RISK-BASED RESERVOIR OPERATION UNDER DROUGHT CONDITIONS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

MUSTAFA KEMAL TÜRKERİ

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
CIVIL ENGINEERING

DECEMBER 2019

Approval of the thesis:

RISK-BASED RESERVOIR OPERATION UNDER DROUGHT CONDITIONS

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ABSTRACT

RISK-BASED RESERVOIR OPERATION UNDER DROUGHT CONDITIONS

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December 2019, 225 pages

This study introduces a practical drought risk assessment methodology for reservoirs and hydraulic structures, which can be used in basin drought risk management. Reservoir operation study is used as a main tool in the risk assessment methodology.

The methodology developed in this study contains a probabilistic deficiency analysis approach for reservoir inflows. Different scenarios are developed which include hydrological deficiencies for various return periods. Developed scenarios are also modified for climate change by utilizing trend slope. In addition, past hydrological drought events are also evaluated in order to compare probabilistic scenarios with historical drought events. The probabilistic scenarios and reservoir operation studies are modeled by using Water Evaluation and Planning (WEAP) software of Stockholm Environment Institute (SEI).

In the discussion part, the vulnerability status of reservoirs is determined by evaluating the reservoir behaviors under drought conditions and supply insufficiencies obtained with operation studies. By utilizing determined vulnerabilities, operation strategies to mitigate hydrological drought impacts are determined.

The developed methodology is tested successfully on a reservoir system which includes three dams and one diversion weir located in Sivas, Turkey. A catastrophic drought event with 100-years return period was assessed and a future operation plan was recommended for the hydraulic structures located in the case study area. With the application of recommended operation strategies, it is determined that Sivas Province and Hafik District will have sufficient municipal water until 2050 even if a catastrophic drought occurs in the study area, provided that there is no change in the conditions considered in this study.

Keywords: Drought, Drought Risk Management, Reservoir Operation, Drought Mitigation, WEAP

ÖZ

KURAKLIK KOŞULLARINDA RİSK ESASLI REZERVUAR İŞLETMESİ

Türkeri, Mustafa Kemal
Yüksek Lisans, İnşaat Mühendisliği
Tez Danışmanı: Prof. Dr. Zuhal Akyürek

Aralık 2019, 225 sayfa

Bu çalışma, rezervuarlar ve hidrolik yapılar için havza kuraklık risk yönetiminde kullanılabilecek pratik bir kuraklık risk değerlendirme metodolojisi sunmaktadır. Risk değerlendirme metodolojisinde rezervuar işletme çalışması ana araç olarak kullanılmıştır.

Çalışma kapsamında geliştirilen metodoloji, rezervuar giriş akımları için olasılıksal bir eksiklik analizi yaklaşımı içermektedir. Çeşitli tekerrür süreleri için hidrolojik eksiklikleri içeren birçok senaryo geliştirilmiştir. Geliştirilen senaryolar, trend eğimi kullanılarak iklim değişikliği için de modifiye edilmiştir. Ek olarak, olasılıksal senaryoları tarihsel kuraklık olayları ile karşılaştırabilmek adına geçmiş hidrolojik kuraklık olayları da incelenmiştir. Olasılıksal senaryolar ve rezervuar işletme çalışmaları Stockholm Çevre Enstitüsü'nün (SEI) Su Değerlendirme ve Planlama (WEAP) yazılımı kullanılarak modellenmiştir.

Tartışma bölümünde, kuraklık koşulları altında rezervuar davranışlarının ve işletme çalışmaları sonucunda elde edilen arz yetersizliklerini değerlendirerek rezervuarların etkilenebilirlik durumu belirlenmiştir. Belirlenen etkilenebilirlik durumundan faydalanarak, hidrolojik kuraklık etkilerini azaltmak için işletme stratejileri belirlenmiştir.

Geliştirilen metodoloji, Sivas, Türkiye'de bulunan üç baraj ve bir regülatör içeren bir rezervuar sisteminde başarıyla test edilmiştir. 100-yıl tekerrürlü katastrofik bir kuraklık olayı değerlendirilmiş ve çalışma alanında yer alan hidrolik yapılar için gelecek için bir işletme planı önerilmiştir. Bu çalışmada değerlendirilen durumların değişmemesi koşuluyla, önerilen işletme stratejileri uygulandığında, çalışma alanında katastrofik bir kuraklık gerçekleşse dahi Sivas İli ve Hafik İlçesi'nin 2050 yılına kadar yeterli içmesuyuna sahip olacağı tespit edilmiştir.

Anahtar Kelimeler: Kuraklık, Kuraklık Risk Yönetimi, Rezervuar İşletmesi, Kuraklık Etkilerini Azaltma, WEAP

To Humanity…

ACKNOWLEDGEMENTS

First of all, I would like to express my gratitude to my supervisor, Dr. Zuhal Akyürek for her patience, encouragement, guidance and support in the thesis process.

I would like to thank my colleagues Emre Köken, Sibel Alan, Çağdaş Şimşek, Murat Şahin, Melek Güner Gökdağ, F. Onuralp Mescigil and Emre Fatih Sucu and my supervisors Adil Akyatan and Adil Bacak in Dolsar Engineering Inc. Co. for their utmost technical support and encouragements. They have a great amount of influence in my personal and professional life.

I also would like to thank all members of the examining committee, Dr. Melih Yanmaz, Dr. Elçin Kentel Erdoğan, Dr. İsmail Yücel and Dr. Ersoy Yıldırım for their kind support and interest in my study.

My special thanks to Dr. Zekâi Şen, for his support and assistance in my thesis process.

I also would like to thank to administrators in General Directorate of State Hydraulic Works, Study, Planning and Allocations Department for providing the required data for my thesis.

I would like to express my gratitude and thankfulness to my family for their precious support, motivation and patience in every step of my life. They made me the person who I am now, and it is impossible to thank them enough.

Lastly, I would like to express my love and gratitude to Ezgi Pamuk for her utmost support, tolerance and love. Without her support, it was impossible to complete this study.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

CDF	Cumulative Distribution Function
DHI	Danish Hydraulic Institute
DSİ	State Hydraulic Works of Turkey (Devlet Su İşleri)
DWR	Downstream water rights
GEV	Generalized Extreme Value
GIS	Geographic Information System
GWP	Global Water Partnership
HEC	Hydraulic Engineering Center of US Army Corps of Engineers
ICHARM	The International Center for Water Hazard and Risk Management
IDMP	Integrated Drought Management Program
IPCC	The Intergovernmental Panel on Climate Change
MOS	Meteorological Observation Station(s)
PDF	Probability Distribution Function
PDSI	Palmer Drought Severity Index
PHDI	Palmer Hydrological Drought Index
PNI	Percent of Normal Precipitation Index
SDI	Streamflow Drought Index
SEI	Stockholm Environmental Institute
SII	Standardized Inflow Index
SPI	Standardized Precipitation Index
SRI	Standardized Runoff Index
SRSI	Standardized Reservoir Storage Index
SWAT	Soil Water Assessment Tool
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Program
WEAP	Water Evaluation and Planning (Software)
WMO	World Meteorological Organization

CHAPTER 1

INTRODUCTION

Drought is a natural disaster that significantly reduces the recorded normal levels of precipitation, which adversely affects the resulting soil and water resources and production systems and leads to severe hydrological imbalances (UNCCD, 1995). Mean land and ocean surface temperature has increased approximately 0.85 °C due to the increase of greenhouse gas emissions between 1880 and 2012 (IPCC, 2014) (Figure 1.1). Climate change impacts on hydrologic cycle lead to variations in precipitation, temperature, soil moisture and increase the frequency and duration of drought events especially after 1980s in the Mediterranean region (Sheffield & Wood, 2008; Hoerling et al., 2012). Drought risk in the Mediterranean region already increased due to climate change impacts and it is expected to increase more because of the human effects on the region (Gudmundsson & Seneviratne, 2016; Cook et al., 2018).

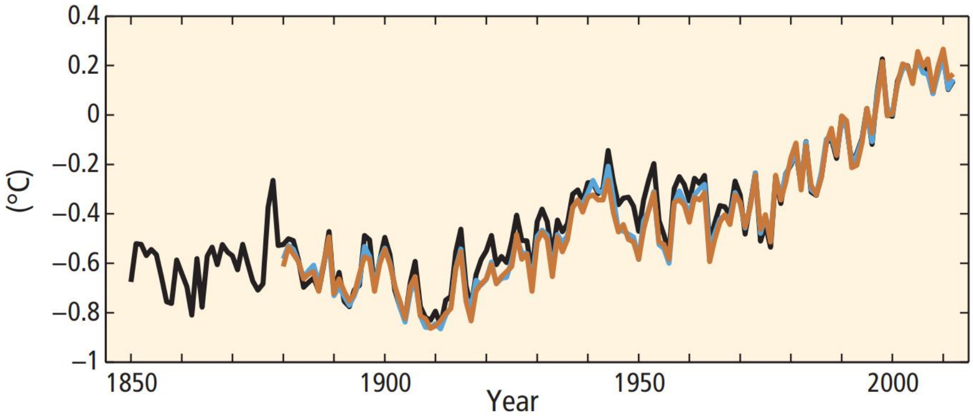


Figure 1.1. Globally averaged combined land and ocean surface temperature change in the last century *(IPCC, 2014)*[1]

[1] Colors indicate different datasets.

Drought reveals itself as a decrease in precipitation and an increase in temperature. If dry period persists by causing variations in the precipitation and temperature; soil moisture decreases, potential evapotranspiration increases and eventually deficiencies occur in streamflow and inflow of the reservoirs (National Drought Mitigation Center, 2018a). Drought impacts cause many socio-economic outcomes such as crop losses, animal deaths and drinking water insufficiencies and severe water shortages which lead to death of humans.

According to United Nations Convention to Combat Desertification drought is *a complex and slowly encroaching* natural disaster (UNCCD, 2018). The slow character of drought makes detection of the beginning and the end of drought period very hard (Şen, 2015). Drought differs from other natural hazards as it causes less structural damage than the other natural disasters such as floods and hurricanes (Wilhite, 2000). In addition, drought hazards occur as various site-specific impacts based on the drought conditions and characteristics. This issue reflects the complex character of drought events. (World Meteorological Organization and Global Water Partnership, 2017).

In the recent fifty years, many statistical drought indices have been developed to detect drought durations and severities using meteorological, hydrological and agricultural parameters (Integrated Drought Management Program, 2018). It is possible to determine drought durations, magnitudes and severities by using drought indices (Svoboda & Fuchs, 2016). They are powerful tools to provide information about the severity and duration of drought events. Drought indices use hydrometeorological indicators such as changes in precipitation and temperature, or streamflow and reservoir water level as input. By calculating drought indices, magnitude, severity and frequency of drought events can be determined statistically. Besides, probabilistic approaches can also be utilized to calculate drought hazards. Probability of occurrence can be calculated based on historical data.

However, drought indices do not quantify severity of a drought hazard and do not exhibit potential consequences of a drought period directly. Drought indices should be supported with socio-economic parameters to determine and measure the actual impact of a dry period (Shahid & Behrawan, 2008). These parameters can differ from time to time and from region to region. Regional capabilities for coping with drought impacts determine the damage done by a severe drought and may improve or get worse in time. Therefore, vulnerability of different regions to the identical drought hazards can be different. Drought vulnerability assessment is performed to characterize and examine region-specific reactions to drought hazards. Many indicators –affected human and animal population, wildlife susceptibility, reliable water demand availability, etc.- can be used in vulnerability assessment. Some of those indicators might be not even quantifiable. Thus, the most relevant indicators should be selected according to the studied region and the aim of study (Rajsekhar et al., 2015).

Although Turkey experiences frequent and severe drought hazards, droughts are not considered among primary design parameters for the design of hydraulic structures. However, with the recent impacts of climate change, the interest in drought-resistant hydraulic structure design has been increased. State Hydraulic Works (DSİ) has initiated preparation of “Drought Operation Directive” for dry periods (DSİ, 2017). This directive covers short-term actions; in other words this directive serves for crisis management. Crisis management is a fast solution for drought event, which occurred recently or about to occur in a short span of time. Most of the time, unless crisis management is not supported with risk management which includes long-term actions, crisis management will not be sufficient to mitigate drought events (Şen, 2015). So, the mitigation of an unexpected drought event is costly (World Meteorological Organization and Global Water Partnership, 2017). It is shown that with a risk management approach, drought mitigation costs can be reduced and preparedness to drought events increases (World Meteorological Organization and Global Water Partnership, 2017). However, a risk assessment methodology for hydraulic structures is missing in Turkey. Therefore, in order to develop a better ability to manage and operate hydraulic structures under drought, a drought risk assessment methodology should be applied and risk-based operation strategies for drought periods should be developed for reservoir operation.

Considering the drought risk assessment methodology requirement for reservoirs in Turkey, this study aims to develop an efficient risk assessment methodology for reservoir operations which can be used by engineers directly. Main objectives of this study are listed below:

- Determination of deficit parameters by calculating exceedance probabilities from historical deficit data.
- Development of an algorithm which generates hydrological deficiency hydrographs from hydrological drought and deficiency probabilities for different return periods,
- Application of a simple trend-based climate change modification to the determined exceedance probability levels,
- Utilizing reservoir operation as the main tool of impact and vulnerability assessments and eventually develop a drought risk assessment for reservoirs,
- Validation of the risk assessment methodology by comparing selected historical drought hazards determined with different hydrological drought indices.

As a case study, the risk assessment methodology developed in this study is applied to two existing and two planned reservoirs in Sivas, Turkey. Then the results are assessed, and applicability of the proposed methodology is discussed.

This thesis consists of 6 chapters. The organization of the thesis is given below:

- In Chapter 2, a brief literature review on drought risk management, drought and deficit analyses, trend-based climate change predictions and applications, drought-based reservoir operation and available reservoir operation tools and previous applications, are presented.
- In Chapter 3, the methodology and utilization procedure of the methodology is given in detail. Chapter 3 also includes case study characteristics and input data.
- Chapter 4 includes applications for the case study. Deficit analyses, climate change modifications, deficiency hydrograph production and determination of historical drought periods for the case study area are given. Chapter 4 also includes input parameters and the results of operation model.
- In Chapter 5, discussion of results and recommendations for operation strategy policies in the case study are given. Additionally by using the results acquired from the case study, the methodology is discussed.
- In Chapter 6, final remarks and further recommendations are given.

CHAPTER 2

LITERATURE REVIEW

This chapter includes previous studies, methods and tools available to develop a hydrological drought risk management methodology for reservoir operation. According to the given objectives in Chapter 1, literature review is divided into six different topics, which are drought risk management, hydrological drought and deficit analyses, trend-based climate change predictions, drought indices, drought-based reservoir operation and reservoir operation tools.

2.1. Drought Risk Management

Though drought is a natural disaster and its occurrence can be evaluated with the physical and climatic characteristics of the study site as in all of the other natural disasters, drought is different from other natural disasters with its region-specific impacts (Wilhite, 2000). The vulnerability and resilience of the affected sites are different. Therefore, impacts of the same drought event can be felt differently from location to location (World Meteorological Organization and Global Water Partnership, 2017). In addition, the slow character of droughts causes the impacts of drought events to be felt longer. Longer durations and complex socio-economic impacts make drought one of the costliest disasters (National Drought Mitigation Center, 2018a).

The traditional management approach for drought is *crisis management* (Wilhite, 2000). Crisis management includes short term actions during drought events and actions for relief after drought events. Crisis management approach does not give weight on mitigation, preparedness, prediction and monitoring (Wilhite, 2000). This approach is often costly and does not include permanent precautions for drought hazard. The second approach is *risk management*. Risk management focuses on possible drought hazards and aims to form medium- and long-term action plans in order to prevent or mitigate possible drought events. Risk management increases preparedness to drought events, provides an action plan before drought event occurs and a monitoring system to predict drought events. After a detailed risk management plan and realization of the actions determined by the plan, it is much easier to mitigate drought impacts during the drought. The risk management approach reduces the drought damage, increases the resistance to drought events and most importantly, decreases the cost (World Meteorological Organization and Global Water Partnership, 2017).

Drought risk assessment includes two major steps, drought impact assessment and drought vulnerability assessment. Most of the studies regarding drought management are based on impact assessment alone. However, a full-scale drought management approach should also include socio-economic vulnerability in addition to drought hazard (Rajsekhar et al., 2015). Drought risk management including socio-economic vulnerability parameters is a rather new concept and there are a few studies available. Keenan and Krannich (1997) and Wilhite (1993) give weight on vulnerability issue in drought hazard. In his book, Wilhite (2000) shows the procedure and definitions for drought risk management approach. Wilhelmi and Wilhite (2002) proposed a geographical information system (GIS) based vulnerability analysis that mainly focuses on agricultural drought. Sönmez et al. (2005), introduced an impact assessment procedure for agricultural drought based on Standardized Precipitation Index (SPI) (McKee et al., 1993). Shahid and Behrawan (2008) further developed the methodology of Sönmez et al. (2005) and introduced many socio-economic vulnerability parameters and make the calculation procedure more fitting for risk management. Shahid and Behrawan also extend the methodology of Sönmez et al. (2005) in order to fit for all drought types. There are many application studies that include the risk management procedure of Shahid and Behrawan such as He et al. (2011), Kim et al. (2013) and Zhang et al. (2014). Lastly, Rajsekhar et al. (2015) also use the same procedure, however in their study, the authors focused on the strong and weak points of previous risk management studies and proposed a more robust risk assessment using a multivariate drought index which is applicable to all types of droughts.

Although there are many academic studies related to drought risk management, the application of risk management is mostly a governmental issue and the decision makers are mostly governmental bodies. Therefore, practical studies such as drought management plans and action plans are very important in drought risk management. Wilhite (1996) proposed a step by step drought mitigation and preparedness methodology for governmental bodies. This approach along with the other academic resources on drought risk management has been used in Colorado Drought Mitigation and Response Plan (Colorado Water Conservation Board, 2013).

In Turkey, drought risk management is a new topic. However, there are some academic resources about vulnerability assessment. Sönmez et al. (2005), used SPI and performed agricultural vulnerability assessment of Turkey. Even though the name of study implies vulnerability assessment, this study mainly focuses on impact assessment and does not include socio-economic impacts of drought events. Türkeş (2017) also has a similar study which includes a detailed risk management methodology for Turkey. The first comprehensive study in Turkey which introduces drought risk management approach is Konya Basin Drought Management Plan (General Directorate of Water Management, 2015). This report is an enhanced application of risk management studies done in Colorado Drought Mitigation and Response Plan and it is an adaptation of academic literature on drought risk management studies to Konya Basin in Turkey. Drought management plans for other river basins in Turkey are still ongoing and many of them have already been completed.

2.2. Hydrological Drought and Deficit Analyses

According to Wilhite and Glantz (1985), there are four types in drought definition; meteorological, agricultural, hydrological and socio-economic droughts. The first three items caused by the physical aspects of drought such as precipitation deficit, crop yield loss, streamflow deficit, etc. The last one, socio-economic drought includes perception or reaction of the affected people to drought events. Socio-economic drought affects health, well-being and quality of life. Socio-economic impacts can be considered as a supply and demand problem for the people affected by drought events (Yevjevich, 1967). Mitigation of socio-economic drought includes mitigations and precautions regarding covering the demand of the people; such as operational study scenarios, alternative water resources, etc. Socio-economic drought can be considered as the final effect of a drought event.

A comprehensive explanation of different types of droughts is given in Figure 2.1.

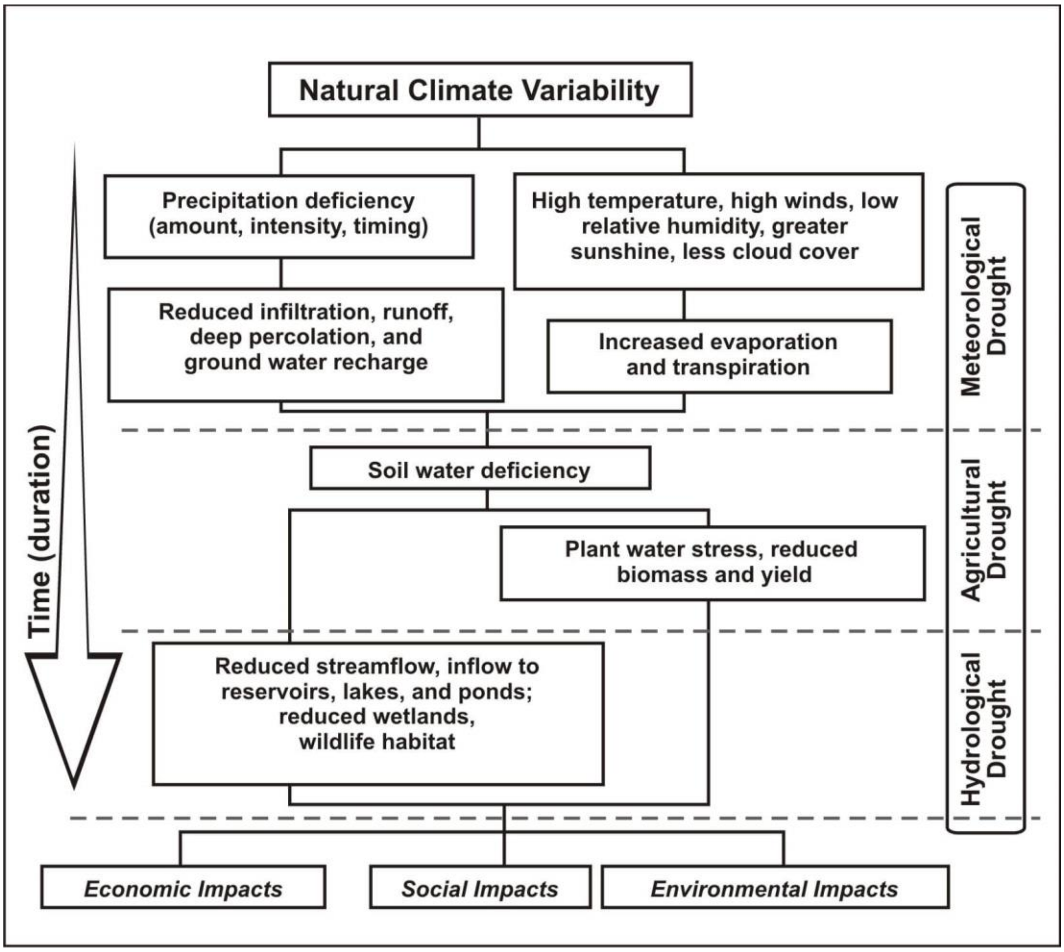


Figure 2.1. Causes and effects of different types of drought *(Wilhite & Glantz, 1985)*

The impacts of drought often depend on the viewpoint of the affected people, and a drought event may impact different people in different ways. Therefore, developing a general drought definition is difficult. Because of this issue, early researchers focused on the climatologic impacts on the precipitation, temperature, soil moisture and runoff in order to define objective drought periods. One of the first and important studies is Yevjevich's study (1967) which includes definition of hydrologic drought. The study contains clear explanations of different drought types and definitions for agriculturist, engineer, geophysicist and economist point of view. Then, using runs theory as a statistical distribution; three types of runs are defined for hydrologic drought; run-length of negative deviations of a time series (i.e. duration), run-sum of negative deviations between a downcross and an upcross of a time series (i.e. severity) and area-run as the deficit of water over a time duration and area. Yevjevich (1967) states that the drought runs can be determined analytically for simple cases or determined by using a data generation method such as Monte Carlo method for complex cases. In addition, Yevjevich introduces possible deficit (or drought) shapes of runs. Figure 2.2 shows different possible drought (deficit) shapes. The vertical axis is the moisture supply amount and horizontal axis is time. Here, x_0 shows the level of critical moisture supply. Shape 1 shows increase in deficit and reaches a point of maximum then slow decrease to zero. Shapes 2 and 3 show early and late high deficits, respectively. Shape 4 shows a drought run consists of many different run parts. Shapes 5 and 6 show non-continuous drought run, and it can also have wet periods as it is in number 6.

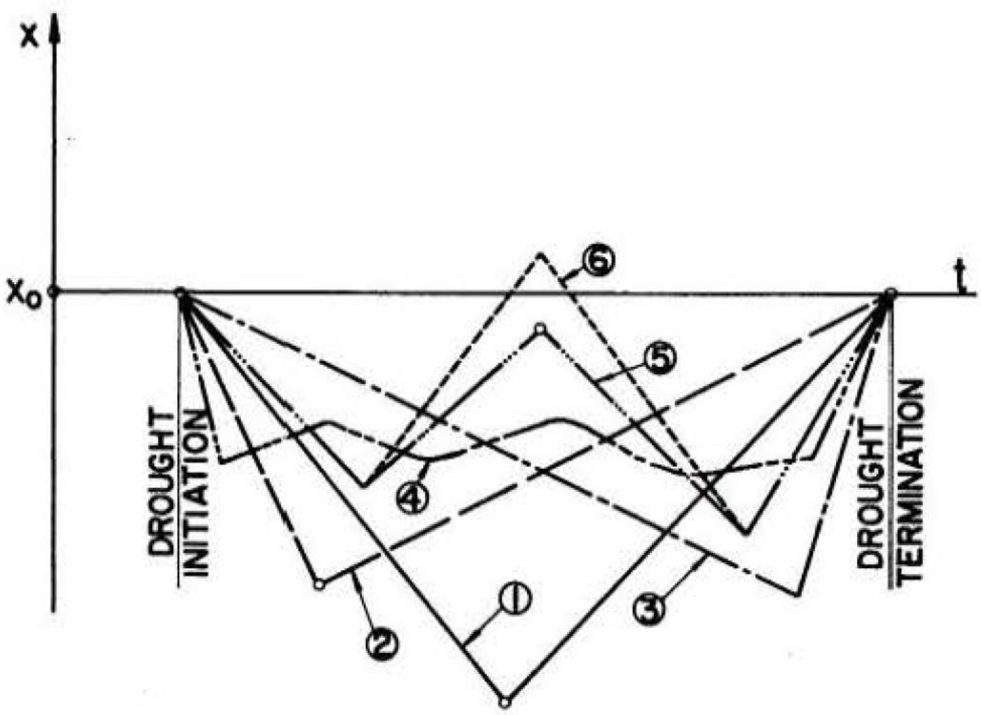


Figure 2.2. Various shapes of drought time-runs *(Yevjevich, 1967)*

Şen (1976; 1977; 2015) proposed a practical and easy methodology in order to calculate deficit quantities. Deficit quantities, have been defined and probabilistic analysis of drought runs has been performed which is based on Bernoulli trials and recurrence theory. The used methodology defines drought state (or dry spell) and wet state (or wet spell) as a comparison to the threshold levels. A single data in time series can be wet or dry only; and if the threshold level is too high, the entire time series may become a long dry spell. In reverse, if the threshold level is too low, the entire time series may become a wet spell. By using below normal periods (dry periods or drought runs), deficit quantities can be determined. These deficit quantities are used to define various traits of drought events such as length, amount and magnitude. For each quantity, exceedance probabilities are determined by fitting a probability distribution function (PDF) to the historical deficit data. This process gives extensive information about deficit lengths, deficit amounts and severity of deficit periods of different return periods.

The methodology proposed by Şen (1976; 1977; 2015) requires a goodness-of-fit algorithm to decide the best fitting PDF for exceedance probability calculations. In order to choose the best possible distribution functions applicable to hydrology, previous studies and the studies especially applicable to Turkey and Mediterranean were examined. Langat et al. (2019) analyzed probability distribution functions applicable for maximum, minimum and mean streamflow and the authors tested Gamma, log-normal, Weibull, generalized extreme value, Gumbel and normal distributions. The results of the study show that Gamma (Pearson Type III) and log-normal are the best fit for maximum streamflows (i.e. floods); Weibull, GEV and Gumbel functions are the best fit for minimum streamflows (i.e. deficits) and lastly log-normal and GEV distributions are the best fit for mean flows. In addition, McKee et al. (1993) used 2-parameter Gamma PDF in calculation of SPI. Guttman (1999) revised this distribution and showed that 3-parameter Gamma (Pearson Type III) fits better for SPI. Nalbantis and Tsakiris (2009) used log-normal distribution for calculation of SDI from streamflow data in the Mediterranean Region. Eris et al. (2018) tested 2- and 3-parameter Weibull, generalized extreme value, 2- and 3-parameter Gamma (Pearson Type III) and 2- and 3-parameter log-normal distributions for low flow frequency analysis in Turkey and found that 3-parameter log-normal and 3-parameter Weibull fit majority of basins in Turkey.

2.3. Trend-Based Climate Change Projections

Climate change causes variations in hydro-meteorological processes. Climate change especially has impacts on precipitation which is the main supply of water resources. This situation directly affects reservoirs and other water resources engineering structures. Therefore, climate change effects should be taken into account while developing a risk management approach for reservoirs.

In the literature, there are many studies available for climate change models. However, the implementation of climate change for risk management of water resources engineering structures is a new research area. There are a few studies available to implement climate change into the water resources risk management, and guidelines are not sufficient for quantitative calculations of climate change impacts on water resources.

In their study, Sung et al. (2018) state that, results of climate change projections to determine the impacts of climate change on hydraulic structures may cause the requirement of modifying design standards for extreme events. Therefore, it is required to modify probabilities for extreme events to increase the performance of hydraulic structures in climate change conditions. For example, reconstruction of a spillway might be necessary after risk assessment of floods. In reverse, drought events which can also be affected by climate change, may cause increased deficiencies and may have cause unmet demands in the water supply system and should be taken into consideration while designing the structure or modifying the operation policy of the existing structures.

In order to modify probabilities for extreme events, Şen et al. (2017) developed a simple exceedance probability modification methodology for climate change which is applicable to reservoirs. It alters the exceedance probability for corresponding return periods by adding a climate change modification parameter while converting exceedance probability to certain return period event.

In order to determine the climate change modification parameter, trend slope calculations for different trend analysis methodologies are evaluated. Trend analysis is used in order to predict future changes with the available data. There are a number of trend analysis methodologies or significance tests are available in the literature and the most common ones are Mann-Kendall Test (Mann, 1945; Kendall, 1975) and Şen Innovative Trend Analysis methodology (Şen, 2012; 2017).

Mann-Kendall Test is a non-parametric monotonic trend analysis method. With this test, the existence of a trend is assessed with a null hypothesis of “There is no trend”. Because of its non-parametric structure, it can be applied to any kind of data without considering distribution type. Because of this issue, many scientists used Mann-Kendall method for hydrological data (Yıldırım & Önöz, 2015).

According to Şen (2012; 2017), most of the Mann-Kendall trend detection studies are based on sample data serially independent assumption. However, in streamflow trend analysis the data is serially dependent most of the time. The positive serial correlation increases trend detection possibility while negative serial correlation decreases the trend detection possibility (Yue & Wang, 2002).

The other trend methodology evaluated in this study is Şen Innovative Trend Analysis methodology (Şen, 2012; 2017). This methodology divides the data into two halves and assesses the trend in the complete data. The methodology is practical, easy to use and visualize.

In addition, Innovative Trend Analysis with data clusters (sub-groups) includes different output parameters, such as change in low, middle and high clusters. These output parameters provide a more comprehensive analysis regarding the partial trends in each different data cluster.

A comparison between Mann-Kendall and Şen's method was made by Yıldırım and Önöz (2015). Even though the data was checked for the serially independence, Mann-Kendall test results no trend whereas Şen's method shows a trend in the data. Also, the study recommends using Şen's Innovative Trend Analysis method because of the simplicity and visually traceability.

2.4. Drought Indices

Early studies about drought mainly aim to define different types of droughts in order to assess the possible impacts of the drought hazard (Wilhite & Glantz, 1985; Wilhite, 2000). In order to define drought events, start and end times of the drought events (i.e. duration) and magnitudes (i.e. severity) should be determined. Newer studies mainly focus on monitoring these parameters. At this point, drought indices specifically developed for prediction of drought events are used. Drought indices, which can be calculated statistically by using drought indicators as input data, are numerical representations of drought severities and drought durations. Drought indicators, on the other hand, include the raw data or parameters to describe drought conditions; such as precipitation, temperature, streamflow, groundwater, etc. (Svoboda & Fuchs, 2016).

Various drought indices are available in the literature to examine drought events. The indices involved in drought monitoring and detection are mainly used for determining the beginning and the end of drought periods, monitoring drought events and determining the magnitude of drought hazard. There are many drought indices available to use and registered in Integrated Drought Management Program (IDMP) database (Integrated Drought Management Program, 2018) developed by World Meteorological Organization. Some important drought indices were reviewed here:

The Percent of Normal Precipitation Index (PNI) is one of the simplest and oldest statistical analyses of precipitation (Wilhite, 2000). It is calculated by dividing the precipitation value by the mean of long years precipitation (usually 30-year normal) and multiplying by 100. PNI is currently used in different drought management projects in Bosnia and Herzegovina, Democratic Republic of the Congo, Iran, Pakistan, Tanzania and the United States of America (Integrated Drought Management Program, 2018).

PNI can be computed on daily, weekly, monthly, seasonal and annual timescales. Longer timescale gives information about both meteorological and agricultural droughts. The strength of this index is ease of use and the only input is precipitation. PNI does not fit to the normal distribution. It is susceptible to the dry periods (zero rainfall) and if this is the case, comparison with any other index is hard (Türkeş, 2017).

Palmer Drought Indices (Palmer, 1965) were one of the first attempts to identify droughts by using other data rather than precipitation. Before Palmer Indices, most drought monitoring attempts used representation of precipitation, but these were not appropriate for many applications (Şen, 2015). The Palmer indices include precipitation, temperature and available water holding capacity parameters as inputs. Although it is an old methodology, Palmer indices are still being used worldwide as a robust drought index (Integrated Drought Management Program, 2018).

There are three indices generated with Palmer methodology. The first output is Palmer Drought Severity Index (PDSI) which aims to identify meteorological and agricultural droughts; the second one is Palmer Hydrological Drought Index (PHDI) which identifies hydrological droughts and lastly, Palmer Z Score which identifies meteorological droughts.

PDSI had been one of the most popular drought indices available until Standardized Precipitation Index (SPI) developed. However, it is still being used in many countries as the indices provide comprehensive information about drought using not only the precipitation data, but also temperature and soil water holding capacity. PDSI is currently used by Bosnia and Herzegovina, Brazil, Bulgaria, Canada, Greece, Macedonia, Peru, Trinidad and Tobago, Turkey and the United States of America (Integrated Drought Management Program, 2018).

The timescale of PDSI is approximately equal to 9 months (Integrated Drought Management Program, 2018). It means; PDSI gives information about both agricultural and hydrological droughts as 9 months nearly a transition zone between agricultural and hydrological droughts. Therefore, it can be used for the detection of both agricultural and hydrological droughts.

The second index of Palmer Drought Indices is PHDI and it is mainly based on original PDSI, but it is modified to identify longer dry periods to determine hydrological droughts. PHDI has the ability to calculate when a drought will end based on precipitation needed by using a ratio of moisture received to moisture required to end a drought (Integrated Drought Management Program, 2018).

As it is a powerful index for drought monitoring, the methodology includes evapotranspiration calculation. Therefore, along with precipitation, temperature and available water holding capacity of soil should also be used as input data. However, Palmer Indices are difficult to calculate, and indices require gapless precipitation and temperature data as input.

The second breaking point for drought monitoring is the development of Standardized Precipitation Index (SPI). SPI (McKee et al., 1993) is the most popular drought index available. SPI is an effective index as well as it is easy to use. SPI is applicable in all climate regimes, and outcomes for different climates can be compared with each other because of the standardization (Integrated Drought Management Program, 2018).

SPI is currently used by Argentina, Austria, Belize, Bosnia and Herzegovina, Brazil, Bulgaria, Canada, Chile, Croatia, Cyprus, Dominican Republic, Germany, Greece, Hong Kong, Iran, Israel, Jamaica, Jordan, Kazakhstan, Libya, Lithuania, Macedonia, New Zealand, Pakistan, Peru, Slovenia, Spain, Sri Lanka, Switzerland, Tanzania, Thailand, Trinidad and Tobago, Turkey, Ukraine and the United States of America (Integrated Drought Management Program, 2018).

SPI has an advantage to run the index at different timescales, and this gives SPI an ability to be calculated for different types of droughts. Shorter timescales (e.g. 1 to 3 months) can be used for meteorological, medium-range timescales (e.g. 6 to 9 months) can be used for agricultural and longer range timescales (e.g. more than 9 months) can be used for hydrological droughts (McKee et al., 1995; Guttman, 1999).

A complete and long (more than 30 years) dataset is required for robust calculations because a long dataset can include more extreme conditions (Guttman, 1998; 1999). If there are gaps, they should be completed before calculating SPI.

The simplicity of the SPI methodology attracted many researchers to develop SPI-like standardized drought indices. By changing the input data, different drought indices can be achieved. For example, Gusyev et al. (2015) developed three different drought indices; Standardized Inflow Index, Standardized Reservoir Storage Index and Standardized Discharge Index using SPI methodology with different inputs. Those indices use reservoir inflows, reservoir storages and reservoir discharges, respectively instead of rainfall input of SPI. The calculation process is entirely the same; the new drought indices use gamma distribution and they can be calculated using the same SPI calculation algorithm. Even though the indices had been developed recently, one of those indices, Standardized Reservoir Storage Index, was applied to several Asian river basins by The International Center for Water Hazard and Risk Management (ICHARM, 2017).

One drawback of the drought indices developed by Gusyev et al. (2015) is that these indices are using Gamma probability distribution function (PDF) in the calculation process. According to McKee et al. (1993), Gamma distribution fits precipitation data. However, this does not mean that Gamma distribution fits perfectly for all kind of hydrometeorological data. The best distribution function has to be investigated for stremflow and reservoir inflows, before using standardized indices.

In their study, Kim et al. (2018) used Standardized Inflow Index and compared log-normal, Gamma, Gumbel, Weibull and Gaussian distributions. There are eight different datasets in the study and the authors selected the best distribution for each of eight different datasets. In the results of eight different Kolmogorov-Smirnov tests, it is seen that Gamma distribution is not the best distribution for any of those datasets.

Other popular drought indices based on SPI methodology are Standardized Runoff Index (SRI) developed by Shukla and Wood (2008) and Streamflow Drought Index (SDI) developed by Nalbantis and Tsakiris (2009). SRI uses streamflow data instead of precipitation which is used in the original SPI methodology. SDI, on the other hand, is calculated annually and uses cumulative values of seasonal periods. Therefore, SDI can detect seasonal variations in streamflow. Both indices use log-normal distribution, instead of using Gamma distribution, which is used for rainfall data in the original SPI methodology.

A comprehensive comparison between different PDFs used in streamflow drought indices was examined by Vicente-Serrano et al. (2012). The authors examined six three-parameter PDFs (log-normal, Pearson Type III, log-logistic, general extreme value, generalized Pareto, and Weibull). The study did not choose best distribution for streamflow data, however it indicates that every distribution has its own limitations. Therefore, an error in the selection process of a PDF for streamflow data may lead to incorrect results for standardized drought indices and goodness of fit should be checked before calculating a standardized drought index.

On the other hand, in order to achieve a better solution for this problem, Farahmand and AghaKouchak (2015) developed a non-parametric algorithm to calculate SPI in order to eliminate the parametric character of SPI. In this methodology, instead of Gamma PDF (or any other parametric PDF), an empirical Gringorten plotting position is used. The advantage of non-parametric approach is, it can be used with any other data without considering the goodness of fit. The non-parametric calculation algorithm of Farahmand and AghaKouchak can be used with any standardized drought index.

2.5. Drought Based Reservoir Operation

Examination of drought impacts on dam reservoirs is one of the most important subjects as the changes in the reservoir may lead to negative effects on agricultural and municipal water use along with hydropower generation. Therefore, the examination of drops in reservoir levels caused by drought impacts is a complex subject which includes many different aspects. However, dam reservoirs have an advantage; with an effective operating strategy, drought impacts on reservoirs can be mitigated.

Hashimoto et al. (1982) developed three criteria for water resources systems which are reliability, resiliency and vulnerability. These criteria can be used for evaluating reservoir operation performance.

Kelly (1986) examined past drought events in California and formed many methods for operating reservoirs during drought conditions. The study includes examinations for both single and multiple reservoir systems. Several case studies for a variety of different reservoir operation methods are inspected and the powerful aspects of those studies are clarified.

Simonovic and Burn (1989) developed a methodology for forecasting reservoir inflows and real-time operation strategy by using Kalman filtering algorithm. Then, Burn et al. (1990) utilized this methodology to develop risk-based performance criteria for real-time reservoir operation.

Cancelliere et al. (1998) compared operating policies on drought conditions. The study utilizes deficit parameters and defines hypothetical drought characteristics. Then, the reservoir performance on hypothetical drought events has been evaluated. Also, the study uses different demand schemes and operating policies in order to mitigate drought events.

Akyürek and Özkaya (2014) operated seven dams located in the Upper Kızılırmak Basin in Sivas, Turkey for hypothetical variations in dam inflows. The operation studies are demand-based and demand coverage abilities of the studied dams are assessed for existing and three different hypothetical reservoir inflow conditions. These hypothetical conditions are decreasing the inflow values by 20%, keeping the initial reservoir level at minimum and decreasing the inflow values by 20% and lastly decreasing the inflow values to a critical level which can supply the demand.

Melo et.al (2016) developed a relationship between meteorological and hydrological droughts based on remote sensing, modeling and monitoring which eventually clarifies drought impacts on hydropower generation in Parana River Basin located at south-eastern Brazil. The study emphasizes the importance of available tools for drought monitoring for effective reservoir operations on drought conditions. SPI and SDI were selected as main tools for determination of drought events and drought propagation conditions for hydrological drought have been achieved.

Mateus and Tullos (2016), analyzed reservoir operation vulnerability, reliability and sensitivity on climate change conditions based on variable rule curve approach. The study uses eight climate change scenarios and examined the reservoir operation difficulties in climate change conditions.

Ngo et al. (2018) assessed hydropower generation with nine different scenarios, utilizing the impacts of climate change. In the study, it is determined that monthly variation of streamflow can change with climate change impacts. The study also includes operation strategy modifications for hydropower generation when climate change affects streamflow in a negative way.

2.6. Reservoir Operation Tools

In this study, reservoir operation is required to develop a bridge between drought impacts and demand coverage. Reservoir operation is important for the evaluation of drought impacts on reservoirs.

Here, different hydraulic basin modeling tools to utilize in operation studies are evaluated. These modeling tools include three popular modeling tools; HEC-ResSim, MIKE HYDRO Basin and WEAP. Previous applications which use these tools for reservoir operation studies are presented here.

2.6.1. HEC-ResSim

HEC-ResSim is a reservoir operation software developed by United States Army Corp of Engineers (USACE). The software can be used for flood management, low-flow analyses, water supply, real-time support system development (USACE, 2019). This software is powerful especially for hydropower generation and used in many hydropower studies.

HEC-ResSim is the successor of the popular HEC-5 program by USACE and it is free to use. It has a map interface and powerful operation algorithms which causes a longer learning period. Although the software is powerful, input and output structure is difficult to use and the results are not presented user-friendly. Also, daily data should be used in order to work with HEC-ResSim; which is a huge amount of computational cost for long-term drought calculations. Hydropower abilities of the software are very powerful, however, it is hard to use the program for irrigation and municipal water and those data should be entered as water demand only.

Özbakır (2009), operated the multi-reservoir system in Seyhan and Ceyhan Basins in Turkey with HEC-ResSim program. The study includes demand coverage alternatives, relationships of the reservoirs with each other and water transfer between basins. In addition, the study also includes municipal and irrigation water supply along with hydropower.

İmamoğlu (2013) analyzed cascade reservoir system financially by using HEC-ResSim for reservoir operations. This study includes many alternative scenarios for both hydropower dams and pumped storage applications. In this study, HEC-ResSim was used to formulate many alternative scenarios for calculation of detailed financial analyses of four cascade dams.

Mateus and Tullos (2016) used HEC-ResSim in order to calculate reservoir reliability, resilience and vulnerability under climate change conditions. In this study 13 different reservoirs were operated with HEC-ResSim in daily basis. HEC-ResSim software was used for the definition of operation rule curves for reservoirs and seasonal reservoir reliability calculations.

Calvo Gobbetti (2017) applied HEC-ResSim to analyze new water sources for Panama Canal and simulated water levels of many lakes. According to the author, HEC-ResSim is an effective tool for simulation of reservoir operation if the operation zones and rules are correctly identified. Additionally, the author states that HEC-ResSim is able to reproduce daily outputs even when monthly data is used.

2.6.2. MIKE HYDRO Basin

MIKE HYDRO Basin (DHI, 2019) is a comprehensive software that can develop a basin network simulation. The computer software is developed by Danish Hydraulic Institute (DHI). MIKE HYDRO Basin can be used for multipurpose reservoir operations and it is powerful in calculation algorithms such as basin routing methods. Almost any possible basin management analysis can be done with the software and it is very easy to use.

However, although it is powerful, the software is too expensive even for companies or governmental organizations.

Akyürek and Özkaya (2014) used a prior version of MIKE HYDRO Basin, which is called MIKE HYDRO, and modeled a system of seven dams. The modeled system includes both irrigation and municipal water demands. The model runs for both rainfall-runoff simulation and reservoir operation cases to develop streamflow prediction models.

Yang et al. (2015) analyze MIKE HYDRO Basin in order to be used as a decision support system for a large basin. The study explains the capabilities of MIKE HYDRO Basin in a detailed manner.

Santos et al. (2018) use MIKE HYDRO Basin for simulation of water allocation for irrigation and municipal water. They used SWAT software also to delineate sub-basins and develop the rainfall-runoff model. This study shows that MIKE HYDRO Basin can also be used for water allocation simulations.

2.6.3. WEAP (Water Evaluation and Planning)

WEAP (Stockholm Environmental Institute, 2018) software was firstly developed in 1988 as an integrated and flexible planning tool. One year after, in 1989, the United States Center of Stockholm Environmental Institute was established, and the development has continued in the US since today. Over the years many countries used the software for its simplicity and powerful graphical reporting system.

WEAP software has many capabilities such as water supply, rainfall-runoff model, crop yields, groundwater/surface water interactions and water quality. It has a simple drag and drop based user interface and dynamic scenario development system. The program can handle many different dams and water use scenarios in the same model and different water uses can be prioritized.

WEAP is free to use for academic purposes and free for governmental organizations of a developing country. Many operation study scenarios can be made at once and the software gives the user time to focus on operation scenarios rather than computations.

The most important feature of WEAP is the powerful reporting tool, which dynamically displays the outputs of the model run and the output figures, tables, etc. are well designed, clear and easily understandable. The program also features a comparison tool between scenarios, which is very important for the assessment of the analyses.

WEAP is used in many operation studies. Loon et al. (2007) modeled Gediz Basin with WEAP in order to show the applicability of the model to Turkey. The study mainly focuses on irrigation and has different scenarios in order to use WEAP as a decision support tool.

Okyereh et al. (2019) assessed the impacts of hydropower operations on the downstream of the studied structures by using WEAP software. In this study, WEAP is used for two different aims; the first is to explore the availability of water resources under climate change conditions; and the second is to use WEAP along with Long-Range Energy Alternative Planning System (LEAP) module of SEI to calculate energy production, consumption and resource extraction for the study area.

CHAPTER 3

METHODOLOGY AND MATERIAL

3.1. Definitions

For better understanding of the methodology, this section includes basic definitions of the terms used in the study.

Hydrological Deficit and Surplus

The term hydrological deficit and surplus used in this study refer to the difference between observed streamflow (or reservoir inflow) and a pre-determined threshold level. In this study, as threshold level, average streamflow or reservoir inflows are used. Therefore, negative deviation from average streamflow is called hydrological deficit, on the other hand, positive deviations from average streamflow is called hydrological surplus.

Drought Run

A drought run refers to a deficit period, which has an initiation (a downcross) and a termination (an upcross) in time dimension; and has negative deviations from the threshold level throughout this period. A drought run provides statistical properties to define a drought event; therefore, this concept provides a basic definition of drought (Yevjevich, 1967). Statistical properties of a drought run include the time between initiation and termination points (deficit length), the sums of negative deviations (deficit amount), peak deficit in the run (deficit magnitude) and average deficit over time (deficit intensity). Definitions of these parameters are detailed in Section 3.2.1.

In this study, drought run term is used with a hydrological point of view and corresponds to the period of negative deviations of streamflow or reservoir inflow from the average streamflow or reservoir inflow level.

Impact

A drought impact, as used in the context of this study, refers to the insufficient supply of the required water demands because of the negative effects of drought hazard on streamflow and reservoir inflow. Impact is mainly caused by drought hazard. However in this study, the impact term also includes the exposure, which refers to the affected people and assets from hydrological drought hazard (Şen, 2015). In this study, the exposure caused by the drought impacts on reservoirs is only related to insufficient water supply. Therefore, instead of defining an additional term, both hazard and exposure terms are used as a part of the impact term.

Impact Assessment

In this study, drought impact assessment refers to the procedure to analyze magnitude and severity of hydrological drought hazard along with the evaluation of insufficient water supply caused by the drought hazard.

Vulnerability

Vulnerability term used in this study refers to the case or region-specific aspects of reservoirs and water supply system which is potentially preventing mitigation of possible drought events. Any difficulties in coping with drought events are considered as a part of vulnerability issue. These difficulties include both physical (such as insufficient active volume amount, dependence to another reservoir or diversion requirements, fast dropping reservoir level in dry periods, capacity limitations of transmission pipes) and operational (such as improper operation strategies which are unable to mitigate drought events) aspects.

Adaptive Capacity

In this study, adaptive capacity is used as the antonym of vulnerability. It is the powerful aspects of reservoirs or operational actions which support mitigation of hydrological droughts.

Vulnerability Assessment

In this study, vulnerability assessment term is used for the procedure of evaluation and identification of vulnerabilities and adaptive capacities of reservoirs which may occur in hydrological drought events. Vulnerability assessment does not evaluate socio-economic damages of drought events and assumes that those damages are completely caused by demand coverage insufficiencies. Therefore, in this study the vulnerability assessment is completely demand-based and it is assumed that unless the demand is satisfied, socio-economic damage is inevitable.

Risk

Disaster risk is the potential of losing valuable assets, resources or life caused by a natural disaster. This potential is determined probabilistically as a function of hazard, exposure, vulnerability and adaptive capacity (United Nations Office for Disaster Risk Reduction, 2017). Therefore in drought point of view, the risk is defined as the probability of negative effects of hydrological drought events on people; which includes hazard, exposure, vulnerability and adaptive capacity aspects altogether. In this study, hazard and exposure are evaluated in impact as well as adaptive capacity is included in vulnerability.

Risk Assessment

Risk assessment term used in this study is the entire procedure of calculating possible hydrological drought impacts as well as determination of corresponding vulnerabilities of reservoirs. In addition to impact and vulnerability steps, this procedure also includes evaluation of existing operation strategies and developing new strategies to manage the risk.

3.2. Details of the Methodology

Flowchart of the methodology of the study is given in Figure 3.1.

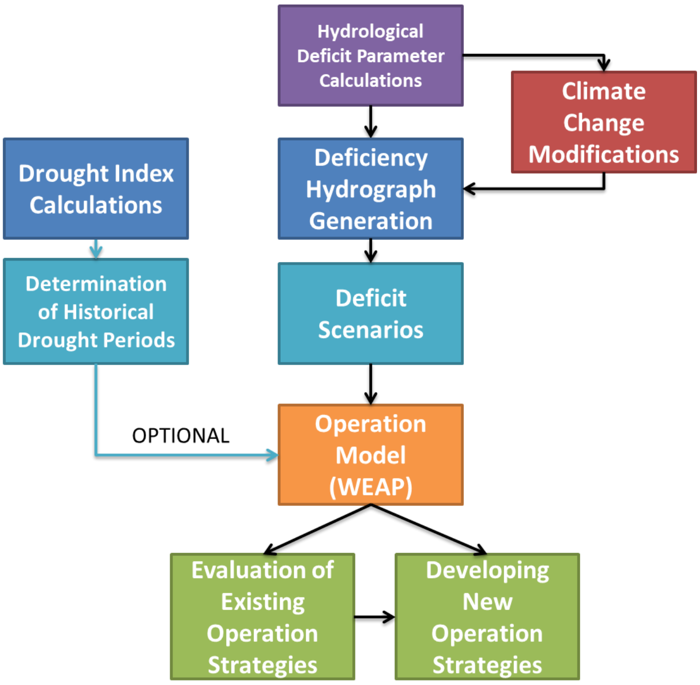


Figure 3.1. Flowchart of the methodology

3.2.1. Hydrological Deficit Parameter Calculations

The methodology proposed by Şen (1976; 1977; 2015) is used for the calculation of hydrological deficit parameters. By calculating these parameters, which are determined by using historical streamflow dataset, hydrological deficit predictions for different return periods can be determined. The methodology is simple to apply for reservoirs and hydraulic structures. Unlike drought indices which provide only statistical classification of drought events, this methodology provides an output which is a quantified metric and has a unit.

However, the methodology requires a goodness-of-fit algorithm to decide the best fitting PDF for exceedance probability calculations. The evaluation of available

PDFs which are applicable to streamflow data and fits to the hydrometeorological conditions of Turkey is given in Section 2.2.

Therefore, the curve fitting trial includes five different PDFs, and according to the goodness of fit results, the best fitting PDF for streamflow is selected. Used PDFs are listed below:

- 2-Parameter Gamma PDF
- Log-Normal PDF
- Gumbel PDF
- 3-Parameter Gamma (Pearson Type III) PDF
- Weibull PDF

There are four hydrological deficit parameters that can be applied to any summable variable such as precipitation or streamflow. Those parameters (or features) are deficit amounts, deficit lengths, deficit magnitudes and deficit intensities. Graphical explanation of all parameters is given in Figure 3.2, and they are explained in the following sections.

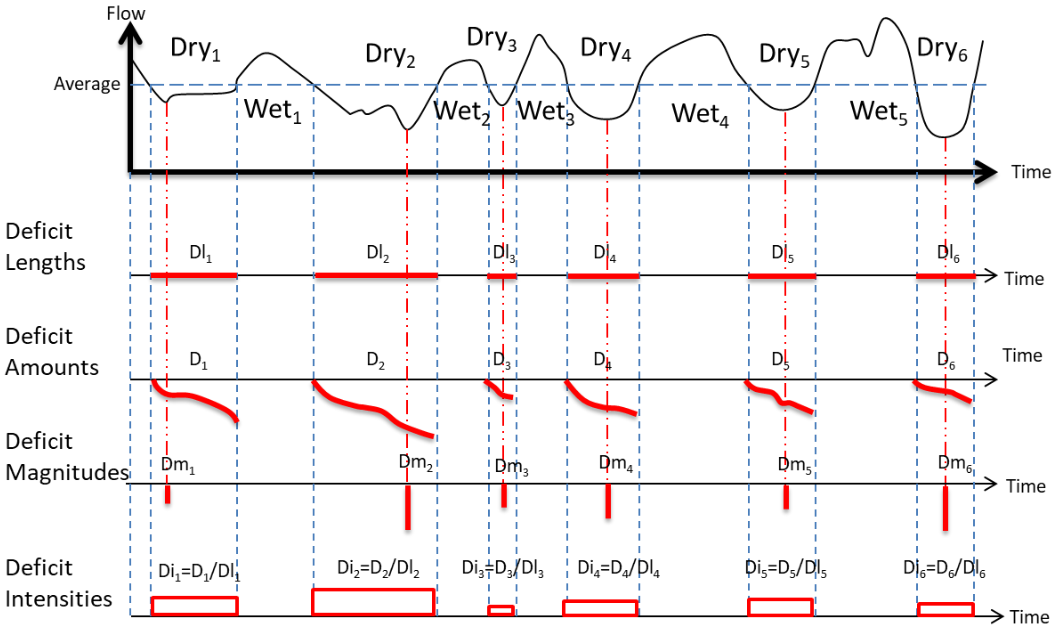


Figure 3.2. Graphical explanation of deficit calculation (Şen, 2015)

In Figure 3.2, D_l, D, D_m, and D_i notations are hydrological deficit length, hydrological deficit amount, hydrological deficit magnitude and hydrological deficit intensity, respectively.

Hydrological Deficit Amounts

The hydrological deficit amount is defined as the summation of negative deviations from normal in a drought run (i.e. cumulative deficits in a drought period). The graphical explanation of hydrological deficit amounts is given in the second row of Figure 3.2.

Mathematical representation of the deficit amount is given below:

$$D = \sum_{t=t_s}^{t_e} (x_0 - x_t)\Delta t \tag{3.1}$$

where t_s is the start time of dry run and t_e is the end time of drought run, D is the deficit amount in the dry period between t_s and t_e times, x_0 is the mean in the entire time series and x_t is the observed data amount at time t. For all deficit parameters, normal value x_0 is selected as the monthly average of the observed period. The units of deficit amounts are in hm^3.

The input data for hydrological deficit calculation in this study is reservoir inflows. Hydrological deficit amount mathematically defines an area. Deficit amount, D, is also shown as the shaded area in Figure 3.3.

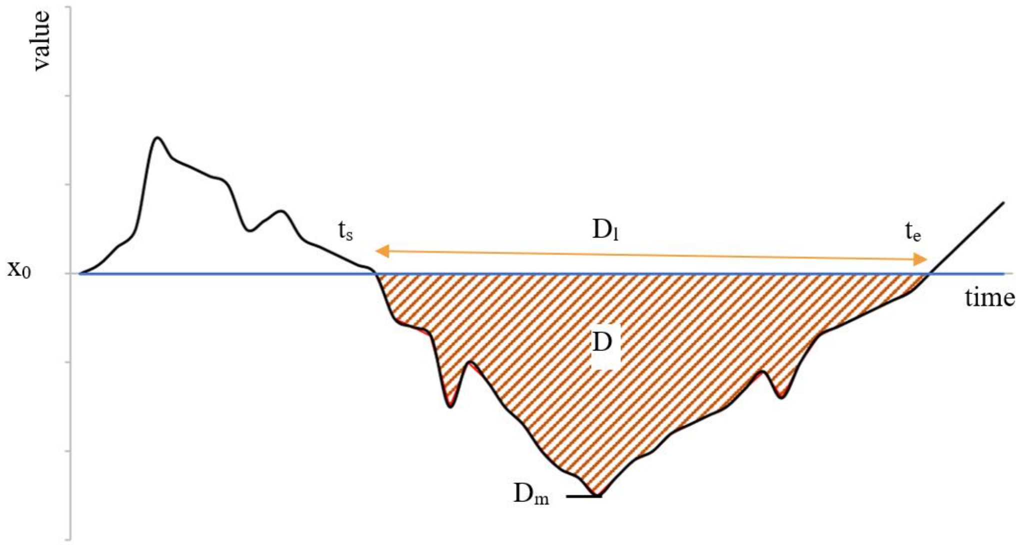


Figure 3.3. Hydrological deficit parameters graphical meanings

Hydrological Deficit Lengths

Hydrological deficit lengths are the time between initiations and terminations of drought runs. Hydrological deficit lengths give the duration of the deficit period. In this study, the unit of hydrological deficit length is years. The graphical representation of hydrological deficit lengths is given in the first row of Figure 3.2.

Mathematical representation of deficit length is given below:

$$D_l = t_e - t_s \tag{3.2}$$

where D_l is the deficit length in the dry period between t_s and t_e times. Deficit length is shown in Figure 3.3.

Hydrological Deficit Magnitudes

Hydrological deficit magnitudes are the peak deficit of each drought run. The unit of hydrological deficit magnitude used in this study is hm^3 and it is mathematically defined by a point location in time series. Graphical representation of deficit magnitudes is given in the third row of Figure 3.2.

Mathematical representation of deficit length is given below:

$$D_m = \max_{t_s \le t \le t_e} (x_0 - x_t) \tag{3.3}$$

where t_s is the start time of dry run and t_e is the end time of drought run, D_m is the deficit magnitude in the dry period between t_s and t_e times, x_0 is annual mean time series and x_t is the observed data amount at time t. x_t should smaller than the normal x_0 for all drought runs. Deficit magnitude is shown in Figure 3.3 as the maximum deficit of the drought run between t_s and t_e. In this study, the unit of deficit magnitudes is in hm^3.

Hydrological Deficit Intensities

Hydrological deficit intensities are average deficit amount in a drought run. They are calculated by dividing hydrological deficit amount to hydrological deficit length for each deficit period. Graphical representation of hydrological deficit intensities is given in the fourth row of Figure 3.2.

In this study, deficit magnitudes are calculated in hm^3/year for each individual month. Mathematical representation of deficit intensity is given as:

$$D_i = \frac{\sum_{t=t_s}^{t_e}(x_0 - x_t)}{t_e - t_s} \tag{3.4}$$

Probabilistic Hydrological Deficit Analysis

Deficit parameters are calculated for each deficit period. Exceedance probabilities of the calculated parameters can be determined by simple non-parametric rank-order statistics. However, extreme or catastrophic events such as a 100-years return period cannot be ranked as long as it is not observed in the historical data. Therefore, fitting a parametric PDF to ranked data is required for calculating extreme drought events.

