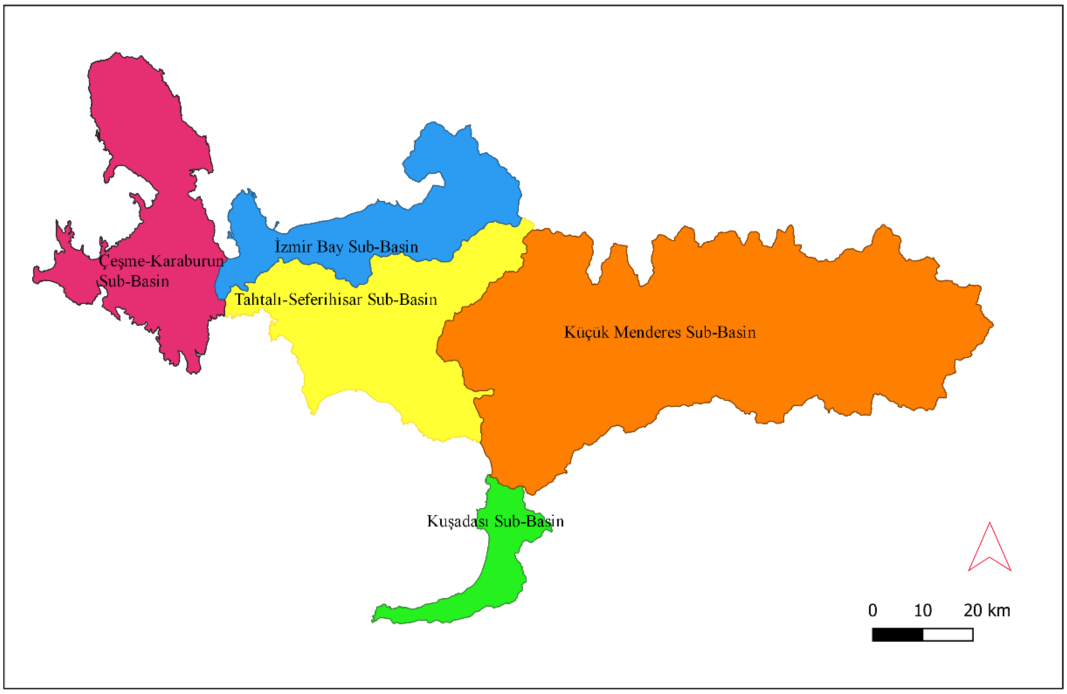

Figure 3.2. Sub-basins of Küçük Menderes Basin

Table 3.2. Küçük Menderes Basin's Sub-Basin Areas

Sub-Basin Name	Area (km^2)	Ratio to Total Area (%)
Küçük Menderes Sub-Basin	3.490,95	50,13
Tahtalı-Seferihisar Sub-Basin	1.248,92	17,94
İzmir Bay Sub-Basin	816,68	11,73
Çeşme-Karaburun Sub-Basin	1.114,270	16,00
Kuşadası Sub-Basin	292,425	4,20

3.2.1. Tahtalı-Seferihisar Sub-Basin

The study area, Tahtalı-Seferihisar Sub-Basin, is located in the southwest of İzmir province in the Aegean Region of Turkey, between 37° 58' and 38° 23' north latitudes and 26° 40' and 27° 22' east longitudes. The basin has an area of approximately 1249 km^2.

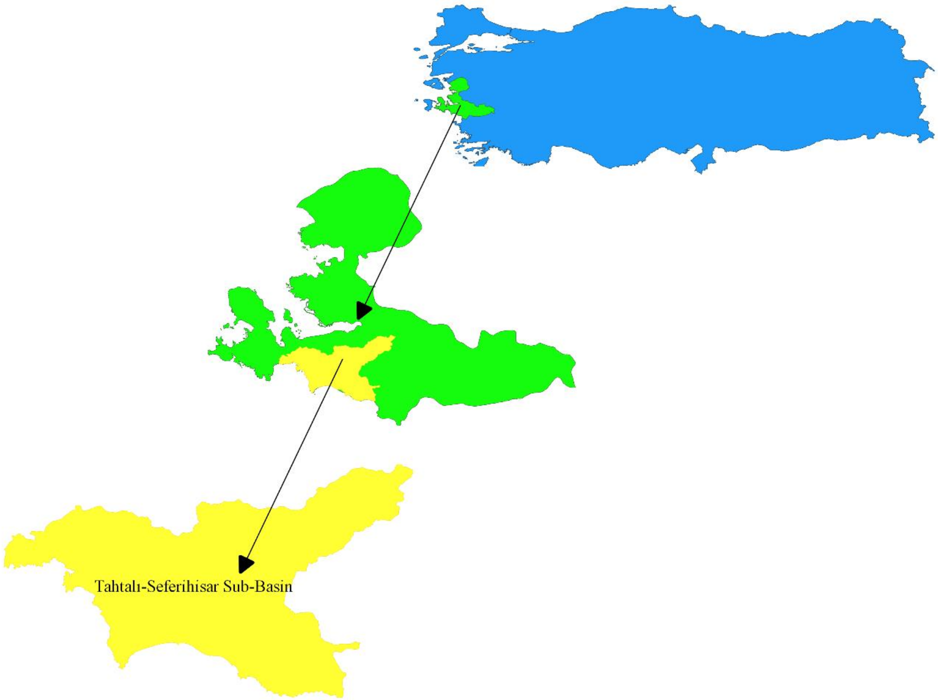

Figure 3.3. Location of the Study Area on the Map of Turkey

Since Tahtalı-Seferihisar Sub-Basin is located in the Aegean region, the climate type that dominates the entire basin is Mediterranean Climate. In this climate type, summers are hot and dry, and winters are warm and rainy. There are meteorology stations at three different points within the borders of the basin. These stations are: Seferihisar, Gümüldür and Değirmendere Meteorology Stations. According to the data of the mentioned meteorology stations, the annual average precipitation is around 731.1 mm. Similar climatic characteristics are observed in the Küçük Menderes Basin, and the temperature distribution does not differ much. Average yearly temperatures range from 12.4 °C to 17.7 °C. The hottest months are July and August, and the coldest months are January and February.

Table 3.3. Seferihisar Meteorology Station Average, Maximum and Minimum Temperatures (°C)

Meteorology Observation Station Name	Seferihisar		
	Avg.	Max.	Min.
Jan.	8.3	19.8	-6.2
Feb.	8.8	22.9	-6
Mar.	10.8	27.3	-3.8
Apr.	14.5	30.5	-2
May.	19.2	34.1	3.4
Jun.	24.2	39.3	8.7
Jul.	26.9	42.9	11.5
Aug.	26.4	41.8	12.2
Sep.	22.4	37.2	8.7
Oct.	17.7	34.3	1.7
Nov.	13	28.6	-3.6
Dec.	9.9	23.9	-4.1
Annual	16.9	42.9	-6.2

According to the report named Sectoral Water Allocation Action Plan and Circular (2020-2025) prepared by the Ministry of Agriculture and Forestry, General Directorate of Water Management, Basin Management Department, the usable surface water potential of Tahtalı-Seferhisar Sub-Basin is calculated by taking into account the standard and dry conditions. It is predicted that the potential water value of 131.44 hm^3/year in normal conditions will decrease to 29.75 hm^3/year in very severe dry conditions for surface water potential.

According to the same report, in groundwater recharge calculations, the monthly average groundwater recharge value for many years was calculated as 10.7 hm^3/month, and the annual average groundwater recharge value for many years was calculated as 121 hm^3/year. In the drought scenarios, the potential groundwater value to be taken into account in the allocation was found to be 121 hm^3/year for normal conditions and 31 hm^3/year for very severe dry conditions (Republic of Turkey, Ministry of Agriculture and Forestry, General Directorate of Water Management, Department of Basin Management 2019).

3.2.1.1. Surface Water Resources of Tahtalı-Seferihisar Sub-Basin

Tahtalı Seferihisar Sub-Basin has a vital role for İzmir because approximately 40 percent of the drinking water of 11 districts in İzmir's city center is supplied from Tahtalı Dam located in this sub-basin. The basin is quite rich in terms of surface waters. In addition to Tahtalı Dam fed by Tahtalı Stream and Şaşal Stream, Ürkmez Dam on Ürkmez Stream, Seferihisar Dam on Yassıçay and Kavakdere Dam on Kavak Stream are important dams and streams within the borders of the basin. These dams provide drinking and irrigation water. In addition to these surface water sources, the streams feeding the ponds in the basin have an important place for the study area.

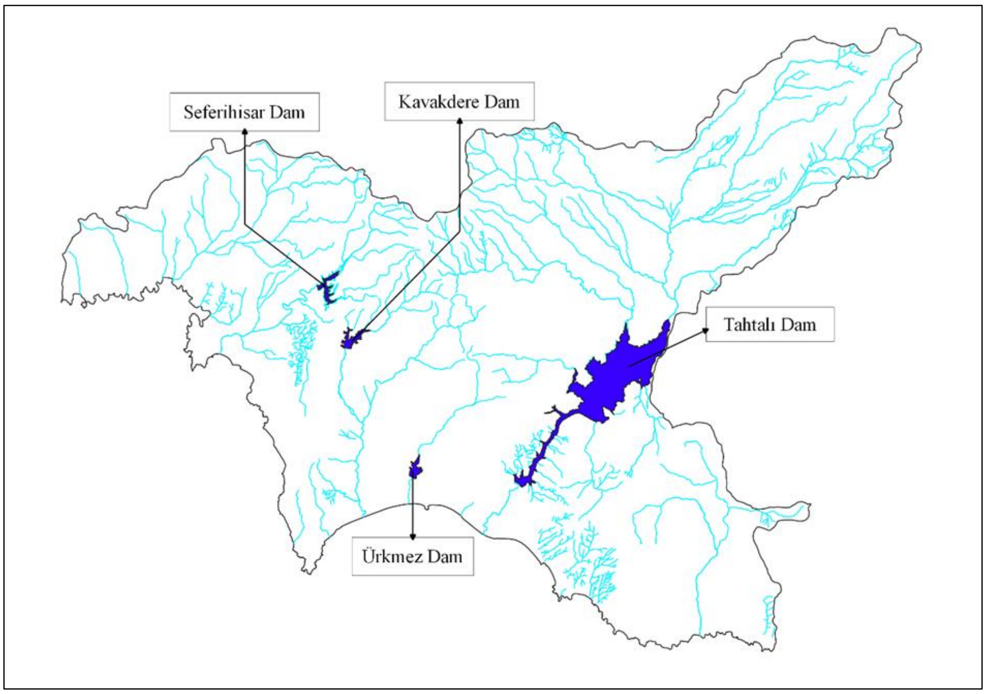

Figure 3.4. Surface Water Resources Map of Tahtalı-Seferihisar Sub-Basin

In addition to the dams, there are many large and small ponds within the borders of the basin. Ataköy Pond, Yeniorhanlı Pond, Özdere Pond, and Gümüldür Pond can be given as examples of the ponds built by the State Hydraulic Works. There are Yeniköy Balabandere Pond, Bademler Dokuz Eylül Pond, Ulamış Kavakçayı Pond, Payamlı Pond, Ulamış Ağalardere Pond, and Çatalca Şandidere Pond in the basin, the construction of which has been completed by the Special Provincial Administration. Some of these ponds are used for irrigation purposes.

Table 3.4. Information of the Ponds in the Tahtalı-Seferihisar Sub-Basin

Name of Pond	Location of Pond (district, town, village)	Name of Resource (stream,creek)	Gross Storage Volume (m^3)	Implementation Years
Bademler 9 Eylül Pond	Urla-Bademler	Kavaklıçeşme	$0,345 \times 10^6$	1979
Ulamış Kavakçayı Pond	Seferihisar Ulamış	Kavakçayı	$0,936 \times 10^6$	1985
Çatalca Şandidere Pond	Menderes Çatalca	Şandideresi (Pekmezci-Onbaşı)	$0,879 \times 10^6$	1986
Yeniköy Balabandere Pond	Menderes Yeniköy	Balanbandere	$2,325 \times 10^6$	1988
Ulamış Ağalardere Pond	Seferihisar Ulamış	Ağalardere	$1,593 \times 10^6$	1998
Payamlı Pond	Seferihisar Doğanbey Payamlı	Nardere	$0,792 \times 10^6$	2008
Yeniorhanlı Pond*	Seferihisar Orhanlı	Aşılıçay	1.527×10^6	–
Özdere Pond*	Menderes Özdere	Değirmendere	1.003×10^6	2015
Gümüldür Pond*	Menderes Gümüldür	Şeytandere	$0,650 \times 10^6$	2018
Ataköy Pond*	Menderes Ataköy	Karacadağ	1.470×10^6	2008

* Ponds of State Hydraulics Works

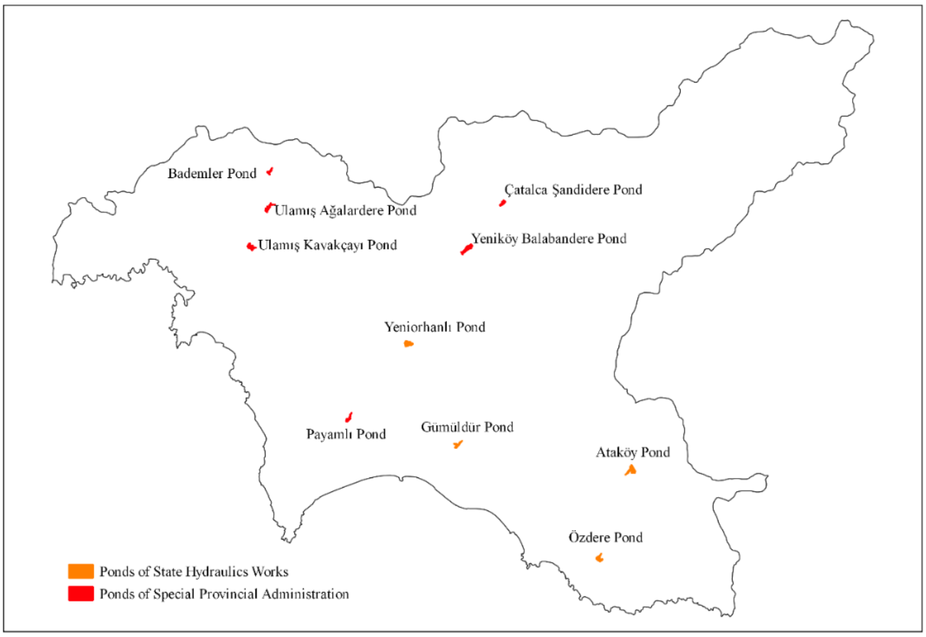

Figure 3.5. Location Map of the Ponds

As previously stated in the Sectoral Water Allocation Action Plan and Circular (2020-2025) report, the surface water potential of Tahtalı-Seferihisar Sub-Basin was examined according to different climatic conditions potentials under these climatic conditions were also given.

Table 3.5. Tahtalı-Seferihisar Sub-Basin Usable Surface Water Potential (Source: Republic of Turkey, Ministry of Agriculture and Forestry, General Directorate of Water Management, 2019)

Climate Conditions	Usable Surface Water Potential (hm^3/year)
Normal	131.44
Mild Arid	111.74
Medium Arid	77.34
Severe Drought	33.04
Very Severe Drought	29.75

As revealed in the report, when there is a very severe drought in the basin, the usable surface water potential of the basin decreases to 29.75 hm3/year. There are approximately 4.5 times the surface water potential under normal conditions and the potential in the worst-case scenario.

3.2.1.1.1. Ürkmez Dam

Ürkmez Dam is located on Ürkmez Stream, three kilometers north of Ürkmez town of Seferihisar district. The dam is for irrigation and drinking water. Whose project and construction was built by the State Hydraulic Works, was completed in 1990 and Ürkmez Dam was put into operation in 1991 and there have been operating inflows since January 1991.

Figure 3.6. Ürkmez Dam's Reservoir Area
(Source: İzmir Water and Sewerage Administration General Directorate, 2021)

Table 3.6. Technical Specifications of Ürkmez Dam

Rainfall basin area:	30.81 km^2
Average potential water flow per year:	$7.03x10^6$ m^3
Dam lake minimum water elevation:	23 m
Dam lake normal water height:	43.9 m
Dam lake maximum water height:	46.63 m
Lake volume at the minimum water elevation of the dam:	375,000 m^3
Lake volume at normal water elevation of the dam:	6,880,000 m^3
Lake volume at the maximum water elevation of the dam:	8,625,000 m^3

After completing the drinking water treatment facilities built by the Bank of Provinces in 2004, it started to provide drinking water to Ürkmez. Later, the drinking water treatment plant was transferred to the General Directorate of IZSU (İzmir Water and Sewerage Administration General Directorate) in 2004. In the Küçük Menderes Basin Master Plan Final Report, the missing data of the Ürkmez Dam between 1980 and 1990, while the correlation of the Seferihisar Dam Inlet flows was completed, the values for October-December of 1991 were achieved by taking the long-term average values of the relevant months (Republic of Turkey Ministry of Forestry and Water Affairs, General

Directorate of State Hydraulic Works, Department of Surveying, Planning and Allocations 2016).

The dam meets the irrigation water need of the State Hydraulics Works-controlled Ürkmez Dam Irrigation. The gross area of irrigation is 370 hectares.

	Months												Annual Total (mm)
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Evaporation from Free Water Surface (mm)				71.8	114.6	159.7	184.5	180.0	143.1	100.8			954.5
Precipitation (mm) (Gümüldür Met. Obs. Sta.)				37.7	17.1	9.4	1.6	0.5	10.5	31.5			108.2
Net Evaporation				34.2	97.6	150.3	182.9	179.5	132.6	69.3			846.4

Figure 3.7. Ürkmez Dam Monthly Average Evaporation Values

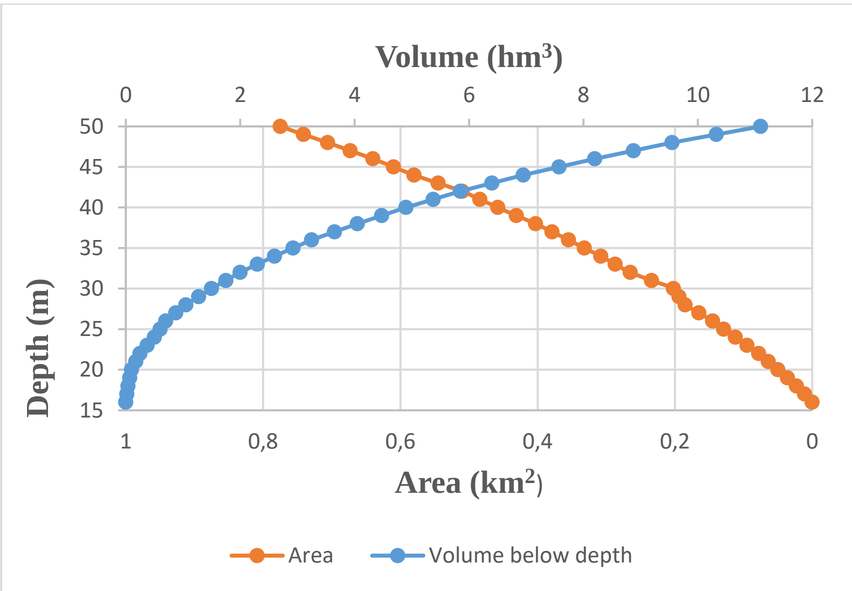

Figure 3.8. Volume-Depth-Area Graph of Ürkmez Dam

3.2.1.1.2. Seferihisar Dam

Seferihisar Dam is a dam for irrigation purposes and was built on Yassıçay in the Tahtalı-Seferihisar Sub-Basin. There is a Yassıçay-Çukurköy flow observation station with the code D06A010 just downstream of the dam. The precipitation area of the flow observation station is 41 km^2, and the precipitation area of Seferihisar Dam is 40.7 km^2.

Figure 3.9. Reservoir Area of Seferihisar Dam

(Source: Seferihisar Municipality, 2016)

Table 3.7. Technical Specifications of Seferihisar Dam

Rainfall basin area:	41 km^2
Average potential water flow per year:	$12.10x10^6$ m^3
Dam lake minimum water elevation:	111.6 m
Dam lake normal water height:	144.1 m
Dam lake maximum water height:	146.81 m
Lake volume at the minimum water elevation of the dam:	885,000 m^3
Lake volume at normal water elevation of the dam:	29,100,000 m^3
Lake volume at the maximum water elevation of the dam:	34,200,000 m^3

Due to the fact that the precipitation areas of the flow observation station and the dam are roughly the same, the water supply values of the Yassıçay-Çukurköy flow observation station with the code D06A010 have been taken precisely for the dam site in the Küçük Menderes Master Plan Final Report. In this information line, the annual average natural flow value of Seferihisar Dam is 7.28 hm^3.

Seferihisar Dam Irrigation, which provides irrigation water from Seferihisar Dam, has a gross area of 1277 hectares and a net area of 1200 hectares.

Seferihisar Dam evaporation values were calculated using the evaporation and precipitation observations of the Beyler Meteorology Observation Station together with the monthly average temperatures of the Seferihisar Meteorological Observation Station.

	Months											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Evaporation from Free Water Surface (mm)				71.3	137.7	207.5	246.1	239.0	181.9	116.3		
Precipitation (mm) (Beyler Met. Obs. Sta.)				49.3	24.7	3.4	0.9	0.8	7.7	35.9		
Net Evaporation				22.1	113.0	204.1	245.2	238.2	174.2	80.4		

Figure 3.10. Seferihisar Dam Monthly Average Evaporation Values

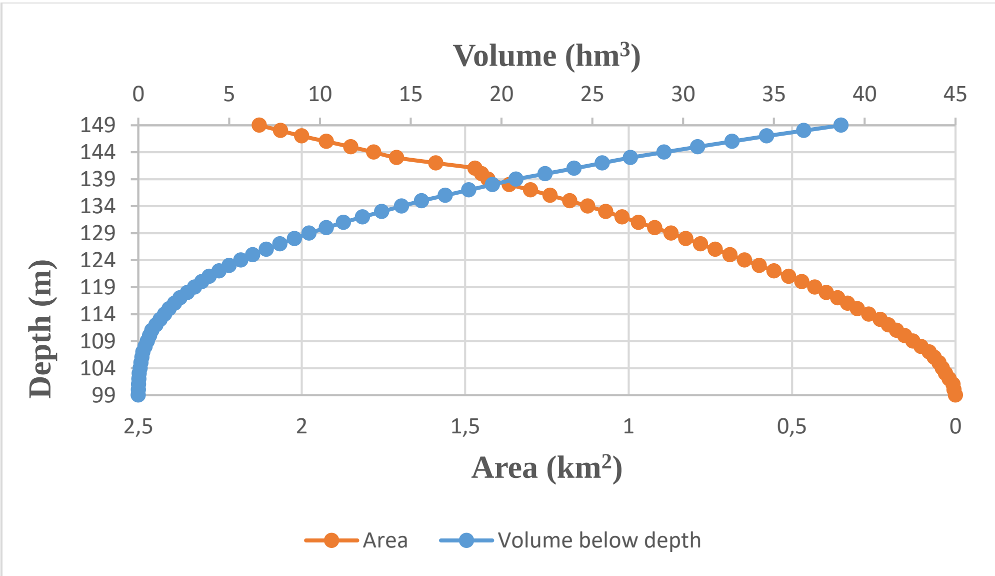

Figure 3.11. Volume-Depth-Area Graph of Seferihisar Dam

3.2.1.1.3. Tahtalı Dam

Tahtalı Dam is the second-largest structure in terms of water potential among İzmir surface drinking water resources. The dam is located 40 kilometers south of İzmir, 5 kilometers east of Gümüldür, on the Tahtalı Stream. Tahtalı Dam, which was built by the State Hydraulic Works, was completed in 1996. The dam started to supply water to İzmir on 27 August 1997. Tahtalı Çayı-Dereboğazı flow observation station with the code D06A007 is operating just upstream of the dam. The precipitation area of the flow observation station is 524.4 km^2, and the precipitation area of the Tahtalı Dam is 554.3 km^2.

Figure 3.12. Reservoir Area of Tahtalı Dam

Table 3.8. Technical Specifications of Tahtalı Dam

Rainfall basin area:	554 km^2
Average potential water flow per year:	$1533x10^6$ m^3
Dam lake minimum water elevation:	31 m
Dam lake normal water height:	60.5 m
Dam lake maximum water height:	60.5 m
Lake volume at the minimum water elevation of the dam:	19,600,000 m^3
Lake volume at normal water elevation of the dam:	306,650,000 m^3
Lake volume at the maximum water elevation of the dam:	306,650,000 m^3

While calculating the Tahtalı Dam evaporation values, the monthly average temperature values of Seferihisar Meteorology Observation Station were moved to the elevation of Gümüldür Meteorology Observation Station, and the temperature values were obtained.

Evaporation was calculated by using the precipitation observations of Gümüldür Meteorology Observation Station and Değirmendere Meteorology Observation Station to find the amount of falling precipitation. As a result of the Thiessen polygons drawn, the Tahtalı Dam's lake surface is under the impact rates of Değirmendere Meteorology Observation Station at a rate of 93% and Gümüldür Meteorology Observation Station at a rate of 7%. From the calculated evaporation values, the precipitation falling on the dam surface was deducted by considering the impact rates of the stations, and net evaporation losses were found.

The approximate elevation of the Tahtalı Çayı-Dereboğazı flow observation station with the code D06A007 is 19 m, and the precipitation area is 524 km^2. 1969 April-September, 1970-1988, and 1990 years were evaluated. The flow observation station was closed on 19.11.1997, and Tahtalı Dam was put into operation on the same date.

Table 3.9. Tahtalı Dam Monthly Average Evaporation Values

	Months												Annual Total
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Evaporation from Free Water Surface (mm)				71	113.8	158.8	183.7	179.1	142.3	100			948.6
Precipitation (mm) (93% Değirmendere + 7% Gümüldür Met. Obs. Sta.)				54.6	29.4	10.4	4	1.7	8.9	47.2			156.1
Net Evaporation				16.3	84.4	148.5	179.7	177.4	133.4	52.8			792.5

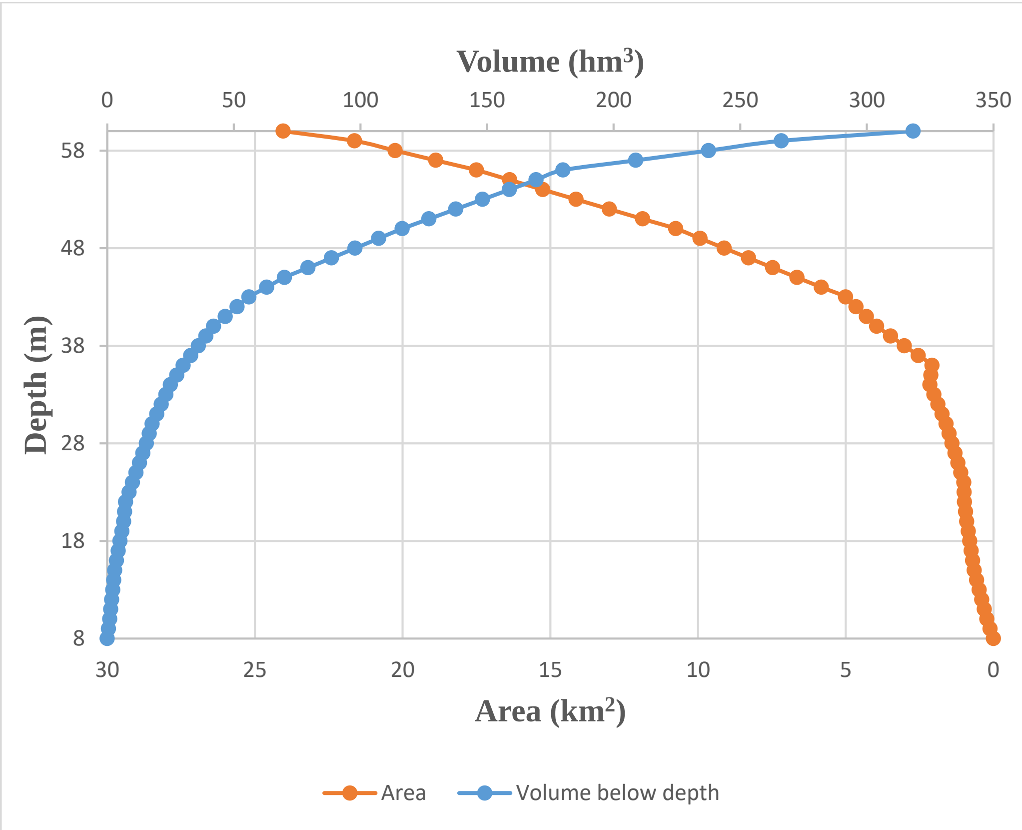

Figure 3.13. Volume-Depth-Area Graph of Tahtalı Dam

3.2.1.1.4. Kavakdere Dam

Kavakdere Dam is for irrigation purposes and is located on Kavakdere in Tahtalı-Seferihisar Sub-Basin. The dam was put into operation in 2006, since April of the same year, there are operational inflow values. The precipitation area of the Kavakdere Dam is 27.8 km^2. The required values for the missing years (before 2006) in the Küçük Menderes Basin Master Plan Final Report were completed by making various correlations. The annual average natural flow value of the Kavakdere Dam is equal to 5.18 hm^3.

Figure 3.14. Reservoir Area of Kavakdere Dam

Table 3.10. Technical Specifications of Kavakdere Dam

Rainfall basin area:	27 km^2
Average potential water flow per year:	$5.66x10^6$ m^3
Dam lake minimum water elevation:	76.4 m
Dam lake normal water height:	101.65 m
Dam lake maximum water height:	103.5 m
Lake volume at the minimum water elevation of the dam:	289,000 m^3
Lake volume at normal water elevation of the dam:	14,100,000 m^3
Lake volume at the maximum water elevation of the dam:	16,200,000 m^3

In order to calculate the evaporation values of the Kavakdere Dam, the monthly average temperature values of the Seferihisar Meteorology Observation Station were moved to the dam elevation. A correlation study was conducted between the carried temperatures and the monthly total evaporation values of the Beyler Meteorology

Observation Station. Net evaporation losses were calculated by subtracting the precipitation values of Beyler Meteorology Observation Station from the calculated evaporation values.

Table 3.11. Kavakdere Dam Monthly Average Evaporation Values

	Months												Annual Total
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Evaporation from Free Water Surface (mm)			23.4	74.8	141.2	211	249.5	242.5	185.4	119.7	54		1278
Precipitation (mm) (Beyler Met. Obs. Sta.)	115.4	81.5	74.6	49.3	24.7	3.4	0.9	0.8	7.7	35.9	96.4	139	629.6
Net Evaporation				25.5	116.4	207.6	248.7	241.7	177.7	83.8			1101.3

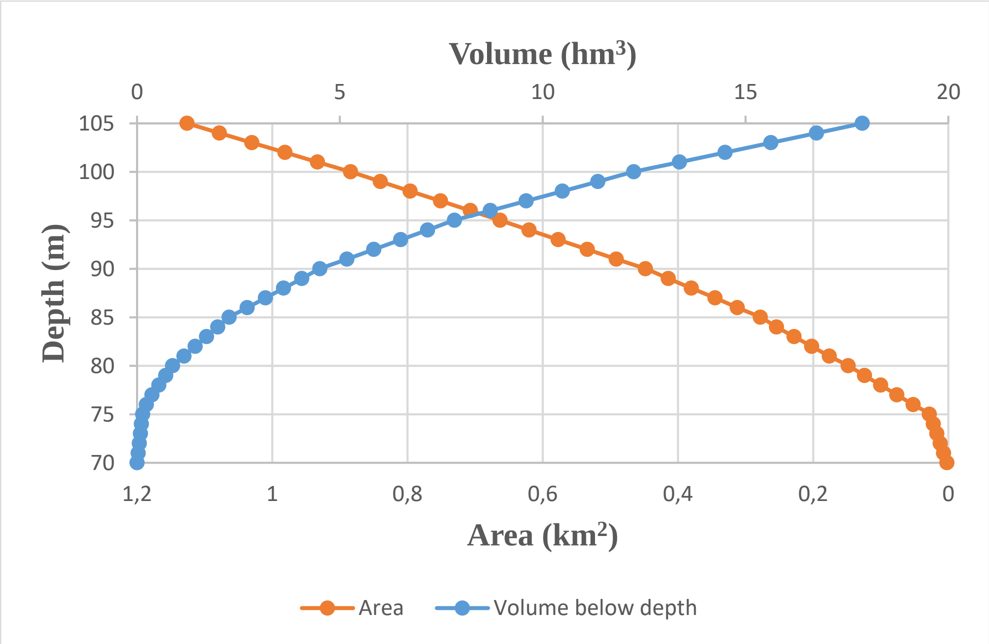

Figure 3.15. Volume-Depth-Area Graph of Kavakdere Dam

3.2.1.2. Groundwater Resources of Tahtalı-Seferihisar Sub-Basin

Tahtalı Seferihisar Sub-basin is the second sub-basin with the highest groundwater potential among the sub-basins of the Küçük Menderes Basin. The groundwater sub-basin area of the basin is 1248.92 km^2. There are many groundwater resources within the borders of the basin, and some of the wells drilled to benefit from groundwater resources by the public, that is, the wells drilled by the people with permission from the municipalities, and some of them are drilled by the Special Provincial

Administration or cooperatives. The number of wells drilled by State Hydraulics Works within the sub-basin borders is 26, the number of wells drilled by the local people is 866.

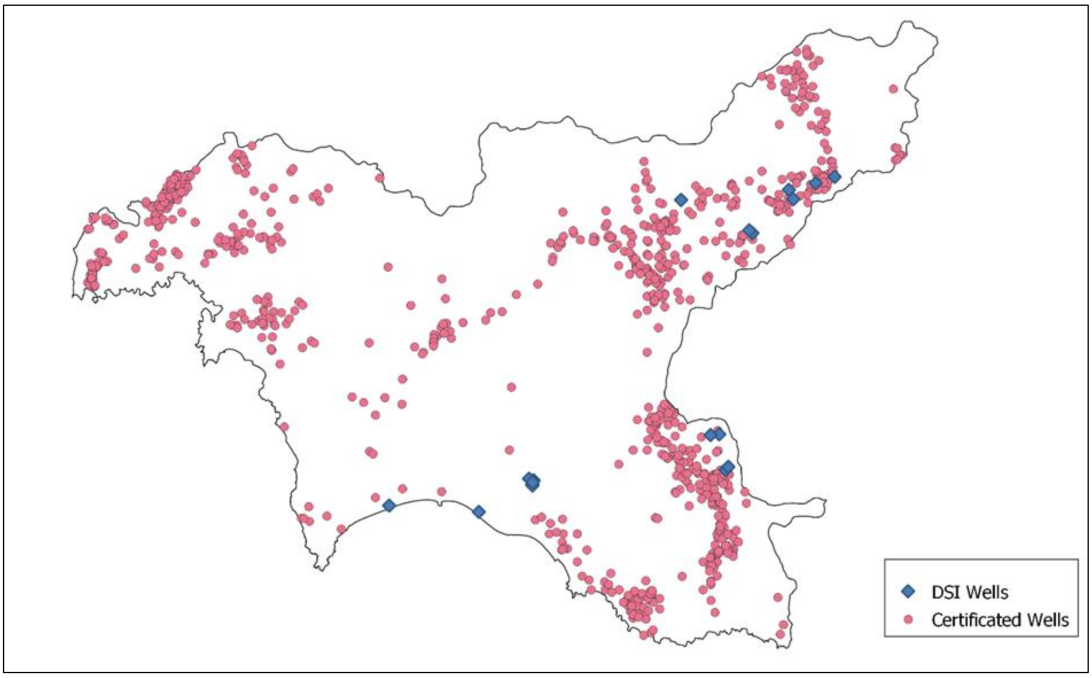

Figure 3.16. Locations of DSI Wells and Certified Wells in Tahtalı Seferihisar Sub-Basin

Most of the wells providing water supply in the basin are used for irrigation water purposes and according to the Küçük Menderes Basin Master Plan Final Report, it has been observed that the total amount of actual consumption from wells in the basin exceeds the annual safe groundwater reserve amount (Republic of Turkey Ministry of Forestry and Water Affairs, General Directorate of State Hydraulic Works, Department of Surveying, Planning and Allocations 2016). Therefore, attention should be paid to the use of groundwater in the basin, and precautions should be taken for excessive withdrawals in aquifers. A large amount of groundwater use in the basin is consumed by the agricultural areas located within the basin boundaries and using groundwater as irrigation water.

The agricultural areas from which these wells drilled by individuals provide irrigation water are specified in the Küçük Menderes Master Plan Final Report (the agricultural areas in the same region are collected and expressed as a single agricultural area). During the modeling study, wells drilled in the same district were transferred to the program as a single well, and agricultural areas in the same neighborhood were transferred to the program as a single agrarian area. The wells drilled by the local people and providing agricultural activities in the territory are given in Table 3.12.

Table 3.12. Table of Groundwater Irrigation in the Basin

<table>
<tr><th>Name of Groundwater Irrigation</th><th>Area (ha)</th></tr>
<tr><td>Kaynakça Public Irrigation</td><td>693</td></tr>
<tr><td>Oğlananası Public Irrigation</td><td rowspan="2">4311.82</td></tr>
<tr><td>Oğlananası Public Irrigation (Greenhouse)</td></tr>
<tr><td>Künerlik Public Irrigation</td><td rowspan="2">1862.12</td></tr>
<tr><td>Künerlik Public Irrigation (Greenhouse)</td></tr>
<tr><td>Eskibağ Public Irrigation</td><td rowspan="2">332.41</td></tr>
<tr><td>Eskibağ Public Irrigation (Greenhouse)</td></tr>
<tr><td>Çamönü Public Irrigation</td><td rowspan="2">1643.46</td></tr>
<tr><td>Çamönü Public Irrigation (Greenhouse)</td></tr>
<tr><td>Çileköy Public Irrigation</td><td rowspan="2">394.61</td></tr>
<tr><td>Çİleköy Public Irrigation (Greenhouse)</td></tr>
<tr><td>Özdere Public Irrigation</td><td>202.47</td></tr>
<tr><td>Yeniorhanlı Public Irrigation</td><td>215.91</td></tr>
<tr><td>Turgutlu Ulamış Public Irrigation</td><td rowspan="2">473.54</td></tr>
<tr><td>Turgutlu Ulamış Public Irrigation (Greenhouse)</td></tr>
<tr><td>Buruncuk Public Irrigation</td><td rowspan="2">520.24</td></tr>
<tr><td>Buruncuk Public Irrigation (Greenhouse)</td></tr>
<tr><td>Demirciler Public Irrigation</td><td>119.9</td></tr>
<tr><td>Kuşçular Public Irrigation</td><td rowspan="2">941.49</td></tr>
<tr><td>Kuşçular Public Irrigation (Greenhouse)</td></tr>
</table>

In the Küçük Menderes Basin Master Plan Final Report, the actual consumption of Public Irrigation for Tahtalı Seferihisar Sub-Basin is stated as 88.56 hm^3/year. When the irrigation water needs of the agricultural areas given in Table 3.12. Table of Groundwater Irrigation in the Basinin the same report were compared, it was determined that approximately half of Kuşçular Public Irrigation was located within the study region. For this reason, half of the total area of that irrigation is included in the area part of the table.

In the groundwater recharge calculations in the basin, the monthly average value for many years was found to be 10.7 hm^3/month, and the annual average recharge amount for many years was 121 hm^3/year. The groundwater potential in the basin is as in Table 3.13 according to different drought scenarios (Republic of Turkey, Ministry of Agriculture and Forestry, General Directorate of Water Management, Department of Basin Management 2019).

Table 3.13. Tahtalı-Seferihisar Sub-Basin Groundwater Potential Values

Climate Conditions	Range	Groundwater Potential Value to be Considered in Allocation (hm^3/year)
Normal	>121	121
Mild Arid	104 – 121	104
Medium Arid	73 – 104	73
Severe Drought	34 – 73	34
Very Severe Drought	<31	31

The annual recharge value of groundwater under normal condition is approximately four times the amount of recharge in a very severe drought period.

In the Küçük Menderes Basin Master Plan Final Report, the water height differences in the sub-basin-based wells were measured as the beginning of the season (September/2015) and the end of the season (April/2016). The highest drop difference occurred in Tahtalı Seferihisar Sub-Basin was in well number 35 located in Bademler Aquifer, and the difference in drop found was 24.84 m (Republic of Turkey Ministry of Forestry and Water Affairs, General Directorate of State Hydraulic Works, Department of Surveying, Planning and Allocations 2016) (Table 3.14).

Table 3.14. Tahtalı-Seferihisar Sub-Basin Groundwater Level Measurement Wells Table

	Name of Aquifer	**Well No**	**September 2015**	**April 2016**	**Elevation Difference**
Tahtalı-Seferihisar Sub-Basin	**Yeniköy**	90	26.7	24.8	1.9
		91	36.84	23.7	13.14
		92	29.28	18.92	10.36
		94	56.3	31.8	24.5
	Menderes	31	18.61	11.68	6.93
		32	18.46	13.47	4.99
		33	13.65	5	8.65
		34	7.3	4.96	2.34
		38	12.16	1.5	10.66
		93	20.2	12.68	7.52
	Ürkmez	95	13.5	10.47	3.03
	Bademler	35	36.7	11.86	24.84
		41	10.06	7.71	2.35
		42	4.72	3.08	1.64
		43	48	42.14	5.86
		44	5	1.75	3.25
		57	18.15	16.06	2.09
		58	6.04	1.13	4.91
		59	18.51	4	14.51
		60	71.27	67.25	4.02

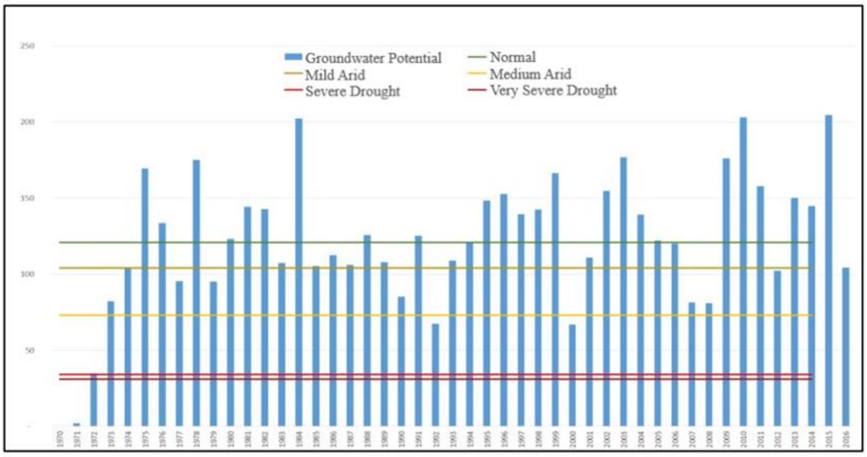

Figure 3.17. Tahtalı-Seferihisar Sub-Basin Groundwater Drought Scenarios (Source: Republic of Turkey, Ministry of Agriculture and Forestry, General Directorate of Water Management, 2019)

3.3. Population

İzmir province has an area of 11,891 km^{2}, and the value of "the number of people per 1 km", which is expressed as population density, is 363. Konak is the district with the highest population density of 14,857 people, and Karaburun has the lowest with 25 people. İzmir ranks 3rd in population density after İstanbul and Kocaeli provinces.

In 2018, a total of 4.320.519 people, 2.152.585 men, and 2,167,934 women constituted the population of İzmir. This value reached 4,394,694 people in 2020, and 49.8% of the population is male, while 50.2% is female. When the population of İzmir in 2020 is compared with the total population of Turkey, it covers 5.26% of the population of Turkey. While the annual population growth rate of İzmir province between 2018 and 2019 was ‰10.8, this value was 6.3‰ between 2019-2020.

When the Tahtalı-Seferihisar Basin is examined, there are two districts within the borders of the basin. These districts are Menderes and Seferihisar districts. In 2020, 101,338 and 48,320 people reside in these districts, respectively.