Step by step calculations of probabilistic hydrological deficit analysis is given below. Numerical example of the calculation procedure is given in Section 4.1.

a. Determine the hydrological deficit parameters and determine the deficit period count.
b. Rank each deficit parameter for each deficit period in ascending order.
c. Calculate empirical exceedance probabilities of each ranked deficit parameter by using Eq. 3.5 where *P* is the exceedance probability; *m* is the rank of evaluated data and *n* is the deficit period count.

$$P = \frac{m}{n+1} \tag{3.5}$$

d. With the ranked empirical exceedance probabilities, plot a scatter diagram for each deficit parameter.
e. Determine the best fitting PDF to the scattered empirical exceedance probabilities by calculating parameters of all tried PDFs. For this procedure, check the goodness-of-fit of each different PDF and find the best-fitting PDF. Proposed PDFs are given below:
    i. 2-Parameter Gamma PDF
    ii. Log-Normal PDF
    iii. Gumbel PDF
    iv. 3-Parameter Gamma (Pearson Type III) PDF
    v. Weibull PDF
f. Plot the cumulative distribution function (CDF) of the best-fitting PDF on the same empirical scatter diagram (which is previously plotted in step d).
g. On the graph, calculate deficit parameter exceedance probabilities for 2-, 5-, 10-, 25-, 50- and 100-years return periods.

In the calculation process of deficit quantities, it is assumed that every month is independent and monthly values do not affect the consecutive months. This approach is used in order to maintain the seasonality effect and reach most severe conditions for an individual month. Using the most severe data for an individual month provides achieving the most severe conditions for that month regardless from previous and next months. In addition, if the data of all months are dependent instead of independent, it is still possible to define deficit parameters and exceedance probabilities; however, it is impossible to determine the monthly extremes. Using dependency provides a stochastic approach instead of a probabilistic approach and it does not fit to the aims of this thesis. Therefore, deficit parameter calculations are repeated for all individual months and deficit parameters to ensure the extreme conditions are calculated independent from each other.

3.2.2. Climate Change Modifications

Climate change modifications are required to assess climate change impacts for reservoirs. For this purpose, return period modification methodology proposed by Şen et al. (2017) is used.

At this point, Şen's Innovative Trend Analysis Method is selected for the trend slope calculations because of the robustness and simplicity. The selection process of the trend slope calculation method is given in Section 2.3.

In order to implement climate change to the probabilistic calculations, the calculated exceedance probability levels are modified. There are two assumptions at this stage; the first one is that the trend slope is an indicator of climate change and the second one is that the trend is linear.

The relationship between exceedance probability and return period is shown in the equation below:

$$P = \frac{1}{T_r} \tag{3.6}$$

where P is the exceedance probability and T_r is the return period.

By introducing a climate change effect to the exceedance probability, the exceedance probability and return period relationship can be altered as shown below (Şen et al., 2017):

$$P' = \frac{1 + \alpha}{T_r} \tag{3.7}$$

where P' is modified exceedance probability and α is the climate change parameter defined in Şen et al. (2017).

In this study, Şen's innovative trend slope (2017) is used as climate change parameter. With this methodology, climate change parameter α can be determined by the mean slope of the trend line, which is adopted from Şen (2017):

$$\alpha = \frac{2(\overline{y_2} - \overline{y_1})}{n} \tag{3.8}$$

where, $\overline{y_2}$ is the mean of the second half of the data, $\overline{y_1}$ is the mean of the first half of the data and n is the data count.

Substituting α determined in Eq. 3.7 into climate change modified risk and return period relationship (Eq. 3.8) results in the climate change modification formula used in this study, which is given below:

$$P' = \frac{1 + \frac{2(\overline{y_2} - \overline{y_1})}{n}}{T_r} \tag{3.9}$$

As can be deduced from Eq. 3.8 and 3.9, there are two possible outcomes of the climate change modification. The first is an decreasing trend slope (i.e. negative) and the second is an increasing trend slope (i.e. positive):

$$\begin{aligned} &if\ \overline{y_2} < \overline{y_1} \quad \alpha < 0, \quad then \quad P' < P \\ &if\ \overline{y_2} > \overline{y_1} \quad \alpha > 0, \quad then \quad P' > P \end{aligned} \tag{3.10}$$

Therefore, if the climate change modification parameter, the trend slope, is negative, then the modified exceedance probability becomes lover than the previous one and it means a more dangerous deficit probability for the same return period level (i.e. hydrologic conditions are worsened by climate change).

In reverse, if the trend slope is positive, then the modified exceedance probability becomes higher than the previous one and resulting deficit probability is milder than the previous exceedance probability for the same return period (i.e hydrological conditions are becoming better by climate change).

The trend slopes are calculated for annual total reservoir inflows and the same value is used for all months. In the methodology, the return period is kept as the same and only exceedance probability is modified.

3.2.3. Deficiency Hydrograph Development

In order to be used in operation studies, probabilistic hydrological deficit parameters should be converted into hypothetical hydrographs (i.e. monthly streamflows). Therefore, a simple conversion algorithm is developed; which uses deficit amount, deficit length and deficit magnitude parameters as input.

After calculation of both climate change modified and unmodified deficit parameters, a scenario generation algorithm is required to convert the deficit parameters to usable hydrographs. Here, drought shapes of Yevjevich (1967) can be used to develop a geometric algorithm to convert deficit parameters to deficit hydrographs for different return periods. In this study, a new algorithm has been developed for this purpose.

The methodology proposed in this study takes Yevjevich's (1967) first shape and modifies the geometric shape with several deficit quantities in order to get the most critical drought shape. Geometrical calculations while developing deficiency hydrograph are repeated for all individual months.

There are two assumptions while developing the deficiency hydrograph to ensure the most extreme drought case:

- The worst drought conditions are reached at the mid-point of a single drought run and drought shape is completely symmetrical.
- There is no surplus in a complete drought run.

Figure 3.4 shows the initial triangular drought shape used in this study, which is exactly Yevjevich's (1967) first shape. For any exceedance probability level and individual month, using the parameters deficit length (D_l), deficit amount (D) and deficit magnitude (D_m) which are calculated previously, a drought shape is produced.

The shape reaches its maximum value (D_m) at the time *0.50* D_l. The total length (duration) of the drought run is deficit length (D_l).

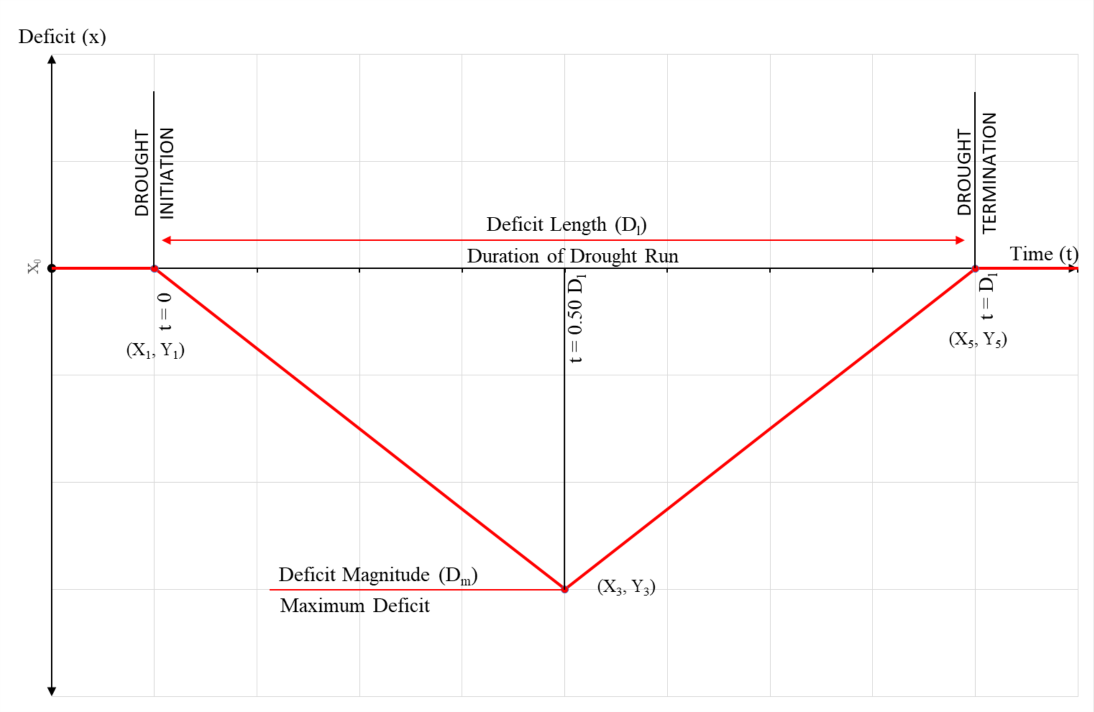


Figure 3.4. Initial deficiency hydrograph

The aim to develop a methodology to convert probabilistic deficit parameters into a hydrograph is to reflect severe drought conditions into flows. Therefore, it is important to use as many deficit parameters as possible in developing the hydrograph. In Figure 3.4, the deficit amount parameter (*D*) is not included. *D* should also be included in the hydrograph for more robust hypothetical hydrograph generation. This can be possible by making the shape area equal to parameter *D* and in order to make the shape area equal to *D*, two break locations are added to the triangular shape, which are located at *0.25* D_l and *0.75* D_l times. This modification converts Yevjevich's first shape to a pentagon (Figure 3.5).

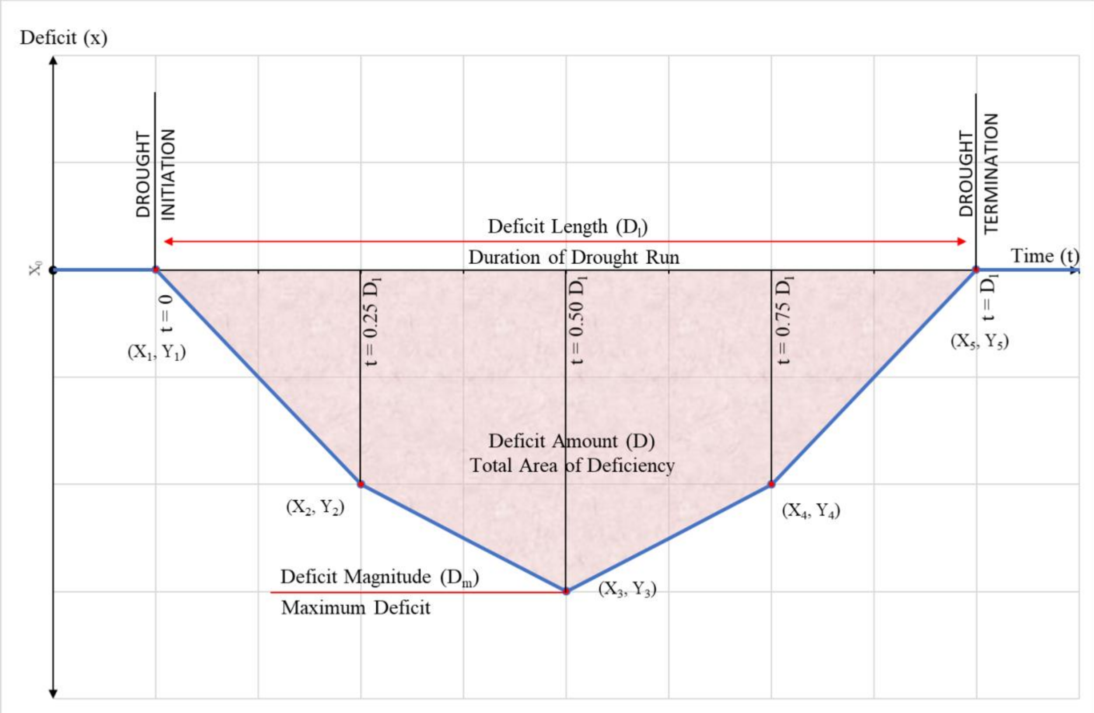


Figure 3.5. Deficiency hydrograph geometric properties

Deficits at *0.25* D_l and *0.75* D_l times are calculated with the equation below, which is determined with the simple geometric calculations:

$$x_{0.25D_l\ and\ 0.75D_l} = \frac{\frac{4D}{D_l} - D_m}{2} \quad (3.11)$$

where x shows the deficits at time *0.25* D_l and *0.75* D_l.

In addition, implementing the deficit intensity parameter (D_i) to hydrograph is also checked. However, by definition D_i is calculated by dividing deficit amount (D) to deficit length (D_l). Therefore, it is not required as deficit intensity is naturally implemented in the hydrograph by using deficit amount and length parameter.

Deficiency hydrograph calculations are repeated for each month and each return period. A detailed numerical calculation process of deficiency hydrograph is given in Section 4.3 on a case study example.

3.2.4. Deficit Scenarios

With the help of deficiency hydrographs, probabilistic scenarios are developed for 2-, 5-, 10-, 25-, 50- and 100-years return periods. After calculating the individual monthly deficits by deficiency hydrographs for each month, this data can be converted into a single hydrograph for a certain return period. Consequently, many hydrographs are developed for 2-, 5-, 10-, 25-, 50- and 100-years return periods and each return period forms deficiency scenarios in order to be used in the operation model.

The assumption in this study is consideration of no wet period while developing probabilistic scenario inputs. In the first year, the inflow values are monthly average inflows. The first year is the warm-up year and there will be no drought in this year. The drought begins at the second year. The hydrograph in drought period is calculated by subtracting deficit from the average inflow value of a specific month. After termination of drought period in the deficiency hydrograph for all 12 months, inflows return to monthly average inflow values again.

Step by step calculation procedure of developing a scenario from deficiency hydrograph is detailed below.

a. At first, calculate the area under deficiency hydrograph of a selected month between beginning of the year two (which is the initiation of deficiency period) and year three. This amount is the total deficiency in year two (the first deficit year) for the selected month.
b. Subtract the deficiency amount determined by the deficiency hydrograph from the monthly average flow of the selected month. This amount is the monthly streamflow amount in the selected month of the first deficit year. And this is output of the probabilistic scenario.

c. Repeat this process for all 12 months in a year to generate deficiency data of a single year.
d. Go back to part a and repeat the entire process to calculate for a successive year. Stop the process if there is no deficit remains for all months.

A numerical step by step example is given in Section 4.4.

The entire process is repeated with the deficiency hydrograph parameters of 2-, 5-, 10-, 25-, 50- and 100-years return periods. In the end, for each return periods, a scenario is developed.

Additionally, this procedure is also the same for the climate change modified deficit data and deficiency hydrograph. The process is also repeated for 2-, 5-, 10-, 25-, 50- and 100-years return periods of climate change modified scenarios.

In the end, streamflow input which is directly used in the operation model is achieved.

3.2.5. Drought Index Calculations and Determination of Historical Drought Periods

An optional step in the methodology is the determination of historical drought periods. Although this step is not part of the required methodology, it is important to understand the realistic equivalences of probabilistic operation scenarios. Therefore, different drought events are selected in the observation period by utilizing meteorological and hydrological drought indices used in the study inflows for all hydraulic structures in the determined drought periods are extracted. The extracted (isolated) observation data is used in reservoir operation directly to see the impacts of historical drought periods.

This assessment provides a preliminary knowledge on the study area and previous drought events. In addition, in the modeling phase, operating the isolated data in this part can be used for comparison of the probabilistic droughts with previous drought events. Therefore, this analysis is highly recommended for the users of the methodology.

All indices have some powerful aspects as well as drawbacks; therefore, using many indices rather than depending only one is the best choice for drought monitoring and management (Türkeş, 2017). Consequently, several drought indices have been used to determine past drought events.

Standardized Precipitation Index (SPI) is the most popular and widely used drought index available in the literature because of the simplicity and easily understandable normalized output. The index only uses precipitation as input data. Therefore, it is selected as one of the indices used in this study.

On the other hand, as SPI only uses precipitation as input, the index can miss some hydrological drought periods where other indices such as Palmer indices can detect. Palmer indices also utilize temperature and available water holding capacity data in addition to precipitation. Therefore, Palmer indices have been used in the process, too. Results of the two Palmer indices Palmer Drought Severity Index (PDSI) and Palmer Hydrological Drought Index (PHDI) have been evaluated in this study. Palmer Z-Index, however, is completely a meteorological index and it is not used for detection of hydrological drought events.

In addition to the meteorological data-based drought indices, one hydrological data-based drought index has been also used. The most suitable standardized hydrological drought index for this study is Streamflow Drought Index (SDI) (Nalbantis & Tsakiris, 2009). SDI methodology uses a cumulative analysis approach rather than monthly time series, which is more suitable to hydrological data because of the seasonality of stream flows. SDI uses water year in the calculation process and there are four different calculation periods available. They are October to December (3 months), October to March (6 months), October to June (9 months) and October to September (12 months, entire water year). By this way, deficiencies in different periods or seasons of the year can be detected separately. The output is always in annual. In this study, inflow data of the reservoirs are used as the input data of SDI.

One modification was made to the original log-normal based calculation process of SDI. The calculation has been modified to a non-parametric (empirical) version (Farahmand & AghaKouchak, 2015). By this way, the effects of statistical parameters have been eliminated.

Drought indices used in this study are shown in Table 3.1.

Table 3.1. *Used drought indices in this study (Integrated Drought Management Program, 2018)*

Index	**Type**	**Input Parameters**	**Additional Information**
Standardized Precipitation Index (SPI)	Meteorology	precipitation	Highlighted by the WMO as a starting point for meteorological drought monitoring
Palmer Drought Severity Index (PDSI)	Meteorology	precipitation, temperature, available water content	Not green due to complexity of calculations and the need for serially complete data
Palmer Hydrologic Drought Index (PHDI)	Hydrology	precipitation, temperature, available water content	Serially complete data required
Streamflow Drought Index (SDI)	Hydrology	streamflow	Similar calculations to SPI, but using streamflow data instead of precipitation

3.2.6. Operation Model (WEAP Model)

After developing deficiency hydrographs and reservoir inflows, it is possible to operate reservoirs by using a reservoir modeling software. For the reservoir operation and scenario comparison, WEAP software is selected.

The reason for choosing WEAP is its simplicity and its ability to complete reservoir operation for many dams at the same time. In addition, water uses can be prioritized (i.e. if there is a deficit, municipal water is more important than the irrigation).

A multi-reservoir system is modeled with WEAP. All the analyses are done on a monthly basis for the water year. In this study the first year is used as a warm-up period and all reservoirs are full in every month of the first year. To evaluate all impacts of hydrological droughts in the system a sufficiently long time period should be selected; in this study a period of 44 years was selected.

In WEAP, the user has an ability to draw complex models along with the simple ones. The program does not require any detailed input therefore, it is possible to develop very simple models in a very short span of time. Consequently, using river, reservoir, demand site, transmission link and return flow elements is enough to form a simple WEAP schematic.

In the operation model, all water uses can be defined as a demand site. WEAP is completely a demand-based software, therefore it can automatically convert population and agricultural area to water use as long as monthly water use rate is known.

For reservoirs, storage capacity, initial storage, volume elevation curve, monthly net evaporation and operation rules must be entered in WEAP. These data are required for every reservoir operation study regardless of the software. However, the simple user interface of WEAP provides user the ability to enter data in a very short time.

Transmission links and return flows are very important in WEAP. The capacity of all transmission links can be determined. Therefore, the software can limit the water transmission with pipe diameter or capacity of the system. Similarly, a diversion can be defined in the same manner. Although there is a diversion element in WEAP, it is not recommended. To control the diversion amount, a demand site item can be used and demands of diversion items are set to the diversion amount required in the system. This approach provides control over the diversions and when they are not satisfied, it can be reviewed by the user directly.

3.3. Study Area Characteristics

The study area is in Upper Kızılırmak Basin and it is located in Sivas Province. Total drainage area of the study area is 550.6 km². There are two existing (Pusat-Özen Dam and Dört Eylül Dam) and one planned dam reservoirs (Beydilli Dam); and one planned diversion weir (Beydilli Weir). Those four hydraulic structures are used to supply municipal water to Sivas Province Center.

The study area is a mountainous area which accumulates most of the precipitation of Upper Kızılırmak Basin. The precipitation is mostly orographic, as air masses leave their humidity at the high regions. The average annual precipitation is 455 mm in 1980-2013 period at Sivas meteorological observation station (Figure 3.6). The diversity between daily temperatures is high. Lowest temperatures are recorded in January and highest temperatures are recorded in July. The annual average temperature of Sivas meteorological observation station is 9.1 °C in 1980-2014 period.

Main driving force of the selecting the study area is to determine drought impacts on Sivas municipal water supply. For the existing case, Sivas municipal water is supplied from Dört Eylül Dam and Tavra groundwater sources. In the future (upstream development case), existing Pusat-Özen Dam and planned Beydilli Dam with Beydilli Diversion Weir will also supply municipal water to Sivas Province via diversion. Pusat-Özen Dam also has irrigated areas; therefore, the analyses include both municipal and agricultural perspective in probabilistic deficiency analysis.

For all analyses and model, it is assumed that allocated amount of municipal water is the actual water demand of Sivas Province and Hafik District although the real municipal demand is much lower than the allocated amount.

For both existing and upstream development conditions, the map of the study area is given in Figure 3.6 and Figure 3.7; and characteristics of the hydraulic structures are given in Table 3.2 and Table 3.3, respectively. For each structure, real demand amounts in 2014 for existing case and 2050 for upstream development case and allocated amount for municipal water are also presented in Table 3.2 and Table 3.3.

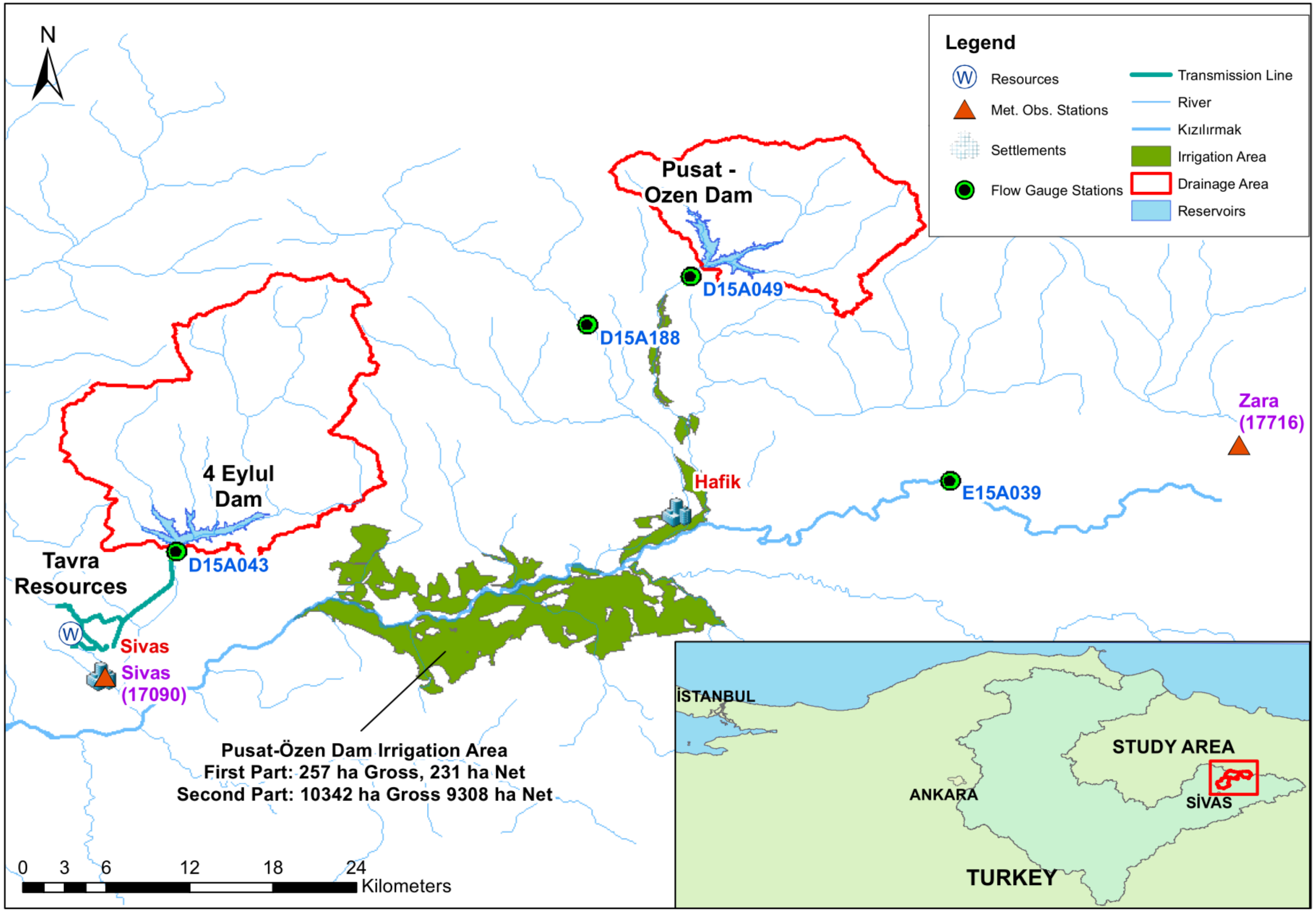


Figure 3.6. Study area map for existing conditions (DSİ, 2019)

Table 3.2. *Characteristics for existing conditions (DSİ, 2019)*

	Existing Conditions	
Dam/Weir Name	**Pusat-Özen Dam**	**Dört Eylül Dam**
Purpose	Municipal+Irrigation	Municipal
Drainage Area (km²)	130.70	236.80
Normal Storage Volume (hm³)	95.25	85.05
Normal Water Level (m)	1494.00	1390.60
Minimum Storage Volume (hm³)	6.00	4.45
Minimum Water Level (m)	1452.00	1355.00
Annual Average Inflow (hm³/year)	53.71	32.69
Net Evaporation (mm/year)	386.46	455.27
Municipal Water Transmitted To	Hafik District	Sivas Province
Municipal Water Demand (hm³/year)	0.23 (2014)	26.70 (2014)
Allocated Municipal Water (hm³/year)	0.95	30.38
Irrigation Area (ha)	231+9308 (9539)	-
Crop Water Requirement (m³/ha/year)	3910.53	-
Diversion Received From	-	-
Received Diversion Amount (hm³/year)	-	-
Diversion Transmitted To	-	-
Diverted Flow Amount (hm³/year)	-	-
Environmental Flow Percentage (%)	10.00	Released for DWR only
Environmental Flow Amount (hm³/year)	5.43	Released for DWR only
Additional Water Resource for Demand Site	-	Tavra Resources
Ad. Water Resource Capacity (l/s)	-	1000.00
Ad. Water Resource Capacity (hm³/year)	-	31.54
Downstream Water Rights (DWR) (Public Irrigations)	-	Mısmıl and Çayboyu Public Irrigations
Downstream Water Rights Demand (hm³/year)	-	0.48

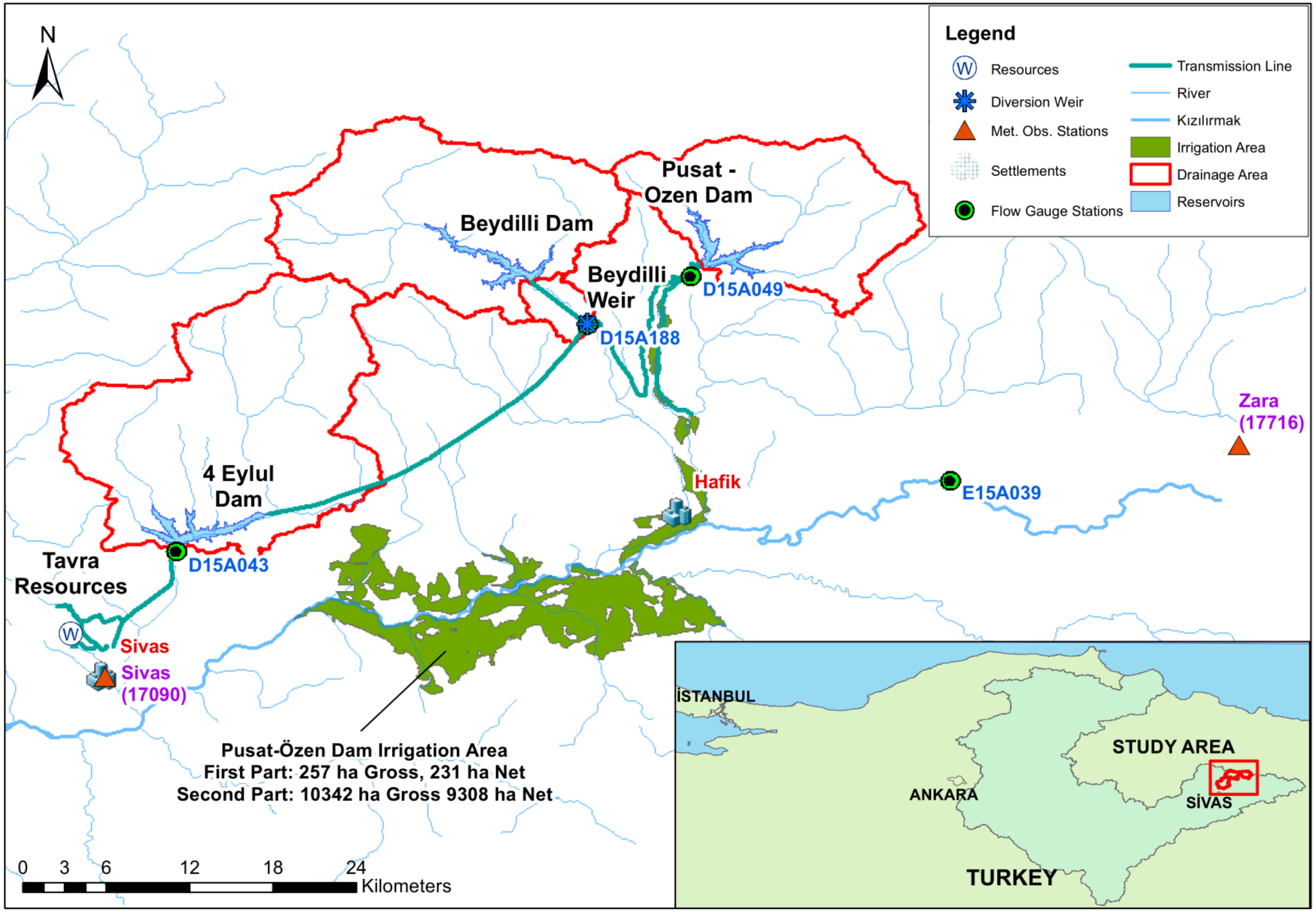


Figure 3.7. Study area map for upstream development conditions (DSİ, 2019)

Table 3.3. *Upstream development conditions characteristics (DSİ, 2019)*

	Upstream Development Conditions			
Dam/Weir Name	**Pusat-Özen Dam**	**Dört Eylül Dam**	**Beydilli Dam**	**Beydilli Weir**
Purpose	Municipal+Irrigation	Municipal	Municipal	Municipal
Drainage Area (km²)	130.70	236.80	183.10	15.6 (Mid-Basin) 198.7 (Total)
Normal Storage Volume (hm³)	95.25	85.05	102.45	-
Normal Water Level (m)	1494.00	1390.60	1457.48	-
Minimum Storage Volume (hm³)	6.00	4.45	5.10	-
Minimum Water Level (m)	1452.00	1355.00	1421.90	-
Annual Average Inflow (hm³/year)	53.71	92.10 (with diversions)	62.40	5.32 (Tributary) 47 (from Beydilli Dam)
Net Evaporation (mm/year)	386.46	455.27	397.00	-
Municipal Water Transmitted To	Hafik Dist. + Diversion	Sivas Province	Diversion	Diversion
Municipal Water Demand (hm³/year)	0.33 for Hafik Dist. (2050)	53,2 (2050)	-	-
Allocated Municipal Water (hm³/year)	0.95 for Hafik Dist. 8.42 for Diversion	88.55	47.00	%75 of tributary inflows Average 3.99 for Diversion
Irrigation Area (ha)	231+9308 (9539)	-	-	-
Crop Water Requirement (m³/ha/year)	3910.53	-	-	-
Diversion Received From	-	Beydilli Weir	-	Beydilli and Pusat-Özen Dams
Received Diversion Amount (hm³/year)	-	8.42+4.00+47.00 (59.42)	-	8.42+47 (55.42)
Diversion Transmitted To	Beydilli Weir	-	Beydilli Weir	Dört Eylül Dam
Diverted Flow Amount (hm³/year)	8.42	-	47.00	3.99+8.42+47.00 (59.42)
Environmental Flow Percentage (%)	7.88	Released for DWR only	Released for diversion to Beydilli Weir	25 % of tributary flow
Environmental Flow Amount (hm³/year)	4.28	Released for DWR only	Released for diversion to Beydilli Weir	1.33
Additional Water Resource for Demand Site	-	Tavra Resources	-	-
Ad. Water Resource Capacity (l/s)	-	1000.00	-	-
Ad. Water Resource Capacity (hm³/year)	-	31.54	-	-
Downstream Water Rights (DWR) (Public Irrigations)	-	Mısmıl and Çayboyu Public Irrigations	-	-
DWR Demand (hm³/year)	-	0.48	-	-

In this study, hydrological study and naturalization process were not conducted. Characteristics of the hydraulic structures, irrigation and municipal water demands, reservoir inflows and meteorological data have been acquired from Kızılırmak Basin Master Plan Final Report (DSİ, 2019) which has been prepared for General Directorate of State Hydraulic Works (DSİ).

The reservoir schematics of Pusat-Özen, Dört Eylül and Beydilli Dams are given in Figure 3.8, Figure 3.9 and Figure 3.10, respectively. The schematics show normal and minimum water levels in m along with normal and minimum storage volumes in hm^3. In this study, it is assumed that the operation water level always kept between minimum and normal water levels.

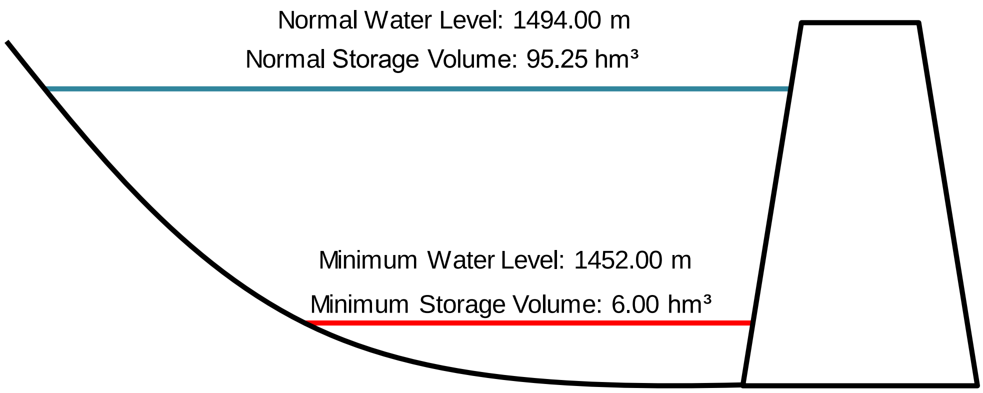


Figure 3.8. Reservoir schematic of Pusat-Özen Dam

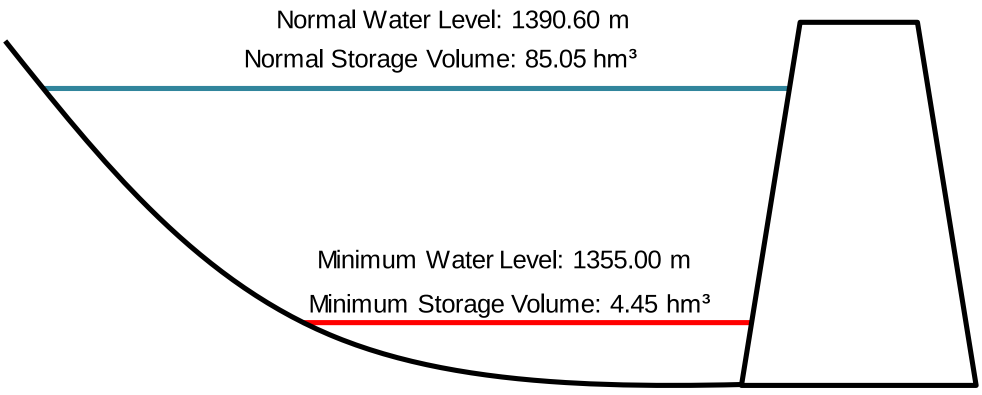


Figure 3.9. Reservoir schematic of Dört Eylül Dam

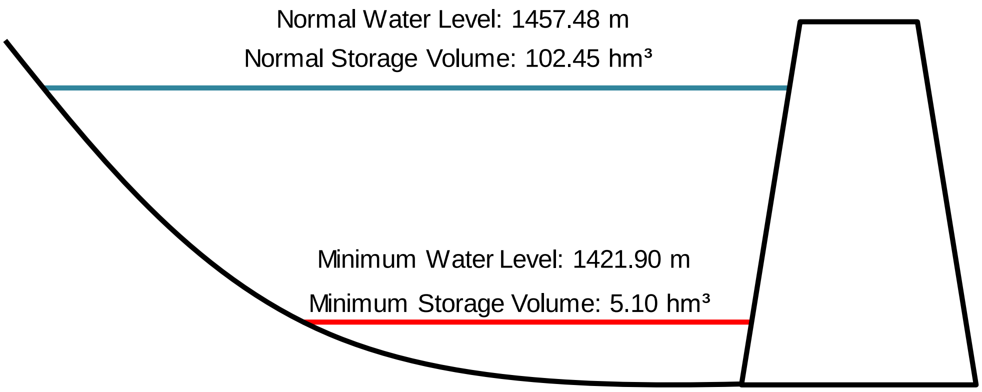


Figure 3.10. Reservoir schematic of Beydilli Dam

For the case study, in order to calculate drought indices for determination of past drought durations, precipitation and temperature observation data of two different meteorological observation stations were used. Both stations have very long observation period, which is important for calculation of drought indices. Used meteorological observation stations for drought analysis are given in Table 3.4 and they are presented in Figure 3.6 and Figure 3.7.

Table 3.4. *Selected meteorological observation stations data sheet*

Station Name	Station Number	Precipitation Data	Temperature Data	Altitude (m)	Latitude	Longitude
Sivas	17090	1929-2014	1930-2014	1285	39°45’	37°1’
Zara	17716	1957-2014	1965-2010	1347	39°54’	37°45’

Source: (DSİ, 2019)

The hydrologic reference period in this study is 1970-2013. This period was used in all deficit calculations and operation scenarios. Hydrological data used in this study was naturalized reservoir inflow data which is taken from Kızılırmak Master Plan Final Report (DSİ, 2019). Used flow gauge stations to calculate natural inflows are given in Table 3.5 and locations are shown on the map given in Figure 3.6 and Figure 3.7.

Table 3.5. *Flow gauge stations data sheet*

Flow Gauge Station Number	Latitude	Longitude	Elevation (m)	Drainage Area (km²)	Observation Period
D15A049	40°00’	37°24’	1386	141.1	1966-1994
D15A043	39°50’	37°04’	1330	245.0	1964-1994
E15A039	39°53’	37°34’	1298	1642.0	1972-
D15A188	39°59’	37°19’	1370	198.7	1979-1999

Source: (DSİ, 2019)

Lastly, monthly average evaporation data at reservoirs are obtained from Kızılırmak Master Plan Final Report (DSİ, 2019). Used data for monthly average evaporations at reservoirs is generated by moving the monthly average evaporation data of Sivas Meteorological Observation Station (17090). The location of Sivas Meteorological Observation Station is shown in Figure 3.6 and Figure 3.7.

CHAPTER 4

APPLICATION OF METHODOLOGY FOR CASE STUDY

4.1. Hydrological Deficit Parameter Calculations

For the study area, hydrological deficit analyses were performed by utilizing the methodology given in Section 3.2.1. Deficit parameters (deficit amounts, deficit lengths, deficit magnitudes and deficit intensities) were calculated for natural inflows of Pusat-Özen Dam, Beydilli Dam, Beydilli Diversion Weir Mid-Basin and Dört Eylül Dam in monthly basis.

As an example, the calculation process of deficit amounts for Dört Eylül Dam inflows in January is given in Figure 4.1.

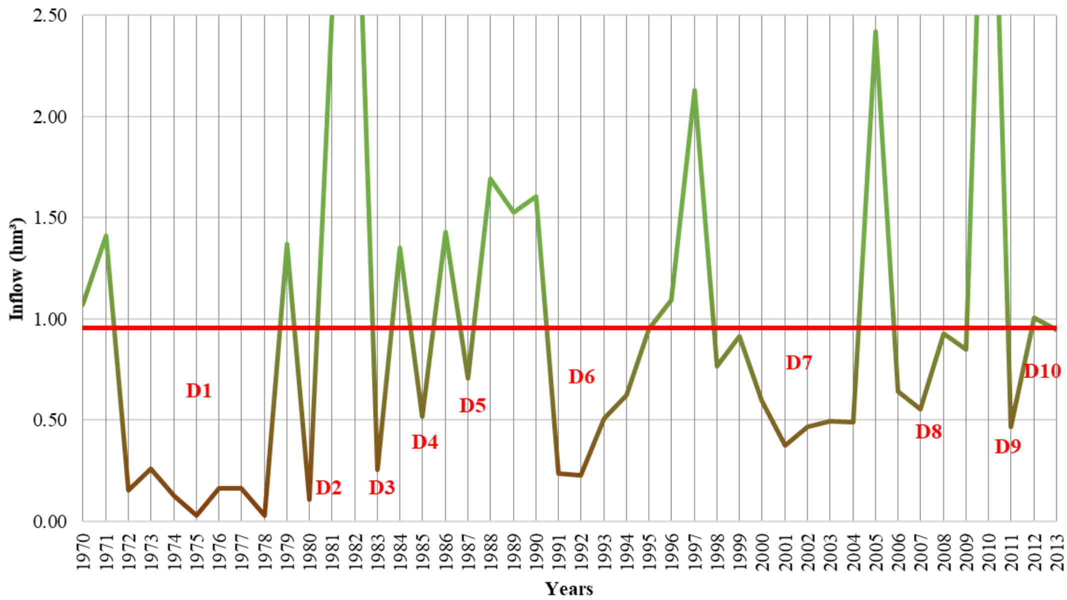


Figure 4.1. Dört Eylül Dam inflows time series and visual representation of deficits in January

In Figure 4.1 variation of January inflows can be seen. The red line shows the average inflow in January and consequently, the inflows above average can be recalled "wet periods or surpluses". In reverse, the values below the average value can be recalled "dry periods or deficits". All deficit periods are shown with D notation.

Dört Eylül Dam inflows in January contain 10 different dry periods (marked with D1 to D10 in Figure 4.1). With these periods; deficit lengths, deficit amounts, deficit magnitudes and deficit intensities are calculated and given in Table 4.1.

Table 4.1. Drought parameters for Dört Eylül Dam inflows in January

No	**Dry Period**		**Deficit Length (Year)**	**Deficit Amount (hm^3)**	**Deficit Magnitude (hm^3)**	**Deficit Intensity (hm^3/year)**
	Start	**End**				
D1	1972	1978	7	**5.754**	0.925	0.822
D2	1980	1980	1	**0.849**	0.849	0.849
D3	1983	1983	1	**0.701**	0.701	0.701
D4	1985	1985	1	**0.437**	0.437	0.437
D5	1987	1987	1	**0.248**	0.248	0.248
D6	1991	1995	5	**2.227**	0.727	0.445
D7	1998	2004	7	**2.578**	0.579	0.368
D8	2006	2009	4	**0.844**	0.400	0.211
D9	2011	2011	1	**0.487**	0.487	0.487
D10	2013	2013	1	**0.011**	0.011	0.011

In the example case, deficit amounts in Table 4.1 are used to develop extreme case deficits for Dört Eylül Dam inflows in January. For this process, firstly the deficit amounts are sorted in descending order and exceedance probabilities for all 10 deficit periods are determined by rank-order statistics. The calculation is given in Table 4.2.

Table 4.2. Empirical exceedance probability calculations for deficit amounts (Dört Eylül Dam inflows in January)

Sorted Deficit Amount (hm^3)	**Rank**	**Exceedance Probability 1-(Rank/(Datacount+1))**
0.011	1	0.909
0.248	2	0.818
0.437	3	0.727
0.487	4	0.636
0.701	5	0.545
0.844	6	0.455
0.849	7	0.364
2.227	8	0.273
2.578	9	0.182
5.754	10	0.091

Using the empirical exceedance probability calculations, different PDFs are fitted to the deficit amounts data. The used PDFs and their parameters are given in Table 4.3. In Table 4.3, goodness-of-fit is calculated by using coefficient of determination (R^2) and mean square error. Goodness-of-fit calculations for all reservoirs, months and parameters are given in Appendix A.

Table 4.3. Parameters of used PDFs and goodness of fit calculations (Dört Eylül Dam inflows in January)

Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**
2-Parameter Gamma	0,7371	1,9177	-	0,9499	0,0039
Log-Normal	-0,4679	1,7135	-	0,9267	0,0059
Gumbel	2,3533	2,1157	-	0,7331	0,0193
Pearson Type III	**0,6008**	**0,5878**	**0,5321**	**0,9711**	**0,0030**
Weibull	1,2780	0,8250	-	0,9530	0,0037

Deficit amounts exceedance probability chart only for month January is given in Figure 4.2. When this approach is applied for all months drought parameters for extreme conditions can be determined. Therefore, the corresponding results of deficit amounts calculations are given in Table 4.4. The calculated values on the chart are painted with red color in Table 4.4. The goodness of fit results show that Pearson probability distribution function is fitted best, therefore Pearson Type III PDF is used for curve fitting (red curve). By using the fitted curve, it is possible to predict deficit amounts for different return periods. The purple line in Figure 4.2 shows how to calculate deficit amounts for 5 years return period (which has 1/5 = 0.2 exceedance probability).

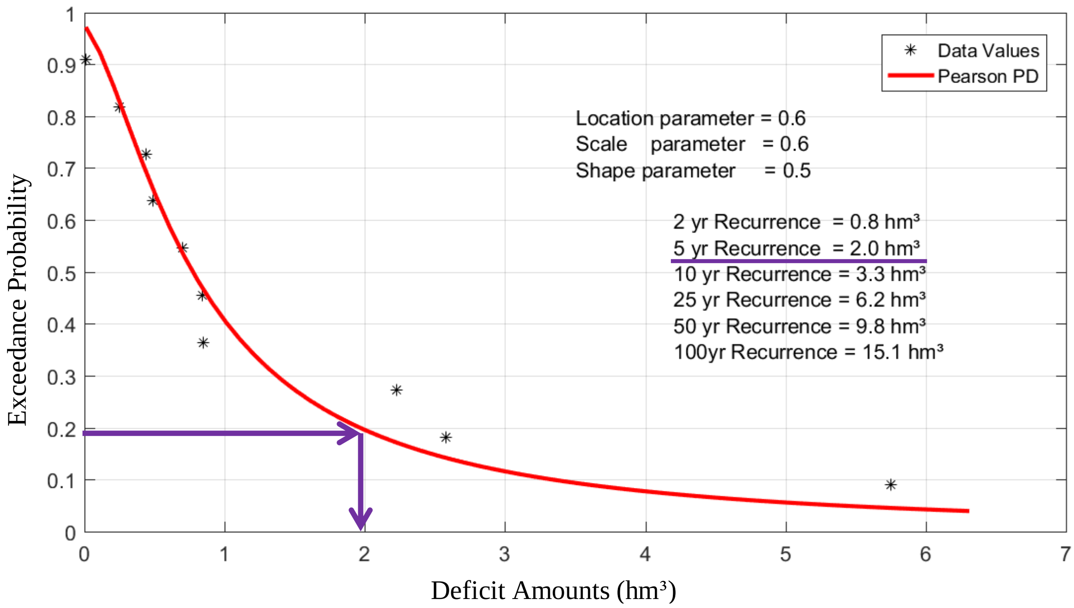


Figure 4.2. Dört Eylül Dam inflows deficit amounts exceedance probability chart for January

Table 4.4. Deficit amounts for Dört Eylül Dam inflows (in hm³)

	Dört Eylül Dam Inflows - Deficit Amounts (hm³) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	**0.773**	**1.963**	**3.335**	**6.238**	**9.754**	**15.070**
Feb	2.813	6.811	10.813	17.701	24.337	32.408
Mar	2.625	6.987	13.006	28.143	49.651	87.042
Apr	7.332	19.309	29.143	42.831	53.593	64.646
May	5.814	6.847	7.098	7.232	7.274	7.294
Jun	1.264	2.519	3.612	5.304	6.799	8.500
Jul	0.980	2.577	3.845	5.559	6.873	8.198
Aug	1.351	2.882	4.283	6.533	8.582	10.968
Sep	0.778	1.771	2.722	4.304	5.788	7.553
Oct	0.848	1.195	1.343	1.481	1.562	1.629
Nov	0.346	1.484	4.544	19.617	58.676	174.532
Dec	0.856	3.386	8.763	29.557	73.110	179.834

The same approach is applicable for all return periods and all four deficit quantities. Deficit parameter calculations are based on a revised version of Şen's deficit computer program originally written in Fortran language in 1977 and converted into Matlab in 2002 (Şen, 2015). Some minor modifications were applied by the author to the code in collaboration with Şen. The revised version of Matlab code is given in Appendix B.

Calculated deficit parameters which include deficit amounts, deficit lengths, deficit magnitudes and deficit intensities (considering no climate change) are given in Appendix C.

4.2. Climate Change Modifications

In this chapter, trend slopes are used as climate change parameter for the determination of changes in the hydrological processes caused by climate change and the analyses were performed for annual total inflows of the hydraulic structures in the study area (Pusat-Özen Dam, Beydilli Dam, Beydilli Weir and Dört Eylül Dam). Detailed analysis for Dört Eylül Dam annual total inflows is given here as an example.

By using Eq. 3.7 in Chapter 3, calculation of climate change parameter for Dört Eylül Dam is given below:

$$\alpha = \frac{2(\overline{y_2} - \overline{y_1})}{n} = \frac{2(31.17 - 34.22)}{22} = -0.138 \qquad (4.1)$$

In Dört Eylül Dam, the first half annual total inflows are compared with the second half annual total inflows. Overall, the trend slope for annual total inflows is -0.138 hm^3/year for Dört Eylül Dam, which indicates decrease in flows in the future. Mean of the entire dataset is 32.69 hm^3. Considering that this point is placed at the mid-point of the entire data geometrically, a line with known slope (-0.138 hm^3/year) and mean location (32.69 hm^3) can be drawn from the vertical axis. The drawn line crosses vertical axis at 35.74 hm^3 which is the intersection point. And the resulting line is called the trend line and can be seen for Dört Eylül Dam annual inflows in Figure 4.3. In Figure 4.3, the blue line shows the Dört Eylül Dam annual inflow values, red dot shows the mean of the entire time series and the orange line shows the trend line.

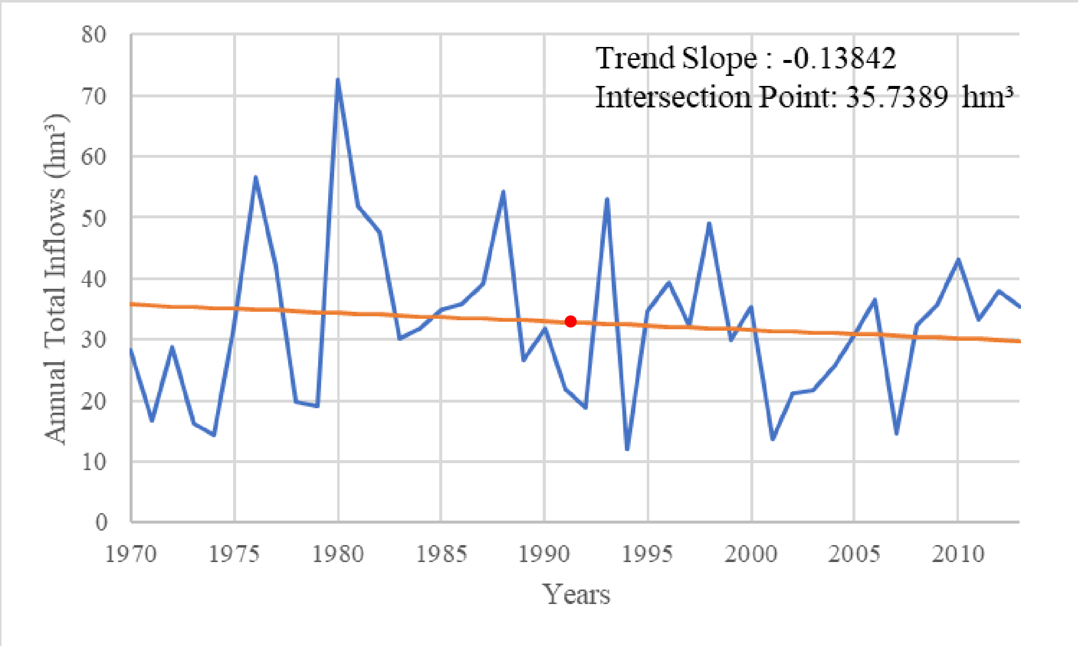


Figure 4.3. Dört Eylül Dam annual inflows series and visualization of the mean trend

Trend parameters calculated for all reservoirs are given in Table *4.5*.

Table 4.5. *Trend parameters for all hydraulic structure inflows*

Reservoir Name	**Climate Change Parameter (α) Mean Slope (hm^3/year)**
Pusat-Özen Dam	-0.09672
Beydilli Dam	-0.78987
Beydilli Weir Mid-Basin	-0.06730
Dört Eylül Dam	**-0.13842**

As an example, 25-years return period climate change modification analysis for Dört Eylül Dam is given below:

No Climate Change

$$P = \frac{1}{T_r} = \frac{1}{25} = 4.00\%$$

With Climate Change

$$P' = \frac{1+\alpha}{T_r} = \frac{1-0.138}{25} = 3.45\%$$

3.45% exceedance probability level equals to approximately 29-years return period (1/R) of the no climate change scenario.

Exceedance probability level modifications and corresponding return periods for all hydraulic structures are given in Table 4.6.

Table 4.6. *Climate change modifications table for study area*

		Hydraulic Structure Inflow Locations							
	Structure Name	**Pusat-Özen Dam**		**Beydilli Dam**		**Beydilli Weir (Mid-Basin)**		**Dört Eylül Dam**	
	Mean Trend Slopes	-0.09672		-0.78987		-0.0673		-0.13842	
Return Period T_r (Years)	**Exceedance Probability P (%)**	**Climate Change Modified Exceedance Probability (P') (%) and Corresponding Return Periods (T_r) of No Climate Change Scenario (Years)**							
		P' (%)	**T_r (Years)**	**P' (%)**	**T_r (Years)**	**P' (%)**	**T_r (Years)**	**P' (%)**	**T_r (Years)**
2	**50.00%**	45.16%	2.21	10.51%	9.52	46.64%	2.14	43.08%	2.32
5	**20.00%**	18.07%	5.54	4.20%	23.79	18.65%	5.36	17.23%	5.80
10	**10.00%**	9.03%	11.07	2.10%	47.59	9.33%	10.72	8.62%	11.61
25	**4.00%**	3.61%	27.68	0.84%	118.97	3.73%	26.80	3.45%	29.02
50	**2.00%**	1.81%	55.35	0.42%	237.95	1.87%	53.61	1.72%	58.03
100	**1.00%**	0.90%	110.71	0.21%	475.90	0.93%	107.22	0.86%	116.07

As an example, climate change modified deficit amounts for Dört Eylül Dam Inflows are given in Table 4.7. This table is the climate change modified version of Table 4.4. In order to compare both tables, values for month January are given in red color.

Example comparison between standard and climate change modified month January deficit amounts for Dört Eylül Dam is given in Table 4.8.

Table 4.7. *Climate change modified deficit amounts for Dört Eylül Dam inflows (in hm³)*

	Dört Eylül Dam Inflows - Deficit Amounts (hm³) **Return Period (with Climate Change Modification)**					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	**0.935**	**2.215**	**3.708**	**6.877**	**10.719**	**16.530**
Feb	3.379	7.593	11.801	19.016	25.944	34.350
Mar	3.158	8.022	14.785	31.821	56.041	98.157
Apr	9.172	21.377	31.321	45.118	55.946	67.055
May	6.102	6.920	7.130	7.244	7.279	7.297
Jun	1.459	2.742	3.867	5.609	7.146	8.894
Jul	1.229	2.847	4.122	5.841	7.157	8.483
Aug	1.581	3.164	4.616	6.947	9.065	11.529
Sep	0.923	1.959	2.953	4.601	6.142	7.973
Oct	0.928	1.232	1.369	1.500	1.577	1.642
Nov	0.435	1.889	5.772	24.842	74.197	220.512
Dec	1.090	4.169	10.703	35.934	88.747	218.126

Table 4.8. *Dört Eylül Dam month January inflows comparison of deficit amounts for climate change modified and standard deficit amounts*

	Dört Eylül Dam Inflows - Deficit Amounts for Month January					
Return Period (years)	**2**	**5**	**10**	**25**	**50**	**100**
No Climate Change Modification (hm³)	0.773	1.963	3.335	6.238	9.754	15.070
With Climate Change Modification (hm³)	0.935	2.215	3.708	6.877	10.719	16.530
Percent Increase in Deficit Amount (%)	120.96%	112.84%	111.18%	110.24%	109.89%	109.69%
Corresponding Climate Return Period (years)	**2.32**	**5.8**	**11.61**	**29.02**	**58.03**	**116.07**

For the calculation of climate change modifications, the calculation methodology explained here is implemented by the author into Şen's Matlab program for curve fitting to deficit quantities and goodness of fit calculations. The program is given in Appendix B. Climate change modified deficit parameters which include deficit amounts, deficit lengths, deficit magnitudes and deficit intensities are given in Appendix D.

4.3. Deficiency Hydrograph

Deficiency hydrographs for all studied structures are calculated for all risk levels and they are also recalculated for climate change modified deficit parameters.

Geometric properties of deficiency hydrograph are given in Figure 4.4. In this section as an example, the calculation procedure for Dört Eylül Dam climate change modified deficiency hydrograph parameters for 25-years return period are given in Table 4.9 and Figure 4.5.

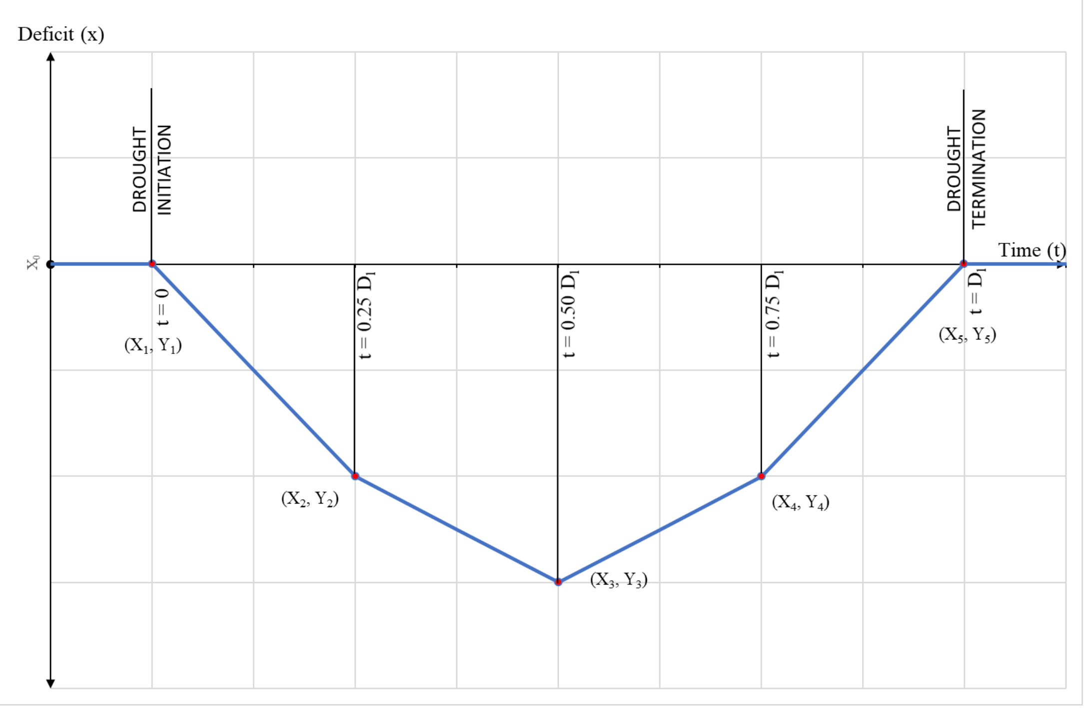


Figure 4.4. Geometric properties of deficiency hydrograph

Table 4.9. *25-years return period deficiency hydrograph geometric parameters for Dört Eylül Dam including climate change modifications*

	Deficiency Hydrograph Parameters (X in years, Y in hm³)									
Month	**X_1**	**Y_1**	**X_2**	**Y_2**	**X_3**	**Y_3**	**X_4**	**Y_4**	**X_5**	**Y_5**
Jan*	0	0	-	-	3.64	1.89	-	-	7.28	0
Feb	0	0	7.44	0.48	14.87	1.59	22.31	0.48	29.74	0
Mar	0	0	1.69	4.63	3.38	9.59	5.07	4.63	6.76	0
Apr	0	0	2.42	4.43	4.85	9.76	7.27	4.43	9.70	0
May**	0	0	1.44	0	2.88	5.75	4.33	0	5.76	0
Jun	**0**	**0**	**0.97**	**1.6**	**1.94**	**2.59**	**2.91**	**1.6**	**3.88**	**0**
Jul	0	0	4.81	0.31	9.62	0.59	14.42	0.31	19.24	0
Aug	0	0	6.25	0.36	12.49	0.39	18.74	0.36	24.98	0
Sep	0	0	6.19	0.21	12.38	0.32	18.56	0.21	24.76	0
Oct	0	0	2.33	0.13	4.66	0.39	6.99	0.13	9.32	0
Nov*	0	0	-	-	4.78	5.2	-	-	9.56	0
Dec*	0	0	-	-	4.96	7.24	-	-	9.92	0

* Special triangular case 1 is used for calculation of deficiency hydrograph for the marked months.