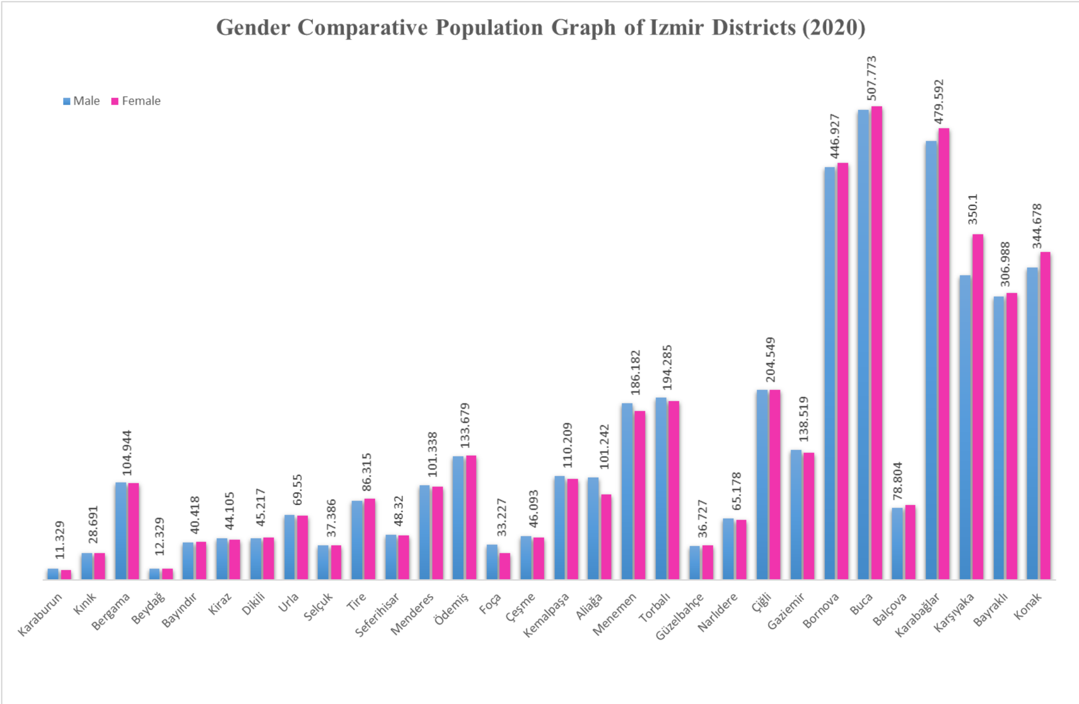

Figure 3.18. İzmir Districts Gender Comparison Population Graph for 2020 (Districts are listed according to their population density)

3.4. Agricultural Areas and Crop Water Consumption Values

The agricultural lands in Tahtalı-Seferihisar Sub-Basin can be grouped under four headings: State Hydraulic Works Irrigation, Provincial Special Administration Irrigation, Public Irrigation, and Cooperative Irrigation. The agricultural products grown in these irrigation areas are mainly cereals, wheat, silage corn, grain corn, citrus fruits, artichokes, olives, fruit varieties, vegetables, garden products, and tomato and cucumber, among the greenhouse products.

In the Küçük Menderes Basin Master Plan Final Report, the products are grown in that agricultural area, the areal distribution of these products, and the annual irrigation water need was calculated for each agrarian area within the borders of the basin.

For agricultural lands in Tahtalı-Seferihisar Sub-Basin, detailed information in Figure 3.19 for Public Irrigation, Figure 3.20 for Special Provincial Administration Irrigation, Figure 3.21 for State Hydraulic Works, and Figure 3.22 for Cooperative Irrigation given (Republic of Turkey Ministry of Forestry and Water Affairs, General

Directorate of State Hydraulic Works, Department of Surveying, Planning and Allocations 2016).

Since transmission losses are taken into account while calculating the irrigation water need in the master plan final report, no extra transmission losses are entered in the WEAP program.

When calculating the irrigation water requirement in agricultural areas, each value is specific to that agricultural area due to reasons such as the temperature and precipitation values of the Meteorology Station used for each agricultural area are different from each other, the transmission losses in each agricultural area differ and the growth times of the products grown differ. For example, among public irrigations: the irrigation water requirement calculated for olive products grown in Buruncuk Irrigation is 1158.46 m^3/ha, while this value is 786.91 m^3/ha for olive products grown in Künerlik Irrigation.

While transferring the water need for agricultural irrigation to the WEAP program, each product is defined one by one on the program, and the annual water requirement for each product grown is transferred to the program. The monthly variation values of water consumption were obtained by looking at the monthly total water requirement of the products grown in each agricultural area, and the percentage ratio was obtained and transferred to the Water Evaluation and Planning Program.

Name of Public Irrigations+B2:G7	Water Supply	Total Area (ha)	Total Water Consumption (hm^3)	Primary Product Pattern	Secondary Product Pattern
Buruncuk Irrigation	Groundwater Source	520.24	3.93	Olive (14%), Greenhouse (10%), Ornamental Plant (6%), Citrus (60%), Artichoke (10%)	Greenhouse (%10)
Özdere Irrigation	Groundwater Source	202.47	1.73	Citrus (%100)	X
Künerlik Irrigation	Groundwater Source	1862.12	15.70	Wheat (32%), S. Corn (1%), Olive (7%), Tomato (5%), Vegetables (1%), Grain Corn (7%), Fruit (2%), Cotton (4%) , Greenhouse (39%), Vineyard (2%)	S. Corn (15%), Vegetables (24%), Greenhouse (39%)
Kaynakça Irrigation	Groundwater Source	693.00	5.26	Grains (10%), Olive (15%), Tomatoes (15%), Vegetables (16%), Fruit (20%), Cherry (24%)	Vegetables (%10)
Çileköy Irrigation	Groundwater Source	394.61	2.75	Grains (10%), S. Corn (20%), Olive (10%), Tomato (20%), Vegetables (20%), Greenhouse (20%)	S. Corn (13%), Vegetables (30%), Greenhouse (20%)
Oğlananası Irrigation	Groundwater Source	4311.82	30.10	Grain (42%), Garden (5%), S. Corn (3%), Olive (7%), Tomato (16%), Vegetables (5%), Grain Corn (16%), Cotton (2%), Greenhouse (3%), Vineyard (1%)	S. Corn (8%), Vegetables (6%), Greenhouse (3%)
Turgutlu Ulamiş Irrigation	Groundwater Source	473.54	3.24	Wheat (5%), S. Corn (15%), Vegetables (20%), Olive (26%), Fruit (7%), Greenhouse (3%), Citrus (24%)	Greenhouse (%3)
Çamönü Irrigation	Groundwater Source	8936.58	14.69	Garden (9%), S. Corn (15%), Vegetables (6%), Red Pepper (9%), Grain Corn (33%), Greenhouse (28%)	S. Corn (10%), Vegetables (25%), Cabbage (1%), Greenhouse (28%)
Yeniorhanli Irrigation	Groundwater Source	215.91	1.49	Grains (6%), Olive (30%), Pomegranate (10%), Citrus (41%), Vegetables (13%)	X
Eskibağ Irrigation	Groundwater Source	332.41	1.45	Tomato (25%), Vegetable (11%), Grain Corn (10%), Greenhouse (40%), Vineyard (14%)	Greenhouse (%40)
Demirciler Irrigation	Groundwater Source	119.90	0.68	Grain (11%), Garden (17%), S. Corn (11%), Tomato (21%), Vegetables (22%), Chestnut (10%), Fruit (8%)	X
Kuşçular Irrigation	Groundwater Source	941.49	7.53	Olive (15%), Fig (6%), Peach (3%), Pomegranate (5%), Greenhouse (3%), Ornamental Plant (35%), Alfalfa (6%), Garden (5%), Red Pepper (3%), Artichoke (10%), Vegetables (9%)	S. Corn (3%), Vegetables (5%), Cabbage (2%), Legumes (3%), Greenhouse (3%)
Ahmetbeyli Irrigation	Surface Water Source	89.70	0.78	Vegetable (%8 D), Peach (%7 D), Citrus (%85 S)	X

Figure 3.19. Public Irrigations

Name of Special Provincial Administration's Irrigations	Water Supply	Total Area (ha)	Total Water Consumption (hm^3)	Primary Product Pattern	Secondary Product Pattern
Çatalca Şandidere	Surface Water Source	128.14	0.80	Grains (10%), S. Corn (6%), Olive (8%), Vegetables (51%), Vineyard (16%), Citrus (8%), Greenhouse (1%)	Greenhouse (%1)
Yeniköy Balaban	Surface Water Source	280.00	0.66	Grain (8%), Olive (8%), Vegetable (11%), Vineyard (72%), Greenhouse (1%)	Greenhouse (%1)
Payamlı	Surface Water Source	84.20	0.63	Citrus (100%)	X
Ulamış Düzce Kavakçayı	Surface Water Source	92.76	0.53	S. Corn (9%), Vegetables (43%), Olive (14%), Peach (7%), Greenhouse (3%), Citrus (24%)	X
Ulamış Ağalardere	Surface Water Source	187.48	1.24	Grain (6%), S. Corn (7%), Vegetables (22%), Olive (13%), Fruit (10%), Greenhouse (4%), Citrus (38%), Greenhouse (4%)	X
Bademler 9 Eylül	Surface Water Source	133.26	0.98	Tomato (20%), Vegetable (10%), Peach (35%), Greenhouse (5%), Ornamental Plant (30%)	Vegetable (22%), Greenhouse (5%)

Figure 3.20. Special Provincial Administration Irrigation

Name of State Hydraulic Works' Irrigations	Water Supply	Total Area (ha)	Total Water Consumption (hm^3)	Primary Product Pattern	Secondary Product Pattern
Seferihisar Dam Irrigation	Surface Water Source	1277.00	10.21	Corn (19%), Fruit (53%), Vegetables (28%)	X
Kavakdere Dam Irrigation	Surface Water Source	489.00	5.17	Citrus (40%), Fruit (2%), Artichoke (1%), Vineyard (20%), Vegetables (2%), Olive (7%), Grains (28%)	X
Ürkmez Dam Irrigation	Surface Water Source	370.00	4.17	Citrus (97%), Vegetables (3%)	X
Ataköy Irrigation	Surface Water Source	228.00	1.06	Grains (8%), Garden (4%), S. Corn (9%), Olive (4%), Vegetables (10%), Grain (10%), Greenhouse (8%), Grain (29%), Fallowing (18%)	X

Figure 3.21. State Hydraulic Works Irrigation

Name of Cooperative's Irrigations	Water Supply	Total Area (ha)	Total Water Consumption (hm^3)	Primary Product Pattern	Secondary Product Pattern
Gümüldür-Tahtalı	Surface Water Source	882.50	5.48	Citrus (100%)	X
Çamönü	Groundwater Source	150.00	0.89	Cereals (%26), Garden (%8), Vegetable (%8), Red Pepper (%13), Corn (%10), Coton (%15)	S.Corn (%15), Vegetable (%25), Pepper (%5)

Figure 3.22. Cooperative Irrigation

CHAPTER 4

METHODOLOGY

4.1. WEAP

WEAP was created in 1988 to be a flexible, integrated, and transparent planning tool for evaluating the sustainability of current water demand and supply patterns and exploring alternative long-range scenarios. The first major application of WEAP was in the Aral Sea region in 1989 with the sponsorship of the newly formed Stockholm Environment Institute (SEI) (WEAP).

Many regions today are struggling to cope with water management challenges because of the limited water resources. Besides the use of water resources, issues such as the importance of the quality of these resources and climate change cause concern about water management.

WEAP places the evaluation of specific water problems in a comprehensive framework. The integration is over several dimensions: between demand and supply, between water quantity and quality, and between economic development objectives and environmental constraints. (Sieber 2015)

The WEAP program, which basically includes the relationship of supply and demand, ie. water balance, can be applied to municipal and agricultural areas, a single basin, or multiple basins that contain transboundary rivers. In addition, WEAP can conduct analyzes on sectoral demand analysis, water conservation, water rights and demand priorities, groundwater and stream modeling, reservoir operation, hydropower generation, pollutant monitoring, ecosystem requirements, vulnerability assessments, and cost-benefit of projects.

Water supply and demand data can be transferred to the program using various time intervals. For example, these data can be annual, monthly, weekly, or even daily data. The program provides its users with a simple but powerful tool thanks to its GIS-based graphical interface so that the user can easily reveal the scheme of the model he/she will create by using the "drag-and-drop" feature of the program.

Apart from the analysis it performs, WEAP provides great convenience to users with its highly flexible and comprehensive reporting system. The user can generate reports based on a table, chart, or map-based format, and the user can format these reports using attributes such as metric or English units, years, absolute levels, percent shares, or growth rates.

WEAP offers its users the ability to develop models with built-in functions, user-defined variables and equations, embedded linear solution programs of water allocation equations, and flexible and expandable data structures.

In addition to offering a unique approach to integrated water resources management, WEAP is also linked to programs and software such as MODFLOW, MODPATH, QUAL2K, and Excel.

The program can prepare alternative scenarios to the created model and answer many "what if" questions, such as:

- What if population growth and economic development patterns change?
- What if reservoir operating rules are altered?
- What if groundwater is more fully exploited?
- What if a water recycling program is implemented?
- What if a more efficient irrigation technique is implemented?
- What if the pattern of agricultural crops changes?
- What if climate change alters demand and supplies? (WEAP)

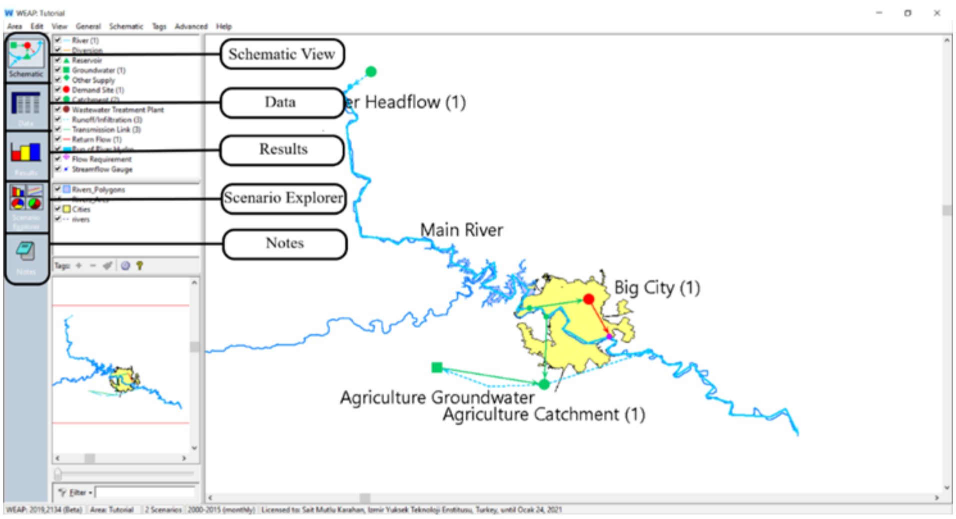

Figure 4.1. WEAP Program Interface View

4.1.1. WEAP Main Menu Functions

The main menu of the WEAP program forms the basis of the program, and there are seven main menu functions in this area. These functions are **area**, **edit**, **schematic**, **general**, **advanced**, **help**, respectively.

Area: The area menu provides the operations of creating, saving, and managing the area to be studied. In addition to these, there are options to manage scenarios, set print options, and change the program's language. With Manage Areas, users can see all the areas available in the WEAP program and the planning processes, last save times, file sizes, and compression options in these areas. In addition, with the Manage Areas option, the following operations can be done: opening a new area, renaming, opening an existing area, backing up, and sending mail. The repair command is used to repair and check the WEAP's area's database files under study. There is also an option to create a password for the WEAP fields. With the Manage Scenarios option, new scenarios can be created, and created designs can be copied, renamed, and deleted. During these operations, the user is also allowed to take notes by making explanations about the scenarios.

Edit: The edit menu includes standard commands such as cut, copy, paste, undo. The Undo command can be used only once in text editing options. The program does not support the multiple undo option. In addition, thanks to Edit, the entered data can be transferred to Excel, as well as the data entered in Excel can be transferred to the program, and automatic calculations can be performed.

View: The View menu allows users to switch between the five basic interface views of the program, as well as to open and close the view of the interfaces on the screen with the View Bar option. Thus, a broader view of the working area is obtained.

General: With the General option, the water quality parameters of the model can be changed, as well as the time intervals of the analysis to be made. In addition, the units used can be changed here.

Schematic: The schematic main menu function can be used in various formatting operations, the working area can be limited, the labels of the objects placed on the map can be changed, the size of these objects on the map can be adjusted, the objects on the map can be hidden, and the appearance of the priority supply and demand points can be changed. In addition, adding and removing GIS-defined vector and raster files can be done.

Advanced: With Advanced, the WEAP program can be linked to programs such as MODPATH, MODFLOW, and LEAP, and the model can be associated.

Help: The Help menu provides access to the content, index, and search pages of the WEAP program. We can also use these features by opening a window on the work screen with the F1 key. Technical assistance can be requested from the Stockholm Environment Institute (SEI) through this menu. To use this feature, MAPI (Messaging Application Programming Interface) mail programs such as Microsoft Outlook or Netscape Navigator must be installed on the user's computer. In addition, with this menu, it can be checked whether there is an updated version of the program. With the About WEAP option, information to connect with SEI can be obtained via phone, fax, or mail.

Tree: The Tree menu appears when the user opens Data View. Thanks to the Tree menu, the user can view the branches of the model. The Tree menu can add new branches, delete them, add them under another header and rename them.

Favorites: It is the menu option that appears when the user activates the Results view bar. It allows you to save the desired favorite graphics, charts, or tables and make changes on them. With the saved chart as a favorite feature, tables can be kept and highlighted with later modifications.

Explorer: The Explorer menu appears when the user uses the Scenario Explorer view bar. This menu creates tables of input or results of prepared scenarios and allows the user to compare them in a single window.

4.1.2. Interface View Bars

There are five different view bars in the interface of the WEAP program. These view bars are located on the left side of the screen and are listed from top to bottom as follows: **Schematic**, **Data**, **Results**, **Scenario Explorer**, and **Notes**. To see these view bars on the screen, the View Bar option under the View main menu function must be selected.

4.1.2.1. Schematic View

Schematic View is the main working area where the drawings in the WEAP program are made, the objects are placed, and the connections between them are established. Drawings can be more accurate and effective by adding GIS vectors or raster files. Placing supply and demand points on the map can be easily accomplished with "drag-and-drop" logic. When using Schematic View, modeling tools will appear next to the interface view bars. These modeling tools are listed from top to bottom as follows: river, diversion, reservoir, groundwater, other supply, demand site, catchment, runoff/infiltration, transmission link, wastewater treatment plant, return flow, run of river hydro, flow requirements, and streamflow gauge. In order to add the modeling tool to the prepared model, it can be added to the desired point on the map by clicking and dragging any of the modeling tools. By right-clicking on the modeling tools added to the model, operations such as data entry, data editing, viewing results, deleting, and moving the modeling tool can be performed.

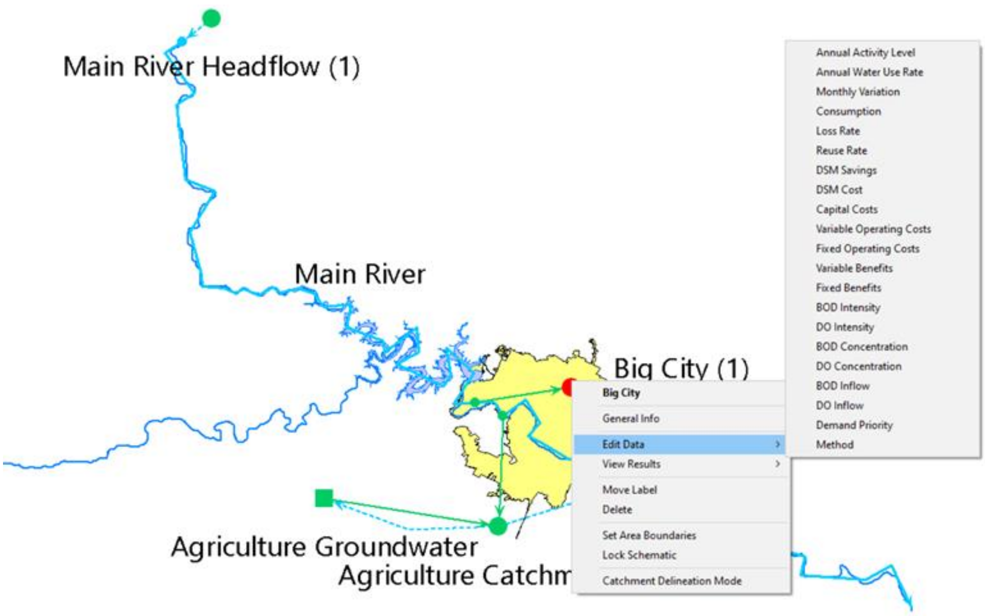

Figure 4.2. Schematic View

4.1.2.2. Data View

The data view is the section where the data of the tools used in the models are entered and databases and assumptions are created. There is an overview of the data view section in Figure 3. Data view consists of 4 sections: There is an order of modeling tools according to headings in the upper left part. These headings are key assumptions, demand sites and catchments, hydrology, supply and resources, other assumptions. A mini schematic view is seen at the bottom left of the screen. In the upper left part, the modeling tool selected for entering data is highlighted in the mini schematic view. In addition, operations such as zooming in and out can be performed in a mini schematic view. In the upper-right part, there are tables that allow the data of the selected modeling tool to be entered. In Figure 4.3, the data table entered for the agriculture and catchments section can be seen. In the Current Accounts section at the top, changes can be made by switching over scenarios. On the lower right part of the screen, there is a graphical display of the entered data. Changes can also be made on the graphical and tabular views. These changes are made in the area just to the right of the graphics.

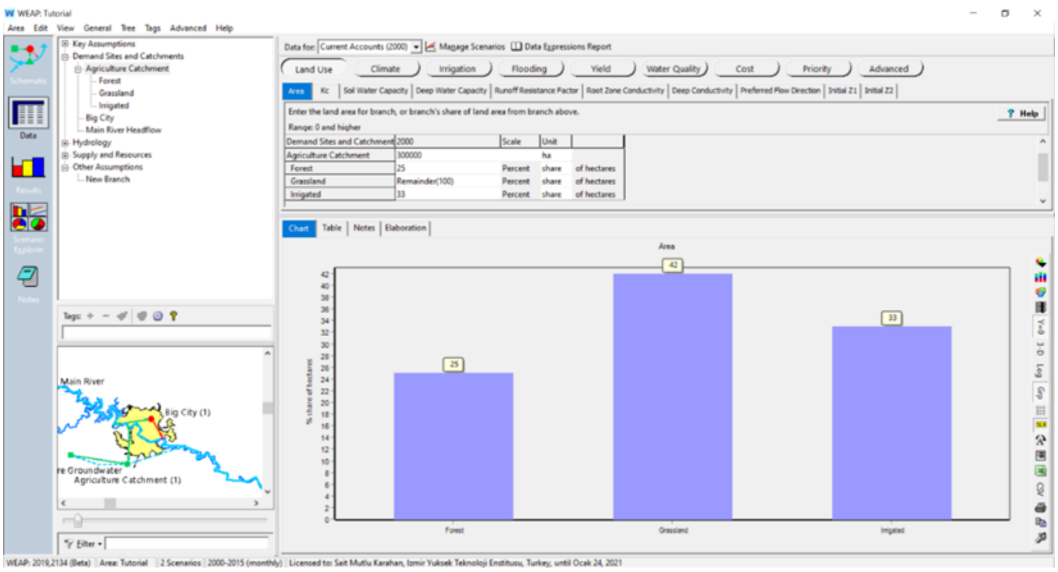

Figure 4.3. Data View

4.1.2.3. Result View

The results view calculates the data entered in the model tools and allows the data to be analyzed in multiple ways. It enables the comparison of properties such as supply and demand, stream flows, reservoir, groundwater capacities, and transmission and returns flow losses entered into the model. The results view can create many graphs or tables, and the created table and graphs can be customized. The result view also enables comparisons of underprepared scenarios. For Result View to work, data must be entered into the modeling tools used on the model. Here, the results can be obtained and compared monthly, yearly, or in total. The created tables and charts can be customized using features such as 3D, 2D, or pie charts and then added to favorites to use later. The charts and tables created in this section can be exported to Excel.

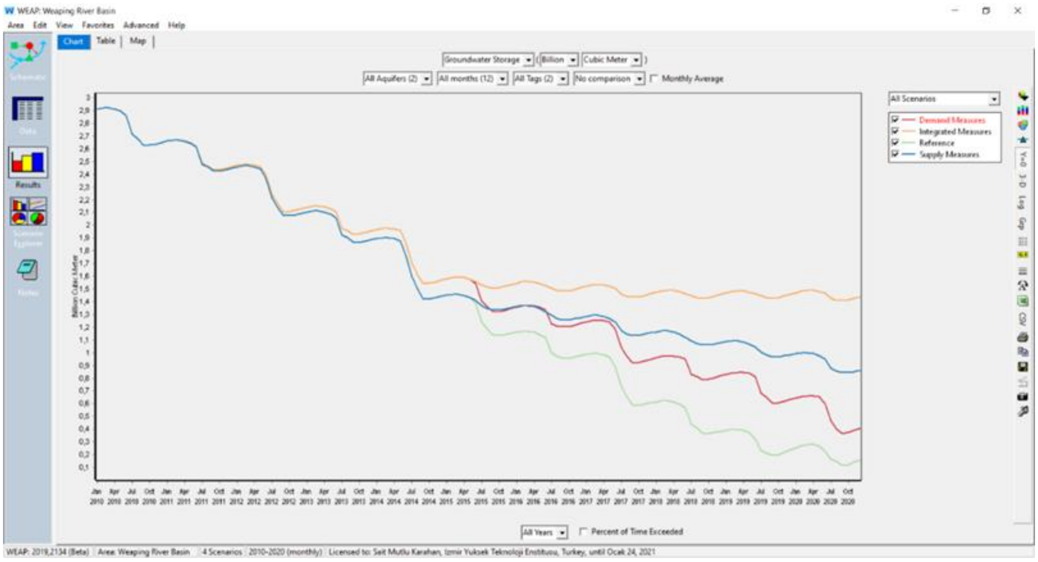

Figure 4.4. Results View

4.1.2.4. Scenario Explorer

Scenario Explorer is used to show and display the user's favorite graphics and tables created by Results View simultaneously, thanks to multiple screen panes. It enables the comparison of features such as flow, demand, and reservoir level defined on the model over scenarios. Scenario Explorer not only shows the results together but also shows the effects of the hypothetical changes to be made over the created scenarios on the results.

Some data entered for modeling can be changed here without going to Data View. The effect of these changes on the results can be realized graphically with the Auto Calculate feature without going to the Results View.

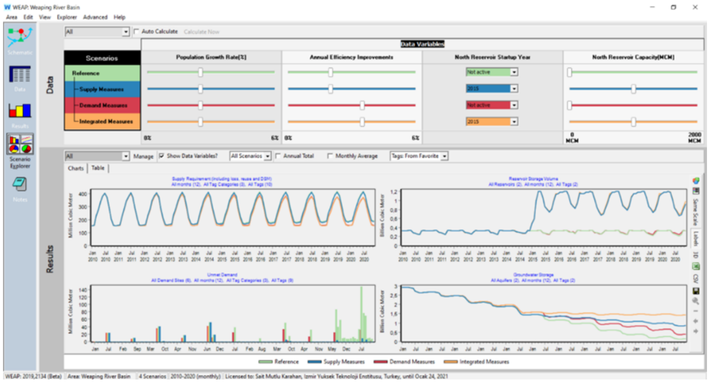

Figure 4.5. Scenario Explorer View

4.1.2.5. Notes

Notes main menu is a convenient tool for the user to take notes and specify references for modeling tools. The Notes main screen consists of three parts: the first part is the main screen where the notes can be taken, the second part is the data branches in the upper left part, and the mini schematic view just below the data branches. To take notes, you can use the screen that opens directly, as well as selecting one of the data branches and taking notes specifically for that data branch. Operations such as the classic Word file can be performed. These are: changing the font, adjusting the thickness, adjusting the font size. Notes taken on this screen can also be exported to a Word file.

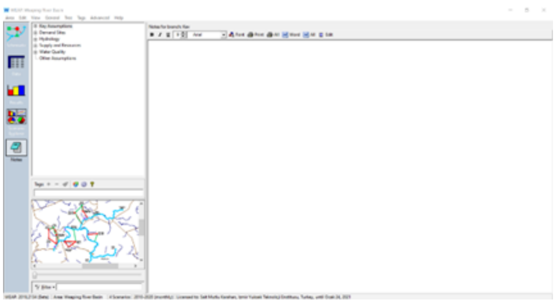

Figure 4.6. Notes View

4.1.3. General Model Parameters

General parameters to be used while creating a model in WEAP can be accessed through the "General" menu in the main menu. These general parameters are: “years and time steps”, “units”, “water quality constituents” and “basic parameters”.

Years and time steps: When the user selects this option, the user can see Time Horizon in the upper left part of the window that opens. From here, the user can define the years between the scenarios. From this option, scenarios from the past to the present can be prepared, as well as scenarios for the future from today. The monthly time interval can be changed in the Time Step Boundary section in the left middle. The number of days can be selected as in the calendar, and there are also options to think as if there are an equal number of days per month and also user can define the length of the months. In the Water Year Start section, the user can select the month and day. On the right side of the screen that opens, there are values such as the starting and ending values of the months and the length of each month.

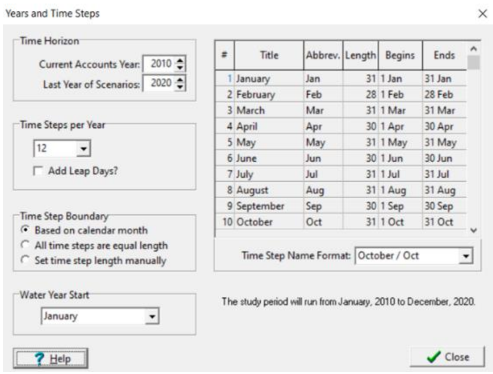

Figure 4.7. Years and Time Steps Window

Units: In the Units section, the units of the data entered in the tools used in modeling are defined. The units of demand, rivers, reservoirs, groundwater, other local supplies, land use, wastewater treatment, and monetary headers can be changed from this window. In the Unit Definitions section at the bottom of the screen, translations can be made between units and add a new units by the user.

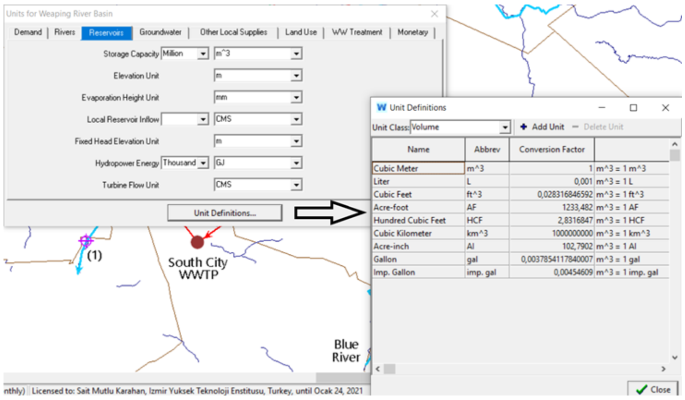

Figure 4.8. Units Window

Water Quality Constituents: The WEAP program can model water quality where pollution at demand points and return waste from wastewater treatment plants. The program can follow the modeling of waste and pollutants to surface and groundwater and water quality in rivers. For water quality modeling, the user can define ten different components in the program. In the program, details such as temperature, TSS (total suspended solids), nitrogen, phosphorus, and BOD (biochemical oxygen demand) are included by default. The user can add new components or delete existing components from this window.

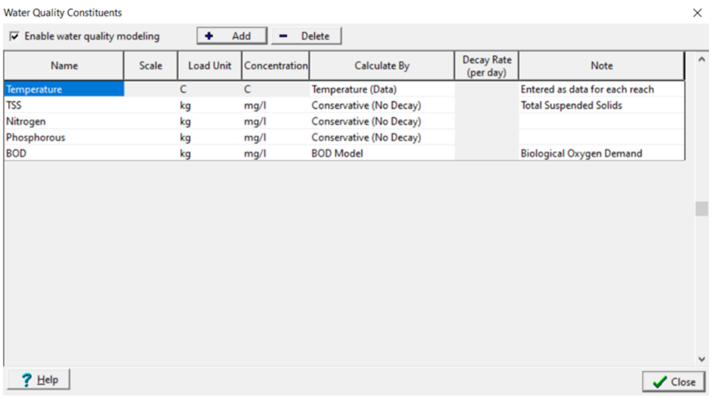

Figure 4.9. Water Quality Constituents Window

Basic Parameters: Basic Parameters allow editing whether demand points and climate data have the same or several variations for all points. In addition, the lowest allowed demand priority value can be changed here. This value is vital in the following way: the distribution of water delivered to demand points is distributed according to demand priority values. The demand point with the highest lowest demand priority is the one to get water last. This means that the amount remaining in the system after the water is distributed is transferred to the demand point with the highest lowest demand priority.

In addition, the Results Precision option is available from here. There are two options: the first one is "single-precision" which gives the value of 7-8 significant digits. The second option is "double precision", which gives the result 15-16 significant digits.

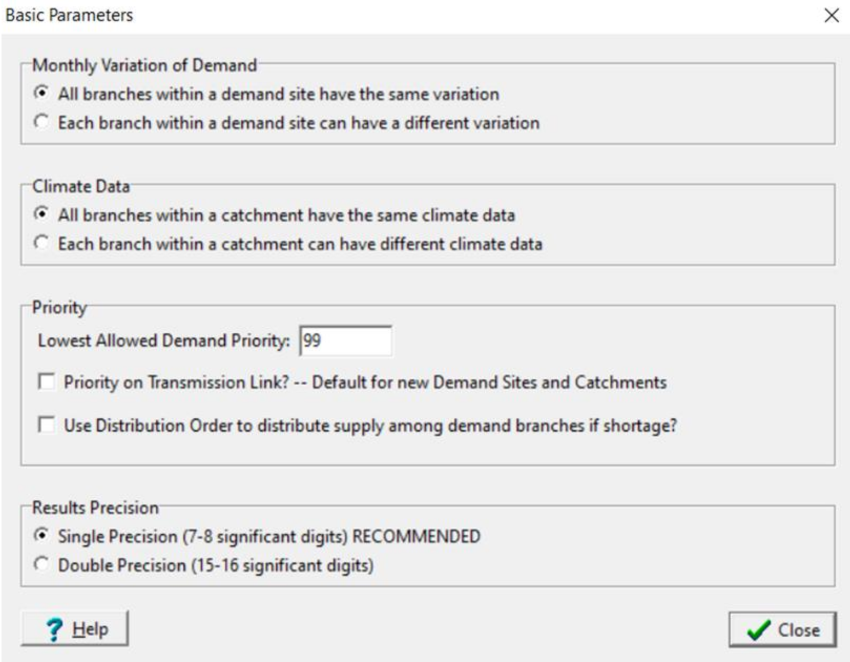

Figure 4.10. Basic Parameters Window

4.1.4. Modelling Tools

River: River tool, which is used to draw surface waters in the model, is implemented with a drag and drop procedure. Drawing is performed starting from the starting point of the surface water towards the region where it leaves the basin. To connection between the two rivers can be established by double-clicking on the previously drawn river. Modeling tools such as a reservoir can also be added on the river.

Diversion: It is used to transfer the water to another river or an artificial channel.

Reservoir: Reservoirs represent water storage areas on the rivers. It can be used to simulate, direct water allocation to demand points and agricultural areas of those located downstream of the reservoir or hydroelectric power generation.

Groundwater: It allows the groundwaters to be displayed on the model. It can be placed in the desired area with drag and drop logic. It needs data such as storage capacity and initial storage.

Other Supply: Other supplies include a predetermined amount of water defined monthly. It does not have the feature of storing unused water for months.

Demand Sites: The demand site indicates the area where water allocation is required, distributes the incoming water as a percentage. Detailed definition of demand points varies according to the level of detail of the analysis requested.

Catchment: A catchment is a modeling tool that determines variables such as rain, snow, evaporation, plant water consumption, irrigation on agricultural lands. When the catchment is placed in the model, a screen appears in the pop-up window asking options and whether there will be irrigation in the basin or not.

Wastewater Treatment Plant: Wastewater Treatment Plant ensures the purification of the dirty water taken from the demand points and ensures that the treated water is transferred to the desired area (demand point, discharge area, etc.).

Runoff/Infiltration: This tool represents transmission channels that carry water from catchments to rivers, reservoirs, and groundwater. Catchment runoff/infiltration represents the water obtained from rainfall events that do not disappear through evaporation and are intended not to meet any demand.

Transmission Link: A transmission link is a tool that enables water to be transmitted to the desired area. It takes the water from the supply and reservoir and sends it to the demand points. Losses in transmission links play an essential role in creating alternative simulations.

Return Flow: Return flow allows the water not consumed at the demand points to be transported to wastewater treatment plants or directly to the discharged area. The returned water amount is entered into the program by giving the percentage.

Run of River Hydro: This tool is placed on rivers and generates hydroelectricity depending on the changing stream flows, but a fixed water head in the river.

Flow Requirement: Flow requirement nodes are used to control the minimum flow requirements on a river or features such as flow, water quality, etc., on a diversion.

Streamflow Gauge: Streamflow gauges are placed on rivers and used to compare the actual streamflow values entered on the model with the values revealed in the simulation results.

4.2. Population Projections

The water needs of municipalities consist of many sub-categories. These include: domestic, public, and industrial, etc. can be given as examples, and domestic usage can be said to be the most important of these categories.

Population density and living standards play an essential role in domestic use. For this reason, it is more logical to express the water need per person because the amount of water usage per person differs from region to region. The amount of water use per capita in developed countries is higher than in other countries (Yanmaz, Applied Water Resources Engineering 2018).

Models that calculate annual water use help calculate the water needs of regions according to population. By making a population projection, the answer to how much water will be needed in the future can be sought. The topography, socio-economic, and climatic conditions of the place where the water needs are calculated are also critical because these conditions cause the region to receive immigration and thus affect the population growth. Many methods are used to perform population projections. The following methods were used in the study.

1) The Arithmetic Extrapolation Method
2) The Geometric Extrapolation Method
3) The Turkish Bank of Provinces Method
4) The Average Growth Rate Method

4.2.1. The Arithmetic Extrapolation Method

In the arithmetic projection method, the population in the coming years is calculated based on the assumption that the amount of change in the population will be constant until the year to be projected.

$$P_n = P_{last} + K_a(t_n - t_{last}) \qquad (4.1)$$

where;

K_a is the rate of population growth rate

$$K_a = \frac{P_{last} - P_{previous}}{t_{last} - t_{previous}} \qquad (4.2)$$

P_{last} is the population of the present or population of the known last year

$P_{previous}$ size of the population in the previous year

t_{last} is the year of the current population

$t_{previous}$ is the year of the previous year's population

P_n is the population projection in the future

t_n is the year of the projection

4.2.2. The Geometric Extrapolation Method

In this method, the population change is assumed to be proportional to the population. The Turkish State Institute of Statistics uses this method.

$$K_g = \frac{\ln(P_{last}) - \ln(P_{previous})}{t_{last} - t_{previous}} \qquad (4.3)$$

$$\ln(P_n) = \ln(P_{last}) + K_g(t_n - t_{last}) \qquad (4.4)$$

where;

K_g is the coefficient of the geometric extrapolation method

P_{last} is the population of the present or population of the known last year

$P_{previous}$ size of the population in the previous year

t_{last} is the year of the current population

$t_{previous}$ is the year of the previous year's population

P_n is the population projection in the future

t_n is the year of the projection

4.2.3. The Turkish Bank of Provinces Method

The Turkish Bank of Provinces Method is the limited version of the geometric extrapolation method. This method is used to prepare drinking water and sewerage projects for settlements according to the current provincial bank drinking water regulations.

$$k = \left(\sqrt[t_{last}-t_{previous}]{\frac{P_{last}}{P_{previous}}} \right) \times 100 \tag{4.5}$$

$$P_n = P_{last} \left(1 + \frac{k}{100}\right)^{35+n} \tag{4.6}$$

where;

k is the growth rate if $k \geq 3$, k is taken as $k=3$

if $k \leq 1$, k is taken as $k=1$

if $1<k<3$, k is taken as it is

P_{last} is the population of the present or population of the known last year

$P_{previous}$ size of the population in the previous year

t_{last} is the year of the current population

$t_{previous}$ is the year of the previous year's population

P_n is the population projection in the future

n is the years between the projected year and the year between the last census

4.2.4. The Average Growth Rate Method

In this method, the average growth rate coefficient between the years with known population values is found. The average is used for the year in which the population projection is desired.

$$k = \frac{P_{last} - P_{previous}}{P_{previous}} \tag{4.7}$$

$$k_{avg} = \frac{k_1 + k_2 + \cdots + k_n}{n} \tag{4.8}$$

$$P_n = P_{last} \times k_{avg} \tag{4.9}$$

where;

k is the growth rate coefficient

k_{avg} is the average growth rate

n is the number of years between the year of the last average growth rate calculated and the year of the first average growth rate calculated

P_{last} is the population of the present or population of the known last year

P_n is the population projection in the future

Table 4.1. Populations and Average Population Growth Rate for 11 Central Districts

Years	Population	Growth Rate Coefficient
2008	2683842	–
2009	2740306	0.021
2010	2786863	0.017
2011	2796931	0.0036
2012	2816632	0.007
2013	2842604	0.0092
2014	2861542	0.0067
2015	2891492	0.0105
2016	2916298	0.0086
2017	2938546	0.0076
2018	2947000	0.0029
2019	2972900	0.0088
2020	2959835	-0.0044
		0.0082

Table 4.2. Populations and Average Population Growth Rate for Seferihisar

Years	Population	Growth Rate Coefficient
2008	26945	–
2009	28603	0.0615
2010	32655	0.1417
2011	30890	-0.054
2012	31467	0.0187
2013	33588	0.0674
2014	35960	0.0706
2015	36335	0.0104
2016	37697	0.0375
2017	40785	0.0819
2018	43546	0.0677
2019	44526	0.0225
2020	48320	0.0852
		0.0509

When the population growth rate coefficient values of the central 11 districts of İzmir and the district of Seferihisar are taken into consideration, it is seen that the growth rate coefficient in the district of Seferihisar is approximately six times higher.

4.2.5. Population Projections of the Regions Used in the Study Area

The city of İzmir is Turkey's third-largest city in terms of population, with a population of 4.320.519 (2018). A significant increase in the population of the city is seen between 1970-1985. Until 1945, İzmir maintained its distinction as Turkey's second-largest city (İzmir Governorship Provincial Directorate of Environment and Urbanization 2019).

In the study, the projected population values calculated for the central 11 districts of İzmir (Balçova, Bayraklı, Bornova, Buca, Çiğli, Gaziemir, Güzelbahçe, Karabağlar, Karşıyaka, Konak, Narlıdere) where Tahtalı Dam meets the water needs are given in Figure 1. It is known that Tahtalı Dam meets approximately 40% of the water needs of the central districts. Therefore, the population projection of these 11 districts plays a vital role in calculating the future state water need.

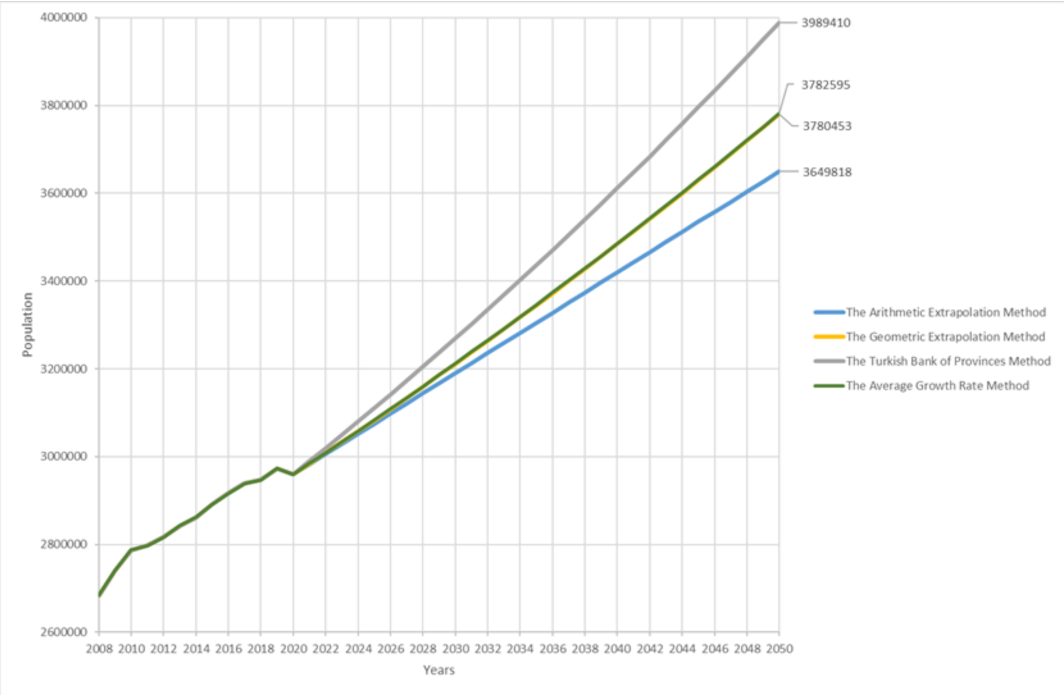

Figure 4.11. Projected Population Values of 11 Central Districts of İzmir

Ürkmez Dam, located in the study area, also meets the drinking and industrial water needs of the Seferihisar district. For this reason, population projections of the Seferihisar district were also made and given in Figure 4.12.