** Special triangular case 2 is used for calculation of deficiency hydrograph for the marked months.

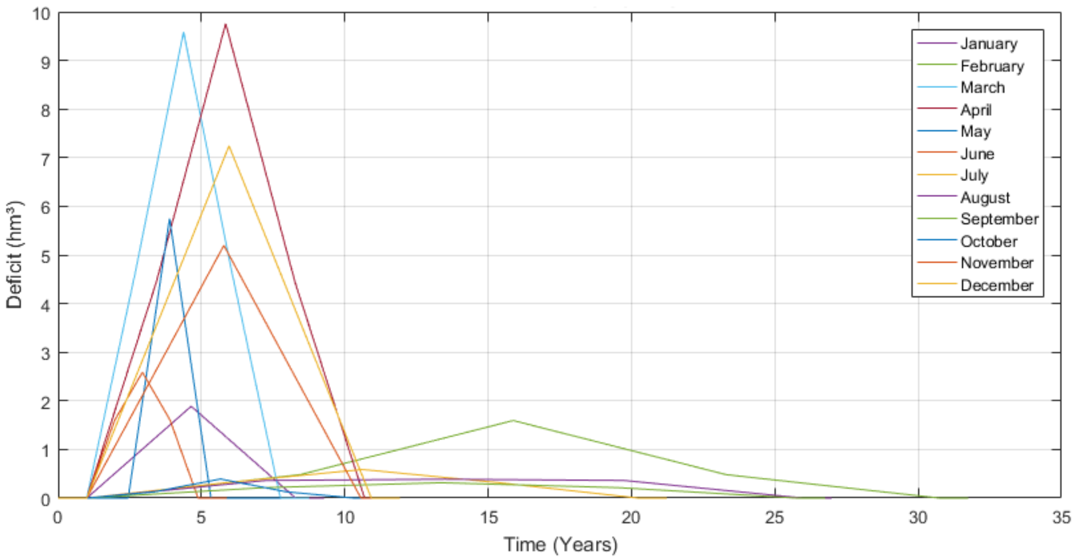


Figure 4.5. Dört Eylül Dam climate change modified 25-years return period based deficiency hydrographs

In this study, it is assumed that the maximum dry point (D_m) on the deficiency hydrograph is always at $0.50D_l$, which is at the half of the drought run. However, in some cases, there may be inconsistencies between deficit amount (*D*) and deficit magnitude (D_m). In those cases, the maximum can change location on the pentagonal shape. The second assumption in the pentagonal shape is no wet period assumption. Therefore, there can be no surpluses in the calculation. As in Table 4.9, for months January, May, November and December abovementioned inconsistencies occur. For those months, two triangular modifications made to the deficiency hydrograph to ensure the most extreme drought case for all calculations and two assumptions in the deficiency hydrograph methodology. Those modifications are detailed in the next section.

4.3.1. Special Triangular Cases for Deficiency Hydrograph

If deficit amount (*D*) is much higher than the deficit magnitude (D_m) deficiency hydrograph converts into another geometric shape which has two identical local maximum points at $0.25D_l$ and $0.75D_l$; and the maximum drought location at $0.50D_l$ is not possible. Although this is a possibility and the shape is given also in Yevjevich's (1967) drought shapes (fifth and sixth drought run shapes in Figure 2.2), this case is not considered while developing the deficiency hydrograph.

In this study, it is assumed that maximum deficit amount is reached at time $0.50D_l$ and that value is the maximum deficiency in all dry periods. If the deficit magnitude cannot be the largest deficit in the drought run and there are two different maximum points at the dry period, which means the impacts of the dry period are mitigated in the dry period. In that case, it is impossible to see the most extreme impacts of a dry period. Therefore, deficiency hydrograph is modified for those cases.

The hydrograph calculated with both normal and triangular methodologies is given in Figure 4.6. The red line shows the pentagonal methodology result and the blue line shows the triangular methodology. It can be seen the triangular shape is the same in terms of area and dry period length, however, the maximum point on the triangle is below the pentagonal maximum values at $0.25D_l$ and $0.75D_l$ (both shapes are symmetrical).

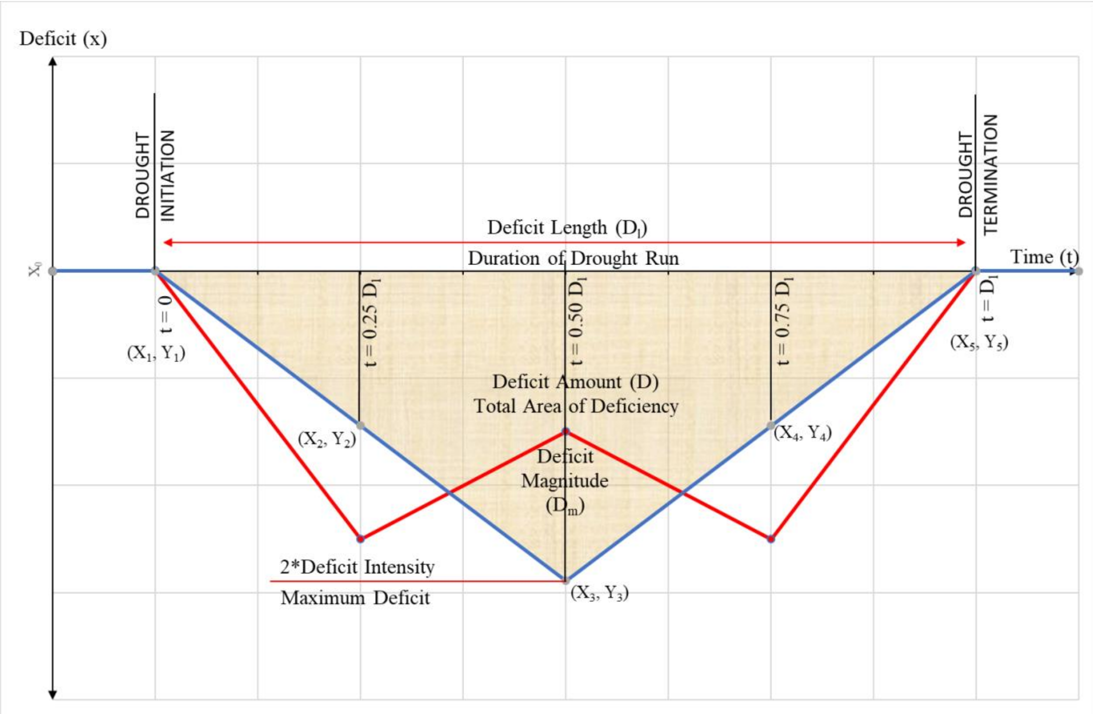


Figure 4.6. Triangular deficiency hydrograph (Special case 1)

The maximum value at the triangular shape can be calculated by the equation below:

$$x_{0.50D_l} = 2\,\frac{D}{D_l} = 2 * Deficit\ Intensity \quad (4.2)$$

Another special case may occur when the deficit magnitude (D_m) is larger than the deficit amount (D). In this case, at the locations $0.25D_l$ and $0.75D_l$ there is surplus, not deficit (see Figure 4.7).

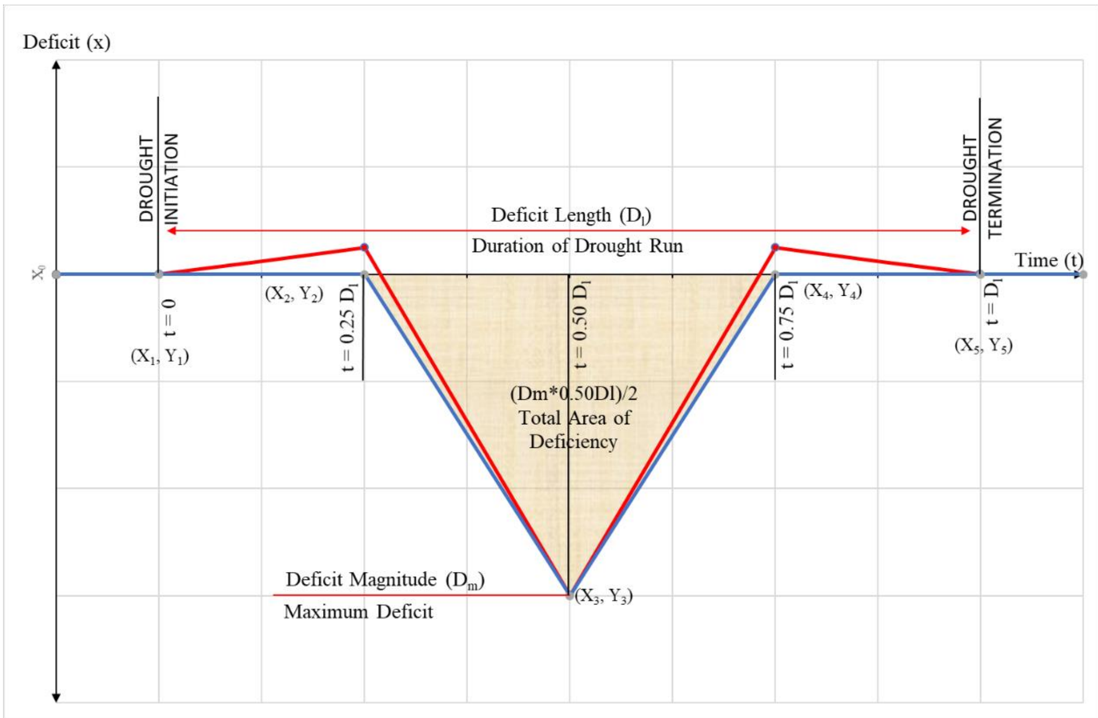


Figure 4.7. Triangular deficiency hydrograph (Special case 2)

This is not an expected outcome. Therefore, the deficiency hydrograph modified as keeping the deficit magnitude (D_m) at the maximum and shifting the surplus values to zero (i.e. no surplus). This will increase the total amount of deficit, which is given in the equation below:

$$Total\ Deficit\ Amount = \frac{D_m * 0.50D_l}{2} \tag{4.3}$$

Both assumptions (i.e. special cases) ensure the examined case is the worst-case scenario for given exceedance probability level.

Matlab code for calculation of deficiency hydrograph including special cases is given in Appendix E.

4.4. Deficit Scenarios

When the deficiency hydrographs of all months are combined for the corresponding years and months, probabilistic deficiency hydrographs can be obtained. The first year is assumed as a reference year, therefore the deficit period initiates at the beginning of the second year. The first year and the years with no deficits will have average inflow values. Then the total deficit of each month is subtracted from the average flow and scenario flows (which are also reservoir inflows in this study) are developed. The details of the methodology are given in Section 3.2.4. Scenario flow data with and without climate change modification is calculated for 2-, 5-, 10-, 25-, 50- and 100-years return periods and for all inflow locations in the study (which are Pusat-Özen Dam, Beydilli Dam, Beydilli Weir Mid-Basin and Dört Eylül Dam inflows).

In this section as a numerical example, generation procedure of 25-years return period climate change modified scenario inflows for Dört Eylül Dam is given. Geometric properties of deficiency hydrographs are given and explained previously in Section 4.3, Figure 4.5 and Table 4.9. For scenario development stage, monthly deficiencies are calculated by using deficiency hydrographs. Then the deficiencies are subtracted from monthly average values and resulting hydrograph is the scenario hydrograph.

As example, calculation for month June is given in Figure 4.8. In the figure, the first year (year 0) is the warm-up period and includes no deficiency. The drought initiates at the beginning of year 1 and lasts 3.88 years (X_5 value given in Table 4.9). When the warm-up period also added to this value, 4.88 years is calculated, which is the termination year of deficit period in month June. At this point, deficit period is divided into yearly parts and the area under deficiency hydrograph for each yearly period is calculated. In Figure 4.8, the yearly parts are shown with different colors. These areas show the total deficiency for calculated years in month June. For example, total deficiency between years 1 and 2 is 0.822 hm³. This value is the deficiency in month June and year 1.

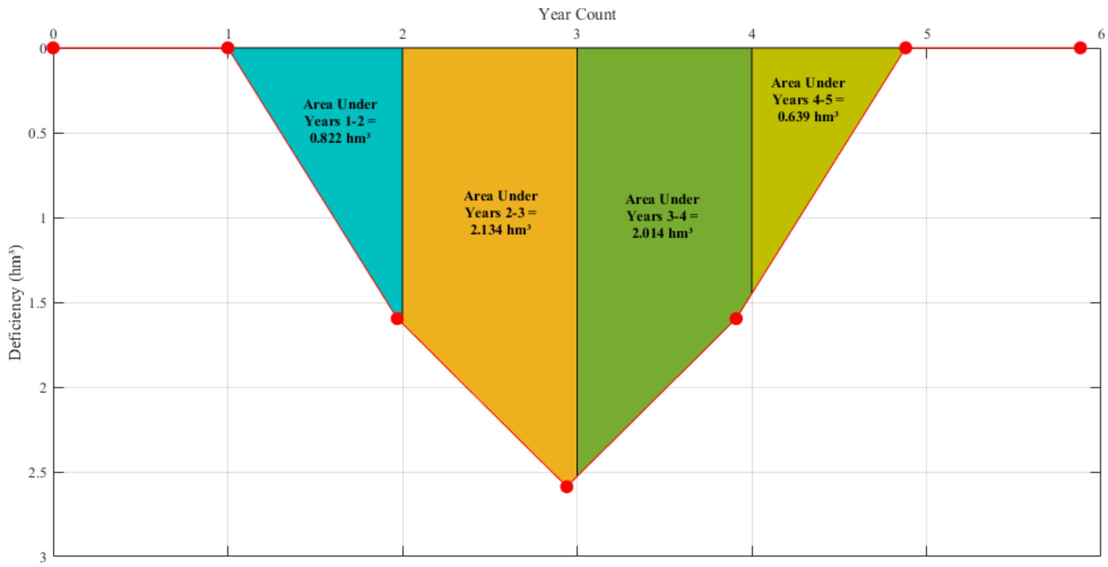


Figure 4.8. Deficiency calculations for month June, 25-years return period climate change modified scenario for Dört Eylül Dam inflows.

The deficiency calculations are repeated for all months and years to generate monthly deficiency values. 25-years return period, climate change modified Dört Eylül Dam inflow deficiency calculations for all months and years are given in Table 4.10. In the table, green to red colors indicate the years of deficiency occur. Deficiencies for all months terminate at year 30. In addition, the deficiencies in month June are given in bold for comparison with Figure 4.8.

Table 4.10. *25-years return period deficiency calculations for Dört Eylül Dam including climate change modifications*

	Months											
Years	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
0	0	0	0	0	0	0	0	0	**0**	0	0	0
1	0.03	0.54	0.73	0.26	0.03	1.37	0.91	0.00	**0.82**	0.03	0.03	0.02
2	0.08	1.63	2.19	0.78	0.10	4.12	2.74	0.62	**2.13**	0.10	0.09	0.05
3	0.15	2.72	3.65	1.30	0.16	7.01	4.64	4.15	**2.01**	0.16	0.15	0.09
4	0.26	3.80	5.11	1.75	0.23	8.81	6.80	3.31	**0.64**	0.23	0.20	0.12
5	0.36	4.84	6.57	1.44	0.29	6.29	8.95	0.22	**0**	0.29	0.26	0.16
6	0.30	4.41	6.46	0.93	0.36	3.44	8.32	0	**0**	0.35	0.32	0.19
7	0.18	3.33	5.00	0.41	0.42	0.78	6.12	0	**0**	0.41	0.36	0.22
8	0.10	2.24	3.54	0.02	0.50	0	4.02	0	**0**	0.47	0.37	0.24
9	0.04	1.15	2.08	0	0.64	0	2.18	0	**0**	0.52	0.37	0.25
10	0.00	0.17	0.62	0	0.79	0	0.44	0	**0**	0.57	0.38	0.27
11	0	0	0	0	0.94	0	0	0	**0**	0.54	0.38	0.28
12	0	0	0	0	1.09	0	0	0	**0**	0.48	0.38	0.30
13	0	0	0	0	1.24	0	0	0	**0**	0.42	0.39	0.31
14	0	0	0	0	1.39	0	0	0	**0**	0.37	0.38	0.30
15	0	0	0	0	1.54	0	0	0	**0**	0.31	0.38	0.28
16	0	0	0	0	1.50	0	0	0	**0**	0.24	0.38	0.26
17	0	0	0	0	1.35	0	0	0	**0**	0.18	0.37	0.25
18	0	0	0	0	1.20	0	0	0	**0**	0.11	0.37	0.23
19	0	0	0	0	1.05	0	0	0	**0**	0.05	0.36	0.21
20	0	0	0	0	0.90	0	0	0	**0**	0	0.32	0.18
21	0	0	0	0	0.75	0	0	0	**0**	0	0.26	0.15
22	0	0	0	0	0.60	0	0	0	**0**	0	0.20	0.11
23	0	0	0	0	0.47	0	0	0	**0**	0	0.14	0.08
24	0	0	0	0	0.40	0	0	0	**0**	0	0.09	0.04
25	0	0	0	0	0.34	0	0	0	**0**	0	0.03	0.01
26	0	0	0	0	0.27	0	0	0	**0**	0	0	0
27	0	0	0	0	0.21	0	0	0	**0**	0	0	0
28	0	0	0	0	0.15	0	0	0	**0**	0	0	0
29	0	0	0	0	0.08	0	0	0	**0**	0	0	0
30	0	0	0	0	0.02	0	0	0	**0**	0	0	0
31	0	0	0	0	0	0	0	0	**0**	0	0	0
32	0	0	0	0	0	0	0	0	**0**	0	0	0

The last step in the deficit scenario generation procedure is to subtract the calculated deficiencies from the monthly average values of Dört Eylül Dam inflows. When this process is completed, the resulting hydrograph is the scenario hydrograph and can be used directly in operation model. The calculated scenario inflows for 25-years return period, climate change modified Dört Eylül Dam is given in Table 4.11.

Table 4.11. *25-years return period scenario inflows for Dört Eylül Dam including climate change modifications*

	Months											
Years	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
0	0.40	0.65	1.03	0.96	1.29	7.00	12.20	6.18	**1.81**	0.57	0.30	0.30
1	0.37	0.11	0.30	0.70	1.26	5.63	11.29	6.18	**0.99**	0.54	0.27	0.28
2	0.32	0.00	0.00	0.18	1.19	2.88	9.46	5.57	**0.00**	0.48	0.22	0.25
3	0.25	0.00	0.00	0.00	1.13	0.00	7.56	2.03	**0.00**	0.41	0.16	0.21
4	0.14	0.00	0.00	0.00	1.06	0.00	5.40	2.87	**1.17**	0.35	0.10	0.18
5	0.04	0.00	0.00	0.00	1.00	0.71	3.25	5.96	**1.81**	0.28	0.04	0.14
6	0.10	0.00	0.00	0.03	0.93	3.56	3.88	6.18	**1.81**	0.22	0.00	0.11
7	0.22	0.00	0.00	0.55	0.87	6.22	6.08	6.18	**1.81**	0.16	0.00	0.08
8	0.30	0.00	0.00	0.93	0.79	7.00	8.18	6.18	**1.81**	0.11	0.00	0.06
9	0.35	0.00	0.00	0.96	0.65	7.00	10.02	6.18	**1.81**	0.05	0.00	0.05
10	0.40	0.48	0.41	0.96	0.50	7.00	11.76	6.18	**1.81**	0.00	0.00	0.03
11	0.40	0.65	1.03	0.96	0.35	7.00	12.20	6.18	**1.81**	0.04	0.00	0.01
12	0.40	0.65	1.03	0.96	0.20	7.00	12.20	6.18	**1.81**	0.09	0.00	0.00
13	0.40	0.65	1.03	0.96	0.05	7.00	12.20	6.18	**1.81**	0.15	0.00	0.00
14	0.40	0.65	1.03	0.96	0.00	7.00	12.20	6.18	**1.81**	0.21	0.00	0.00
15	0.40	0.65	1.03	0.96	0.00	7.00	12.20	6.18	**1.81**	0.27	0.00	0.02
16	0.40	0.65	1.03	0.96	0.00	7.00	12.20	6.18	**1.81**	0.33	0.00	0.03
17	0.40	0.65	1.03	0.96	0.00	7.00	12.20	6.18	**1.81**	0.40	0.00	0.05
18	0.40	0.65	1.03	0.96	0.09	7.00	12.20	6.18	**1.81**	0.46	0.00	0.07
19	0.40	0.65	1.03	0.96	0.24	7.00	12.20	6.18	**1.81**	0.53	0.00	0.08
20	0.40	0.65	1.03	0.96	0.39	7.00	12.20	6.18	**1.81**	0.57	0.00	0.12
21	0.40	0.65	1.03	0.96	0.54	7.00	12.20	6.18	**1.81**	0.57	0.04	0.15
22	0.40	0.65	1.03	0.96	0.69	7.00	12.20	6.18	**1.81**	0.57	0.10	0.18
23	0.40	0.65	1.03	0.96	0.82	7.00	12.20	6.18	**1.81**	0.57	0.16	0.22
24	0.40	0.65	1.03	0.96	0.89	7.00	12.20	6.18	**1.81**	0.57	0.22	0.25
25	0.40	0.65	1.03	0.96	0.95	7.00	12.20	6.18	**1.81**	0.57	0.28	0.29
26	0.40	0.65	1.03	0.96	1.02	7.00	12.20	6.18	**1.81**	0.57	0.30	0.30
27	0.40	0.65	1.03	0.96	1.08	7.00	12.20	6.18	**1.81**	0.57	0.30	0.30
28	0.40	0.65	1.03	0.96	1.14	7.00	12.20	6.18	**1.81**	0.57	0.30	0.30
29	0.40	0.65	1.03	0.96	1.21	7.00	12.20	6.18	**1.81**	0.57	0.30	0.30
30	0.40	0.65	1.03	0.96	1.27	7.00	12.20	6.18	**1.81**	0.57	0.30	0.30
31	0.40	0.65	1.03	0.96	1.29	7.00	12.20	6.18	**1.81**	0.57	0.30	0.30
32	0.40	0.65	1.03	0.96	1.29	7.00	12.20	6.18	**1.81**	0.57	0.30	0.30

It is important to notice that some values can be zero if the calculated deficiency amount is higher than the monthly average value (for example year 2 of month June). This is an important trait of the methodology to ensure the extremity for all months, which can be also no flow condition.

In Figure 4.9, the combination of probabilistic monthly deficiency hydrographs and resulting reservoir inflows for climate change modified 25-years return period reservoir inflows for Dört Eylül Dam is given.

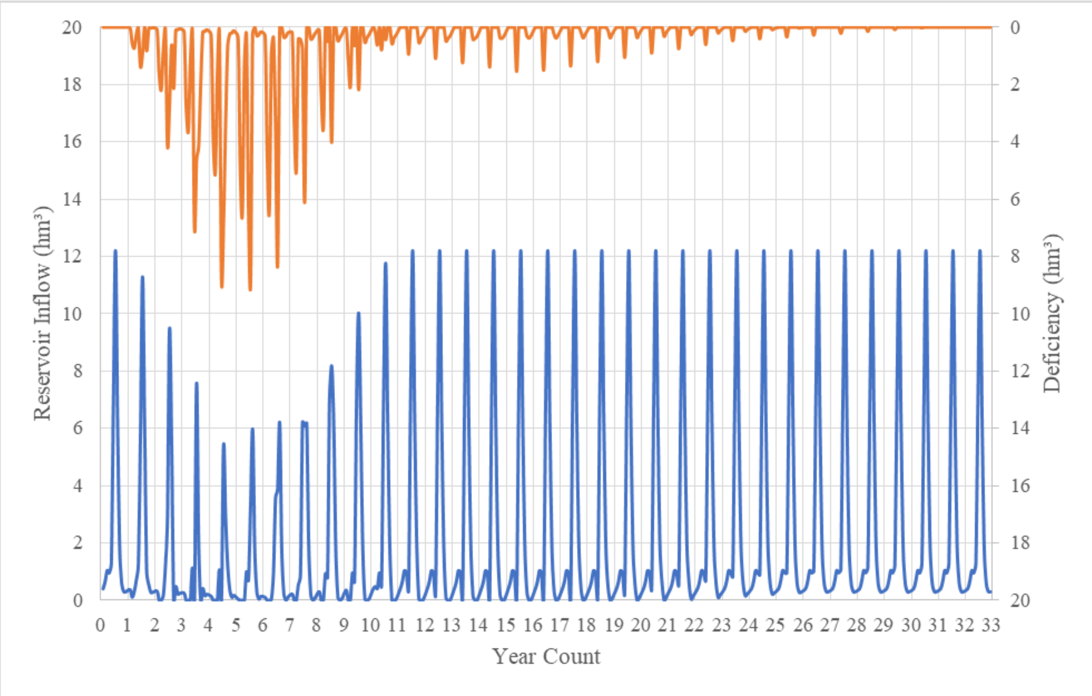


Figure 4.9. 25-years return period reservoir inflows and deficiencies for Dört Eylül Dam (including climate change modification)

4.5. Drought Index Calculations and Determination of Historical Drought Periods

In this study, SPI (9- and 12-month timescales) and Palmer Drought Indices (PDSI and PHDI) by using two different meteorological observation stations (MOS); Sivas and Zara MOS. In addition, SDI (3-, 6-, 9- and 12-months, October to September) for reservoir inflows of the studied hydraulic structures (Dört Eylül, Pusat-Özen, Beydilli Dams and Beydilli Weir inflows) were calculated. The observations and reservoir inflows are monthly and all of them are equal or longer than 30 years.

For drought indices which use meteorological data (SPI, PDSI and PHDI), the entire observation period of the observation stations was used in order to get more accurate results.

Sivas MOS 9- and 12-months SPI, PDSI and PHDI and Dört Eylül Dam 12-months SDI (October to September) results are given in the following chapters as an example. All drought index results are given in Appendix F.

4.5.1. Standardized Precipitation Index (SPI)

For calculation of SPI, a computer program called *SPI_SL_6* developed in National Drought Mitigation Center in University of Nebraska-Lincoln is used (National Drought Mitigation Center, 2018b). The program only uses monthly precipitation data as input.

An easy way to view all drought types at once is multiple time-scale diagram. In this way, it is possible to visualize all time-scales in one chart. By using a cross-section on the multiple time-scale diagram, one can extract specific time series easily. Multiple time-scale graph is given for SPI calculations.

For all timescales of SPI (1- to 60-months), multiple time-scale diagram for Sivas station has been given in Figure 4.10. And consequent 9- and 12-months SPI time series are given in Figure 4.11 and Figure 4.12, respectively.

According to 9-month SPI for Sivas MOS, the longest recorded drought is the 19 month-long drought period in 1973-1974. There are several severe droughts in 1932-1933, 1956-1957, 1961, 2013-2014, 1934-1935, 1954-1956, 1945-1946, 1970-1971 and 1929-1930 (which are sorted by their severities). In recent years, there are moderate droughts in 1984-1985, 1989, 1994, 1997, 2001, 2005 and 2007.

According to 12-month SPI for Sivas MOS, the longest recorded drought is the 23 month-long drought period in 1961-1963. There are several severe droughts in 1932-1933, 1973-1974, 1956-1957, 1944-1946, 1934-1935, 2013-2014, 1970-1971, 1929-1930, 1955-1956 and 1994-1995 (which are sorted by their severities). In recent years, there are moderate droughts in 1982-1983, 1984-1985, 1989, 1994-1995, 2001, 2004-2005 and 2007.

For longer timescales (e.g. 12- to 60-months), there are six very long moderate to severe droughts marked in Figure 4.10. They are 1933-1936, 1945-1949, 1955-1962, 1972-1975, 1983-1985 and 2004-2008.

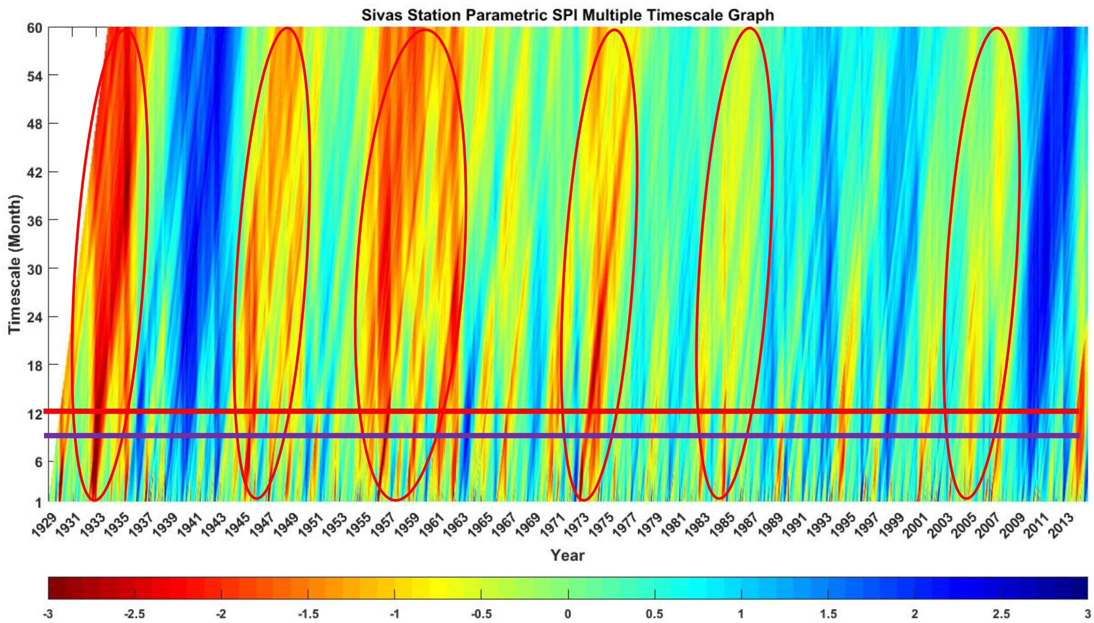


Figure 4.10. SPI multiple time-scale graph for Sivas station

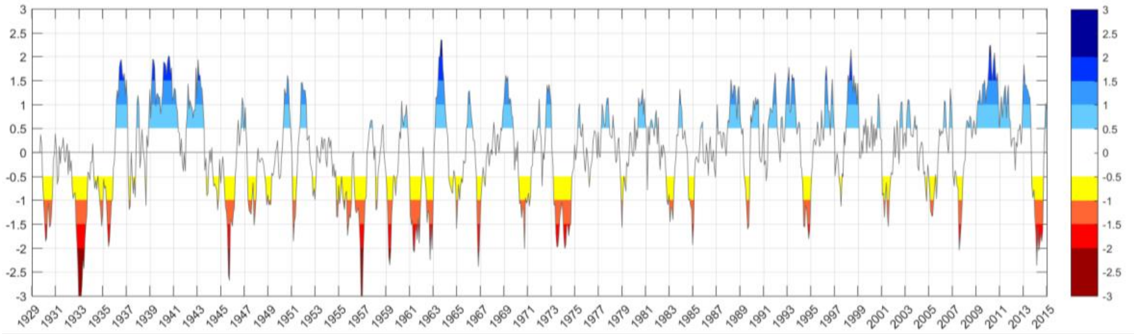


Figure 4.11. Sivas station 9-month SPI time series (Purple cross-section)

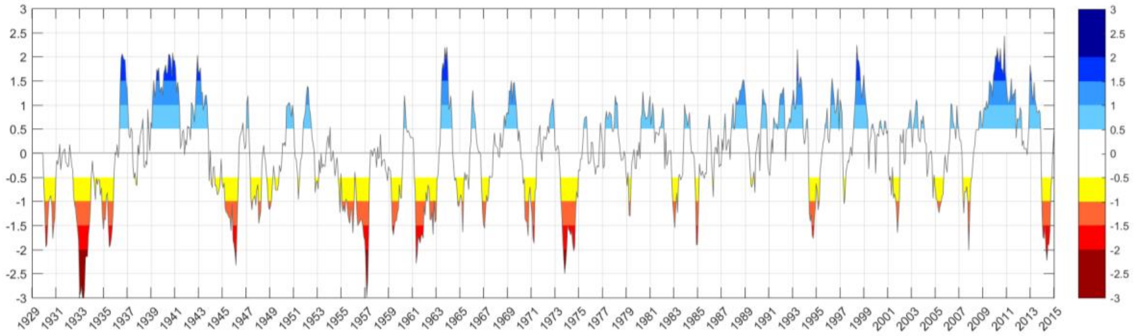


Figure 4.12. Sivas station 12-month SPI time series (Red cross-section)

4.5.2. Palmer Drought Severity Index (PDSI)

The computer software used for calculating Palmer indices (PDSI and PHDI) is developed in University of Nebraska-Lincoln (Wells, 2003). Inputs of the program are monthly or weekly precipitation data, monthly or weekly temperature data, normal (mean) temperature data of the reference period, the latitude of the location of interest and lastly the soil water holding capacity.

Palmer Drought Indices which include PDSI and PHDI are calculated based on the methodology given in Chapter 3 the results of PDSI for Sivas meteorological observation station have been given in this chapter.

Palmer indices also use temperature data as input along with precipitation. Thus, Palmer calculations have been limited to the temperature observation data period (which is 1930-2014 for Sivas) for Palmer indices.

PDSI time series for Sivas station is given in Figure 4.13.

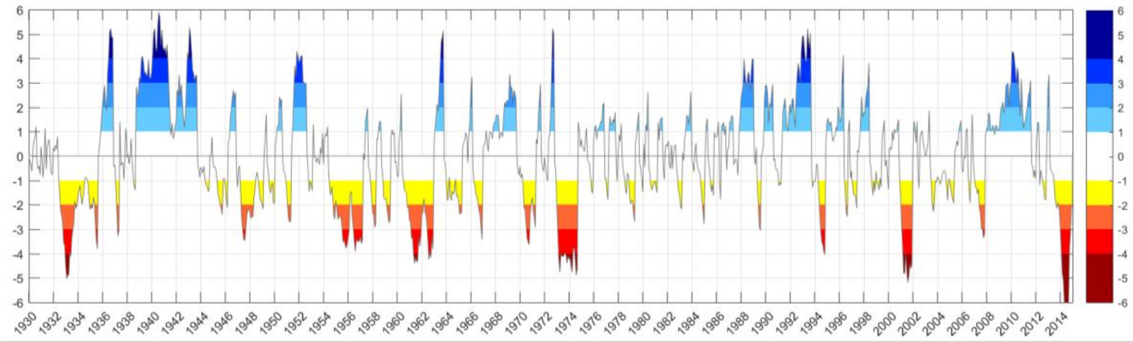


Figure 4.13. Sivas station PDSI time series

According to PDSI for Sivas station, the longest recorded drought is the 33 month-long drought period in 1954-1957. There are several severe droughts in 1960-1962, 1972-1974, 2013-2014, 1932-1934, 2000-2001, 1947-1948, 1970-1971, 1934-1935 and 2007 (which are sorted by their severities). In recent years, there are moderate droughts in 1980-1981, 1994 and 2003.

4.5.3. Palmer Hydrological Drought Index (PHDI)

The results of PHDI for Sivas meteorological observation station are given in this chapter. PHDI time series for Sivas station is given in Figure 4.14.

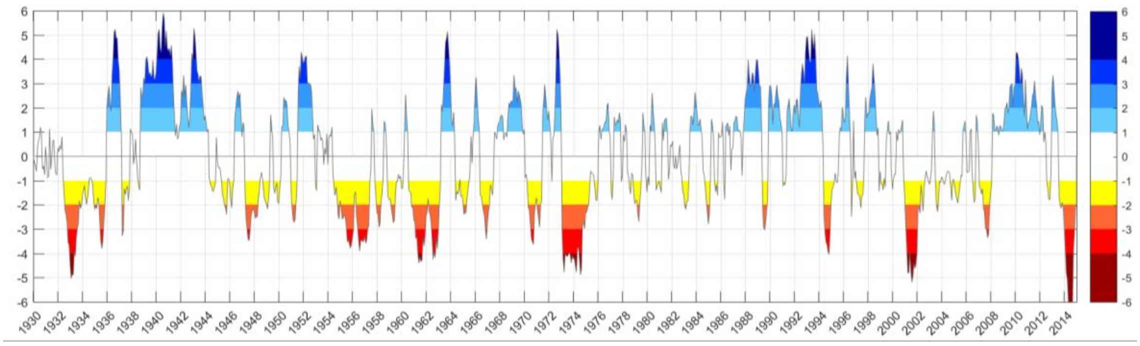


Figure 4.14. Sivas station PHDI time series

According to PHDI for Sivas station, the longest recorded drought is the 36 month-long drought period in 1954-1957. There are several severe droughts in 1973-1975, 1960-1963, 2013-2014, 1932-1934, 2000-2002, 1947-1948, 1970-1971, 1934-1935, 1994-1995, 1966-1967, 2007-2008 and 1958-1959 (which are sorted by their severities). In recent years, there are moderate droughts in 1980-1981, 1982-1983, 1984-1985, 1989, 1997, 2003 and 2005.

4.5.4. Streamflow Drought Index (SDI)

For non-parametric SDI calculations, a Microsoft Excel program developed by the author is used. The non-parametric calculations are implemented by using the same methodology developed by Farahmand and AghaKouchak (2015).

The results of October to September SDI calculation for Dört Eylül Dam is given in Figure 4.15. According to yearly (12-months) SDI calculation (October to September) for Dört Eylül Dam inflows, the longest drought events have occurred in 1970-1975, 1977-1978, 1989-1992, 2000-2004 and 2006-2008. In 1994, SDI reaches to a highly severe value, however the duration is short, and the drought period is followed by a wet period.

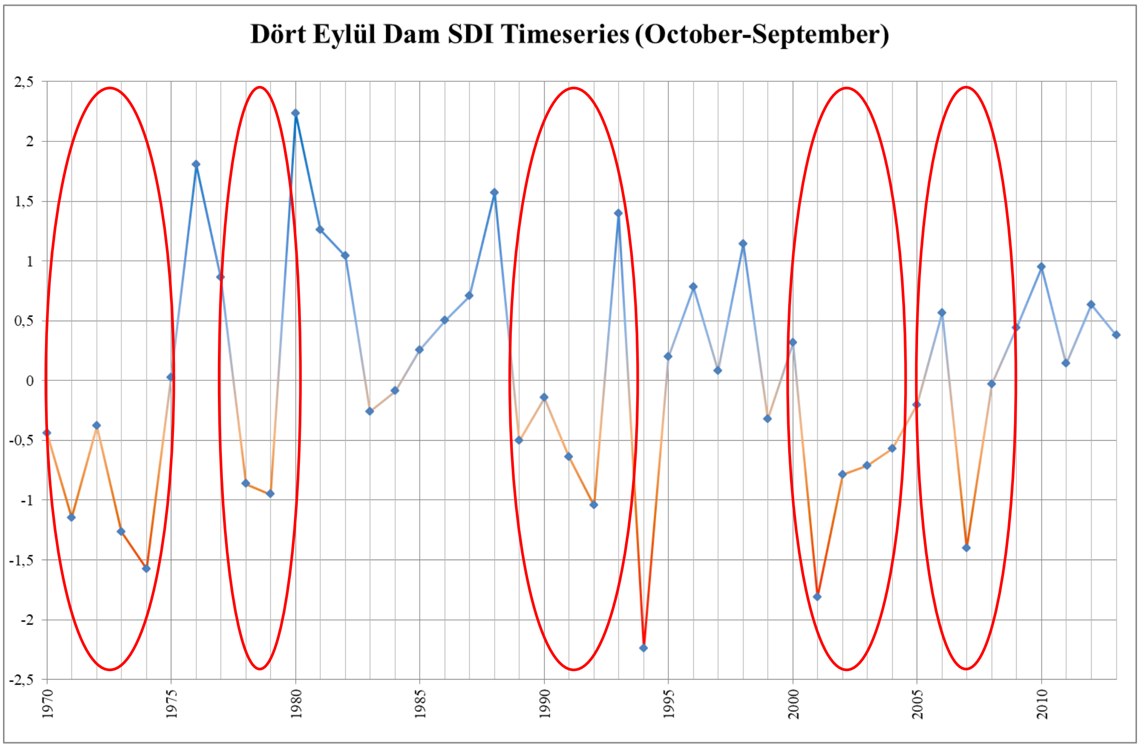


Figure 4.15. Dört Eylül Dam SDI monthly time series

4.5.5. Determination of Past Drought Periods

According to the results of hydrological drought indices 9- and 12-months PNI, 9- and 12-months SPI, PDSI, PHDI and 12-months SDI, long and severe droughts were determined in 1970-2013 reference period. These periods were assessed to four important drought periods. The selection process is detailed below.

The severe drought periods 1970-1971 and 1972-1974 were determined by all drought indices. Although there is a short normal or close to normal period in 1972, SDI shows that the hydrological impacts of drought in 1970-1971 continued also in 1972. In addition, PHDI results show that the drought in 1972-1974 continued hydrologically in 1975 also. Therefore, 1970-1975 period was selected for further examination and this period is the most severe drought event in 1970-2013 reference period.

There is a long deficiency period in 2000-2004 which was detected by SDI. This period is partially verified by other drought indices. PHDI results also show that there is a severe drought period in 2000-2002. Although there is a wet period in 2003-2004 detected by PHDI, the results of SDI imply that hydrological impacts persisted in 2003-2004 period also. The entire period of 2000-2004 was selected for further examination.

In addition to the drought period in 2000-2004, a new hydrological drought event is detected in 2007-2009 period with PHDI. Hydrological deficiencies are also detected at the beginning of 2009 with SDI even if there is wet period in the first months. Nevertheless, the entire period of 2006-2009 has been selected for further evaluation.

Lastly, a long drought has been detected by SDI in 1989-1992 period. This drought event is partially detected by other drought indices for 1989. However, no other drought index shows a severe drought in this period. Even though there is no certain detection of a drought event in this period, 1989-1992 period was also selected for further evaluation because of the duration of the hydrologic deficiencies detected by SDI.

The drought event in 1977-1978 was also evaluated, however, none of the drought indices show that there is a drought in this period. Considering the duration of the period being short, this period was not selected for evaluation. The drought in 1994 is also a significant drought which is detected by many drought indices, however the duration of the drought is short. Therefore, the drought event in 1994 was not selected for evaluation.

In the end, four drought periods were selected for evaluation in impact assessment. Selected drought events are given in Table 4.12 in chronological order.

Table 4.12. *List of selected past drought events and detection sheet*

No	**Drought Period**	**Detection by Drought Index**			
		SPI	**PDSI**	**PHDI**	**SDI**
1	1970-1975	√	√	√	√
2	1989-1992				√
3	2000-2004	√	√	√	√
4	2006-2009		√	√	√

The inflow data from determined drought periods were isolated and used as additional deficit scenarios in the operation model. The isolated period was moved to the beginning of the operation scenario year to ensure consistency with hypothetical scenarios. After the drought period ends, inflows continue as average value. In Figure 4.16 isolated 2000-2004 drought period for Dört Eylül Dam inflows is given as an example.

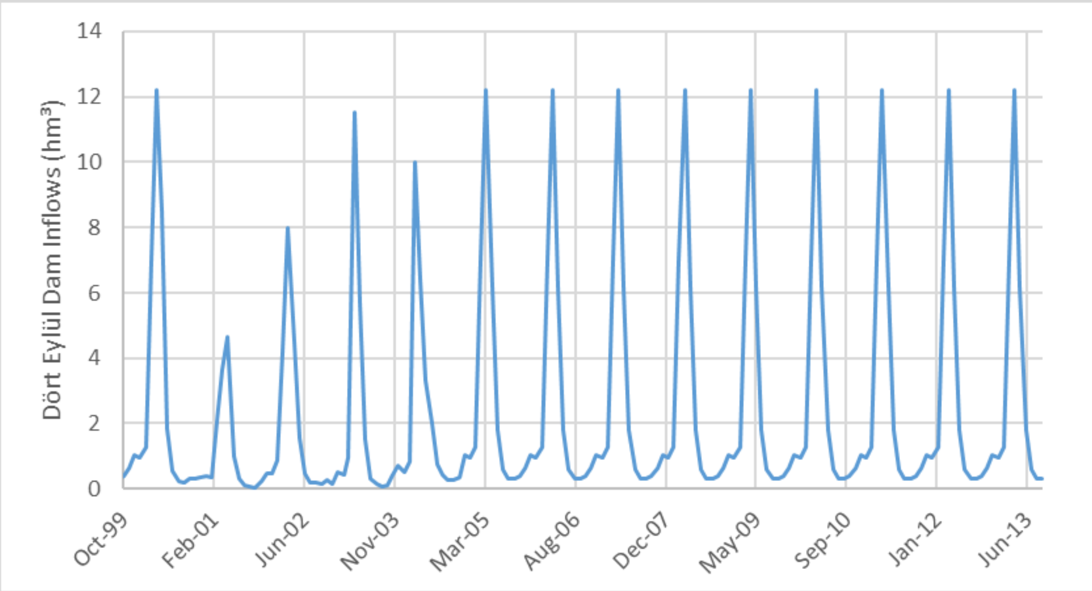


Figure 4.16. Isolated 2000-2004 dry period for Dört Eylül Dam reservoir inflows

4.6. Operation Model

In the case study, for probabilistic deficiency analyses, different scenarios were developed in WEAP software.

There are six different return period levels used in this study (2-, 5-, 10-, 25-, 50- and 100-years). Grouped under two base scenarios (existing and upstream development conditions), there are twelve different probabilistic scenarios in this study. Climate change modifications have been examined under another group of scenarios; therefore, the count of the probabilistic scenarios is doubled (i.e. 24 scenarios).

For comparison with the probabilistic scenarios, four historical drought events (1970-1975, 1989-1991, 2000-2004 and 2006-2009) were developed as different scenarios for both existing and upstream development cases. There are in total of 8 scenarios which use historical drought periods. Additionally, there are two base scenarios which include historical data completely to check if the operation model is performing well.

Consequently, there are 34 scenarios (24 probabilistic and 10 past observation data-based scenarios) developed for this study.

In the operation model, a manual deficit irrigation scheme definition has been developed for Pusat-Özen irrigation area. Deficit irrigation rules and regulations currently being used by State Hydraulic Works (DSİ) (Yavuz, 2011) were utilized for developing different deficit irrigation schemes. These rules include the items below:

- 65% of the irrigation demand must be covered in the most critical year.
- In the entire observation period, the demand must be fully covered for 50% of the time.
- Deficit irrigation can last 5 consecutive years at most.
- In the most critical consecutive 5 years, at least 75% of the total demand must be covered.
- In the entire observation period, 95% of the demand must be covered.

Existing Conditions Case

For the existing conditions case scenario, the operation model has been developed by the study area characteristics for existing case given in Chapter 3 (in Table 3.2). The WEAP model schematic is given in Figure 4.17.

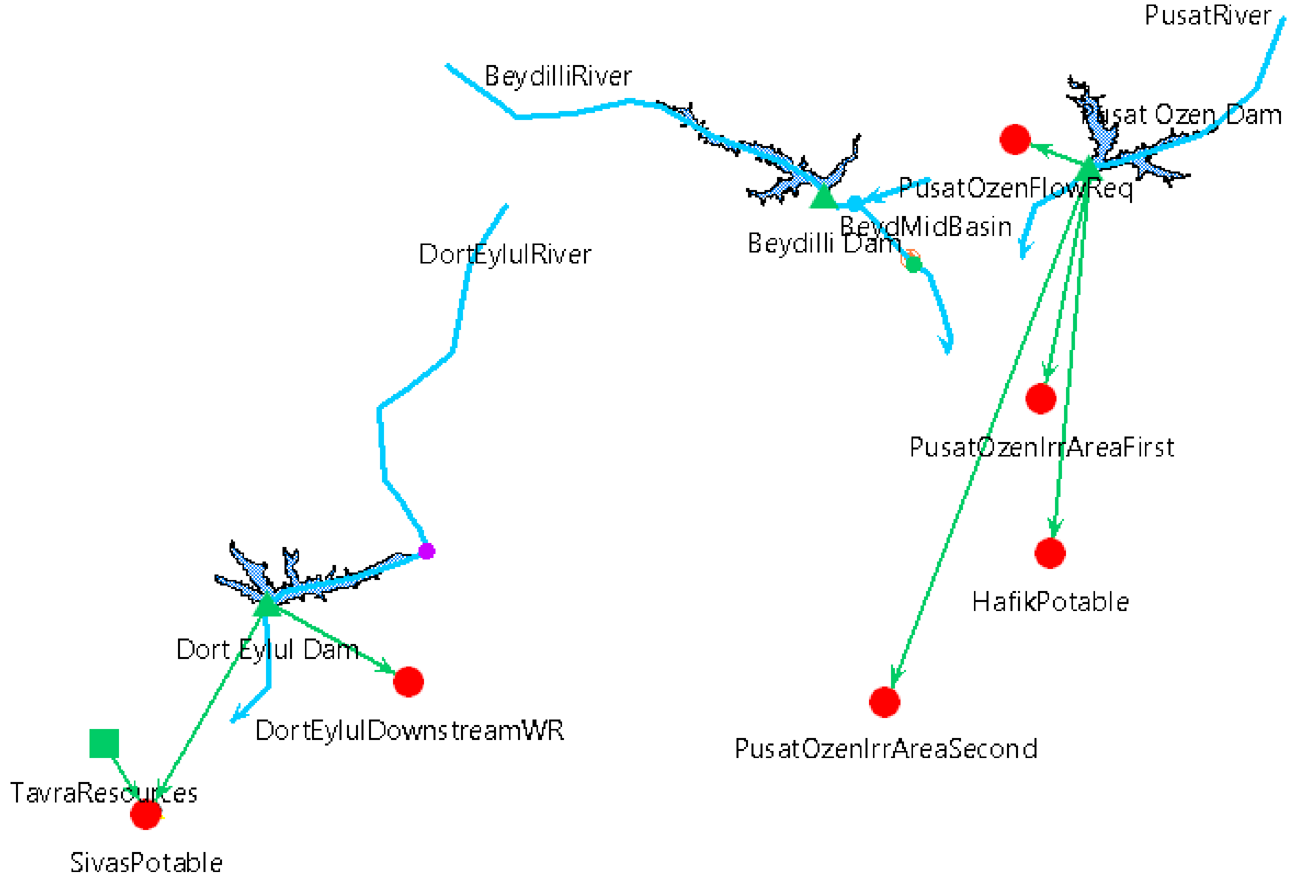


Figure 4.17. WEAP model schematic for the existing case scenarios

The remarks and model assumptions for the existing conditions in addition to the characteristics given in Section 3.3 are given below:

1) Pusat-Özen Dam priorities are municipal water supply to Hafik District (1), environmental flow (2) and irrigation (3). This means if the storage cannot satisfy all the demands, the model will give water in this priority order.
2) Priorities of Dört Eylül Dam are municipal water supply to Sivas Province (1) and downstream water rights (2), respectively.
3) In addition to Dört Eylül Dam, Sivas Province has another municipal water resource, which is Tavra Valley groundwater resource. In the model formulation, this source kept as an emergency source (i.e. secondary). In case Dört Eylül Dam is not enough to cover the demand when the reservoir level reaches to minimum, municipal water will be taken from Tavra Resources. The secondary resource kept for recharge if there is no deficit.
4) Existing conditions case reference period is 1970-2013 in water years (i.e. October to September). The base case uses real observation data between 1970-2013. However, the model starts for calculation in 1969 water year (named as year zero). Year zero is the same for all 34 scenarios and not included in any of the assessments. In year zero, all reservoir levels kept at the normal water level and in the year one (1970 water year) all reservoirs started at normal water level (i.e. full).
5) There is no upstream water use in the upstream of any hydraulic structure in the case study other than the structures stated in the characteristics in Chapter 3.

Upstream Development Conditions Case

For the upstream development conditions case scenario, the WEAP model schematic is given in Figure 4.18. The scenario consists of future conditions. All four hydraulic structures will be available in the future, which will be Pusat-Özen, Beydilli and Dört Eylül Dams, and Beydilli Diversion Weir.

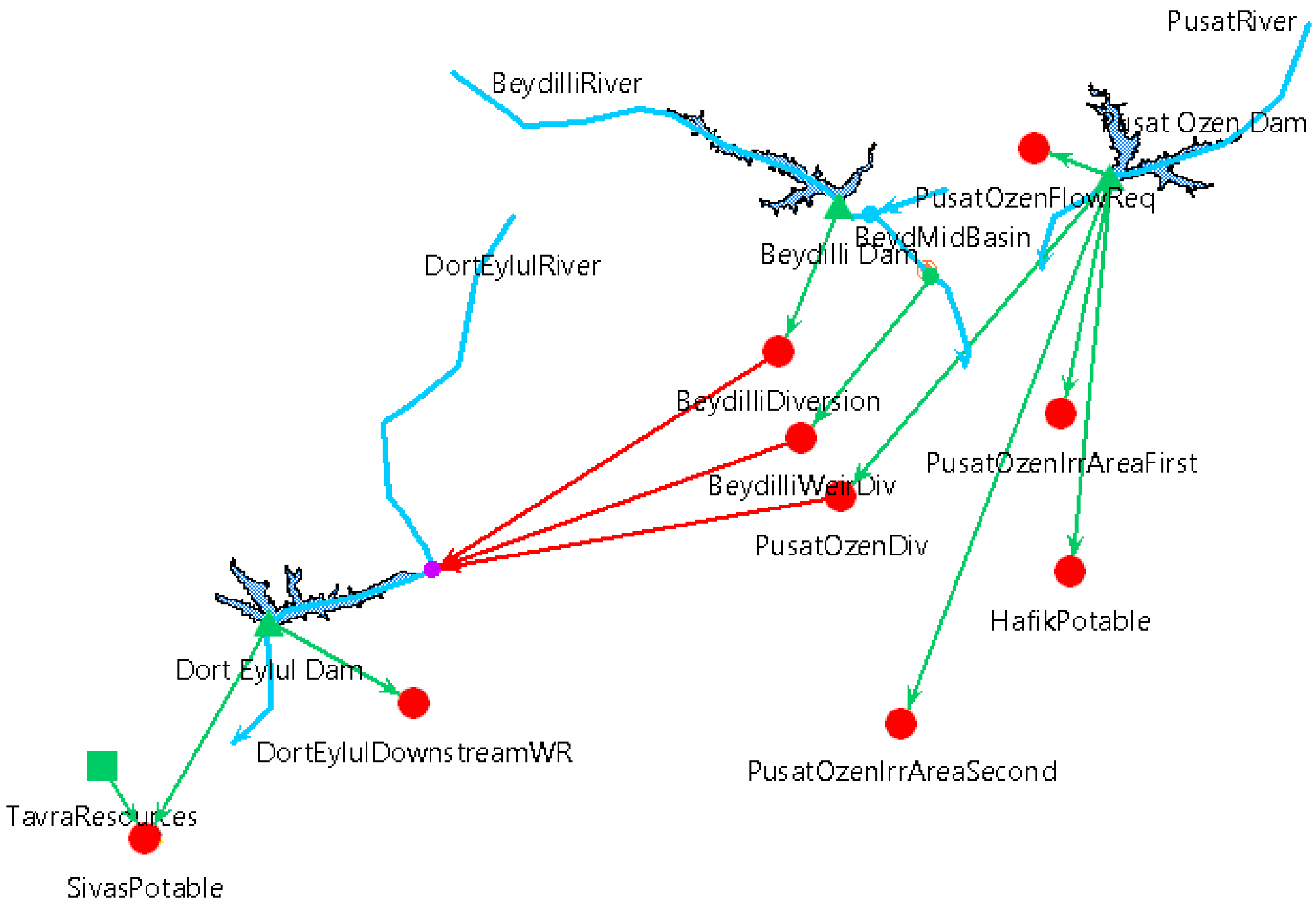


Figure 4.18. WEAP model schematic for the upstream development case scenarios

The remarks and model assumptions for the upstream development conditions in addition to the characteristics given in Section 3.3 are given below:

1) The upstream development base case consists of 1970-2013 water years and observed inflow data with future water uses and diversions.
2) Beydilli Dam and Beydilli Weir have become operational in this scenario. Both structures have only one purpose; to supply municipal water to Sivas Province Center (47 and 4 hm^3/year, respectively).
3) In addition to the purposes in the existing case, Pusat-Özen Dam also supplies municipal water (8.42 hm^3/year) to Sivas District by diverting the water to the upstream of Beydilli Weir.
4) Pusat-Özen Dam priorities are municipal water supply to Hafik District (1), environmental flow (2) and irrigation (3).
5) Pusat Özen Dam's water supply priority which diverts municipal water to Sivas Province is selected as (4). Even if the purpose is municipal water supply, Pusat-Özen Dam's own demand is also important. There are many alternatives for municipal water supply to Sivas Province. However, without Pusat-Özen Dam, Hafik District has no municipal water resource and irrigation areas cannot be irrigated.
6) Deficit irrigation scheme is used for Pusat-Özen Dam irrigation in the upstream development scenario.
7) In the upstream development scenarios, Beydilli Weir collects the water from Pusat-Özen Dam, Beydilli Dam and mid-basin of Beydilli Weir and diverted to Dört Eylül Dam reservoir. In the model schematic, this system has been divided into three separate conveyance lines; which is not the real case. Purpose of this approach is to easily detect and control the amount of water diverted from a specific reservoir.

4.7. Results of Operation Scenarios

In this section, the results of 25- and 100-years existing, upstream development and climate change upstream development operation scenarios are given. This section also includes the results of 1970-1975 dry period which is determined as the most severe drought event in the observation period (Table 4.12).

The aim of the model is to satisfy allocated municipal water demands of Sivas and Hafik, Pusat-Özen irrigation demand and environmental flow demands. However, it is important to state that the allocated municipal water amount is much more than the real municipal water demands. Both allocated and real municipal water demands (for 2014 and 2050) taken from Kızılırmak Basin Master Plan Final Report (DSİ, 2019) are given in the study area characteristics which are shown by Table 3.2 and Table *3.3*.

4.7.1. Dry Period 1970-1975

Existing Case

The dry period in 1970-1975 is the most severe drought in the hydrological reference period (1970-2013). There is no unmet demand in the existing case 1970-1975 isolated drought. Therefore, if a dry period such as 1970-1975 reoccurs, there will be no problem regarding drought impacts. In Figure 4.19, supply-demand graph for all demand sites is given. Additionally, reservoir levels of Dört Eylül and Pusat Özen Dam do not drop to minimum level in the entire simulation period (Figure 4.20).

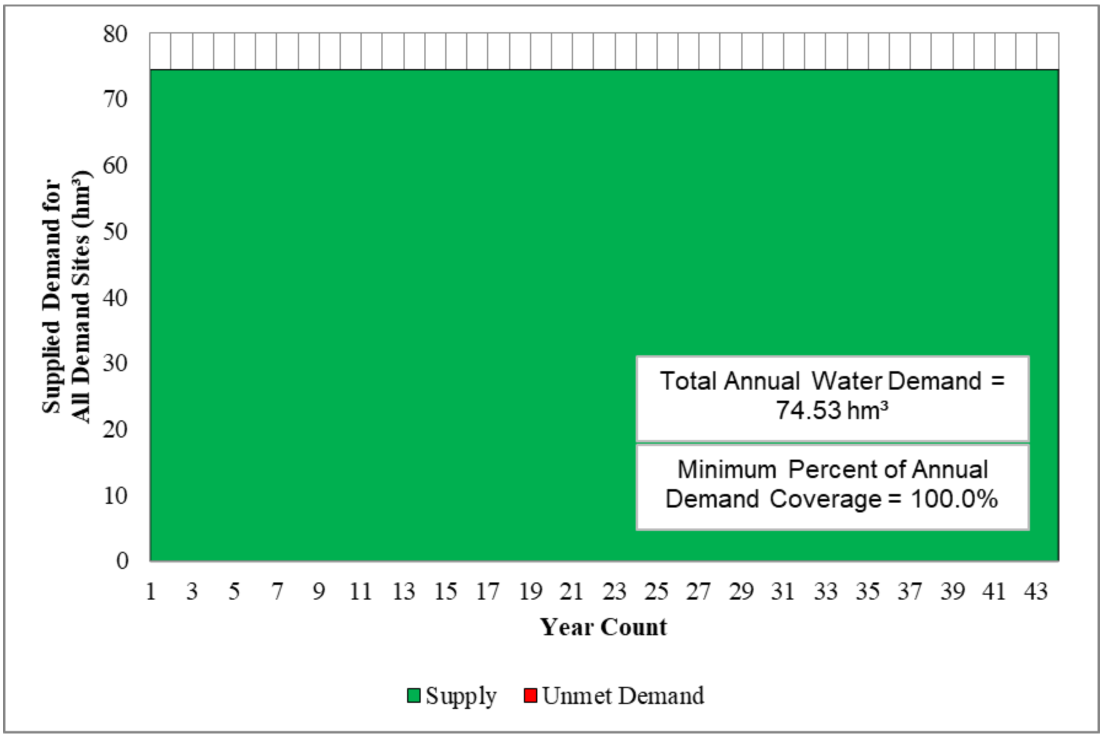


Figure 4.19. Supply-demand graph of for existing case, 1970-1975 dry period

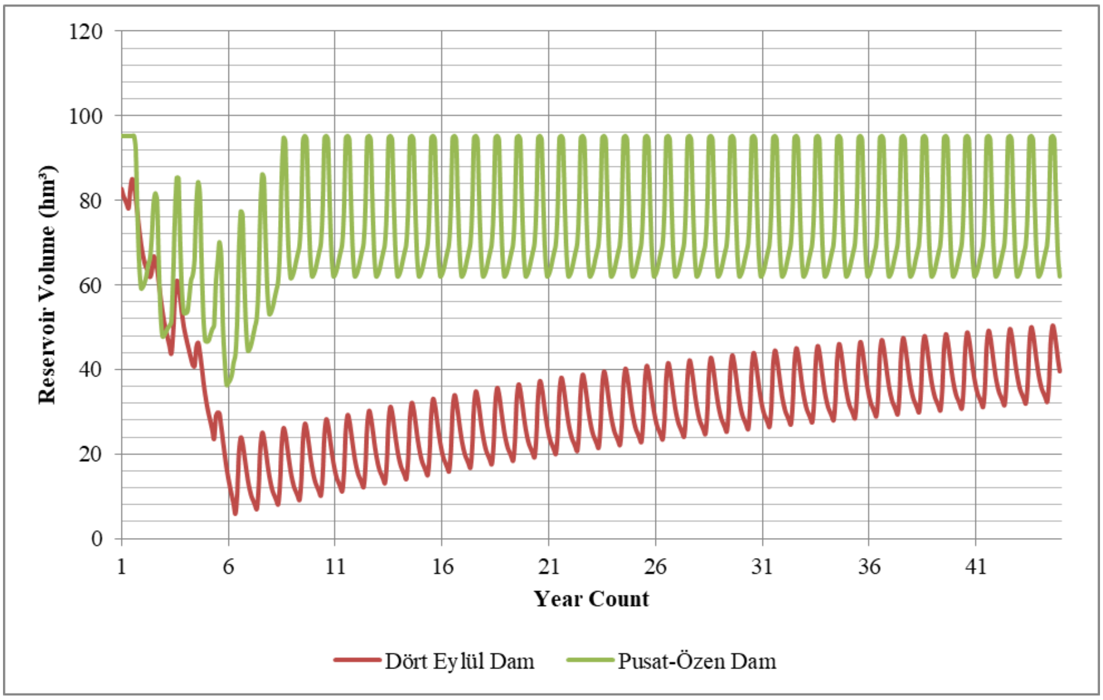


Figure 4.20. Reservoir storage volumes of Dört Eylül and Pusat-Özen Dams for existing case, 1970-1975 dry period

Upstream Development Case

Impacts of a drought occurred in 1970-1975 for the upstream development case is worse than the existing case. Both Dört Eylül Dam and Pusat Özen Dam drops to minimum and Dört Eylül Dam cannot mitigate this drought without the support of Tavra Resources. In Figure 4.21, it is shown that Dört Eylül Dam cannot refill after the deficit and the recovery of Pusat-Özen Dam is much longer when compared to the existing case.