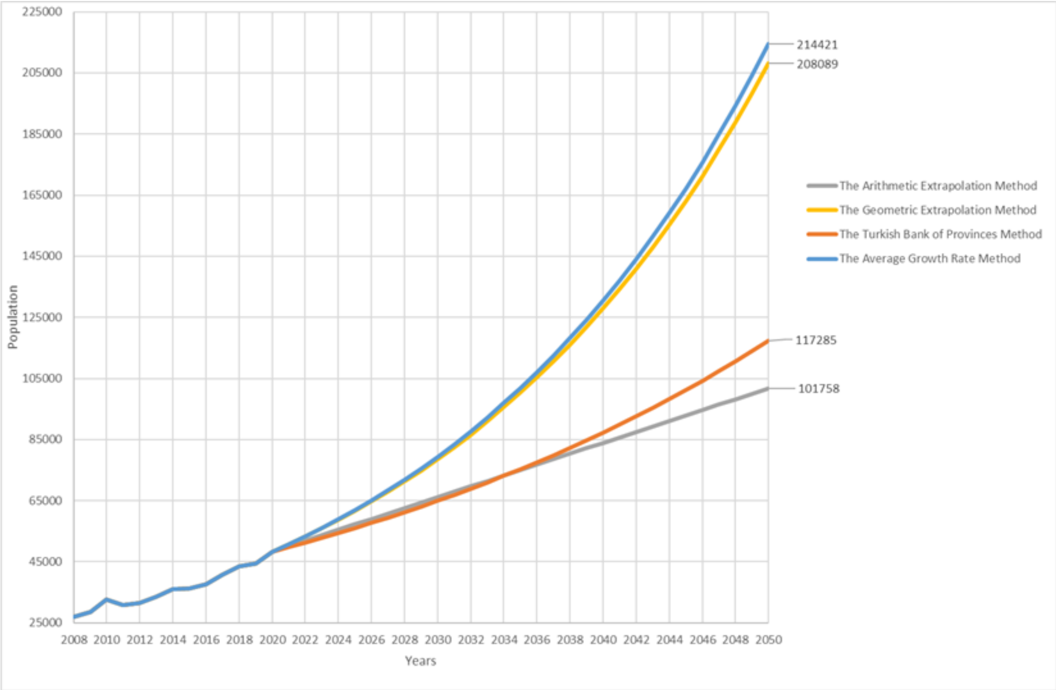

Figure 4.12. Projected Population Values of Seferihisar

4.3. Evapotranspiration

Evapotranspiration is to be expressed in general and simply; the total value of evaporation and transpiration gives evapotranspiration.

The study calculated the irrigation water needs of the crops grown in agricultural areas based on the Küçük Menderes Basin Master Plan Final Report. In the report, the water needs of agricultural products were calculated using the Blaney-Criddle method. The irrigation water needs of each crop grown in each agricultural area in the Tahtalı-Seferihisar Sub-Basin were calculated one by one and transferred to the Water Evaluation and Planning (WEAP) program separately.

The State Hydraulic Works calculates the irrigation water need with an excel macro using variables such as reference plant water consumption, adequate monthly precipitation, transmission efficiency, and product variety. (An Excel macro is a series of commands written to perform multiple and complex calculations with a simple click or press of a button.)

4.3.1. Blaney-Criddle Method

The Blaney-Criddle method is a simple method for calculating crop evapotranspiration. In countries with semi-arid climates such as Turkey, the Blaney Criddle method is widely used to calculate plants' water consumption. In this method, the monthly water consumption amount, U, of the desired crop type is found by the following formula:

$$U = 25.4kf \tag{4.10}$$

The k value in the formula is obtained by multiplying the seasonal k_1 value and the monthly k_2 value for the selected crop type. These k values are used by finding from the tables prepared for the Blaney Criddle method. The other variable in the formula, f, is the climatic factor and is found with the formula:

$$f = \left(\frac{1.8t + 32}{100}\right)P \tag{4.11}$$

The t value in this formula represents the monthly average temperature (^{o}C), and the P-value represents the ratio of monthly daytime hours to annual daytime hours. P-value can also be found from the tables prepared for this method, and P-value is the function of latitude of the place where the evapotranspiration calculation is to be made and the desired month (Usul 2017).

As an example of calculating the water needs of the plants grown in the agricultural areas in the study area, the water consumption values of the crops grown in Kaynakça Public Irrigation are given in Table 4.3.

Table 4.3. Water Consumption Values Per Hectare of Products Grown in Kaynakça Public Irrigation

Kaynakça Public Irrigation			
Crop Types	Percentage Distribution (%)	Area (ha)	Plant Water Consumption Values (m^3/ha)
Cereals	10	69.3	2498.1
Olive	15	104	8803.1
Tomato	15	104	6813.8
Vegetable	16	110.9	4770.5
Fruit	44	304.9	8803.1
Vegetable 2nd Crop	10	69.3	3661.4

Calculated plant water consumption was repeated for each agricultural area and recalculated for each crop. This is because agricultural areas have different meteorological values according to the regions they are located in.

4.4. Determination of Volume Depth Graphs of Ponds via QGIS

Since the volume-surface curves of the ponds of the Special Provincial Administration in Tahtalı-Seferihisar Sub-Basin could not be reached, the ponds' volume-height values required for the WEAP were calculated using the QGIS program. Ponds of the Special Provincial Administration in the basin are as follows: Bademler 9 Eylül Pond, Ulamış Ağalardere Pond, Ulamış Kavakçayı Pond, Payamlı Pond, Çatalca Şandidere Pond and Yeniköy Balaban Pond.

QGIS or Quantum GIS is an open-source geographic information system that helps to view, organize and evaluate geographic data. Thanks to the Raster Surface Volume Tool in the QGIS program, the volume, and area values calculated corresponding to the height value by entering the desired area to find the volume-surface curve. By repeating this process with a specific height range, the volume-surface curve is completed. The volume surface curve of the Ulamış Ağalardere Pond, built by the Special Provincial Administration, calculated in the QGIS program is given in Figure 4.13. These processes were repeated for other ponds, and necessary data were obtained for each pond.

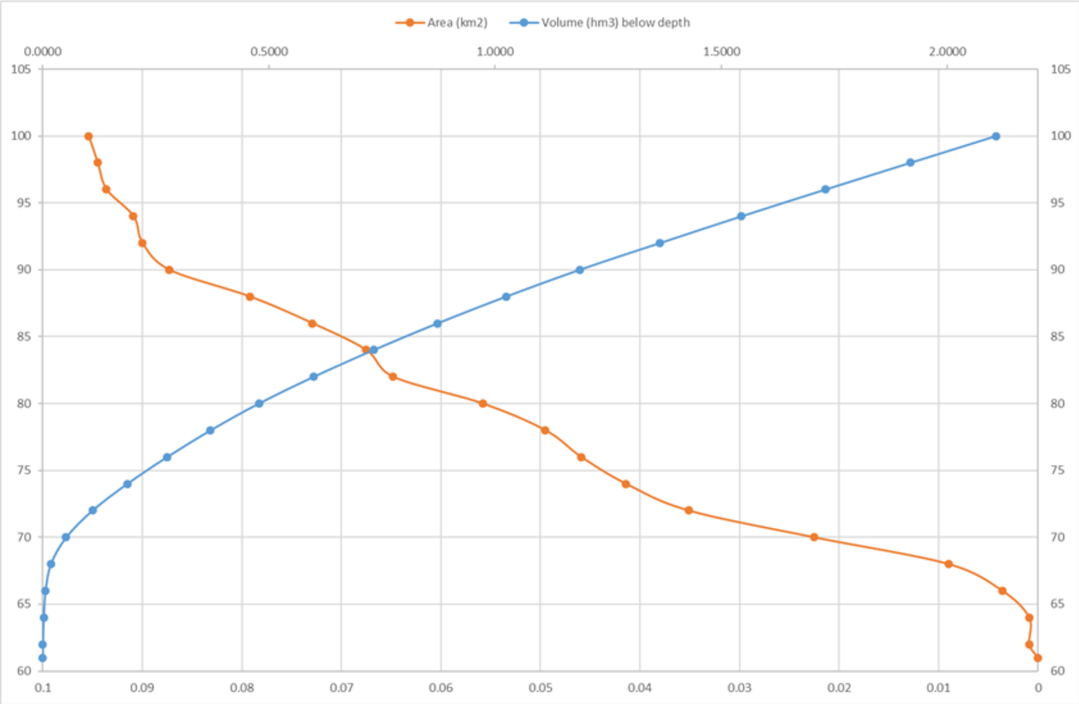

Figure 4.13. Volume Surface Curve of Ulamış Ağalardere Pond

4.5. Flow Forecasting with using Various Methods in R

Within the scope of the study, forecasting methods for finding the water need in the coming years were also used for the flow data of the rivers. R programming language is used for the forecast of flow data.

R is a programming language for statistical computing and graphics. R is highly flexible and offers a wide range of statistical (linear and nonlinear modeling, classical statistical tests, time-series analysis, classification, clustering, etc.) and graphical tools (R-Project).

Mainly three forecasting methods were used in R. These methods are Seasonal Naïve Method, Exponential Smoothing Method, and Autoregressive Integrated Moving Average Method.

The seasonal naïve forecasting method makes its forecasts for the future years using the values from the last observation year. Since the flow data are monthly data, the forecasted data belong to the last observation year, 2019. The Exponential Smoothing Method creates a forecast for future years by averaging the weighted averages of the data used. The weight of the data in the time series decreases as the years to which they belong. Exponential Smoothing Method and Autoregressive Integrated Moving Average Method are the most widely used methods for forecasting. The Exponential Smoothing Method forecasts future data by following a trend and seasonality-based approach in the data, while the Autoregressive Integrated Moving Average Method forecasts using autocorrelations of the data (Hyndman ve Athanasopoulos 2018).

The Seasonal Naïve Method uses the last year of observation, as mentioned earlier, so the value in March of the last observed year has the same value as the March of the next year to be estimated.

In the Exponential Smoothing Method, on the other hand, as the data goes back in time, the weights of those data in the estimation decrease.

In the Autoregressive Integrated Moving Average Method (ARIMA), transferred time-series values are decomposed firstly, and trend and seasonality values are separated. Then, the ARIMA forecast method was used for the trend of time-series values. After this process was completed, the seasonality values of the time-series values were taken and forecasted separately. Flow data for the following years were obtained by combining two different ARIMA forecast values (for trend forecasting, for seasonality forecasting).

In the study, forecasts were made only for the flow data coming to the dams. Because, in line with the available information, the flows coming to the ponds do not show annual and seasonal variability since they are in terms of annual average flow values. For this reason, it is unnecessary to make forecasts for these values since they will continue as a constant value as a result of the estimates to be made.

Flow data coming to the dams were obtained from the operation-maintenance files of the dams. Since these data are in hm^3/month, they are first converted to m^3/second for each month. The start dates of the time-series data were selected from the year the dams were put into operation until 2019 when the last accessible data are available. Since the year in which each dam was put into operation is different, forecasts were also made in R using different time intervals. After that, time-series data for each dam were created as an excel file and read in the R program.

4.5.1. Ürkmez Stream Future Flow Prediction with Seasonal Naïve Method (Ürkmez Dam)

The Seasonal Naïve Method provides a basis for forecasting methods and is often used for comparison with other methods. The result of this method applied for the Ürkmez River is shown in Figure 4.14.

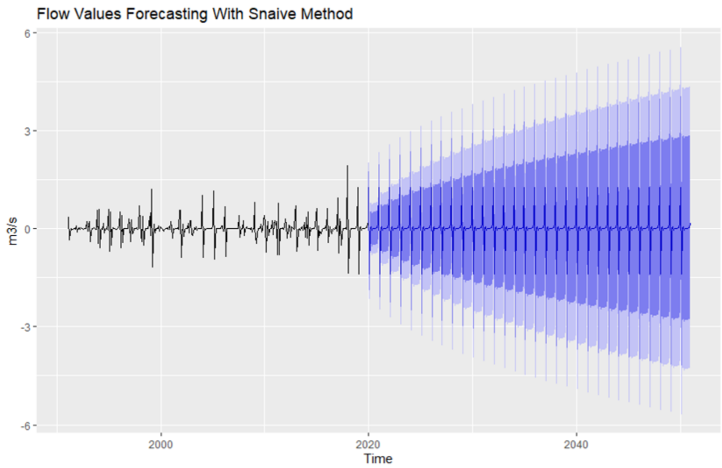

Figure 4.14. Ürkmez Stream Flow Values Forecasting with Seasonal Naïve Method

The results of the residuals values as a result of the method are also given in Figure 4.15. When the autocorrelation function values are examined, it is seen that this method is not an ideal application for the Ürkmez Stream. The reason for this is that the bars must stay within the blue dashed line and it represents 95% confidence level.

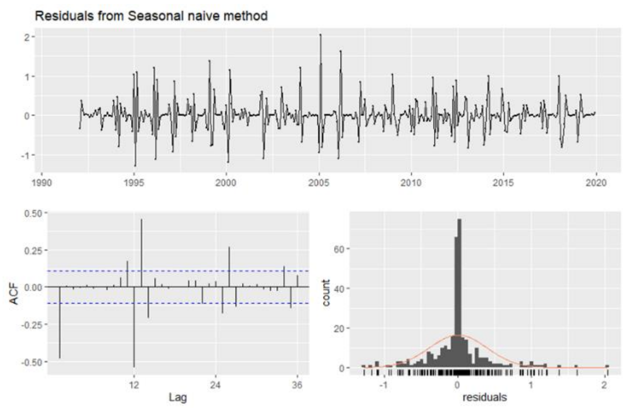

Figure 4.15. Ürkmez Stream Residuals from Seasonal Naïve Method

4.5.2. Yassıçay Stream Future Flow Prediction with Seasonal Naïve Method (Seferihisar Dam)

The Seasonal Naïve Method has been applied to the Yassıçay Stream, and the result obtained is given in Figure 4.16.

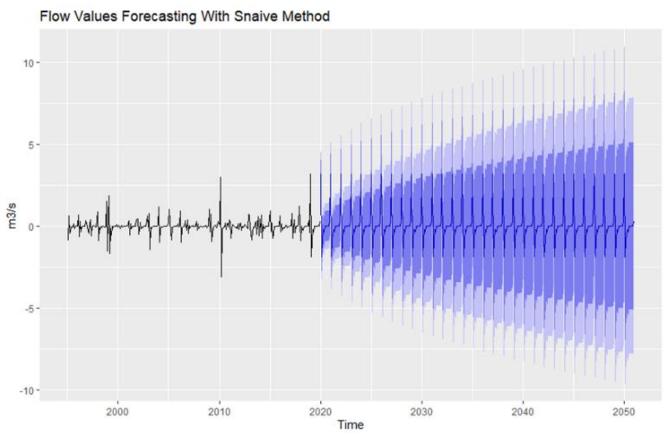

Figure 4.16. Yassıçay Stream Flow Values Forecasting with Seasonal Naïve Method

When the residuals values in the result of the method are examined, it is seen that some bars in the autocorrelation function are outside the blue dashed line. This method gave better results in Yassıçay Stream than Ürkmez Stream.

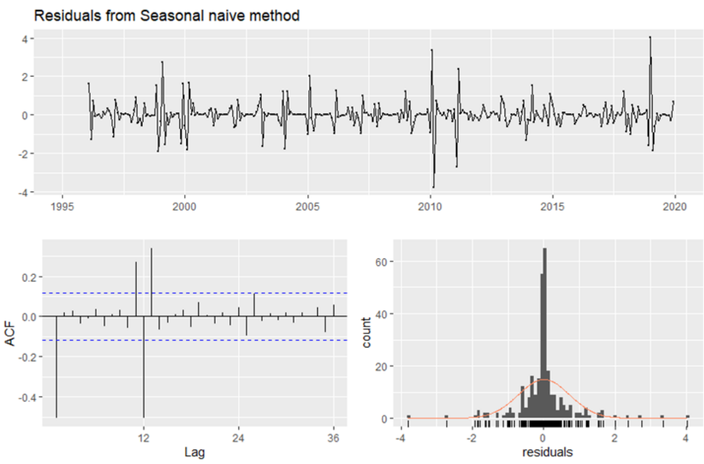

Figure 4.17. Yassıçay Stream Residuals from Seasonal Naïve Method

4.5.3. Tahtalı and Şaşal Streams Future Flow Prediction with Seasonal Naïve Method (Tahtalı Dam)

Seasonal Naïve Method has been applied to the flow values of Tahtalı and Şasal Streams, which supply water to Tahtalı Dam.

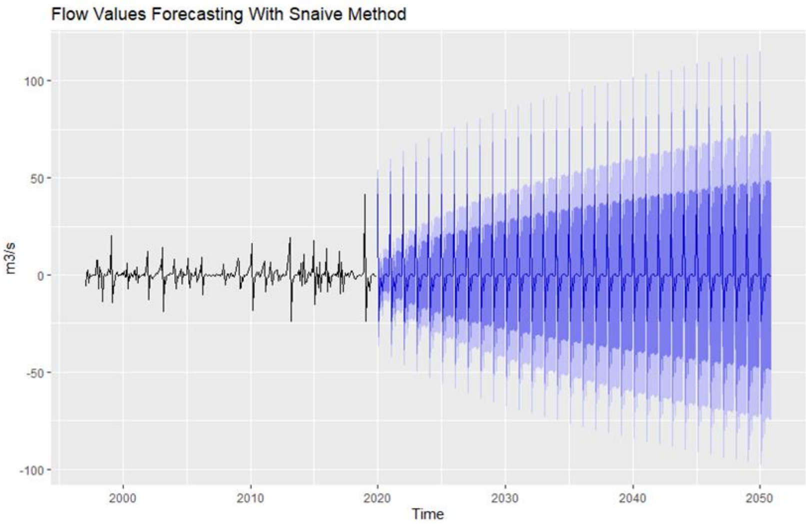

Figure 4.18. Tahtalı and Şaşal Streams Flow Values Forecasting with Seasonal Naïve Method

When the residuals values in the result of the method for Tahtalı and Şasal Streams are examined, some bars in the autocorrelation function are again above the confidence level.

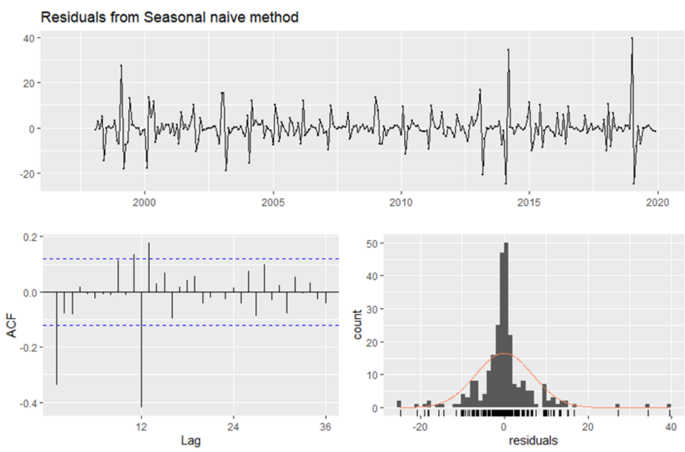

Figure 4.19. Tahtalı and Şaşal Streams Residuals from Seasonal Naïve Method

4.5.4. Kavakdere Streams Future Flow Prediction with Seasonal Naïve Method (Kavakdere Dam)

Seasonal Naïve Method was last applied to Kavakdere Stream.

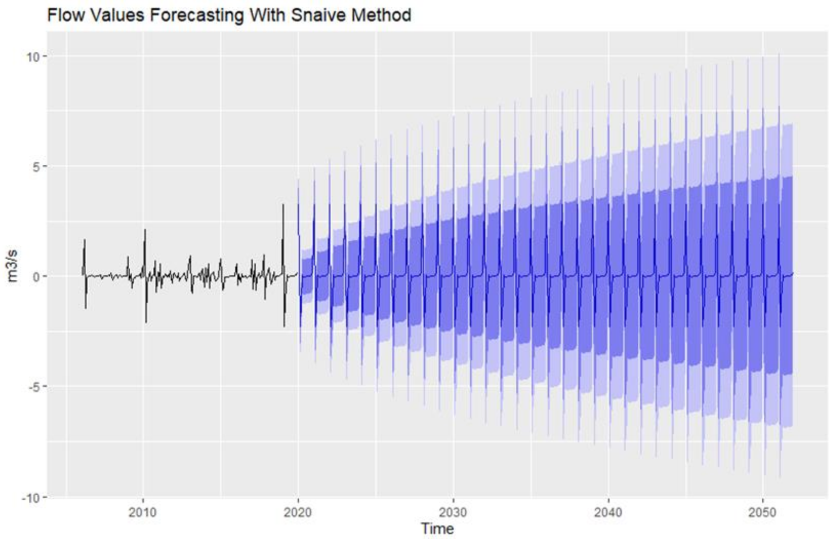

Figure 4.20. Kavakdere Stream Flow Values Forecasting with Seasonal Naïve Method

When the residual values were analyzed, it is seen in the autocorrelation function that it gives better results than other streams.

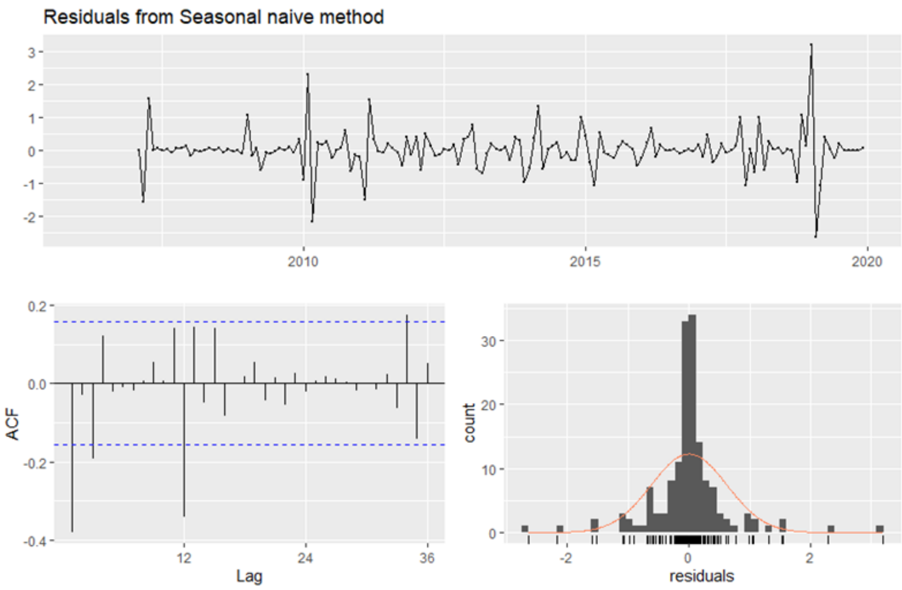

Figure 4.21. Kavakdere Stream Residuals from Seasonal Naïve Method

4.5.5. Ürkmez Stream Future Flow Prediction with Exponential Smoothing Method (Ürkmez Dam)

Exponential Smoothing Method, which is the second method applied for forecasting, was applied to Ürkmez Stream and gave better results than the previous method.

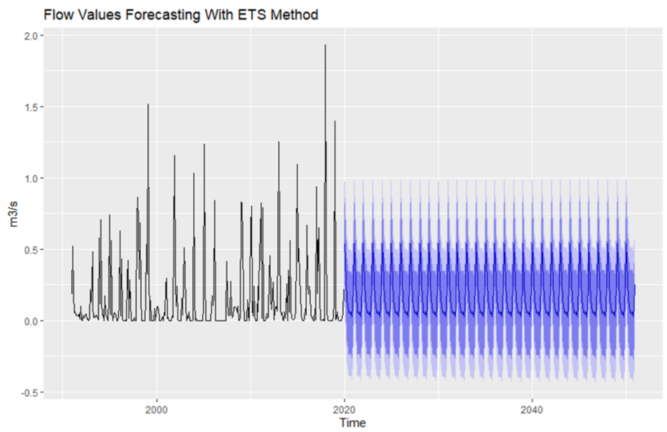

Figure 4.22. Ürkmez Stream Flow Values Forecasting with Exponential Smoothing Method

An indication that this method gives better results is when the residuals values are investigated. When the autocorrelation function is examined, the bars are placed between the blue dashed lines according to the previous method.

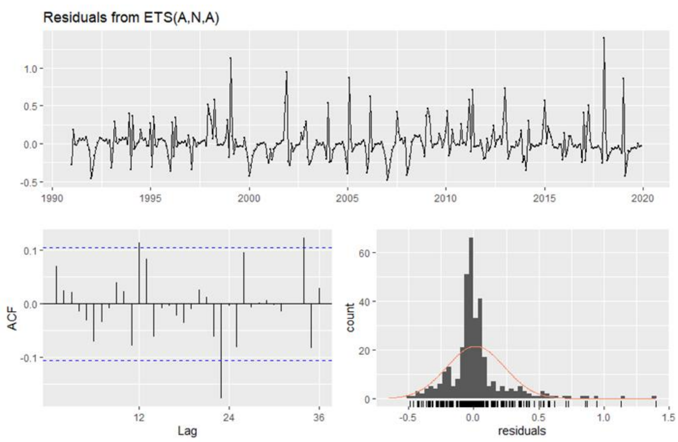

Figure 4.23. Ürkmez Stream Residuals from Exponential Smoothing Method

4.5.6. Yassıçay Stream Future Flow Prediction with Exponential Smoothing Method (Seferihisar Dam)

The Exponential Smoothing Method was also applied to the Yassıçay Stream, which supplies water to Seferihisar Dam.

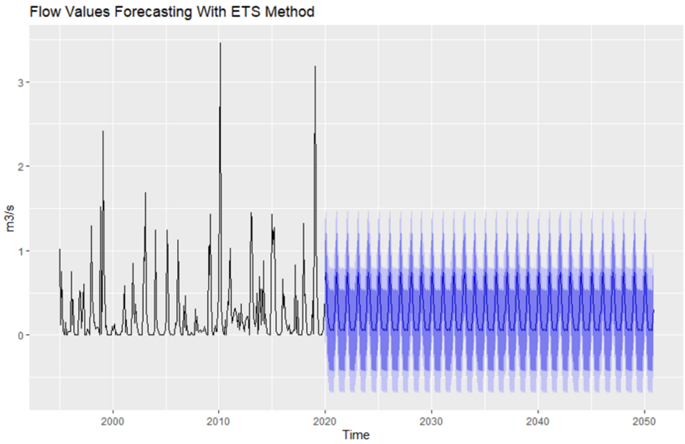

Figure 4.24. Yassıçay Stream Flow Values Forecasting with Exponential Smoothing Method

This method also gave better results in Yassıçay Stream.

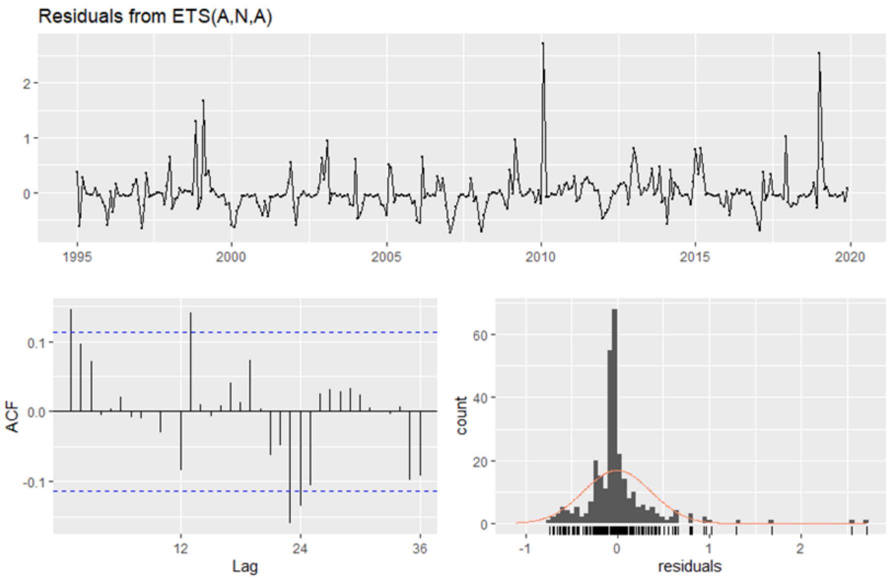

Figure 4.25. Seferihisar Stream Residuals from Exponential Smoothing Method

4.5.7. Tahtalı and Şaşal Streams Future Flow Prediction with Exponential Smoothing Method (Seferihisar Dam)

While applying this method, Tahtalı and Şasal Streams were considered as a single river and the method was utilized.

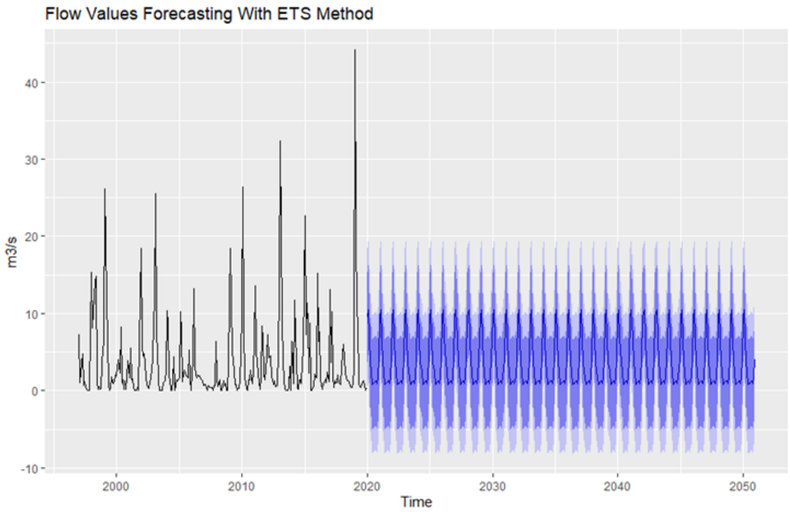

Figure 4.26. Tahtalı and Şaşal Streams Flow Values Forecasting with Exponential Smoothing Method

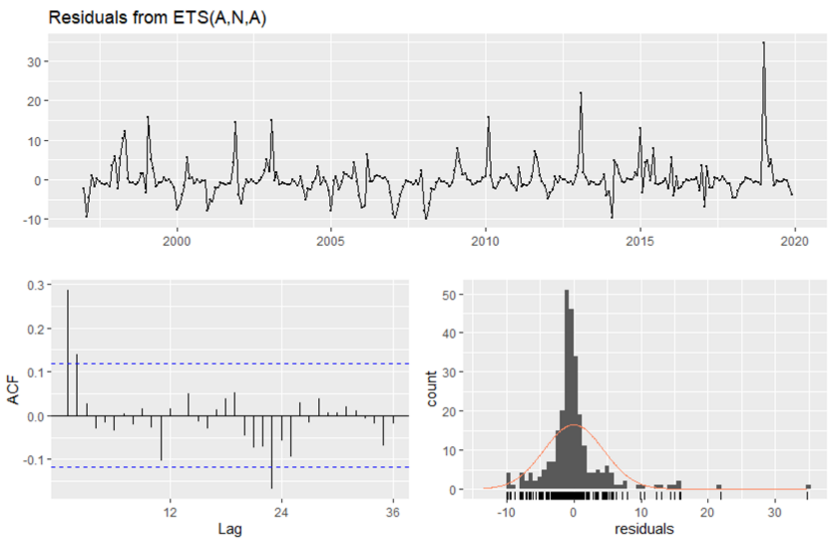

Figure 4.27. Tahtalı and Şaşal Streams Residuals from Exponential Smoothing Method

4.5.8. Kavakdere Stream Future Flow Prediction with Exponential Smoothing Method (Seferihisar Dam)

Lastly, the Exponential Smoothing Method was applied to the Kavakdere Stream.

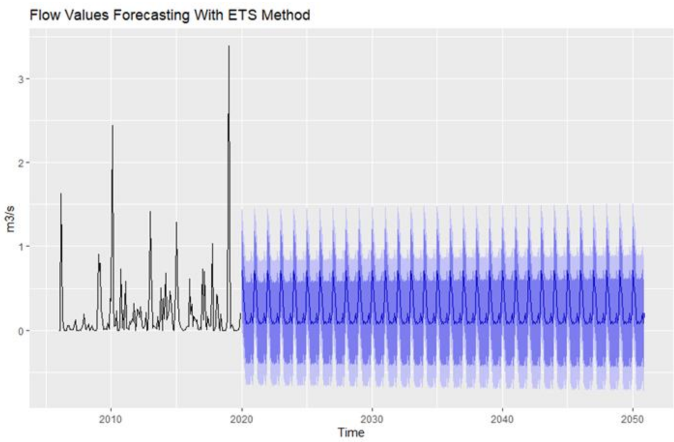

Figure 4.28. Kavakdere Stream Flow Values Forecasting with Exponential Smoothing Method

Exponential Smoothing Method gave better results than the previous method (Seasonal Naïve Method) in Kavakdere Stream, which is the last stream applied.

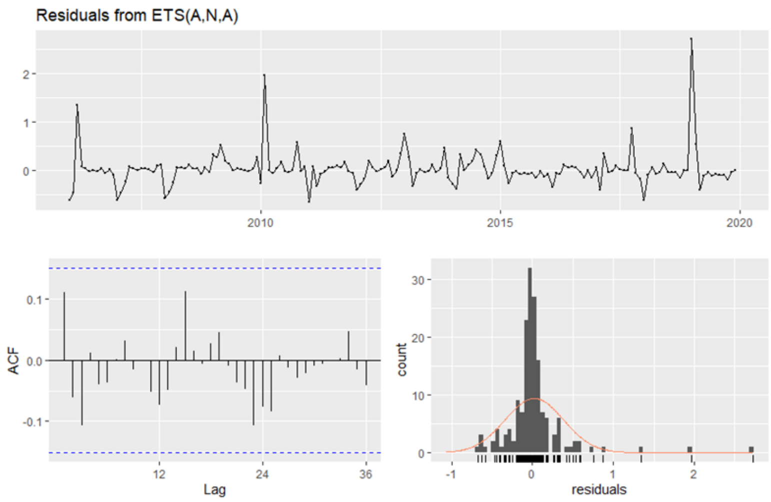

Figure 4.29. Kavakdere Stream Residuals from Exponential Smoothing Method

4.5.9. Ürkmez Stream Future Flow Prediction with ARIMA Method (Ürkmez Dam)

Flow data to Ürkmez Dam has been available since 1991, so the data were started from this year. The time-series data of the Ürkmez Stream transferred to the R program was first decomposed.

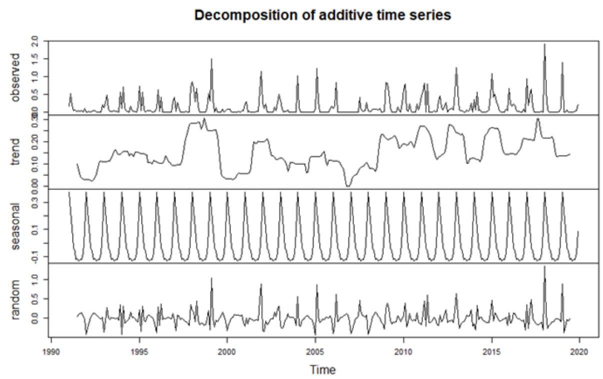

Figure 4.30. Decomposition of time-series data of Ürkmez Stream

Decomposed data was predicted with a 95% confidence level for the future. First, the trend was obtained from the time-series data of the Ürkmez Stream, and the ARIMA method was used.

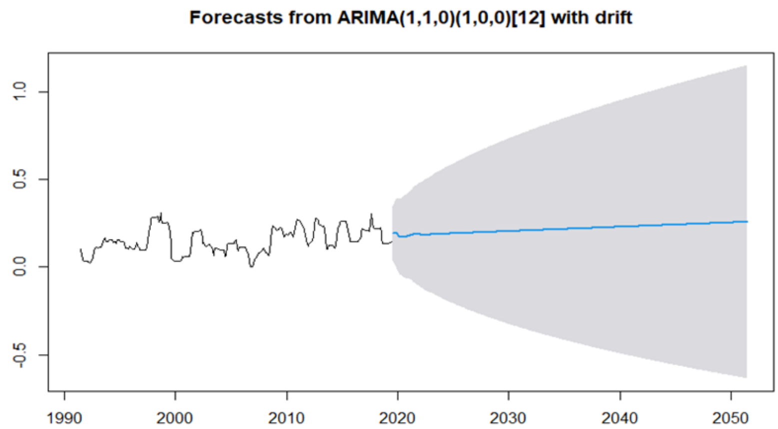

Figure 4.31. Forecast of Trend of Ürkmez Stream Time-Series Data

After this process, the ARIMA method forecasted the seasonality values obtained from the time-series data of the Ürkmez Stream.

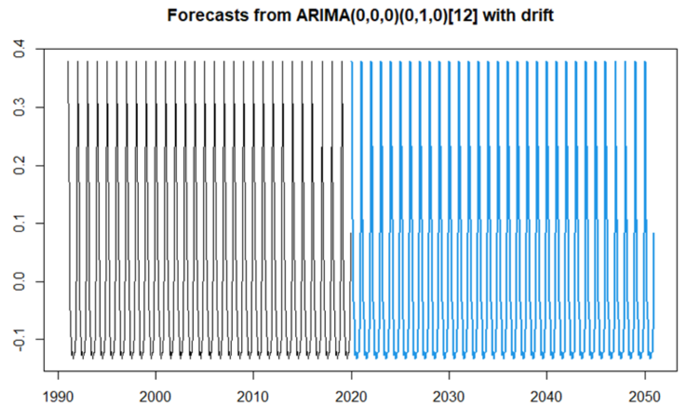

Figure 4.32. Forecast of Seasonality of Ürkmez Stream Time-Series Data

After performing two different future predictions, these two forecasts are combined, and seasonality values have been added to trend values.

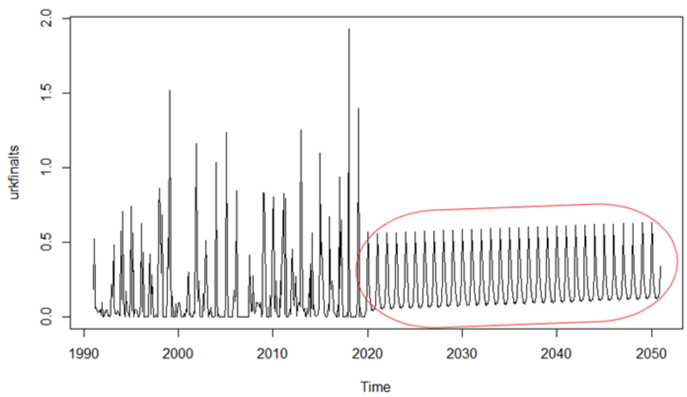

Figure 4.33. Ürkmez Stream Forecasted Flow Values

4.5.10. Yassıçay Stream Future Flow Prediction with ARIMA Method (Seferihisar Dam)

An excel file was created for the time series data of Yassıçay River, which is the stream source of Seferihisar Dam, from 1995 to 2019 and transferred to R. Next, the time series data is decomposed.

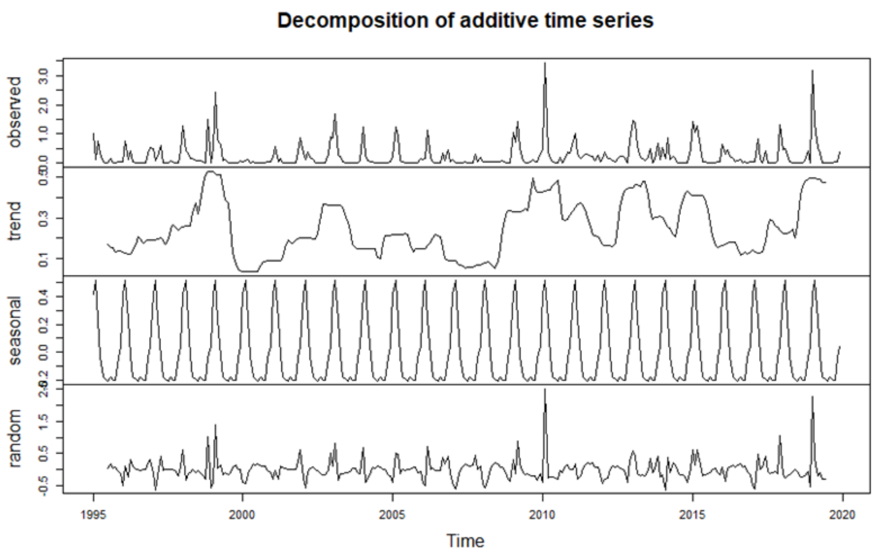

Figure 4.34. Decomposition of time-series data of Yassıçay Stream

From the decomposed time-series data, firstly, the trend data was forecasted and given in Figure 4.34. Later, seasonality data was predicted separately and shown in Figure 4.35.

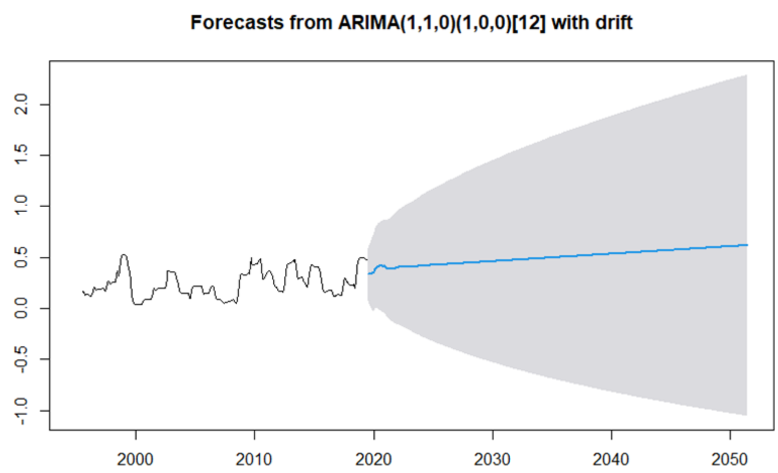

Figure 4.35. Forecast of Trend of Yassıçay Stream Time-Series Data

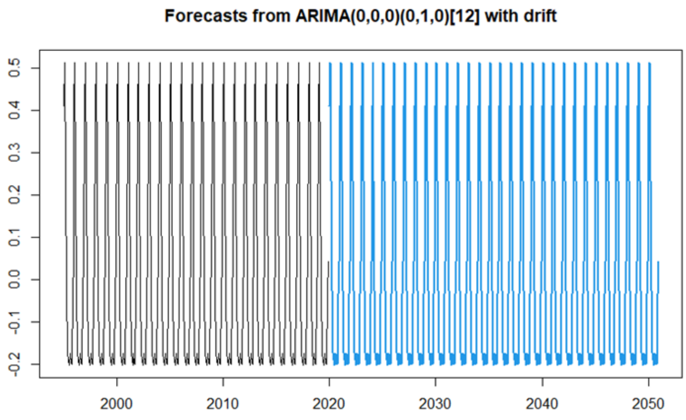

Figure 4.36. Forecast of Seasonality of Yassıçay Stream Time-Series Data

By adding a seasonality forecast to the obtained trend forecast, future flow data for Yassıçay Stream are obtained.

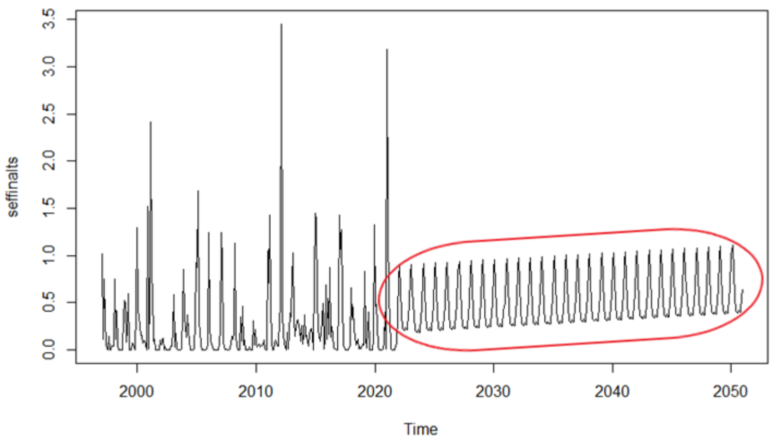

Figure 4.37. Yassıçay Stream Forecasted Flow Values

4.5.11. Tahtalı and Şaşal Streams Future Flow Prediction with ARIMA Method (Tahtalı Dam)

Tahtalı Dam has two essential water sources. These are the Şasal and Tahtalı Streams. These two streams are forecasted together because the two streams come together as a single stream before coming to the dam. In other words, the flow data coming to the dam lake in the dam operation-maintenance file corresponds to the sum of the flow data of these two streams. For this reason, these two streams are forecasted together and then separated. Since flow data to Tahtalı Dam has been available since 1997, time-series data also started this year. Decomposed time series data is shown in Figure 4.38.

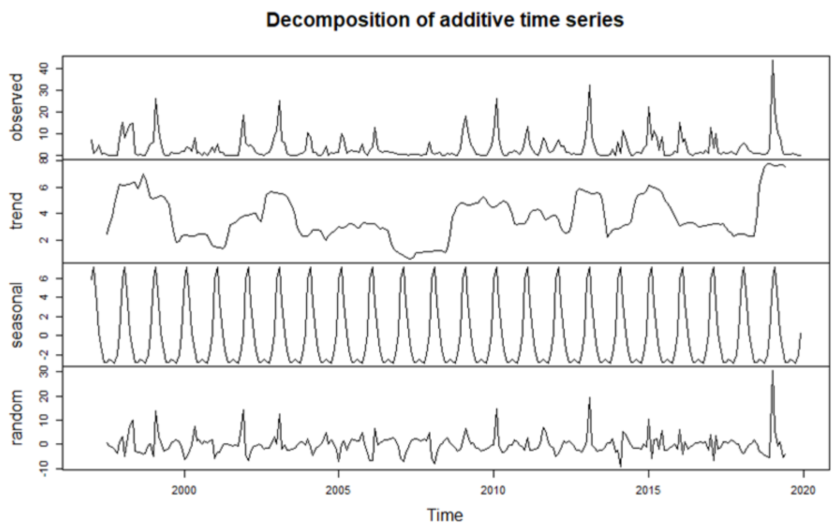

Figure 4.38. Decomposition of time-series data of Tahtalı and Şaşal Streams

After the flow data coming to Tahtalı Dam were decomposed, the forecast was carried out with ARIMA Method using only trend data.

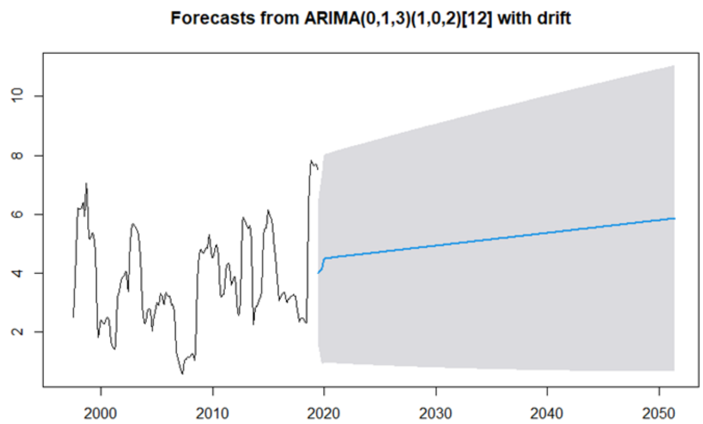

Figure 4.39. Forecast of Trend of Tahtalı and Şaşal Streams Time-Series Data

The seasonality values obtained from the Tahtalı and Şasal Streams time-series data are also forecasted until 2050.

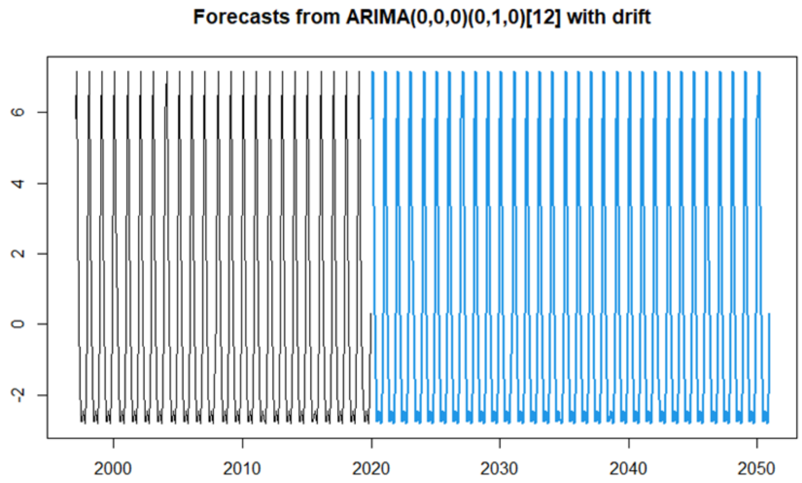

Figure 4.40. Forecast of Seasonality of Tahtalı and Şaşal Streams Time-Series Data

Future flow values are obtained by adding seasonality values to trend forecast values.

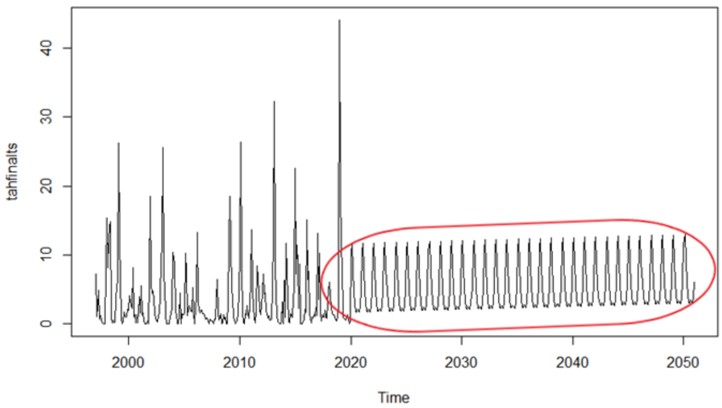

Figure 4.41. Tahtalı and Şaşal Streams Combined Forecasted Flow Values

4.5.12. Kavakdere Stream Future Flow Prediction with ARIMA Method (Kavakdere Dam)

Kavakdere Dam is a relatively new dam compared to other dams and started to be operated in 2006. For this reason, the flow data coming to the dam lake are based on the operation-maintenance file that began in 2006. The time-series data of the Kavakdere Stream was firstly decomposed.

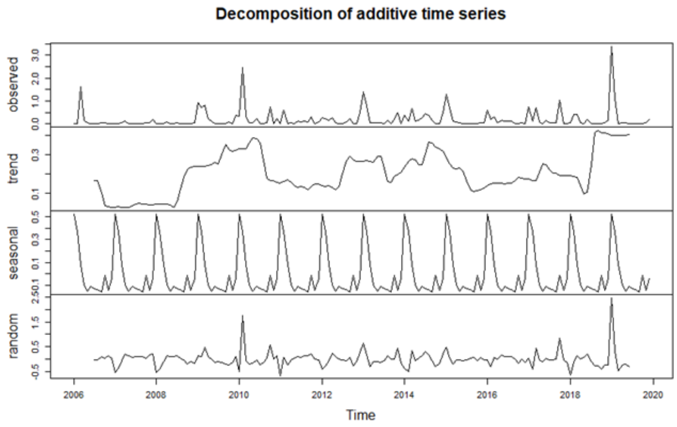

Figure 4.42. Decomposition of time-series data of Kavakdere Stream

By taking only the trend values of the decomposed time series data, its prediction was made with the ARIMA method until 2050, shown in Figure 4.43. Then, the same process was performed by taking only seasonality values, and it is shown in Figure 4.44.

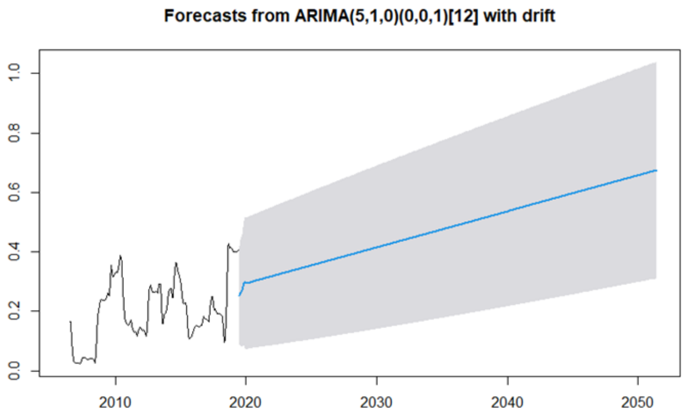

Figure 4.43. Forecast of Trend of Kavakdere Stream Time-Series Data

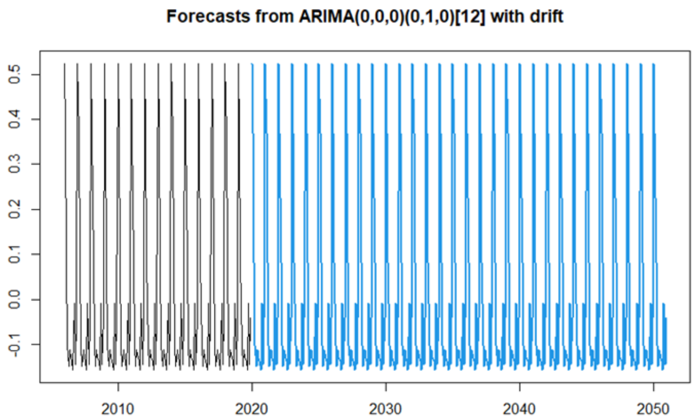

Figure 4.44. Forecast of Seasonality of Kavakdere Streams Time-Series Data

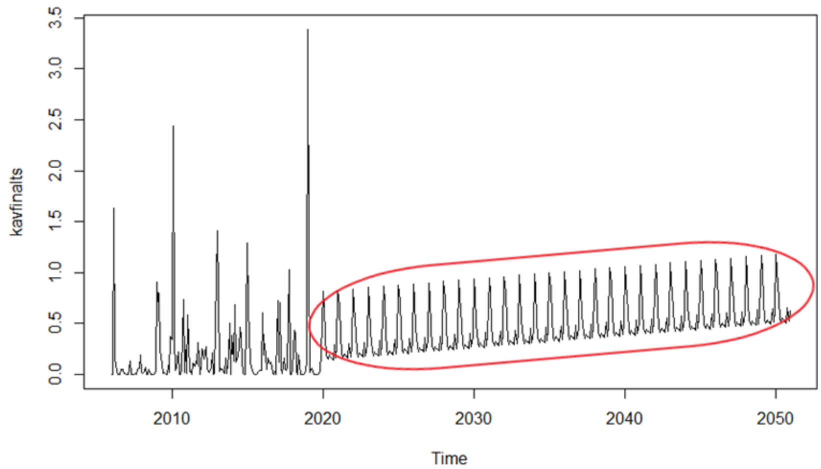

Figure 4.45. Kavakdere Streams Forecasted Flow Values

4.6. Finding Net Evaporation Values of Special Provincial Administration Ponds

In the Water Evaluation and Planning program, the ponds are introduced to the program as reservoirs, and the net evaporation values required for the reservoirs are not available for the ponds. Because the planning reports of the ponds belonging to the Special Provincial Administration in the basin are not available and detailed information about small water structures such as ponds are not included in the Küçük Menderes Basin Master Plan Final Report, for these reasons, net evaporation values must be found for the ponds. The net evaporation amounts to be transferred to the WEAP program have been prepared in accordance with the master plan report. If the Ulamış Ağalardere Pond is taken as an example: the temperature values taken from the Seferihisar Meteorological Observation Station were moved to the normal water level of the Ulamış Ağalardere Pond, and evaporation amounts from the free water surface were obtained. After that, corrections were made with the precipitation information obtained from the same meteorology station, and the net evaporation amounts of the pond were obtained and given in Table 4.4.

These processes were repeated for the other Provincial Administration Ponds: Ulamış Kavakçayı Pond, Bademler 9 Eylül Pond, Payamlı Pond, Çatalca Şandidere Pond and Yeniköy Balabandere Pond.

Table 4.4. Net Evaporation Values of Ulamış Ağalardere Pond

MONTHS	Seferihisar Meteorological Observation Station Average Temperature (°C) Elevation: 22 m	Seferihisar Average Evaporation (mm)	Ulamış Ağalardere Pond Normal Water Level: 87 m				
			Temperature Transported from Seferihisar to Ulamış Ağalardere Pond Normal Water Level Elevation (°C)	Evaporation (mm)	Evaporation from Free Water Surface (mm)	Seferihisar Precipitation (mm)	Net Evaporation (mm)
January	8.3		7.9				
February	8.8		8.4				
March	10.8	67.4	10.5	38.3	26.8	69.2	
April	14.5	104.2	14.1	87.3	61.1	41	20.1
May	19.2	167.9	18.9	150.6	105.5	23.6	81.8
June	24.2	230.6	23.8	217.2	152.1	4.2	147.8
July	26.9	276.2	26.6	254	177.8	0.7	177.1
August	26.4	252.7	26.1	247.3	173.1	1.2	171.9
September	22.4	171.4	22	192.8	135	13.8	121.2
October	17.7	107.1	17.3	130.2	91.1	52.3	38.9
November	13	52.8	12.6	67.4	47.2	75.8	
December	9.9		9.6				
Total	**16.9**	**1430.3**	**16.5**	**1346.8**	**942.8**	**281.9**	**758.8**
Seferihisar MOS Elevation		22 m					
Seferihisar MOS Latitude		38° 12'					
Ulamış Ağalardere Pond Normal Water Level		87 m					
Ulamış Ağalardere Pond Latitude		38° 15'					
Elevation Correction		-0.325					
Latitude Correction		-0.05					
Total Correction		-0.38					

CHAPTER 5

NUMERICAL MODELING VIA WEAP MODEL

5.1. Creating a Model with the WEAP Program

To create the study area, a new area must be created in the WEAP program. If no work has been done on the program before, the Weaping River Basin model will be opened by default. Therefore, in order to create the study area, a New Area is created by selecting the Area from the Main Menu and using the Create Area command. In the window that opens: naming the model for the new model, creating a new model or creating a new model by copying the existing models, adding a description for the model, or setting a password for the security of the model can be performed. After completing the necessary operations for the new model in the window that opens, WEAP opens the Set Area Boundaries window to determine the boundaries of the field of study. The world map opens in the Set Area Boundaries window, with layers for countries, cities, oceans, and great rivers on the map. The study area is enclosed in a rectangle on this map by drawing a slightly wider border. The boundaries selected for the workspace can be changed and expanded later.

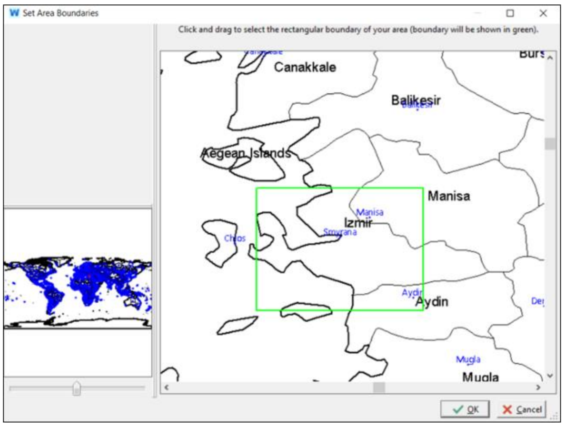

Figure 5.1. Set Area Boundaries Window

One of the important features of the Water Evaluation and Planning program is that it can add Geographical Information System (GIS) based files for the model and use these layers as a map base for the model. As mentioned before, raster and vector layer files can be added to the program. In order to perform this operation, the desired file can be transferred to the model by clicking the Schematic submenu from the Main Menu and selecting the Add Vector Layer or Add Raster Layer options. The layers to be added to the model must have the same geographical projection to carry out this process. The WEAP program uses the WGS84 projection. When a layer with a different projection, then this projection is wanted to be added to the model. Since the existing projection system is effective, the added layer also has the current projection. However, the layers will be lost when changed using different projections.

After adding the necessary layers to the model, the supply and resources, and demand sites to be created for the workspace are placed in the desired places in the model. Elements that are not available in the added layers can be added to the model manually.

In the study area, modeling tools such as a river, reservoir, and groundwater, located under the title of supply and resources, are placed on the model by drag-and-drop method. After these processes are completed, the demand sites that meet the water need from these sources are transferred to the model. Finally, the basis of the model is formed by connecting water resources and demand sites with transmission links.

After the model elements are placed and general adjustments are completed during modeling, the model data required for the model elements must be entered to calculate and evaluate the analysis and results. By clicking the Years and Time Steps option in the general submenu in the main menu, information such as the start and end date of the model or the start month of the model is arranged. The data is transferred to the program according to the start year determined on the years and time steps screen, and the evaluation of the data, analysis and scenario researches of the data are carried out starting from this year, that is, the current account time period.

Completing the necessary data and carrying it to the program for the model can be done by right-clicking on each model tool, or a hierarchical tree is used to create and organize data structures in the Data View. Changes can be made to the scenarios using the Manage Scenarios option on the same screen.

With the completion of the data, the main purpose of the WEAP program is to create future scenarios and to answer the (what if) questions.

Before the model of the entire basin was created, a calibration model was designed to show that the WEAP model works successfully by using the flow and volume values of the dam lakes, which are the most reliable data available. For this reason, Ürkmez, Seferihisar, Tahtalı, and Kavakdere Dams, will be created, and operation studies will be carried out by obtaining simulation results of these reservoirs. The WEAP model should be calibrated to obtain real-life operation standards by using necessary parameters into the program to represent the streams and rivers on which the dams are located, the dam reservoir features, the details of the demand points, etc. These parameters are storage capacity, initial storage, volume elevation curve values, net evaporation, monthly variation, annual activity level, annual water use rate.

5.2. Calibration Modeling of Reservoir Volumes via WEAP

One of the critical stages for model creation is the calibration part. In this part, the model parameters are adjusted by using the values observed in the study area of the model, and the process continues until the values obtained as a result of the model, and the field values are compared, and it is decided that the results are "reasonably good" (Moore ve Doherty 2005).

For this reason, before starting the simulation models for future years, a calibration model was created. Four dams (Ürkmez, Seferihisar, Tahtalı, and Kavakdere Dams) in Tahtalı-Seferihisar Sub-Basin, were examined separately since water losses in the reservoirs, water transmissions, and the amount of water coming into the dam lake are known more clearly than groundwater resources.

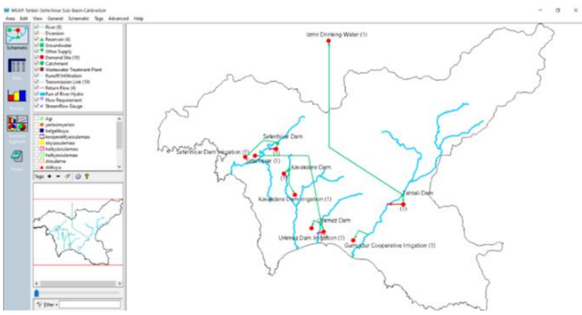

Figure 5.2. Calibration Model of Tahtalı-Seferihisar Sub-Basin

Therefore, a model was created based on the historical data of the past years. Using the data between 2005 and 2019 for Ürkmez, Seferihisar, and Tahtalı Dam, it has been shown how successful the calibration model is and to show how successful the WEAP program is in modeling reservoir volumes. The year range of the data used in the calibration model for Kavakdere Dam is between 2007 and 2019. The difference in the year range of the data used for the Kavakdere Dam is that the dam was started to be taken into operation in 2006, and it is due to the presence of operation inflows starting from April 2006.

In line with the use of the data obtained from the State Hydraulic Works, it was observed that the month-end operating volumes graphics created by the model and the month-end operating volume values in the State Hydraulic Works data follow each other as a pattern. To compare the results obtained as a result of the model with the field data, root mean square error (RMSE), normalized root mean square error (NRMSE), Nash Sutcliffe efficiency/coefficient (NSE), and percent bias/deviation (PBIAS) values were calculated. The calculated values (RMSE, NRMSE, NSE, PBIAS) are in suitable intervals, and it shows that the calibration model created on the WEAP program is quite successful for modeling reservoir volumes. Thus, it has been revealed how reliable the simulations can be created for future years.

5.2.1. Ürkmez Dam

Ürkmez Dam is located in Ürkmez town of Seferihisar District. It provides irrigation and drinking water, as mentioned earlier.

Figure 5.3 shows the end-of-month operating volumes of the Ürkmez Dam obtained from State Hydraulic Works' data source. The values of some ups and downs in the month-end operating volume chart are also given on the graph.

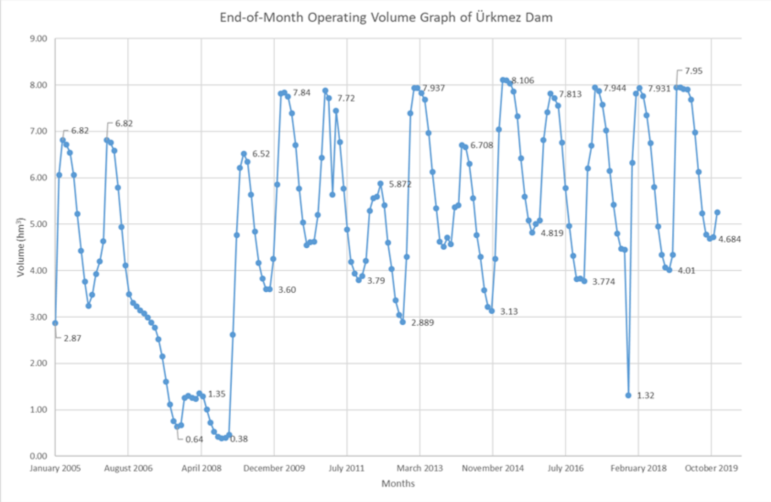

Figure 5.3. Ürkmez Dam's End-of-Month Operating Volumes

For each dam (Ürkmez, Seferihisar, Tahtalı, and Kavakdere Dams) created in the calibration model, firstly, the flow values of the river or stream it is located on were entered. The amount of water coming into the dam lakes is in the monthly hm^3 unit in the maintenance-operation files received from the State Hydraulic Works and represents the flow data of the river on which the dam is located. These flow values given monthly were converted into cubic meters per second and transferred to the WEAP program.

After the flow data was completed, the Ürkmez Dam was placed to the desired area on the Schematic View screen of the program by the drag and drop method. Then, Storage Capacity, Initial Storage, Volume Elevation Curve, Net Evaporation, and Observed Volume values were also transferred to the program for Ürkmez Dam.

The storage capacity corresponds to the maximum volume the reservoir can hold, which is 8.625 hm^3 for the Ürkmez Dam. The initial storage value represents the water volume value in the reservoir lake at the start date of the model. Since the calibration model started in January 2005, the volume value in December 2004 was entered for the initial storage value. For the Volume Elevation and Net Evaporation data, the values found in the Küçük Menderes Basin Master Plan Final Report were used. The net evaporation values are taken from the master plan report because the values in the report are the averages of the long-term obtained. On the other hand, observed volume values have been transferred to the program by entering the values corresponding to the operating volumes at the end of each month.

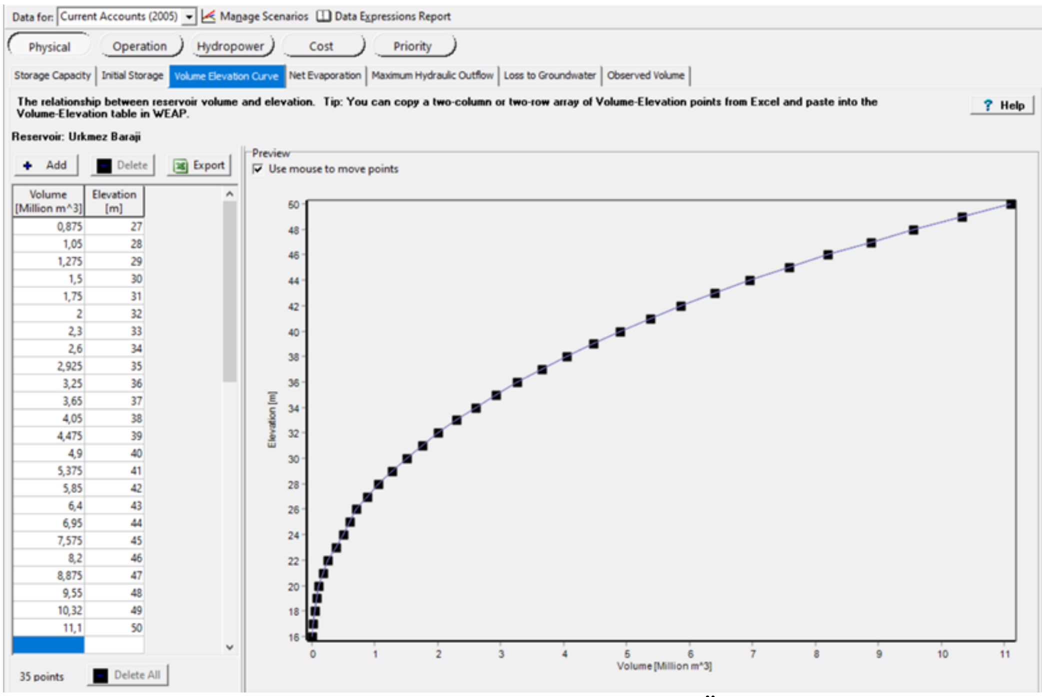

Figure 5.4. Volume Elevation Curve for Ürkmez Dam

Since the Ürkmez Dam was built to provide irrigation water and drinking water, three demand points were established to supply water from the reservoir. The first demand point is the Ürkmez Dam Irrigation, and the second one is the drinking water provided to Seferihisar. The data under the irrigation heading available in the data file received from State Hydraulic Works is used for Ürkmez Dam Irrigation, and the data under the title of drinking entered into the program as drinking water supplied Seferihisar. The amount of water drawn from the dam under the headings of flood and other in the dam operation and maintenance data was transferred to the demand point named Other Uses of Ürkmez Dam.

Ürkmez Dam Irrigation covers an area of 370 hectares, and this area was kept constant throughout the calibration model. A monthly water supply was provided considering the water needs of the crops grown in the agricultural area.

After the requested water amounts were entered into the program, the calibration model was run for the Ürkmez Dam, and the observed and simulated reservoir volume values were compared. The graphic resulting from the calibration model is as in Figure 5.5. The graph with triangular symbols represents values corresponding to end-of-month operating volumes. The graph with square symbols corresponds to the simulated reservoir volumes formed as a result of the model in the WEAP program.

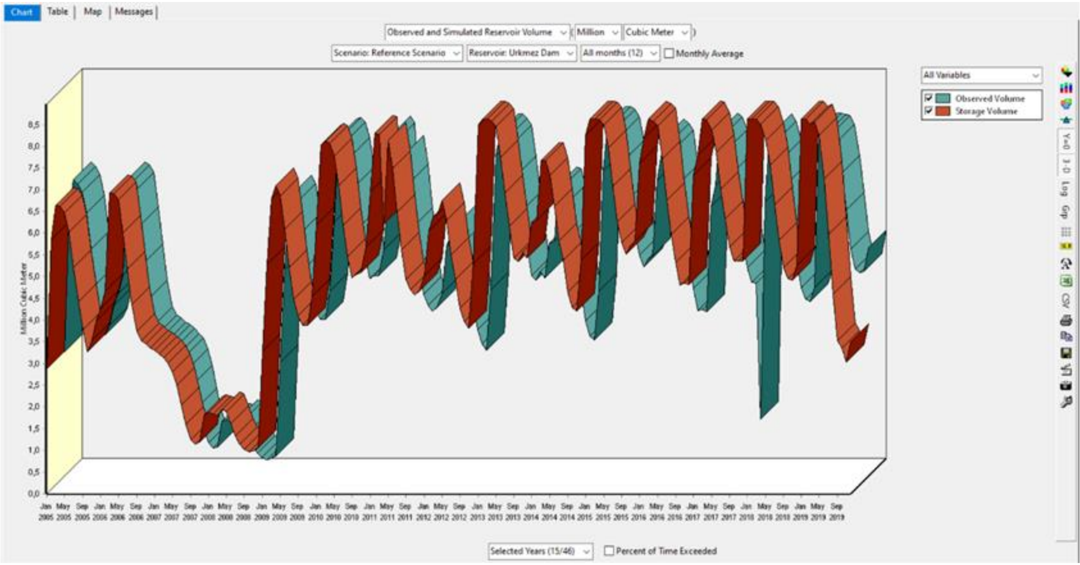
Figure 5.5. Observed and Simulated Reservoir Volume

The generated graphics data were exported from the WEAP program and the observed and simulated reservoir capacity data were compared. Model performance evaluation values were calculated among these data. Firstly, root mean square error was calculated and then, normalized root mean square error, Nash Sutcliffe Efficiency/Coefficient, and Percent Bias/Deviation values are also calculated.

5.2.2. Seferihisar Dam

The Seferihisar Dam was constructed for irrigation purposes. First, the Yassıçay Stream on which the dam is located on was drawn on the Schematic View of the program, and the Seferihisar Dam was placed on the program by the drag and drop method. Since Seferihisar Dam is a dam for irrigation purposes, the water in the reservoir has been transferred with the transmission link to Seferihisar Dam Irrigation. After completing the supply and demand points in the schematic view, the data was transferred to the program by switching to the Data View screen. Figure 5.6, there is month-end operating volume data obtained from State Hydraulic Works.

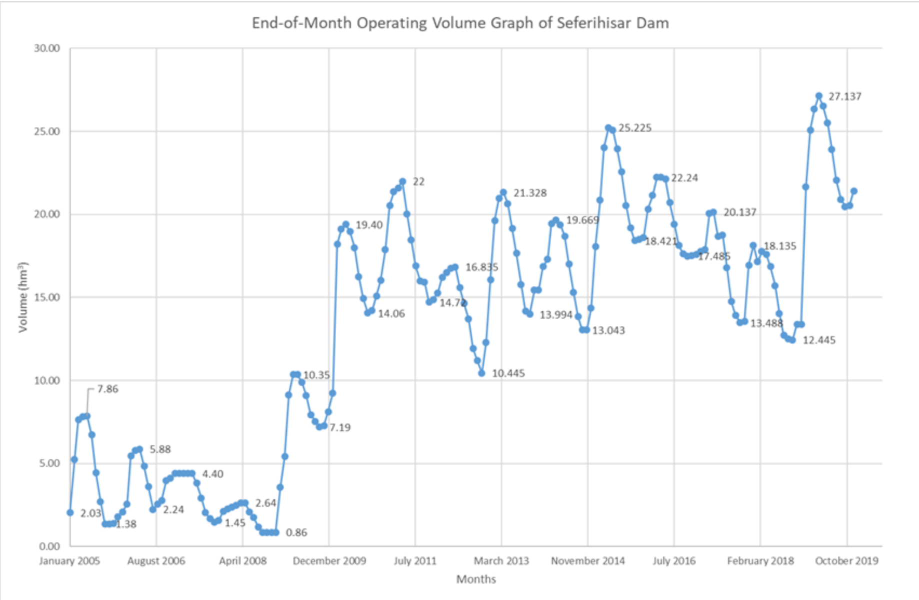

Figure 5.6. Seferihisar Dam's End-of-Month Operating Volumes

Flow data, which is the amount of water coming from Yassıçay to the dam’s lake, was converted into cubic meters per second and entered into the program.

After this step, the necessary data for the Seferihisar dam has been transferred to the program. 34.2 hm^3 Storage Capacity and the volume value at the end of December 2004 (2.64 hm^3) Initial Storage values were entered the WEAP. Volume Elevation Curve values are arranged with the data taken from Küçük Menderes Basin Master Plan Final Report. Net Evaporation and Observed Volume values were also obtained from the same source.

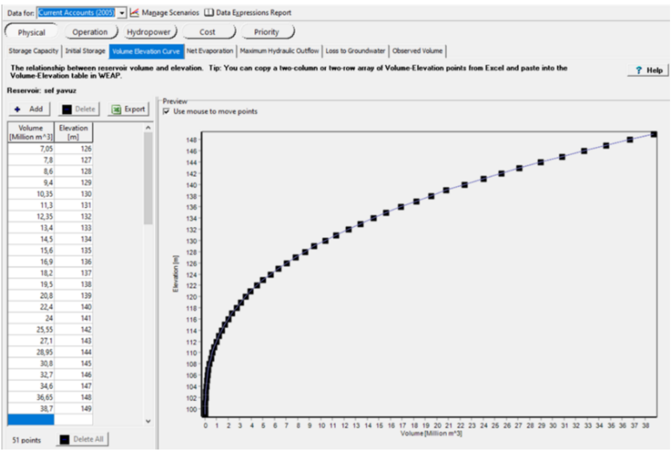

Figure 5.7. Volume Elevation Curve for Seferihisar Dam

Seferihisar Dam Irrigation has a net area of 1200 hectares. Therefore, while editing data for irrigation, under the Annual Activity title, the unit was first changed to

Area-Hectare, and irrigation data was used after this. The values under the irrigation heading in the data file obtained from State Hydraulic Works were collected and converted into irrigation water need. Under the other uses heading in the data file, the values were transferred to the Other Uses of Seferihisar demand point. The annual total amount of water consumed was distributed on a monthly basis. The information on how many percent of water was consumed per month was transferred to the program for Monthly Variation.

Figure 5.8. Monthly Variation of Seferihisar Irrigation

After the necessary data entry process for Seferihisar Dam was completed, the calibration model was run. The graphic resulting from the model is as in Figure 5.9. The curve with the triangle shapes represents the field data, and the curve with the square shapes represents the model results.

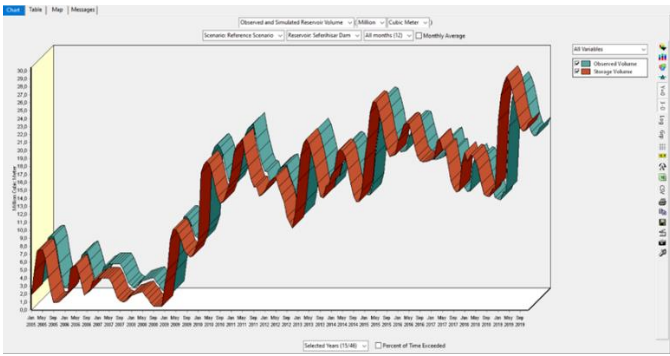
Figure 5.9. Observed and Simulated Reservoir Volume for Seferihisar Dam

As shown in Figure 5.9 the two graphs follow each other in the same pattern, and the values are very close to each other. The graphic values obtained after the model run are exported to Excel. RMSE, NRMSE, NSE coefficient, and PBIAS values were calculated between these two data sets (observed and simulated), and the results are given at the end of the calibration part.

5.2.3. Tahtalı Dam

The second-largest water potential building in İzmir is the Tahtalı Dam. For this reason, it is important to calibrate this dam and to give results compatible with real life in terms of planning the drinking water of İzmir in the future.

When creating the calibration model, the end-of-month operating volumes of the Tahtalı Dam's master plan final report and the data obtained from the State Hydraulic Works were compared, and a big difference was observed. To ensure the data at hand, the calibration was carried out in line with these data using the data obtained from the State Hydraulic Works.

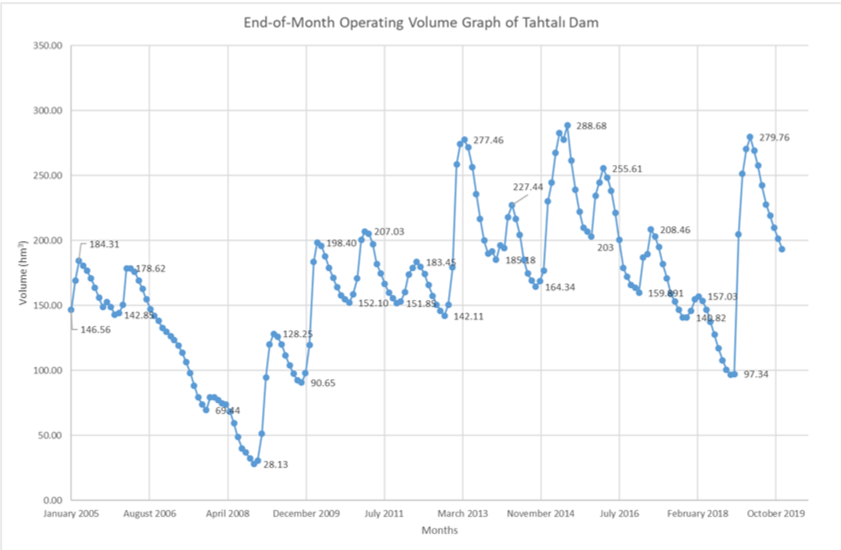

Figure 5.10. Tahtalı Dam's End-of-Month Operating Volumes

While the Tahtalı Dam was created in the model, first of all, Tahtalı Stream and Şaşal Stream were drawn, and the dam was placed on them. After completing the drawing process of streams, the unit of the monthly amount of water coming into the lake has been changed. For the Storage Capacity value, a value of 306.7 hm^3, and for the Initial Storage value, 146.56 hm^3 has been entered into the program.

The Volume Elevation Curve and Net Evaporation values were entered in line with the values in the master plan report. Finally, current month-end operating volumes were used for the observed volume values.

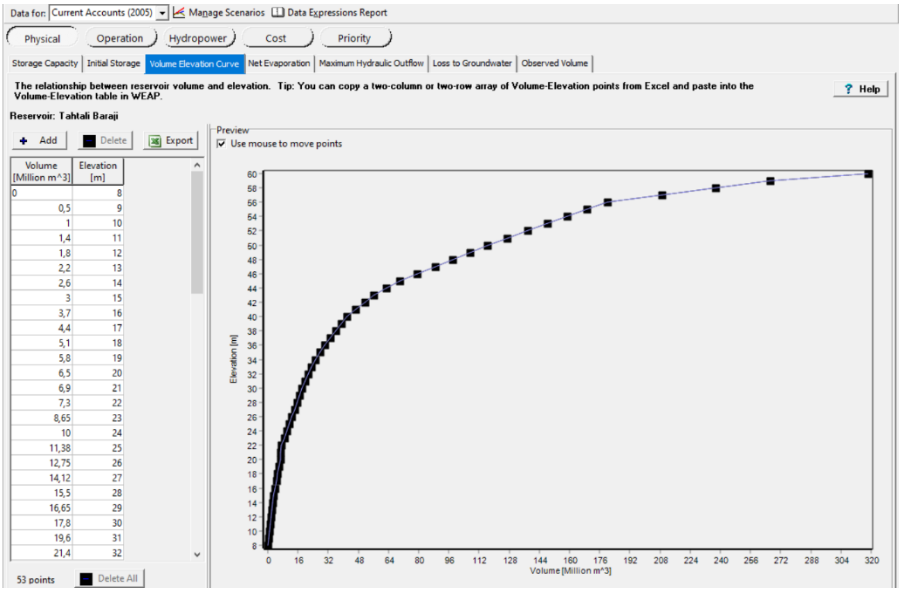

Figure 5.11. Volume Elevation Curve for Tahtalı Dam

Monthly variations are observed while drinking water is being supplied to İzmir province from the dam. The annual water consumption is distributed according to these monthly variations. Although Tahtalı Dam is for drinking water purposes, the water released from the dam lake is used for irrigation. Gümüldür Cooperative Irrigation, located downstream of the dam, uses this water and covers an area of 882.5 hectares. Since irrigation water needs will vary monthly, this variability is also transferred to the program, and it is assumed that the same crops are grown throughout the calibration model.

When the consumptions under the irrigation heading in the maintenance and operation data file are used for irrigation water, the amount of water withdrawn under the flood heading was transferred to the Other Uses of Tahtalı Dam demand point. The drawn water was conveyed to downstream of the dam from that demand point.

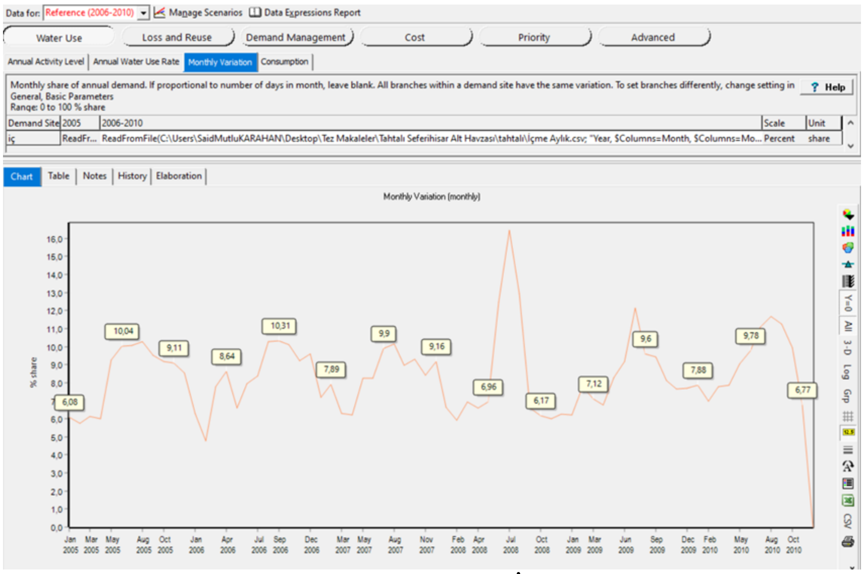

Figure 5.12. Monthly Variations of İzmir's Drinking Water

After entering the necessary data for the Tahtalı Dam, the calibration model was run, and the observed month-end operating volumes were compared with the result volume values created by the model. The values in the resulting graph were converted into hm^3 and the RMSE, NRMSE, NSE coefficient, and PBIAS values were calculated. The comparison graph of the volumes can be seen in Figure 5.13.

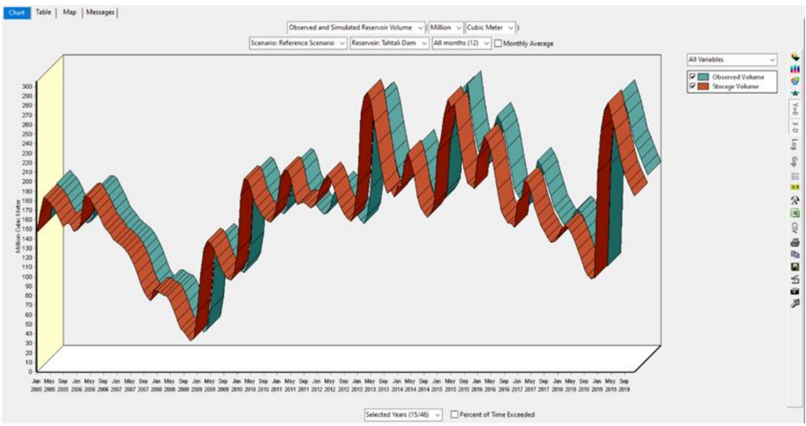

Figure 5.13. Observed and Simulated Reservoir Volume For Tahtalı Dam

As can be seen from the graph formed as a result of the calibration model of Tahtalı Dam, the observed and simulated values follow each other. This shows the success of WEAP in reservoir modeling.

5.2.4. Kavakdere Dam

The dam was constructed in 2006, and according to the data obtained from the State Hydraulic Works for the Kavakdere Dam, the end-of-month operation volume graph for the years 2007-2019 is given in Figure 5.14.

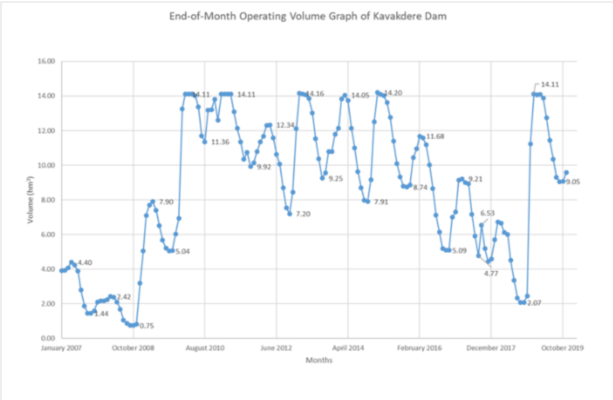

Figure 5.14. Kavakdere Dam's End-of-Month Operating Volumes

As stated at the beginning of the calibration section, the time range of the data selected for the Kavakdere Dam is between 2007 and 2019 were used because the flow data entered for the dam starts from April 2006.