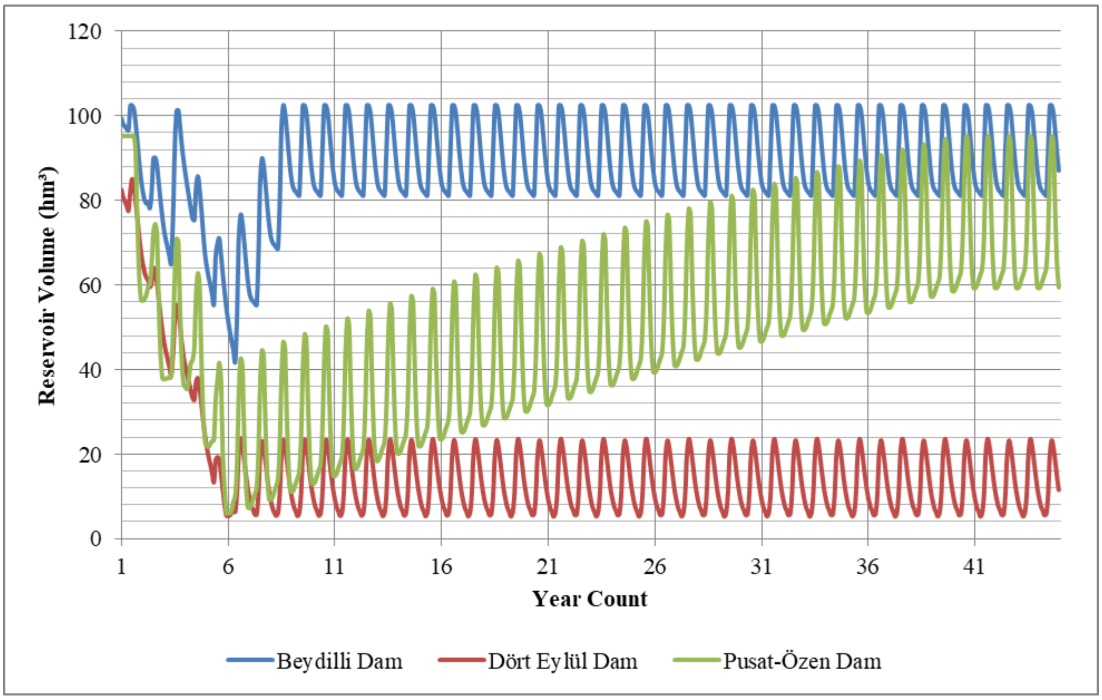


Figure 4.21. Reservoir storage volumes of Dört Eylül, Pusat-Özen and Beydilli Dams for upstream development case, 1970-1975 dry period

As Dört Eylül Dam reservoir level drops to minimum, secondary Tavra Groundwater Resources are used in order to supply municipal water to Sivas Province. Reservoir level of Dört Eylül Dam does not go higher in the simulation period and drops to minimum once in a year, therefore Tavra Resources are constantly used until the end of simulation. Tavra Resources water use amounts are given in Figure 4.22.

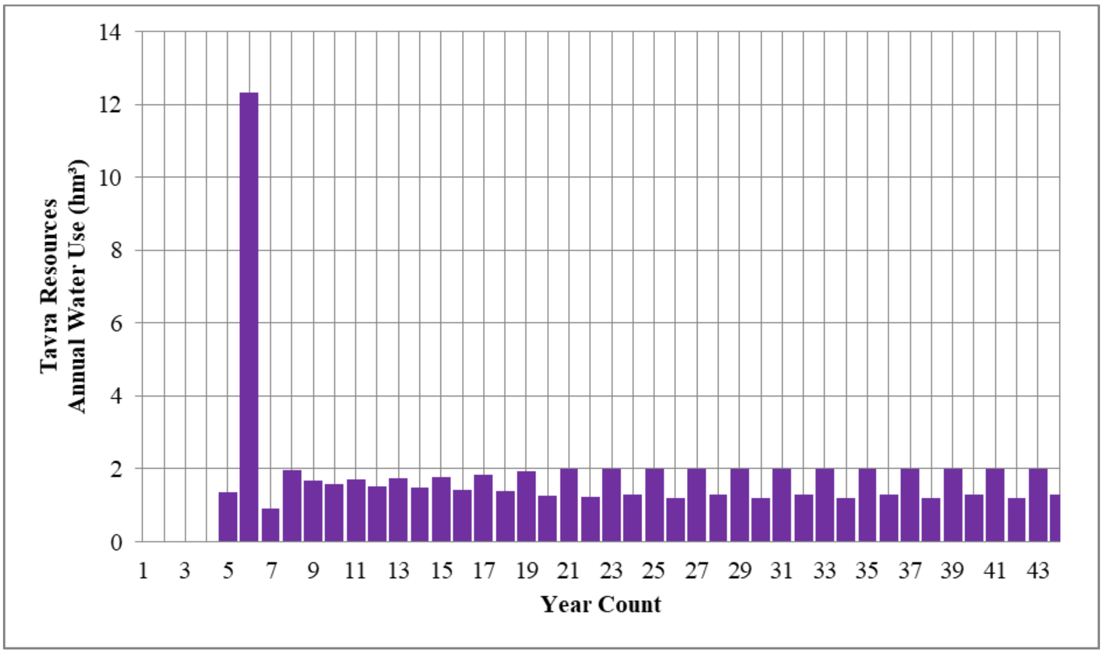


Figure 4.22. Tavra Resources annual water use amount for upstream development case, 1970-1975 dry period

Even though Dört Eylül Dam reservoir levels drop to minimum and secondary Tavra Resources are required for supplying municipal water to Sivas Province, there is no unmet demand in the system. Supply-demand graph of all demand sites are given in Figure 4.23.

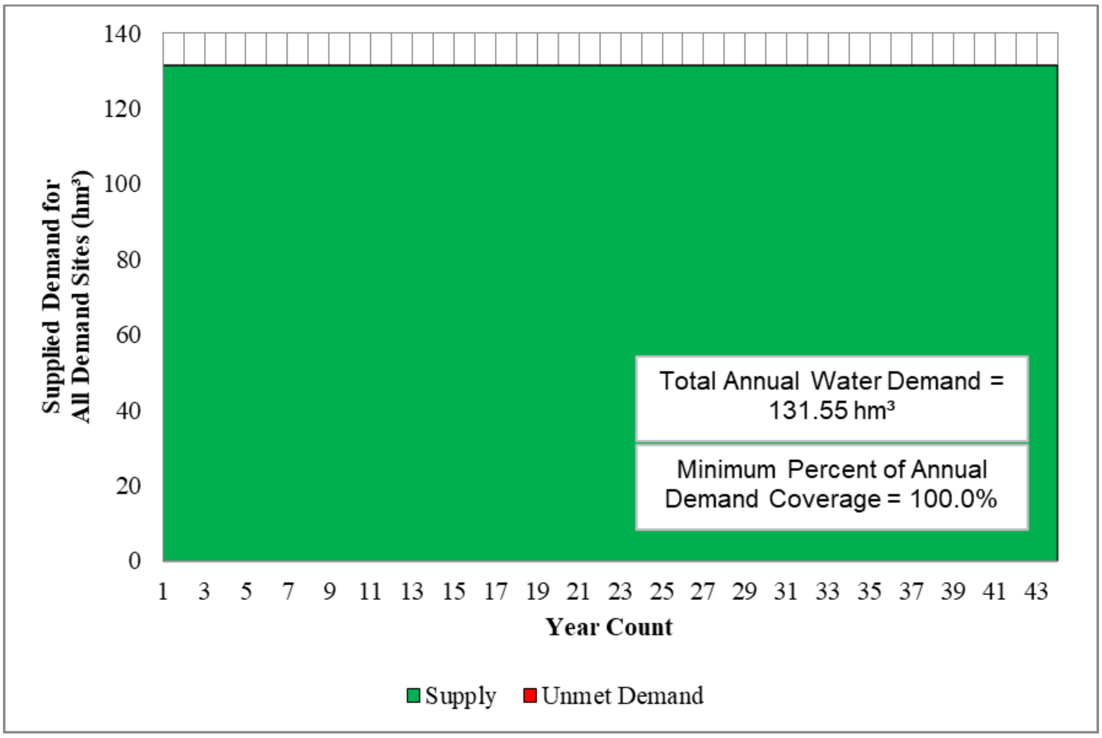


Figure 4.23. Supply-demand graph for upstream development case, 1970-1975 dry period

4.7.2. 25-Years Return Period Scenario

Existing Case

25-years return period deficit event is a very rare event. It is determined that the most severe drought event in the last 50 years (which is 1970-1975 drought event) is not severe as a 25-years return period deficit event.

For the existing case, 25-years return period deficit without climate change modification, reservoir levels of Dört Eylül Dam drops to minimum. However, Pusat-Özen Dam has no problem regarding to supplying the demand and after the deficit period ends, reservoir levels of Pusat-Özen Dam returns to normal (Figure 4.24).

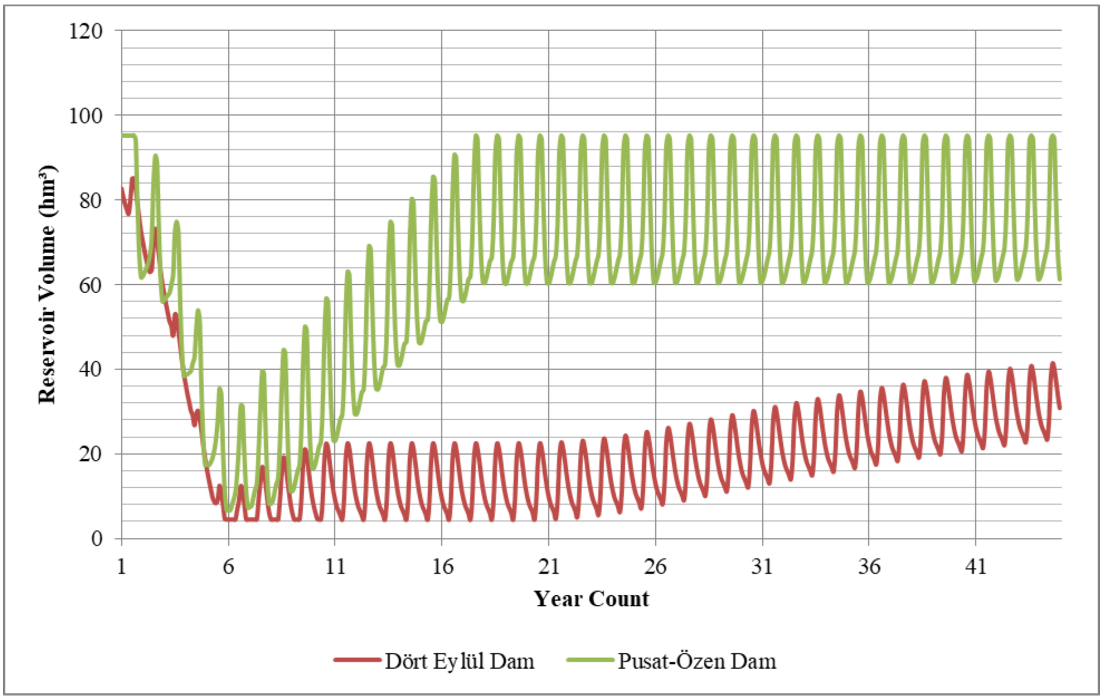


Figure 4.24. Reservoir storage volumes of Dört Eylül and Pusat-Özen Dams for existing case, 25-years return period without climate change modification

For Pusat-Özen Dam Irrigation, a deficit irrigation scheme is used in order to satisfy the irrigation demand along with the municipal water demand of Hafik District. By using the deficit irrigation, unmet demand amounts of Pusat-Özen irrigation areas are reduced to zero. Pusat-Özen reservoir refills after deficit period and there is no problem regarding Hafik District municipal water demand.

Dört Eylül Dam downstream water rights demand (public irrigation demands in the downstream) is not satisfied in September and October months of four consecutive years. The unmet demand amount of Dört Eylül downstream water rights is 0.122 hm^3.

The unmet demand amounts and supply-demand graph for all demand sites are given in Figure 4.25 and Figure 4.26, respectively.

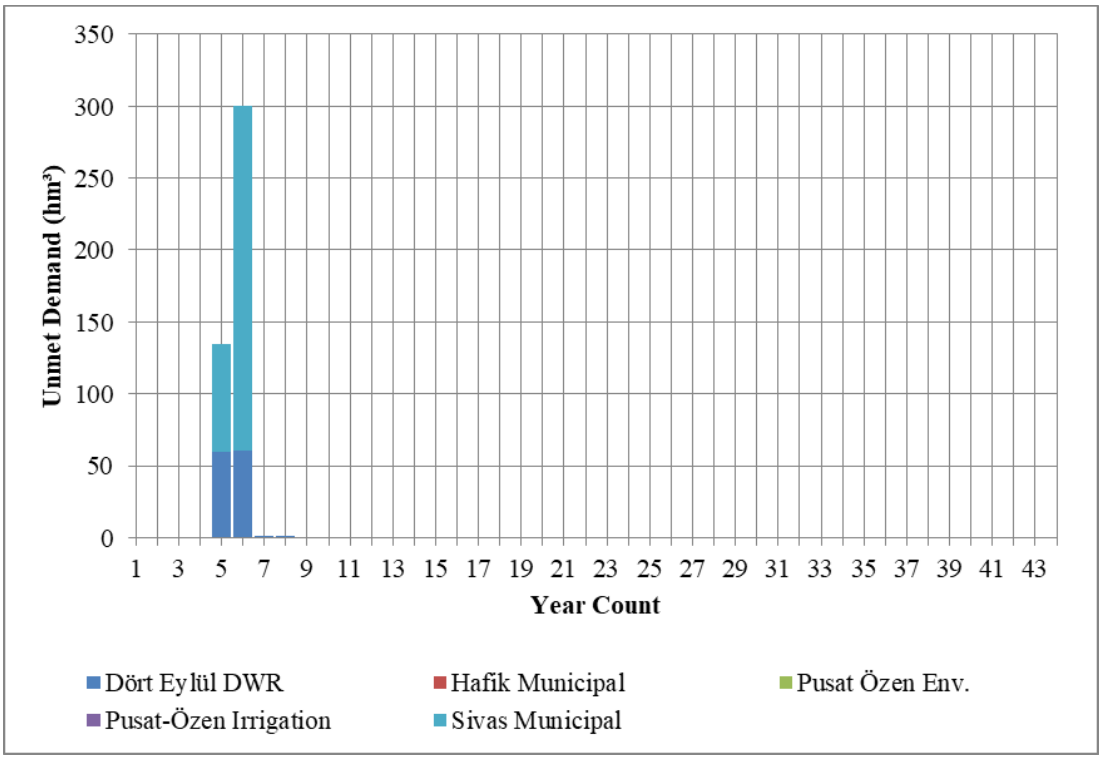


Figure 4.25. Unmet demand amounts for existing case, 25-years return period without climate change modification

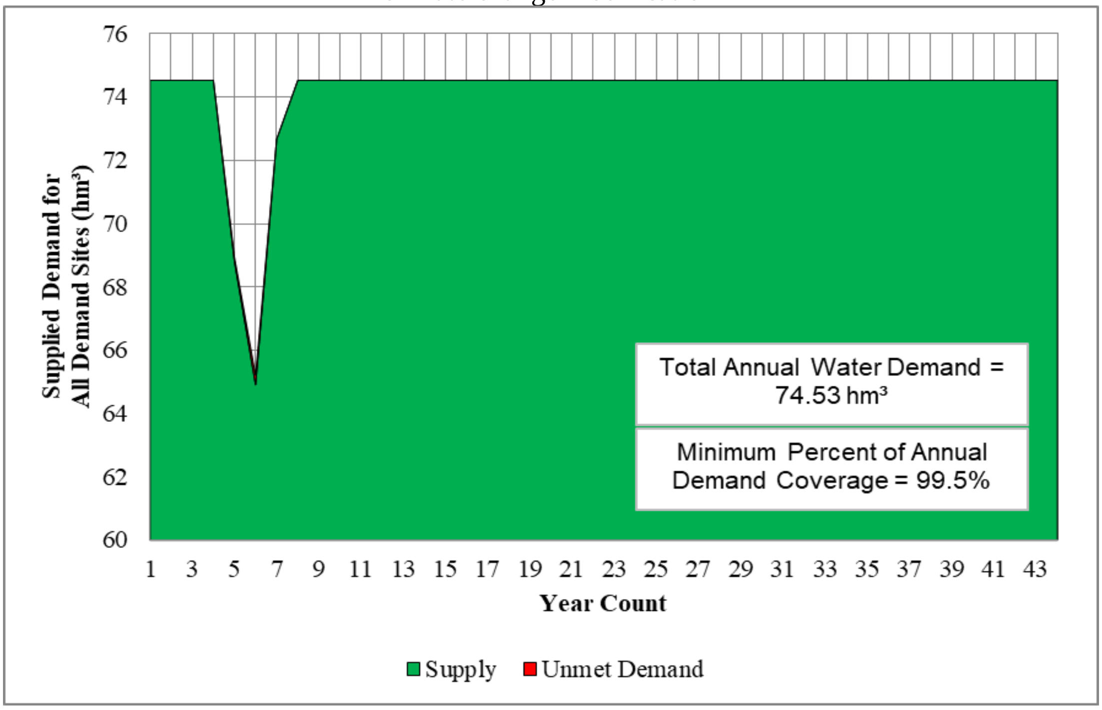


Figure 4.26. Supply-demand graph for existing case, 25-years return period without climate change modification

The decrease in water demand which is shown in Figure 4.26, caused by the deficit irrigation in Pusat-Özen Dam Irrigation. When deficit irrigation scheme is used, agricultural demand decreases in the deficit periods.

By itself, Dört Eylül Dam does not satisfy the allocated municipal water demand of Sivas Province Center. Tavra Resources are used in order to satisfy the remaining demand of Sivas Province. Yearly allocated water amount of Tavra Resources is enough to provide an additional 48.44 hm^3 for 16 years. However, in September month of the sixth dry year, Tavra Resources transmission line is reached its maximum capacity and it introduces 0.32 hm^3 unsatisfied demand for two years in total (Figure 4.27).

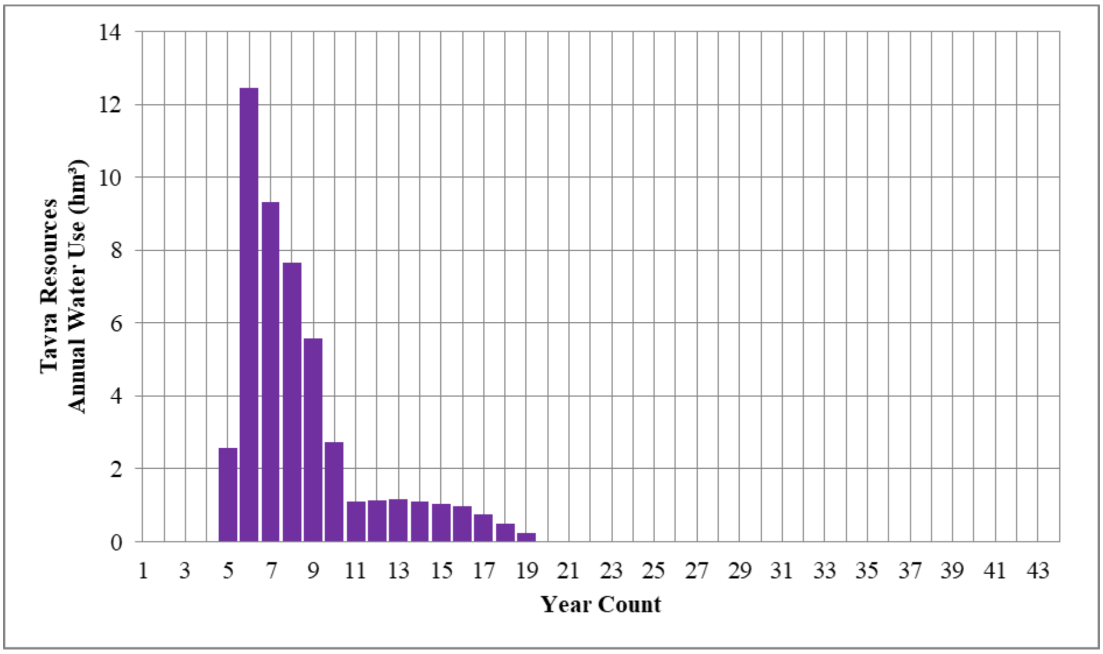


Figure 4.27. Tavra Resources annual water use amount for existing case, 25-years return period without climate change modification

Provided that Tavra Resources is not sufficient also, demand coverage of Sivas Province drops to 99.2% at the minimum level. Supply-demand graph of Sivas Province is given in Figure 4.28.

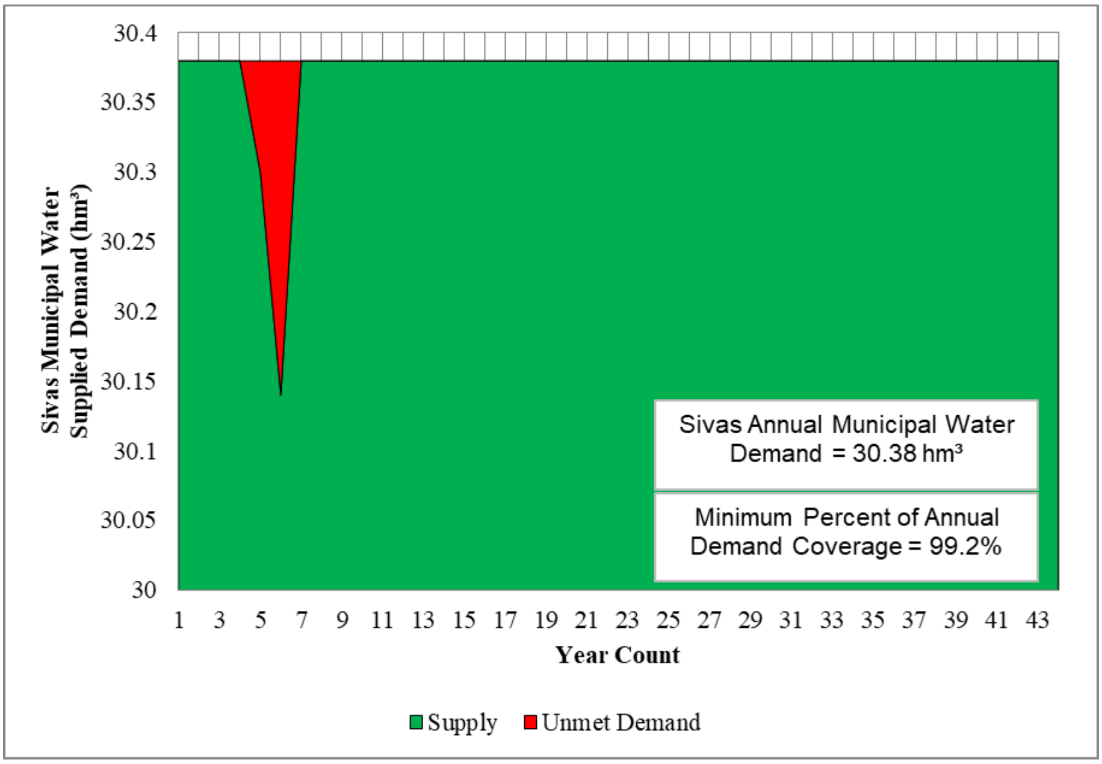


Figure 4.28. Supply-demand graph of Sivas municipal water demand for existing case, 25-years return period without climate change modification

Upstream Development Case

In 25-years return period upstream development case no climate change modified scenario, Pusat-Özen, Dört Eylül and Beydilli dam reservoir levels drop to minimum. After the deficit period ends, Dört Eylül Dam does not recover in the simulation period, whereas Pusat-Özen Dam slightly recover at the last 10 years of the simulation period. Beydilli Dam, on the other hand does not have a problem regarding to recovery after deficit period. Reservoir storage levels are given in Figure 4.29.

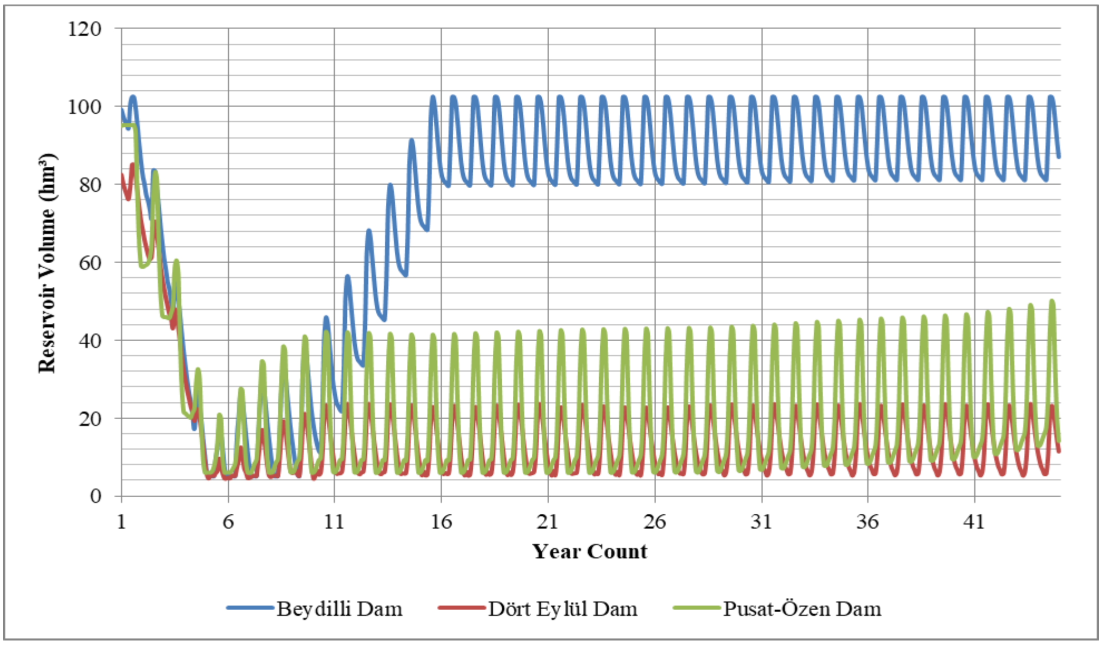


Figure 4.29. Reservoir storage volumes of Dört Eylül, Pusat-Özen and Beydilli Dams for upstream development case, 25-years return period without climate change modification

There is unmet demand for all demand sites; and Tavra Resources are not sufficient even though the source provides additional municipal water (174.42 hm³ for 40 years). Tavra Resources annual water use is given in Figure 4.30.

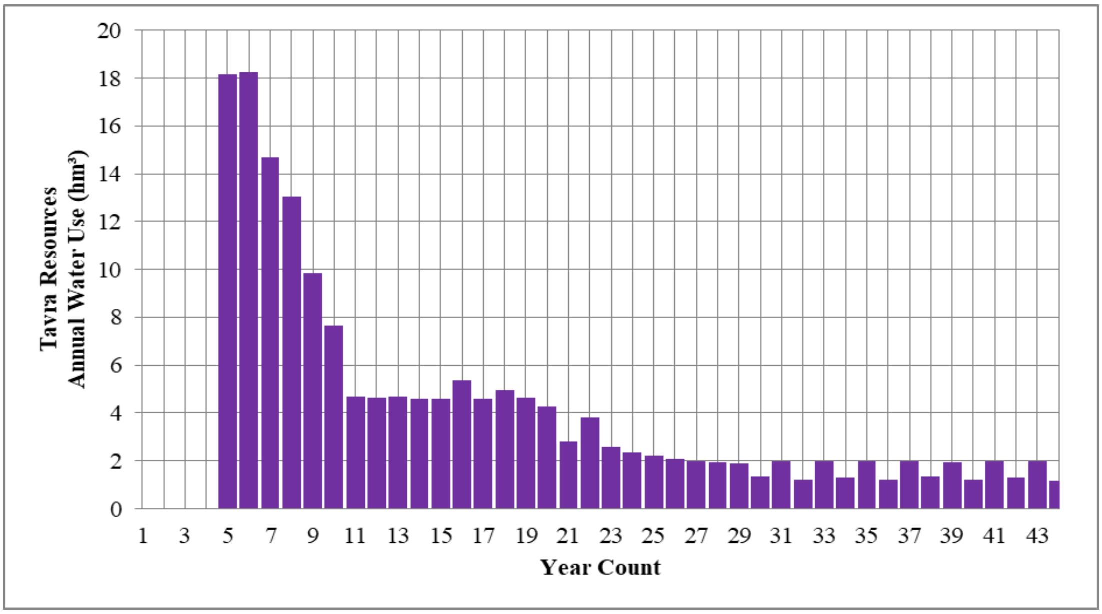


Figure 4.30. Tavra Resources annual water use amount for upstream development case, 25-years return period without climate change modification

Total unmet allocated demand amount of Sivas Province for no climate change scenario is 43.08 hm³ for 5 years. Minimum demand coverage drops to 81.6% for Sivas. Supply-demand graph of Sivas is given in Figure 4.31.

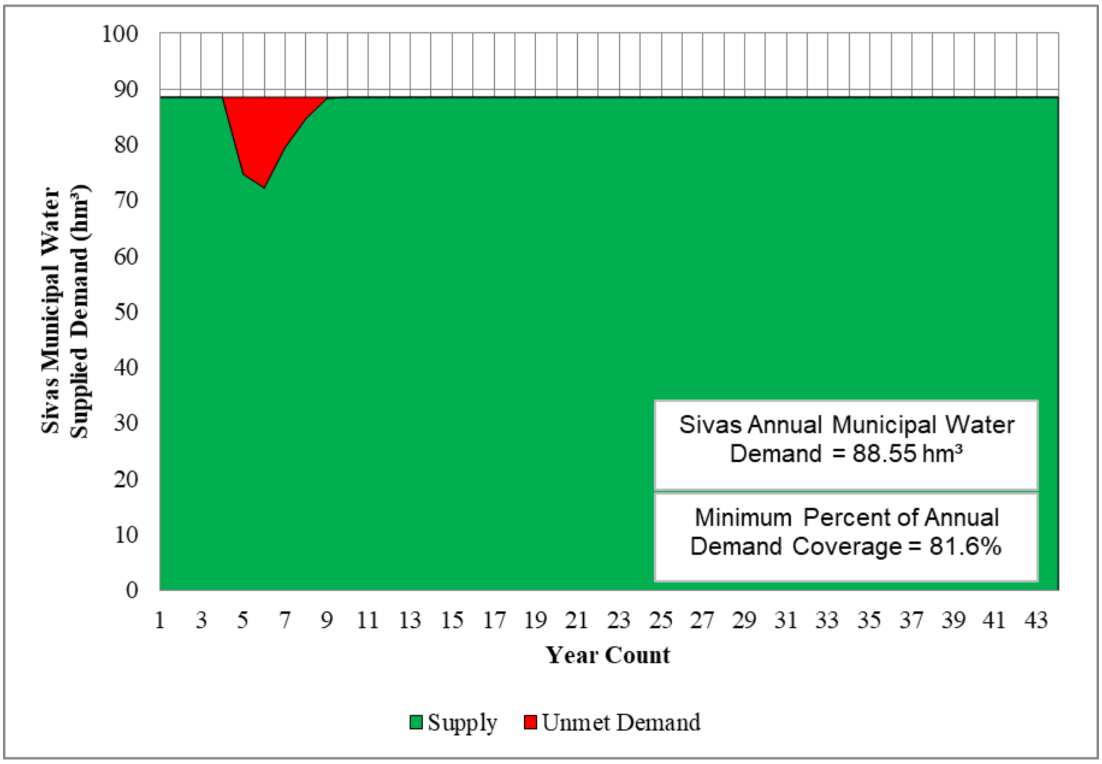


Figure 4.31. Supply-demand graph of Sivas for upstream development case, 25-years return period without climate change modification

Also, the allocated municipal water demand of Hafik District is unmet; the unmet demand amount is 0.08 hm³ for 2 years. Overall unmet demand amount is 55.43 hm³ which includes all demand sites. Unmet demand amounts and supply-demand graph for all demand sites are given in Figure 4.32 and Figure 4.33, respectively.

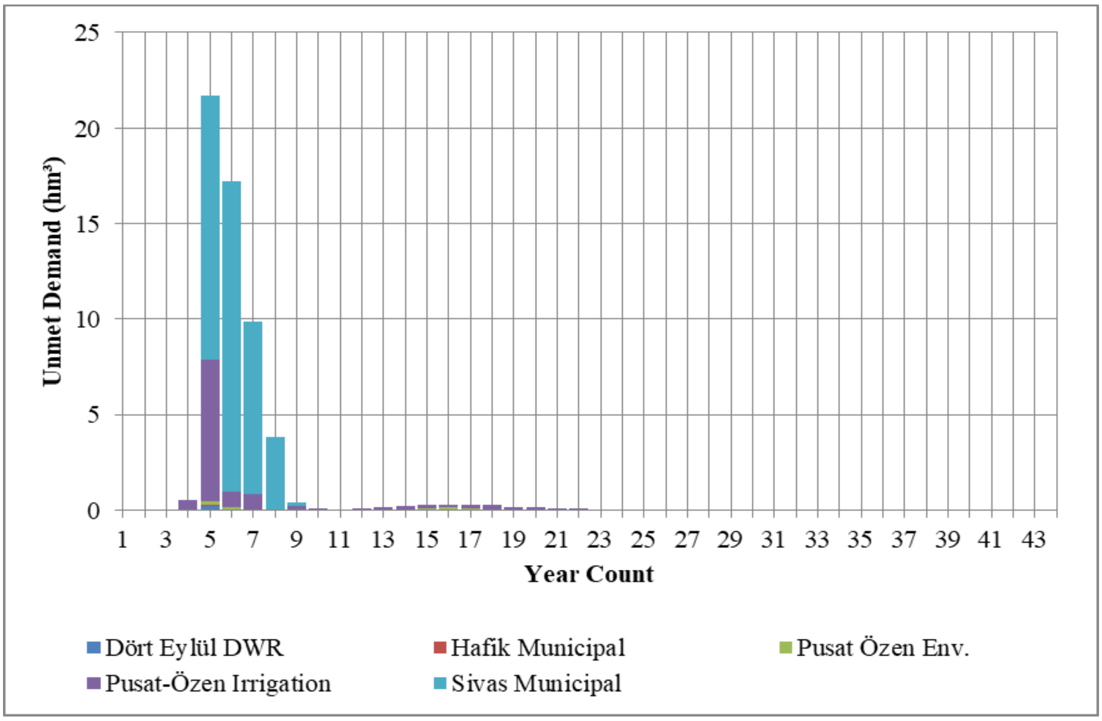


Figure 4.32. Unmet demand amounts for upstream development case, 25-years return period without climate change modification

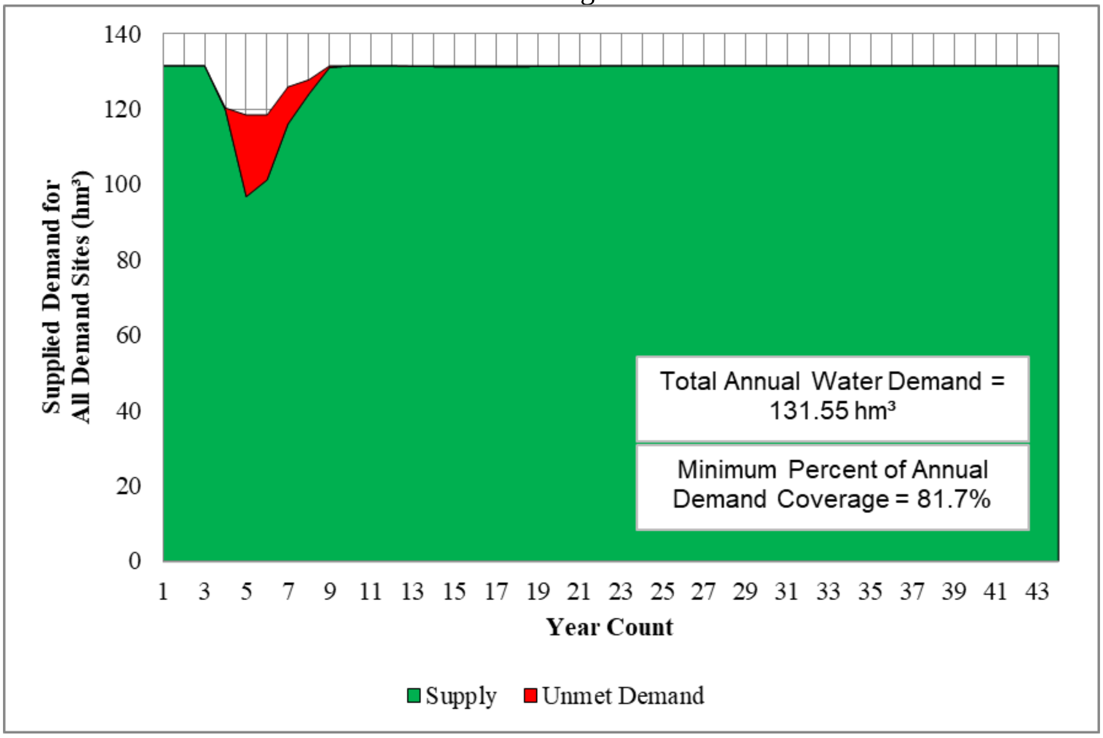


Figure 4.33. Supply-demand graph for upstream development case, 25-years return period without climate change modification

Climate Change Modified Upstream Development Case

In 25-years return period climate change modified scenario, all reservoir levels drop to minimum. Although the reservoir level variations of Pusat-Özen and Dört Eylül Dams are similar with no climate change scenario, Beydilli Dam reservoir level recover more slowly than the no climate change scenario (Figure 4.34).

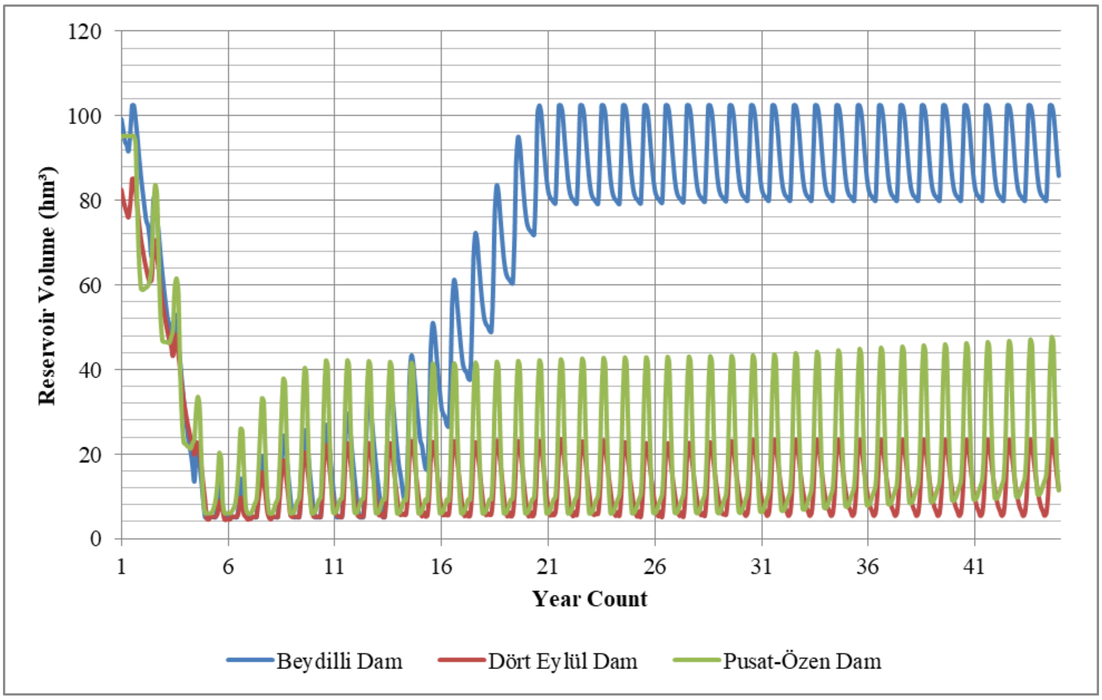


Figure 4.34. Reservoir storage volumes of Dört Eylül, Pusat-Özen and Beydilli Dams for upstream development case, 25-years return period witho climate change modification

There is unmet demand for all demand sites; and Tavra Resources are not sufficient even though the source provides additional municipal water (204.56 hm^3 for 40 years). Total unmet allocated demand amount of Sivas Province for climate change modified scenario is 94.51 hm^3 for 9 years. Annual water usage of Tavra Resources and supply-demand graph for Sivas are given in Figure 4.35 and Figure 4.36, respectively.

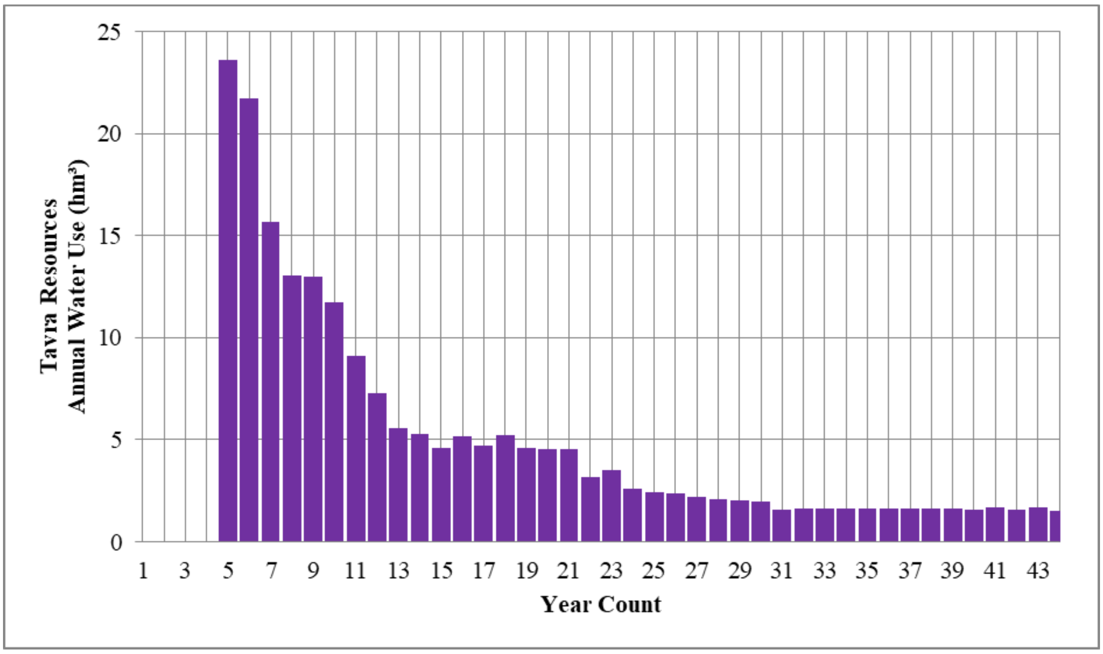


Figure 4.35. Tavra Resources annual water use amount for upstream development case, 25-years return period with climate change modification

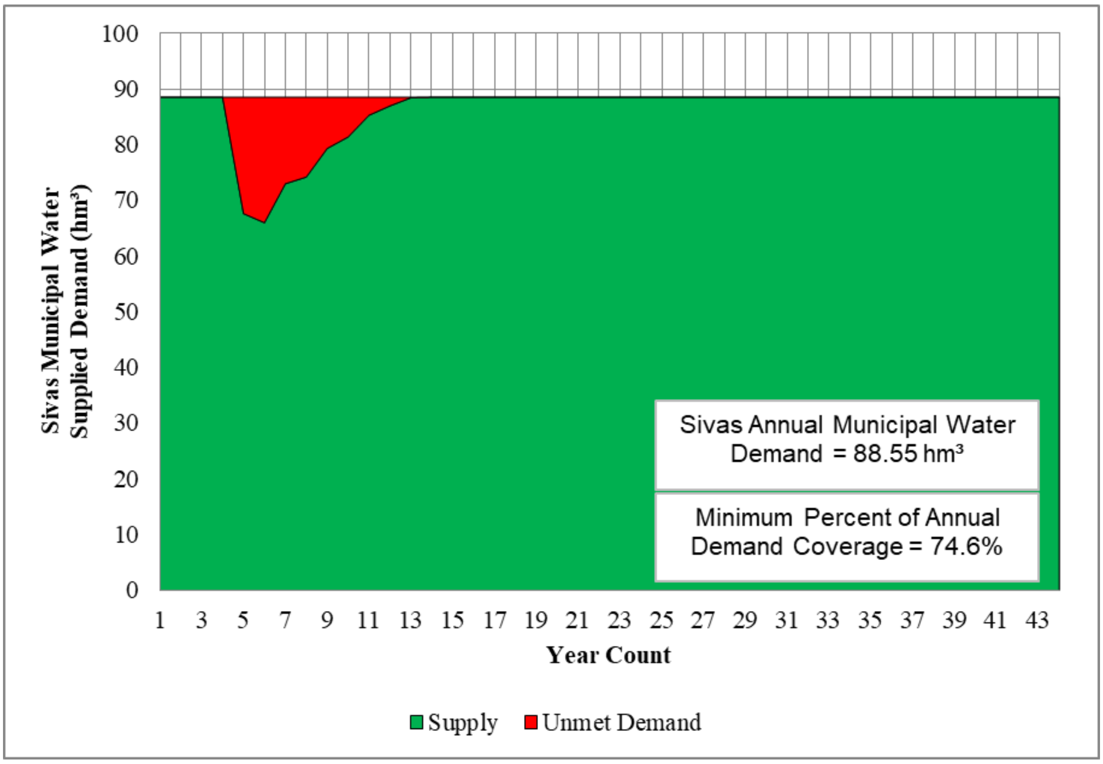


Figure 4.36. Supply-demand graph for upstream development case, 25-years return period with climate change modification

The allocated municipal water demand of Hafik District is unmet; the unmet demand amount is 0.16 hm³ for 3 years. Overall unmet demand amont is 108.85 hm³ which includes all demand sites. Unmet demand amounts and supply-demand graph for all demand sites are given in Figure 4.37 and Figure 4.38, respectively.

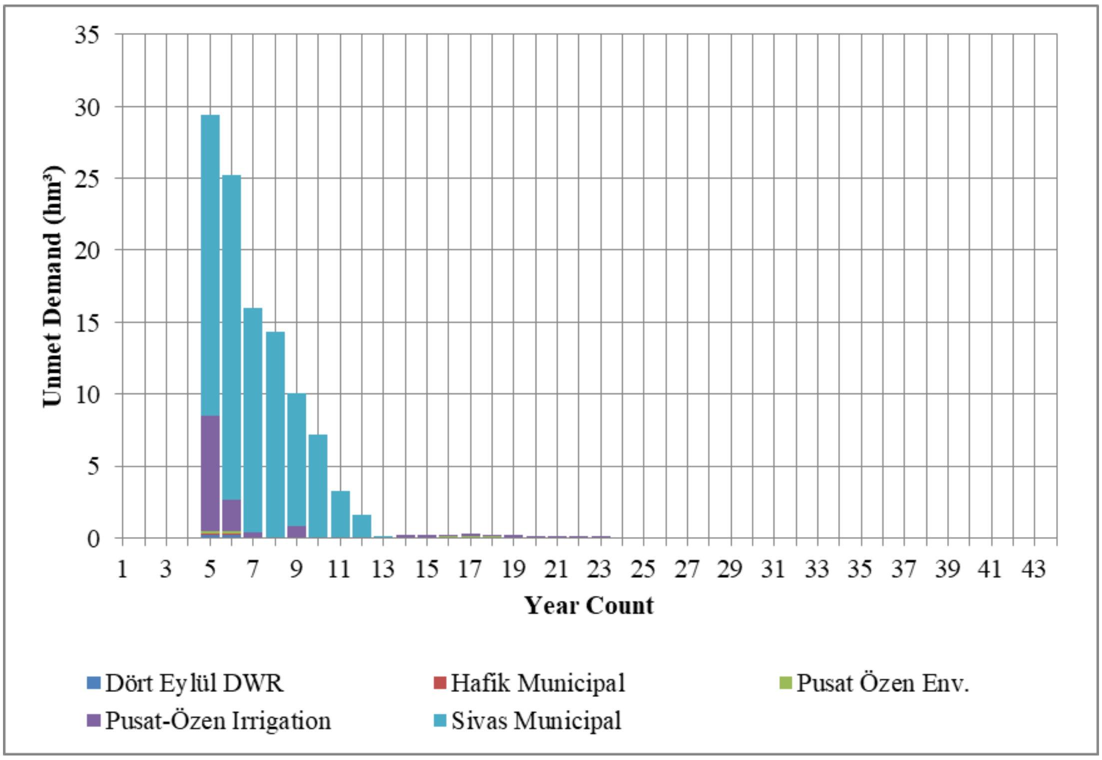


Figure 4.37. Unmet demand amounts for upstream development case, 25-years return period with climate change modification

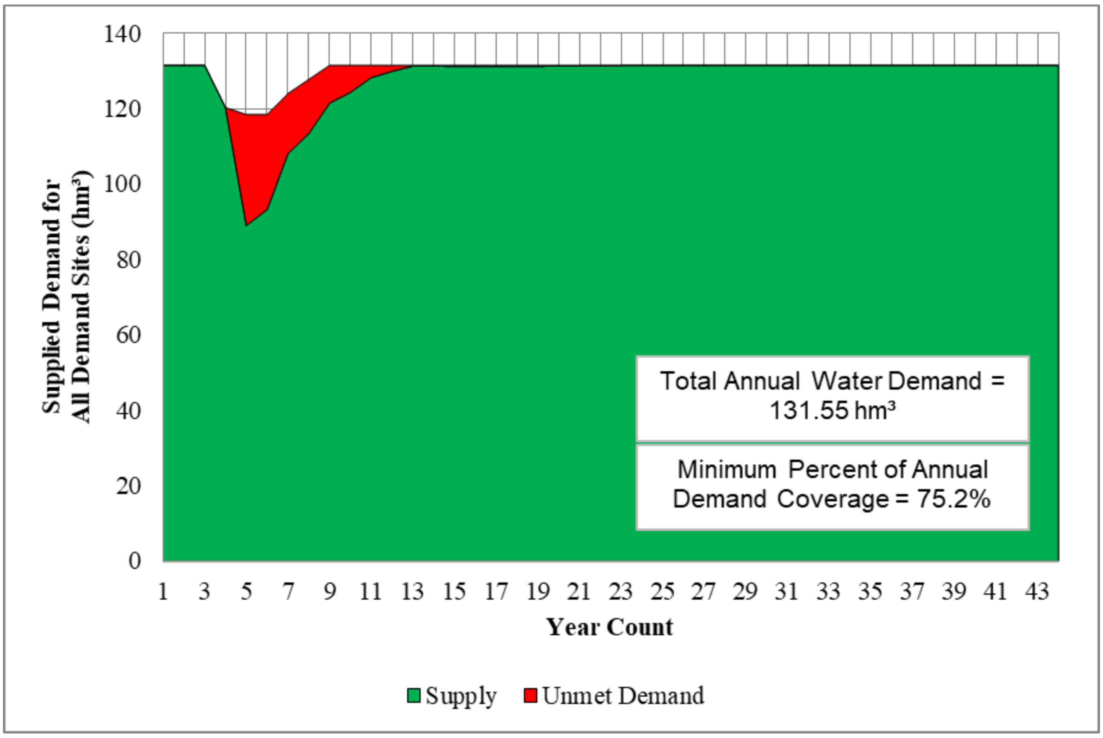


Figure 4.38. Supply-demand graph for upstream development case, 25-years return period with climate change modification

4.7.3. 100-Years Return Period Scenario

Existing Case

100-years return period is the catastrophic scenario. In the recorded observation period (1929-ongoing for Sivas meteorological observation station), a 100-years return period drought event has never occurred in the study area.

In an event of a catastrophic drought (or deficit) the main aim must be preserving the municipal water resources at all costs. The impacts of the drought event in this scenario last almost 20 years for Pusat-Özen Dam.

In the existing case scenario, which does not include climate change modification, both reservoir levels drop to minimum. Pusat-Özen Dam refills after drought, however without a wet period after the drought event, Dört Eylül Dam cannot mitigate the impacts of the drought by itself (Figure 4.39).

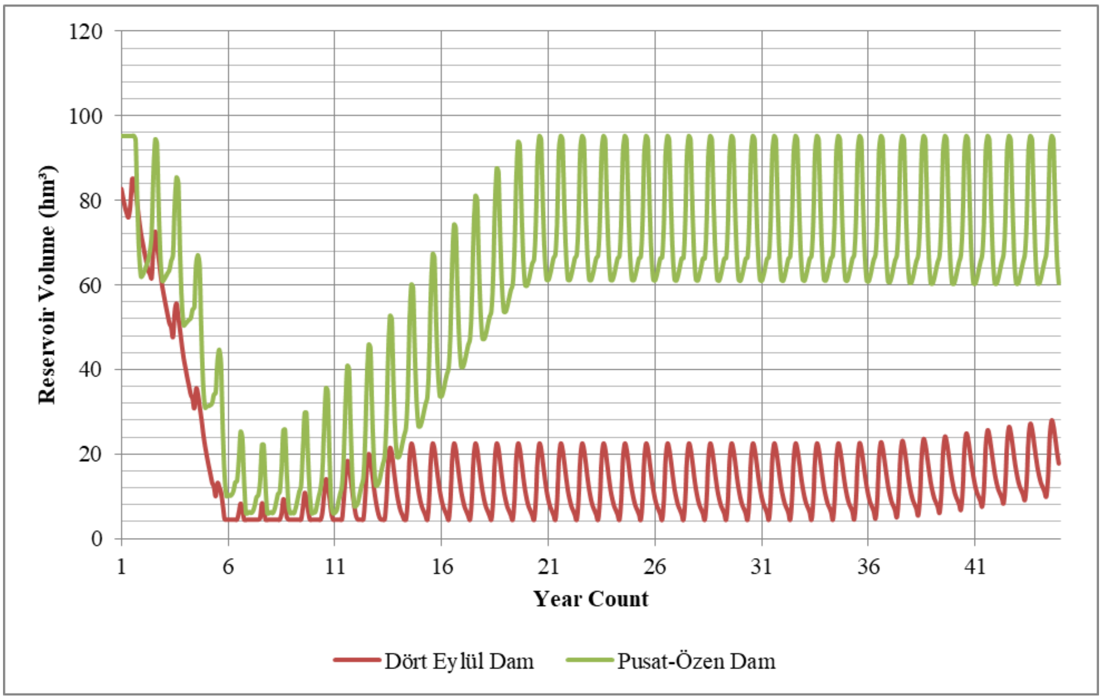


Figure 4.39. Reservoir storage volumes of Dört Eylül and Pusat-Özen Dams for existing case, 100-years return period without climate change modification

With the support of the secondary Tavra Resources, some of the Sivas Province demand can be satisfied after Dört Eylül Dam reservoir level reaches minimum. However, Tavra Resources transmission line reaches maximum capacity and even though Tavra Resources provide an additional 110.52 hm^3 municipal water in total for 30 years, Sivas Province allocated municipal water unmet demand amount is 2.00 hm^3 in total for five years. Annual water usage of Tavra Resources and supply-demand graph for Sivas are given in Figure 4.40 and Figure 4.41, respectively.

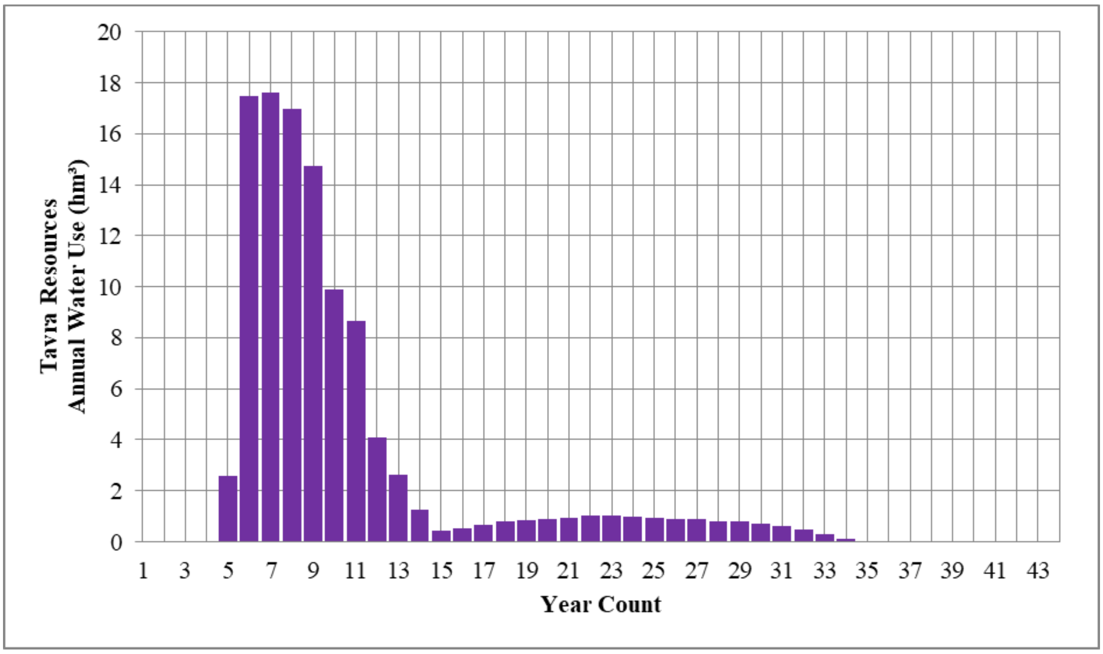


Figure 4.40. Tavra Resources annual water use amount for existing case, 100-years return period without climate change modification

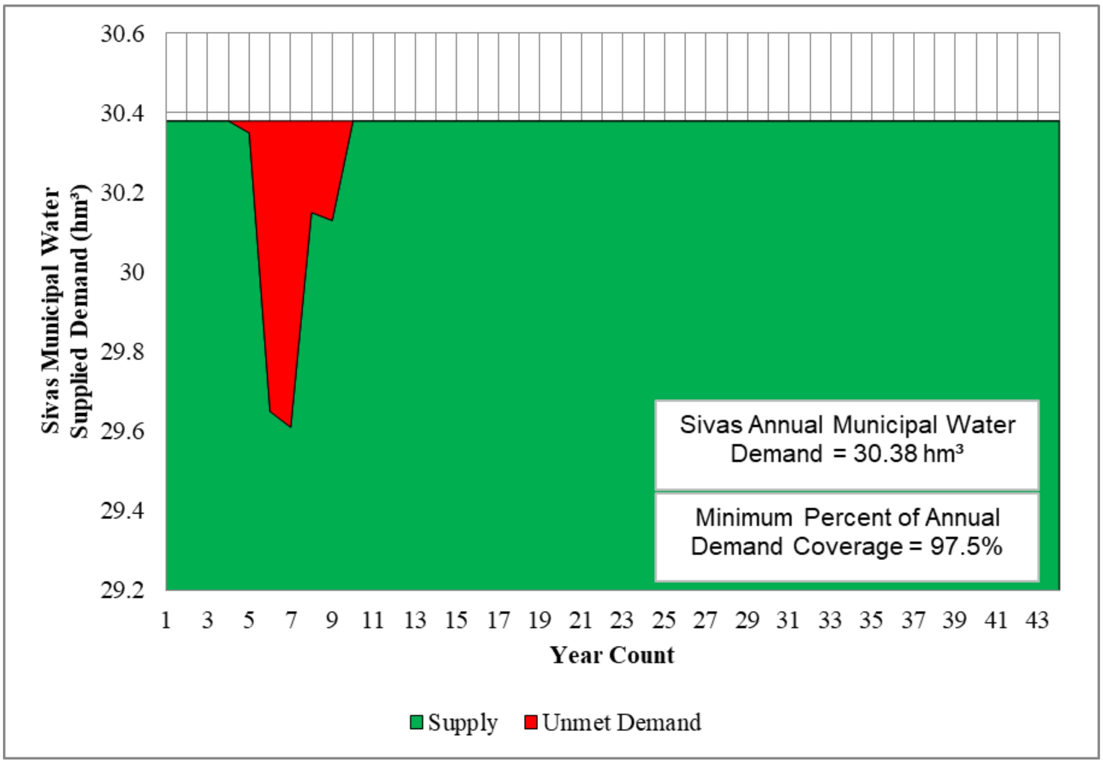


Figure 4.41. Supply-demand graph of Sivas for existing case, 100-years return period without climate change modification

Dört Eylül Dam cannot release water for downstream water rights for six years and the demand coverage reaches zero percent. The total insufficiency amount is 1.25 hm³ for six years.

In addition, even though deficit irrigation scheme is used, the irrigation demand of Pusat-Özen Dam is not satisfied for five years, the total unmet demand amount is 13.93 hm³. Also, the environmental flow requirement is not satisfied for three years which has a total unmet demand amount of 0.06 hm³. Unmet demand amounts and supply-demand graph for all demand sites are given in Figure 4.42 and Figure 4.43, respectively.

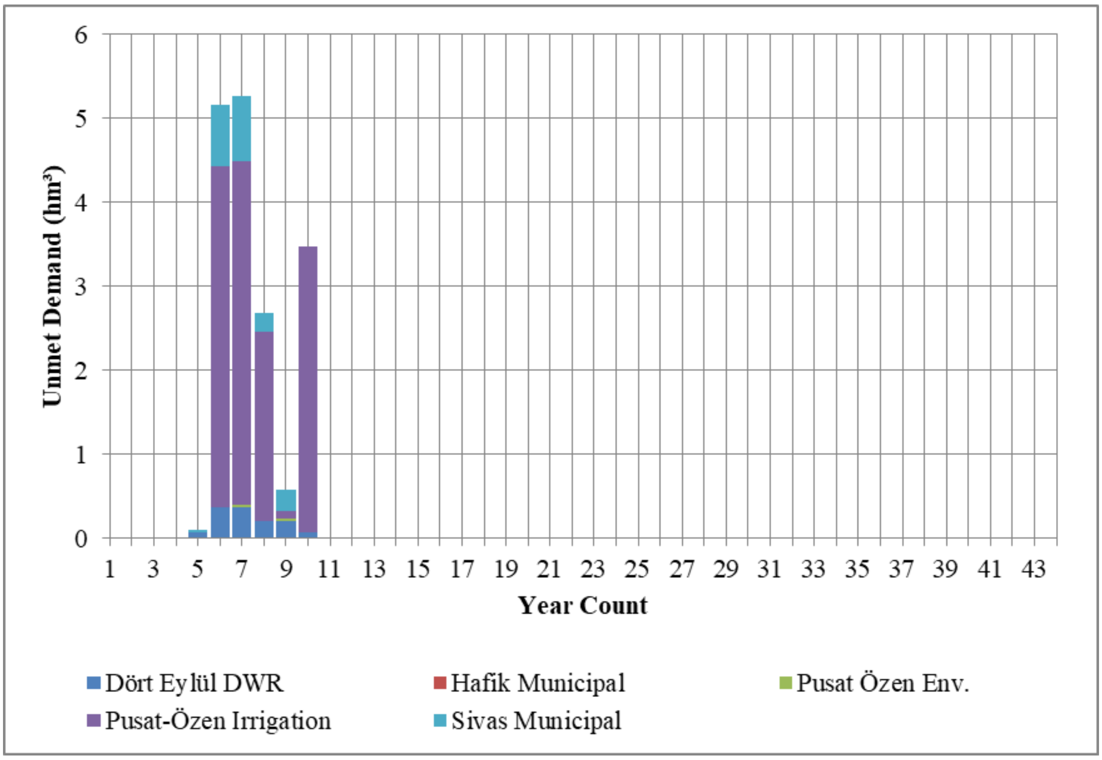


Figure 4.42. Unmet demand amounts for upstream development case, 100-years return period without climate change modification

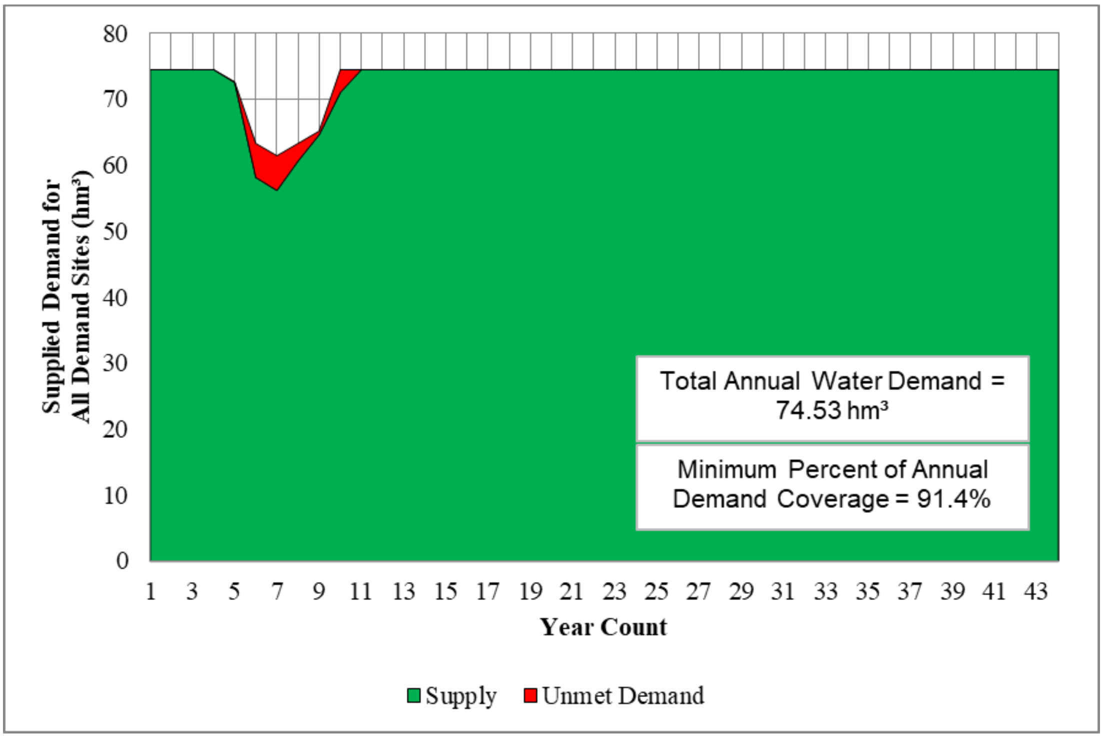


Figure 4.43. Supply-demand graph for upstream development case, 100-years return period without climate change modification

Upstream Development Case

In 100-years return period scenario, in both climate change modified and unmodified scenarios, all reservoir levels drop to minimum. Pusat-Özen and Dört Eylül Dams cannot recover after deficit period. Beydilli Dam, on the other hand, recovers after catastrophic deficit period ended (Figure 4.44).

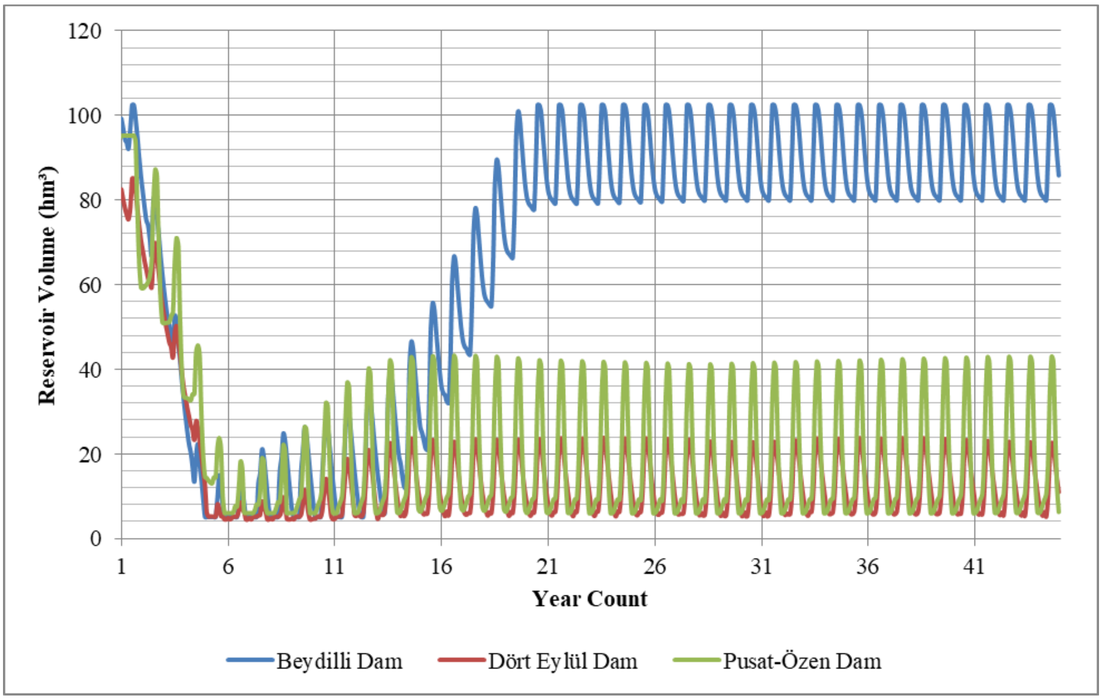


Figure 4.44. Reservoir storage volumes of Dört Eylül, Pusat-Özen and Beydilli Dams for upstream development case, 100-years return period without climate change modification

There is unmet demand for all demand sites; and Tavra Resources are not sufficient even though the source provides additional municipal water (in no climate change scenario 273.50 hm^3 for 40 years). The total allocated unmet demand amount of Sivas Province for no climate change scenario is 105.66 hm^3 for 8 years (Figure 4.45 and Figure 4.46)

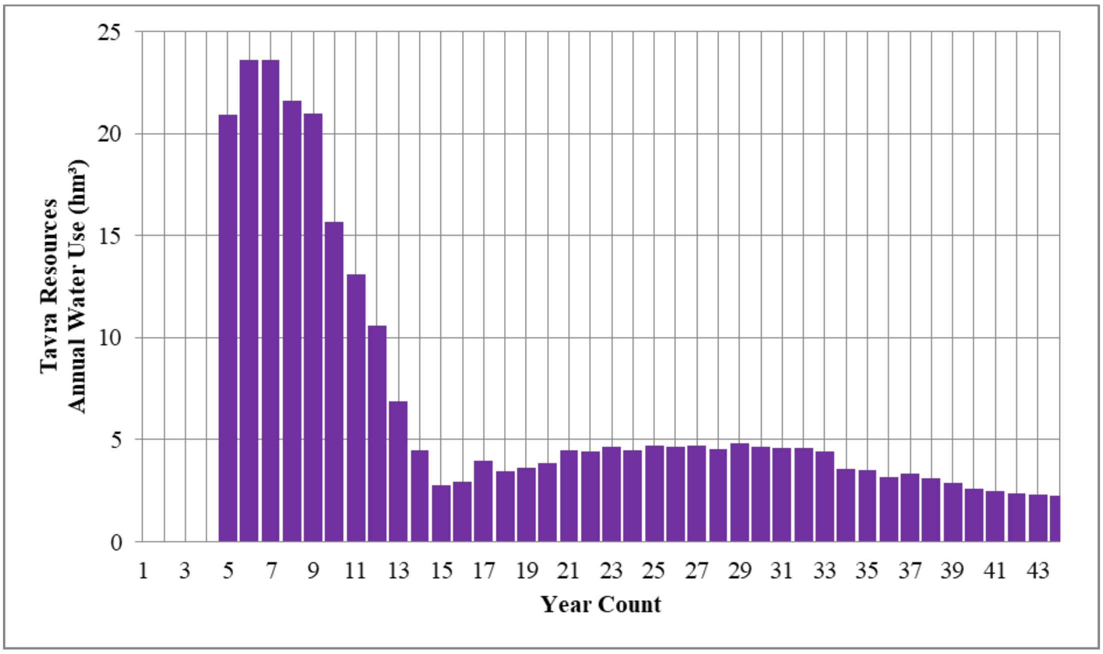


Figure 4.45. Tavra Resources annual water use amount for upstream development case, 100 years return period without climate change modification

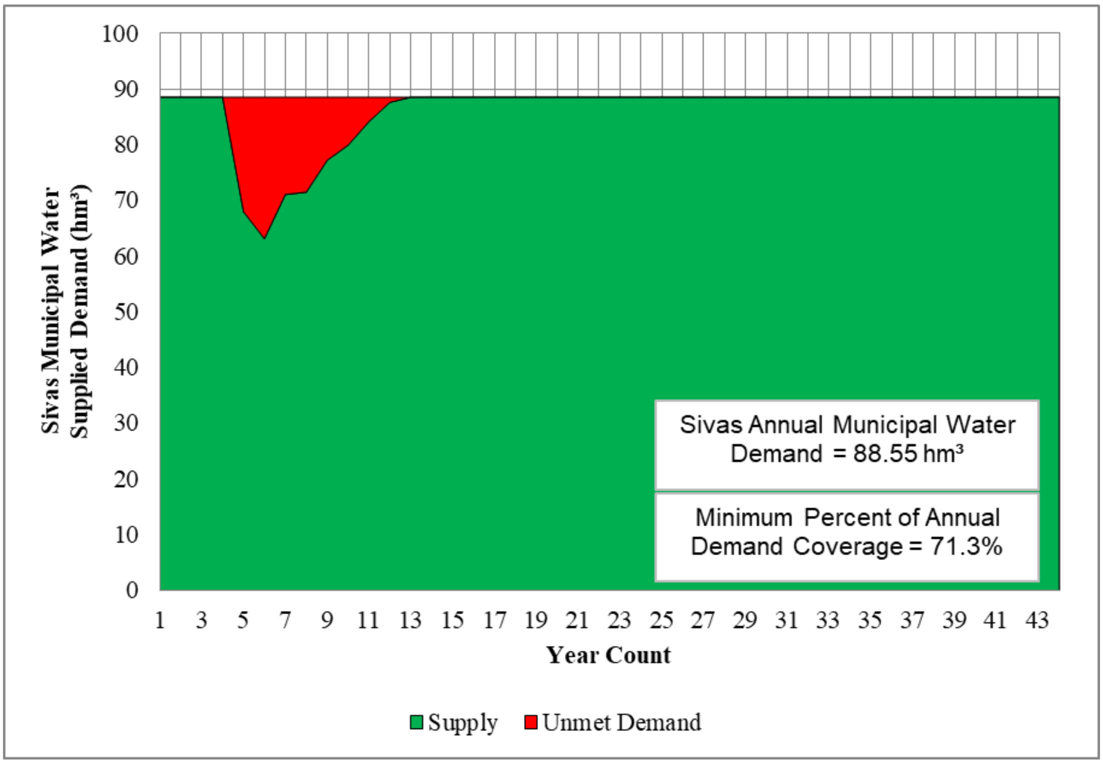


Figure 4.46. Supply-demand graph of Sivas for upstream development case, 100 years return period without climate change modification

The allocated municipal water demand of Hafik District is unmet; the unmet demand amount is 0.34 hm³ for 5 years. Overall unmet demand amount is 163.250 hm³ which includes all demand sites (Figure 4.47 and Figure 4.48).

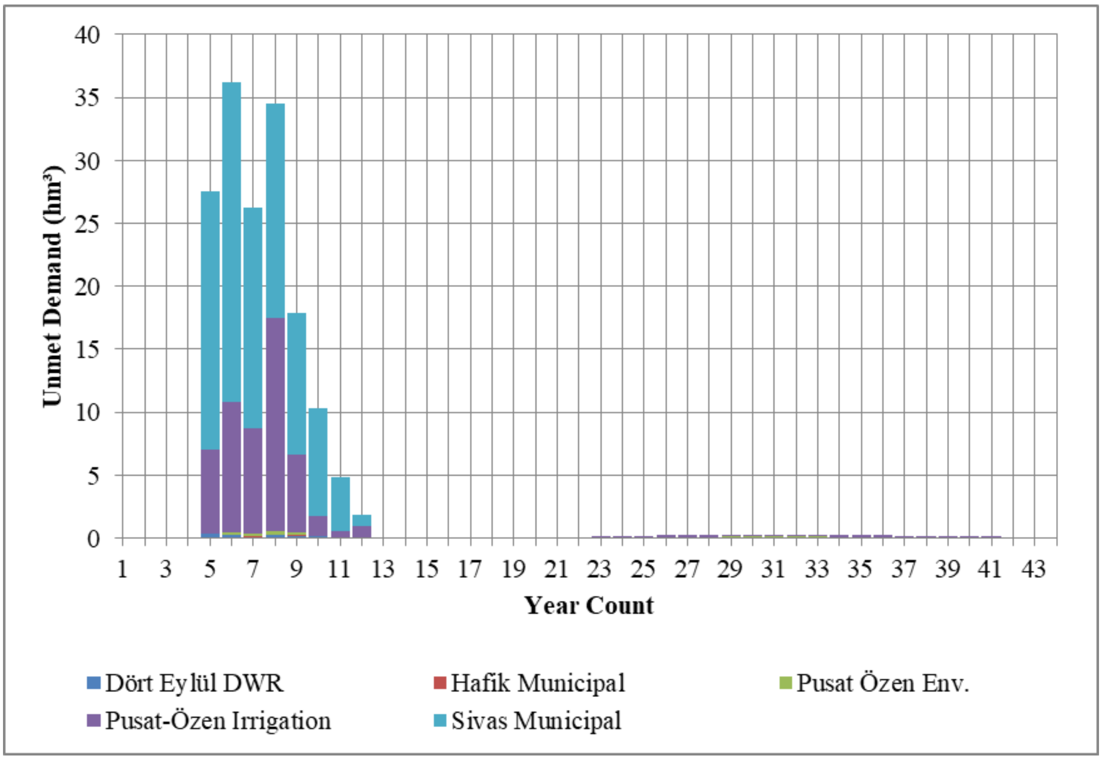


Figure 4.47. Unmet demand amounts for upstream development case, 100 years return period without climate change modification

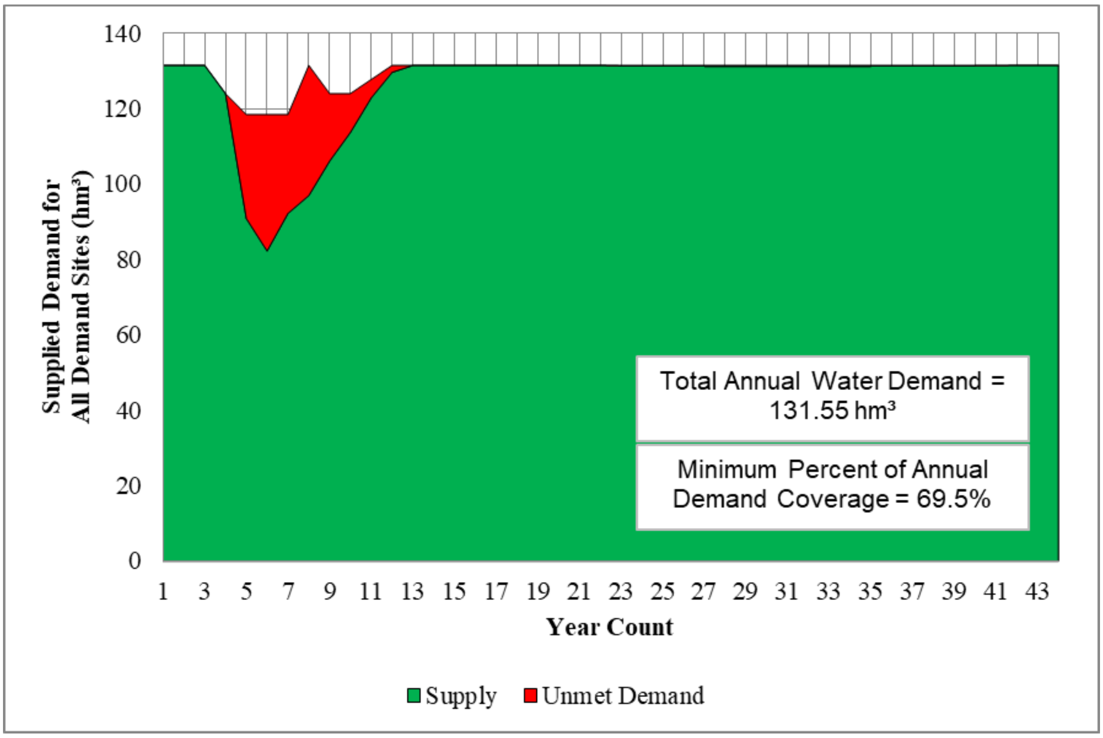


Figure 4.48. Supply-demand graph for upstream development case, 100 years return period without climate change modification

Climate Change Modified Upstream Development Case

In 100-years return period scenario, in both climate change modified and unmodified scenarios, all reservoir levels drop to minimum. There is unmet demand for all demand sites; and Tavra Resources are not sufficient.

It is determined that Pusat-Özen Dam cannot refill in this scenario. The diversion for municipal water to Sivas is highly effective for Pusat-Özen Dam in a 100-years return period drought event. Even though the inflows are Dört Eylül Dam increased by the diversion from Beydilli and Pusat-Özen Dams, the vulnerable behavior of Dört Eylül Dam does not change, and the reservoir does not refill. On the other hand, after the deficit period, the reservoir level of Beydilli Dam can be recovered (Figure 4.49).

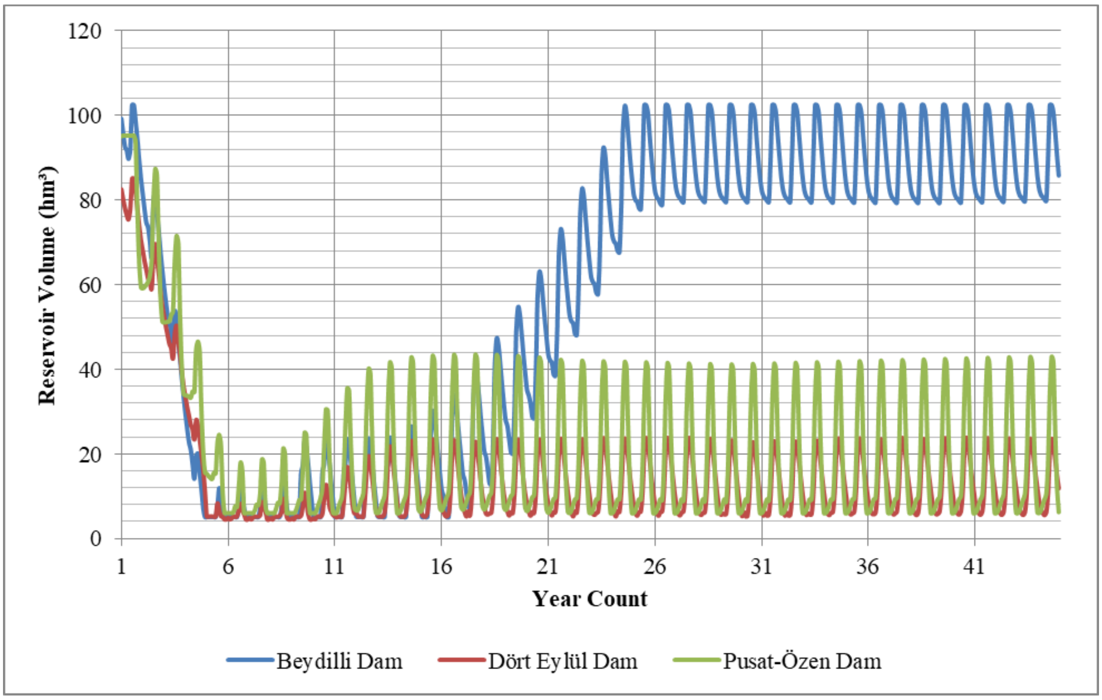


Figure 4.49. Reservoir storage volumes of Dört Eylül, Pusat-Özen and Beydilli Dams for upstream development case, 100 years return period with climate change modification

The total unmet demand amount of Sivas Province for climate change modified scenario is 158.48 hm³ for 11 years. The allocated municipal water demand of Hafik District is unmet; the unmet demand amount is 0.33 hm³ for 4 years. Overall unmet demand amount is 215.16 hm³ which includes all demand sites.

The unmet demand amounts are given in Figure 4.50 and supply-demand graph of Sivas province are given in Figure 4.51.

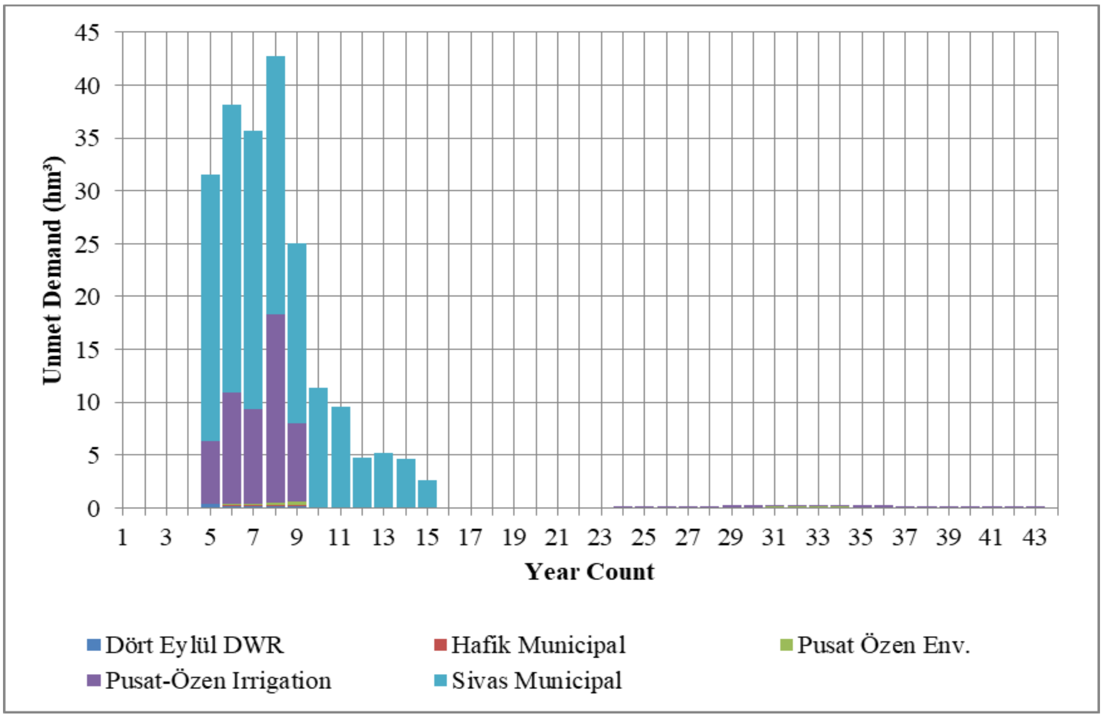


Figure 4.50. Unmet demand amounts for upstream development case, 100 years return period with climate change modification

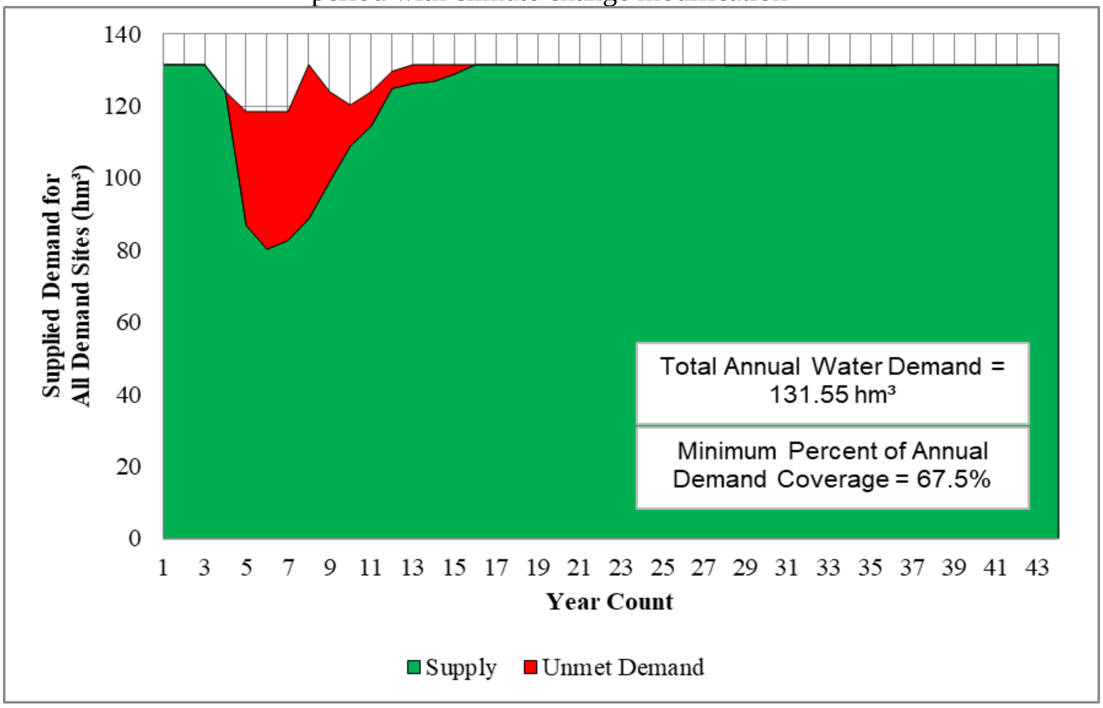


Figure 4.51. Supply-demand graph for upstream development case, 100 years return period with climate change modification

Tavra Resources provides additional 303.51 hm³ for 40 years (Figure 4.52). However, the transmission line capacity of Tavra Resources has been highly effective in 100-years deficit period and there is a huge amount of unmet demand for Sivas Province. On the other hand, even though the impacts of a 100-years drought can be persistent for more than 15 years, requirement for Tavra Resources does not reach zero after the deficit period. This is mainly caused by the vulnerability of Dört Eylül Dam to reservoir drops. Annual water usage of Tavra Resources and supply-demand graph for Sivas are given in Figure 4.52 and Figure 4.53, respectively.

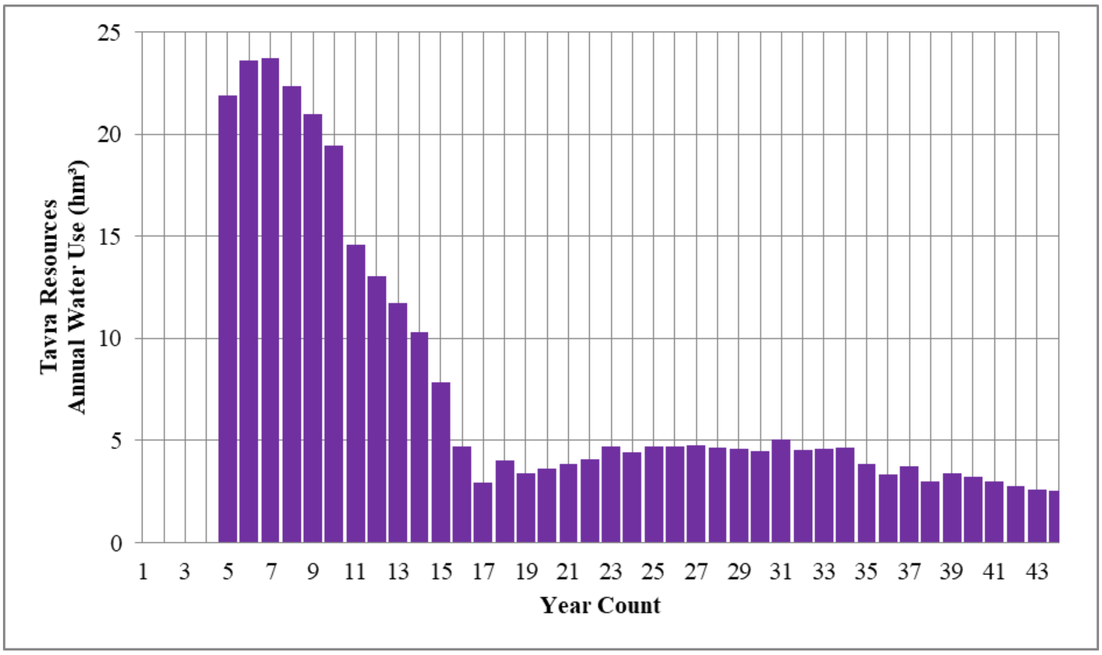


Figure 4.52. Tavra Resources annual water use amount for upstream development case, 100 years return period without climate change modification

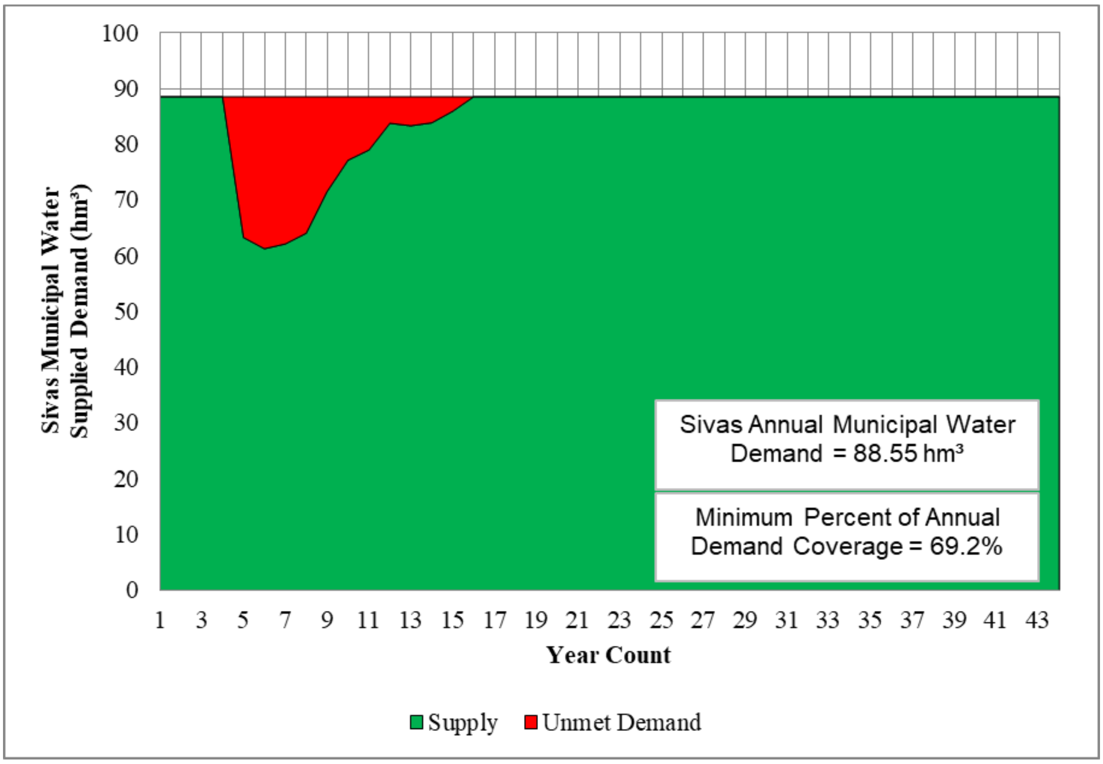


Figure 4.53. Supply-demand graph of Sivas for upstream development case, 100 years return period with climate change modification

Climate change modified 100-years return period scenario is the most extreme scenario developed in this study. No hydraulic structure is able to mitigate a climate change modified 100-years return period drought event.

CHAPTER 5

DISCUSSIONS OF THE RESULTS

5.1. Demand Coverage Assessment

According to the results determined with the operation model, vulnerabilities and adaptive capacities of all hydraulic structures were determined. Factors affecting vulnerability are highly visible in 100-years return period scenario. Considering all operation scenarios, the vulnerability issues given below are determined:

- In the observation period and existing case, the most severe deficit occurred is approximately 5- to 10-years recurrence deficit in 1970-1975 and that dry period can be mitigated by both Dört Eylül and Pusat-Özen Dams.
- In the observation period and upstream development case, the most severe deficit occurred is approximately 5-years recurrence deficit in 1970-1975 and that dry period can be mitigated by Pusat-Özen and Beydilli Dams. However, by itself (i.e. without the help from Tavra) Dört Eylül Dam cannot mitigate the deficit completely.
- Dört Eylül Dam is very vulnerable to hydrological drought events. The reservoir level drops very quickly and cannot refill with only average inflowsafter a deficit period.
- Dört Eylül Dam cannot mitigate a drought which is more severe than 10-years return period without the support of secondary Tavra Resources. For more severe droughts (such as 25-years) even Tavra Resources are not sufficient.
- Pusat-Özen Dam is mostly resistant to the drought events even though there are some unmet demand amounts for irrigation. After a deficit period, it can recover quickly for the existing case. However, the diversion in the upstream

development case affects Pusat-Özen Dam in a severe way and introduces municipal water unmet demands for Hafik District along with significant amount of unmet demands in irrigation. In addition, Pusat-Özen reservoir levels cannot recover quickly after a deficit period; and it cannot refill in 100-years return period scenario.

- Beydilli Dam has enough inflows to recover after a deficit period. However, the dam is very susceptible to climate change. The climate change modifications made a significant decrease in the inflows of Beydilli Dam and climate change modified 100-years return period can have impacts of 475-years return period of the no modification scenario.
- It is impossible to supply the allocated amount of municipal water to Sivas Province in a catastrophic drought event even though there are four different water sources available (including Tavra Resources).
- Tavra Resources have a transmission limit of 1000 l/s. This issue causes unmet demands in Sivas municipal water demands even though 5/6 of the maximum capacity of Tavra Resources in a year is achieved (Approximately 24 hm^3 of 31.54 hm^3 maximum withdrawal amount is used in 100-years return period scenario.). In the operation scenario, Tavra Resources was used as an emergency resource. However, in order to increase the maximum support of Tavra Resources can provide in catastrophic drought events, a good operation strategy should be determined.

5.2. Discussion of the Results of the Case Study and Recommendations for Operation Strategy Policies in a Catastrophic Drought Event

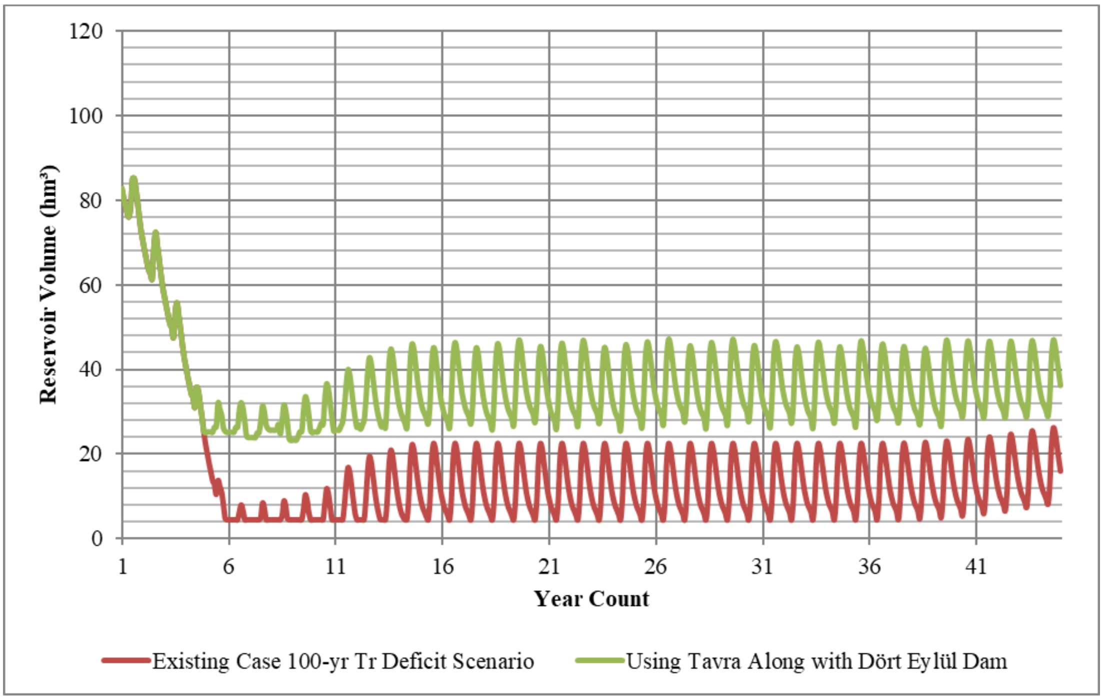
Both existing and upstream development cases were assessed by using 100-years return period scenario. However, it is determined that the current operation approach does not completely mitigate 100-years drought for both existing and upstream development cases. Therefore, in the assessment phase, drought-resistant policies for the operation of the structures should be developed.

5.2.1. Assessment of Existing Case Scenarios and Operation Policy Recommendations

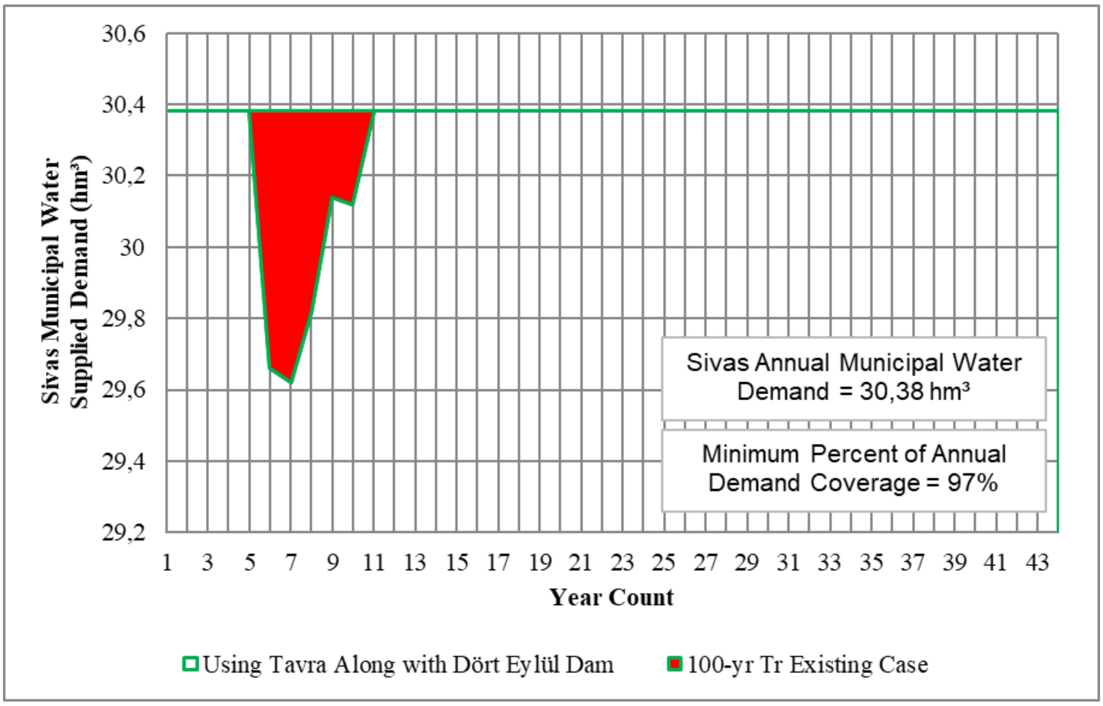
The assessment of results for overall existing case scenarios are detailed below:

a. Dört Eylül Dam reservoir level does not rise after a dry period unless there is a significantly wet period occurs after drought. This is caused by the insufficiency of the inflows. This issue makes the structure very vulnerable against consecutive mild drought events, without a wet period between them. Because Dört Eylül Dam is a municipal water reservoir, a diversion in order to increase the inflow is a good solution.
b. However, until new structures (Beydilli Dam and Beydilli Weir) become operational, Dört Eylül Dam operation policy should be adequate to mitigate 100-years return period climate change modified deficit.
c. Consensus about the secondary sources is when a primary source ended or drained, the secondary source becomes active. However, it is determined that, before Tavra Resources become active, waiting for Dört Eylül reservoir level reaches minimum is not a good way to compensate Sivas Province municipal water demand. Because, even though in theory Tavra Resources can provide 31.54 hm^3/year, it is mostly not the case because of the transmission line capacity (which is 1000 l/s). Therefore, when Tavra reaches maximum capacity, there is no other resource for Sivas municipal water demand.

d. As a solution, a simple and cheap operation policy is developed. For the existing conditions case, when Dört Eylül Dam reservoir level drops to 1/3 of the active volume (which indicates there is a deficit period), Tavra Resources also becomes active. By this way, Dört Eylül Dam reservoir level never drops to minimum and even if Tavra transmission line reaches maximum capacity, Dört Eylül Dam works as a secondary resource this time. Using this operation policy, Sivas municipal water demand is completely satisfied in the existing case climate change modified 100-years return period scenario (which is the catastrophic scenario). (Figure 5.1)
e. In this policy scenario, Tavra Resources are used more than the 100-years return period scenario; however, there is no unmet demand for Sivas Province, because both resources are their alternative.
f. The new operation policy is checked for the maximum municipal water demand of Sivas. This operation policy can mitigate 100-years climate change modified drought when the municipal water demand of Sivas Province becomes 45.3 hm^3/year. According to the Master Plan Report, this demand amount will be reached by the end of 2036 (DSİ, 2019). Hence, it is determined that Beydilli Diversion should be constructed before 2036.



(a)



(b)

Figure 5.1. Policy scenario for Dört Eylül Dam and Tavra Resources used together when Dört Eylül Dam reservoir level drops to 1/3 of active volume (a) reservoir level comparison for Dört Eylül Dam, (b) demand coverage comparison for Sivas province

g. Pusat-Özen Dam can successfully mitigate 25-years return period deficit for both climate change modified and no modification scenario. In 1970-2013 observation period no 25-years return period deficit occurred. Therefore Pusat-Özen can successfully mitigate similar deficits. There is no problem regarding to Hafik District municipal water demand in any of the scenarios. There may be unmet demand in the environmental flow amount in catastrophic cases such as 50- or 100-years return period scenarios. However, if there is a catastrophic drought happens, deficit irrigation scheme based on DSİ Criterion is not enough to keep the unmet demand amount at zero.
h. There are four solutions for the irrigations in general; replacing the irrigation method to a less water consuming method, crop pattern replacement, less irrigation water supplied for farmers in drought period and lastly compensate the loss of farmers during or after a catastrophic drought event.
i. Pusat-Özen Irrigation completely includes drip and sprinkler irrigation and robust transmission line, because it is a new DSİ irrigation project (DSİ, 2019). Reducing the crop water requirement further is not possible, in terms of the distribution system.
j. Using drought-resistant crops in drought events is an alternative. However, this topic is out of the scope of this study and it is not studied in detail.
k. The last two of the methods given here are the subjects included in crisis management and does not relate to operation strategies. Therefore, they are not evaluated in this study.
l. For the existing case, Kızılırmak Master Plan Final Report (DSİ, 2019) there is no problem regarding both Pusat-Özen and Dört Eylül Dams and municipal water demands of Sivas and Hafik can be satisfied without any problem. Deficit irrigation is not needed for Pusat-Özen irrigation. However, this study shows that in the existing case if there is a severe drought occurs there may be some problems regarding satisfying the demand. A deficit irrigation scheme is used for Pusat-Özen irrigation and Dört Eylül Dam cannot provide required demand amount to Sivas Province without the

assistance of Tavra Resources. This situation proves that the methodology developed in this study has advantages over traditional operation methodology.

5.2.2. Assessment of Upstream Development Case Scenarios and Operation Policy Recommendations

The assessment of results for overall upstream development case scenarios are given below:

a. Beydilli Weir and Beydilli Dam introduce a significant rise (around 51 hm^3/year) in Dört Eylül Dam reservoir level. However, Dört Eylül reservoir is highly vulnerable to drought events. Reservoir level may drop very quickly even in mild droughts.
b. It is not possible that the diversion system (Three dams and one diversion weir) and Tavra Resources mitigate the deficits in any return period with allocated municipal water demand of Sivas, which is 88.55 hm^3/year. In addition, the allocated amount of 88.55 hm^3/year does not seem like a realistic value; which is nearly twice the expected water demand of Sivas in 2050 (53.20 hm^3/year). Therefore, a policy scenario includes real water demand of Sivas is studied.
c. The real water demand case is compared with the climate change modified 100-years return period scenario (which is the most severe scenario in the study). It is determined that there is no unmet demand for Sivas municipal water demand if the demand amount is lowered to the municipal water demand in 2050 (which is 53.20 hm^3/year). This child scenario is completely the same as the ancestor, which is the 100-years return period scenario. The only difference is the municipal water demand amount of Sivas Province. In the scenario, Dört Eylül Dam reservoir level drops to minimum only once at the ninth year of the drought and the loss is perfectly satisfied with Tavra Resources (Figure 5.2).

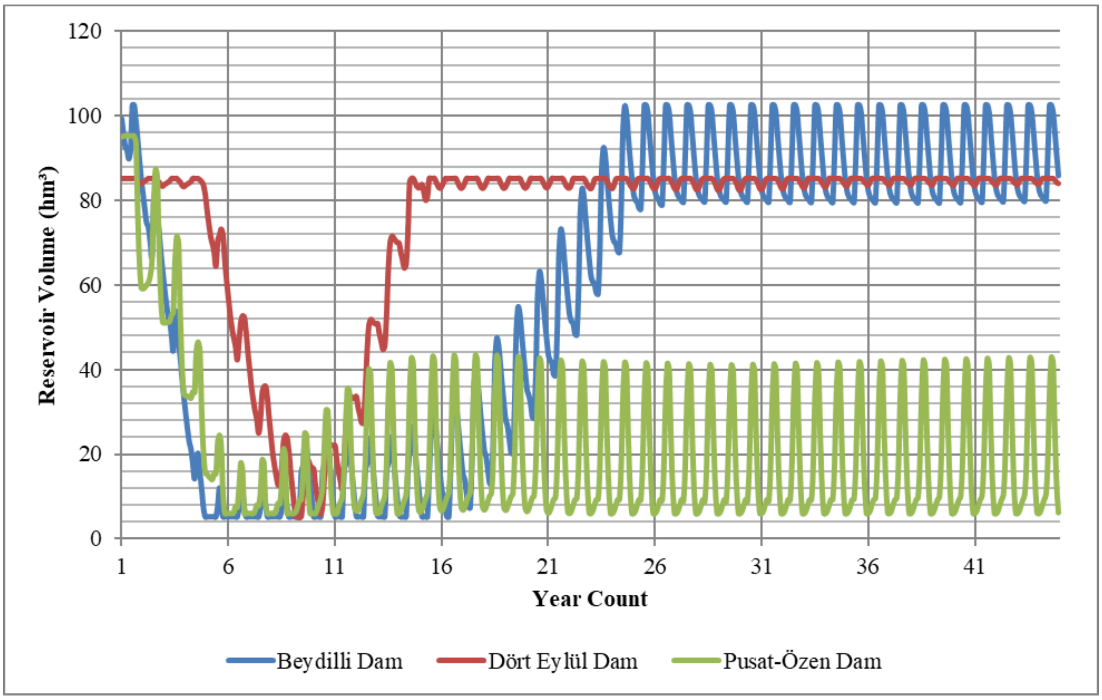


Figure 5.2. Policy scenario when 2050 expected water demand of sivas is used in the operation study

d. Also, in order to satisfy the allocated amount and increase the possible allocation amount, some additional operation policies have been tried for Dört Eylül Dam and Tavra Resources.

e. Increasing the dam height of Dört Eylül has been tried with a new policy scenario. In this scenario, it is assumed that the crest elevation of Dört Eylül Dam is increased from 1390.60 m to 1392 m elevation (approximately 1.5 m higher). This provides additional 9.45 hm^3 active volume. When operated for 100-years return period scenario, it is determined that the resulting unmet demand is nearly the same as the 100-years return period scenario. Therefore, it is determined that increasing the height of Dört Eylül Dam cannot provide any advantage regarding drought mitigation. (Figure 5.3)

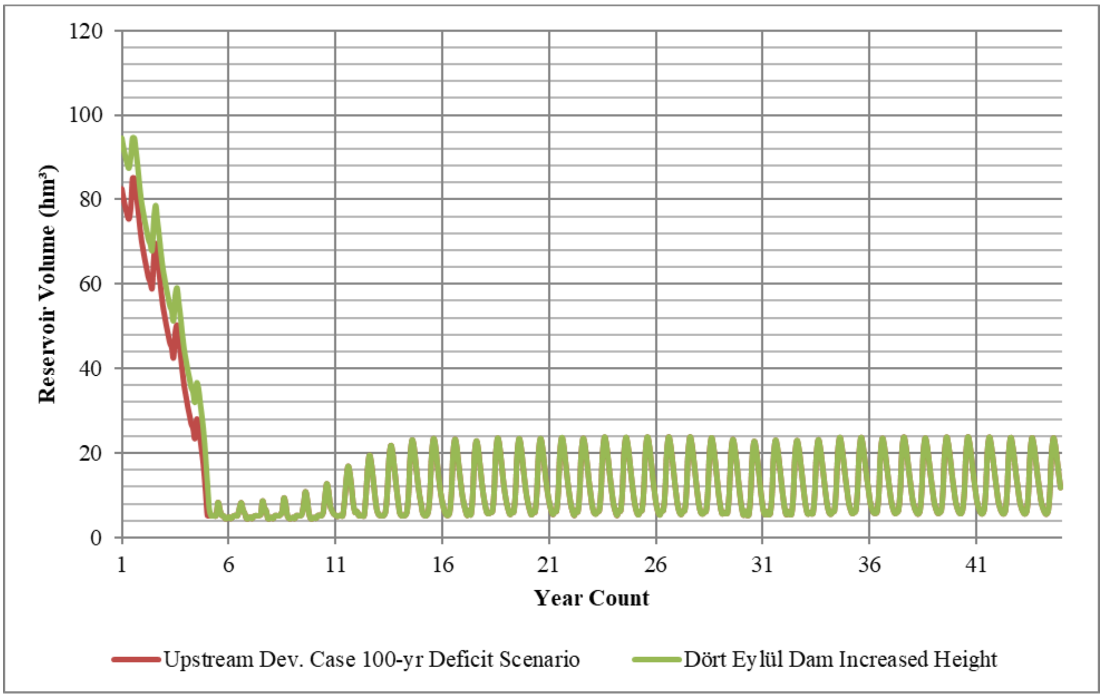


Figure 5.3. Storage volume comparison of Dört Eylül Dam increased height

f. Another policy is completely canceling the Pusat-Özen irrigation in a catastrophic drought scenario and using that water also for satisfying Sivas municipal water demand (i.e. the irrigation water will be diverted to Sivas municipal water). For this case unmet demand of Sivas Province drops to 32.25 hm³ from 158.48 hm³. This is a huge amount, however the total unmet demand including Pusat-Özen Dam irrigation increases dramatically as the irrigation is completely canceled. Therefore, this does not seem a feasible option unless there is no other option available (Figure 5.4).

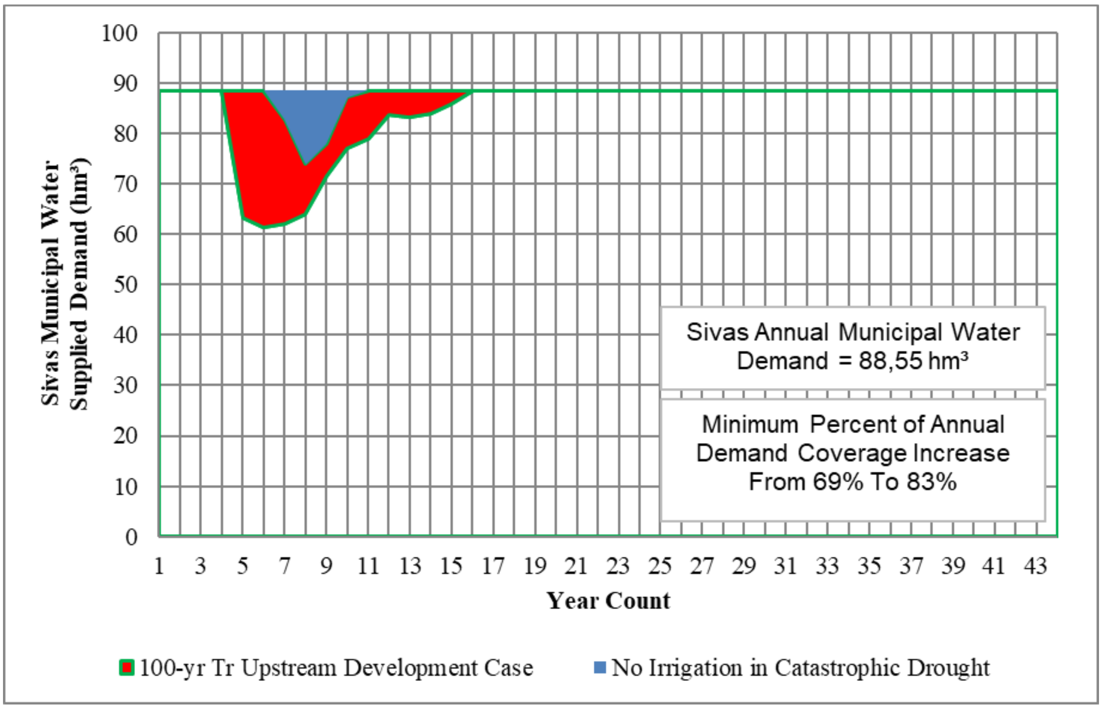


Figure 5.4. Comparison of 100-years return period unmet demand with no irrigation in catastrophic conditions scenario

g. Additional operation policy is using Tavra Resources along with Dört Eylül Dam, not as a secondary but a primary source also in a catastrophic drought event. For this case unmet demand of Sivas Province drops to 24.58 hm^3 from 158.48 hm^3. This is also a good way to satisfy the allocated demand. In this scenario, Tavra Resources are always used and Dört Eylül Dam refills after drought. However, this solution is an expensive solution because using groundwater resources requires electrical costs in addition to using the valuable groundwater resources (Figure 5.5 and Figure 5.6).