Based on the information obtained, the calibration year was changed as mentioned earlier, and the river tool was selected in the program in the schematic screen view, and Kavakdere Stream was drawn. After the drawing was completed, the flow data were transferred to the model, and the Kavakdere Dam was placed in the Schematic View with the drag and drop method.


Figure 5.15. Kavakdere's Flow Values

The storage capacity (14.1 hm^3) was entered to the program and, for the initial storage, the December value of 2006, which is 3.91 hm^3 was used. Net Evaporation and Observed Volume values were taken from the master plan report and State Hydraulics Works, respectively. All necessary data for the dam has been completed by entering the WEAP program.

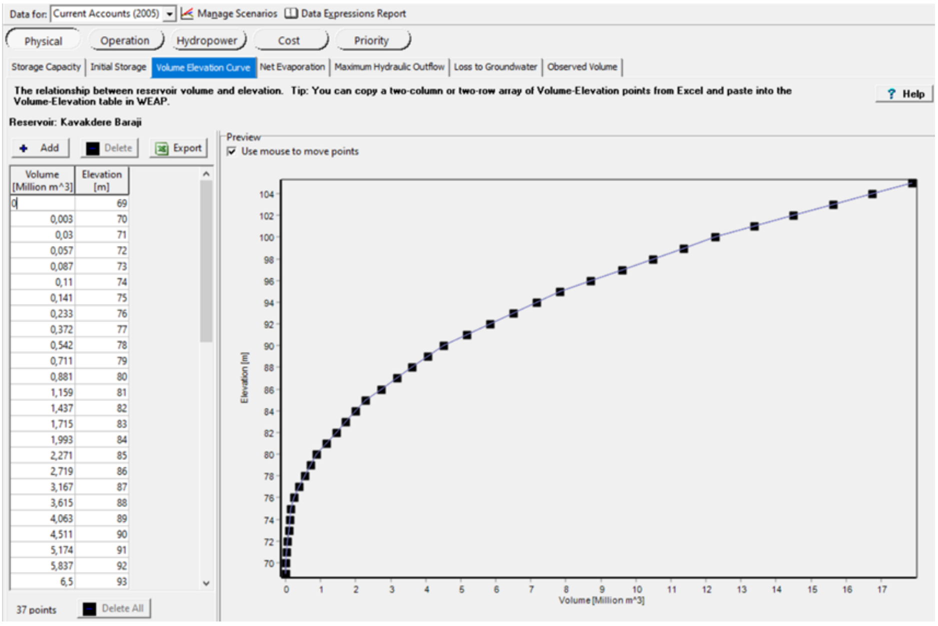

Figure 5.16. Volume Elevation Curve for Kavakdere Dam

Since Kavakdere Dam is an irrigation dam, the water drawn from its reservoir is transferred to Kavakdere Dam Irrigation. The gross area of Kavakdere irrigation is 506 hectares, and the net agricultural area is 489 hectares. During the calibration model, the net area of Kavakdere Irrigation was accepted as constant. Considering the variety of products grown in the agricultural field, it was assumed that the same agricultural products were raised throughout the period. The flood flows that would force the dam's maximum capacity were conveyed to the Other Uses of Kavakdere Dam demand point to be transferred downstream of the dam in a controlled manner.

The water needs of the products grown in Kavakdere Irrigation vary according to months. For this reason, considering the water need of each grown crop per month, the annual amount of water consumed is distributed over the months at these rates. After the irrigation water was transferred from the reservoir to the agricultural area via a transmission link, the model was also run for the Kavakdere Dam.

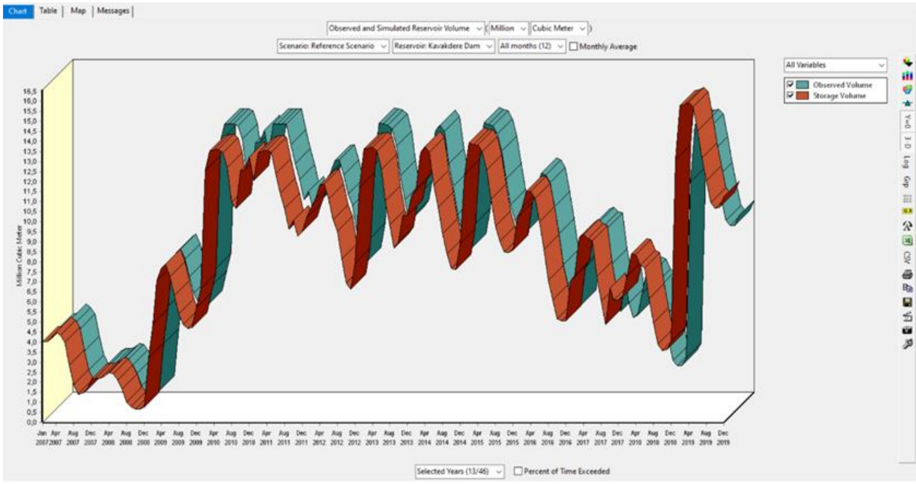

Figure 5.17. Observed and Simulated Volumes of Kavakdere Dam

As can be seen from the graph above, the graph of the observed volume values with the graph created by the program shows the same behavior.

5.2.5. Calibration Modeling of Reservoir Volumes via WEAP Results

Before the WEAP program creates simulations for future years, the calibration model was compared in terms of observed and simulated volumes of four different dams (Ürkmez, Seferihisar, Tahtalı, and Kavakdere Dams) located in the Tahtalı-Seferihisar Sub-Basin. Throughout the model period, the surface areas of the agricultural lands and the types of crops grown were fixed for each dam providing irrigation. Since the irrigation water needs in the Küçük Menderes Basin Master Plan Final Report are calculated considering transmission losses, no transmission loss has been identified in the calibration model. For dams supplying drinking water, the monthly amount of water withdrawn varies according to the seasons, so the annual total amount of water consumed was distributed to monthly percentages and transferred to the program accordingly.

In the calibrated model, it can be seen for all four dams that the graphs created for the observed and simulated volumes follow the same pattern for each dam. This shows how well the WEAP program works. The data constituting the graph was exported from the WEAP program to Excel, and the model performance evaluation values (RMSE, NRMSE, NSE coefficient, and PBIAS value) were obtained for each dam.

The Root Mean Square Error (RMSE) indicates how the residuals between the model and the observed values are distributed or how concentrated the data is around the line of best fit. The RMSE value can vary from 0 to ∞, and the closer to 0 it is, the better the model results. The RMSE value is calculated as given in Eq (4.1).

$$RMSE = \sqrt{\frac{\sum_{t=1}^{T}\left({Volume_{Observed}}^{t} - {Volume_{Model}}^{t}\right)^{2}}{T}} \tag{4.1}$$

where ${Volume_{Observed}}^{t}$ is the observed volume at a given time step

${Volume_{Model}}^{t}$ is the modeled volume at a given time step

T is the data size

After calculating the root mean square error, the normalized root mean square error (NRMSE) value was calculated for each dam. There is no specific rule for normalization in the literature. Therefore, in this study, the RMSE values were normalized using the formula given below and expressed as a percentage. The NRMSE can be interpreted as part of the overall range, with lower values indicating less residual distribution.

$$NRMSE = \frac{RMSE}{Volume_{observed_{max}} - Volume_{observed_{min}}} x100 \tag{4.2}$$

where $Volume_{observed_{max}}$ is the observed maximum value in the time interval

$Volume_{observed_{min}}$ is the observed minimum value in the time interval

In order to evaluate the model performance, Nash Sutcliffe efficiency/coefficient (NSE) values and percent bias/deviation (PBIAS) values were calculated separately for each dam. NSE coefficient takes a value between −∞ and 1. In the literature, the NSE value between 0 and 1 is at an acceptable level, the closer the value to 1, the better the model performance is achieved (Nash ve Sutcliffe 1970) (Yaykiran, Cuceloglu ve Ekdal 2019). NSE coefficients were calculated for each dam according to Eq. (4.3).

$$NSE = 1 - \frac{\sum_{t=1}^{T}(V_{model}^{t} - V_{observed}^{t})^2}{\sum_{t=1}^{T}(V_{observed}^{t} - \overline{V_{observed}})^2} \tag{4.3}$$

PBIAS ranges from -∞ to +∞. For the PBIAS value, it can be said that the closer the result is to 0, the more successful the model works. If the PBIAS value is greater than zero, it means the model is overestimating, but if the PBIAS value is less than zero, it means underestimation (Moriasi, and others 2015). PBIAS values are calculated as given by Eq. (4.4).

$$PBIAS = \frac{\sum_{t=1}^{T}(V_{observed}^{t} - V_{model}^{t})}{\sum_{t=1}^{T}(V_{observed}^{t})} x100 \tag{4.4}$$

where $V_{observed}^{t}$ is the observed volume at a given time step

V_{model}^{t} is the modeled volume at a given time step

$\overline{V_{observed}}$ is the mean of observed volumes

Table 5.1. Model Performance Evaluation Values for Each Dam (hm^3)

Dams	RMSE Values	NRMSE Values (%)	NSE Values	PBIAS Values (%)
Ürkmez Dam	0.79	10.26	0.85	-11.63
Seferihisar Dam	0.92	3.50	0.98	-2.00
Tahtalı Dam	8.29	3.18	0.98	-1.78
Kavakdere Dam	0.76	5.65	0.97	-0.59

The root mean square error (RMSE), normalized root mean square error (NRMSE), Nash Sutcliffe efficiency/coefficient (NSE), and percent bias/deviation (PBIAS) values were found to determine the performance of the calibrated model is acceptable and desired levels, which shows that the program works quite successfully.

It is not a coincidence that the dam with the highest RMSE value is Tahtalı Dam. When Tahtalı Dam is compared with other dams in terms of volume, it covers quite a lot of volumetric area. For this reason, the difference between the observed and simulated values is higher than the other reservoirs, and the RMSE value is higher than that.

The smaller the normalized root mean square error value means, the less residual variance is observed between the values created by the WEAP model and the observed values. In other words, there is not much difference between the observed and simulated values. As can be seen in Table 5.1, NRMSE values are in the almost same range for each dam as a percentage.

As stated before, the NSE value close to 1 shows how successful the model is. In this study, the NSE value of Seferihisar and Tahtalı Dams was found to be 0.98 and the most successful result were obtained. All dams were less than 0 according to the PBIAS value, which means the model has underestimated for these reservoir areas. The dam with the PBIAS value farthest from zero is the Ürkmez Dam with a value of -11.63. Even for the Ürkmez Dam, the PBIAS value is still at an acceptable level in percentage terms.

In short, in line with the calculations made to observe the model performance, it is accepted that the WEAP program will yield a very successful approach for the simulations created for future years.

5.3. Creating the Tahtalı-Seferihisar Sub-Basin Model with WEAP Program

In order to model the Tahtalı-Seferihisar Sub-Basin in the WEAP program, shapefiles showing the sub-basin boundary, the locations of streams, dams and ponds, irrigation areas, and wells were added to the model after the successful results of the calibration model. Then, the map bases are transferred, the model is created using the WEAP modeling tools. The point that should not be forgotten while transferring shapefiles to the model is that the layers added for the model are transferred to the program only visually. Any information carried by the layers is not taken to the program. If it is desired to carry the information in the layers to the model, this process is performed using the modeling tools of WEAP.

In Figure 5.18, there is a schematic view created by adding the required shapefiles for the sub-basin to the program and using the modeling tools.

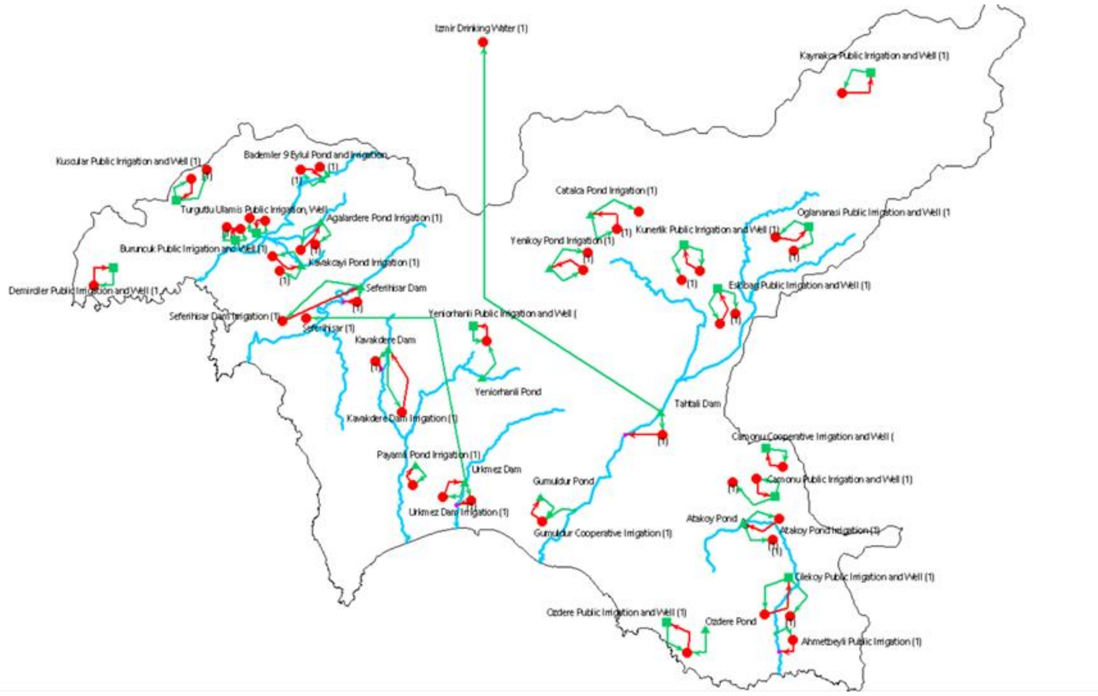

Figure 5.18. Schematic View of Tahtalı-Seferihisar Sub-Basin on WEAP program

The schematic view shows that the streams, irrigations, reservoirs, demand points, transmission links, and return flows within the basin boundaries are defined. Scenarios can be started for the design created as a result of entering the necessary information into each model tool used for modeling. An example of the information to be transferred to the model for agricultural areas: the total irrigation area (ha), the percentage area distribution of the products grown, the monthly percentage water distribution information should be entered as well as the information on how many m^3 of water the products consume per hectare. Flow data for streams, capacity values, volume-elevation curve, net evaporation, and observed volume values for reservoirs are used. These can be given as examples of information to be entered into the model.

CHAPTER 6

CREATION OF SCENARIOS

6.1. Baseline Year (2005)

The WEAP program aims to create scenarios and work on these scenarios and gives the user an idea about the results by comparing the changes made in the designs. While creating the strategies, the year chosen as the starting year of the studies is defined as "Current Accounts" in the program. The start and end years specified in the study are 2005 and 2050, respectively. Therefore, the "Current Accounts" is the year when data entries are made for the initial year 2005. The data transferred to the program for this year should reflect the actual situation of the study area. Defining the water structures that will be activated or whose construction will be completed after the baseline year can also be carried out this year. Although the ponds and water demand points, which will be completed or put into operation after the "Current Accounts" are included in the Schematic View screen of the WEAP program, no action will be taken in the program until the year they will be activated. For these structures to be put into operation and included in the calculations, the "Startup Year" values for each of them are entered into the program.

The monthly flow values of the Yassıçay Stream to Seferihisar Dam Lake in 2005 are shown in Figure 1. The flow rates entered in the program are calculated from the dam's operation-maintenance file by converting the amount of water coming into the dam lake to m^3/s monthly.

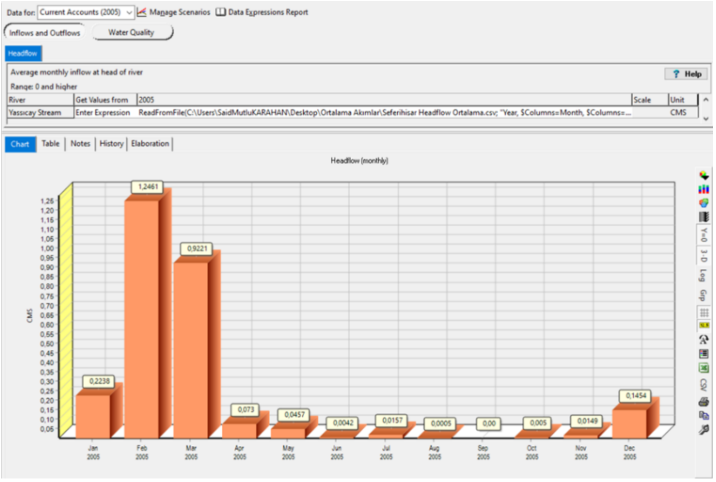

Figure 6.1. Monthly Flow Values of Yassıçay Stream in 2005 (m^3/s)

This process was repeated for other dams as well in the study area. The amount of water coming into the dam lake of each dam has been converted into monthly m^3/s and transferred to the program. Thus, the "Headflow" values of all the dam's rivers are completed in the basin.

Since the planning reports of the ponds belonging to the Special Provincial Administration are not available, the "Inflow" and "Headflow" values coming to these ponds are also unknown. (For ponds located on the streams, the program requests "Headflow" values, while for ponds not found on the streams, then it requests the "Inflow" values). Instead of assuming that the flow of these ponds, whose annual average flow values are in m^3/s, is constant, the yearly incoming flow value is calculated, and it is accepted that this value will show flow behavior in proportion to the precipitation falling on the agricultural area where the ponds will provide irrigation water. In other words, it is accepted that the flow data will be high in the months when the precipitation falling on the agricultural area is high, and it will be low in the months when it is low. The reason for accepting this situation is that the ponds and the agricultural areas where they provide irrigation water are close to each other and show similar meteorological characteristics.

The flow data entered for the baseline year (2005) of the scenario of Yeniköy Balabandere Pond, which is one of the ponds of the Special Provincial Administration in the basin, is given in Figure 6.2.

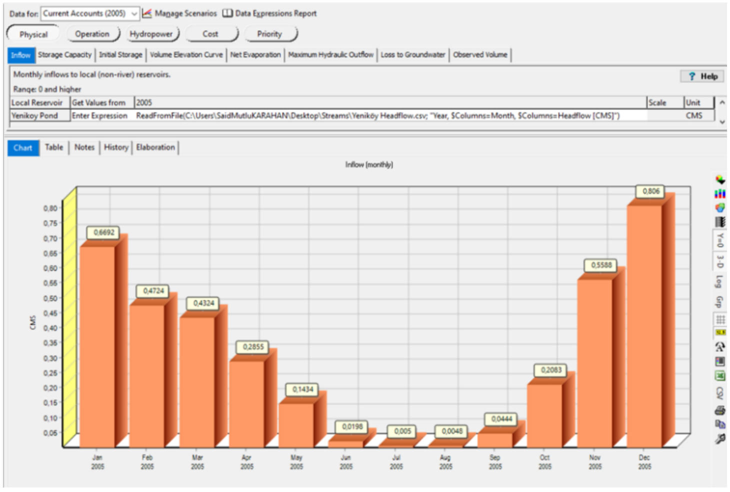

Figure 6.2. Monthly Inflow Values of Yeniköy Balabandere Pond in 2005 (m^3/s)

The information on the dams in the study area should also be transferred to the program. The information that needs to be defined for dams is Storage Capacity (the dam's maximum capacity), Initial Storage (the capacity it had in December 2004), Volume-Elevation Curve values, Net Evaporation, and finally Observed Volume values, if any. Storage Capacity, Volume Elevation Curve, and Net Evaporation values of the dams were obtained from the Küçük Menderes Basin Master Plan Final Report. Initial Storage and Observed Volume values were obtained from the operation-maintenance file of the dams got from the State Hydraulic Works (DSI). The Initial Storage value entered for the Ürkmez Dam can be seen in Figure 6.3.

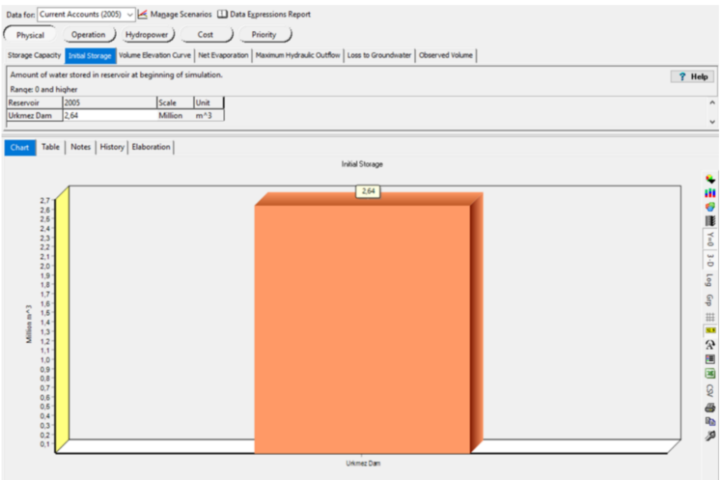

Figure 6.3. Initial Storage Volume of Ürkmez Dam

Since the ponds do not have maintenance-operation files, the "Initial Storage" values are also unknown. Therefore, to find the initial volume values, a separate model was created between 1979 and 2005, and the capacity values for December 2004 were tried to be obtained. This situation is detailed in the next section.

No capacity information (Storage Capacity, Initial Storage) is measured by the State Hydraulic Works (DSI) for the groundwater wells in the Tahtalı-Seferihisar Sub-Basin. For this reason, capacity values are equally transferred to the program based on the water requirement of the irrigation. In other words, the "Initial Storage" capacity values of the wells have been taken as equal to the irrigation water requirement of the irrigated agricultural area in the Küçük Menderes Basin Master Plan Report. Since the Storage Capacity values of the wells, that is, the maximum amount of water they can store, are not known, they can be left empty in the model. Leaving this value blank means that the capacity of the well is maximum, and it can accumulate an unlimited amount of water. Since such a situation is not possible in real life, the "Storage Capacity" values of the irrigation wells were chosen as a maximum of three times their "Initial Storage" capacity values.

Table 6.1. Initial Storage and Storage Capacity Values of Groundwater Irrigation

Irrigation Well Name	Initial Storage	Storage Capacity
Kaynakça Public Irrigation Well	5.26	15.79
Oğlananası Public Irrigation Well	30.1	90.3
Eskibağ Public Irrigation Well	1.45	4.35
Künerlik Public Irrigation Well	15.7	47.1
Çamönü Public Irrigation Well	14.69	44.07
Çileköy Public Irrigation Well	2.75	8.26
Özdere Public Irrigation Well	1.73	5.18
Yeniorhanlı Public Irrigation Well	1.49	4.46
Turgutlu Public Irrigation Well	3.24	9.73
Buruncuk Public Irrigation Well	3.93	11.79
Demirciler Public Irrigation Well	0.68	2.05
Kuşçular Public Irrigation Well	7.53	22.58
Çamönü Cooperative Irrigation Well	0.89	2.66

Figure 6.4. Initial Storage of Oğlananası Irrigation Well

The "Natural Recharge" values required for irrigation wells, on the other hand, are considered that the amount of water to be given to irrigation from the well will be proportional to the precipitation falling on the agricultural area, and the total amount of water consumed is distributed to the months with this logic. Since irrigation wells and farming areas are in regions with the same topographic characteristics and show similar meteorological factors, it is assumed that the recharge value of the well will be high in the months when the rainfall on the agricultural area is high, and it will be low in the months when the precipitation is low.

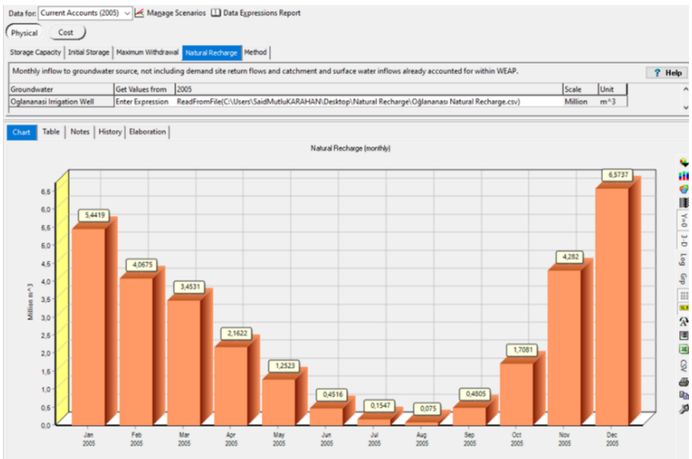

Figure 6.5. Natural Recharge Values of Oğlananası Irrigation Well

In calculating the drinking water need, the daily water consumption value per person should be known. To determine the amount of water used by a person in İzmir, the values of the Municipal Water Statistics announced by the Turkish Statistical Institute (TSI) were examined. In 2016, the amount of water used by a person in a day in Turkey was declared as 217 liters, while this value was 173 liters for the province of İzmir. According to the data announced in 2018, the average value of a person's water consumption in Turkey was 224 liters, while this value was 208 liters for İzmir. The water consumption value of a person in İzmir corresponds to approximately 80% of Turkey's average. The country average per capita daily water consumption value in 2005 was determined as 250 liters by interpolating the values in 2004 and 2006. 80% of this value was used for İzmir (200 liters). Converting this value to a person's annual water consumption value can be obtained by first converting the value in liters (l) to cubic meters (m^3) and multiplying by the number of days in a year.

Table 6.2. Daily Water Consumption Value per Person

	2004	2006	2008	2010	2012	2014	2016	2018
Water abstraction per capita in municipalities (liters/capita-day) Average of Turkey	255	245	215	216	216	203	217	224
Water consumption value per person per day in İzmir	204	196	172	173	173	162	173	208

Figure 6.6. A Person's Annual Water Consumption (m^3/person)

The drinking water values obtained from the dams also vary according to the months and seasons. While the amount of water delivered increases in the summer months, this rate is relatively minor in winter. This variability is reflected in the program with "Monthly Variation" which is one of the data types to be entered for the demand point. Monthly variation of drinking water delivered from Tahtalı Dam to İzmir's central districts (2005) is given in Figure 6.7.

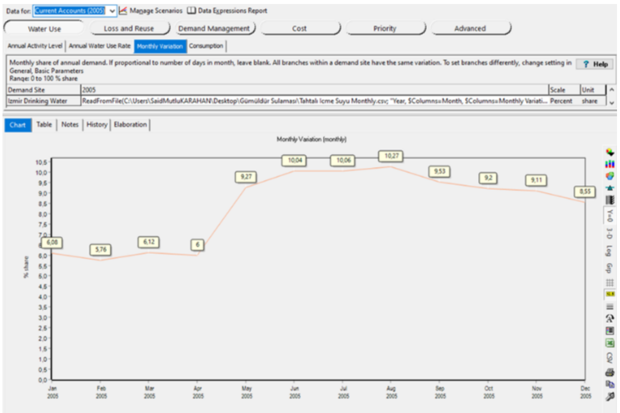

Figure 6.7. Monthly Distribution of Drinking Water Delivered to İzmir's Central Districts

The total irrigation area for agricultural areas is entered in the program in hectares (ha) and, the crops grown in the farm area were transferred to the farming areas according to their percentage values. In order to calculate the amount of water consumed by any agrarian product grown in the agricultural area, the WEAP program first determines how many hectares the product is planted on by multiplying the total irrigation area with the percentage value for that agricultural product. Then multiply the result with the "Annual Water Use Rate" (m^3/ha) entered annually. Calculates the annual water requirement of that agricultural product.

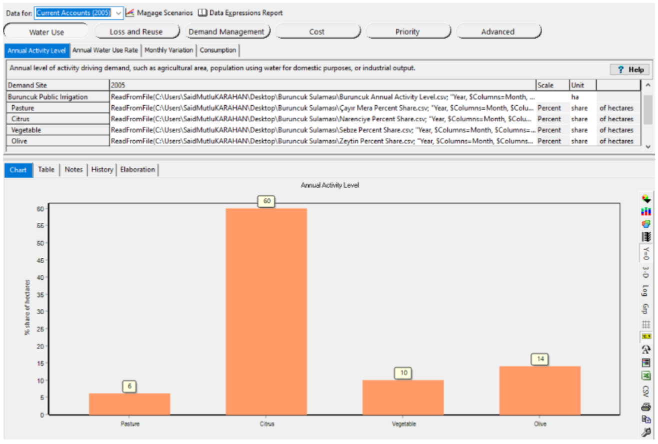

Figure 6.8. Spatial Distribution of Buruncuk Public Irrigation Crops (%)

Some agricultural areas also have greenhouses. In the study, agricultural fields and greenhouses were included in the program as separate demand points. This is because the monthly distribution of water needs of agricultural products grown in greenhouses differs considerably compared to the monthly allocation of water needs of agricultural areas.

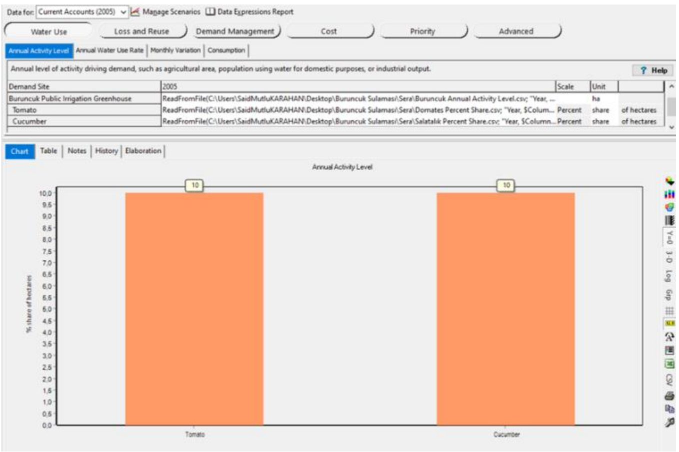

Figure 6.9. Spatial Distribution of Buruncuk Public Irrigation Greenhouse Products (%)

The water requirement values in agricultural areas vary on a monthly basis. In addition to climatic factors, this variability is also affected by factors such as crop diversity, planting and harvesting time. In the Current Accounts, water needs were calculated separately for each product grown in an agricultural area, and then the collected water needs were distributed according to monthly rates.

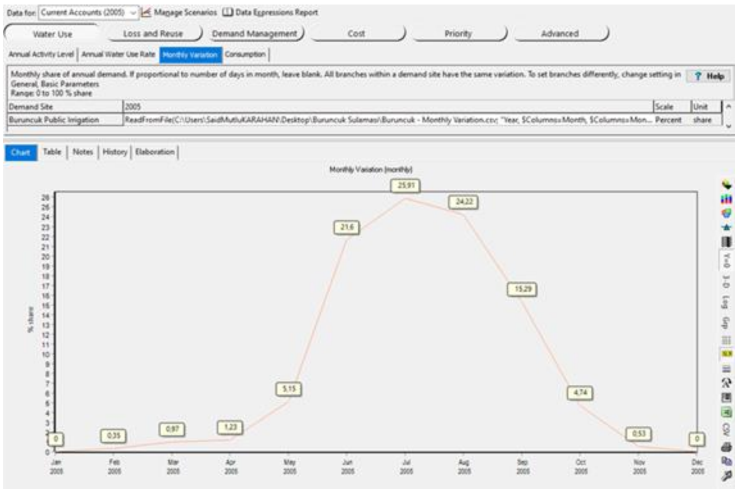

Figure 6.10. Buruncuk Public Irrigation Monthly Water Consumption Rates (%)

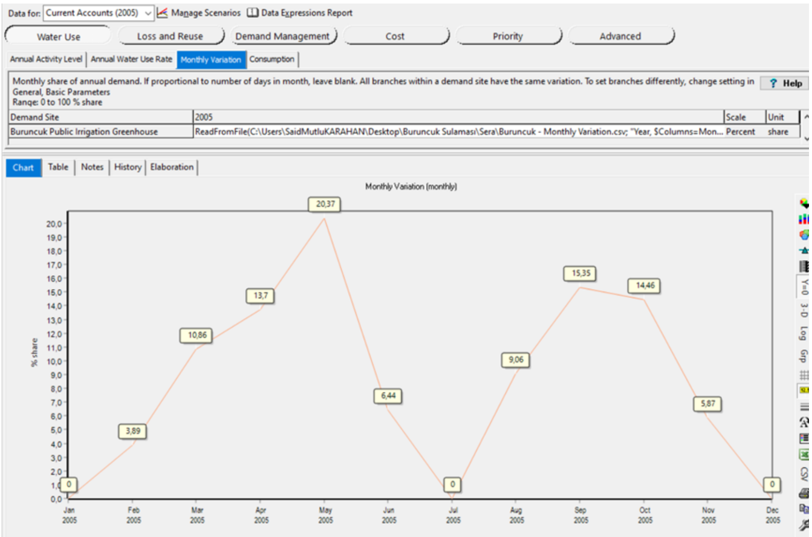

Figure 6.11. Buruncuk Public Irrigation Greenhouse Monthly Water Consumption Rates (%)

No transmission loss is defined for the agricultural areas and drinking water demand points, "Transmission Links" are used in the baseline year (Current Accounts). Because the water requirement values calculated for the agricultural areas are already the values where the transmission losses are included and found, re-defining losses in the transmission channels in the program will create additional water needs. Transmission loss is not defined in drinking water transmission lines because the values used in the study are taken from the maintenance-operation files of the dams and give the exact transmitted amounts.

6.1.1. Determination of Initial Storage Values of Ponds

There are many ponds built by the State Hydraulic Works and the Special Provincial Administration in the study area. Ponds were imported into the program using the reservoir modeling tool. Therefore, Storage Capacity, Initial Storage, Volume Elevation Curve, Net Evaporation, and Observed Volume values, if any, should be transferred to the program. The Observed Volume section is left blank because the operational data of the ponds are not available. The Storage Capacity value equals the gross volume value, the sum of the active and dead volume.

Table 6.3. List of Ponds

Name of the Ponds	The Year of Operation of the Ponds	Storage Capacity (hm^3)	Annual Average Flow (m^3/sec)
Ulamış Ağalardere Pond	1998	1.59	0.25
Ulamış Kavakçayı Pond	1985	0.94	0.134
Bademler 9 Eylül Pond	1979	0.35	0.05
Çatalca Pond	1986	0.88	0.181
Yeniköy Pond	1988	2.33	0.3
Payamlı Pond	2008	0.79	0.085
Ataköy Pond	2008	1.47	0.045
Gümüldür Pond	2018	0.65	0.05
Özdere Pond	2015	1	0.028
Yeniorhanlı Pond*	2025 (assumed)	1.53	0.042

*Since Yeniorhanlı Pond is still at the project stage, 2025 was accepted as the year of opening the pond for operation in the modeling.

"Volume Elevation Curve" values for each pond were found with the help of the QGIS program, and "Net Evaporation" values were obtained as a result of moving and correcting the meteorology station's data to the pond's location, as described in the previous sections.

For the Initial Storage values of the ponds, the construction of which was completed before 2005, the capacity values of December 2004 should be found. Since the operational data were not available, a new model was created to find the Initial Storage values of the ponds.

Figure 6.12. Model of Finding Initial Storage Values of Ponds

For ponds whose construction is completed after the scenario year, entering the "Initial Storage" value is unnecessary.

The "Headflow" and "Inflow" values of the ponds are distributed according to precipitation falling on the irrigation areas where they provide water, and values were shared in this direction. The reason for distributing flow data with this method is that ponds and irrigations show the same topographic and climatic characteristics as explained earlier.

Table 6.4. Ulamış Ağalardere Pond Monthly Headflow Values (m^3/s)

Ağalardere Stream Monthy Flow Distribution						
Average Flow (m^3/s)	Annual Average Flow (m^3/year)	Months	Monthly Average Precipitation Falling on the Ulamış Ağalardere Pond Irrigation (mm/month)	Percentage (%)	Monthly Flow Distribution Values (m^3/month)	Monthly Flow Distribution Values (m^3/s)
0.25	7884000	January	114.07	18.13	1429388	0.551
		February	95.88	15.24	1201453	0.464
		March	69.23	11	867507	0.335
		April	41.01	6.52	513888	0.198
		May	23.63	3.76	296103	0.114
		June	4.23	0.67	53005	0.02
		July	0.7	0.11	8772	0.003
		August	1.21	0.19	15162	0.006
		September	13.75	2.19	172298	0.066
		October	52.28	8.31	655110	0.253
		November	75.82	12.05	950085	0.367
		December	137.35	21.83	1721105	0.664
		Total	**629.17**		**788400**	

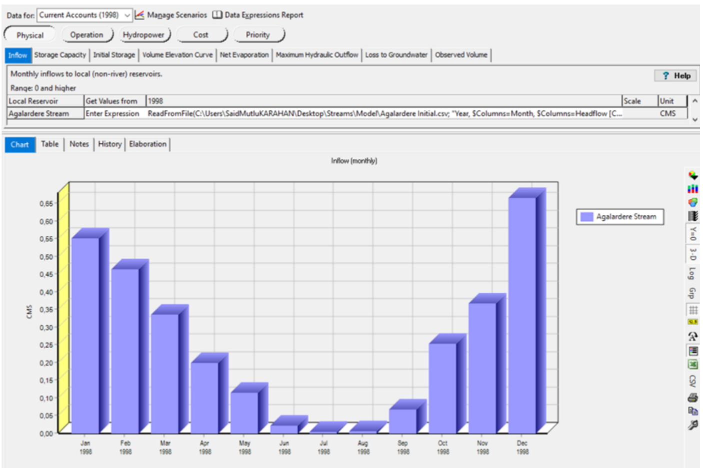

Figure 6.13. Ağalardere Stream Monthly Flow Values (m^3/s)

The process shown in Table 6.4 was repeated for the other ponds (Bademler Dokuz Eylül Pond, Ulamış Kavakçayı Pond, Çatalca Şandidere Pond, Yeniköy Balabandere Pond) whose construction was completed and opened before 2005.

By running the model created for the ponds, storage volume values were obtained for all ponds. The capacity value in December 2004 was taken from the storage volume values and used as the "Initial Storage" value in the Baseline Year scenario.

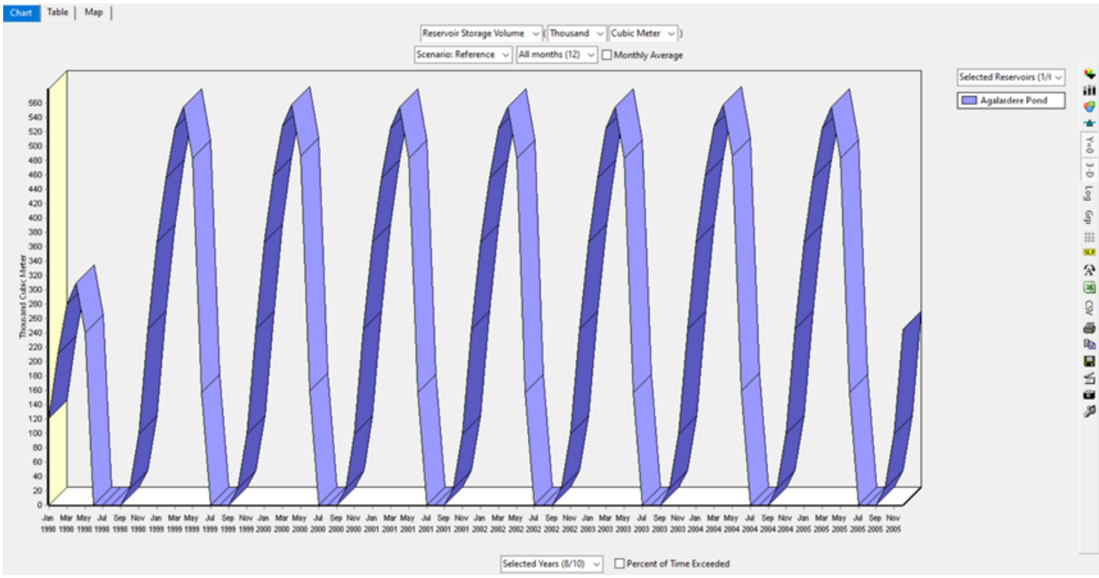

Figure 6.14. Monthly Reservoir Volume Graph of Ulamış Ağalardere Pond

As a result of the model studies, the Initial Storage values of the ponds were found as the values in Table 6.5.

Table 6.5. Initial Storage Values for the Ponds of the Special Provincial Administration

Name of the Ponds	**Initial Storage (hm^3)**
Ulamış Ağalardere Pond	1.593
Ulamış Kavakçayı Pond	0.936
Bademler 9 Eylül Pond	0.345
Çatalca Şandidere Pond	0.879
Yeniköy Balabandere Pond	2.325

6.2. The Scenarios used in Simulations

The Water Evaluation and Planning program basically aims to create scenarios and make inferences by comparing the results of simulations with each other. For this reason, a total of sixteen scenarios were created in the study, and five of these scenarios (Reference Scenario, Report Consumption Scenario, Best Case Scenario, Return Flow Scenario, and Worst Case Scenario) can be referred as the main scenarios. On the other hand, the remaining scenarios are based on the question of what percentage of the population's need for drinking water to be supplied from Tahtalı Dam to the central districts of İzmir (Balçova, Bayraklı, Bornova, Buca, Çiğli, Gaziemir, Güzelbahçe, Karabağlar, Karşıyaka, Konak, Narlıdere) in 2050.

Reference Scenario is the main scenario and constitutes, a basis for others. In this scenario, data from 2005-2019 available for the study were used. It is assumed that results close to the average values of these data will be obtained in the future. Average values for streamflow rates were taken, and these data were used throughout the scenario. For the net evaporation values of the dams, the long-term averages in the Küçük Menderes Basin Master Plan Final Report were used.

On the other hand, the net evaporation values of the ponds with planning reports are taken from the ponds' planning reports. The net evaporation values prepared following the basin master plan report were used for the ponds without planning reports. In this scenario, initial storage volumes for groundwater wells were chosen according to their agricultural areas' water needs. The recharge values of the wells are equal to the amount of water they transmit for irrigation and proportionally distributed to the amount of rainfall per month of the agricultural area where they irrigate.

The Küçük Menderes Basin Master Plan Final Report was used for the size of the irrigation areas of the agricultural lands and the diversity of the cultivated products.

In this section, The Turkish Bank of Provinces Method has been used for the population projection required for the coming years. The values published by the Turkish Statistical Institute (TSI) were used for the per capita daily water consumption value.

The Report Consumption Scenario (RCS) is a scenario created for irrigation of dams and groundwater wells. This scenario was considered due to the differences between the irrigation water needs of the dams given in the master plan report and the irrigation water amounts in the operation-maintenance data of the dams. It was created to investigate the difference between these two reported conditions. It was designed for groundwater wells because the recharge values are not equal to the consumption amounts as in the Reference Scenario. For the recharge values, the efficient groundwater recharge amount is given in the report is shared with other consumptions, and the remaining amount is accepted as the total groundwater recharge value of the basin. Other conditions are planned to be the same as the Reference Scenario.

The Best Case Scenario is the scenario in which the best conditions for the basin are accepted. Flow rates calculated with the Autoregressive Integrated Moving Average (ARIMA) method have been used for the possible future values of the flow values coming to the dams. The reason for choosing this method is that an increase in the trend values of the time series data of the flows is observed. For the net evaporation values of dams and ponds, it is assumed that values will be 20% less than the average values. In this case, it has been accepted that the groundwater recharge amount of Tahtalı-Seferihisar Sub-Basin, which is included in the master plan report, will be shared only by the irrigation wells. The Average Growth Rate Method, which gives less population value in 2050 compared to other scenarios, was used for the population projection. The amount of water use per person has been reduced by 20% based on the assumption that people will reduce their water consumption amounts by acting more consciously in the future. For the water consumption values of the agricultural areas, the values in the Küçük Menderes Master Plan Final Report are accepted for the irrigations where they have reduced water consumption. Since it is assumed in the report that the need for irrigation water for public irrigation will be the same in the future, it is assumed that they will consume less water by eliminating transmission losses for public irrigation in this scenario.

The Return Flow scenario is basically based on the Reference Scenario. In this case, and the main difference is that 20 percent of the water supplied for irrigation will return to the water source and can be used as a source for irrigation demand. Other conditions are also considered to be the same as the Reference Scenario.