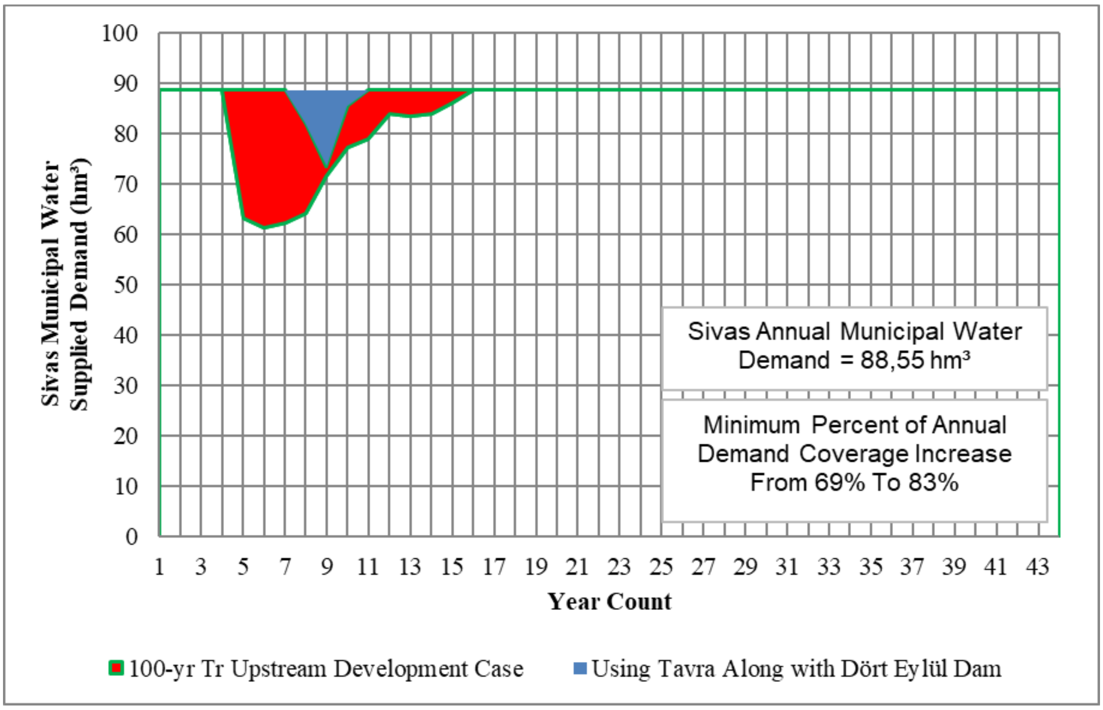


Figure 5.5. Comparison of 100-years return period unmet demand with using Tavra Resources along With Dört Eylül Dam scenario

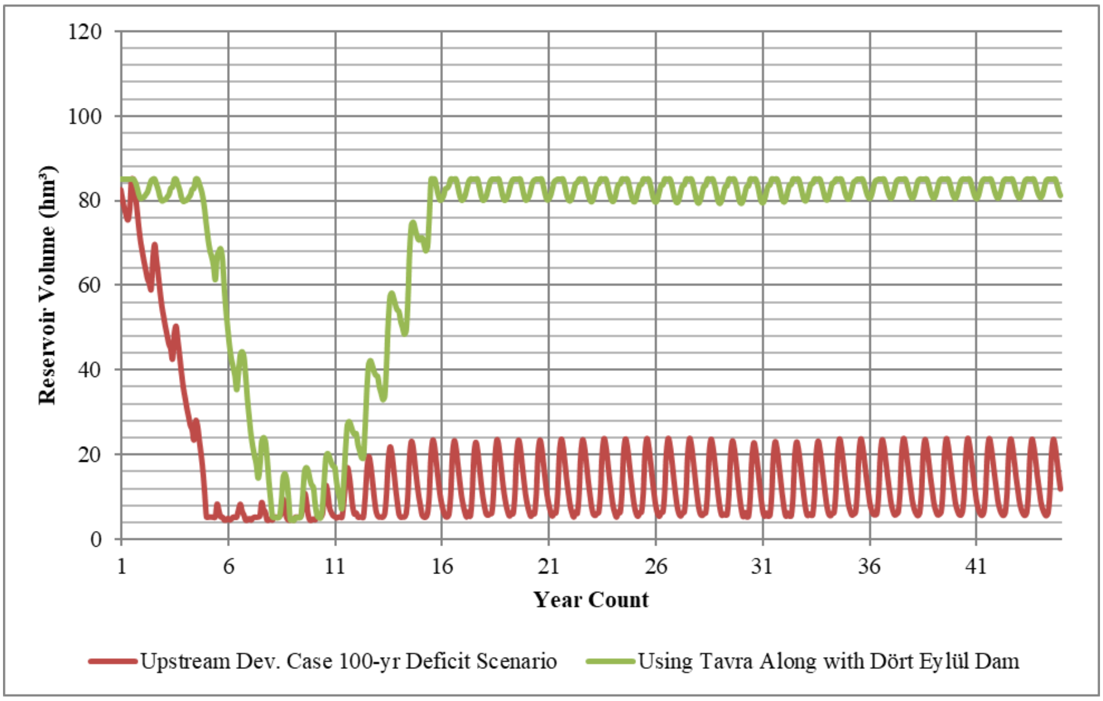


Figure 5.6. Comparison of 100-years return period reservoir volumes with using Tavra Resources along with Dört Eylül Dam scenario

h. 88.55 hm³/year allocated municipal water demand for Sivas cannot be supplied for catastrophic drought conditions. Therefore, the maximum amount of demand which can be mitigated for 100-years return period is calculated and it is 53.80 hm³/year. In the calculation process, Tavra Resource is kept as a secondary source (which will be used after Dört Eylül Dam drained) and municipal water demands of Sivas Province are completely satisfied. This scenario does not change the assumptions in the original 100-years return period scenario; only Sivas Province water demand is reduced from 88.55 hm³/year to 53.80 hm³/year. This means the system in the original state can provide 53.80 hm³/year municipal water to Sivas without any unmet demand (Figure 5.7).

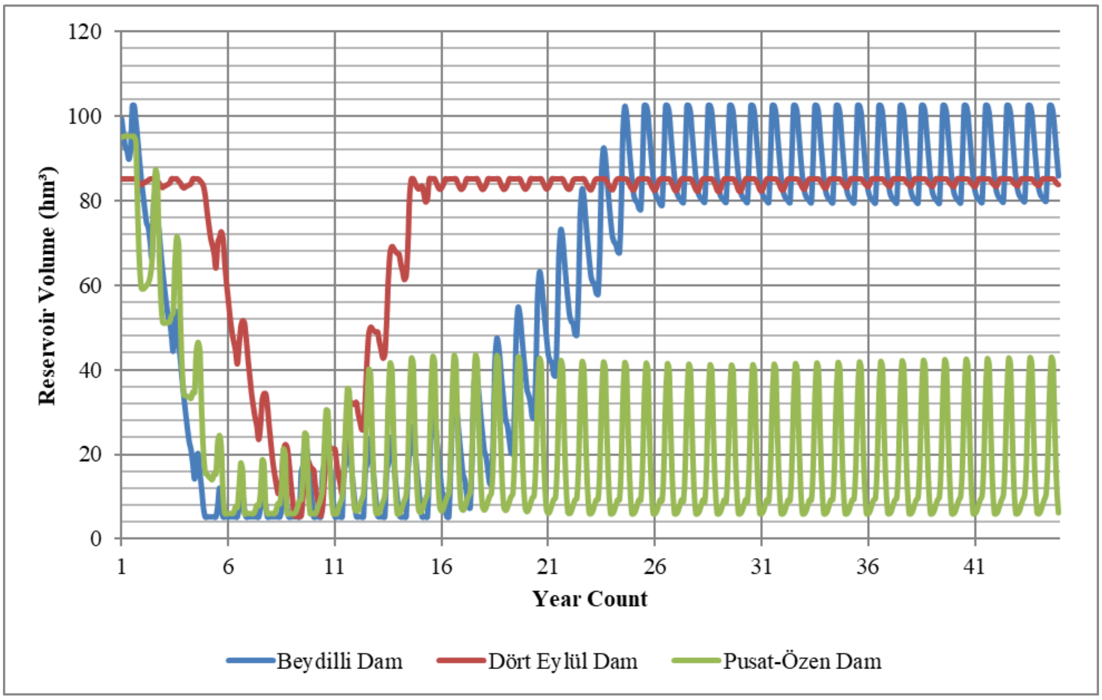


Figure 5.7. Reservoir volumes for maximum allocated water using Tavra as a secondary source

i. As can be seen in the existing case operation strategies, using Tavra Resources not as secondary source can provide toleration between Dört Eylül

Dam and Tavra Resources and both become their redundant. Therefore, using Tavra Resources as a primary source also is a possibility.

j. In order to determine the best operation scenario, Tavra Resource is added as a primary source when the active volume of Dört Eylül Dam reaches its 1/3 (see the existing case). This time the maximum allowable municipal water amount for Sivas Province in order to mitigate 100-years deficit increases to 72 hm³/year.

k. In this case, Dört Eylül and Beydilli Dam refill; however, Pusat-Özen suffers a large amount of irrigation loss. Therefore, it is proposed that using Pusat-Özen section of diversion as an emergency source for Sivas Municipal demand. (Figure 5.8)

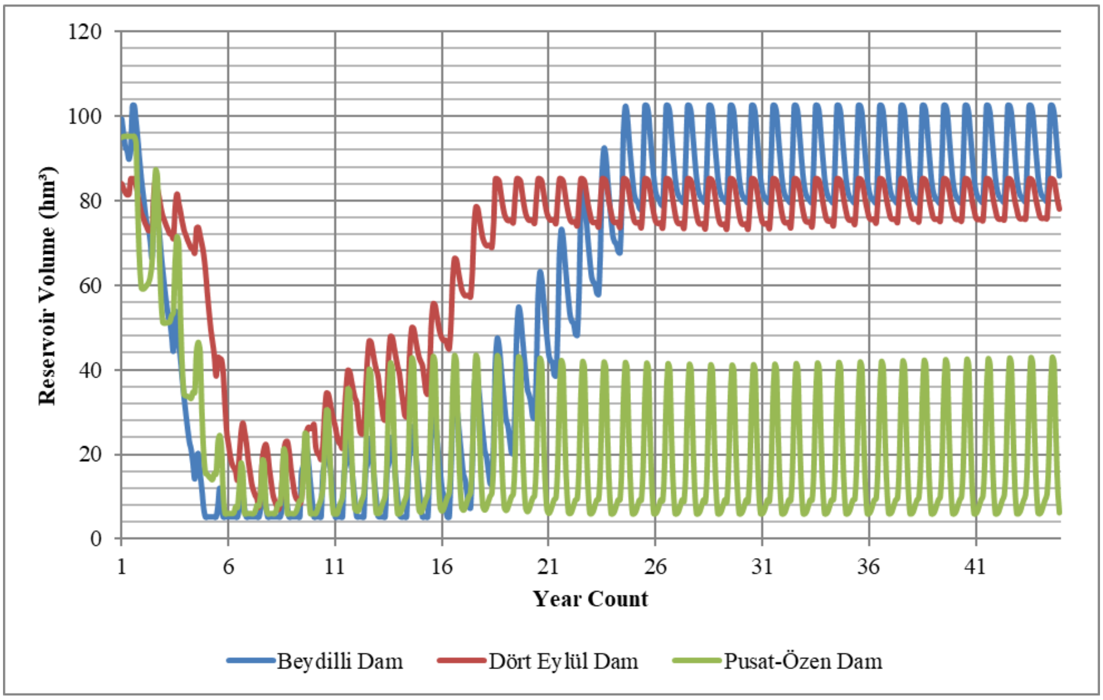


Figure 5.8. Maximum allowable municipal water (72 hm³) scenario reservoir volumes

l. When Pusat-Özen diversion is completely deactivated, the amount of maximum allocated water demand falls to 66 hm³/year (6 hm³/year smaller than the maximum possible demand). This operation scenario can also be called as "no unmet demand scenario". Pusat-Özen side of this scenario is identical to existing case climate change modified 100-years return period scenario. It means, there are some unmet irrigation demands; which can be resolved by using the methods given in the existing case.

m. Finally, it is recommended that using Pusat-Özen as a secondary emergency source for the upstream development case; whereas using Tavra when the active volume of Dört Eylül Dam reaches its 1/3.

n. It is not possible to mitigate 88.55 hm³/year allocated amount. The demand cannot go higher than 72 hm³/year; and it should be controlled. If the demand increase is higher than 72 hm³/year, a new municipal water resource for Sivas Province may be required. If Pusat-Özen Dam is kept as an emergency source; the maximum possible demand cannot go higher than 66 hm³/year (Figure 5.9).

o. As a result, with a good operation strategy, the structures can successfully mitigate 100-years return period climate change modified deficit.

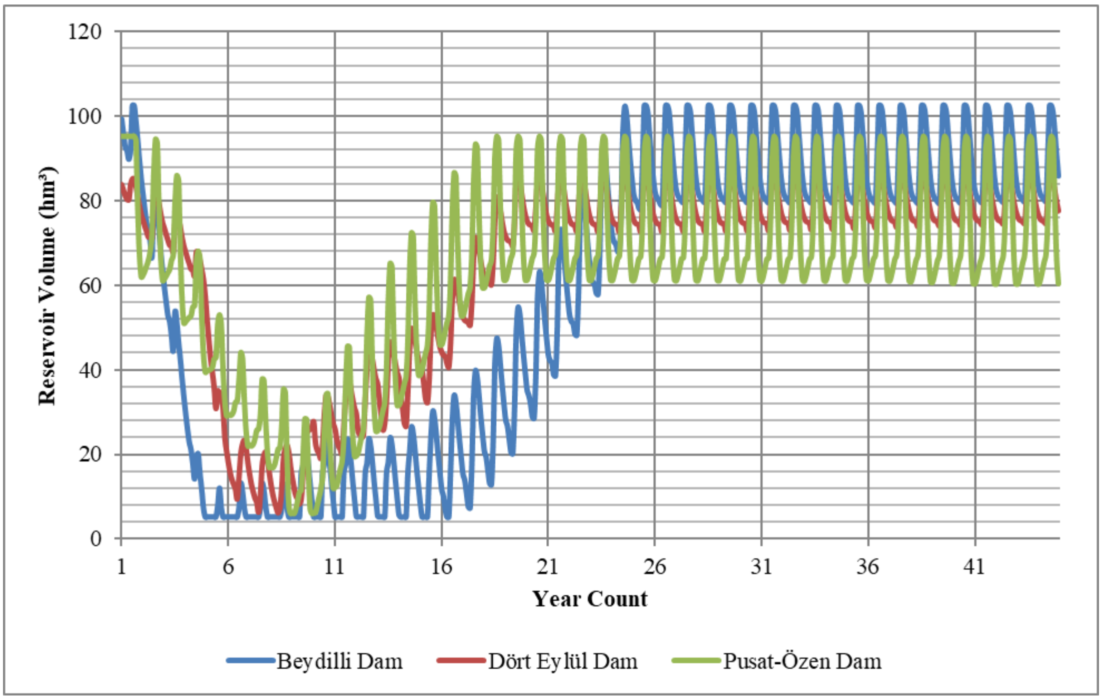


Figure 5.9. Maximum allowable municipal water (66 hm³) and no Pusat-Özen Dam scenario reservoir volumes

p. For the upstream development case, Kızılırmak Master Plan Final Report (DSİ, 2019) states that Pusat-Özen irrigation is not satisfied and it can be satisfied only when the deficit irrigation scheme is used for Pusat-Özen Dam. Dört Eylül Dam has enough inflow from Beydilli Dam, Beydilli Weir and Pusat-Özen Dam and it can satisfy the municipal water demand of Sivas Province. However, climate change and drought are not included in the scope of Kızılırmak Master Plan Project. Therefore, the data is not modified for climate change. Although there is no problem regarding Kızlırmak Master Plan, when extreme drought events are considered with the help of developed methodology in this study, it is determined that there are problems regarding municipal water. In addition to the advantages of the methodology over traditional methods, climate change modifications are also an important trait.

5.2.3. Summary of the Recommended Operation Policies for Case Study

Summary of recommended operation policies is given for both existing and upstream development cases in Table 5.1. All policies are given with a reference of the previous section.

Table 5.1. *Summary of the recommended operation policies for the case study*

<table>
<tr><th rowspan="2">Case</th><th colspan="3">Structure Name</th></tr>
<tr><th>Pusat-Özen Dam</th><th>Dört Eylül Dam</th><th>Beydilli Dam and Weir</th></tr>
<tr><td>Existing Case *</td><td>Use a deficit irrigation scheme in drought periods (EX g)

Replace crops with drought-resistant crops in drought periods (EX j)

Use drought crisis management actions in catastrophic drought periods (EX g)</td><td>Start to use Tavra Resources when reservoir level drops to 1/3 of the active volume (EX a-e)

Sivas Municipal Water Demand will be met until 2036 (45.3 hm^3) with this policy (EX f)</td><td>Not available in the existing case</td></tr>
<tr><td rowspan="5">Upstream Development Case **</td><td rowspan="3">Do not use Pusat-Özen diversion until municipal water demand of Sivas increases to 66 hm^3 (UD k-m)

Continue with the same policy in the existing case (EX g, j, UD l))</td><td>Use Tavra Resources when reservoir level drops to 1/3 of the active volume (EX a-e and UD g-m)</td><td>Beydilli Dam and Weir should be constructed and become operational until 2036 (EX f)</td></tr>
<tr><td>The diversion includes only Beydilli Dam and Weir will be sufficient to supply 66 hm^3 (UD k-m)</td><td rowspan="2">Beydilli Dam and Weir are able to provide required municipal water demand of Sivas in 2050 (UD c)</td></tr>
<tr><td>This amount is much higher than the required municipal water demand of Sivas Province in 2050 (53.20 hm^3) (UD c)</td></tr>
<tr><td>When the municipal water demand of Sivas Province is higher than 66 hm^3, start to use Pusat-Özen diversion (UD j, n)</td><td>The diversion includes Pusat-Özen, Beydilli Dam and Weir will be sufficient to supply 72 hm^3 (UD j, n)</td><td>Beydilli Dam and Weir are able to support Dört Eylül Dam (UD-p)</td></tr>
<tr><td colspan="3">If the municipal water demand of Sivas Province increases more than 72 hm^3, the system cannot provide the amount of demand in a catastrophic drought

Find other emergency water resources for drought periods.</td></tr>
</table>

* ***EX a*** refers to paragraph **a** of existing conditions assessments in Section 5.2.1.

** ***UD a*** refers to paragraph **a** of upstream development conditions assessments in Section 5.2.2.

5.3. Discussion of the Methodology

This methodology is one of the first attempts in drought risk management for hydraulic structures. However, risk management in hydraulic structures is not a new concept and it has been already in use for floods. Because of the similarities with the hydrological design discharge calculations for structural design such as spillways, tunnels, canals, etc., the methodology proposed in this study is understandable by many water resources engineers. With this methodology, it is possible to operate the structure in order to determine the possible impacts of a severe drought. In addition, without any climate change projections, this methodology also includes climate change impacts on hydraulic structures.

The methodology proposed here can be used by any engineer who has prior experience in flood risk calculations. Detailed knowledge on droughts, drought indices and indicators or calculation process of climate change projections are not required in order to utilize this methodology.

Deficiency hydrograph provides simulating probable droughts in different return periods. Afterwards by using the hydrographs developed by the methodology, it is possible to predict drought impacts on hydraulic structures for different risk levels.

The workflow of the methodology provides assessments for different return periods. With the case study, it is shown that the methodology is functional for all possible return periods. Although the methodology is not used in this study for planning purposes, the methodology can be easily used for dam body selection and dam location selection which is quite similar to use flood frequency analyses in spillway, sluiceway and diversion designs.

No wet period assumption in the study shows that how much time required for the reservoir to refill. This assumption, in fact, is not realistic; however, it is a good way to assess worst-case conditions as the aim of this methodology is to develop drought-resistant operation strategy. In addition, this methodology relies on probabilistic scenarios (which have different return periods and drought severities) instead of modifying the observed data or producing future data with statistical methods. Assessing droughts by only modifying the observed data will eventually have wet periods in the time series as the average of the data is changed. This situation may result reservoirs to react different than they will actually react a highly severe drought event. Therefore, no wet period assumption, which is used in this study, provides better assessment of severe drought impacts.

A comparison of probabilistic scenarios with the historical drought event scenarios shows that return periods longer than 25-years can be called as a catastrophic drought event. While using this methodology, selection of a return period longer than 25-years may result an overdesign issue if lifespan of structure is not very long.

The methodology also includes climate change modifications and it provides climate change assessment without requiring a climate change projection. The methodology provides to develop actions for drought and climate change mitigation in a short span of time with less effort and less cost.

Results of the risk assessment phase for the case study show that it is possible to develop an action program for drought mitigation. With the proposed methodology in this study, it is easy to determine required precautions for increasing adaptive capacity against vulnerabilities thus increasing drought resistance of the hydraulic structure. Especially for basin management studies, decision makers can utilize this study for basin-wide drought risk assessment of the existing structures. It is shown that with an evaluation of the operation studies for catastrophic drought, drought vulnerabilities or adaptive capacities of the structures can easily be detected. With this methodology, drought vulnerability assessment for all country can be developed and the structures which require immediate action for drought preparedness can be determined.

By utilizing this risk assessment methodology, it is possible to reduce costs required for the drought crisis management and increase drought preparedness for hydraulic structures. When an operation or rule curve is available for a hydraulic structure it is easier to adapt drought conditions and reduce the drought impacts.

The risk assessment methodology developed in this study has been utilized for the case study. The results of assessment provide a comprehensive evaluation of the system for drought mitigation issues. After evaluating the results, it is able to develop an action plan for future drought events. In addition to the utilization of methodology, this study also includes a future action plan recommendation for the case study (Table 5.1). If proposed recommendations have been applied, it is shown that there will be no unmet demands for municipal water supply of Sivas Province and Hafik District until 2050s even if a 100-years drought event occurs.

In the case study, WEAP software has been used to develop an operation model and perform operation studies. The usage of WEAP provides good and easily understandable outputs and ability to develop many scenarios. 34 scenarios were developed by using WEAP and the structure of the software simplifies the scenario generation process. After assessing the deficiencies, WEAP software was also used for developing recommendations and actions for the case study. In addition, a manual deficit irrigation scheme based on DSİ criteria was developed in WEAP with a simple programming process. WEAP is very powerful, fast and highly responsive while designing new scenarios with the software. The usage of WEAP is highly recommended for developing new studies with this methodology. However, it is not a strict requirement, other programs or even simple Excel calculations can be also sufficient for the methodology as it is simple and practical.

5.3.1. Limitations

In this section, the limitations of the methodology are evaluated.

Deficiency hydrograph methodology primarily uses deficit amount, deficit length and deficit magnitude parameters as input. In this study, return periods for all individual parameters are kept as the same. Therefore, at the same time, deficit amounts, lengths and magnitudes become more extreme when the return period increased. For example, when deficit amount has 25-years return period, deficit length and deficit magnitude will also have 25-years return period. This situation neglects the possibility of severe short-term or mild long-term drought events. However, the assumption of this study is to consider the most extreme case available in order to examine the required demand is satisfied or not. Consequently, severe short-term or mild long-term drought events are not extreme cases in terms of demand.

On the other hand, in this study, the impacts of consecutive drought events are not evaluated. Extreme cases are available for only a single drought event. There are no drought events which follow another drought event. In this study, instead of evaluating cumulative mild drought events, one severe drought is studied. This study assumes that combination of consecutive drought events can be equivalent to one severe drought event. Therefore, extreme events such as 100-years drought are also considered in this study to compensate this issue.

In the methodology, the trend parameter in climate change modifications is based on the observed data and completely stationary. This approach requires repeating the analysis for the studied area in a few year periods. There are no climate change models or scenarios used in this study to consider future changes in flows. A non-stationary trend approach may provide more robust results. However, another aspect of this study is to keep the methodology as simple as possible. A stationary approach is simple and sufficient to evaluate extreme drought impacts on reservoirs.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

In this study, a practical drought risk assessment methodology for hydraulic structure operation studies was developed and assessed with an example case study. The methodology is simple, accurate and practical. The methodology forms one of the first steps in drought risk management for hydraulic structures.

In the case study, it is shown that the proposed methodology can be used for drought risk assessment for the existing structures. The case study includes future hydraulic structures as well as existing dams. For both cases, the same methodology can be used. The methodology was assessed for 2-, 5-, 10-, 25- , 50- and 100-years return periods and it is shown that the methodology can be used for all return periods. In addition, the methodology includes climate change modifications which provide no climate change projection development in calculations for the future.

A probabilistic scenario development algorithm was developed and tested in this study. The tool is able to develop many different drought scenarios including catastrophic droughts. Deficiency hydrograph is very advantageous in order to develop probabilistic hydrographs which are quite similar to the flood risk assessment and flood risk assessment is well known by authorities. Therefore, the output of deficiency hydrograph is easy to understand by many hydraulic engineers who are working in hydraulic structure design. However, it is in primitive stage and should be developed more.

6.1. Recommendations and Required Further Studies

The methodology proposed in this study is one of the first steps towards drought risk assessment for hydraulic structures. However, the study is in a primitive stage and there are some weaknesses or further study requirements. Recommendations and required further studies are stated below:

- Deficiency hydrograph methodology is in a primitive stage in this study. It should be expanded with different geometrical deficit shapes in further studies. The results of long duration mild droughts and short duration severe droughts should also be evaluated further.
- Consecutive droughts are not studied in this study; only single drought impacts are assessed. The change in the impacts of the multiple consecutive droughts should be compared with the higher return period scenarios. Because the impacts of three consecutive 2-years return period droughts might be equal to 50-years return period. The cumulative impacts of droughts should be studied further.
- In this study, municipal water is the focal point and even though there is irrigation, it is not detailed. In addition, for drought, crop pattern changes and automated operation policies (or rule curves) based on soil humidity should be developed for agricultural drought resistance. In this study, it is shown that the proposed methodology can also be applied for irrigation-based operation policies. However further analysis of agricultural vulnerability is required.
- Another important point is hydropower. The case study provided here does not include any hydropower plants. However, the demand-based approach is still the same and hydropower can also be converted into demand; therefore, the methodology can be applied to any energy reservoir.
- By using the deficiency hydrograph methodology, drought impacts on municipal water, irrigation and hydropower generation should also be studied

further and validity and the improvement of the methodology should be assessed in detail.

- Researchers should give more weight on the design of hydraulic structures based on drought. Usage of the term “design drought” should be included in all practical engineering applications and traditional crisis management approach in hydraulic structures should be replaced with risk management.
- Exceedance probability modification for climate change methodology used in this study (Şen et al., 2017) should be enhanced more and climate change parameter selection algorithms should be developed for more robust climate change predictions. The results of trend analyses were not assessed in this study, more detailed trend analyses and climate change predictions might make the methodology more reliable.
- A drought early warning system based on the relationship between deficiency hydrograph and statistical drought indices can be developed. This will provide a further prediction of droughts and drought impacts before a few months. In this way, it is possible to reduce drought costs caused after the drought period even more.

REFERENCES

Akyürek, Z., & Özkaya, A. (2014). *Kızılırmak Havzasında akım ölçümü yapılmayan akarsu kollarında coğrafi bilgi sistemleri tabanlı akım tahmin modellerinin geliştirilmesi ve ön havza yönetim planının oluşturulması - 3. gelişme ve sonuç raporu.* Ankara: Turkish National Union of Geodesy and Geophysics.

Burn, D. H., Venema, H. D., & Simonovic, S. P. (1990). Risk-based performance criteria for real-time reservoir operation. *Canadian Journal of Civil Engineering, 18*(1), 36-42. doi:10.1139/l91-005

Calvo Gobbetti, L. E. (2017). Application of HEC-ResSim in the study of new water sources in the Panama Canal. *Journal of Applied Water Engineering and Research*. doi:10.1080/23249676.2017.1355759

Cancelliere, A., Ancarani, A., & Rossi, G. (1998). Susceptibility of water supply reservoirs to drought conditions. *Journal of Hydrologic Engineering, 3*(2), 140-148.

Colorado Water Conservation Board. (2013). *Colorado Drought Mitigation and Response Plan.* Colorado Department of Natural Resources, State of Colorado.

Cook, B. I., Mankin, J. S., & Anchukaitis, K. J. (2018). Climate change and drought: from past to future. *Curr Clim Change Rep, 4*(164). doi:10.1007/s40641-018-0093-2

DHI. (2019). *MIKE HYDRO Basin Overview*. Retrieved July 15, 2019, from https://www.mikepoweredbydhi.com/products/mike-hydro-basin

DSİ. (2017). *Stratejik plan 2017-2021.* Ankara: Devlet Su İşleri Strateji Geliştirme Dairesi Başkanlığı.

DSİ. (2019). *Kızılırmak Basin Master Plan Final Report.* Ankara: General Directorate of State Hydraulic Works.

Eris, E., Aksoy, H., Önöz, B., Çetin, M., Yüce, M. İ., Selek, B., . . . Karakuş, E. Ü. (2018). Frequency analysis of low flows in intermittent and non-intermittent rivers from hydrological basins in Turkey. *Water Science & Technology: Water Supply, 19*(1), 30-39. doi:10.2166/ws.2018.051

Farahmand, A., & AghaKouchak, A. (2015). A generalized framework for deriving nonparametric standarized drought indicators. *Advances in Water Resources, 76*, 140-145. doi:10.1016/j.advwatres.2014.11.012

General Directorate of Water Management. (2015). *Konya Basin Drought Management Plan.* Ankara.

Gudmundsson, L., & Seneviratne, S. I. (2016). Anthropogenic climate change affects meteorological drought risk in Europe. *Environ. Res. Lett., 11*. doi:10.1088/1748-9326/11/4/044005

Gusyev, M., Hasegawa, A., Magome, J., Kuribayashi, D., Sawano, H., & Lee, S. (2015). Drought assessment in the Pampanga River basin, the Philippines – Part 1: Characterizing a role of dams in historical droughts with standardized indices. *21st International Congress on Modelling and Simulation*, 1586-1592.

Guttman, N. B. (1998). Comparing the Palmer drought index and the standardized precipitation index. *Journal of the American Water Resources Association, 34*(1), 113-121. doi:10.1111/j.1752-1688.1998.tb05964.x

Guttman, N. B. (1999). Accepting the standardized precipitation index: a calculation algorithm. *Journal of the American Water Resources Association, 35*(2), 311-322. doi:10.1111/j.1752-1688.1999.tb03592.x

Hashimoto, T., Stedinger, J. R., & Loucks, D. P. (1982). Reliability, resiliency, and vulnerability criteria for water resource system performance evaluation. *Water Resour. Res., 18*(1), 14-20. doi:10.1029/WR018i001p00014

He, B., Lv, A., Wu, J., Zhao, L., & Liu, M. (2011). Drought hazard assessment and spatial characteristics analysis in China. *Journal of Geographical Sciences, 21*, 235-249. doi:10.1007/s11442-011-0841-x

Hoerling, M., Eischeid, J., Perlwitz, J., Quan, X., Zhang, T., & Pegion, P. (2012). On the increased frequency of Mediterranean drought. *Journal of Climate, 25*(6), 2146-2161.

ICHARM. (2017). *SRSI*. Retrieved from http://www.icharm.pwri.go.jp

İmamoğlu, B. Y. (2013). *Operation of cascade dams considering various scenarios and financial analysis of scenarios (MSc Thesis).* Middle East Technical University, Ankara.

Integrated Drought Management Program. (2018). *Indicators and Indices*. Retrieved May 3, 2018, from Integrated Drought Management Program: http://www.droughtmanagement.info/indices/

IPCC. (2014). *Fifth Assessment Report: Climate Change 2014.* Geneva: Intergovernmental Panel on Climate Change.

Keenan, S. P., & Krannich, R. S. (1997). The social context of perceived drought vulnerability. *Rural Sociology*, 69-88. doi:10.1111/j.1549-0831.1997.tb00645.x

Kelly, K. (1986). *Reservoir Operation During Drought: Case Studies.* Davis, CA: US Army Corps of Engineers.

Kendall, M. G. (1975). *Rank correlation methods.* New York: Oxford University Press.

Kim, H., Park, J., Yoo, J., & Kim, T. (2013). Assessment of drought hazard, vulnerability, and risk: A case study for administrative districts in South Korea. *Journal of Hydro-environment Research, 9*(1), 28-35. doi:10.1016/j.jher.2013.07.003

Kim, K., Lee, S., & Jin, Y. (2018). Forecasting quarterly inflow to reservoirs combining a Copula-based Bayesian Network method with drought forecasting. *Water, 10*(233).

Langat, P. K., Kumar, L., & Koech, R. (2019). Identification of the most suitable probability distribution models for maximum, minimum and mean streamflow. *Water, 11*(734). doi:10.3390/w11040734

Loon, A. V., Mathijssen, H., & Droogers, P. (2007). *Water evaluation and planning system Gediz Basin - Turkey.* WatManSup Project - WatManSup Report No 5.

Mann, H. B. (1945). Nonparametric tests against trend. *Econometrica, 13*, 245-259.

Mateus, M. C., & Tullos, D. (2016). Reliability, sensitivity, and vulnerability of reservoir operation under climate change. *Journal of Water Resources Planning and Management, 143*(4). doi:10.1061/(ASCE)WR.1943-5452.0000742

McKee, T. B., Doesken, N. J., & Kleist, J. (1993). The relationship of drought frequency and duration to time scales. *Proceedings of the 8th Conference on Applied Climatology* (pp. 179-183). Boston, MA, USA: American Meteorological Society.

McKee, T. B., Doesken, N. J., & Kleist, J. (1995). Drought monitoring with multiple time scales. *Ninth Conference on Applied Climatology.* Boston: American Meteorological Society.

Melo, D., Scanlon, B., Zhang, Z., Wendland, E., & Yin, L. (2016). Reservoir storage and hydrologic responses to droughts in the Parana River basin, south-eastern Brazil. *Hydrol. Earth Syst. Sci., 20*, 4673-4688.

Nalbantis, I., & Tsakiris, G. (2009). Assessment of hydrological drought revisited. *Water Resources Management, 23*(5), 881-897.

National Drought Mitigation Center. (2018a). *Types of Drought*. Retrieved from National Drought Mitigation Center | University of Nebraska-Lincoln: http://drought.unl.edu/DroughtBasics/TypesofDrought.aspx

National Drought Mitigation Center. (2018b). *Program to Calculate Standardized Precipitation Index*. Retrieved May 3, 2018, from The National Drought Mitigation Center | University of Nebraska-Lincoln: http://drought.unl.edu/monitoringtools/downloadablespiprogram.aspx

Ngo, L. A., Masih, I., Jiang, Y., & Douven, W. (2018). Impact of reservoir operation and climate change on the hydrological regime of the Sesan and Srepok Rivers in the Lower Mekong Basin. *Climatic Change, 149*(1), 107-119. doi:10.1007/s10584-016-1875-y

Okyereh, S. A., Ofosu, E. A., & Kabolah, A. T. (2019). Modelling the impact of Bui dam operations on downstream competing water uses. *Water-Energy Nexus, 2*(1), 1-9. doi:10.1016/j.wen.2019.03.001

Özbakır, B. (2009). *Modelling of Seyhan and Ceyhan River Basin with using HEC-ResSim program (MSc Thesis).* Ankara: Gazi University.

Palmer, W. (1965). *Meteorological Drought.* Washington, D.C.: U.S. Department of Commerce - Weather Bureau.

Rajsekhar, D., Singh, V. P., & Mishra, A. K. (2015). Integrated drought causality, hazard, and vulnerability assessment for future socioeconomic scenarios: An information theory perspective. *J. Geophys. Res. Atmos., 120*, 6346-6378. doi:10.1002/2014JD022670.

Santos, R., Fernandes, L. S., Cortes, R., & Pacheco, F. (2018). Analysis of hydrology and water allocation with swat and mike hydro basin in the Sabor River Basin, Portugal. *WIT Transactions on Ecology and the Environment, 215*, 347-355. doi:10.2495/EID180311

Shahid, S., & Behrawan, H. (2008). Drought risk assessment in the western part of Bangladesh. *Natural Hazards, 46*(1), 391-413. doi:10.1007/s11069-007-9191-5

Sheffield, J., & Wood, E. F. (2008). Global trends and variability in soil moisture and drought characteristics, 1950–2000, from observation-driven simulations of the terrestrial hydrologic cycle. *Journal of Climate, 21*(3), 432-458. doi:10.1175/2007JCLI1822.1

Shukla, S., & Wood, A. W. (2008). Use of a standardized runoff index for characterizing hydrologic drought. *Geophys. Res. Lett., 35*(2). doi:10.1029/2007GL032487.

Simonovic, S. P., & Burn, D. H. (1989). An improved methodology for short-term operation of a single multipurpose reservoir. *Water Resour. Res., 25*(1). doi:10.1016/0022-1694(92)90222-H

Sönmez, F. K., Kömüscü, A. Ü., Erkan, A., & Turgu, E. (2005). An analysis of spatial and temporal dimension of drought vulnerability in Turkey using the standardized precipitation index. *Natural Hazards*, *35*(2), 243-264. doi:10.1007/s11069-004-5704-7

Stockholm Environmental Institute. (2018). *WEAP: Water Evaluation and Planning System*. Retrieved October 2018, from http://www.weap21.org

Sung, J. H., Eum, H., Park, J., & Cho, J. (2018). Assessment of climate change impacts on extreme precipitation events: applications of CMIP5 climate projections statistically downscaled over South Korea. *Advances in Meteorology*, 1-12. doi:10.11.55/2018/4720523

Svoboda, M., & Fuchs, B. A. (2016). *Handbook of Drought Indicators and Indices.* Integrated Drought Management Programme (IDMP). World Meteorological Organization (WMO) and Global Water Partnership (GWP).

Şen, Z. (1976). Wet and dry periods of annual flow series. *Journal of the Hydraulics Division, 102*(10), 1503-1514.

Şen, Z. (1977). Run-sums of annual flow series. *Journal of Hydrology, 35*, 311-324.

Şen, Z. (2012). Innovative trend analysis methodology. *J Hydrol Eng, 17*(9), 1042-1046.

Şen, Z. (2015). *Applied Drought Modeling, Prediction and Mitigation.* Elsevier.

Şen, Z. (2017). Innovative trend significance test and applications. *Theoretical and Applied Climatology, 127*(3-4), 939-947.

Şen, Z., Mohorji, A. M., & Almazroui, M. (2017). Engineering risk assessment on water structures under climate change effects. *Arabian Journal of Geosciences, 10*(517).

Türkeş, M. (2017). Türkiye'nin İklimsel Değişkenlik Ve Sosyo-Ekolojik Göstergeler Açısından Kurakliktan Etkilenebilirlik Ve Risk Çözümlemesi. *Ege Coğrafya Dergisi, 26*(2), 47-70.

UNCCD. (1995). *The United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa.* Geneva: United Nations Environment Programme (UNEP).

UNCCD. (2018). *Land and Drought*. Retrieved June 2018, from https://www.unccd.int/issues/land-and-drought

United Nations Office for Disaster Risk Reduction. (2017). *Terminology - UNDRR.* Retrieved August 20, 2019, from https://www.unisdr.org/we/inform/terminology

USACE. (2019). *HEC-ResSim*. Retrieved July 15, 2019, from HEC-ResSim Overview: https://www.hec.usace.army.mil/software/hec-ressim/

Vicente-Serrano, S. M., López-Moreno, J. I., Beguería, S., Lorenzo-Lacruz, J., Azorin-Molina, C., & Morán-Tejeda, E. (2012). Accurate computation of a streamflow drought index. *Journal of Hydrologic Engineering, 17*(2), 318-332.

Wells, N. (2003). *PDSI Users Manual Version 2.0.* University of Nebraska-Lincoln.

Wilhelmi, O. V., & Wilhite, D. A. (2002). Assessing vulnerability to agricultural drought: a nebraska case study. *Natural Hazards, 25*(1), 37-58. doi:10.1023/A:1013388814894

Wilhite, D. A. (1993). The enigma of drought, Chapter 1. In D. A. Wilhite, *Drought Assessment, Management, and Planning: Theory and Case Studies* (pp. 3-15). Boston, MA: Kluwer Academic Publishers. doi:10.1007/978-1-4615-3224-8_1

Wilhite, D. A. (1996). A methodology for drought preparedness. *Natural Hazards, 13*(3), 229-252. doi:10.1007/bf00215817

Wilhite, D. A. (2000). Drought as a natural hazard: Concepts and definitions, Chapter 1. In D. A. Wilhite, *Drought: A global assessment* (Vol. I). London, UK: Routlegde Publishers.

Wilhite, D. A., & Glantz, M. H. (1985). Understanding the drought phenomenon: the role of definitions. *Water International, 10*(3), 111-120.

World Meteorological Organization and Global Water Partnership. (2017). Benefits of action and costs of inaction: Drought mitigation and preparedness - a literature review (N. Gerber and A. Mirzabaev). *Integrated Drought Management Programme Working Paper No. 1*. WMO, Geneva, Switzerland and GWP, Stockholm, Sweeden.

Yang, Y., Disse, M., Yu, R., Yu, G., Sun, L., Huttner, P., & Rumbaur, C. (2015). Large-scale hydrological modeling and decision-making for agricultural water consumption and allocation of Main Stem Tarim River, China. *Water, 7*, 2821-2839. doi:10.3390/w7062821

Yavuz, M. (2011). Planlama Çalışmalarında Su Temini ve Bitki Su İhtiyaçlarının Hesaplanması, Taşkın Hesapları ve İşletme Çalışmalarının Yapılması. *Etüd ve Plan Dairesi Başkanlığı Planlama Semineri* (pp. 121-168). Şanlıurfa: DSİ.

Yevjevich, V. (1967). An objective approach to definitions and investigations of continental hydrologic drought. *Hydrology Paper No. 23 Colorado State University, Fort Collins, Co.*

Yıldırım, A., & Önöz, B. (2015). Trend analiz yöntemleri: Orta Fırat Havzası uygulaması. In K. Yenigün, V. Gümüş, R. Gerger, M. H. Aydoğdu, & M. Y. Sepetçioğlu (Ed.), *VIII. Ulusal Hidroloji Kongresi Bildiriler Kitabı* (pp. 320-329). Şanlıurfa: Harran Üniversitesi.

Yue, S., & Wang, C. Y. (2002). Applicability of prewhitening to eliminate the influence of serial correlation on the Mann-Kendall test. *Water Resources Research, 38*(6), 4-1-4-7. doi:10.1029/2001wr000861

Zhang, Q., Peng, S., Li, J., Mingzhong, X., & Singh, V. (2014). Assessment of drought vulnerability of the Tarim River basin, Xinjiang, China. *Theoretical and Applied Climatology, 121*, 337-347. doi:10.1007/s00704-014-1234-8

APPENDICES

A. Goodness-of-fit Calculations for Deficit Quantities

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,0692	1,0837	-	0,9735	0,0032	**Weibull**
Log-Normal	0,5468	0,8267	-	0,9584	0,0038	
Gumbel	3,0463	1,6987	-	0,9125	0,0067	
Pearson Type III	0,0963	1,0824	1,5081	0,9727	0,0037	
Weibull	**2,4981**	**1,5484**	**-**	**0,9754**	**0,0028**	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2880	4,6672	-	0,8596	0,0142	**Log-Normal**
Log-Normal	**1,3577**	**0,9981**	**-**	**0,8959**	**0,0094**	
Gumbel	9,4370	7,1523	-	0,6630	0,0242	
Pearson Type III	4,9351	0,7946	1,7507	0,8791	0,0206	
Weibull	6,2219	1,0809	-	0,8574	0,0120	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,9023	9,4346	-	0,8160	0,0151	**Pearson Type III**
Log-Normal	1,4939	1,1212	-	0,8683	0,0090	
Gumbel	16,3687	18,6533	-	0,4273	0,0403	
Pearson Type III	**0,5508**	**2,8608**	**3,2177**	**0,8913**	**0,0077**	
Weibull	7,7338	0,8636	-	0,8275	0,0124	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8415	18,1302	-	0,9864	0,0019	**Weibull**
Log-Normal	2,0243	1,4105	-	0,9814	0,0019	
Gumbel	25,2653	22,6606	-	0,7580	0,0179	
Pearson Type III	0,6862	6,1808	5,5062	0,9889	0,0022	
Weibull	**14,2880**	**0,8810**	**-**	**0,9881**	**0,0016**	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,3312	5,9107	-	0,8996	0,0095	**Pearson Type III**
Log-Normal	1,6424	1,3942	-	0,7973	0,0169	
Gumbel	10,3031	4,9852	-	0,9356	0,0050	
Pearson Type III	**-0,1556**	**4,2633**	**5,9742**	**0,9651**	**0,0031**	
Weibull	8,4553	1,4109	-	0,9297	0,0065	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,0732	2,6341	-	0,9504	0,0064	**Gumbel**
Log-Normal	0,5056	1,3420	-	0,9013	0,0091	
Gumbel	**3,9381**	**2,2150**	**-**	**0,9527**	**0,0038**	
Pearson Type III	-0,0430	1,7809	1,8509	0,9712	0,0049	
Weibull	2,9305	1,1178	-	0,9563	0,0064	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,4853	1,4519	-	0,8419	0,0181	**Gumbel**
Log-Normal	0,3956	1,1370	-	0,8182	0,0160	
Gumbel	**2,7898**	**1,1024**	**-**	**0,9229**	**0,0090**	
Pearson Type III	-0,7186	1,5585	1,9828	0,9199	0,0090	
Weibull	2,3519	1,4485	-	0,8524	0,0189	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,5240	8,6193	-	0,9012	0,0204	**Log-Normal**
Log-Normal	**0,3042**	**2,0287**	**-**	**0,9611**	**0,0080**	
Gumbel	7,4907	5,6287	-	0,7771	0,0271	
Pearson Type III	5,4853	1,2555	0,4617	0,9471	0,0278	
Weibull	3,1856	0,6340	-	0,9202	0,0174	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,2861	14,0010	-	0,7798	0,0289	**Log-Normal**
Log-Normal	**-1,0410**	**3,0525**	**-**	**0,8042**	**0,0179**	
Gumbel	6,9586	5,5905	-	0,7511	0,0289	
Pearson Type III	5,5577	0,0218	0,0536	0,9821	0,0211	
Weibull	1,3192	0,4011	-	0,7891	0,0262	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,9213	3,1718	-	0,8634	0,0171	
Log-Normal	**0,4397**	**1,2459**	**-**	**0,9281**	**0,0081**	
Gumbel	4,7793	3,7338	-	0,6902	0,0254	**Log-Normal**
Pearson Type III	3,9829	0,1402	0,5497	0,8377	0,0161	
Weibull	2,7506	0,8975	-	0,8741	0,0133	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,0537	1,9330	-	0,9408	0,0064	
Log-Normal	**0,1668**	**1,0562**	**-**	**0,9768**	**0,0029**	
Gumbel	3,4647	3,2459	-	0,6621	0,0237	**Log-Normal**
Pearson Type III	1,4233	0,4370	0,5930	0,9642	0,0042	
Weibull	1,9916	0,9586	-	0,9453	0,0045	

Pusat Özen Dam - Deficit Amounts goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,8957	1,2558	-	0,9658	0,0039	
Log-Normal	**0,5810**	**0,7900**	**-**	**0,9810**	**0,0022**	
Gumbel	3,4761	2,4653	-	0,8151	0,0143	**Log-Normal**
Pearson Type III	0,4905	0,8830	1,3143	0,9830	0,0026	
Weibull	2,6205	1,3539	-	0,9612	0,0033	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,6622	1,0518	-	0,9552	0,0053	
Log-Normal	0,8302	0,6760	-	0,9481	0,0055	
Gumbel	3,7691	2,0763	-	0,8839	0,0088	**Weibull**
Pearson Type III	0,3929	1,0370	1,7639	0,9352	0,0078	
Weibull	**3,1573**	**1,6854**	**-**	**0,9548**	**0,0044**	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,0609	6,2212	-	0,9183	0,0097	**Log-Normal**
Log-Normal	**1,3467**	**1,1395**	**-**	**0,9677**	**0,0041**	
Gumbel	10,6860	8,5404	-	0,6708	0,0236	
Pearson Type III	1,1101	1,8059	2,1311	0,9658	0,0057	
Weibull	6,5206	0,9761	-	0,9229	0,0075	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,1724	2,2177	-	0,6302	0,0307	**Log-Normal**
Log-Normal	**0,4718**	**0,8286**	**-**	**0,7129**	**0,0220**	
Gumbel	4,8970	5,4610	-	0,3815	0,0437	
Pearson Type III	1,8197	0,0000	1,0000	0,7273	0,0827	
Weibull	2,5279	0,9549	-	0,6285	0,0265	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2382	2,2613	-	0,7565	0,0209	**Weibull**
Log-Normal	0,5743	0,8750	-	0,7802	0,0181	
Gumbel	4,8940	4,9053	-	0,5367	0,0327	
Pearson Type III	3,9218	0,0431	1,0110	0,7529	0,0731	
Weibull	**2,8130**	**1,0088**	**-**	**0,7532**	**0,0179**	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,0881	0,7360	-	0,8897	0,0115	**Log-Normal**
Log-Normal	**0,6504**	**0,6085**	**-**	**0,8981**	**0,0100**	
Gumbel	2,9968	1,4490	-	0,8062	0,0159	
Pearson Type III	5,1155	0,6910	1,1351	0,7806	0,0400	
Weibull	2,5767	1,8089	-	0,8794	0,0112	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,8042	0,8559	-	0,9171	0,0108	**Log-Normal**
Log-Normal	**0,6867**	**0,6571**	**-**	**0,9147**	**0,0099**	
Gumbel	3,1441	1,4289	-	0,8855	0,0105	
Pearson Type III	3,4615	0,0031	1,0009	0,7474	0,0627	
Weibull	2,7160	1,7895	-	0,9165	0,0101	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,9564	0,9689	-	0,9013	0,0095	**Gumbel**
Log-Normal	1,2121	0,6382	-	0,8485	0,0115	
Gumbel	**4,5783**	**1,3054**	**-**	**0,9679**	**0,0047**	
Pearson Type III	-0,7534	1,8829	3,6546	0,9510	0,0062	
Weibull	4,2978	2,6837	-	0,9477	0,0068	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8269	9,6750	-	0,9300	0,0184	**Log-Normal**
Log-Normal	**1,3648**	**1,5155**	**-**	**0,9762**	**0,0070**	
Gumbel	12,5026	8,5072	-	0,8059	0,0250	
Pearson Type III	5,3267	1,4665	1,2753	0,9004	0,0248	
Weibull	7,3782	0,8613	-	0,9377	0,0163	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,6040	12,6939	-	0,7500	0,0321	**Log-Normal**
Log-Normal	**1,0148**	**1,7578**	**-**	**0,7500**	**0,0215**	
Gumbel	12,6579	9,4502	-	0,7500	0,0290	
Pearson Type III	16,6321	0,0000	1,0000	0,7500	0,1044	
Weibull	5,8981	0,6951	-	0,7500	0,0290	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,0833	6,0004	-	0,9088	0,0127	**Log-Normal**
Log-Normal	**1,3438**	**1,1916**	**-**	**0,9533**	**0,0058**	
Gumbel	10,1656	7,3509	-	0,7208	0,0232	
Pearson Type III	5,2621	2,6571	1,5049	0,7883	0,0240	
Weibull	6,5048	1,0016	-	0,9119	0,0108	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,1504	2,6078	-	0,6967	0,0284	**Weibull**
Log-Normal	0,6047	0,9652	-	0,7037	0,0263	
Gumbel	4,9086	4,1204	-	0,6319	0,0269	
Pearson Type III	4,3921	0,0938	1,0213	0,6893	0,0996	
Weibull	**3,0010**	**1,0006**	**-**	**0,6967**	**0,0247**	

Pusat Özen Dam - Deficit Lengths goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,3226	1,0959	-	0,9253	0,0070	**Log-Normal**
Log-Normal	**0,7039**	**0,6820**	**-**	**0,9307**	**0,0063**	
Gumbel	3,6747	2,5828	-	0,7620	0,0181	
Pearson Type III	4,9304	0,2321	1,0471	0,7769	0,0303	
Weibull	2,8410	1,4561	-	0,9165	0,0064	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,8804	0,2322	-	0,9457	0,0056	**Pearson Type III**
Log-Normal	0,0193	0,5469	-	0,9145	0,0073	
Gumbel	1,3343	0,3443	-	0,9875	0,0029	
Pearson Type III	**-0,7785**	**0,5059**	**1,0899**	**0,9833**	**0,0028**	
Weibull	1,2673	3,0107	-	0,9743	0,0042	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	37,3076	0,0385	-	0,8406	0,0207	**Log-Normal**
Log-Normal	**0,3499**	**0,1868**	**-**	**0,8430**	**0,0157**	
Gumbel	1,5438	0,1650	-	0,8532	0,0228	
Pearson Type III	-1,0549	0,1896	1,4738	0,9134	0,0280	
Weibull	1,5327	8,3636	-	0,8474	0,0233	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,9202	1,3441	-	0,9123	0,0079	**Pearson Type III**
Log-Normal	1,1865	0,7364	-	0,8629	0,0111	
Gumbel	4,8607	1,8019	-	0,9563	0,0033	
Pearson Type III	**-0,3180**	**1,9010**	**3,2956**	**0,9662**	**0,0030**	
Weibull	4,4050	2,1561	-	0,9470	0,0050	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,7495	4,1746	-	0,8972	0,0106	**Gumbel**
Log-Normal	1,6761	1,0449	-	0,8474	0,0126	
Gumbel	**9,1825**	**3,1459**	**-**	**0,9756**	**0,0052**	
Pearson Type III	-1,1016	5,0810	7,7067	0,9660	0,0057	
Weibull	8,0516	1,6812	-	0,9225	0,0096	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,6769	2,9115	-	0,8870	0,0116	**Pearson Type III**
Log-Normal	1,2587	1,2296	-	0,7633	0,0198	
Gumbel	5,9833	1,9464	-	0,9884	0,0019	
Pearson Type III	**-0,5492**	**2,5417**	**4,3762**	**0,9901**	**0,0017**	
Weibull	5,3164	1,7923	-	0,9451	0,0064	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,7091	0,8814	-	0,8835	0,0118	**Gumbel**
Log-Normal	0,0895	1,0345	-	0,8191	0,0154	
Gumbel	**1,9084**	**0,6946**	**-**	**0,9784**	**0,0039**	
Pearson Type III	-1,0619	1,2602	1,4655	0,9489	0,0049	
Weibull	1,6597	1,6370	-	0,9183	0,0096	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,6659	0,2900	-	0,8604	0,0181	**Log-Normal**
Log-Normal	**-0,4565**	**0,7587**	**-**	**0,8447**	**0,0157**	
Gumbel	0,9632	0,3077	-	0,8939	0,0173	
Pearson Type III	-1,1846	0,6026	0,6694	0,9270	0,0204	
Weibull	0,8719	2,0169	-	0,8734	0,0189	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,6880	0,3611	-	0,7531	0,0328	**Log-Normal**
Log-Normal	**-0,8196**	**1,1502**	**-**	**0,7524**	**0,0213**	
Gumbel	0,7668	0,2316	-	0,7585	0,0360	
Pearson Type III	-5,1610	0,1911	0,8217	0,9869	0,0230	
Weibull	0,6731	1,6026	-	0,7537	0,0364	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8294	0,3417	-	0,8246	0,0267	**Log-Normal**
Log-Normal	**-1,9730**	**1,4456**	**-**	**0,8588**	**0,0144**	
Gumbel	0,4491	0,3137	-	0,7693	0,0276	
Pearson Type III	5,2219	0,0071	0,0511	0,9157	0,0217	
Weibull	0,2589	0,8532	-	0,8301	0,0233	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	5,2600	0,1261	-	0,6454	0,0333	**Pearson Type III**
Log-Normal	-0,5084	0,5680	-	0,6374	0,0278	
Gumbel	0,7621	0,1342	-	0,7084	0,0321	
Pearson Type III	**-1,1675**	**0,0729**	**0,7551**	**0,9580**	**0,0267**	
Weibull	0,7390	3,5873	-	0,6663	0,0357	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,7934	0,1729	-	0,9461	0,0082	**Log-Normal**
Log-Normal	**-0,2957**	**0,5113**	**-**	**0,9469**	**0,0064**	
Gumbel	1,0083	0,3209	-	0,9274	0,0094	
Pearson Type III	-0,5977	0,4077	0,7586	0,9328	0,0099	
Weibull	0,9380	2,5513	-	0,9430	0,0089	

Pusat Özen Dam - Deficit Magnitudes goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	7,6488	0,1519	-	0,9549	0,0056	**Gumbel**
Log-Normal	0,0830	0,4010	-	0,9414	0,0059	
Gumbel	**1,3538**	**0,3507**	**-**	**0,9817**	**0,0023**	
Pearson Type III	-0,4229	0,4118	1,0501	0,9809	0,0030	
Weibull	1,2973	3,3834	-	0,9748	0,0040	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	**3,6385**	**0,2390**	-	**0,9685**	**0,0036**	**2-Parameter Gamma**
Log-Normal	-0,2834	0,6333	-	0,9497	0,0044	
Gumbel	1,0636	0,3462	-	0,9442	0,0071	
Pearson Type III	-1,0780	0,5734	0,8920	0,8999	0,0114	
Weibull	0,9797	2,3710	-	0,9719	0,0043	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	14,4766	0,0723	-	0,8584	0,0153	**Pearson Type III**
Log-Normal	0,0110	0,2857	-	0,8659	0,0119	
Gumbel	1,2081	0,3279	-	0,7817	0,0167	
Pearson Type III	**1,1508**	**0,0838**	**0,8466**	**0,9411**	**0,0077**	
Weibull	1,1600	3,6390	-	0,8268	0,0143	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,5389	0,9104	-	0,9142	0,0075	**Pearson Type III**
Log-Normal	1,0221	0,6544	-	0,8733	0,0102	
Gumbel	3,9336	1,3602	-	0,9440	0,0043	
Pearson Type III	**-0,3356**	**1,4621**	**2,7538**	**0,9545**	**0,0039**	
Weibull	3,6200	2,3810	-	0,9440	0,0051	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,2645	2,3853	-	0,8788	0,0116	**Pearson Type III**
Log-Normal	1,4500	0,9047	-	0,8204	0,0145	
Gumbel	6,5845	1,9397	-	0,9859	0,0039	
Pearson Type III	**-1,0826**	**3,2281**	**5,5453**	**0,9821**	**0,0032**	
Weibull	6,0037	2,0611	-	0,9230	0,0091	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,6052	2,3666	-	0,9270	0,0074	**Pearson Type III**
Log-Normal	0,9920	1,1867	-	0,8446	0,0133	
Gumbel	4,8347	1,9214	-	0,9692	0,0032	
Pearson Type III	**-0,3898**	**2,1505**	**3,1748**	**0,9821**	**0,0027**	
Weibull	4,1496	1,6050	-	0,9568	0,0048	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,7801	0,6368	-	0,9631	0,0050	**Weibull**
Log-Normal	-0,1810	0,9440	-	0,9277	0,0068	
Gumbel	1,4974	0,6702	-	0,9399	0,0069	
Pearson Type III	-0,2845	0,6912	0,8813	0,9647	0,0060	
Weibull	**1,2531**	**1,5260**	**-**	**0,9709**	**0,0049**	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,4164	0,1126	-	0,8270	0,0210	**Pearson Type III**
Log-Normal	-0,8165	0,5702	-	0,8106	0,0187	
Gumbel	0,5930	0,1515	-	0,9143	0,0143	
Pearson Type III	**-1,1329**	**0,2121**	**0,5258**	**0,9678**	**0,0105**	
Weibull	0,5607	2,7617	-	0,8567	0,0204	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,3740	0,3783	-	0,8758	0,0233	**Gumbel**
Log-Normal	-1,0606	1,3050	-	0,8469	0,0152	
Gumbel	**0,6738**	**0,2507**	**-**	**0,9879**	**0,0151**	
Pearson Type III	-1,1993	0,4783	0,4599	0,9925	0,0230	
Weibull	0,5624	1,3667	-	0,8888	0,0249	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,9852	0,2336	-	0,8348	0,0260	**Log-Normal**
Log-Normal	**-2,0558**	**1,3038**	**-**	**0,8692**	**0,0138**	
Gumbel	0,3561	0,2383	-	0,7753	0,0272	
Pearson Type III	5,2853	0,0147	0,0525	0,9241	0,0218	
Weibull	0,2241	0,9480	-	0,8383	0,0228	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,7615	0,1237	-	0,9720	0,0080	**Log-Normal**
Log-Normal	**-0,9041**	**0,6417**	**-**	**0,9504**	**0,0061**	
Gumbel	0,5802	0,2165	-	0,9291	0,0098	
Pearson Type III	-0,2072	0,2084	0,3781	0,9782	0,0079	
Weibull	0,5268	2,2202	-	0,9775	0,0076	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,9666	0,1442	-	0,9641	0,0050	**Log-Normal**
Log-Normal	**-0,4379**	**0,4770**	**-**	**0,9786**	**0,0029**	
Gumbel	0,8981	0,3650	-	0,8465	0,0124	
Pearson Type III	0,3626	0,1986	0,5215	0,9871	0,0030	
Weibull	0,8131	2,2749	-	0,9392	0,0059	

Pusat Özen Dam - Deficit Intensities goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	9,0138	0,1038	-	0,9773	0,0023	**Pearson Type III**
Log-Normal	-0,1229	0,3427	-	0,9842	0,0014	
Gumbel	1,1259	0,4240	-	0,8527	0,0118	
Pearson Type III	**0,1374**	**0,2219**	**0,7737**	**0,9917**	**0,0010**	
Weibull	1,0498	2,8175	-	0,9447	0,0045	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7267	6,6539	-	0,9433	0,0056	**Pearson Type III**
Log-Normal	0,7486	2,0351	-	0,8381	0,0124	
Gumbel	7,1447	4,5460	-	0,8204	0,0155	
Pearson Type III	**0,3768**	**2,4509**	**2,3530**	**0,9687**	**0,0043**	
Weibull	4,5604	0,8627	-	0,9493	0,0051	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,9442	6,1760	-	0,9675	0,0047	**Log-Normal**
Log-Normal	**1,1478**	**1,2658**	**-**	**0,9833**	**0,0022**	
Gumbel	9,3547	7,6073	-	0,7812	0,0154	
Pearson Type III	0,7676	2,1755	2,0760	0,9831	0,0032	
Weibull	5,6463	0,9366	-	0,9703	0,0039	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7128	16,3176	-	0,9652	0,0040	**Log-Normal**
Log-Normal	**1,6078**	**1,3951**	**-**	**0,9857**	**0,0018**	
Gumbel	21,7788	24,2591	-	0,6301	0,0280	
Pearson Type III	1,1722	3,1626	2,6311	0,9724	0,0032	
Weibull	9,7871	0,7744	-	0,9746	0,0023	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,4745	16,5369	-	0,9547	0,0047	**Log-Normal**
Log-Normal	**2,8179**	**0,8784**	**-**	**0,9748**	**0,0026**	
Gumbel	38,6339	32,7472	-	0,7061	0,0215	
Pearson Type III	0,8321	7,4248	10,7397	0,9593	0,0046	
Weibull	25,8257	1,1505	-	0,9505	0,0039	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,7735	2,5008	-	0,9076	0,0080	**Pearson Type III**
Log-Normal	1,7457	0,7230	-	0,8714	0,0108	
Gumbel	8,8507	4,0455	-	0,9291	0,0060	
Pearson Type III	**-0,1462**	**3,3416**	**5,4389**	**0,9405**	**0,0048**	
Weibull	7,8014	1,9489	-	0,9298	0,0058	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,1772	1,3731	-	0,9586	0,0070	**Log-Normal**
Log-Normal	**0,8482**	**0,8133**	**-**	**0,9530**	**0,0056**	
Gumbel	3,8902	1,6094	-	0,9416	0,0083	
Pearson Type III	-1,0993	2,8096	2,9343	0,9112	0,0098	
Weibull	3,3491	1,6833	-	0,9596	0,0077	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,0416	2,0588	-	0,8088	0,0183	**Log-Normal**
Log-Normal	**0,2114**	**1,0770**	**-**	**0,8749**	**0,0105**	
Gumbel	3,5794	3,0111	-	0,6146	0,0276	
Pearson Type III	5,2035	0,4580	0,5471	0,7838	0,0187	
Weibull	2,0809	0,9464	-	0,8164	0,0142	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7550	3,3609	-	0,8569	0,0177	**Log-Normal**
Log-Normal	**0,1391**	**1,4084**	**-**	**0,9189**	**0,0089**	
Gumbel	4,2843	3,5132	-	0,6816	0,0261	
Pearson Type III	5,0986	0,5647	0,4634	0,9241	0,0174	
Weibull	2,1925	0,7975	-	0,8729	0,0137	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7662	3,2888	-	0,9030	0,0145	**Log-Normal**
Log-Normal	**0,1451**	**1,4353**	**-**	**0,9536**	**0,0070**	
Gumbel	4,1890	3,3493	-	0,7106	0,0240	
Pearson Type III	5,2488	1,1165	0,5200	0,9171	0,0231	
Weibull	2,2114	0,8096	-	0,9161	0,0114	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,5854	2,5038	-	0,9721	0,0049	**Log-Normal**
Log-Normal	**-0,6769**	**1,7606**	**-**	**0,9808**	**0,0034**	
Gumbel	2,4528	2,0311	-	0,7476	0,0197	
Pearson Type III	4,5163	0,3853	0,1308	0,8679	0,0128	
Weibull	1,1485	0,6924	-	0,9782	0,0043	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,1460	3,6515	-	0,6667	0,0306	**Pearson Type III**
Log-Normal	0,9355	0,9427	-	0,7211	0,0233	
Gumbel	6,9186	5,8050	-	0,5763	0,0325	
Pearson Type III	**1,0946**	**0,6565**	**1,5610**	**0,8965**	**0,0080**	
Weibull	4,1611	0,9892	-	0,6720	0,0259	