The Worst Case Scenario is where the occurrence of the worst conditions are assumed for the study area. In this situation, the flow data of the streams are reduced by 20% relative to their average value, and it is expected that the net evaporation values that will occur in water structures due to global warming will increase by 20%. For the recharge values of the groundwater wells, the severe drought situation in the Küçük

Menderes Basin Sectoral Water Allocation Action Plan Report was taken into account, and this value was distributed according to the water consumption values of the irrigation wells. The population projection was calculated with The Turkish Bank of Provinces Method, and the daily water consumption value per capita was increased by 20% compared to the average. In this scenario, the annual water requirement of each agricultural product grown in farming areas was increased by 20%, assuming that the losses in the transmission channels would increase.

6.3. Reference Scenario

The Reference scenario is the situation where the scenario is continued until 2050 by using the data obtained from the State Hydraulic Works (DSI) and the Küçük Menderes Basin Master Plan Final Report. This is the procedure in which the information obtained between 2005-2019 is used, and the averages of these data will be taken in the next year's scenarios. This scenario aims to create a basis of the other scenarios and to determine the future of the basin under average conditions by using the averages of the available data.

Since the flows to the dam lakes are monthly and in hm^3/month, unit changes were made on these data and converted to m^3/s. The information of the flows coming into the reservoir lake is available until 2019. Since there is no estimation for the following years, the averages of the flow data were taken, and these average values were used. Flow data of ponds are already annual average values; only unit changes were made and distributed monthly with respect to precipitation values and continued throughout all years in the scenario, as shown in the previous section.

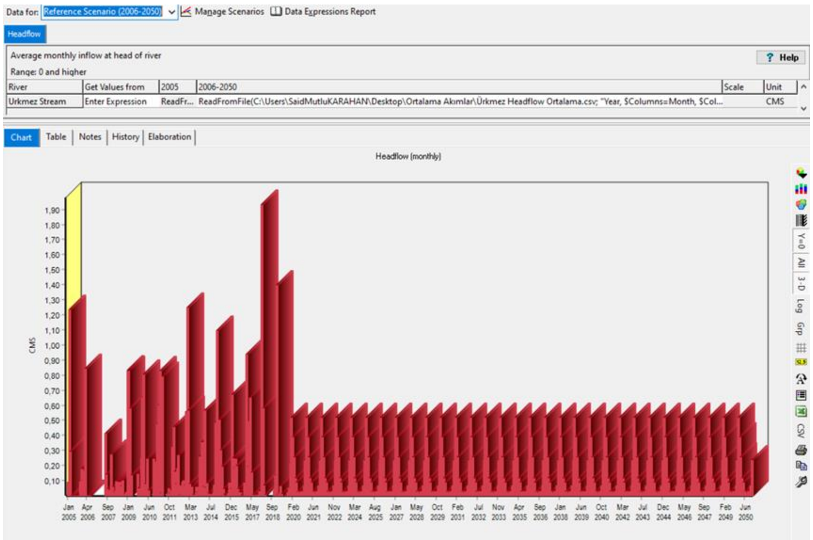

Figure 6.15. Flow Rates of Ürkmez Stream between 2005-2050 (m^3/s)

Küçük Menderes Basin Master Plan Final Report has long-term average Net Evaporation values for dams (Tahtalı, Ürkmez, Kavakdere, and Seferihisar Dams). These values have been left as they are and transferred to the program. For the Net Evaporation values in the ponds, the average net evaporation values obtained from the existing planning reports of the ponds whose construction has been completed or will be completed by the State Hydraulic Works (DSI) are used. The values of the ponds whose construction was completed by the Special Provincial Administration were calculated as described in the Methodology section. It was assumed that the same values continued throughout the scenario years.

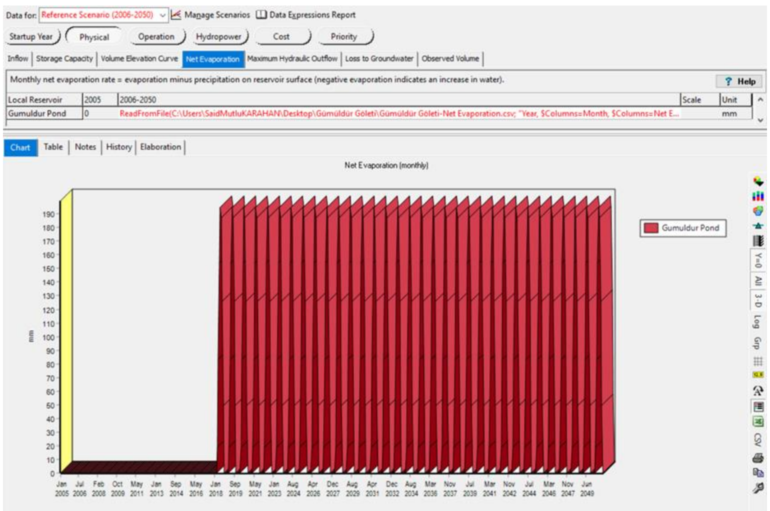

Figure 6.16. Gümüldür Pond Net Evaporation Values (mm)

For the irrigation wells in the study area, the Initial Storage values were chosen as the capacity of the agricultural area's water demand to meet the water needs of the place they irrigate. Storage Capacity for an aquifer (the maximum amount of water it can store) was chosen three times the Initial Storage value in the Baseline Year.

During the scenario, the Natural Recharge value was entered as the amount of water consumed so that there would be no problem with the water adequacy of the irrigation wells.

Since the Natural Recharge values defined for the irrigation wells will be directly proportional to the monthly rainfall distribution on the agricultural areas where the wells provide water, the recharge values are distributed proportionally to the months.

Table 6.6. Monthly Distribution of Natural Recharge Values for Kaynakça Public Irrigation

Natural Recharge (hm^3)	Months	Monthly Average Precipitation (mm/month) Kaynakça Public Irrigation	Percentage (%)	Monthly Natural Recharge Distribution Values (m^3/s)
5.263	January	83.45	16.52	0.869
	February	58.64	11.61	0.611
	March	60.28	11.93	0.628
	April	43.75	8.66	0.456
	May	25.23	4.99	0.263
	June	9.29	1.84	0.097
	July	1.81	0.36	0.019
	August	1.24	0.25	0.013
	September	11.17	2.21	0.116
	October	31.05	6.15	0.324
	November	79.61	15.76	0.829
	December	99.67	19.73	1.038
	Total	**505.19**	**100**	**5.263**

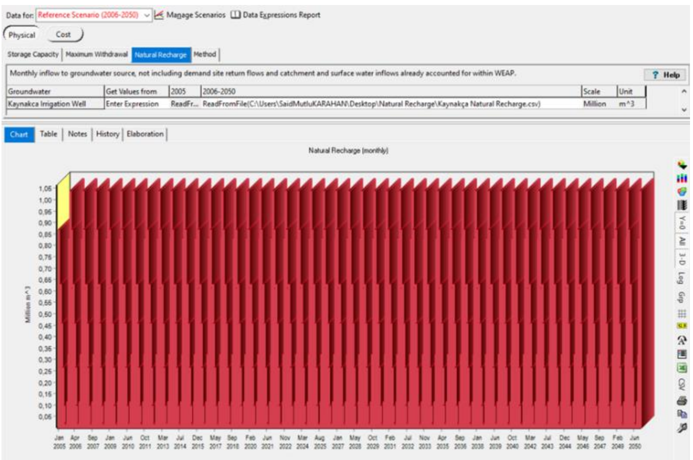

Figure 6.17. Natural Recharge Values of Kaynakça Public Irrigation (hm^3)

Tahtalı Dam and Ürkmez Dam are dams that provide drinking water. For this reason, population projections should also be made in order to meet the drinking water demand. In this scenario, the Turkish Bank of Provinces Method was used for population projection. Tahtalı Dam meets approximately 40 percent of the drinking water demand of 11 central districts (Balçova, Bayraklı, Bornova, Buca, Çiğli, Gaziemir, Güzelbahçe, Karabağlar, Karşıyaka, Konak, Narlıdere). Ürkmez Dam is one of the critical sources providing drinking water to Seferihisar. For this reason, it should also be determined how much of the dam will meet the population's water needs in the future.

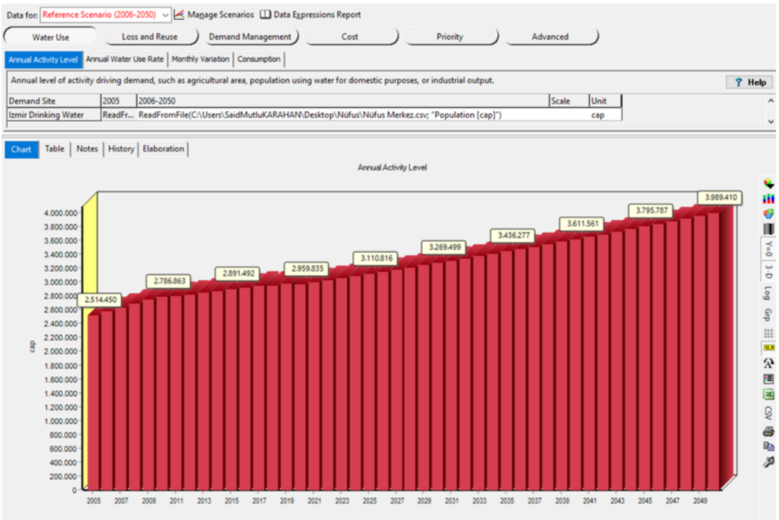

Figure 6.18. Population Values of 11 Central Districts of İzmir Between 2005-2050

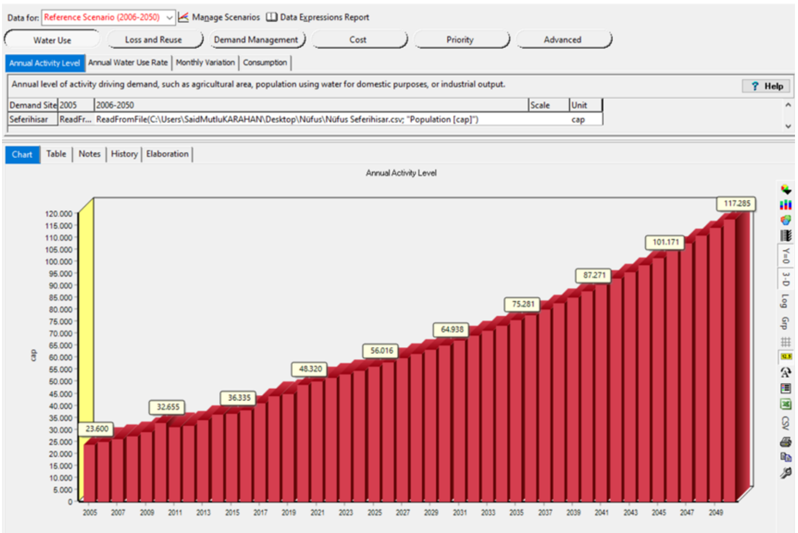

Figure 6.19. Population Values of Seferihisar Between 2005-2050

In Tahtalı-Seferihisar Sub-Basin, no change has been made on the total irrigation area of agricultural lands in hectares in all of the dam irrigations under the control of the State Hydraulic Works, the irrigation of the Special Provincial Administration, and the public irrigations.

Figure 6.20. Ürkmez Dam Irrigation Total Area (ha)

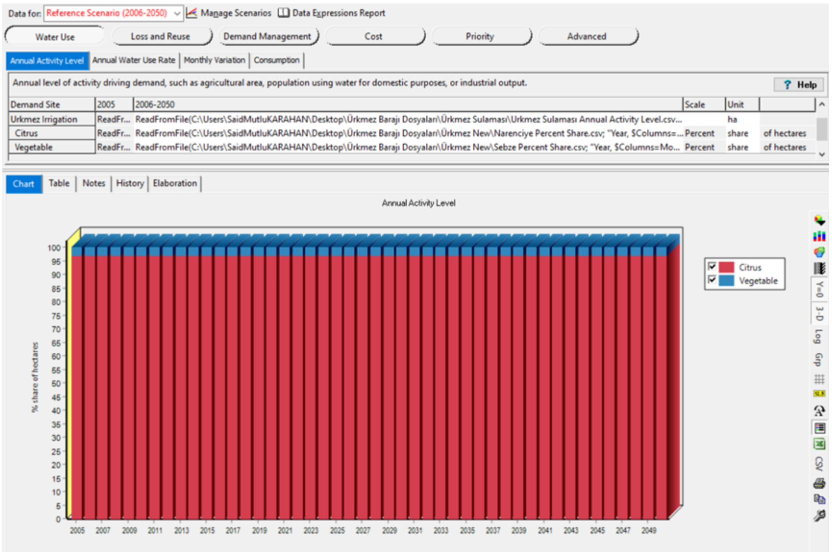

Figure 6.21. Spatial Distribution of the Crops Grown in Ürkmez Dam Irrigation

The water abstraction per capita in municipalities (liters/capita-day) value obtained from the Turkish Statistical Institute (TSI) was used to calculate the daily water consumption value per capita for İzmir as mentioned earlier in Baseline Year. The calculated values for the daily amount of water used by a person in İzmir for 2016 and 2018 are 173 and 208 liters, respectively. The data of the missing years were completed by interpolating to the average values of Turkey, and approximately 80 percent of the values found were reflected in the program as the daily water consumption of a person in İzmir.

If the unit of water consumed daily by a person is converted from liter to m^3 and multiplied by 365, which is the number of days in a year, the annual amount of water consumed by a person can be found in m^3/person.

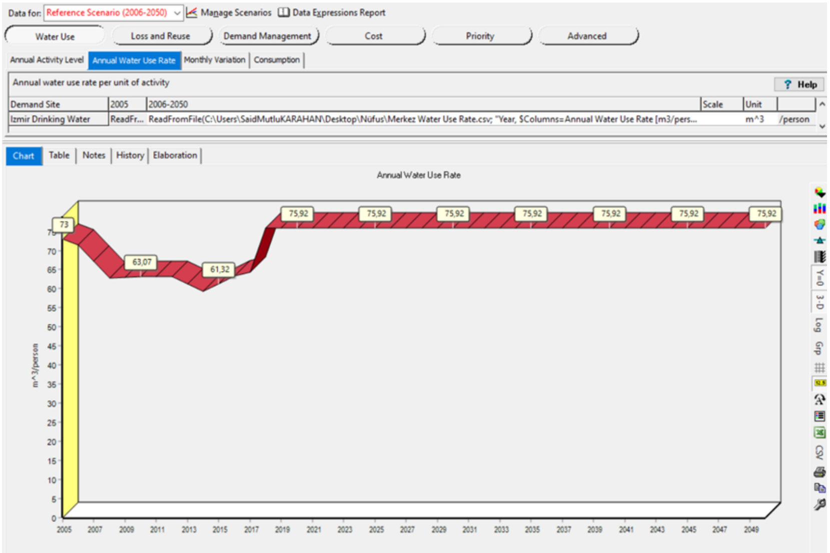

Figure 6.22. Annual Amount of Water Consumed by a Person (m3/person)

6.4. Report Consumption Scenario (RCS)

The Report Consumption Scenario is basically a scenario created for dams and groundwater wells. The purpose of creating this scenario is to apply the irrigation water consumption values given in the Küçük Menderes Master Plan Final Report for dams and to find the variability in the volume values of the dams, as well as to observe the change in the well capacities as a result of the distribution of the natural recharge values of the groundwater wells based on the general recharge amount in the same report. In this scenario, the data between 2005 and 2019 were used, from 2019 to 2022 the average values were used, after this year, changes were made to see the variability compared with other scenarios.

The current state water consumption values were used in the Küçük Menderes Basin Master Plan Final Report in this scenario. Because when looking at the dam operation data obtained from the State Hydraulic Works (DSI), the need for irrigation water supplied from dams varies according to years. In other words, the need for irrigation water cannot be fully met in some years, while more than the need for irrigation water is used in some years. However, since the current state water consumption values in the report fully express the amount of water needed for irrigation. So, this is the scenario where the amount of water required for irrigation is drawn precisely during the procedure.

Table 6.7. Report Consumption Values of Agricultural Fields (hm^3)

Special Provincial Administration Irrigation Name	Current State Water Consumption (hm^3)
Çatalca Sandidere Pond Irrigation	0.8
Yeniköy Pond Irrigation	0.66
Payamlı Pond Irrigation	0.63
Kavakçayı Pond Irrigation	0.53
Ağalardere Pond Irrigation	1.24
Bademler 9 Eylül Pond Irrigation	0.98
State Hydraulic Works Irrigation Name	**Current State Water Consumption (hm^3)**
Ürkmez Barajı Irrigation	4.17
Seferihisar Barajı Irrigation	10.21
Ataköy Irrigation	1.06
Kavakdere Irrigation	5.17
Name of the Public Irrigation	**Current State Water Consumption (hm^3)**
Kaynakça Public Irrigation	5.26
Oğlananası Public Irrigation	30.1
Eskibağ Public Irrigation	1.45
Künerlik Public Irrigation	15.7
Çamönü Public Irrigation	14.69
Çileköy Public Irrigation	2.75
Özdere Public Irrigation	1.73
Yeniorhanlı Public Irrigation	1.49
Turgutlu Ulamış Public Irrigation	3.24
Buruncuk Public Irrigation	3.93
Demirciler Public Irrigation	0.68
Kuşçular Public Irrigation	7.53
Ahmetbeyli Public Irrigation	0.78
Name of the Cooperative Irrigation	**Current State Water Consumption (hm^3)**
Çamönü Cooperative Irrigation	0.89
Gümüldür Tahtalı Cooperative Irrigation	5.48

In this case, stream flows are completed throughout the scenario using average flow data as in the Reference Scenario. The average flow values of Yassıçay Stream, which supplies water to Seferihisar Dam, are given in Figure 6.23.

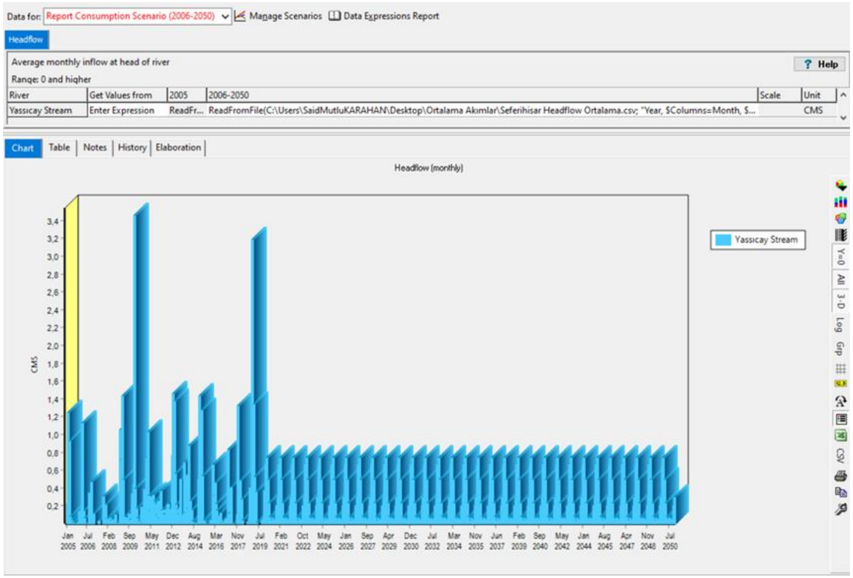

Figure 6.23. Average Flow Values of Yassıçay Stream (m^3/s)

For Net Evaporation values, average data were used for dams and ponds. The average evaporation values found in the Küçük Menderes Basin Master Plan Final Report were used. To calculate monthly net evaporation values of Seferihisar Dam, precipitation data of Beyler Meteorology Station and average temperature values of Seferihisar Meteorology Station were used, and the average temperature values were used by moving them to the elevation of Beyler Meteorology Station.

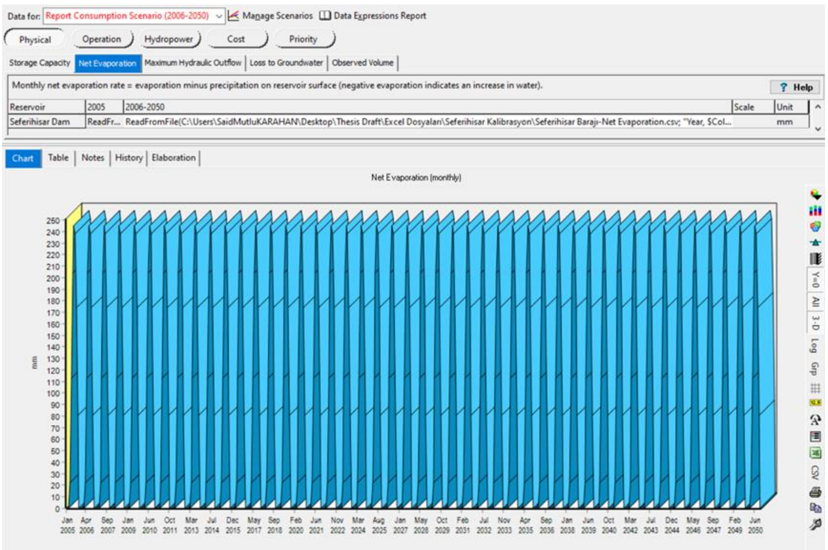

Figure 6.24. Net Evaporation Values of Seferihisar Dam (mm)

In the Report Consumption Scenario, the recharge amount of the basin-wide wells was determined by looking at the Tahtalı-Seferihisar Sub-Basin Groundwater Balance Sheet Table in the master plan report.

Sub-Basin Name	Aquifer Name	Groundwater Recharge (hm3)	Annual Safe Groundwater Recharge (hm3) (1)	Allocation	Special Provincial Administration Groundwater Irrigation	Public Irrigation	Cooperative Irrigation	Urban	Industry	Total Actual Consumption (2)	Amount of Water Remaining in the Aquifer (1)-(2)
Tahtalı-Seferihisar Sub-Basin	Menderes-Ahmetbeyli	31	25	33.16	-	88.56	0.89	34.77	0.41	124.63	-37.13
	Menderes-Cuma Ovası	39	31								
	Ürkmez	26	18								
	Seferihisar	6.5	5								
	Bademler	12.5	8.5								
Total		**115**	**87.5**	**33.16**	**0**	**88.56**	**0.89**	**34.77**	**0.41**	**124.63**	**-37.13**

Figure 6.25. Tahtalı-Seferihisar Sub-Basin Groundwater Balance Sheet

As can be seen from Figure 6.25, 87.5 hm^3 is the Safe Groundwater Recharge value. When sub-basin-based consumptions are subtracted from this value, the amount of water remaining in the aquifers throughout the basin is found. Public irrigation is the area where groundwater is used most. The consumption value of public irrigation corresponds to 71.1% of the total groundwater consumption value. Therefore, 71.1% of the annual safe groundwater recharge value has been taken, which has been accepted as the groundwater irrigation wells' recharge value, which is equal to 62.2 hm^3.

Table 6.8. Report Consumption Scenario Natural Recharge Values (hm^3)

Name of the Public Irrigation Well	Irrigation Water Need (hm^3)	Report Consumption Scenario Natural Recharge Values (hm^3)
Kaynakça Public Irrigation Well	5.26	3.66
Oğlananası Public Irrigation Well	30.1	20.93
Eskibağ Public Irrigation Well	1.45	1.01
Künerlik Public Irrigation Well	15.7	10.91
Çamönü Public Irrigation Well	14.69	10.21
Çileköy Public Irrigation Well	2.75	1.91
Özdere Public Irrigation Well	1.73	1.2
Yeniorhanlı Public Irrigation Well	1.49	1.03
Turgutlu Ulamış Public Irrigation Well	3.24	2.26
Buruncuk Public Irrigation Well	3.93	2.73
Demirciler Public Irrigation Well	0.68	0.47
Kuşçular Public Irrigation Well	7.53	5.23
Total Consumption of Public Irrigations	88.56	
Name of the Cooperative Irrigation Well		
Çamönü Cooperative Irrigation Well	0.89	0.62
Total Consumption of Cooperative Irrigations	0.89	

Since it is assumed in Figure 6.25 that 71.1% of the annual safe recharge yield (62.2 hm^3) will be spent on recharging irrigation wells, the recharge values obtained are also distributed to months in proportion to the amount of precipitation falling on the irrigation area.

Table 6.9. Natural Recharge Value of Turgutlu Ulamış Public Irrigation (hm^3)

Natural Recharge Value For Report Consumption Scenario (hm^3)	Average Monthly Precipitation (mm/month)	Percentage (%)	Monthly Natural Recharge Values (hm^3)
2.26	125.67	19.04	0.43
	101.51	15.38	0.35
	71.68	10.86	0.24
	42.43	6.43	0.14
	24.07	3.65	0.08
	4.5	0.68	0.02
	1.18	0.18	0
	1.1	0.17	0
	13.27	2.01	0.05
	52.61	7.97	0.18
	77.87	11.8	0.27
	144.06	21.83	0.49
	659.94	**100**	**2.26**

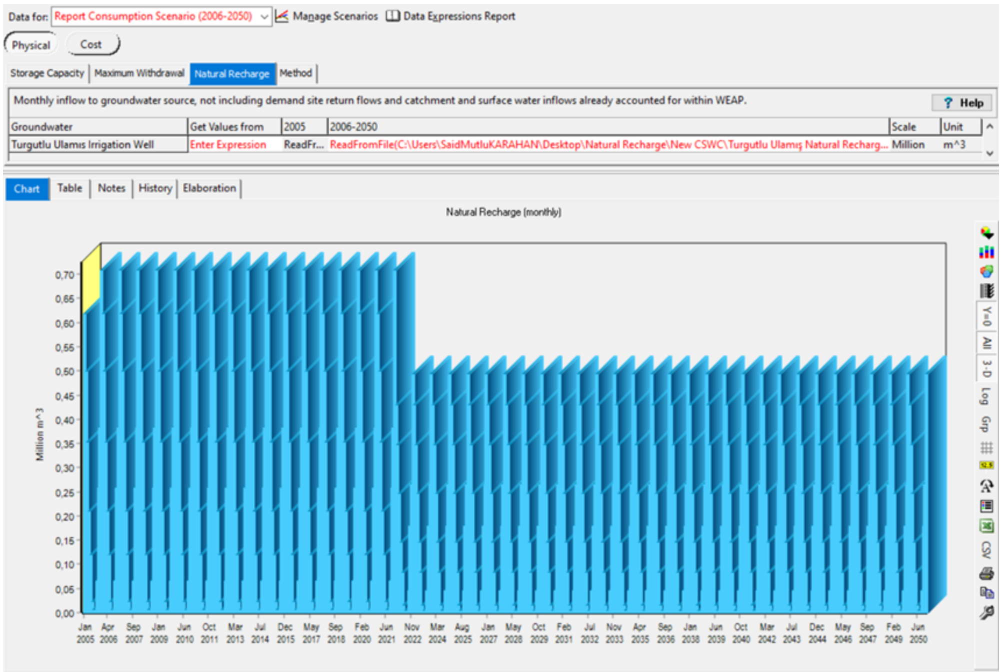

Figure 6.26. Monthly Recharge Values of Turgutlu Ulamış Irrigation for Report Consumption Scenario (hm^3)

In this scenario, The Turkish Bank of Provinces Method was used for population projection, and the daily water consumption value of a person was also used by keeping the average value constant, as in the previous scenario.

While no spatial changes were made in the agricultural areas in the basin, the current water consumption values in dam irrigations were used in terms of the amount of water used.

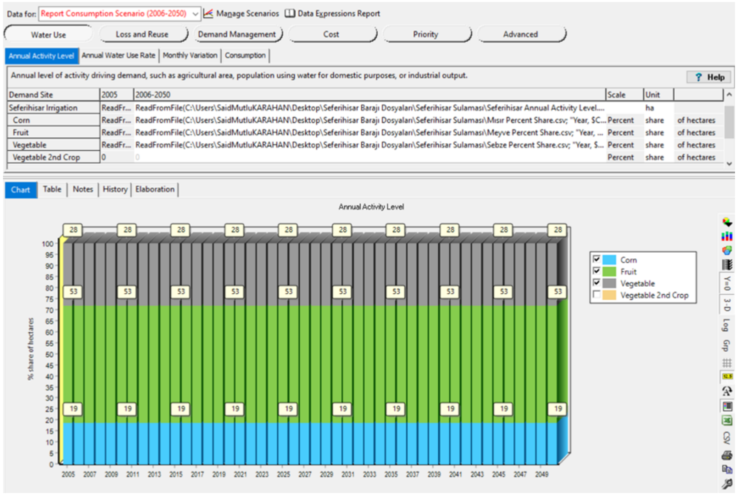

Figure 6.27. Seferihisar Dam Irrigation Total Area and Percentage Distribution of Crops

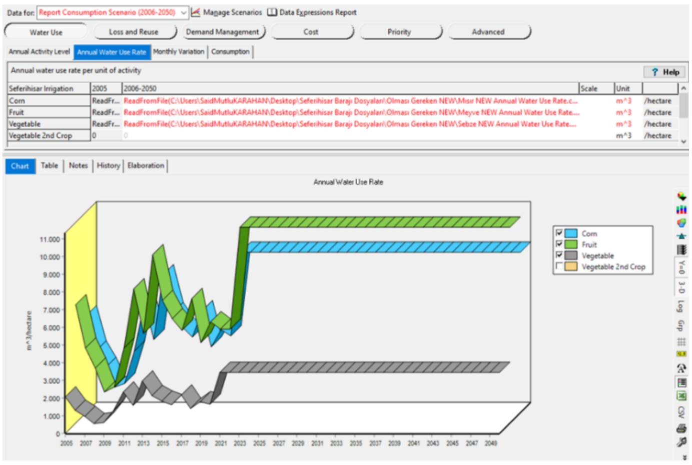

Figure 6.28. Annual Water Consumption Values of Seferihisar Dam Irrigation’s Crops (m^3/ha)

6.5. Best Case Scenario

The Best Case scenario was created to show how effective the use of water resources is in terms of basin water resources, where it is assumed that the best conditions will occur in all water resources. In this scenario, it is assumed that there will be an increase in precipitation amounts and an increase in inflows to dams and ponds in this direction. Net evaporation amounts have been reduced, and it has been assumed that less water is consumed per person per day by changing the amount of daily water consumption per capita.

In this scenario, the flow data produced by the AutoRegressive Integrated Moving Average (ARIMA) method was used because the trend obtained by decomposing the time series data of the flow values coming to the dams in the R programming language is increased. For this reason, these flow values were used. Figure 6.29. shows the monthly flow rates of the Şasal Stream, which supplies water to Tahtalı Dam, produced by the ARIMA method.

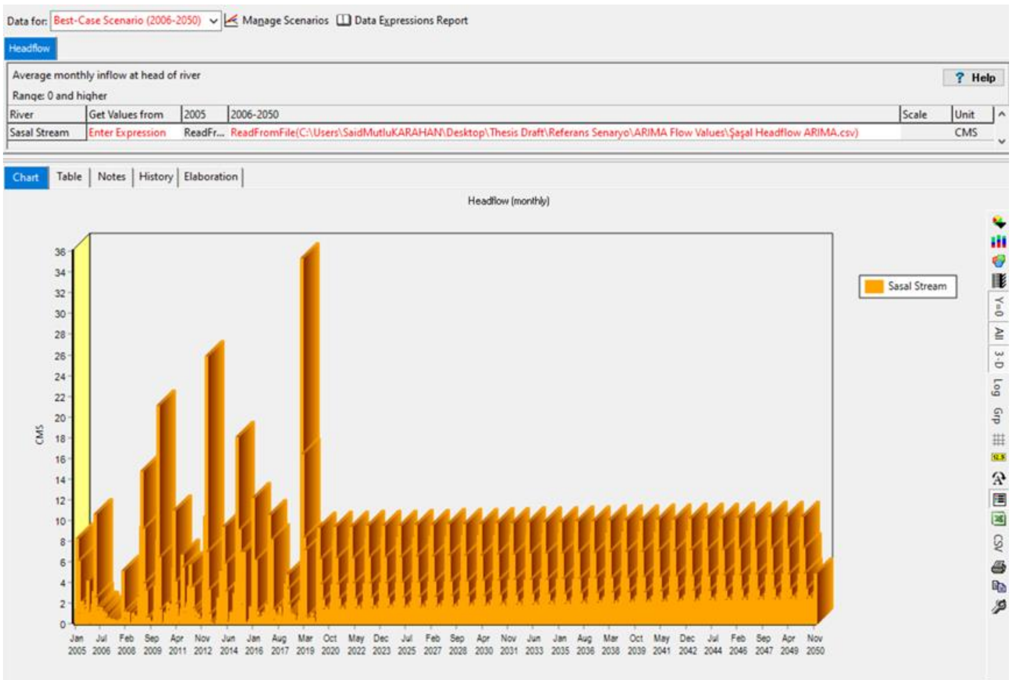

Figure 6.29. Şaşal Stream's Monthly Flow Rates Under the Best Case Scenario (m^3/s)

In the Best Case Scenario, the net evaporation values in dams and ponds were also corrected. A 20% reduction in average net evaporation values was realized and transferred to the program as such.

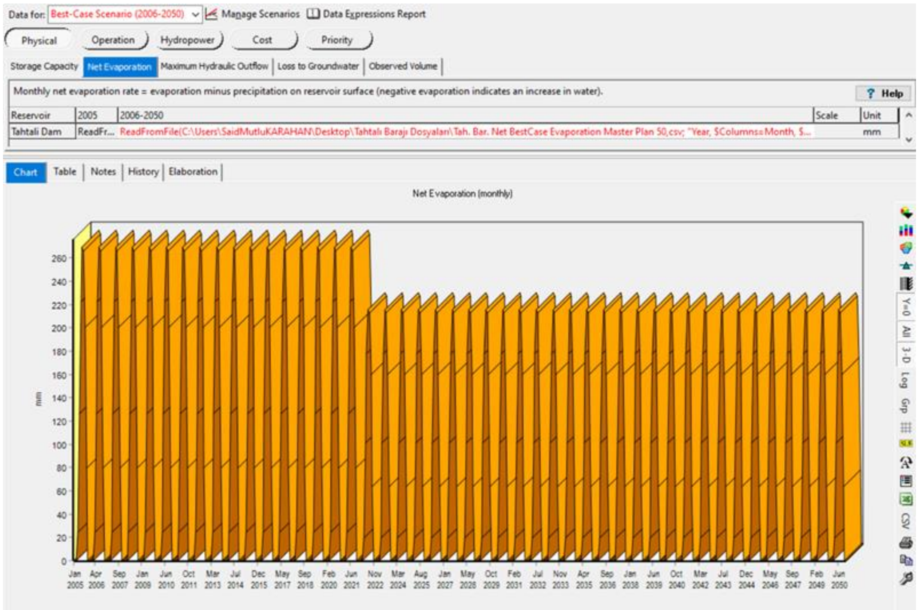

Figure 6.30. Net Evaporation Values Occured in Tahtalı Dam in the Best Case Scenario (mm)

For groundwater wells' Storage Capacity values cannot be unlimited. For that reason, the storage capacity of each well was determined as a maximum of three times the initial storage capacity of that well like in previous scenarios. In other words, the maximum amount of water that a well can store is processed to be equal to three times the water requirement of the agricultural area to which the well supplies water.

In the Best Case Scenario, for the recharge values of the wells, the groundwater recharge value of 115 hm^3, which was given from the groundwater balance in the master plan report, was used (Table 6.10). It is assumed that the total groundwater recharge value will be consumed for irrigation wells instead of the efficient groundwater recharge value. This value was also distributed in proportion to the irrigation water needs of agricultural areas.

Table 6.10. Best Case Scenario Natural Recharge Values (hm^3)

Name of the Public Irrigation Well	Best Case Scenario Natural Recharge Values (hm^3)
Kaynakça Public Irrigation Well	6.77
Oğlananası Public Irrigation Well	38.7
Eskibağ Public Irrigation Well	1.86
Künerlik Public Irrigation Well	20.19
Çamönü Public Irrigation Well	18.89
Çileköy Public Irrigation Well	3.54
Özdere Public Irrigation Well	2.22
Yeniorhanlı Public Irrigation Well	1.91
Turgutlu Ulamış Public Irrigation Well	4.17
Buruncuk Public Irrigation Well	5.05
Demirciler Public Irrigation Well	0.88
Kuşçular Public Irrigation Well	9.68
Name of the Cooperative Irrigation Well	Best Case Scenario Natural Recharge Values (hm^3)
Çamönü Cooperative Irrigation Well	1.14

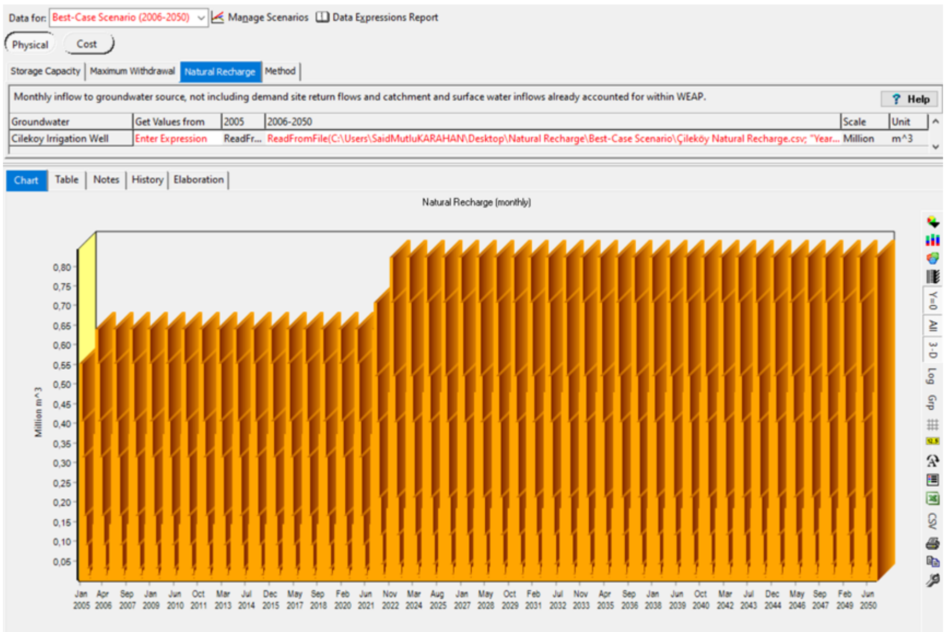

Figure 6.31. Natural Recharge Values of Çileköy Irrigation Well in the Best Case Scenario (hm^3)

In this scenario, the average growth rate method is used for population projection. In this method, the annual population growth rates were compared with the previous year and averaged at the end. Then, it was assumed that the population would increase by this rate each year. For the population projection, the central 11 districts where Tahtalı Dam provides water was used in this scenario.

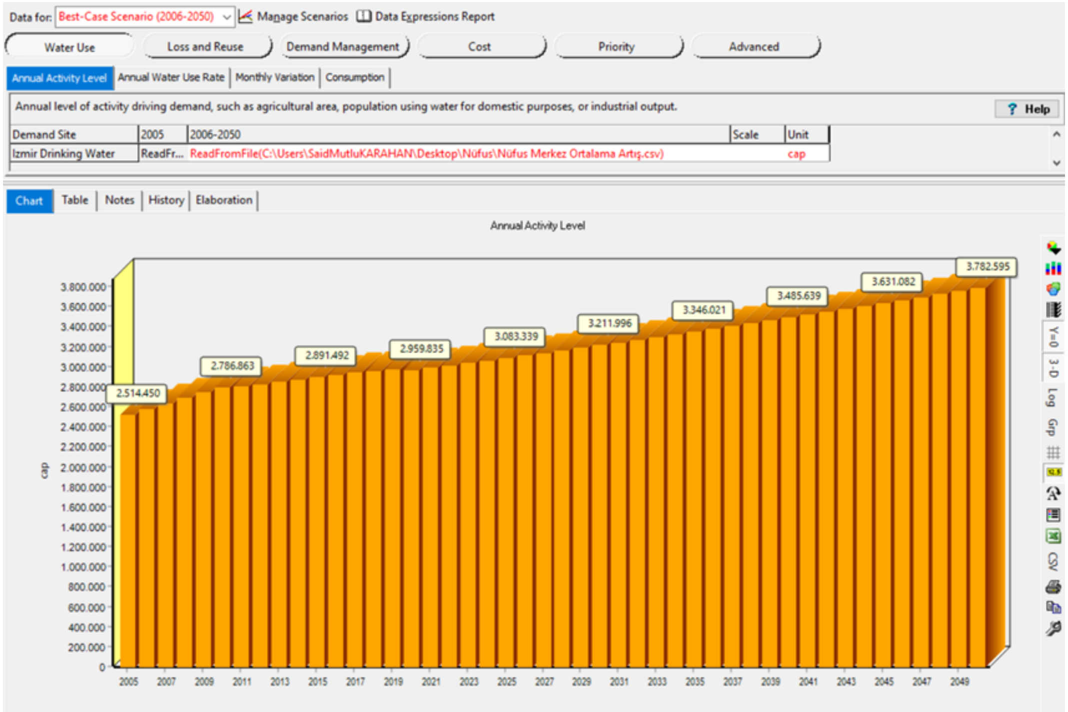

Figure 6.32. Population Projection Value of 11 Districts by the Best Case Scenario

In this scenario, while no spatial changes were made in agricultural areas, product-based changes were made. In the Küçük Menderes Basin Master Plan Final Report, projected irrigations can be realized for the coming years. In the report, there are agricultural areas with projects of State Hydraulic Works, Special Provincial Administration, and Cooperative Irrigations. The amount of water consumed on an annual basis has been reduced by changing the pattern of the products grown or using transmission lines without losses. Projected irrigations in the report were carried out in the Best Case Scenario. In the report, there is no study with a project for public irrigation.

Table 6.11. Future State Water Consumption Values for Agricultural Fields (hm^3)

Special Provincial Administration Irrigation Name	Future State Consumption (hm^3)
Çatalca Sandidere Pond Irrigation	0.69
Yeniköy Pond Irrigation	0.46
Payamlı Pond Irrigation	0.63
Kavakçayı Pond Irrigation	0.52
Ağalardere Pond Irrigation	1.07
Bademler 9 Eylül Pond Irrigation	0.98
State Hydraulic Works Irrigation Name	**Future State Consumption (hm^3)**
Ürkmez Barajı Irrigation	2.13
Seferihisar Barajı Irrigation	7.39
Ataköy Irrigation	0.92
Kavakdere Irrigation	3.12
Name of the Public Irrigation	**Future State Consumption (hm^3)**
Kaynakça Public Irrigation	5.26
Oğlananası Public Irrigation	30.1
Eskibağ Public Irrigation	1.45
Künerlik Public Irrigation	15.7
Çamönü Public Irrigation	14.69
Çileköy Public Irrigation	2.75
Özdere Public Irrigation	0.63
Yeniorhanlı Public Irrigation	0.18
Turgutlu Ulamış Public Irrigation	3.24
Buruncuk Public Irrigation	3.93
Demirciler Public Irrigation	0.68
Kuşçular Public Irrigation	7.53
Ahmetbeyli Public Irrigation	0.78
Name of the Cooperative Irrigation	**Future State Consumption (hm^3)**
Çamönü Cooperative Irrigation	0.81
Gümüldür Tahtalı Cooperative Irrigation	4.9

When the Table 6.8 and Table 6.11 are compared, it is observed that the water consumption amounts of the future situation in Special Provincial Administration's Irrigations, State Hydraulic Works' Irrigations, and Cooperative's Irrigation have decreased. However, there is no study has been carried out for Public Irrigations. The future situation seen in Özdere Public Irrigation and Yeniorhanlı Public Irrigation reflects that less water will be drawn from irrigation wells as a result of the activation of Özdere and Yeniorhanlı Ponds. Since no improvement was made in the master plan report for public irrigation, in the Best Case Scenario, the transmission losses of the public irrigations were reset, and the irrigation water needs were reduced.

Table 6.12. Comparison of Current State Water Consumption and Future State Water Consumption of Yeniorhanlı Public Irrigation in the Best Case Scenario

Yeniorhanlı Public Irrigation	Percentage (%)	Area Distribution (ha)	Current State Water Demand (m^3/ha)	Water Demand with No Transmission Loss (m^3/ha)
Cereals	6	12.95	2403.32	2001.96
Olive	30	64.77	7811.55	6507.02
Fruit	10	21.59	7811.55	6507.02
Citrus	41	88.52	7227.22	6020.27
Vegetable	13	28.07	5012.11	4175.09
Total	**100**	**215.91**	**30265.75**	**25211.37**

In the State Hydraulic Works Irrigations, where the water need is regulated and reduced in the coming years, for some of the irrigations, the products grown in agricultural areas have been changed, while in some, only transmission losses have been eliminated. For Special Provincial Administration and Cooperative Irrigation, it is aimed to eliminate transmission losses in the future and thus to use less water. As shown in Table 6.12, the products grown in the project of Kavakdere Dam Irrigation also vary. Before 2022, when projected irrigation was initiated, the agricultural area was used for citrus, fruit, artichoke, garden, and vegetable cultivation. After this year, cereals, vegetable second crop, strawberries, and corn started to be grown in the farming area.