Beydilli Dam - Deficit Amounts goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2143	3,9755	-	0,8844	0,0120	**Pearson Type III**
Log-Normal	1,1091	0,9819	-	0,9363	0,0065	
Gumbel	7,5881	5,7086	-	0,6916	0,0241	
Pearson Type III	**1,1706**	**1,1152**	**1,7041**	**0,9785**	**0,0031**	
Weibull	4,9372	1,0505	-	0,8854	0,0100	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,1510	1,6852	-	0,9650	0,0055	**Log-Normal**
Log-Normal	**1,0378**	**0,7848**	**-**	**0,9645**	**0,0044**	
Gumbel	4,9211	2,5439	-	0,8611	0,0120	
Pearson Type III	0,3562	1,5013	2,1888	0,9630	0,0057	
Weibull	4,0512	1,5479	-	0,9595	0,0055	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,3059	2,8715	-	0,8652	0,0166	**Gumbel**
Log-Normal	0,8924	1,0096	-	0,8606	0,0153	
Gumbel	**5,4856**	**3,4404**	**-**	**0,8411**	**0,0132**	
Pearson Type III	4,8646	0,0175	1,0036	0,7825	0,0518	
Weibull	3,9492	1,1458	-	0,8659	0,0154	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,4750	0,8418	-	0,8535	0,0128	**Weibull**
Log-Normal	0,5185	0,6335	-	0,8595	0,0122	
Gumbel	3,0488	2,2640	-	0,6928	0,0234	
Pearson Type III	4,7115	0,1039	1,0220	0,7920	0,0507	
Weibull	**2,3293**	**1,4539**	**-**	**0,8431**	**0,0117**	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2382	2,2613	-	0,7565	0,0209	**Weibull**
Log-Normal	0,5743	0,8750	-	0,7802	0,0181	
Gumbel	4,8940	4,9053	-	0,5367	0,0327	
Pearson Type III	3,9218	0,0431	1,0110	0,7529	0,0731	
Weibull	**2,8130**	**1,0088**	**-**	**0,7532**	**0,0179**	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,9117	0,4720	-	0,8440	0,0144	**Weibull**
Log-Normal	0,4799	0,5206	-	0,8461	0,0141	
Gumbel	2,4102	1,1872	-	0,7486	0,0192	
Pearson Type III	2,8527	0,0002	1,0001	0,7541	0,0752	
Weibull	**2,0986**	**1,9497**	**-**	**0,8338**	**0,0134**	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,4978	0,6988	-	0,8741	0,0133	**Gumbel**
Log-Normal	0,7441	0,6037	-	0,8640	0,0134	
Gumbel	**3,0982**	**1,3154**	**-**	**0,8638**	**0,0099**	
Pearson Type III	-0,0684	1,0679	1,8841	0,8776	0,0129	
Weibull	2,7704	2,0783	-	0,8811	0,0116	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,3504	3,8507	-	0,9045	0,0104	**Log-Normal**
Log-Normal	**1,2348**	**1,0043**	**-**	**0,9409**	**0,0058**	
Gumbel	7,9929	5,8161	-	0,6897	0,0223	
Pearson Type III	0,8009	1,6966	2,2028	0,9457	0,0074	
Weibull	5,4561	1,1242	-	0,9012	0,0090	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8188	7,3275	-	0,8728	0,0170	
Log-Normal	**1,0692**	**1,3788**	**-**	**0,8969**	**0,0111**	
Gumbel	9,8310	7,6737	-	0,7185	0,0235	**Log-Normal**
Pearson Type III	3,9339	0,1836	1,0466	0,8442	0,0502	
Weibull	5,4336	0,8442	-	0,8791	0,0144	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8341	7,4927	-	0,8933	0,0161	
Log-Normal	**1,1250**	**1,4003**	**-**	**0,8997**	**0,0116**	
Gumbel	10,0283	7,5239	-	0,7571	0,0209	**Log-Normal**
Pearson Type III	3,6859	0,1668	1,0451	0,8354	0,0527	
Weibull	5,7528	0,8611	-	0,8958	0,0144	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,6412	1,8957	-	0,9035	0,0115	
Log-Normal	**0,8004**	**0,8627**	**-**	**0,9088**	**0,0100**	
Gumbel	4,4891	2,7650	-	0,8103	0,0154	**Log-Normal**
Pearson Type III	3,9706	0,0011	1,0003	0,7686	0,0627	
Weibull	3,3827	1,2818	-	0,9010	0,0103	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8836	3,7724	-	0,5281	0,0440	
Log-Normal	0,5408	1,0752	-	0,5272	0,0408	
Gumbel	**5,8047**	**5,2098**	**-**	**0,5323**	**0,0368**	**Gumbel**
Pearson Type III	4,2971	0,0892	1,0207	0,5262	0,1523	
Weibull	3,0178	0,8562	-	0,5283	0,0385	

Beydilli Dam - Deficit Lengths goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2252	2,8114	-	0,8227	0,0184	
Log-Normal	0,7761	0,9898	-	0,8263	0,0171	
Gumbel	5,3000	3,7674	-	0,7295	0,0217	**Weibull**
Pearson Type III	3,0252	0,0001	1,0000	0,7531	0,0782	
Weibull	**3,5454**	**1,0682**	**-**	**0,8221**	**0,0164**	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2866	1,2383	-	0,5017	0,0417	**Pearson Type III**
Log-Normal	0,0293	1,5972	-	0,4325	0,0420	
Gumbel	1,8251	0,3225	-	0,9314	0,0069	
Pearson Type III	**-1,2371**	**0,5696**	**1,6405**	**0,9252**	**0,0057**	
Weibull	1,6884	1,7240	-	0,5793	0,0368	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,3014	0,4295	-	0,8234	0,0149	**Gumbel**
Log-Normal	0,4930	0,6270	-	0,7553	0,0185	
Gumbel	**2,1297**	**0,4369**	**-**	**0,9547**	**0,0065**	
Pearson Type III	-1,2596	0,5173	2,1010	0,9174	0,0188	
Weibull	2,0442	3,2979	-	0,9049	0,0102	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,4270	3,8990	-	0,9731	0,0044	**Pearson Type III**
Log-Normal	1,3266	1,0519	-	0,9462	0,0058	
Gumbel	7,6105	3,8718	-	0,9378	0,0062	
Pearson Type III	**-0,0231**	**3,2797**	**3,6994**	**0,9781**	**0,0043**	
Weibull	6,0118	1,3070	-	0,9776	0,0043	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	6,9230	1,8165	-	0,7843	0,0215	**Pearson Type III**
Log-Normal	2,4578	0,4374	-	0,7705	0,0208	
Gumbel	14,4192	2,7712	-	0,8757	0,0150	
Pearson Type III	**-1,1994**	**4,6193**	**12,7296**	**0,9505**	**0,0061**	
Weibull	13,9890	3,8234	-	0,8221	0,0204	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,5128	1,0625	-	0,9063	0,0080	
Log-Normal	1,4527	0,5511	-	0,8780	0,0100	
Gumbel	5,7869	1,9262	-	0,9226	0,0059	**Pearson Type III**
Pearson Type III	**-0,3004**	**1,9894**	**4,1148**	**0,9372**	**0,0050**	
Weibull	5,3901	2,6209	-	0,9314	0,0057	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,9497	0,3322	-	0,9763	0,0044	
Log-Normal	**0,3929**	**0,5118**	**-**	**0,9687**	**0,0037**	
Gumbel	1,9867	0,6218	-	0,9684	0,0047	**Log-Normal**
Pearson Type III	-0,4696	0,7318	1,4658	0,9762	0,0051	
Weibull	1,8560	2,6458	-	0,9809	0,0045	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	6,5194	0,0909	-	0,9709	0,0052	
Log-Normal	**-0,6017**	**0,4433**	**-**	**0,9733**	**0,0034**	
Gumbel	0,7201	0,2552	-	0,8628	0,0109	**Log-Normal**
Pearson Type III	0,0819	0,1768	0,4753	0,9792	0,0048	
Weibull	0,6690	2,6563	-	0,9458	0,0060	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	20,2133	0,0230	-	0,9653	0,0105	
Log-Normal	**-0,7912**	**0,2547**	**-**	**0,9719**	**0,0058**	
Gumbel	0,5206	0,1074	-	0,9028	0,0119	**Log-Normal**
Pearson Type III	0,6556	0,0558	0,3921	0,9816	0,0087	
Weibull	0,5081	4,6490	-	0,9370	0,0102	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	18,5011	0,0250	-	0,9455	0,0100	
Log-Normal	-0,7987	0,2770	-	0,9292	0,0075	
Gumbel	**0,5116**	**0,0859**	**-**	**0,9765**	**0,0075**	**Gumbel**
Pearson Type III	-1,2949	0,1515	0,4759	0,8619	0,0212	
Weibull	0,5029	5,4185	-	0,9762	0,0081	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,1770	0,3680	-	0,9195	0,0111	**Gumbel**
Log-Normal	-1,3183	1,2191	-	0,8885	0,0119	
Gumbel	**0,5893**	**0,2801**	**-**	**0,9598**	**0,0060**	
Pearson Type III	-0,5488	0,3472	0,3641	0,9620	0,0068	
Weibull	0,4563	1,1816	-	0,9247	0,0116	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	37,2557	0,0442	-	0,9231	0,0075	**Pearson Type III**
Log-Normal	0,4845	0,1796	-	0,9130	0,0074	
Gumbel	1,7613	0,1883	-	0,9481	0,0075	
Pearson Type III	**-1,3051**	**0,3745**	**1,6282**	**0,9516**	**0,0070**	
Weibull	1,7487	8,5462	-	0,9469	0,0073	

Beydilli Dam - Deficit Magnitudes goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	13,1392	0,1380	-	0,9167	0,0096	**Pearson Type III**
Log-Normal	0,5567	0,3075	-	0,9074	0,0089	
Gumbel	2,0293	0,3525	-	0,9587	0,0073	
Pearson Type III	**-1,0743**	**0,5369**	**1,8589**	**0,9691**	**0,0059**	
Weibull	1,9883	4,8961	-	0,9425	0,0089	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,3319	0,8559	-	0,7168	0,0247	**Pearson Type III**
Log-Normal	-0,2892	1,4907	-	0,5961	0,0297	
Gumbel	1,3601	0,3365	-	0,9630	0,0064	
Pearson Type III	**-1,1635**	**0,5804**	**1,1295**	**0,9866**	**0,0048**	
Weibull	1,2196	1,6382	-	0,7999	0,0190	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,6340	0,3115	-	0,9427	0,0060	**Gumbel**
Log-Normal	0,2554	0,5703	-	0,9020	0,0080	
Gumbel	**1,7051**	**0,4499**	**-**	**0,9935**	**0,0027**	
Pearson Type III	-1,0691	0,8124	1,4203	0,9469	0,0054	
Weibull	1,6153	2,9310	-	0,9801	0,0039	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,6558	2,5004	-	0,9486	0,0062	**Gumbel**
Log-Normal	1,0893	0,9919	-	0,9116	0,0083	
Gumbel	**5,4719**	**2,5592**	**-**	**0,9720**	**0,0025**	
Pearson Type III	-0,2324	2,4979	3,1502	0,9765	0,0037	
Weibull	4,5510	1,4838	-	0,9606	0,0056	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	8,5258	1,1739	-	0,9707	0,0052	**Log-Normal**
Log-Normal	**2,2436**	**0,3704**	**-**	**0,9720**	**0,0040**	
Gumbel	11,7101	3,1113	-	0,9369	0,0075	
Pearson Type III	-0,3478	3,3501	8,9282	0,9592	0,0069	
Weibull	11,1948	3,3272	-	0,9628	0,0059	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,5223	0,8794	-	0,9710	0,0025	**Weibull**
Log-Normal	1,2659	0,5206	-	0,9598	0,0033	
Gumbel	4,9712	2,1522	-	0,9261	0,0066	
Pearson Type III	-0,0424	1,5158	3,1614	0,9728	0,0024	
Weibull	**4,4971**	**2,2819**	**-**	**0,9730**	**0,0021**	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	7,5915	0,1564	-	0,9348	0,0083	**Log-Normal**
Log-Normal	**0,1041**	**0,3958**	**-**	**0,9405**	**0,0063**	
Gumbel	1,4031	0,3990	-	0,9104	0,0098	
Pearson Type III	-0,1855	0,3855	1,0181	0,9298	0,0095	
Weibull	1,3323	3,1024	-	0,9283	0,0090	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	10,3264	0,0366	-	0,8446	0,0147	**Gumbel**
Log-Normal	-1,0234	0,3762	-	0,8101	0,0145	
Gumbel	**0,4234**	**0,0723**	**-**	**0,9453**	**0,0095**	
Pearson Type III	-1,1950	0,1264	0,3759	0,9550	0,0109	
Weibull	0,4145	4,7548	-	0,9162	0,0113	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	36,7213	0,0109	-	0,9281	0,0171	**Log-Normal**
Log-Normal	**-0,9301**	**0,1916**	**-**	**0,9357**	**0,0101**	
Gumbel	0,4325	0,0564	-	0,9307	0,0162	
Pearson Type III	-1,3265	0,1084	0,3988	0,9213	0,0159	
Weibull	0,4282	7,1338	-	0,9294	0,0169	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	22,4941	0,0171	-	0,8850	0,0208	**Log-Normal**
Log-Normal	**-0,9798**	**0,2439**	**-**	**0,8865**	**0,0139**	
Gumbel	0,4250	0,0739	-	0,9027	0,0163	
Pearson Type III	3,4552	0,0019	0,3044	0,8438	0,0259	
Weibull	0,4174	5,3273	-	0,8970	0,0180	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,3610	0,2528	-	0,9038	0,0125	**Pearson Type III**
Log-Normal	-1,4773	1,1054	-	0,8796	0,0125	
Gumbel	0,4608	0,2015	-	0,9104	0,0126	
Pearson Type III	**-1,0987**	**0,3475**	**0,3273**	**0,9191**	**0,0099**	
Weibull	0,3705	1,2993	-	0,9091	0,0130	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	21,7176	0,0699	-	0,9355	0,0097	**Log-Normal**
Log-Normal	**0,3946**	**0,2307**	**-**	**0,9339**	**0,0082**	
Gumbel	1,6768	0,2755	-	0,9367	0,0093	
Pearson Type III	-1,1529	0,5237	1,4609	0,9144	0,0116	
Weibull	1,6494	5,5476	-	0,9407	0,0093	

Beydilli Dam - Deficit Intensities goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	14,6437	0,0986	-	0,9549	0,0063	**Log-Normal**
Log-Normal	**0,3330**	**0,2767**	**-**	**0,9617**	**0,0046**	
Gumbel	1,6459	0,3880	-	0,8956	0,0097	
Pearson Type III	0,1362	0,2819	1,2421	0,9698	0,0048	
Weibull	1,5937	4,0261	-	0,9315	0,0073	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7267	0,5669	-	0,9433	0,0056	**Pearson Type III**
Log-Normal	-1,7142	2,0351	-	0,8381	0,0124	
Gumbel	0,6087	0,3873	-	0,8204	0,0155	
Pearson Type III	**0,3768**	**0,2088**	**0,2005**	**0,9687**	**0,0043**	
Weibull	0,3885	0,8627	-	0,9493	0,0051	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,9442	0,5262	-	0,9675	0,0047	**Log-Normal**
Log-Normal	**-1,3150**	**1,2658**	**-**	**0,9833**	**0,0022**	
Gumbel	0,7970	0,6481	-	0,7812	0,0154	
Pearson Type III	0,7676	0,1854	0,1769	0,9831	0,0032	
Weibull	0,4811	0,9366	-	0,9703	0,0039	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7128	1,3902	-	0,9652	0,0040	**Log-Normal**
Log-Normal	**-0,8549**	**1,3951**	**-**	**0,9857**	**0,0018**	
Gumbel	1,8555	2,0669	-	0,6301	0,0280	
Pearson Type III	1,1722	0,2694	0,2242	0,9724	0,0032	
Weibull	0,8339	0,7744	-	0,9746	0,0023	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,4745	1,4089	-	0,9547	0,0047	**Log-Normal**
Log-Normal	**0,3552**	**0,8784**	**-**	**0,9748**	**0,0026**	
Gumbel	3,2916	2,7900	-	0,7061	0,0215	
Pearson Type III	0,8321	0,6326	0,9150	0,9593	0,0046	
Weibull	2,2003	1,1505	-	0,9505	0,0039	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,7735	0,2131	-	0,9076	0,0080	**Pearson Type III**
Log-Normal	-0,7170	0,7230	-	0,8714	0,0108	
Gumbel	0,7541	0,3447	-	0,9291	0,0060	
Pearson Type III	**-0,1462**	**0,2847**	**0,4634**	**0,9405**	**0,0048**	
Weibull	0,6647	1,9489	-	0,9298	0,0058	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,1772	0,1170	-	0,9586	0,0070	**Log-Normal**
Log-Normal	**-1,6145**	**0,8133**	**-**	**0,9530**	**0,0056**	
Gumbel	0,3314	0,1371	-	0,9416	0,0083	
Pearson Type III	-1,0743	0,2132	0,2693	0,9050	0,0132	
Weibull	0,2853	1,6833	-	0,9596	0,0077	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,0416	0,1754	-	0,8088	0,0183	**Log-Normal**
Log-Normal	**-2,2514**	**1,0770**	**-**	**0,8749**	**0,0105**	
Gumbel	0,3050	0,2565	-	0,6146	0,0276	
Pearson Type III	4,9621	0,0680	0,0528	0,8165	0,0220	
Weibull	0,1773	0,9464	-	0,8164	0,0142	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7550	0,2863	-	0,8569	0,0177	**Log-Normal**
Log-Normal	**-2,3237**	**1,4084**	**-**	**0,9189**	**0,0089**	
Gumbel	0,3650	0,2993	-	0,6816	0,0261	
Pearson Type III	5,2910	0,0138	0,0327	0,8724	0,0133	
Weibull	0,1868	0,7975	-	0,8729	0,0137	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7662	0,2802	-	0,9030	0,0145	**Log-Normal**
Log-Normal	**-2,3176**	**1,4353**	**-**	**0,9536**	**0,0070**	
Gumbel	0,3569	0,2854	-	0,7106	0,0240	
Pearson Type III	5,1686	0,0328	0,0325	0,8799	0,0150	
Weibull	0,1884	0,8096	-	0,9161	0,0114	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,5854	0,2133	-	0,9721	0,0049	**Log-Normal**
Log-Normal	**-3,1397**	**1,7606**	**-**	**0,9808**	**0,0034**	
Gumbel	0,2090	0,1730	-	0,7476	0,0197	
Pearson Type III	3,8878	0,0070	0,0057	0,8101	0,0154	
Weibull	0,0979	0,6924	-	0,9782	0,0043	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,1460	0,3111	-	0,6667	0,0306	**Pearson Type III**
Log-Normal	-1,5273	0,9427	-	0,7211	0,0233	
Gumbel	0,5895	0,4946	-	0,5763	0,0325	
Pearson Type III	**1,0946**	**0,0559**	**0,1330**	**0,8965**	**0,0080**	
Weibull	0,3545	0,9892	-	0,6720	0,0259	

Beydilli Mid-Basin - Deficit Amounts goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2143	0,3387	-	0,8844	0,0120	**Pearson Type III**
Log-Normal	-1,3537	0,9819	-	0,9363	0,0065	
Gumbel	0,6465	0,4864	-	0,6916	0,0241	
Pearson Type III	**1,1706**	**0,0950**	**0,1452**	**0,9785**	**0,0031**	
Weibull	0,4206	1,0505	-	0,8854	0,0100	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,1510	1,6852	-	0,9650	0,0055	**Log-Normal**
Log-Normal	**1,0378**	**0,7848**	**-**	**0,9645**	**0,0044**	
Gumbel	4,9211	2,5439	-	0,8611	0,0120	
Pearson Type III	0,3562	1,5013	2,1888	0,9630	0,0057	
Weibull	4,0512	1,5479	-	0,9595	0,0055	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,3059	2,8715	-	0,8652	0,0166	**Gumbel**
Log-Normal	0,8924	1,0096	-	0,8606	0,0153	
Gumbel	**5,4856**	**3,4404**	**-**	**0,8411**	**0,0132**	
Pearson Type III	4,8646	0,0175	1,0036	0,7825	0,0518	
Weibull	3,9492	1,1458	-	0,8659	0,0154	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,4750	0,8418	-	0,8535	0,0128	**Weibull**
Log-Normal	0,5185	0,6335	-	0,8595	0,0122	
Gumbel	3,0488	2,2640	-	0,6928	0,0234	
Pearson Type III	4,7115	0,1039	1,0220	0,7920	0,0507	
Weibull	**2,3293**	**1,4539**	**-**	**0,8431**	**0,0117**	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2382	2,2613	-	0,7565	0,0209	**Weibull**
Log-Normal	0,5743	0,8750	-	0,7802	0,0181	
Gumbel	4,8940	4,9053	-	0,5367	0,0327	
Pearson Type III	3,9218	0,0431	1,0110	0,7529	0,0731	
Weibull	**2,8130**	**1,0088**	**-**	**0,7532**	**0,0179**	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,9117	0,4720	-	0,8440	0,0144	**Weibull**
Log-Normal	0,4799	0,5206	-	0,8461	0,0141	
Gumbel	2,4102	1,1872	-	0,7486	0,0192	
Pearson Type III	2,8527	0,0002	1,0001	0,7541	0,0752	
Weibull	**2,0986**	**1,9497**	**-**	**0,8338**	**0,0134**	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,4978	0,6988	-	0,8741	0,0133	**Gumbel**
Log-Normal	0,7441	0,6037	-	0,8640	0,0134	
Gumbel	**3,0982**	**1,3154**	**-**	**0,8638**	**0,0099**	
Pearson Type III	-0,0684	1,0679	1,8841	0,8776	0,0129	
Weibull	2,7704	2,0783	-	0,8811	0,0116	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,3504	3,8507	-	0,9045	0,0104	**Log-Normal**
Log-Normal	**1,2348**	**1,0043**	**-**	**0,9409**	**0,0058**	
Gumbel	7,9929	5,8161	-	0,6897	0,0223	
Pearson Type III	0,8009	1,6966	2,2028	0,9457	0,0074	
Weibull	5,4561	1,1242	-	0,9012	0,0090	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8188	7,3275	-	0,8728	0,0170	**Log-Normal**
Log-Normal	**1,0692**	**1,3788**	**-**	**0,8969**	**0,0111**	
Gumbel	9,8310	7,6737	-	0,7185	0,0235	
Pearson Type III	3,9339	0,1836	1,0466	0,8442	0,0502	
Weibull	5,4336	0,8442	-	0,8791	0,0144	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8341	7,4927	-	0,8933	0,0161	**Log-Normal**
Log-Normal	**1,1250**	**1,4003**	**-**	**0,8997**	**0,0116**	
Gumbel	10,0283	7,5239	-	0,7571	0,0209	
Pearson Type III	3,6859	0,1668	1,0451	0,8354	0,0527	
Weibull	5,7528	0,8611	-	0,8958	0,0144	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,6412	1,8957	-	0,9035	0,0115	**Log-Normal**
Log-Normal	**0,8004**	**0,8627**	**-**	**0,9088**	**0,0100**	
Gumbel	4,4891	2,7650	-	0,8103	0,0154	
Pearson Type III	3,9706	0,0011	1,0003	0,7686	0,0627	
Weibull	3,3827	1,2818	-	0,9010	0,0103	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8836	3,7724	-	0,5281	0,0440	**Gumbel**
Log-Normal	0,5408	1,0752	-	0,5272	0,0408	
Gumbel	**5,8047**	**5,2098**	**-**	**0,5323**	**0,0368**	
Pearson Type III	4,2971	0,0892	1,0207	0,5262	0,1523	
Weibull	3,0178	0,8562	-	0,5283	0,0385	

Beydilli Mid-Basin - Deficit Lengths goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2252	2,8114	-	0,8227	0,0184	**Weibull**
Log-Normal	0,7761	0,9898	-	0,8263	0,0171	
Gumbel	5,3000	3,7674	-	0,7295	0,0217	
Pearson Type III	3,0252	0,0001	1,0000	0,7531	0,0782	
Weibull	**3,5454**	**1,0682**	**-**	**0,8221**	**0,0164**	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2866	0,1055	-	0,5017	0,0417	**Pearson Type III**
Log-Normal	-2,4335	1,5972	-	0,4325	0,0420	
Gumbel	0,1555	0,0275	-	0,9314	0,0069	
Pearson Type III	**-1,2204**	**0,0490**	**0,1389**	**0,9270**	**0,0056**	
Weibull	0,1439	1,7240	-	0,5793	0,0368	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,3014	0,0366	-	0,8234	0,0149	**Pearson Type III**
Log-Normal	-1,9698	0,6270	-	0,7553	0,0185	
Gumbel	0,1815	0,0372	-	0,9547	0,0065	
Pearson Type III	**-1,2944**	**0,0741**	**0,1567**	**0,9584**	**0,0040**	
Weibull	0,1742	3,2979	-	0,9049	0,0102	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,4270	0,3322	-	0,9731	0,0044	**Pearson Type III**
Log-Normal	-1,1361	1,0519	-	0,9462	0,0058	
Gumbel	0,6484	0,3299	-	0,9378	0,0062	
Pearson Type III	**-0,0231**	**0,2794**	**0,3152**	**0,9781**	**0,0043**	
Weibull	0,5122	1,3070	-	0,9776	0,0043	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	6,9230	0,1548	-	0,7843	0,0215	**Pearson Type III**
Log-Normal	-0,0049	0,4374	-	0,7705	0,0208	
Gumbel	1,2285	0,2361	-	0,8757	0,0150	
Pearson Type III	**-1,0748**	**0,3059**	**1,1281**	**0,9529**	**0,0079**	
Weibull	1,1919	3,8234	-	0,8221	0,0204	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,5128	0,0905	-	0,9063	0,0080	**Pearson Type III**
Log-Normal	-1,0100	0,5511	-	0,8780	0,0100	
Gumbel	0,4930	0,1641	-	0,9226	0,0059	
Pearson Type III	**-0,3004**	**0,1695**	**0,3506**	**0,9372**	**0,0050**	
Weibull	0,4592	2,6209	-	0,9314	0,0057	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,9497	0,0283	-	0,9763	0,0044	**Log-Normal**
Log-Normal	**-2,0699**	**0,5118**	**-**	**0,9687**	**0,0037**	
Gumbel	0,1693	0,0530	-	0,9684	0,0047	
Pearson Type III	-0,4696	0,0623	0,1249	0,9762	0,0051	
Weibull	0,1581	2,6458	-	0,9809	0,0045	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	6,5194	0,0077	-	0,9709	0,0052	**Log-Normal**
Log-Normal	**-3,0645**	**0,4433**	**-**	**0,9733**	**0,0034**	
Gumbel	0,0614	0,0217	-	0,8628	0,0109	
Pearson Type III	0,0819	0,0151	0,0405	0,9792	0,0048	
Weibull	0,0570	2,6563	-	0,9458	0,0060	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	20,2133	0,0020	-	0,9653	0,0105	**Log-Normal**
Log-Normal	**-3,2539**	**0,2547**	**-**	**0,9719**	**0,0058**	
Gumbel	0,0444	0,0091	-	0,9028	0,0119	
Pearson Type III	0,6556	0,0048	0,0334	0,9816	0,0087	
Weibull	0,0433	4,6490	-	0,9370	0,0102	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	18,5011	0,0021	-	0,9455	0,0100	**Gumbel**
Log-Normal	-3,2614	0,2770	-	0,9292	0,0075	
Gumbel	**0,0436**	**0,0073**	**-**	**0,9765**	**0,0075**	
Pearson Type III	-1,2124	0,0132	0,0396	0,8823	0,0176	
Weibull	0,0428	5,4185	-	0,9762	0,0081	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,1770	0,0314	-	0,9195	0,0111	**Gumbel**
Log-Normal	-3,7811	1,2191	-	0,8885	0,0119	
Gumbel	**0,0502**	**0,0239**	**-**	**0,9598**	**0,0060**	
Pearson Type III	-0,5488	0,0296	0,0310	0,9620	0,0068	
Weibull	0,0389	1,1816	-	0,9247	0,0116	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	37,2557	0,0038	-	0,9231	0,0075	**Weibull**
Log-Normal	-1,9783	0,1796	-	0,9130	0,0074	
Gumbel	0,1501	0,0160	-	0,9481	0,0075	
Pearson Type III	-1,1692	0,0247	0,1420	0,9461	0,0102	
Weibull	**0,1490**	**8,5462**	**-**	**0,9469**	**0,0073**	

Beydilli Mid-Basin - Deficit Magnitudes goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	13,1392	0,0118	-	0,9167	0,0096	**Pearson Type III**
Log-Normal	-1,9060	0,3075	-	0,9074	0,0089	
Gumbel	0,1729	0,0300	-	0,9587	0,0073	
Pearson Type III	**-1,0674**	**0,0488**	**0,1552**	**0,9732**	**0,0045**	
Weibull	0,1694	4,8961	-	0,9425	0,0089	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,3319	0,0729	-	0,7168	0,0247	**Pearson Type III**
Log-Normal	-2,7520	1,4907	-	0,5961	0,0297	
Gumbel	0,1159	0,0287	-	0,9630	0,0064	
Pearson Type III	**-1,1817**	**0,0490**	**0,0973**	**0,9861**	**0,0046**	
Weibull	0,1039	1,6382	-	0,7999	0,0190	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,6340	0,0265	-	0,9427	0,0060	**Gumbel**
Log-Normal	-2,2074	0,5703	-	0,9020	0,0080	
Gumbel	**0,1453**	**0,0383**	**-**	**0,9935**	**0,0027**	
Pearson Type III	-1,1080	0,0700	0,1225	0,9394	0,0062	
Weibull	0,1376	2,9310	-	0,9801	0,0039	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,6558	0,2130	-	0,9486	0,0062	**Gumbel**
Log-Normal	-1,3735	0,9919	-	0,9116	0,0083	
Gumbel	**0,4662**	**0,2180**	**-**	**0,9720**	**0,0025**	
Pearson Type III	-0,2324	0,2128	0,2684	0,9765	0,0037	
Weibull	0,3877	1,4838	-	0,9606	0,0056	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	8,5258	0,1000	-	0,9707	0,0052	**Log-Normal**
Log-Normal	**-0,2191**	**0,3704**	**-**	**0,9720**	**0,0040**	
Gumbel	0,9977	0,2651	-	0,9369	0,0075	
Pearson Type III	-0,3478	0,2854	0,7607	0,9592	0,0069	
Weibull	0,9538	3,3272	-	0,9628	0,0059	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,5223	0,0749	-	0,9710	0,0025	**Weibull**
Log-Normal	-1,1969	0,5206	-	0,9598	0,0033	
Gumbel	0,4235	0,1834	-	0,9261	0,0066	
Pearson Type III	-0,0424	0,1291	0,2693	0,9728	0,0024	
Weibull	**0,3832**	**2,2819**	**-**	**0,9730**	**0,0021**	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	7,5915	0,0133	-	0,9348	0,0083	**Log-Normal**
Log-Normal	**-2,3586**	**0,3958**	**-**	**0,9405**	**0,0063**	
Gumbel	0,1195	0,0340	-	0,9104	0,0098	
Pearson Type III	-0,1855	0,0328	0,0867	0,9298	0,0095	
Weibull	0,1135	3,1024	-	0,9283	0,0090	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	10,3264	0,0031	-	0,8446	0,0147	**Gumbel**
Log-Normal	-3,4861	0,3762	-	0,8101	0,0145	
Gumbel	**0,0361**	**0,0062**	**-**	**0,9453**	**0,0095**	
Pearson Type III	-1,1728	0,0101	0,0324	0,9537	0,0116	
Weibull	0,0353	4,7548	-	0,9162	0,0113	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	36,7213	0,0009	-	0,9281	0,0171	**Log-Normal**
Log-Normal	**-3,3928**	**0,1916**	**-**	**0,9357**	**0,0101**	
Gumbel	0,0369	0,0048	-	0,9307	0,0162	
Pearson Type III	-1,2915	0,0068	0,0357	0,9069	0,0256	
Weibull	0,0365	7,1338	-	0,9294	0,0169	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	22,4941	0,0015	-	0,8850	0,0208	**Log-Normal**
Log-Normal	**-3,4426**	**0,2439**	**-**	**0,8865**	**0,0139**	
Gumbel	0,0362	0,0063	-	0,9027	0,0163	
Pearson Type III	4,6796	0,0054	0,0270	0,9197	0,0289	
Weibull	0,0356	5,3273	-	0,8970	0,0180	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	**1,3610**	**0,0215**	**-**	**0,9038**	**0,0125**	**2-Parameter Gamma**
Log-Normal	-3,9401	1,1054	-	0,8796	0,0125	
Gumbel	0,0393	0,0172	-	0,9104	0,0126	
Pearson Type III	-1,1286	0,0216	0,0357	0,9035	0,0197	
Weibull	0,0316	1,2993	-	0,9091	0,0130	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	21,7176	0,0060	-	0,9355	0,0097	**Log-Normal**
Log-Normal	**-2,0681**	**0,2307**	**-**	**0,9339**	**0,0082**	
Gumbel	0,1429	0,0235	-	0,9367	0,0093	
Pearson Type III	-1,2498	0,0329	0,1369	0,8847	0,0208	
Weibull	0,1405	5,5476	-	0,9407	0,0093	

Beydilli Mid-Basin - Deficit Intensities goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	14,6437	0,0084	-	0,9549	0,0063	**Log-Normal**
Log-Normal	**-2,1298**	**0,2767**	**-**	**0,9617**	**0,0046**	
Gumbel	0,1402	0,0331	-	0,8956	0,0097	
Pearson Type III	0,1362	0,0240	0,1058	0,9698	0,0048	
Weibull	0,1358	4,0261	-	0,9315	0,0073	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7371	1,9177	-	0,9499	0,0039	**Pearson Type III**
Log-Normal	-0,4679	1,7135	-	0,9267	0,0059	
Gumbel	2,3533	2,1157	-	0,7331	0,0193	
Pearson Type III	**0,6008**	**0,5878**	**0,5321**	**0,9711**	**0,0030**	
Weibull	1,2780	0,8250	-	0,9530	0,0037	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2423	3,5644	-	0,8977	0,0144	**Log-Normal**
Log-Normal	**1,0343**	**1,0506**	**-**	**0,9218**	**0,0095**	
Gumbel	6,7345	4,6729	-	0,7884	0,0165	
Pearson Type III	3,2589	0,0522	1,0640	0,7406	0,0421	
Weibull	4,5843	1,0854	-	0,8985	0,0123	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7440	8,9612	-	0,9041	0,0102	**Pearson Type III**
Log-Normal	1,0918	1,1980	-	0,9765	0,0019	
Gumbel	13,7397	17,0374	-	0,4434	0,0398	
Pearson Type III	**0,7999**	**1,7631**	**1,8745**	**0,9883**	**0,0012**	
Weibull	5,4718	0,7751	-	0,9293	0,0059	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8167	14,6872	-	0,9826	0,0033	**Weibull**
Log-Normal	1,7597	1,4266	-	0,9716	0,0038	
Gumbel	19,2956	16,1529	-	0,8273	0,0130	
Pearson Type III	1,0832	4,1225	3,3001	0,9550	0,0055	
Weibull	**11,1739**	**0,8700**	**-**	**0,9824**	**0,0033**	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,2629	1,1939	-	0,7559	0,0214	**Pearson Type III**
Log-Normal	1,5053	0,6015	-	0,7107	0,0237	
Gumbel	5,8989	1,2549	-	0,9209	0,0075	
Pearson Type III	**-1,0317**	**2,2575**	**5,1247**	**0,9133**	**0,0070**	
Weibull	5,6582	3,2014	-	0,8356	0,0161	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,9278	0,8689	-	0,9757	0,0033	**Log-Normal**
Log-Normal	**0,2347**	**0,8190**	**-**	**0,9844**	**0,0018**	
Gumbel	2,3476	1,3773	-	0,8276	0,0134	
Pearson Type III	0,3466	0,7042	0,9868	0,9850	0,0025	
Weibull	1,8541	1,4254	-	0,9682	0,0034	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	**0,7881**	**1,9992**	**-**	**0,9614**	**0,0068**	**2-Parameter Gamma**
Log-Normal	-0,2998	1,6833	-	0,9210	0,0071	
Gumbel	2,4085	1,6760	-	0,8297	0,0137	
Pearson Type III	0,5918	0,7325	0,6191	0,9596	0,0071	
Weibull	1,4790	0,8722	-	0,9610	0,0072	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,1901	0,7886	-	0,9999	0,0130	**Log-Normal**
Log-Normal	**0,3011**	**0,9001**	**-**	**0,9947**	**0,0059**	
Gumbel	2,2947	1,0440	-	0,9292	0,0168	
Pearson Type III	4,2676	0,0927	0,5521	0,8154	0,0284	
Weibull	1,9351	1,6119	-	0,9971	0,0131	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,7165	0,6237	-	0,9840	0,0072	**Log-Normal**
Log-Normal	**-0,2505**	**0,9769**	**-**	**0,9773**	**0,0043**	
Gumbel	1,4499	0,7076	-	0,9295	0,0101	
Pearson Type III	0,1491	0,5475	0,6730	0,9794	0,0080	
Weibull	1,1787	1,4293	-	0,9825	0,0078	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,1671	0,6571	-	0,9217	0,0085	**Gumbel**
Log-Normal	-0,7515	1,4687	-	0,8315	0,0130	
Gumbel	**0,9992**	**0,4124**	**-**	**0,9769**	**0,0048**	
Pearson Type III	-0,6336	0,5430	0,6835	0,9780	0,0051	
Weibull	0,8133	1,2837	-	0,9428	0,0073	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,7875	1,4833	-	0,8556	0,0157	**Pearson Type III**
Log-Normal	-0,5998	1,3054	-	0,8862	0,0119	
Gumbel	1,9708	1,7386	-	0,7311	0,0188	
Pearson Type III	**1,5631**	**0,2055**	**0,2444**	**0,9564**	**0,0048**	
Weibull	1,0380	0,8233	-	0,8625	0,0134	

Dört Eylül Dam - Deficit Amounts goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	0,8707	2,5998	-	0,9415	0,0084	**Pearson Type III**
Log-Normal	0,1428	1,3069	-	0,9667	0,0050	
Gumbel	3,6062	2,8341	-	0,8096	0,0136	
Pearson Type III	**1,2902**	**0,6134**	**0,5690**	**0,9739**	**0,0040**	
Weibull	2,1338	0,8922	-	0,9457	0,0073	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,4744	1,9668	-	0,7706	0,0254	**Gumbel**
Log-Normal	0,6888	0,9032	-	0,7637	0,0244	
Gumbel	**4,2075**	**2,5346**	**-**	**0,7793**	**0,0197**	
Pearson Type III	3,2666	0,0011	1,0003	0,7298	0,0846	
Weibull	3,1085	1,2110	-	0,7724	0,0233	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,0608	6,0333	-	0,9352	0,0092	**Log-Normal**
Log-Normal	**1,3159**	**1,1418**	**-**	**0,9806**	**0,0037**	
Gumbel	10,2830	8,0772	-	0,7059	0,0212	
Pearson Type III	1,2227	1,6308	1,9787	0,9810	0,0046	
Weibull	6,3329	0,9789	-	0,9395	0,0070	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,1478	2,1385	-	0,5656	0,0360	**Log-Normal**
Log-Normal	**0,4028**	**0,8287**	**-**	**0,6022**	**0,0311**	
Gumbel	4,6905	5,3871	-	0,3784	0,0443	
Pearson Type III	5,2927	0,4772	1,0902	0,6159	0,1435	
Weibull	2,3678	0,9438	-	0,5627	0,0314	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2229	2,3715	-	0,7552	0,0213	**Weibull**
Log-Normal	0,6031	0,8985	-	0,7725	0,0193	
Gumbel	4,9910	4,8661	-	0,5695	0,0305	
Pearson Type III	4,6835	0,2339	1,0499	0,7600	0,0793	
Weibull	**2,9172**	**1,0115**	**-**	**0,7536**	**0,0182**	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,9317	0,7752	-	0,9029	0,0091	**Log-Normal**
Log-Normal	**0,6408**	**0,6118**	**-**	**0,9089**	**0,0083**	
Gumbel	3,0988	1,8081	-	0,7923	0,0154	
Pearson Type III	4,5990	0,0461	1,0100	0,7515	0,0324	
Weibull	2,5693	1,6788	-	0,8934	0,0085	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,3705	0,5934	-	0,8429	0,0188	**Gumbel**
Log-Normal	0,5375	0,5901	-	0,8388	0,0176	
Gumbel	**2,5674**	**1,0819**	**-**	**0,8457**	**0,0140**	
Pearson Type III	3,5848	0,0030	1,0008	0,7663	0,0641	
Weibull	2,2722	1,9686	-	0,8466	0,0171	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,9717	2,5359	-	0,9914	0,0044	**Log-Normal**
Log-Normal	**1,3349**	**0,8915**	**-**	**0,9746**	**0,0035**	
Gumbel	6,8113	3,6049	-	0,8864	0,0097	
Pearson Type III	0,1517	2,3924	3,2392	0,9947	0,0044	
Weibull	5,5555	1,5052	-	0,9893	0,0044	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,5131	2,1419	-	0,9725	0,0152	**Log-Normal**
Log-Normal	**2,1538**	**0,5851**	**-**	**0,9875**	**0,0063**	
Gumbel	12,0821	4,4979	-	0,8935	0,0191	
Pearson Type III	4,3274	0,1670	5,0385	0,8179	0,0322	
Weibull	10,9863	2,2670	-	0,9533	0,0153	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,0021	2,8970	-	0,8840	0,0156	**Log-Normal**
Log-Normal	**1,4878**	**0,9462**	**-**	**0,8652**	**0,0123**	
Gumbel	7,3427	2,5104	-	0,9170	0,0160	
Pearson Type III	-1,2277	2,2605	7,1587	0,8841	0,0496	
Weibull	6,4659	1,7346	-	0,8920	0,0174	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,3827	1,3115	-	0,9436	0,0071	**Log-Normal**
Log-Normal	**0,9151**	**0,7243**	**-**	**0,9547**	**0,0050**	
Gumbel	4,2425	2,2229	-	0,8243	0,0145	
Pearson Type III	0,4959	1,1196	1,8472	0,9494	0,0064	
Weibull	3,5101	1,5946	-	0,9330	0,0072	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,1713	2,8814	-	0,7526	0,0266	**Gumbel**
Log-Normal	0,7322	1,0274	-	0,7460	0,0251	
Gumbel	**5,1637**	**3,6228**	**-**	**0,7560**	**0,0193**	
Pearson Type III	3,8030	0,0030	1,0008	0,7182	0,0893	
Weibull	3,4452	1,0474	-	0,7534	0,0241	

Dört Eylül Dam - Deficit Lengths goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,2630	3,0681	-	0,8650	0,0167	**Gumbel**
Log-Normal	0,9090	1,0304	-	0,8613	0,0152	
Gumbel	**5,6746**	**3,4996**	**-**	**0,8368**	**0,0146**	
Pearson Type III	3,8016	0,0104	1,0027	0,7790	0,0593	
Weibull	4,0562	1,1249	-	0,8655	0,0156	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,5193	0,3531	-	0,8831	0,0117	**Gumbel**
Log-Normal	-0,9865	1,3122	-	0,7519	0,0199	
Gumbel	**0,6639**	**0,2250**	**-**	**0,9833**	**0,0028**	
Pearson Type III	-0,6306	0,3014	0,4896	0,9822	0,0030	
Weibull	0,5814	1,6631	-	0,9425	0,0066	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	25,2597	0,0424	-	0,9270	0,0095	**Log-Normal**
Log-Normal	**0,0483**	**0,2301**	**-**	**0,9109**	**0,0081**	
Gumbel	1,1640	0,1529	-	0,9493	0,0107	
Pearson Type III	-1,0678	0,1840	1,1061	0,9193	0,0281	
Weibull	1,1513	6,8190	-	0,9513	0,0100	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,3103	1,2571	-	0,9871	0,0025	**Log-Normal**
Log-Normal	**0,8344**	**0,7840**	**-**	**0,9784**	**0,0024**	
Gumbel	3,8044	1,7230	-	0,9298	0,0066	
Pearson Type III	-0,0460	1,4514	2,1097	0,9829	0,0035	
Weibull	3,2579	1,7071	-	0,9861	0,0029	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,5595	3,7022	-	0,8596	0,0159	**Pearson Type III**
Log-Normal	1,3996	1,0475	-	0,8463	0,0143	
Gumbel	7,4627	2,7528	-	0,8892	0,0153	
Pearson Type III	**-1,0689**	**4,3301**	**5,8197**	**0,9203**	**0,0098**	
Weibull	6,3247	1,4742	-	0,8637	0,0173	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	5,1363	0,7048	-	0,9467	0,0054	**Gumbel**
Log-Normal	1,1860	0,5159	-	0,9177	0,0071	
Gumbel	**4,2919**	**1,1992**	**-**	**0,9748**	**0,0030**	
Pearson Type III	-0,6590	1,6117	3,3949	0,9655	0,0042	
Weibull	4,0596	2,9235	-	0,9738	0,0035	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,8228	0,2706	-	0,9372	0,0074	**Log-Normal**
Log-Normal	**-0,1025**	**0,5791**	**-**	**0,9433**	**0,0054**	
Gumbel	1,2886	0,4616	-	0,8886	0,0126	
Pearson Type III	-1,0794	0,7310	1,0653	0,8587	0,0169	
Weibull	1,1725	2,2320	-	0,9273	0,0090	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,1320	0,1480	-	0,9255	0,0092	**Gumbel**
Log-Normal	-1,4057	0,9302	-	0,8640	0,0108	
Gumbel	**0,4007**	**0,1539**	**-**	**0,9621**	**0,0069**	
Pearson Type III	-0,5905	0,1952	0,2815	0,9617	0,0080	
Weibull	0,3521	1,7963	-	0,9545	0,0080	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	22,5546	0,0109	-	0,9576	0,0164	**Log-Normal**
Log-Normal	**-1,4271**	**0,2637**	**-**	**0,9503**	**0,0087**	
Gumbel	0,2693	0,0399	-	0,9987	0,0137	
Pearson Type III	-1,2368	0,0744	0,2400	0,9714	0,0233	
Weibull	0,2656	6,0500	-	0,9886	0,0151	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	45,9105	0,0052	-	0,9406	0,0067	**Log-Normal**
Log-Normal	**-1,4527**	**0,1646**	**-**	**0,9381**	**0,0053**	
Gumbel	0,2550	0,0363	-	0,8709	0,0104	
Pearson Type III	-0,1139	0,0309	0,2216	0,9457	0,0064	
Weibull	0,2522	6,9506	-	0,9010	0,0086	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,0324	0,1441	-	0,6767	0,0266	**Pearson Type III**
Log-Normal	-1,4938	1,0772	-	0,5851	0,0305	
Gumbel	0,3409	0,0693	-	0,9196	0,0097	
Pearson Type III	**-1,1710**	**0,1029**	**0,3057**	**0,9752**	**0,0047**	
Weibull	0,3193	2,2756	-	0,7748	0,0210	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,5534	0,0749	-	0,9912	0,0032	**Log-Normal**
Log-Normal	**-1,1898**	**0,5211**	**-**	**0,9930**	**0,0020**	
Gumbel	0,4242	0,1648	-	0,9420	0,0050	
Pearson Type III	0,0304	0,1248	0,2643	0,9908	0,0035	
Weibull	0,3865	2,3151	-	0,9856	0,0031	

Dört Eylül Dam - Deficit Magnitudes goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,6188	0,1349	-	0,9641	0,0051	**Gumbel**
Log-Normal	-0,5851	0,5494	-	0,9407	0,0056	
Gumbel	**0,7482**	**0,2226**	**-**	**0,9861**	**0,0034**	
Pearson Type III	-0,5801	0,2869	0,5710	0,9882	0,0036	
Weibull	0,7017	2,6966	-	0,9837	0,0043	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month January						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,4749	0,3105	-	0,9255	0,0076	**Weibull**
Log-Normal	-1,1567	1,2788	-	0,8216	0,0148	
Gumbel	0,5868	0,2377	-	0,9361	0,0065	
Pearson Type III	-0,4086	0,2664	0,3834	0,9582	0,0054	
Weibull	**0,4969**	**1,5241**	**-**	**0,9569**	**0,0047**	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month February						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	8,9838	0,0889	-	0,8953	0,0146	**Pearson Type III**
Log-Normal	-0,2816	0,3683	-	0,9060	0,0103	
Gumbel	0,9476	0,2923	-	0,8520	0,0135	
Pearson Type III	**0,8266**	**0,1170**	**0,6061**	**0,9512**	**0,0079**	
Weibull	0,8962	3,0519	-	0,8832	0,0128	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month March						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	3,1890	0,7365	-	0,9708	0,0027	**Weibull**
Log-Normal	0,6890	0,6623	-	0,9485	0,0043	
Gumbel	2,9864	1,3300	-	0,9436	0,0046	
Pearson Type III	-0,1035	1,0540	1,8362	0,9815	0,0019	
Weibull	**2,6501**	**2,0314**	**-**	**0,9797**	**0,0018**	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month April						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	1,9479	2,1555	-	0,9713	0,0044	**Gumbel**
Log-Normal	1,1567	0,8914	-	0,9461	0,0052	
Gumbel	**5,5191**	**2,5112**	**-**	**0,9674**	**0,0035**	
Pearson Type III	-0,1909	2,3808	3,1752	0,9833	0,0039	
Weibull	4,6689	1,5984	-	0,9798	0,0041	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month May						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,7209	1,0601	-	0,9809	0,0029	**Weibull**
Log-Normal	0,8645	0,7081	-	0,9670	0,0033	
Gumbel	3,7205	1,6094	-	0,9295	0,0063	
Pearson Type III	-0,0880	1,3853	2,1774	0,9823	0,0031	
Weibull	**3,2533**	**1,8614**	**-**	**0,9830**	**0,0028**	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month June						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	4,2675	0,1955	-	0,9745	0,0040	**Weibull**
Log-Normal	-0,3029	0,5361	-	0,9688	0,0038	
Gumbel	1,0415	0,4166	-	0,9513	0,0039	
Pearson Type III	-0,0277	0,3254	0,6519	0,9726	0,0044	
Weibull	**0,9456**	**2,2656**	**-**	**0,9785**	**0,0031**	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month July						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,5458	0,0944	-	0,9525	0,0084	**Log-Normal**
Log-Normal	**-1,6347**	**0,8198**	**-**	**0,9121**	**0,0081**	
Gumbel	0,3007	0,1042	-	0,9787	0,0082	
Pearson Type III	-1,0906	0,1308	0,2770	0,9229	0,0228	
Weibull	0,2701	1,9801	-	0,9726	0,0084	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month August						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	13,9633	0,0116	-	0,8630	0,0238	**Log-Normal**
Log-Normal	**-1,8527**	**0,3416**	**-**	**0,8555**	**0,0146**	
Gumbel	0,1812	0,0287	-	0,9321	0,0208	
Pearson Type III	-1,7167	0,0597	0,1649	0,9895	0,0231	
Weibull	0,1781	5,1892	-	0,8995	0,0239	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month September						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	19,5562	0,0092	-	0,9217	0,0078	**Log-Normal**
Log-Normal	**-1,7383**	**0,2582**	**-**	**0,9096**	**0,0071**	
Gumbel	0,2005	0,0382	-	0,8919	0,0091	
Pearson Type III	-0,3217	0,0400	0,1671	0,9226	0,0078	
Weibull	0,1964	5,0218	-	0,9181	0,0077	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month October						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	2,0925	0,1168	-	0,8113	0,0163	**Gumbel**
Log-Normal	-1,6667	1,0236	-	0,7066	0,0219	
Gumbel	**0,2921**	**0,0758**	**-**	**0,9492**	**0,0081**	
Pearson Type III	-1,0376	0,1484	0,2109	0,9716	0,0108	
Weibull	0,2687	2,1290	-	0,8898	0,0113	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month November						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	8,6310	0,0324	-	0,9706	0,0036	**Weibull**
Log-Normal	-1,3321	0,3799	-	0,9611	0,0036	
Gumbel	0,3267	0,0914	-	0,9553	0,0036	
Pearson Type III	-0,2371	0,0880	0,2458	0,9764	0,0031	
Weibull	**0,3122**	**3,3574**	**-**	**0,9764**	**0,0027**	

Dört Eylül Dam - Deficit Intensities goodness of fit calculations for month December						
Probability Distribution Function	**Location Parameter (a)**	**Scale Parameter (b)**	**Shape Parameter (c)**	**Goodness of Fit (R^2)**	**Mean Square Error (-)**	**Selected PDF**
2-Parameter Gamma	6,9226	0,0723	-	0,9763	0,0034	**Weibull**
Log-Normal	-0,7662	0,4392	-	0,9558	0,0041	
Gumbel	0,5846	0,1523	-	0,9869	0,0026	
Pearson Type III	-0,5093	0,1876	0,4592	0,9914	0,0026	
Weibull	**0,5589**	**3,3041**	**-**	**0,9943**	**0,0025**	

B. Matlab Codes to Calculate Deficit Parameters and Exceedance Probability Levels

```
function [output]= ZSenDroughtAnalysis(X,Title)
% This program has been written by Zekâi Şen in 1978 in Fortran
% language and converted to Matlab in 2002
% Small performance adjustments has been made and code is shortened
% by Mustafa Kemal Türkeri
% X is a given time series
% T is time interval series (years, months, etc.)
% X0 is the truncation level
% C is the crossing vector
% S (D) is the surplus (deficit) sum vector
% SL (DL) is the surplus (deficit) length vector
% SM (DM) is the surplus (deficit) magnitude vector
% SI (DI) is the surplus (deficit) intensity vector
% Unit1 is the basic for instance mm or m^3/s
% Unit2 is the duration for instance month or year
% Unit3 is the intensity for instance mm/month, mm/year,
% (m^3/s)/month,
% (m^3/s)/year
Unit1='hm³';
Unit2='Year';
Unit3='hm³/Year';
Xo=mean(X);
n=length(X);
X(1)=Xo+0.1;
j=0;
for i=2:n
    sign =(X(i-1)-Xo)*(X(i)-Xo);
    if sign < 0
        j=j+1;
        C(j)=i-1;
    else
    end
end
j1=j-1;
for i=1:C(1)
    surplus(i)=(X(i)-Xo);
end
S(1)=sum(surplus(1:C(1)));
SM(1)=max(surplus(1:C(1)));
SL(1)=C(1);
SI(1)=S(1)/SL(1);
m=1;
for i=2:2:j1
    m=m+1;
    for k=(C(i)+1):C(i+1)
        surplus(k)=(X(k)-Xo);
    end
    S(m)=sum(surplus(C(i)+1:C(i+1)));
    SM(m)=max(surplus(C(i)+1:C(i+1)));
    SL(m)=C(i+1)-C(i);
```

```
    SI(m)=S(m)/SL(m);
end
m=0;
for i=1:2:j1
    m=m+1;
    for k=(C(i)+1):C(i+1)
        deficit(k)=(X(k)-Xo);
    end
    D(m)=sum(deficit(C(i)+1:C(i+1)));
    DM(m)=min(deficit(C(i)+1:C(i+1)));
    DL(m)=C(i+1)-C(i);
    DI(m)=D(m)/DL(m);
end
if X(end) >= Xo
    for i=(C(end)+1):n
           surplus(i)= (X(i)-Xo);
    end
    S(m+1)=sum(surplus(C(end)+1:n));
    SM(m+1)=max(surplus(C(end)+1:n));
    SL(m+1)=n-C(end);
    SI(m+1)=S(m+1)/SL(m+1);
else
    for i=(C(end)+1):n
        deficit(i)= (X(i)-Xo);
    end
    D(m+1)=sum(deficit(C(end)+1:n));
    DM(m+1)=min(deficit(C(end)+1:n));
    DL(m+1)=n-C(end);
    DI(m+1)=D(m+1)/DL(m+1);
end
output.D=D;
output.DL=DL;
output.DM=DM;
output.DI=DI;
output.Unit1=Unit1;
output.Unit2=Unit2;
output.Unit3=Unit3;
output.Title=Title;
end
```

```
function [rf] =
ProbabilityDistributionFunctionChoice(D,Xtitle,StName,Unit,isPlot,
CCenabled,trendSlope)
% Original version of the program is written on 13 September 2015
% Sunday
% by Zekâi Şen from Istanbul Technical University
%
% In this program, Gamma, Log-Normal, Extreme Value (EV Gumbel) and
% Generalized Etreme Value (GEV, Pearson) probability distribution
% functions are considered.
% This program produces Intensity-frequency curve for any given time
% duration.
%
% The program is modified for climate change by Mustafa Kemal
% Türkeri with respect to the study of Şen et al. (2017).
% If climate change variable is set to 1, this program modifies the
% risk levels with respect to the trend slope.
% The output does not show the risk level; instead it shows the
% return periods.
%
% INPUTS:
% D                  : Time series data
% Xtitle             : Time series data variable name with unit
% StName             : Station name
% Unit               : The unit of the input data
% isPlot             : If it is 1, the code will produce plot.
% CCenabled          : If it is 1, the risk levels will be modified
%                      according to the trend slope (i.e. Climate
%                      Change Enabled).
% trendSlope         : (Optional) If CCenabled is 1, the program will
%                      ask for trendSlope variable. If CCenabled is 0,
%                      this variable is unused.
% R                  : Risk levels
% RI                 : Return period
% V                  : It is the least sum of squares of probability
deviations
%                      from the theoretical probability distribution
% I                  : The number of PDF
%                      If I = 1 Gamma PDF
%                      If I = 2 Log-Normal PDF
%                      If I = 3 Extreme value (Gumbel)PDF
%                   If I = 4 Generalized extreme value (Pearson III)PDF
%                      If I = 5 Weibull PDF

if nargin == 6 && CCenabled == 1 %Input error control phase.
    error('ProbabilityDistributionFunctionChoice: You should enter a
trend slope!');
elseif nargin < 7 && CCenabled == 1
    error('ProbabilityDistributionFunctionChoice: arguments are not
enough to calculate PDF!');
end
```

```
Risk=0.001:0.001:0.999;
% Climate Change Modification:
if CCenabled == 1
    RI=1./Risk;
    R=[1-(1+trendSlope)/RI(500)...
        1-(1+trendSlope)/RI(200)...
        1-(1+trendSlope)/RI(100)...
        1-(1+trendSlope)/RI(40)...
        1-(1+trendSlope)/RI(20)...
        1-(1+trendSlope)/RI(10)...
        1-(1+trendSlope)/RI(4)...
        1-(1+trendSlope)/RI(2)];
else

    R=[1-Risk(500) 1-Risk(200) 1-Risk(100) 1-Risk(40) 1-Risk(20) 1-
Risk(10) 1-Risk(4) 1-Risk(2)];
end
n=length(D);
DM=1.1*max(D);
Dm=min(D);
x=Dm:0.1:DM;
pp=(1:1:n)/(n+1); % Data probability in ascending order
p=1-pp'; % Data probability in descending order
SD=sort(D); % Sorted time series in ascending order
pgam=gamfit(D); % Gamma PDF parameters
ygam=1-gamcdf(x,pgam(1),pgam(2));
ptgam=1-gamcdf(SD,pgam(1),pgam(2));
ppt2gam=(p-ptgam).^2;
GTest=mean(ppt2gam);
plon=lognfit(D); % Log-Normal PDF parameters
ylon=1-logncdf(x,plon(1),plon(2));
ptlon=1-logncdf(SD,plon(1),plon(2));
ppt2lon=(p-ptlon).^2;
LNTest=mean(ppt2lon);
pevd=evfit(D); % Extreme value PDF parameters
yevd=1-evcdf(x,pevd(1),pevd(2));
ptevd=1-evcdf(SD,pevd(1),pevd(2));
ppt2evd=(p-ptevd).^2;
EVTest=mean(ppt2evd);
pgev=gevfit(D); % Generalized extreme value PDF parameters
ygev=1-gevcdf(x,pgev(1),pgev(2),pgev(3));
ptgev=1-gevcdf(SD,pgev(1),pgev(2),pgev(3));
ppt2gev=(p-ptgev).^2;
GEVTest=mean(ppt2gev);
pwbl=wblfit(D); % Weibull PDF parameters
ywbl=1-wblcdf(x,pwbl(1),pwbl(2));
ptwbl=1-wblcdf(SD,pwbl(1),pwbl(2));
ppt2wbl=(p-ptwbl).^2;
WBLTest=mean(ppt2wbl);
rgam=gaminv(R,pgam(1),pgam(2));
rlon=logninv(R,plon(1),plon(2));
revd=evinv(R,pevd(1),pevd(2));
rgev=gevinv(R,pgev(1),pgev(2),pgev(3));
rwbl=wblinv(R,pwbl(1),pwbl(2));
```

```
[V I]=min([GTest LNTest EVTest GEVTest WBLTest]);
if I == 1
    yf=ygam;
    rf=rgam;
    pr=pgam;
    PR='Gamma PDF';
    elseif I ==2
        yf=ylon;
        rf=rlon;
        pr=plon;
        PR='Log-normal PDF';
        elseif I == 3
            yf=yevd;
            rf=revd;
            pr=pevd;
            PR='Gumbel';
elseif I == 4
    yf=ygev;
    rf=rgev;
    pr=pgev;
    PR='Pearson PD';
else
    yf=ywbl;
    rf=rwbl;
    pr=pwbl;
    PR='Weibull PDF';
end
if isPlot
    scatter(SD,p,'k*')
    title(StName)
    xlabel(Xtitle)
    ylabel('Exceedance Probability')
    hold on
    grid on
    box on
    plot(x,yf,'LineWidth',2,'Color','r') % Theoretical PDF plot
    legend('Data Values',PR,'Location','Northeast')
    % Second Modification: Return periods are written and if Climate
    % change is enabled, slope of the trend is written.
    if CCenabled == 1
        text(0.5,0.70,['Trend Slope = '
num2str(trendSlope,'%0.3f')],'Units','normalized');
    end
    text(0.5,0.80,['Location parameter = '
num2str(pr(1),'%0.1f')],'Units','normalized')
    text(0.5,0.75,['Scale    parameter    = '
num2str(pr(2),'%0.1f')],'Units','normalized')
    text(0.60,0.60,['2 yr Recurrence  = ' num2str(rf(1),'%0.1f'),'
',Unit],'Units','normalized')
    text(0.60,0.55,['5 yr Recurrence  = ' num2str(rf(2),'%0.1f'),'
',Unit],'Units','normalized')
    text(0.60,0.50,['10 yr Recurrence = ' num2str(rf(3),'%0.1f'),'
',Unit],'Units','normalized')
    text(0.60,0.45,['25 yr Recurrence = ' num2str(rf(4),'%0.1f'),'
```

```
',Unit],'Units','normalized')
    text(0.60,0.40,['50 yr Recurrence = ' num2str(rf(5),'%0.1f'),'
',Unit],'Units','normalized')
    text(0.60,0.35,['100yr Recurrence = ' num2str(rf(6),'%0.1f'),'
',Unit],'Units','normalized')
    % Modification ends here.
    if I == 4 && CCenabled == 1
        text(0.5,0.65,['Shape parameter      = '
num2str(pr(3),'%0.1f')],'Units','normalized')
    elseif I == 4
        text(0.5,0.70,['Shape parameter      = '
num2str(pr(3),'%0.1f')],'Units','normalized')
    end
end
end
```

C. Deficit Parameters with No Climate Change

Deficit parameters which include deficit amounts, deficit lengths, deficit magnitudes and deficit intensities are given in the following tables. Base parameter definitions include no climate change modifications.