Figure 6.33. Kavakdere Dam Irrigation Changing Crop Pattern

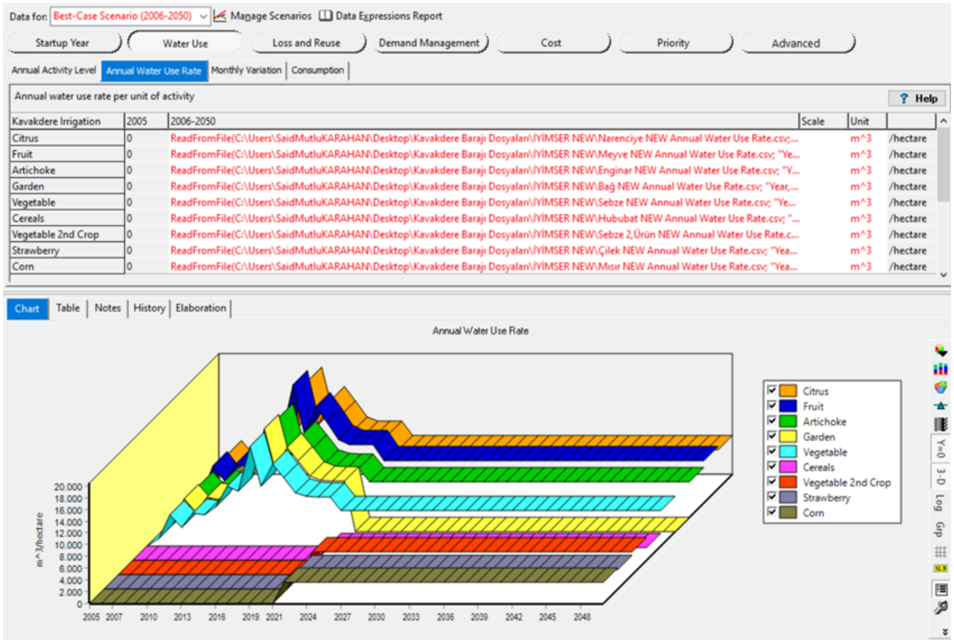

Figure 6.34. Water Needs of Crops Grown in Kavakdere Dam Irrigation in the Best Case Scenario (m^3/ha)

In this scenario, the amount consumed per person per day in the coming years has also been reduced. Assuming that people are more sensitive to global warming and will be more educated about this issue, the daily water consumption value per person has been reduced by 20%.

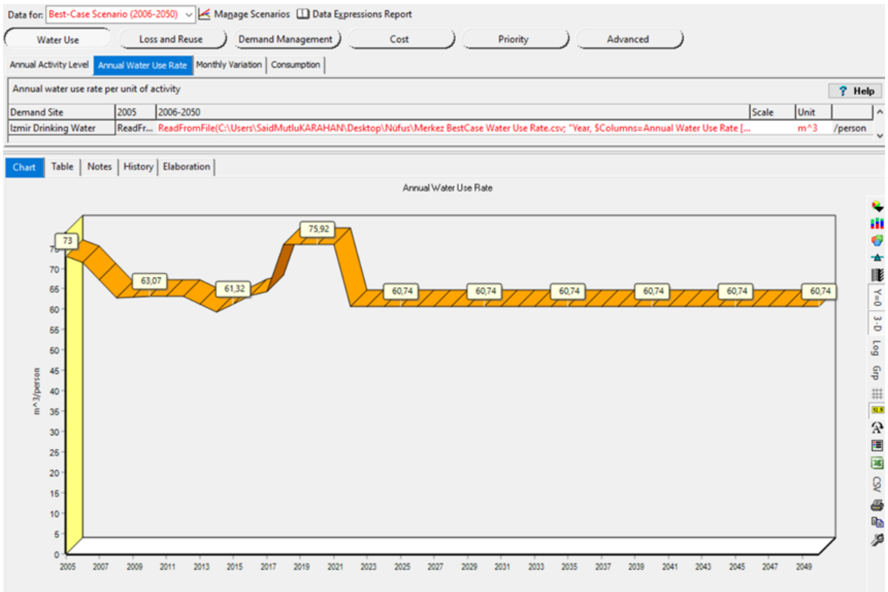

Figure 6.35. The Amount of Water a Person Will Use Annually (m^3/person)

6.6. Worst Case Scenario

This scenario is designed as a combination of worst-case scenarios that could happen in the future. Decrease in streamflow values, evaporation values caused by increased temperatures as a result of global warming, increased transmission losses in irrigation canals and more water consumption needs, decreased precipitation amounts and decrease in recharge values of groundwater wells, population growth, and per capita daily water consumption situations such as the unconscious increase of its value are used in this scenario. In order to observe the variability, changes in this scenario were started as of 2022.

It is assumed that there will be a 20% decrease in flow rates and inflow value to ponds. Flow rates of Karacadağ Stream, which supplies water to Ataköy Pond, are given in Figure 6.36.

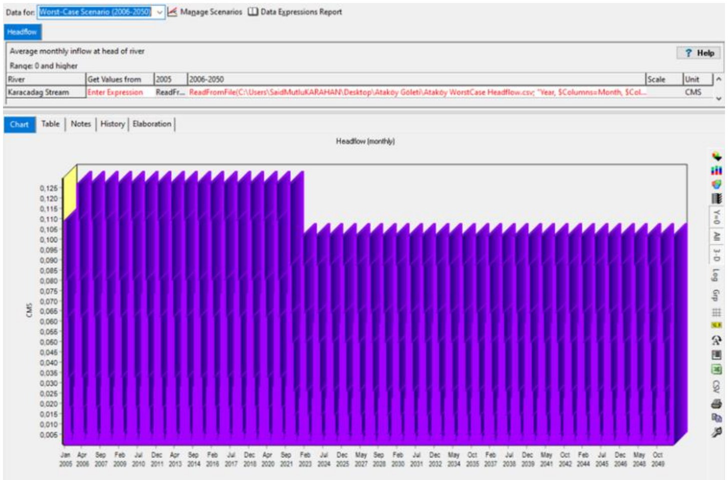

Figure 6.36. Karacadağ Stream Flow Rates Values (m^3/s)

It is assumed that there will be an increase of 20% in the Net Evaporation values, which are obtained as a result of subtracting the falling precipitation values from the evaporation values from the free water surface occurring in the reservoirs and ponds, as a result of the increase in temperatures brought by global warming.

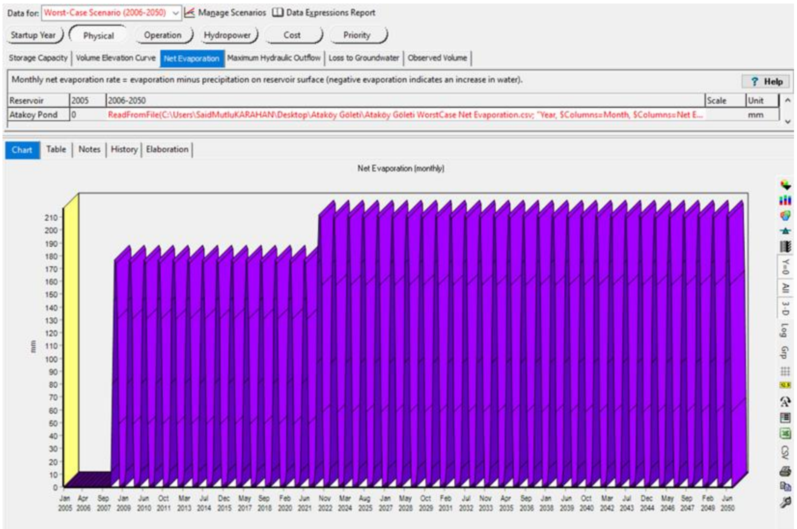

Figure 6.37. Net Evaporation Values of Ataköy Pond in the Worst Case Scenario (mm)

For the recharge values of the groundwater wells, severe-drought conditions were selected from the Tahtalı-Seferihisar Sub-Basin drought scenarios obtained from the Küçük Menderes Basin Sectoral Water Allocation and Action Plan (2020-2025) Report, and the potential groundwater value to be considered in the allocation was 34 (hm^3/year) has been selected (Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Water Management, Basin Management Department 2019). The value of 34 hm^3/year has been divided proportionally for each irrigation well, taking into account the water requirement rates of the agricultural areas. The shared values were then entered into the program by being distributed as a percentage according to the precipitation falling on the irrigation areas.

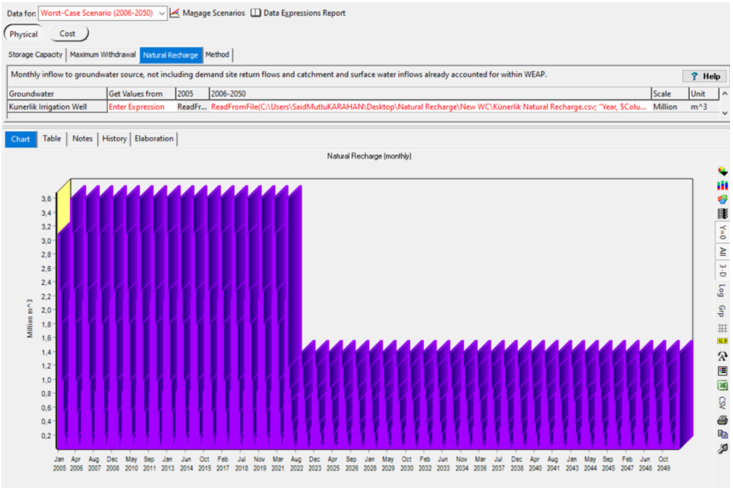

Figure 6.38. Natural Recharge Values of Kunerlik Irrigation in the Worst Case Scenario (hm^3)

In this scenario, the Turkish Bank of Provinces method was used for population projection, and no increase was made outside of this method.

The irrigation water needs of the crops grown in agricultural areas have been increased by 20% as transmission losses will increase and the effects of global warming will be seen. This increase was realized for each agricultural area.

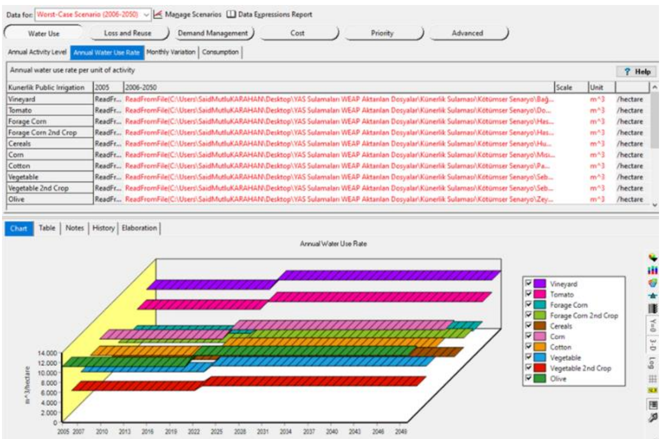

Figure 6.39. Water Needs of Crops Grown in Künerlik Public Irrigation (m^3/ha)

Assuming that the per capita daily water consumption value will increase due to people's unconscious behaviors in this scenario, the daily water consumption value has risen by 20%, and the graph of the annual amount of water used by a person in terms of m^3 is given in Figure 6.40.

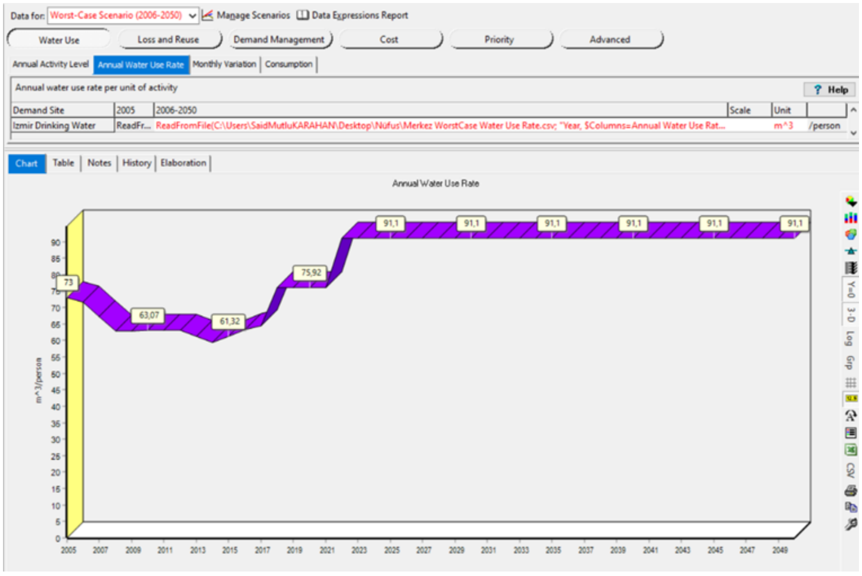

Figure 6.40. Amount of Water Consumed by a Person for One Year in the Worst Case Scenario (m^3/person)

6.7. Return Flow Scenario

In this scenario, it is thought that not all of the amount of water given to agricultural areas can be consumed by the crops grown in the farming areas, and some of it will recharge the irrigation source (well, dam or pond) again.

The average values of the flows to the dams and ponds are used in the scenario. Average values were also used for the Net Evaporation values that should be transferred to the program for dams and ponds.

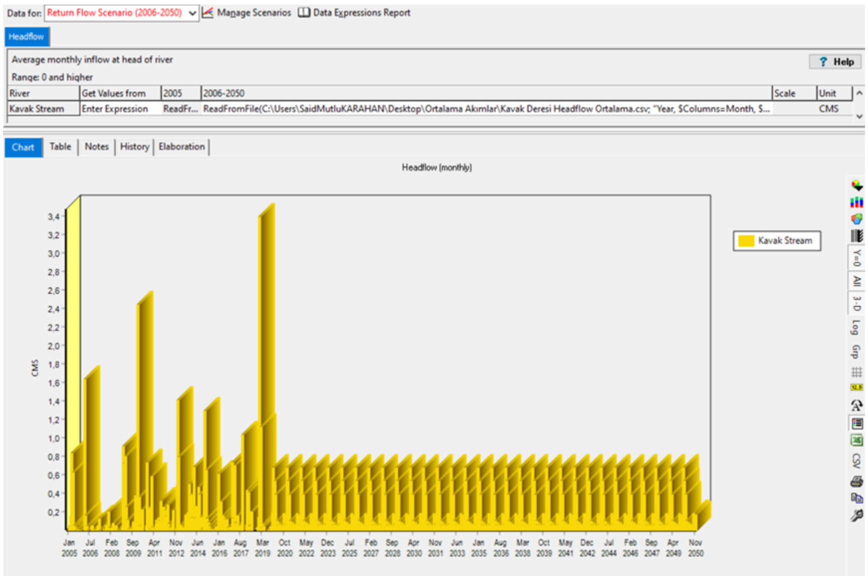

Figure 6.41. Average Flow Values of Kavak Stream (m^3/s)

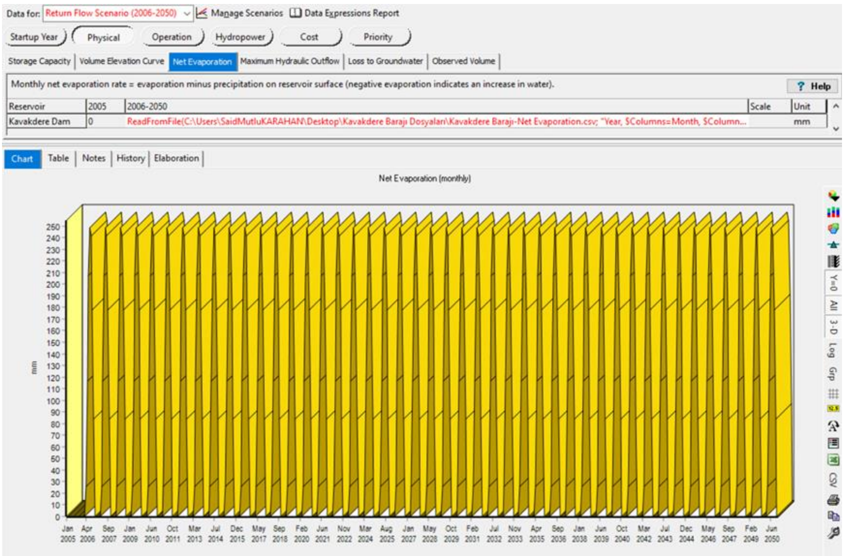

Figure 6.42. Average Net Evaporation Values of Kavakdere Dam (mm)

While the Initial Storage values of the groundwater wells were selected according to the irrigation water needs, and the Natural Recharge values were entered as equal to the consumption amount and distributed with respect to precipitation falling on the irrigation area as in the reference scenario.

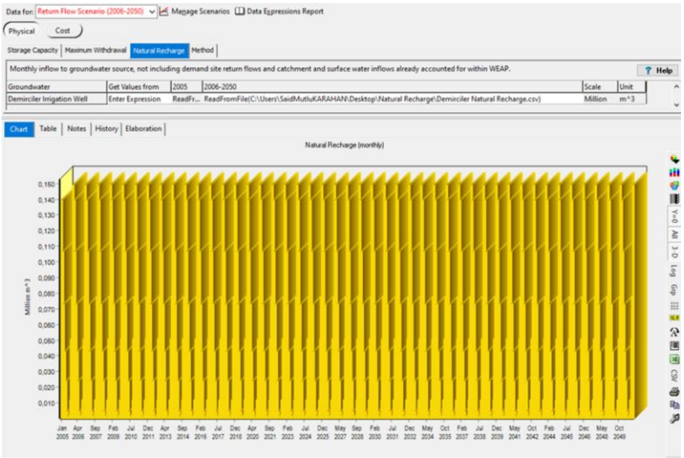

Figure 6.43. Average Natural Recharge Values of Demirciler Irrigation Well (hm^3)

The Turkish Bank of Provinces Method was used for the population projection process, and the average value was taken for the annual water consumption per capita.

In this scenario, no changes were made on the total irrigation areas of agricultural lands and the pattern of cultivated products. Based on the assumption that the entire amount of water given to irrigation from the water source cannot be consumed by the products grown, it has been accepted that 20% of it returns to feed the water source.

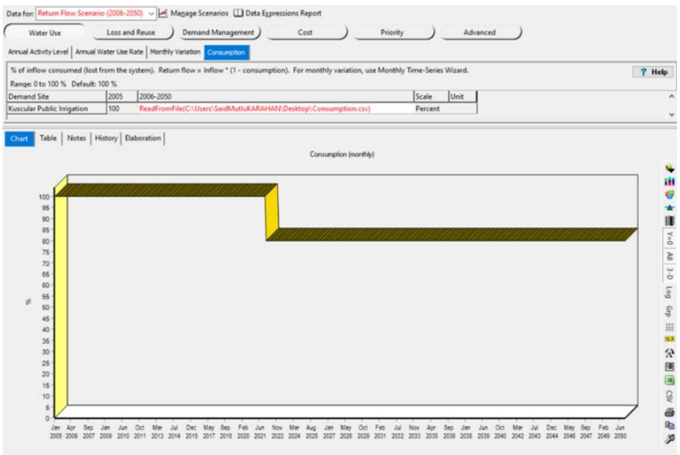

Figure 6.44. Consumption Values of Kuşçular Public Irrigation (%)

As shown in Figure 6.44, the water consumption value of Kuşçular Public Irrigation had decreased to 80% since 2022, when changes were made on all scenarios.

As of this year (2022), it is assumed that 20% of the amount that is given to irrigation but cannot be consumed will return to the irrigation source with the Return Flow modeling tool. In Figure 41, it is seen that the Return Flow Routing value has been entered as 100% starting from 2022. This shows that all of the water that irrigation cannot consume will return to the water source.

Figure 6.45. Return Flow Routing Values for Kuşçular Public Irrigation (%)

6.8. Population Extrapolation Scenario

The purpose of this scenario is to find an answer to the question of what percentage of the water needs of the central 11 districts will be met by the Tahtalı Dam in the future in the face of the increasing population of İzmir.

Under different population projection methods, it will be found out what percent of the population of İzmir can be supplied with water from Tahtalı Dam in 2050.

The population of İzmir in 2050 was calculated using four different methods. The first of these methods is the Arithmetic Extrapolation Method. According to this method, the population of 11central districts of İzmir at the end of the scenario equals 3649818 people.

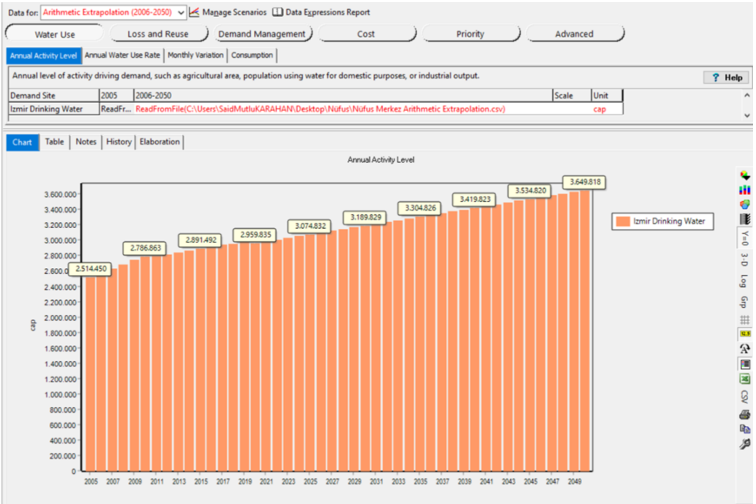

Figure 6.46. Population projection of 11 Central Districts İzmir as a result of the Arithmetic Extrapolation Method

The second method used is the Geometric Extrapolation Method. This method is applied in population projections by the Turkish State Institute of Statistics. As a result of this method, the population of 11 central districts of İzmir at the end of the scenario is 3780453 people.

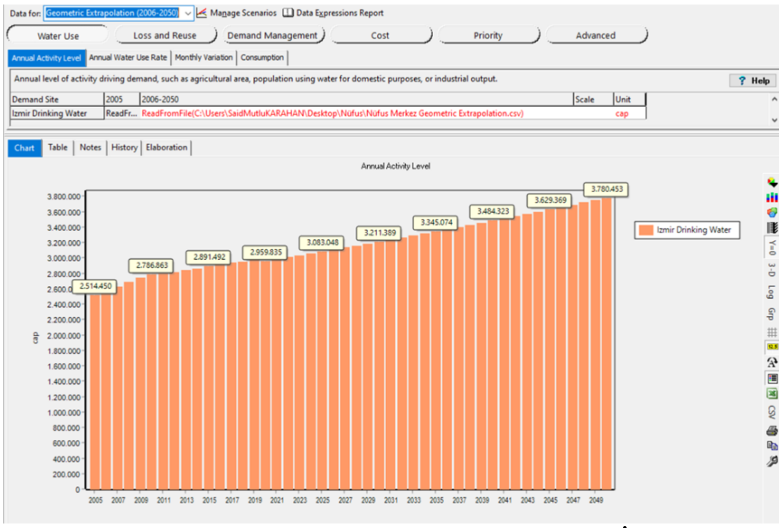

Figure 6.47. Population Projection of 11 Central Districts İzmir as a result of the Geometric Extrapolation Method

The third method used is the Turkish Bank of Provinces method, which has also been used in other scenarios. This method is an alternative version of the geometric extrapolation method. As a result of this method, the population of 11 central districts of İzmir in 2050 is equal to 3989410.

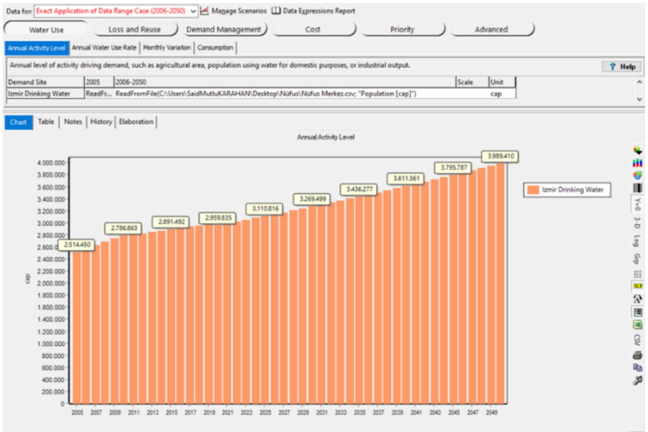

Figure 6.48. Population Projection of 11 Central Districts İzmir as a result of the Turkish Bank of Provinces Method

As a last method, the population growth rates obtained by looking at the population of central districts and comparing it with the population one year ago is to continue by applying the average population growth rate to the people of the central 11 districts. This method was also used in the Best Case Scenario. As a result of this method, the population of the central districts is equal to 3782595.

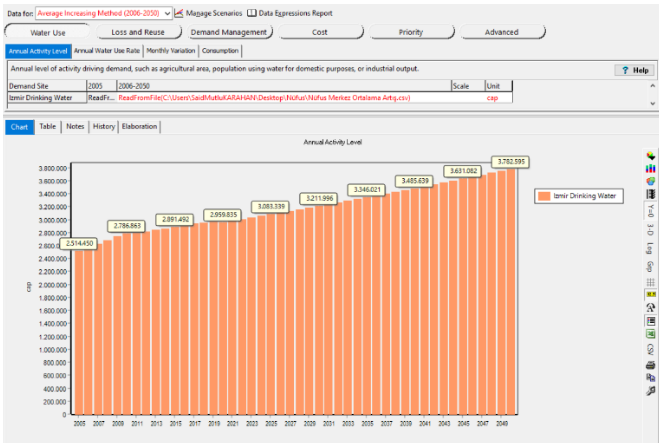

Figure 6.49. Population Projection of 11 Central Districts İzmir as a result of the Average Growth Rate Method

In line with the population values calculated as a result of different methods, an analysis was carried out on what percentage of the water demand need will correspond to three different conditions: good situation, bad situation, and current situation. According to Tahtalı Dam operation study data in good condition, the capacity of the year with the most drinking water supply was increased by 20%, and water supply to the 11 central districts of İzmir was carried out under different population projections. In the bad case condition, again, by looking at the operational data of the dam, the water supply amount of the central districts was calculated by reducing the capacity of the year with the least drinking water supply between the years 2005-2019 by 20%. In the current situation, the drinking water transmission values between 2005 and 2019 were transferred to the program as the same values in the operation data file. The average of the available data was taken for the subsequent years, and these data were continued.

6.9. Various Forecast Scenario

The aim to be examined in this scenario is how the stream flows coming to the dams will yield results under different forecasting methods. It has been investigated to what extent these differences will create a change for the basin.

Since different forecast methods will process the available data differently from each other and create forecasts for the future, the monthly distribution of stream flows will vary in each method.

Stream flows to the dams were compared using three different methods. The first of these methods is the Seasonal Naïve Method. Forecasted flow values of Kavakdere River as a result of this method are given in Figure 6.50.

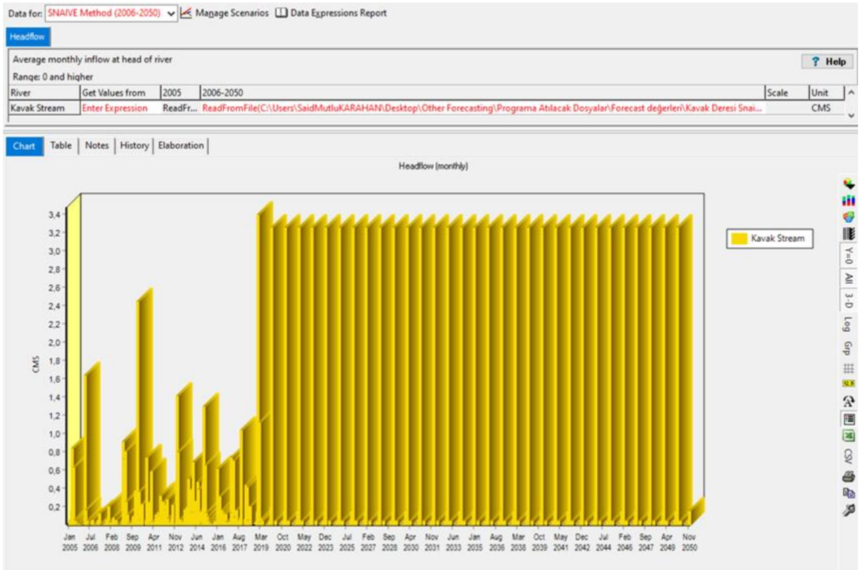

Figure 6.50. Forecasted Flow Values of Kavakdere Stream Under Seasonal Naïve Method

The second of the methods used is the Exponential Smoothing Method. Kavakdere Stream flow data obtained as a result of this method are given in Figure 6.51.

Figure 6.51. Forecasted Flow Values of Kavakdere Stream Under Exponential Smoothing Method

The last method used is the Autoregressive Integrated Moving Average Method. This method is more advanced and complicated than other methods. The flow values of the Kavakdere Stream formed by this method are given below.

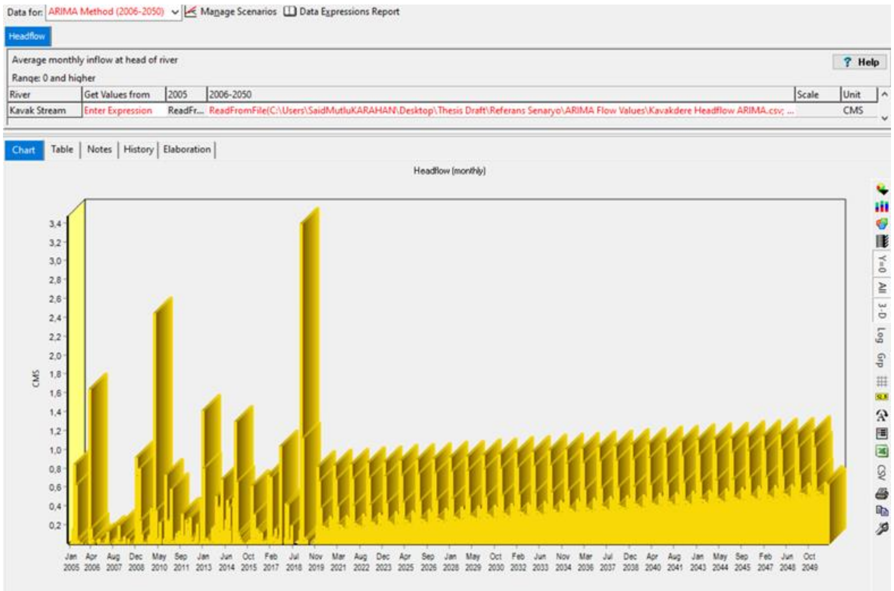

Figure 6.52. Forecasted Flow Values of Kavakdere Stream Under Autoregressive Integrated Moving Average Method

By applying the forecasted flow values obtained as a result of these three different methods to the dams in the basin, the monthly average capacity values of the dams during the scenario years and the flows entering the basin were compared.

CHAPTER 7

RESULTS AND FINDINGS

All scenarios created in the Water Evaluation and Planning program are discussed in the Results section. As a result of the modelling processes, the requested area for presentation of the results is selected, and the results are tabulated in tables or shown in graphics. During the study phase, 16 different scenarios were created to make the required comparisons and make predictions about the future years. Basically, there are five main scenarios where the future of the water resources in the watershed are discussed. Other scenarios were created to find the percentage of water needs of the central districts of İzmir under different states of the population projections. These five scenarios are Reference Scenario, Report Consumption Scenario, Best-Case Scenario, Return Flow Scenario, and Worst Case Scenario. In line with the values obtained from running the scenarios, the scenarios can be examined individually or comparatively.

After running the scenarios, we first present the amount of water demand of the basin that cannot be met under different scenarios in the Results section. The amount of unmet demand includes the unmet water need of all demand points created throughout the study area.

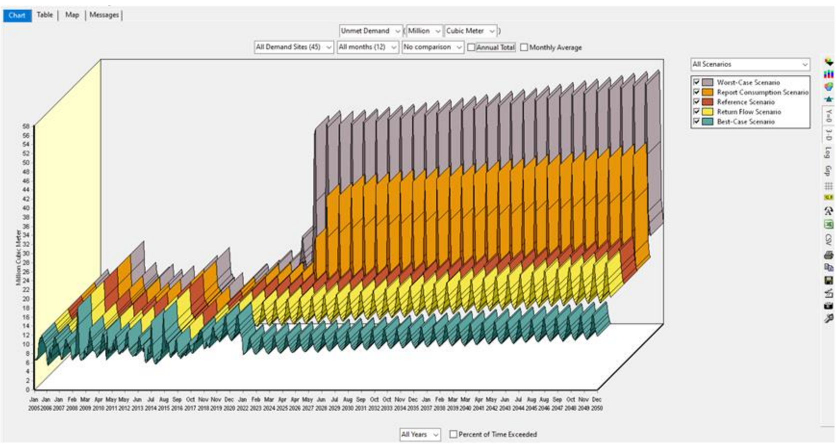

Figure 7.1. Unmet Water Demand Amounts of Scenarios Created in the Basin (hm^3)

As shown in Figure 7.1, the scenario with the highest unmet water demand is the Worst-Case scenario, as expected. Obviously, there is also an unmet water demand in the Reference Scenario. It is observed that even when the Best-Case scenario is implemented to the model for the Tahtalı-Seferihisar Sub-Basin, the unmet demand still is unavoidable although a lesser amount of the demand is observed, and compared to other scenarios. The most significant factor in the emergence of the unmet demand in the Best-Case scenario is that the per capita daily water consumption will not be met in the face of the increasing population.

When the scenarios are compared according to their unmet water demand values for all demand sites, while this value reaches 373.16 hm^3 in the Worst Case Scenario, where the unmet demand is the highest, and the unmet demand value is equal to 236.3 hm^3 for the Reference Scenario. The difference in the amount of unmet demand between the two cases is around 136.86 hm^3. In the Best Case Scenario, where there will be the least unmet water demand is equal to 157.52 hm^3, almost the difference between the Worst Case Scenario and the Reference Scenario.

Drinking water is supplied from two different dams in the study area. Tahtalı Dam, the first of these dams, delivers drinking water to the central districts of İzmir province, while Ürkmez Dam supplies drinking water to the Seferihisar district. It is also essential to determine the amount of demand that cannot be met in the coming years for these two demand points. Considering the situation for the central districts of İzmir, the need that cannot be met in the Worst-Case scenario in 2050, the last year of the scenarios, is 289.81 hm^3 and 154.36 hm^3 in the Best-Case scenario. As a result of the scenario created with the data at hand, Reference Scenario, the amount of 227.49 hm^3 emerges. (Figure 7.2)

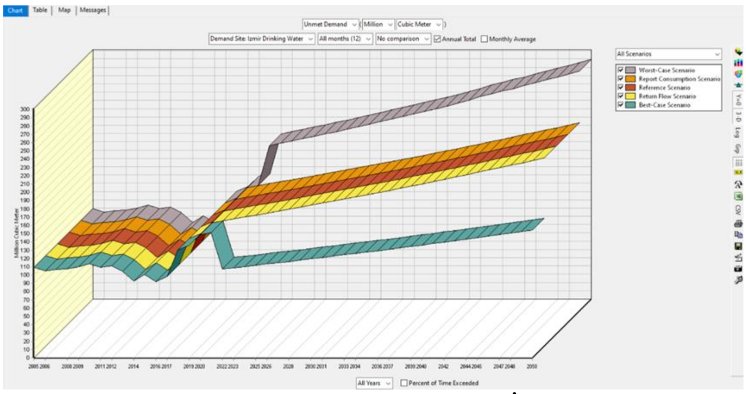

Figure 7.2. Unmet Amount of Water Demand for İzmir Central Districts (hm^3)

When Seferihisar, the other drinking water demand point, is taken into account, the demand that cannot be met in the Best Case scenario is 2.68 hm^3 in 2050, while in the Worst Case scenario, this situation is equal to 9.74 hm^3. The unmet demand value is 7.84 hm^3 in the reference scenario, and this value is 7.95 hm^3 in the Report Consumption Scenario (RCS). The reason for the higher amount of unmet demand for the Seferihisar district in the RCS scenario is that the Ürkmez Dam gives less water to the Ürkmez Irrigation in the Reference Scenario compared to the RCS scenario. Thus the water supply to the Seferihisar district can be carried out more easily in the Reference Scenario. (Figure 7.3)

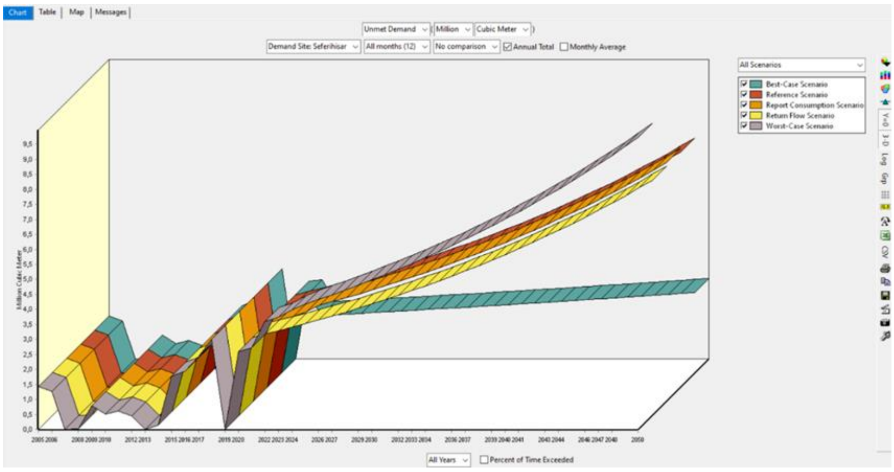

Figure 7.3. Unmet Water Demand for Seferihisar District (hm^3)

The RCS was mainly created for irrigation dams and groundwater wells. Because in the Reference Scenario, the amount of water given to the irrigation from the irrigation dams between the years 2005-2019 is searched at, and the average values for the amount of irrigation water are taken for the following years. However, in the RCS, the current state of water consumption in the Küçük Menderes Master Plan Final Report was accepted and continued. The reason for the difference is that in the Reference Scenario, less water is given to irrigation for some years. For some years, too much water is provided, and the average of these values is used. On the other hand, in the RCS, the current situation draws water from the dams with a constant water consumption starting from 2022.

This situation can be illustrated with Figure 49. In the Reference Scenario, where the average of each data was entered into the program is used, when the demand amounts that cannot be met by the agricultural areas in the catchment and their greenhouses are considered, it will be seen that the Report Consumption Scenario has more unmet demand than the Reference Scenario.

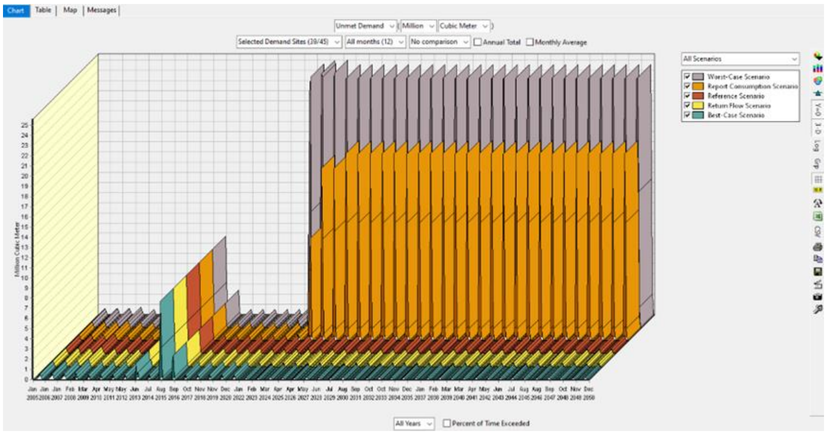

Figure 7.4. Unmet Water Demand for All Irrigations and Greenhouses (hm^3)

When the unmet demand values for all agricultural fields and greenhouses in the study area are considered, it can be said that drinking water needs meet a large part of the unmet water demand in Tahtalı-Seferihisar Sub-Basin.

While creating the scenarios, an answer to an important question was required. This question is how much of the demand of the central districts will be met by the Tahtalı Dam to the 11 central districts of İzmir (Balçova, Bayraklı, Bornova, Buca, Çiğli, Gaziemir, Güzelbahçe, Karabağlar, Karşıyaka, Konak, Narlıdere) in the coming years. It is known that Tahtalı Dam can meet approximately 40 percent of the water needs of the central districts today. In order to show this situation, the coverage graphic was created. The coverage graph shows that the water source that supplies water to the demand point can meet the water need against what percent of the demand. As can be seen from Figure Figure 7.5, 40% of the demand requirement was met between 2017 and 2020. This is another parameter that shows how well the model works.

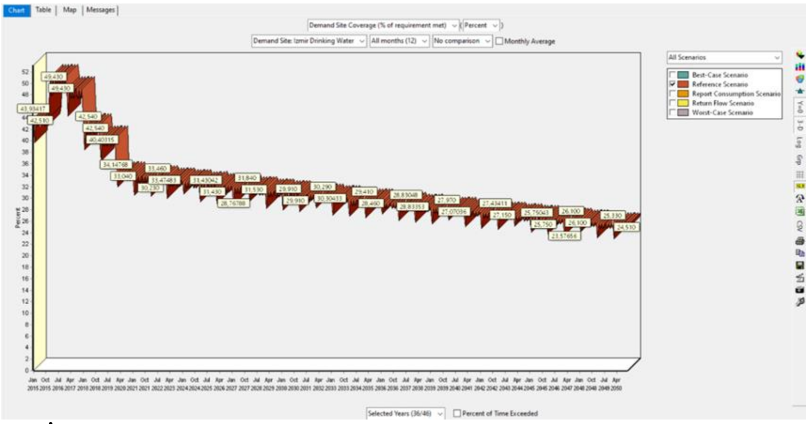

Figure 7.5. İzmir Drinking Water Coverage Values for Reference Scenario (%)

When the five main scenarios are considered, according to the Reference Scenario in 2050, approximately 24.5 percent of the water needs of the central districts can be met. This means a 15 percent difference from today's value. While the RCS shows an approximate value to the Reference Scenario, the Best Case Scenario shows the best result as expected and can meet 32.4 percent of the water need. In the Worst Case Scenario, the percentage of the water need that can be met is only 19.3 percent. As can be understood from these scenarios, in order to meet the water needs of the central districts of İzmir in the coming years, either improvement should be made on the existing resources or alternative resources should be created immediately. (Figure 7.6)

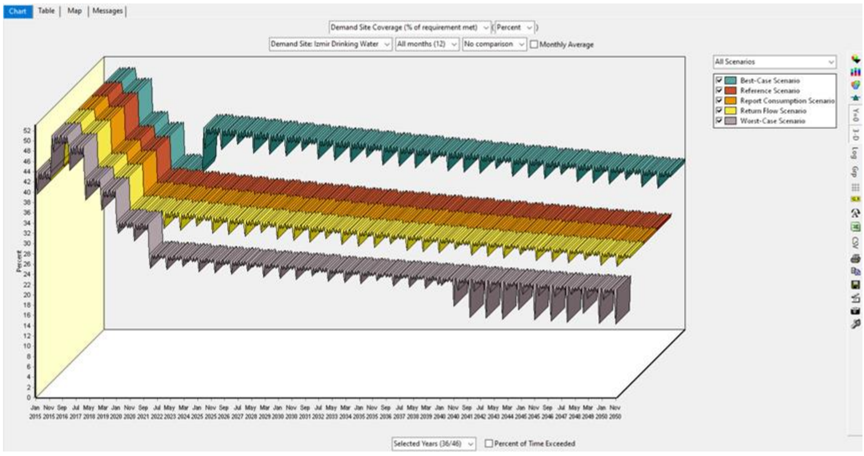

Figure 7.6. Coverage Values Under the Five Main Scenario (%)

When the current, good, and bad conditions are realized under four different population projections utilized in the study, the most critical conditions were simulated under the implementation of the Turkish Bank of Provinces population projection method. When population projections were made using this method only 33.5% of the water demands could be met even in the best scenario. This ratio increase to 36.4% for Arithmetic Extrapolation, to 35.4 % for Geometric Extrapolation and to 35.3% for Average Growth Rate methods respectively (Figure 7.7).

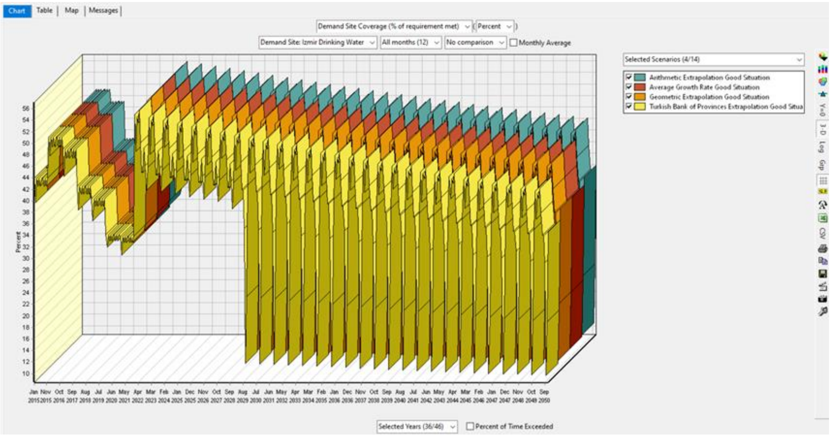

Figure 7.7. Comparison of Good Situation of Four Different Population Projections

Considering the bad case scenario for the population projection, the comparison was made over the month of October, when the least water need could be met in 2050. The lowest value when the Turkish Bank of Provinces method was applied for population projection, the model simulated that only 11.86% of the water needs could be met by the existing resources. According to the model, Geometric Extrapolation and Average Growth Rate scenarios can only meet 12.49 percent of the water needs of central districts for the same month. Whereas Arithmetic Extrapolation can meet 12.92%. (Figure 7.8)

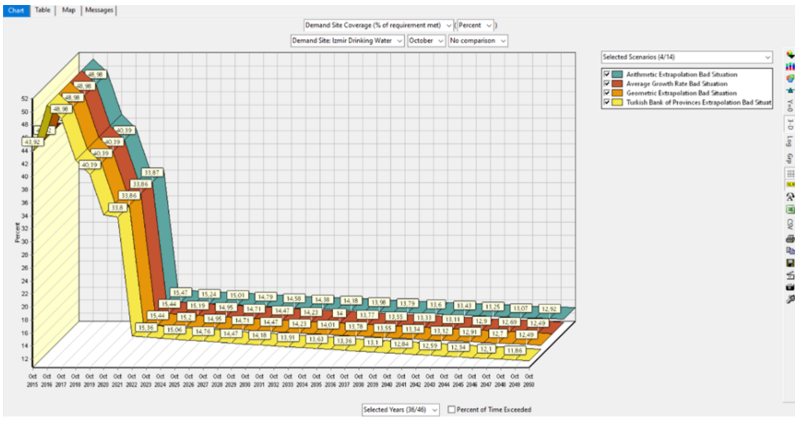

Figure 7.8. Comparison of Coverage Values in October under Bad Situation of Four Different Population Projections

These comparisons are applied only to the central district of İzmir over the Tahtalı Dam because the water obtained from the Ürkmez Dam does not provide a continuous water supply for the district Seferihisar. Therefore, this comparison has not been made for the district of Seferihisar.

When the irrigations that the dams supply water are considered, no unmet water demand has emerged in the Reference Scenario, when the average flow rate and average evaporation values are taken into account in the case where the irrigation is continued by taking the average of the amount of water given between the years 2005-2019. Since the Best Case Scenario is an improved version of the Reference Scenario, that is, in the scenario where the amount of water demand and net evaporation decreased, and the flow rate increased, the demand value could not be met did not emerge expected. The same thing happens in the Return Flow Scenario too. It can be assumed that this scenario is a development of the Reference Scenario, as 20% of the irrigation water requirement is transferred back to the water resource. This situation can be observed in Figure 7.9. for Ürkmez Dam Irrigation and Figure 7.10 for the Seferihisar Dam Irrigation.

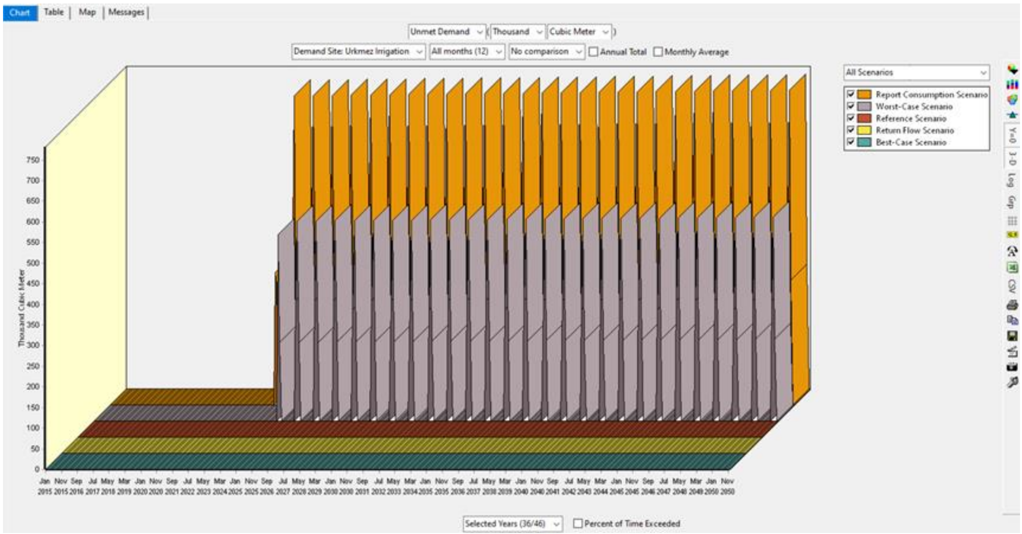

Figure 7.9. Unmet Demand for Ürkmez Dam Irrigation (hm^3)

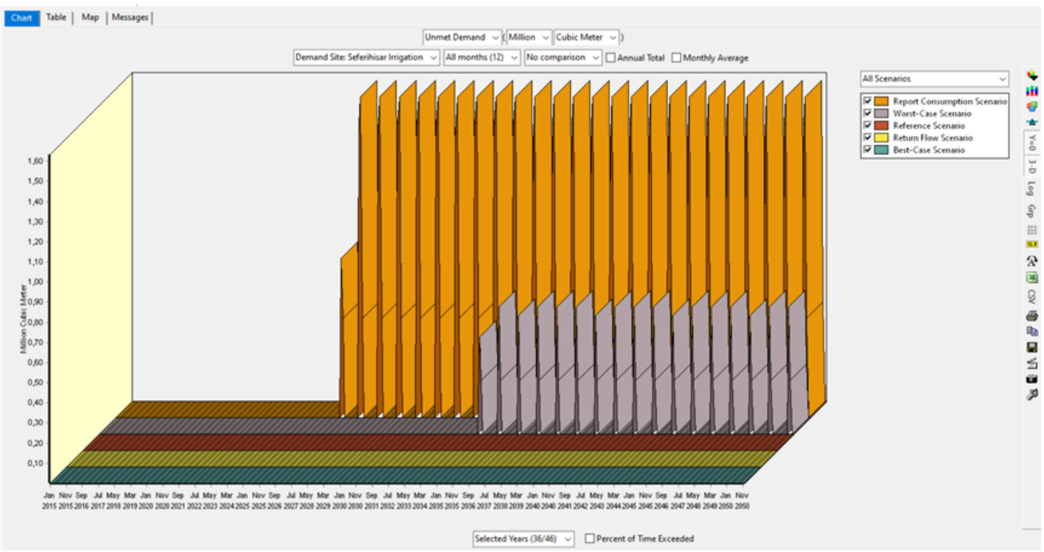

Figure 7.10. Unmet Demand for Seferihisar Dam Irrigation (hm^3)

The reason for the formation of the situation in the figures given above in the irrigation of Ürkmez and Seferihisar is due to the current state water consumption value in the report requiring even more water consumption than in the Worst Case Scenario, the amount of demand that cannot be met is higher in the RCS. For example, the master plan report assumes that the irrigation of Seferihisar Dam consumes 10.21 hm^3 of water annually. However, the average value was less than 10.21 hm^3 since the dam gave less water for irrigation in the mentioned years (2005-2019). In the Worst Case scenario, even the 20% increase in the water consumption compared to the average was not enough to pass the RCS.

In Kavakdere Dam Irrigation, this situation occurred entirely differently from the other two dam irrigations. The unmet water demand in this irrigation occurred only in the Worst Case Scenario. The lack of unmet water demand in the Report Consumption Scenario is that the annual average flow value of the Kavak River was found to be 6.21 hm^3/year. This amount of water, which will come on to the current capacity of the dam, is at a level to meet the water need of Kavakdere Irrigation, whose current water consumption is 5.17 hm^3/year. (Figure 7.11)

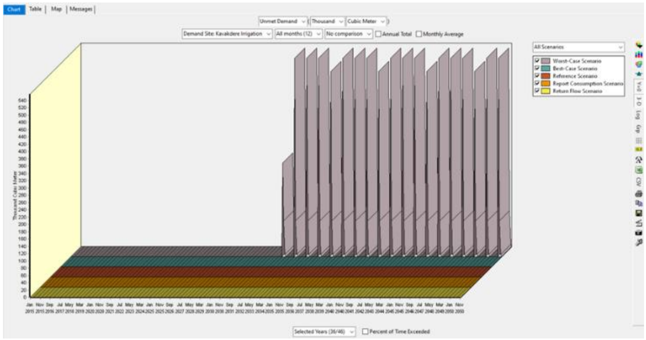

Figure 7.11. Unmet Demand for Kavakdere Dam Irrigation (hm^3)

If the water needs of the demand points in the scenarios are compared, it is obvious that the scenario in which the water demand will be the highest will be the Worst Case Scenario. Because in this scenario, in addition to increasing the water need of each product grown in agricultural areas, the amount of water used by a person daily has been increased too. Therefore, the water needs of the demand points have increased (521.61 hm^3). In the Reference Scenario, where the average of each parameter is used, and no conditions change, water demand of 438.04 hm^3 arises. The reason for the increase in the amount of water demand in the Reference Scenario is the population projection. The water demand amount of the Report Consumption Scenario is higher than the Reference Scenario because the dam irrigations in this scenario demand more water. The water demand amounts of the Return Flow scenario and the Reference scenario are the same because no change is made on the water needs of the demand points in the Return Flow scenario. The scenario where the least water demand will be realized is the Best-Case Scenario where almost all conditions are improved, and there is a water demand of 332.8 hm^3. (Figure 7.12)

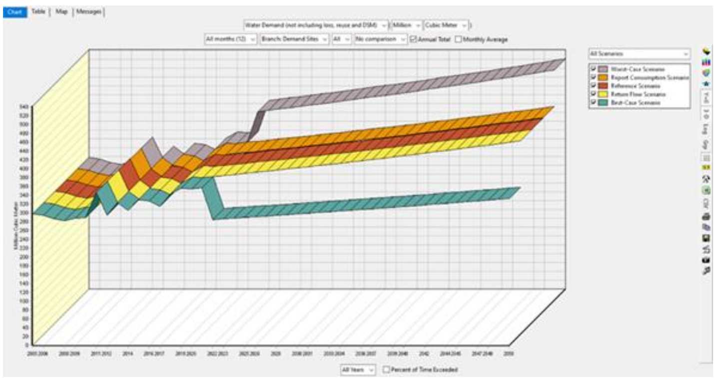

Figure 7.12. The Amount of Water Demand in the Study Area Under Different Scenarios (hm^3)

When the capacities of irrigation wells are examined, no change is expected in the well capacity since the recharge value will be defined as the amount of irrigation water drawn from the well, as mentioned before in the Reference Scenario. In the RCS case, the efficient groundwater recharge value is disaggregated according to consumption values in the basin and 62.2 hm^3 is distributed in proportion to the water needs of the irrigation areas. In the Worst Case Scenario, the recharge value (34 hm^3) is allocated using the groundwater recharge value under severe-drought climatic conditions specified in the Sectoral Water Allocation Action Plan. In the Best-Case scenario, the recharge values were obtained as a result of the distribution of the sub-basin groundwater recharge amount given in the master plan report by the irrigation wells (115 hm^3). The expected capacity graph for all irrigation wells in Tahtalı-Seferihisar Sub-Basin as a result of recharge values being shared in this way is given in Figure 7.13.

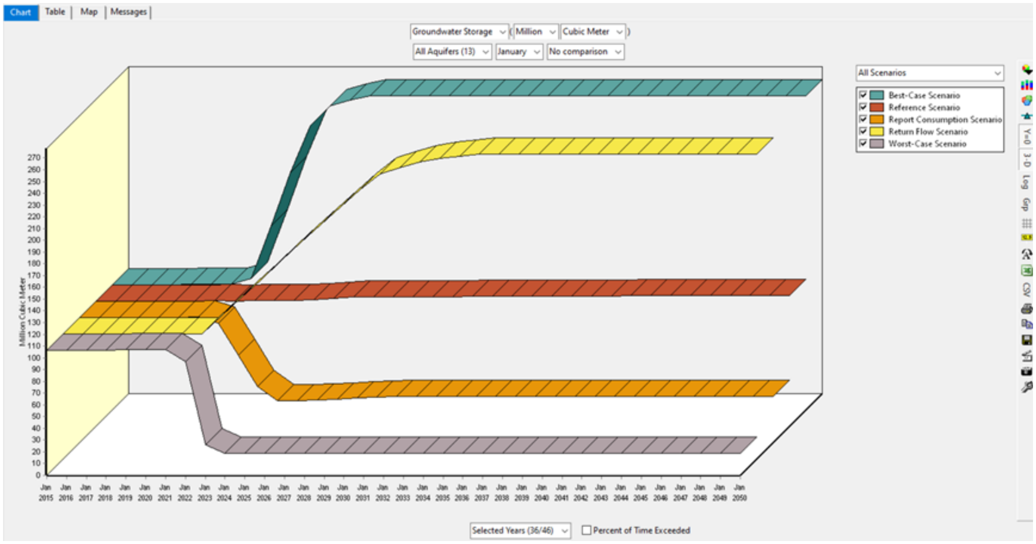

Figure 7.13. All Groundwater Capacity Values in January (hm^3)

The Reference Scenario, in Figure 7.13, shows a slight increase while it should remain constant, as stated above. The reason for this increase is that the ponds located in the irrigation areas of the wells and supplying water to the same agricultural area come into play and reduce the amount of water drawn from the wells.

Özdere Public Irrigation can be given as an example of these irrigations. While the agricultural area provided water only from the Özdere Irrigation Well until 2015, the amount of water drawn from the irrigation well decreased with the Özdere Pond opening in 2015, causing water to accumulate in the well due to the continuation of the recharge values. This situation is also seen in the Worst Case Scenario. With the Özdere Pond, an increase in the well capacity until 2022 was also observed. Then, due to the Worst Case

Scenario conditions starting with the year 2022, the volume of the well decreased. (Figure 7.14)

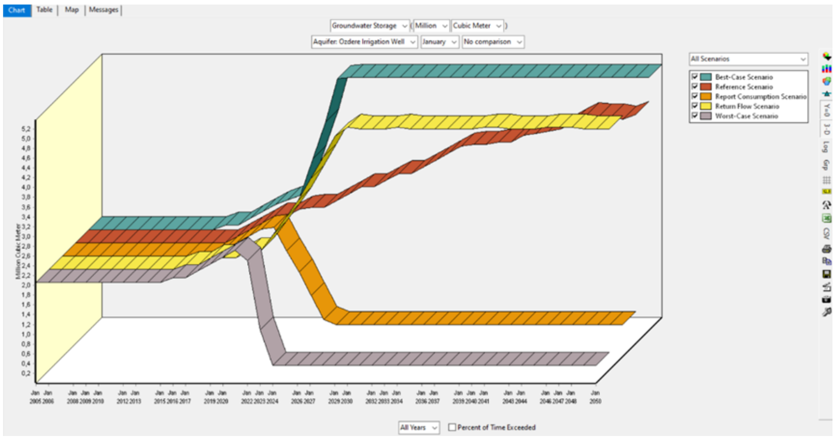

Figure 7.14. Capacity Values of Ozdere Irrigation Well in January During the Scenario Years (hm^3)

By looking at the coverage values of agricultural areas, it can be observed what percentage of the water need can be met in which month. For this reason, the coverage values of the monthly averages taken throughout the scenario of Oğlananası Public Irrigation, which is one of the underground irrigations and has the highest water consumption in the basin, are given in Figure 7.15. The lowest coverage value occurs in the Worst-Case scenario, as expected, and considering the monthly average data, the well that supplies water to the agricultural area had the most problems in providing water to irrigation in the summer months.

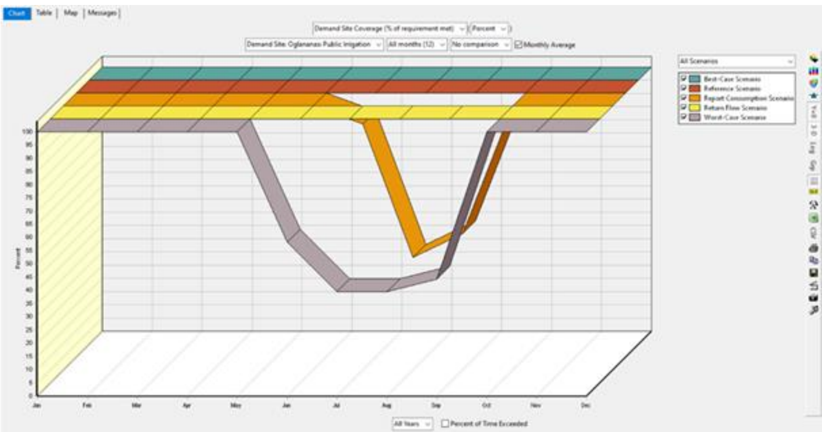

Figure 7.15. Monthly Average Coverage Values for Oğlananası Public Irrigation (%)

When a comparison is made for monthly coverage values throughout the scenario for Ahmetbeyli Public Irrigation, which is the only surface water public irrigation in the basin, the scenario where the coverage values will be the lowest is the Worst Case Scenario. It is seen that the coverage values decrease in the summer months even under the best conditions. This means that the entire water requirement of the agricultural area cannot be met during the summer months. As seen in Figure 7.16, August can be the most problematic month for this irrigation.

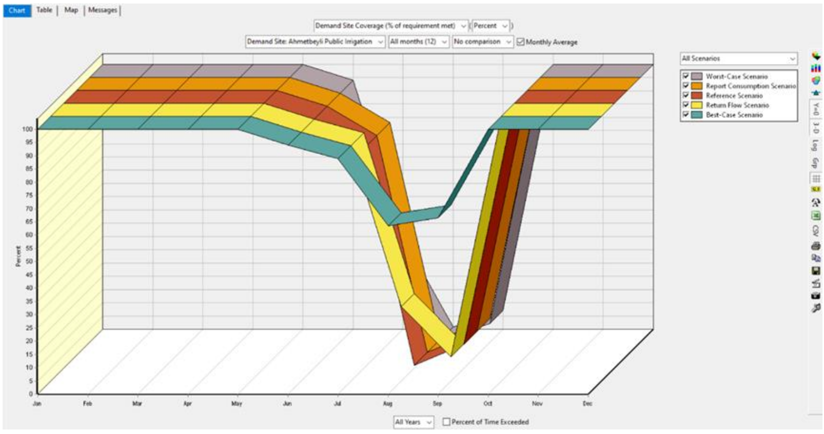

Figure 7.16. Monthly Average Coverage Values for Ahmetbeyli Public Irrigation (%)

Reliability is another fundamental analysis for demand points, and reliability is the percent of the timesteps in which a demand site's demand was fully satisfied. Reliability values for Çamönü Cooperative Irrigation were calculated in five different scenarios. While the reliability value is 100 out of 100 in Reference, Best Case and Return Flow Scenarios, it is 90.22 percent in the Report Consumption Scenario. The reason for this decrease is the decrease in the natural recharge value. The lowest reliability value was observed in the Worst-Case scenario. (Figure 7.17)

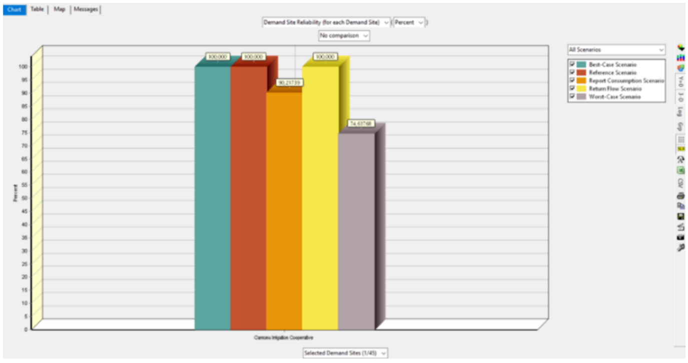

Figure 7.17. Reliability Values for Çamönü Cooperative Irrigation (%)

Scenarios desired to compare the amount of inflow values coming to the basin area during all years. In that case, it is expected that the flow rate values and recharge values will increase in the Best Case Scenario, which is the scenario that will meet the highest inflow value. In this scenario, there is a total inflow value of 392.8 hm^3 for the basin. The reason why the inflow value of the RCS is slightly less than the Reference Scenario is the reduced recharge values. On the other hand, the Return Flow Scenario is between the Reference Scenario and the Best Case Scenario in terms of inflow. In the Worst-Case Scenario, the lowest amount of water enters the basin. (Figure 7.18)

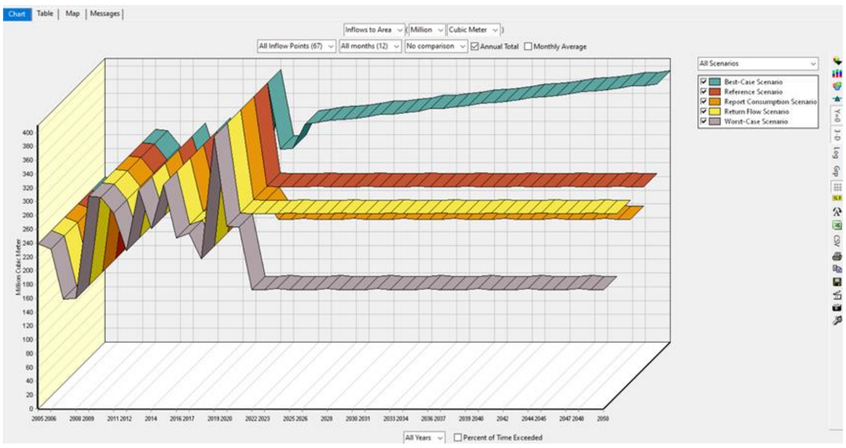

Figure 7.18. Inflow Values Obtained from Five Different Scenarios (hm^3)

When the capacity values of the dams in the basin are examined under the scenarios, the expected situation for the Ürkmez Dam is as in Figure 7.19 for January. The scenario where the dam's capacity value will be maximum will be the Best Case Scenario because in this scenario, in addition to reducing the irrigation water requirement, the amount of water coming into the dam has been increased, and the net evaporation values have been decreased. As expected, the scenario in which the capacity values will be the lowest is observed in the Worst Case scenario. The Reference Scenario has a higher capacity value than the Report Consumption Scenario because the current situation water consumption value is higher than the average amount of water given to irrigation between 2005-2019. Return Flow Scenario is placed between Reference Scenario and the Best Case Scenario as expected.

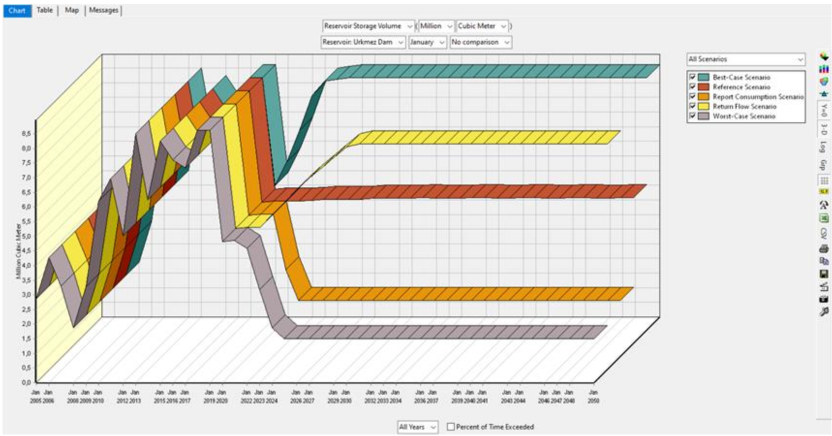

Figure 7.19. Dam Capacity Values for Ürkmez Dam in January (hm^3)

The Return Flow Scenario explained that not all of the water supplied to the agricultural field is consumed and 20% of it returns to the water source. As can be seen in Figure 7.20, while there is no return to the water source in other scenarios for all irrigations and greenhouses in the basin, this situation is defined only in the Return Flow Scenario, and the amount of water that returns to the resources from agricultural fields and greenhouses is 20.45 hm^3.

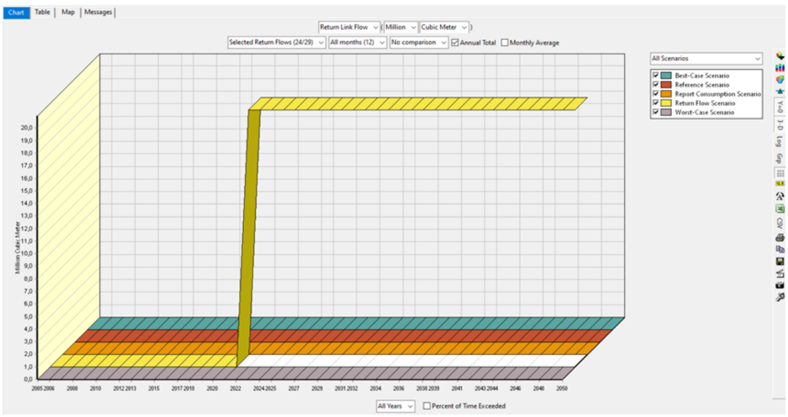

Figure 7.20. Return Flow Water Amount for All Irrigations and Greenhouses (hm^3)

If the amount of water returned for the entire basin is calculated, the "Other Uses" demand points defined for the dams include uses other than irrigation and drinking water supply, such as the flood drawn from the dams, and transmit the water directly to the downstream of the dam. Therefore, some returning water will also appear in other scenarios when dams are included for Return Flow values. (Figure 7.21)

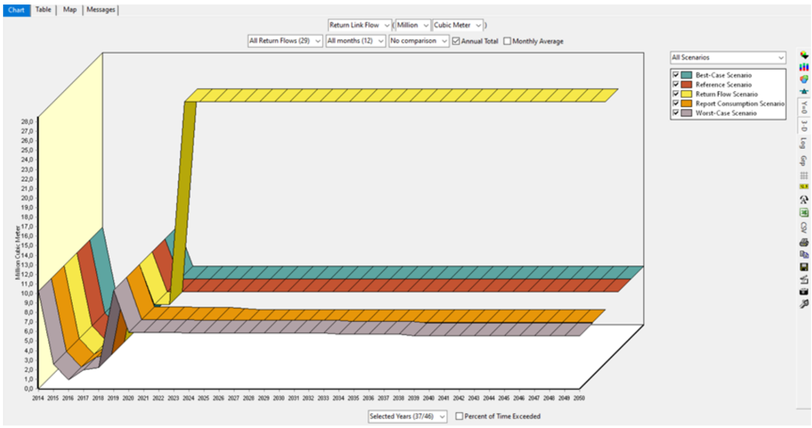

Figure 7.21. Return Flow Water Amount for Tahtalı-Seferihisar Sub-Basin (hm^3)

Since the use of different forecast methods affect the monthly flow distributions that are expected to occur differently from each method, the monthly average capacity values that the dams will show during the scenario years will also differ from each other. This situation is observed for Kavakdere Dam in Figure 7.22 Seasonal Naïve Method gives the lowest average when looking at monthly average capacity values, while Autoregressive Integrated Moving Average Method (ARIMA) gives the highest average storage values.

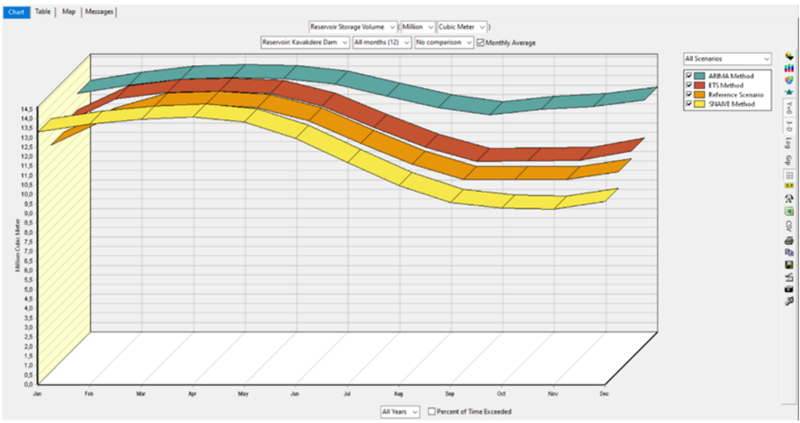

Figure 7.22. Monthly Average Storage Capacity of Kavakdere Dam (hm^3)

Another consequence of estimating monthly flow values using different methods is that the amount of flow that will enter the basin varies. According to Figure 7.23, in the scenario where the ARIMA method was used, in which the flow data showed an increasing trend, the highest inflow to the basin was observed as expected. In scenarios where Exponential Smoothing Method and Seasonal Naïve Methods are used, almost the same amount of water enters the basin over the years of the scenario.

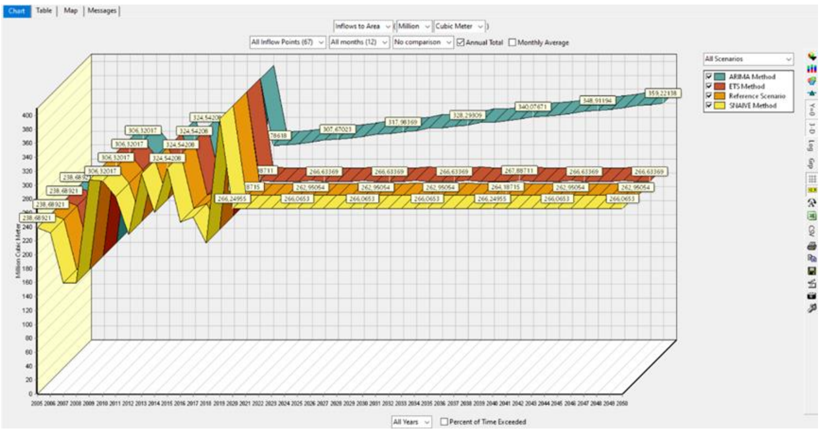

Figure 7.23. Inflow Values to the Basin Under Different Forecasting Methods (hm^3)

As can be understood from the results obtained and announced, it is evident that there will be water shortages due to unmet demands throughout the basin. The water deficit is observed the most is experienced during the water supply process to the 11 central districts of İzmir. As the population increases, the amount of drinking and utility water will increase, the amount of demand that cannot be met will also increase. Even if the Reference Scenario is maintained in the same way, Tahtalı Dam will reach a level that can meet approximately 25% of the water needs of the central districts. This situation shows how necessary it is to carry out studies to increase the efficiency and recharge values of the available resources. And the creation of alternative water resources will be inevitable.

Although there are 866 documented wells throughout the basin, the existence of many undocumented wells is also known. The gradual increase in the number of these wells dramatically affects the amount of groundwater. Therefore, the water use values of the wells in the basin should be controlled.

Reducing transmission loss applied to public irrigations in the Best Case scenario encourages less water use and protects water resources.

Studies should be carried out to eliminate or reduce the evaporation losses in the dams because increasing temperatures due to global warming cause expanding the amount of evaporation on free water surfaces.

It is necessary to grow products that use less water in agricultural areas. Producers should be encouraged to change product patterns.

In terms of water use, it is necessary to raise the awareness of the people regionally in the basin and provide training to increase water saving.

In addition to developing and increasing the number of wastewater treatment plants, it should also be ensured that the extra water given to irrigation can be reused.

REFERENCES

Ahmadaali, Jamal, Gholam-Abbas Barani, Kourosh Qaderi, and Behzad Hessari. "Analysis of the Effects of Water Management Strategies and Climate Change on the Environmental and Agricultural Sustainability of Urmia Lake Basin, Iran." *Water* , 2018.

Amin, Ali, Javed Iqbal, Areesha Asghar, and Lars Ribbe. "Analysis of Current and Future Water Demands in the Upper Indus Basin under IPCC Climate and Socio-Economic Scenarios Using a Hydro-Economic WEAP Model." *Water*, 2018.

Brown, Thomas C., Vinod Mahat, and Jorge A. Ramirez. "Adaptation to Future Water Shortages in the United States Caused by Population Growth and Climate Change." *Earth's Future*, 2019: 219-234.

Chinnasamy, Pennan, Luna Bharati, Utsav Bhattarai, Ambika Khadka, Vaskar Dahal, and Shahriar Wahid. "Impact of planned water resource development on current and future water demand in the Koshi River basin, Nepal." *Water International*, 2015: 1004-1020.

Coşgun, Ömer. *Zamantı Irmağı Alt Havzasındaki DSİ Projelerinin WEAP (Water Evaluation and Plannig System) Programı ile Modellenmesi ve Bahçelik Barajı İşletme Çalışması Örneği Yüksek Lisans Tezi.* Kayseri: Erciyes Üniversitesi, 2017.

Davie, Tim. "Precipitation formation." In *Fundamentals of Hydrology (2nd Edition),* by Tim Davie, 14-17. USA: Routledge/Taylor & Francis Group, 2008.

DSİ. *(Mülga EİE).* DSİ, 2012.

Gao, Jingjing, Per Christensen, and Wei Li. "Application of the WEAP model in strategic environmental assessment: Experiences from a case study in an arid/semi-arid area in China." *Journal of Environmental Management*, 2017: 363-371.

Haddad, Marwan, Anan Jayousi, and Salam Abu Hantash. "ApplicabilityY of WEAP as Water Management Decision Support System Tool on Localized Area of

Watershed Scales: Tulkarem District in Palenstine as Case Study." *Eleventh International Water Technology Conference.* Sharm El-Sheikh, Egypt, 2007.

Hao, Lu, Ge Sun, Yongqiang Liu, and Hong Qian. "Integrated Modeling of Water Supply and Demand Under Management Options and Climate Change Scenarios in Chifeng City, China." *Journal of the American Water Resources Association* , 2015.

Hassan, Daniyal, Rakhshinda Bano, Steven. J. Burian, and Kamran Ansari. "Modeling Water Demand and Supply for Future Water Resources Management." *International Journal of Scientific & Engineering Research*, 2017.

Huber-Lee, Annette, David Yates, David Purkey, Winston Yu, and Benjamin Runkle. *Water, Climate, Food, and Environment in the Sacramento Basin.* ADAPT Project, 2003.

Hyndman, Rob J., and George Athanasopoulos. *Forecasting: Principles and Practice (2nd Edition).* Melbourne, Australia: OTexts, 2018.

İzmir Governorship Provincial Directorate of Environment and Urbanization. *İzmir İli 2018 Yılı Çevre Durum Raporu.* İzmir: Türkiye Cumhuriyeti İzmir Valiliği Çevre ve Şehircilik İl Müdürlüğü, 2019.

İzmir Water and Sewerage Administration General Directorate. *Arsenik İçme Suyu Arıtma Tesisleri: İZSU.* 2019. https://www.izsu.gov.tr/tr/Faaliyet/1.

—. *İçme Suyunun Arıtılması: İZSU.* 2019. https://www.izsu.gov.tr/tr/Faaliyet/1.

—. *İzmir'e Verilen İçme ve Kullanma Suyu: İZSU.* 2019. https://www.izsu.gov.tr/tr/TesisDetay/1/35/2.

—. *Yeraltı Su Kaynakları, İZSU.* 2019. https://www.izsu.gov.tr/tr/TesisDetay/1/4/2.

—. *Yeraltı Su Kaynakları: İZSU.* 2019. https://www.izsu.gov.tr/tr/TesisDetay/1/4/2.

—. "Yerüstü Su Kaynakları: iZSU." *İZSU.* n.d. https://www.izsu.gov.tr/tr/TesisDetay/1/3/2.

Kou, Limin, Xiangyang Li, Jianyi Lin, and Jiefeng Kang. "Simulation of Urban Water Resources in Xiamen Based on a WEAP Model." *Water*, 2018.

Kumar, Pankaj, et al. "Current Assessment and Future Outlook for Water Resources Considering Climate Change and a Population Burst: A Case Study of Ciliwung River, Jakarta City, Indonesia." *Water,* 2017.

Levite, Herve, Hilmy Sally, and Julien Cour. "Testing water demand management scenarios in a water-stressed basin in South Africa: application of the WEAP model." *Physics and Chemistry of the Earth*, 2003: 779-786.

Li, Xue, Yue Zhao, Chunli Shi, Jian Sha, Zhong-Liang Wang, and Yuqiu Wang. "Application of Water Evaluation and Planning (WEAP) model for water resources management strategy estimation in coastal Binhai New Area, China." *Ocean & Coastal Management*, 2015: 97-09.

Loon, A. van, H. Mathijssen, and P. Droogers. *Water Evaluation and Planning System Gediz basin - Turkey*. WatManSup Project, 2007.

Loucks, Daniel P., and Eelco van Beek. "River Basin Modeling." In *Water Resource Systems Planning and Management*, by Daniel P. Loucks and Eelco van Beek, 474-478. Springer, 2017.

Moore, Catherine, and John Doherty. "Role of the calibration process in reducing model predictive error." *Water Resources Research*, 2005.

Moriasi, D. N., M. W. Gitau, N. Pai, and P. Daggupati. "Hydrologic and Water Quality Models: Perfromance Measures and Evaluation Criteria." *Transactions of the ASABE*, 2015: 1763-1785 .

Mounir, Zakari Mahamadou, Chuan Ming Ma, and Issoufou Amadou. "Application of Water Evaluation and Planning (WEAP): A Model to Assess Future Water Demands in the Niger River (In Niger Republic)." *Modern Applied Science*, 2011.

Nash, J.E., and J.V. Sutcliffe. "River flow forecasting through conceptual models part I A discussion of principles." *Journal of Hydrology*, 1970: 282-290.

Olabanji, Mary Funke, Thando Ndarana, Nerhene Davis, and Emma Archer. "Climate change impact on water availability in the olifants catchment (South Africa) with potential adaptation strategies." *Physics and Chemistry of the Earth*, 2020.

Psomas, Alexandros, Yiannis Panagopoulos, Konstantinos Stefanidis, and Maria Mimikou. "Assessing future water supply and demand in a water-stressed catchment after environmental restrictions on abstractions." *Journal of Water Supply: Research and Technology—AQUA*, 2017: 442-453.

Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Water Management, Basin Management Department. *Küçük Menderes Havzası Sektörel Su Tahsisi Eylem Planı Hazırlanması Projesi, Sektörel Su Tahsisi Eylem Planı ve Genelgesi (2020-2025).* Ankara: Republic of Turkey Ministry of Agriculture and Forestry, General Directorate of Water Management, 2019.

Republic of Turkey Ministry of Development. *Su Kaynakları Yönetimi ve Güvenliği Özel İhtisas Komisyonu Raporu.* Ankara: Republic of Turkey Ministry of Development, 2014.

Republic of Turkey Ministry of Forestry and Water Affairs, General Directorate of State Hydraulic Works, Department of Surveying, Planning and Allocations. *Küçük Menderes Havzası Master Plan Raporu Hazırlanması İşi Master Plan Nihai Raporu.* Ankara: SUİŞ Proje, 2016.

Republic of Turkey, İzmir Governorship Provincial Directorate of Environment and Urbanization. *İzmir İli 2019 Yılı Çevre Durum Raporu.* İzmir: Türkiye Cumhuriyeti İzmir Valiliği Çevre ve Şehircilik İl Müdürlüğü, 2020.

Republic of Turkey, Ministry of Agriculture and Forestry. *Çevresel Göstergeler Kitapçığı.* Ankara: Republic of Turkey, Ministry of Agriculture and Forestry, 2009.

Republic of Turkey, Ministry of Agriculture and Forestry. *İklim Değişikliğinin Su Kaynaklarına Etkisi.* Ankara: Republic of Turkey, Ministry of Agriculture and Forestry, 2016.

Republic of Turkey, Ministry of Agriculture and Forestry. *Ulusal Havza Yönetim Stratejisi (2014-2023).* Ankara: T.C. Orman ve Su İşleri Bakanlığı, 2014.

Republic of Turkey, Ministry of Agriculture and Forestry, General Directorate of Water Management, Department of Basin Management. *Sektörel Su Tahsisi Eylem Planı ve Genelgesi.* Ankara: Republic of Turkey, Ministry of Agriculture and Forestry, 2019.

Republic of Turkey, Ministry of Agriculture and Forestry, General Directorate of Water Management,. *Küçük Menderes ve Gediz Havzası Su Tahsis Planlarının Hazırlanması ,Küçük Menderes Havzası,Sektörel Su Tahsisi Eylem Planı.* Ankara: Republic of Turkey, Ministry of Agriculture and Forestry, 2019.

Repuclic of Turkey, Ministry of Agriculture and Forestry. "Türkiye'de Havza Rehabilitasyon Projeleri." *www.tarimorman.gov.tr.* December 2017. https://www.tarimorman.gov.tr/CEM/Belgeler/yay%C4%B1nlar/yay%C4%B1nlar%202018/HAVZA%20BROS%20TR%20KIRIMx220318m2.pdf.

R-Project. *What is R?: R-Project.* n.d. https://www.r-project.org/about.html.

Seferihisar Municipality. *Seferihisar Belediyesi.* June 23, 2016. http://seferihisar.bel.tr/seferihisarda-su-koruma-altinda/.

Shiklamonov, Igor. "World fresh water resources." In *Water in Crisis: A Guide to the World's Freshwater Resources*, by Igor Shiklamonov. Oxford: Oxford University Press, 1993.

Sieber, Jack. *Water Evaluation And Planning System User Guide.* Stockholm Environment Institute, 2015.

State Hydraulics Works (DSI). "Resmi İstatistikler: DSİ." *Devlet Su İşleri.* 10 12, 2019. https://dsi.gov.tr/Sayfa/Detay/972.

Tena, Tewodros M., Phenny Mwaanga, and Alick Nguvulu. "Hydrological Modelling and Water Resources Assessment of Chongwe River Catchment using WEAP Model." *Water*, 2019.

Usul, Nurünnisa. "Blaney Criddle Method." In *Engineering Hydrology*, by Nurünnisa Usul, 125. Ankara: METU Press Publishing Company, 2017.

Usul, Nurünnisa. "Engineering Hydrology." In *Engineering Hydrology*, by Nurünnisa Usul, 290-292. Ankara: METU Press, 2017.

Usul, Nurünnisa. "Evaporation and Transpiration." In *Engineering Hydrology*, by Nurünnisa Usul, 117. Ankara : METU Press Publishing Company, 2017.

Usul, Nurünnisa. "Mass Curve Analysis." In *Engineering Hydrology*, by Nurünnisa Usul, 290-292. Ankara: METU Press Publishing Company, 2017.

Usul, Nurünnisa. "Sequent Peak Analysis." In *Engineering Hydrology*, by Nurünnisa Usul, 294-295. Ankara: METU Press Publishing Company, 2017.

Usul, Nurünnisa. "The Process of the Growth of Droplets." In *Engineering Hydrology,* by Nurünnisa Usul, 43. Ankara : METU Press Publishing Company, 2017.

WEAP. n.d. https://www.weap21.org/index.asp?action=219&NewLang=EN.

World Health Organization (WHO). *World Health Organization/Health Topics/Floods.* n.d. https://www.who.int/health-topics/floods#tab=tab_1.

Yanmaz, A. Melih. *Applied Water Resources Engineering.* Ankara: Metu Press Publishing Company, 2018.

Yanmaz, A. Melih. "Classification of Dams." In *A. Melih Yanmaz,* by Applied Water Resources Engineering, 43-46. Ankara: METU Press Publishing Company, 2018.

Yanmaz, A. Melih. "Classification of Dams." In *Applied Water Resources Engineering (5th Edition)*, by A. Melih Yanmaz, 43-46. Ankara: METU PRESS, 2018.

Yanmaz, A. Melih. "Parts of Dams." In *Applied Water Resources Engineering (5th Edition),* by A. Melih Yanmaz, 47-48. Ankara: METU Press Publishing Company, 2018.

Yaykiran, Salim, Gokhan Cuceloglu, and Alpaslan Ekdal. "Estimation of Water Budget Components of the Sakarya River Basin by Using the WEAP-PGM Model." *Water,* 2019.