Deficit Amounts

	Pusat-Özen Dam Inflows - Deficit Amounts (hm³) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	1.972	3.397	4.281	5.315	6.028	6.698
Feb	3.887	9.005	13.970	22.312	30.194	39.635
Mar	4.380	9.889	15.963	28.265	42.575	63.468
Apr	9.425	24.523	36.824	53.861	67.207	80.878
May	7.493	11.678	14.069	16.717	18.444	19.981
Jun	3.126	4.992	5.785	6.527	6.959	7.321
Jul	2.386	3.314	3.709	4.079	4.294	4.473
Aug	1.356	7.476	18.250	47.271	87.420	151.982
Sep	0.353	4.609	17.654	73.919	186.433	428.454
Oct	1.552	4.429	7.663	13.747	20.054	28.164
Nov	1.182	2.874	4.574	7.508	10.340	13.790
Dec	1.788	3.476	4.920	7.128	9.056	11.232

	Beydilli Dam Inflows - Deficit Amounts (hm³) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	3.316	7.295	11.035	17.557	24.144	32.659
Feb	3.151	9.144	15.958	28.898	42.411	59.887
Mar	4.992	16.151	29.836	57.408	87.618	128.160
Apr	16.742	35.066	51.608	77.928	101.698	129.214
May	6.631	9.940	11.847	13.976	15.375	16.629
Jun	2.336	4.631	6.622	9.699	12.410	15.490
Jul	1.235	3.058	4.911	8.140	11.282	15.131
Aug	1.149	3.760	6.987	13.528	20.730	30.433
Sep	1.156	3.869	7.276	14.266	22.041	32.595
Oct	0.508	2.236	4.852	11.083	18.896	30.536
Nov	1.857	4.059	8.004	20.846	43.907	93.186
Dec	2.215	6.266	14.025	41.027	92.510	208.533

	Beydilli Weir Mid-Basin Inflows - Deficit Amounts (hm³) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.283	0.622	0.940	1.496	2.057	2.783
Feb	0.268	0.779	1.360	2.462	3.613	5.102
Mar	0.425	1.376	2.542	4.891	7.465	10.919
Apr	1.426	2.988	4.397	6.639	8.665	11.009
May	0.565	0.847	1.009	1.191	1.310	1.417
Jun	0.199	0.395	0.564	0.826	1.057	1.320
Jul	0.105	0.261	0.418	0.694	0.961	1.289
Aug	0.098	0.320	0.595	1.153	1.766	2.593
Sep	0.099	0.330	0.620	1.215	1.878	2.777
Oct	0.043	0.191	0.413	0.944	1.610	2.602
Nov	0.158	0.346	0.682	1.776	3.741	7.939
Dec	0.189	0.534	1.195	3.495	7.882	17.767

	Dört Eylül Dam Inflows - Deficit Amounts (hm³) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.773	1.963	3.335	6.238	9.754	15.070
Feb	2.813	6.811	10.813	17.701	24.337	32.408
Mar	2.625	6.987	13.006	28.143	49.651	87.042
Apr	7.332	19.309	29.143	42.831	53.593	64.646
May	5.814	6.847	7.098	7.232	7.274	7.294
Jun	1.264	2.519	3.612	5.304	6.799	8.500
Jul	0.980	2.577	3.845	5.559	6.873	8.198
Aug	1.351	2.882	4.283	6.533	8.582	10.968
Sep	0.778	1.771	2.722	4.304	5.788	7.553
Oct	0.848	1.195	1.343	1.481	1.562	1.629
Nov	0.346	1.484	4.544	19.617	58.676	174.532
Dec	0.856	3.386	8.763	29.557	73.110	179.834

Deficit Lengths

	Pusat-Özen Dam Inflows - Deficit Lengths (year) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	2.540	4.187	5.179	6.317	7.092	7.813
Feb	3.845	10.031	16.561	28.264	39.923	54.466
Mar	1.603	3.220	4.636	6.838	8.790	11.018
Apr	1.956	4.509	6.430	8.963	10.874	12.783
May	1.916	3.198	4.179	5.560	6.686	7.892
Jun	1.987	3.455	4.613	6.278	7.662	9.165
Jul	4.100	5.200	5.667	6.104	6.359	6.572
Aug	3.915	14.017	27.302	55.587	87.991	133.001
Sep	2.759	12.112	26.246	59.867	101.985	164.678
Oct	3.834	10.451	17.653	30.874	44.302	61.305
Nov	2.081	4.828	6.906	9.652	11.730	13.806
Dec	2.022	3.589	4.845	6.672	8.204	9.880

	Beydilli Dam Inflows - Deficit Lengths (year) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	2.823	5.464	7.718	11.153	14.147	17.522
Feb	4.225	7.123	8.355	9.508	10.179	10.740
Mar	1.810	3.231	4.134	5.205	5.952	6.659
Apr	1.956	4.509	6.430	8.963	10.874	12.783
May	1.739	2.679	3.219	3.822	4.225	4.593
Jun	2.616	3.724	4.195	4.636	4.893	5.107
Jul	3.438	8.004	12.451	19.945	27.041	35.556
Aug	2.913	9.296	17.051	32.560	49.450	72.012
Sep	3.080	10.009	18.532	35.746	54.642	80.040
Oct	2.226	4.602	6.726	10.082	13.095	16.567
Nov	3.895	8.284	10.150	11.895	12.911	13.761
Dec	2.516	5.535	7.740	10.591	12.713	14.810

	Beydilli Weir Mid-Basin Inflows - Deficit Lengths (year) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	2.823	5.464	7.718	11.153	14.147	17.522
Feb	4.225	7.123	8.355	9.508	10.179	10.740
Mar	1.810	3.231	4.134	5.205	5.952	6.659
Apr	1.956	4.509	6.430	8.963	10.874	12.783
May	1.739	2.679	3.219	3.822	4.225	4.593
Jun	2.616	3.724	4.195	4.636	4.893	5.107
Jul	3.438	8.004	12.451	19.945	27.041	35.556
Aug	2.913	9.296	17.051	32.560	49.450	72.012
Sep	3.080	10.009	18.532	35.746	54.642	80.040
Oct	2.226	4.602	6.726	10.082	13.095	16.567
Nov	3.895	8.284	10.150	11.895	12.911	13.761
Dec	2.516	5.535	7.740	10.591	12.713	14.810

	Dört Eylül Dam Inflows - Deficit Lengths (year) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	3.279	5.414	6.321	7.171	7.665	8.078
Feb	3.728	9.746	16.105	27.517	38.894	53.096
Mar	1.496	3.005	4.327	6.383	8.205	10.284
Apr	2.031	4.670	6.654	9.266	11.237	13.203
May	1.898	3.177	4.158	5.540	6.669	7.879
Jun	2.171	3.082	3.470	3.832	4.043	4.220
Jul	3.800	8.046	11.910	18.095	23.709	30.231
Aug	8.618	14.102	18.242	24.004	28.661	33.617
Sep	4.427	9.817	14.886	23.205	30.911	40.008
Oct	2.497	4.594	6.317	8.874	11.052	13.464
Nov	3.836	6.888	8.185	9.399	10.105	10.696
Dec	4.392	7.340	8.593	9.766	10.448	11.019

Deficit Magnitudes

	Pusat-Özen Dam Inflows - Deficit Magnitudes (hm³) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	1.251	1.538	1.627	1.686	1.709	1.722
Feb	1.419	1.660	1.803	1.968	2.083	2.191
Mar	3.953	5.563	6.351	7.112	7.545	7.890
Apr	8.029	10.680	11.806	12.860	13.474	13.987
May	5.220	6.974	7.659	8.205	8.461	8.634
Jun	1.654	2.239	2.488	2.720	2.856	2.969
Jul	0.633	1.200	1.675	2.391	3.009	3.700
Aug	0.441	1.160	1.924	3.300	4.676	6.399
Sep	0.139	0.469	0.887	1.747	2.707	4.015
Oct	0.777	0.807	0.813	0.816	0.817	0.817
Nov	0.744	1.144	1.433	1.821	2.127	2.445
Dec	1.225	1.521	1.646	1.764	1.832	1.889

	Beydilli Dam Inflows - Deficit Magnitudes (hm³) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	1.808	2.029	2.072	2.092	2.097	2.099
Feb	1.970	2.338	2.494	2.640	2.726	2.797
Mar	4.896	8.534	10.891	13.811	15.936	18.011
Apr	14.100	15.944	16.322	16.498	16.545	16.565
May	4.805	6.517	7.369	8.204	8.686	9.075
Jun	1.481	2.279	2.854	3.629	4.238	4.872
Jul	0.548	0.796	0.967	1.190	1.362	1.537
Aug	0.453	0.562	0.628	0.708	0.765	0.820
Sep	0.480	0.553	0.583	0.612	0.629	0.643
Oct	0.487	0.723	0.823	0.917	0.971	1.017
Nov	1.737	1.875	1.900	1.911	1.913	1.914
Dec	2.022	2.259	2.314	2.343	2.351	2.355

	Beydilli Weir Mid-Basin Inflows - Deficit Magnitudes (hm³) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.153	0.173	0.176	0.178	0.179	0.179
Feb	0.178	0.206	0.211	0.213	0.214	0.214
Mar	0.417	0.727	0.928	1.177	1.358	1.535
Apr	1.221	1.356	1.387	1.404	1.408	1.411
May	0.409	0.555	0.628	0.699	0.740	0.773
Jun	0.126	0.194	0.243	0.309	0.361	0.415
Jul	0.047	0.068	0.082	0.101	0.116	0.131
Aug	0.039	0.048	0.054	0.060	0.065	0.070
Sep	0.041	0.047	0.050	0.052	0.054	0.055
Oct	0.041	0.062	0.070	0.078	0.083	0.087
Nov	0.143	0.158	0.164	0.171	0.175	0.178
Dec	0.170	0.192	0.197	0.199	0.200	0.201

	Dört Eylül Dam Inflows - Deficit Magnitudes (hm³) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.581	0.771	0.852	0.927	0.971	1.008
Feb	1.049	1.274	1.409	1.570	1.683	1.792
Mar	2.303	4.456	6.291	9.087	11.524	14.270
Apr	7.133	9.056	9.505	9.738	9.808	9.841
May	3.852	4.863	5.292	5.694	5.928	6.123
Jun	0.903	1.469	1.896	2.488	2.965	3.472
Jul	0.344	0.474	0.529	0.581	0.611	0.636
Aug	0.240	0.300	0.337	0.381	0.413	0.443
Sep	0.234	0.269	0.289	0.312	0.328	0.343
Oct	0.336	0.378	0.387	0.392	0.393	0.393
Nov	0.304	0.472	0.593	0.758	0.887	1.023
Dec	0.667	0.854	0.934	1.008	1.052	1.088

Deficit Intensities

	Pusat-Özen Dam Inflows - Deficit Intensities (hm³/year) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.791	1.212	1.481	1.806	2.038	2.262
Feb	0.885	1.183	1.744	3.662	7.264	15.268
Mar	3.258	4.477	5.063	5.621	5.934	6.180
Apr	6.522	7.939	8.266	8.434	8.483	8.507
May	3.909	5.617	6.397	7.106	7.486	7.773
Jun	0.986	1.712	2.164	2.696	3.063	3.409
Jul	0.589	0.679	0.698	0.708	0.711	0.712
Aug	0.582	0.793	0.883	0.967	1.016	1.057
Sep	0.128	0.383	0.680	1.254	1.862	2.657
Oct	0.405	0.695	0.922	1.245	1.513	1.802
Nov	0.645	0.964	1.189	1.488	1.719	1.958
Dec	0.857	1.143	1.359	1.665	1.919	2.197

	Beydilli Dam Inflows - Deficit Intensities (hm³/year) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	1.303	1.541	1.592	1.616	1.623	1.626
Feb	1.540	1.919	2.080	2.231	2.319	2.392
Mar	4.534	6.690	7.606	8.464	8.963	9.380
Apr	9.427	12.876	15.155	18.031	20.174	22.317
May	3.830	5.540	6.481	7.506	8.176	8.782
Jun	1.110	1.548	1.843	2.219	2.502	2.787
Jul	0.397	0.458	0.484	0.508	0.522	0.534
Aug	0.395	0.464	0.504	0.552	0.585	0.616
Sep	0.375	0.461	0.513	0.575	0.619	0.662
Oct	0.432	0.583	0.617	0.634	0.639	0.641
Nov	1.484	1.802	1.994	2.222	2.383	2.538
Dec	1.395	1.761	1.989	2.265	2.463	2.656

	Beydilli Weir Mid-Basin Inflows - Deficit Intensities (hm³/year) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.112	0.132	0.136	0.138	0.138	0.139
Feb	0.131	0.164	0.177	0.190	0.198	0.204
Mar	0.386	0.570	0.648	0.721	0.764	0.799
Apr	0.803	1.097	1.291	1.536	1.719	1.901
May	0.326	0.472	0.552	0.640	0.697	0.748
Jun	0.095	0.132	0.157	0.189	0.213	0.237
Jul	0.034	0.039	0.041	0.043	0.044	0.045
Aug	0.034	0.039	0.043	0.047	0.050	0.052
Sep	0.032	0.039	0.044	0.049	0.053	0.056
Oct	0.023	0.046	0.063	0.084	0.100	0.116
Nov	0.126	0.154	0.170	0.189	0.203	0.216
Dec	0.119	0.150	0.169	0.193	0.210	0.226

	Dört Eylül Dam Inflows - Deficit Intensities (hm³/year) Return Period (without Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.391	0.679	0.859	1.070	1.216	1.354
Feb	0.656	0.954	1.374	2.456	4.026	6.806
Mar	2.213	3.350	3.995	4.712	5.187	5.620
Apr	4.599	6.714	7.614	8.455	8.945	9.354
May	2.672	4.201	5.092	6.096	6.770	7.390
Jun	0.804	1.167	1.366	1.584	1.727	1.855
Jul	0.195	0.389	0.558	0.819	1.050	1.313
Aug	0.157	0.209	0.243	0.285	0.316	0.347
Sep	0.176	0.218	0.245	0.276	0.299	0.321
Oct	0.264	0.328	0.355	0.381	0.396	0.408
Nov	0.280	0.360	0.400	0.442	0.469	0.492
Dec	0.500	0.645	0.719	0.796	0.845	0.887

D. Deficit Parameters with Climate Change Modifications

Climate change modified deficit parameters which include deficit amounts, deficit lengths, deficit magnitudes and deficit intensities are given in the following tables.

Deficit Amounts

	Pusat-Özen Dam Inflows - Deficit Amounts (hm^3) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	2.154	3.534	4.402	5.423	6.129	6.793
Feb	4.389	9.669	14.790	23.379	31.477	41.165
Mar	4.900	10.653	17.051	30.043	45.168	67.258
Apr	11.010	26.290	38.676	55.797	69.194	82.909
May	8.062	12.057	14.387	16.983	18.680	20.192
Jun	3.430	5.128	5.881	6.596	7.016	7.369
Jul	2.537	3.382	3.757	4.113	4.322	4.497
Aug	1.735	8.638	20.495	51.977	95.138	164.136
Sep	0.512	5.729	21.021	85.265	211.741	481.038
Oct	1.806	4.841	8.229	14.572	21.123	29.527
Nov	1.343	3.099	4.859	7.888	10.806	14.354
Dec	1.968	3.677	5.148	7.396	9.359	11.574

	Beydilli Dam Inflows - Deficit Amounts (hm^3) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	10.739	17.148	23.617	35.161	46.934	62.206
Feb	15.395	28.067	41.325	64.980	88.552	118.058
Mar	28.679	55.592	85.148	140.222	197.225	270.779
Apr	50.339	76.366	99.884	136.743	169.507	206.949
May	11.721	13.870	15.281	16.923	18.022	19.014
Jun	6.472	9.519	12.204	16.323	19.915	23.956
Jul	4.764	7.940	11.035	16.219	21.105	26.956
Aug	6.713	13.096	20.140	33.325	47.026	64.759
Sep	6.986	13.802	21.402	35.755	50.788	70.369
Oct	4.616	10.642	18.227	34.207	52.612	78.488
Nov	7.613	19.777	41.622	112.599	239.927	511.885
Dec	13.239	38.716	87.299	255.628	575.915	1297.079

	Beydilli Weir Mid-Basin Inflows - Deficit Amounts (hm³) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.307	0.650	0.976	1.546	2.122	2.866
Feb	0.299	0.829	1.429	2.564	3.747	5.273
Mar	0.478	1.474	2.685	5.115	7.769	11.323
Apr	1.536	3.119	4.552	6.829	8.885	11.264
May	0.591	0.865	1.024	1.203	1.321	1.427
Jun	0.213	0.411	0.583	0.848	1.082	1.348
Jul	0.115	0.275	0.437	0.718	0.991	1.326
Aug	0.110	0.343	0.629	1.206	1.839	2.690
Sep	0.111	0.354	0.656	1.273	1.957	2.883
Oct	0.050	0.208	0.443	0.999	1.693	2.724
Nov	0.167	0.369	0.732	1.913	4.034	8.565
Dec	0.204	0.579	1.296	3.793	8.553	19.279

	Dört Eylül Dam Inflows - Deficit Amounts (hm³) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.935	2.215	3.708	6.877	10.719	16.530
Feb	3.379	7.593	11.801	19.016	25.944	34.350
Mar	3.158	8.022	14.785	31.821	56.041	98.157
Apr	9.172	21.377	31.321	45.118	55.946	67.055
May	6.102	6.920	7.130	7.244	7.279	7.297
Jun	1.459	2.742	3.867	5.609	7.146	8.894
Jul	1.229	2.847	4.122	5.841	7.157	8.483
Aug	1.581	3.164	4.616	6.947	9.065	11.529
Sep	0.923	1.959	2.953	4.601	6.142	7.973
Oct	0.928	1.232	1.369	1.500	1.577	1.642
Nov	0.435	1.889	5.772	24.842	74.197	220.512
Dec	1.090	4.169	10.703	35.934	88.747	218.126

Deficit Lengths

	Pusat-Özen Dam Inflows - Deficit Lengths (year) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	2.755	4.342	5.313	6.435	7.201	7.915
Feb	4.416	10.880	17.676	29.812	41.866	56.871
Mar	1.773	3.415	4.861	7.108	9.099	11.370
Apr	2.240	4.791	6.712	9.243	11.154	13.063
May	2.063	3.340	4.327	5.721	6.858	8.077
Jun	2.152	3.620	4.789	6.474	7.875	9.396
Jul	4.279	5.280	5.723	6.145	6.392	6.600
Aug	4.707	15.615	29.774	59.670	93.731	140.869
Sep	3.416	13.728	29.021	64.997	109.742	176.030
Oct	4.431	11.377	18.898	32.643	46.559	64.138
Nov	2.386	5.133	7.211	9.957	12.034	14.111
Dec	2.196	3.768	5.038	6.888	8.440	10.139

	Beydilli Dam Inflows - Deficit Lengths (year) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	7.548	10.953	13.922	18.432	22.331	26.689
Feb	8.280	9.454	10.135	10.867	11.333	11.743
Mar	4.073	5.150	5.900	6.831	7.498	8.139
Apr	6.293	8.826	10.738	13.261	15.166	17.069
May	3.183	3.792	4.197	4.681	5.018	5.335
Jun	4.167	4.616	4.876	5.156	5.334	5.491
Jul	12.102	19.488	26.490	37.935	48.494	60.923
Aug	16.397	31.541	48.072	78.706	110.263	150.828
Sep	17.811	34.610	53.096	87.602	123.371	169.583
Oct	6.564	9.883	12.865	17.514	21.627	26.311
Nov	10.037	11.814	12.845	13.954	14.659	15.281
Dec	7.585	10.439	12.562	15.333	17.405	19.461

	Beydilli Weir Mid-Basin Inflows - Deficit Lengths (year) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	3.016	5.679	7.960	11.438	14.469	17.884
Feb	4.554	7.269	8.458	9.581	10.239	10.791
Mar	1.934	3.327	4.220	5.282	6.025	6.728
Apr	2.151	4.702	6.623	9.155	11.066	12.974
May	1.827	2.738	3.269	3.865	4.263	4.629
Jun	2.742	3.780	4.235	4.664	4.916	5.127
Jul	3.742	8.409	12.953	20.599	27.829	36.498
Aug	3.273	9.947	18.001	34.035	51.441	74.643
Sep	3.467	10.721	19.581	37.391	56.877	83.010
Oct	2.395	4.801	6.958	10.365	13.422	16.943
Nov	4.394	8.505	10.305	12.007	13.003	13.839
Dec	2.752	5.759	7.959	10.806	12.925	15.020

	Dört Eylül Dam Inflows - Deficit Lengths (year) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	3.772	5.638	6.480	7.285	7.760	8.159
Feb	4.549	10.967	17.711	29.746	41.693	56.562
Mar	1.729	3.274	4.636	6.754	8.629	10.767
Apr	2.462	5.097	7.079	9.690	11.660	13.625
May	2.112	3.384	4.375	5.776	6.922	8.151
Jun	2.382	3.178	3.538	3.881	4.084	4.254
Jul	4.439	8.824	12.828	19.230	25.031	31.761
Aug	9.543	14.981	19.152	24.981	29.700	34.725
Sep	5.222	10.827	16.106	24.752	32.744	42.160
Oct	2.833	4.951	6.710	9.323	11.550	14.015
Nov	4.541	7.209	8.412	9.563	10.241	10.812
Dec	5.073	7.650	8.813	9.924	10.579	11.131

Deficit Magnitudes

	Pusat-Özen Dam Inflows - Deficit Magnitudes (hm³) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	1.303	1.555	1.636	1.690	1.711	1.723
Feb	1.451	1.683	1.822	1.985	2.099	2.207
Mar	4.190	5.695	6.449	7.182	7.601	7.934
Apr	8.460	10.872	11.942	12.958	13.554	14.056
May	5.506	7.096	7.736	8.249	8.491	8.654
Jun	1.749	2.282	2.518	2.742	2.874	2.984
Jul	0.695	1.266	1.749	2.477	3.106	3.808
Aug	0.507	1.259	2.055	3.483	4.906	6.684
Sep	0.166	0.520	0.963	1.869	2.875	4.241
Oct	0.783	0.808	0.814	0.816	0.817	0.817
Nov	0.792	1.187	1.475	1.865	2.172	2.492
Dec	1.273	1.542	1.662	1.775	1.841	1.897

	Beydilli Dam Inflows - Deficit Magnitudes (hm³) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	2.071	2.092	2.097	2.100	2.100	2.101
Feb	2.485	2.634	2.720	2.813	2.872	2.924
Mar	10.729	13.657	15.786	18.525	20.550	22.540
Apr	16.305	16.493	16.543	16.568	16.575	16.578
May	7.316	8.165	8.655	9.159	9.457	9.698
Jun	2.813	3.586	4.194	5.036	5.707	6.411
Jul	0.955	1.178	1.349	1.581	1.762	1.949
Aug	0.624	0.704	0.761	0.833	0.887	0.940
Sep	0.581	0.611	0.628	0.646	0.658	0.668
Oct	0.817	0.912	0.968	1.027	1.065	1.099
Nov	1.899	1.910	1.913	1.915	1.915	1.915
Dec	2.312	2.342	2.351	2.356	2.357	2.358

	Beydilli Weir Mid-Basin Inflows - Deficit Magnitudes (hm³) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.156	0.173	0.177	0.178	0.179	0.179
Feb	0.183	0.207	0.211	0.213	0.214	0.214
Mar	0.444	0.748	0.947	1.195	1.376	1.552
Apr	1.240	1.360	1.389	1.404	1.409	1.411
May	0.424	0.564	0.634	0.704	0.744	0.776
Jun	0.132	0.199	0.248	0.314	0.366	0.421
Jul	0.048	0.069	0.084	0.103	0.117	0.132
Aug	0.039	0.048	0.054	0.061	0.066	0.070
Sep	0.042	0.047	0.050	0.052	0.054	0.055
Oct	0.044	0.063	0.071	0.079	0.083	0.087
Nov	0.144	0.158	0.165	0.171	0.175	0.178
Dec	0.173	0.192	0.197	0.200	0.200	0.201

	Dört Eylül Dam Inflows - Deficit Magnitudes (hm³) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.625	0.791	0.866	0.937	0.979	1.015
Feb	1.092	1.304	1.437	1.595	1.707	1.815
Mar	2.641	4.832	6.715	9.587	12.088	14.904
Apr	7.676	9.188	9.562	9.758	9.818	9.846
May	4.086	4.969	5.367	5.748	5.973	6.162
Jun	0.998	1.560	1.989	2.588	3.071	3.585
Jul	0.374	0.488	0.539	0.588	0.616	0.641
Aug	0.251	0.308	0.344	0.388	0.419	0.450
Sep	0.241	0.273	0.293	0.316	0.331	0.346
Oct	0.349	0.381	0.388	0.392	0.393	0.393
Nov	0.333	0.498	0.620	0.785	0.916	1.053
Dec	0.710	0.874	0.948	1.019	1.060	1.095

Deficit Intensities

	Pusat-Özen Dam Inflows - Deficit Intensities (hm³/year) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.845	1.253	1.518	1.841	2.071	2.294
Feb	0.905	1.240	1.871	4.029	8.078	17.077
Mar	3.438	4.575	5.135	5.672	5.974	6.211
Apr	6.809	8.007	8.295	8.444	8.488	8.509
May	4.168	5.750	6.491	7.169	7.533	7.809
Jun	1.078	1.782	2.227	2.751	3.115	3.458
Jul	0.608	0.683	0.700	0.709	0.711	0.712
Aug	0.616	0.808	0.894	0.975	1.022	1.062
Sep	0.150	0.421	0.733	1.333	1.966	2.792
Oct	0.438	0.727	0.956	1.283	1.554	1.846
Nov	0.684	0.998	1.222	1.521	1.754	1.994
Dec	0.891	1.174	1.391	1.701	1.958	2.240

	Beydilli Dam Inflows - Deficit Intensities (hm³/year) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	1.590	1.615	1.623	1.626	1.627	1.628
Feb	2.071	2.224	2.313	2.409	2.470	2.523
Mar	7.551	8.424	8.930	9.475	9.822	10.127
Apr	14.997	17.878	20.021	22.856	25.023	27.220
May	6.420	7.455	8.130	8.925	9.471	9.979
Jun	1.822	2.199	2.482	2.859	3.150	3.446
Jul	0.482	0.507	0.521	0.537	0.546	0.555
Aug	0.502	0.549	0.583	0.624	0.654	0.683
Sep	0.510	0.572	0.616	0.673	0.714	0.755
Oct	0.615	0.634	0.639	0.642	0.643	0.643
Nov	1.981	2.210	2.372	2.576	2.725	2.872
Dec	1.973	2.250	2.449	2.704	2.893	3.081

	Beydilli Weir Mid-Basin Inflows - Deficit Intensities (hm³/year) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.115	0.132	0.136	0.138	0.138	0.139
Feb	0.135	0.165	0.178	0.191	0.198	0.204
Mar	0.407	0.579	0.655	0.726	0.767	0.802
Apr	0.829	1.117	1.310	1.555	1.737	1.920
May	0.340	0.481	0.559	0.646	0.702	0.753
Jun	0.098	0.135	0.159	0.191	0.216	0.240
Jul	0.034	0.039	0.041	0.043	0.045	0.046
Aug	0.034	0.040	0.043	0.047	0.050	0.053
Sep	0.033	0.040	0.044	0.049	0.053	0.057
Oct	0.024	0.048	0.064	0.086	0.102	0.118
Nov	0.129	0.155	0.171	0.191	0.204	0.218
Dec	0.122	0.152	0.171	0.195	0.212	0.228

	Dört Eylül Dam Inflows - Deficit Intensities (hm³/year) Return Period (with Climate Change Modification)					
Month	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
Jan	0.444	0.720	0.895	1.102	1.246	1.382
Feb	0.692	1.025	1.499	2.722	4.497	7.642
Mar	2.435	3.499	4.121	4.818	5.283	5.709
Apr	5.088	6.936	7.771	8.568	9.038	9.434
May	2.966	4.406	5.267	6.246	6.907	7.517
Jun	0.877	1.213	1.405	1.616	1.755	1.882
Jul	0.225	0.423	0.597	0.866	1.104	1.374
Aug	0.166	0.217	0.250	0.292	0.323	0.354
Sep	0.184	0.224	0.250	0.281	0.304	0.325
Oct	0.279	0.335	0.360	0.384	0.398	0.410
Nov	0.297	0.369	0.408	0.448	0.474	0.497
Dec	0.531	0.663	0.733	0.807	0.854	0.896

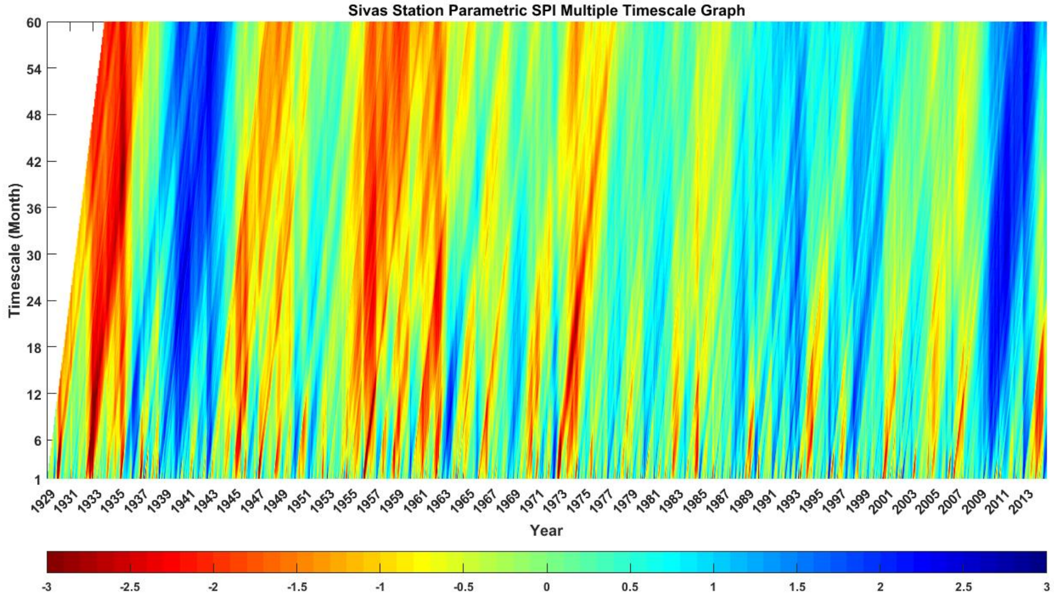
E. Deficiency Hydrograph Calculation Code

```
function [ out ] = CalcTotalDeficit( t1, t2, d, dm, dl, isPlot )

% This program draws the deficit hydrograph by using
% deficits amount, deficit length and deficit magnitude.
%
% Written by Mustafa Kemal Türkeri, December 2018
%
% t1     = start time (year) to calculate area under the shape.
% t2     = end time (year) to calculate area under the shape.
% d      = deficit amount.
% dm     = deficit magnitude.
% dl     = deficit length.
% isPlot= bool value (0 or 1) which determines the code will produce
%          plot or not.
% out    = output of the code (area under pentagonal shape)

refdeficit(1,1)=0;
refdeficit(1,2)=0;
refdeficit(2,1)=1;
refdeficit(2,2)=0;
refdeficit(3,1)=1+dl/4;
refdeficit(3,2)=((4*d/dl)-dm)/2;
refdeficit(4,1)=1+dl/4*2;
refdeficit(4,2)=dm;
refdeficit(5,1)=1+dl/4*3;
refdeficit(5,2)=((4*d/dl)-dm)/2;
refdeficit(6,1)=1+dl;
refdeficit(6,2)=0;
refdeficit(7,1)=2+dl;
refdeficit(7,2)=0;
i=7;
% First Assumption: refdeficit(:,2) should not be below zero (i.e.
% surplus). Therefore it is replaced with triangular case.
if sum(sum(refdeficit<0))>0
    clear refdeficit i
    refdeficit(1,1)=0;
    refdeficit(1,2)=0;
    refdeficit(2,1)=1;
    refdeficit(2,2)=0;
    refdeficit(3,1)=1+dl/4;
    refdeficit(3,2)=0;
    refdeficit(4,1)=1+dl/4*2;
    refdeficit(4,2)=dm;
    refdeficit(5,1)=1+dl/4*3;
    refdeficit(5,2)=0;
    refdeficit(6,1)=1+dl;
    refdeficit(6,2)=0;
    refdeficit(7,1)=2+dl;
    refdeficit(7,2)=0;
    i=7;
end
```

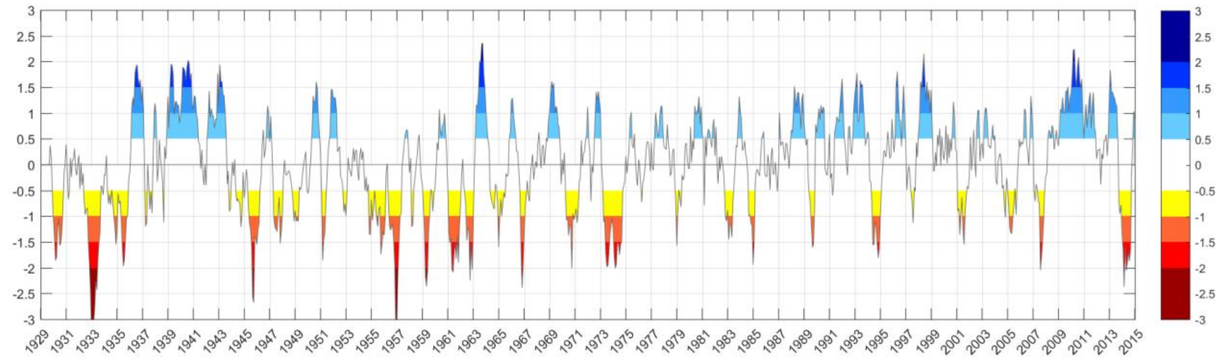
```
% Second Assumption: refdeficit(4,2) will be the greatest point at
the deficit plot!
% If not, deficit magnitude is eliminated; a trianlge with two
parameters
% (deficit length and deficit amount) is drawn.
if refdeficit(3,2)>dm
    clear refdeficit i
    refdeficit(1,1)=0;
    refdeficit(1,2)=0;
    refdeficit(2,1)=1;
    refdeficit(2,2)=0;
    refdeficit(3,1)=1+dl/2;
    refdeficit(3,2)=2*d/dl;
    refdeficit(4,1)=1+dl;
    refdeficit(4,2)=0;
    refdeficit(5,1)=2+dl;
    refdeficit(5,2)=0;
    i=5;
end

y1=interp1(refdeficit(:,1),refdeficit(:,2),t1);
y2=interp1(refdeficit(:,1),refdeficit(:,2),t2);
refdeficit(i+1,1)=t1;
refdeficit(i+1,2)=y1;
refdeficit(i+2,1)=t2;
refdeficit(i+2,2)=y2;

[S I] = sort(refdeficit(:,1));
sorted1 = refdeficit(I,:);
selected = sorted1(sorted1(:,1)<=t2 & sorted1(:,1)>=t1,:);

selected(isnan(selected(:,2)),2)=0;

out=trapz(selected(:,1),selected(:,2));

if isPlot
    plot(sorted1(:,1),sorted1(:,2));
    hold on;
    area(selected(:,1),selected(:,2));
end

end
```

F. Drought Index Results

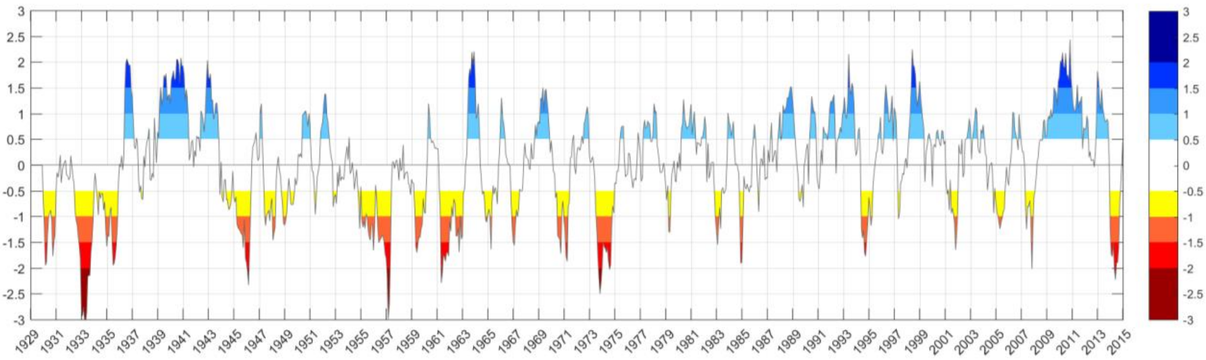
SPI Multiple Time Scale Graph for Sivas Station:



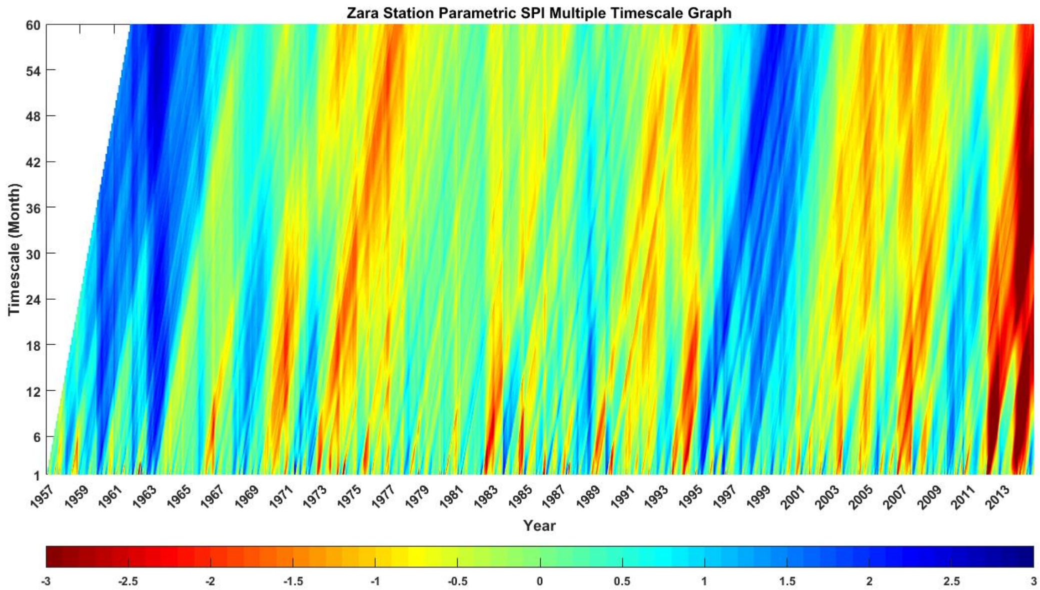
9-Month SPI Results for Sivas Station:



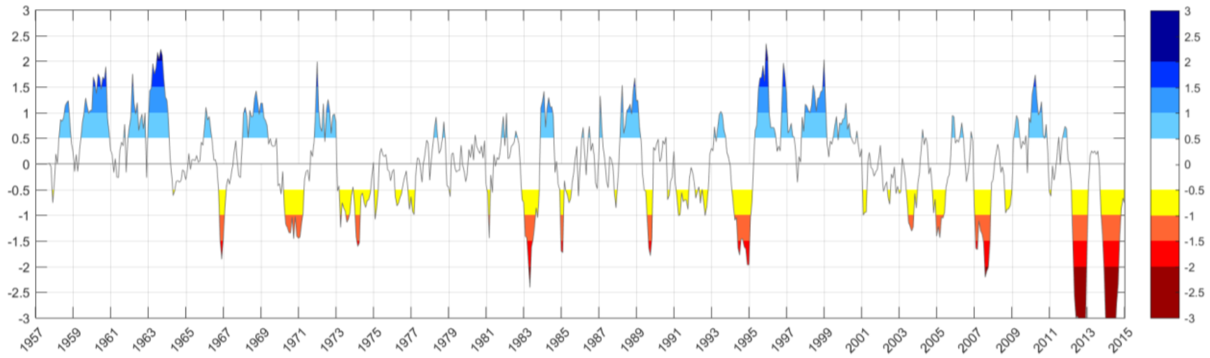
12-Month SPI Results for Sivas Station:



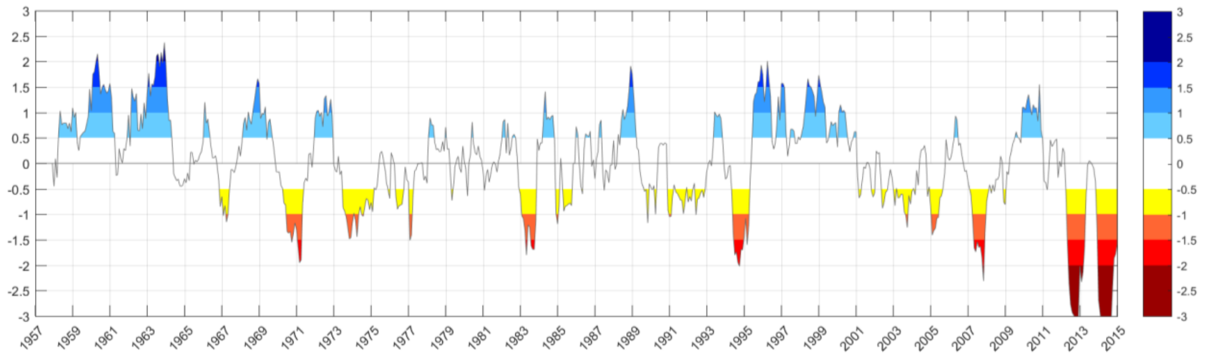
SPI Multiple Time Scale Graph for Zara Station:



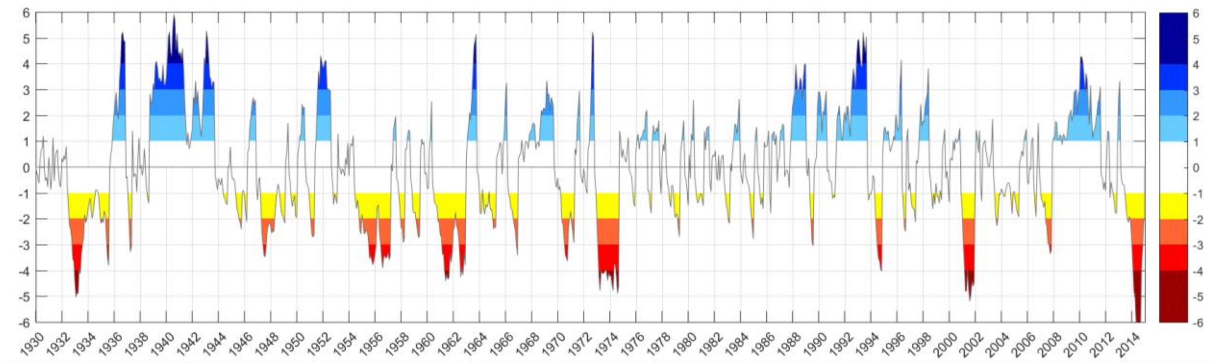
9-Month SPI Results for Zara Station:



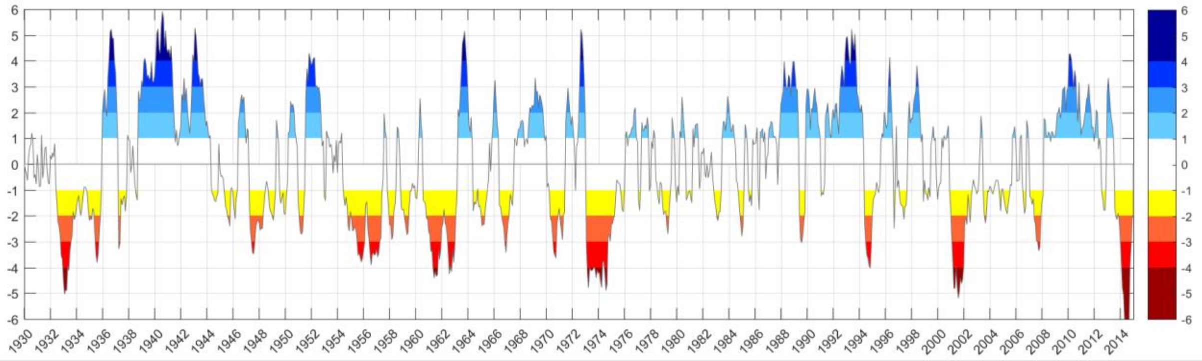
12-Month SPI Results for Zara Station:



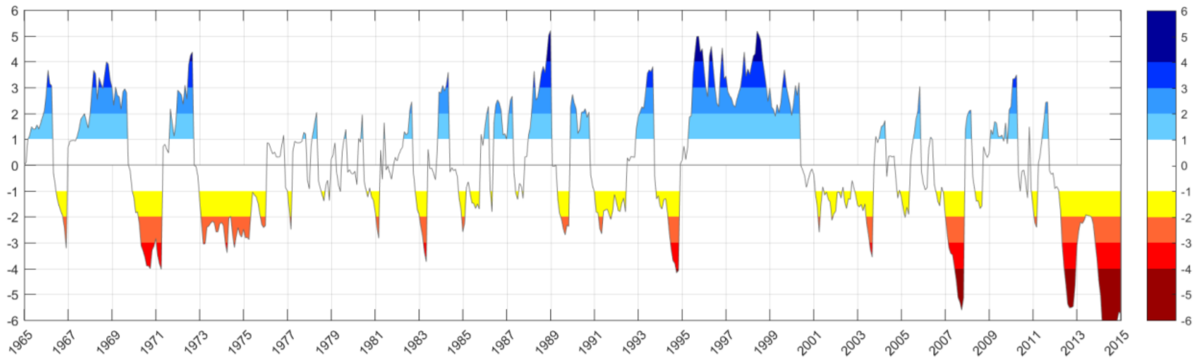
PDSI Results for Sivas Station:



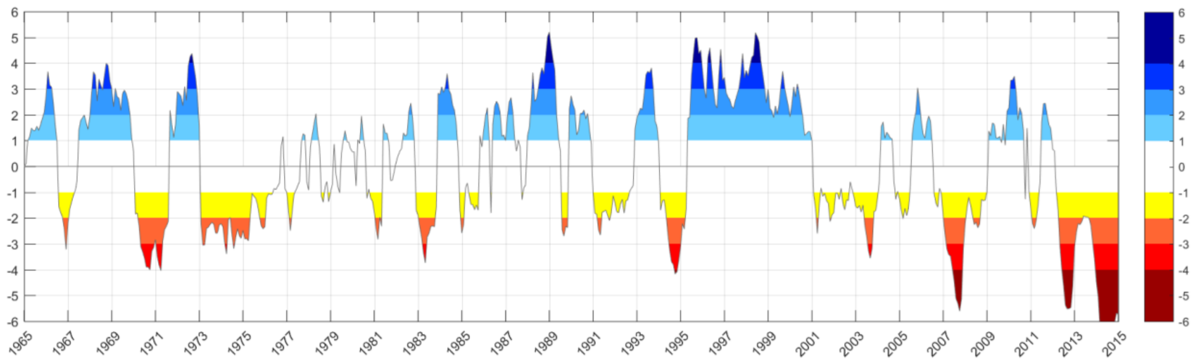
PHDI Results for Sivas Station:

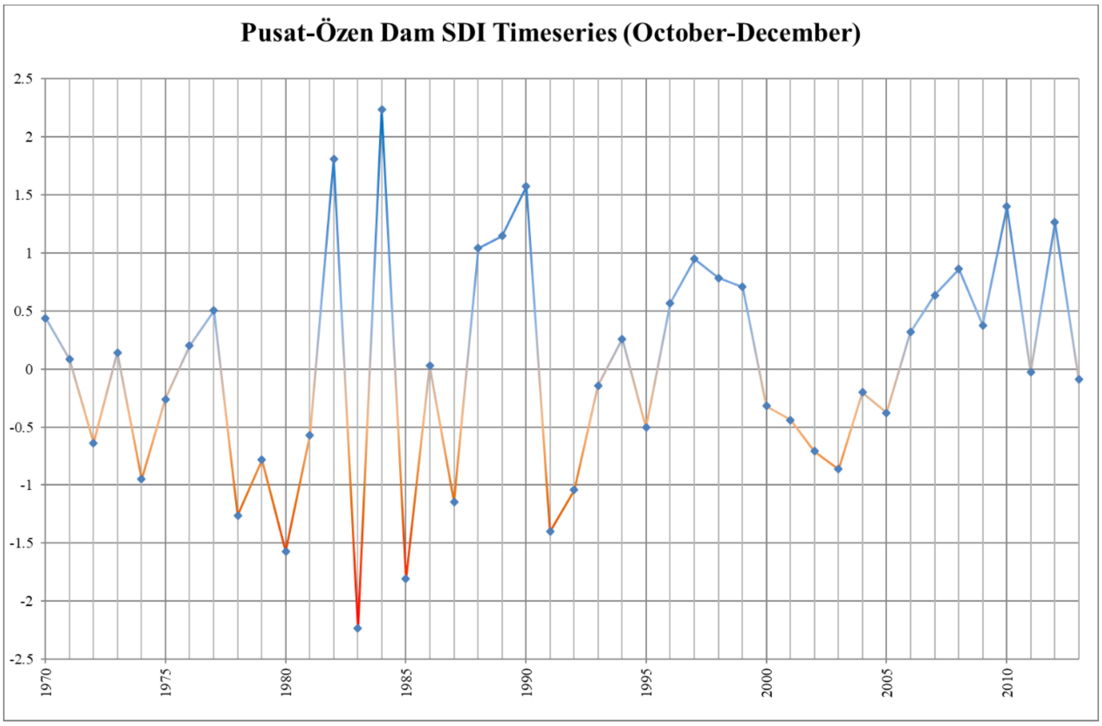


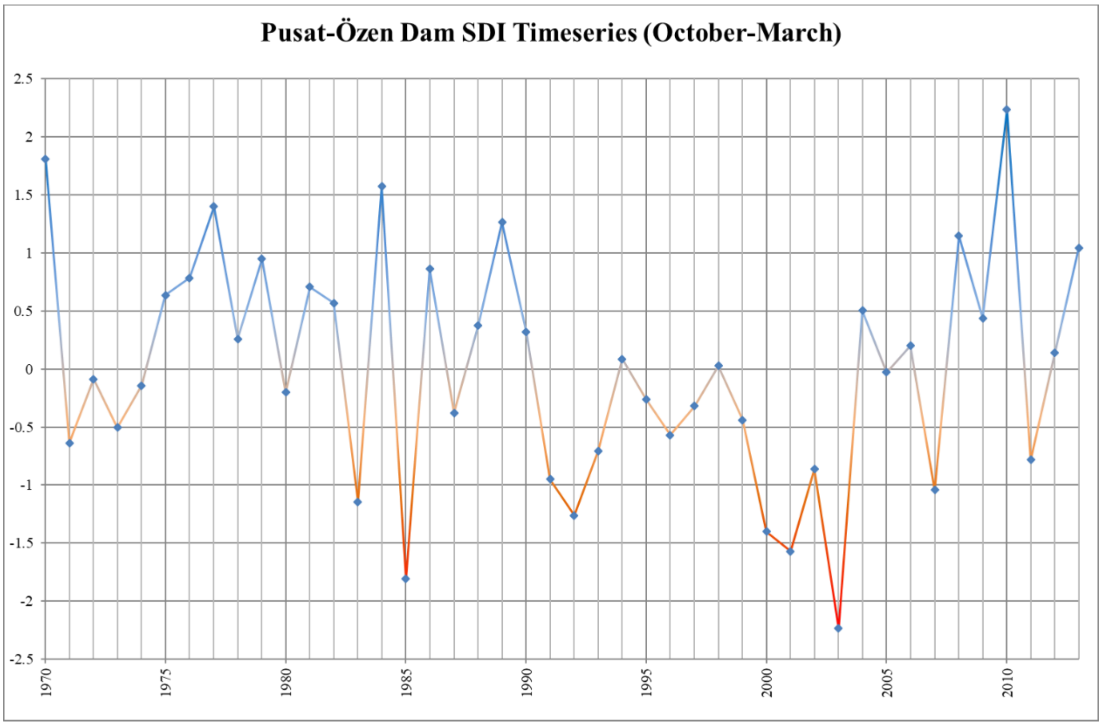
PDSI Results for Zara Station:

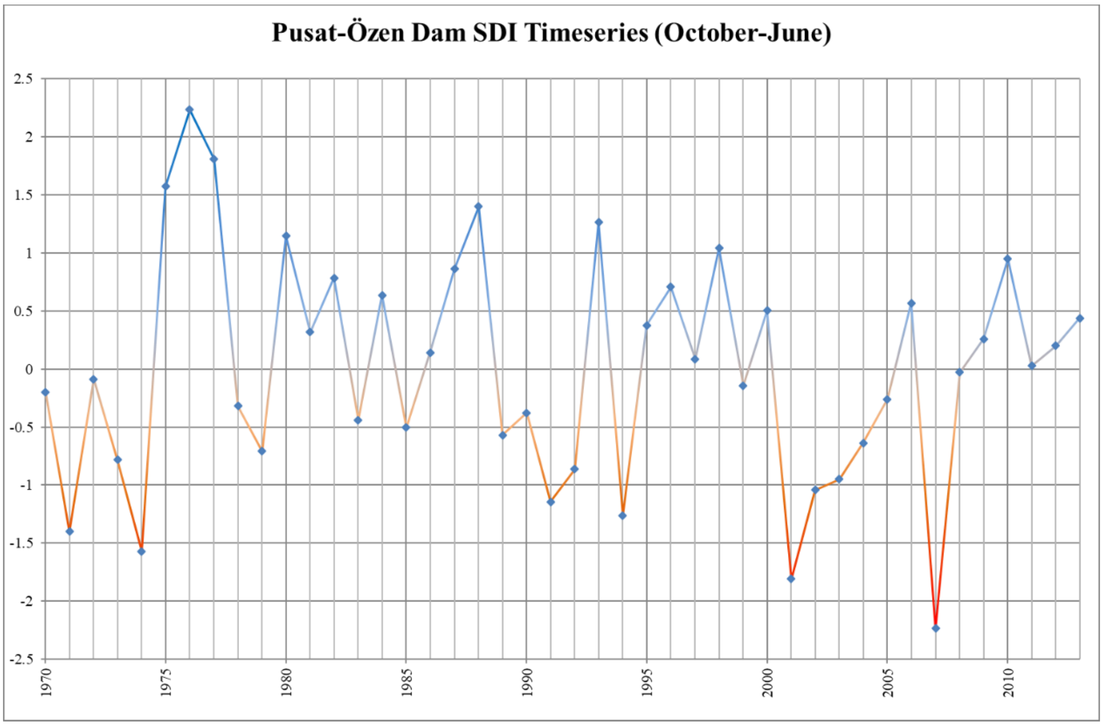


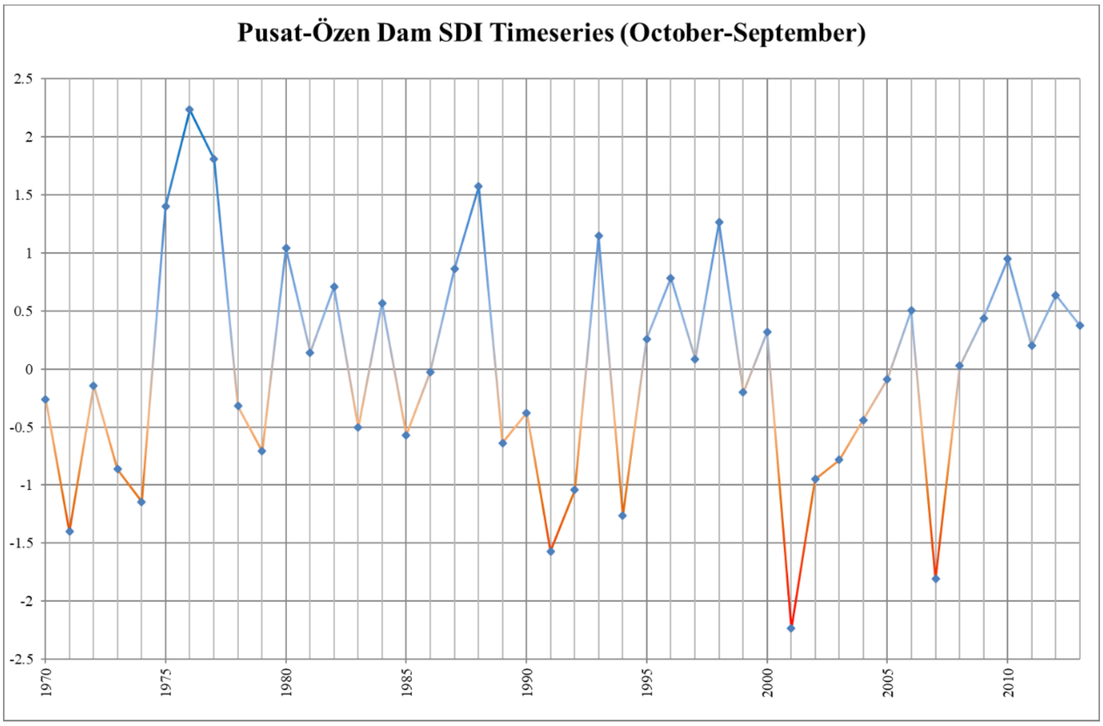
PHDI Results for Zara Station:

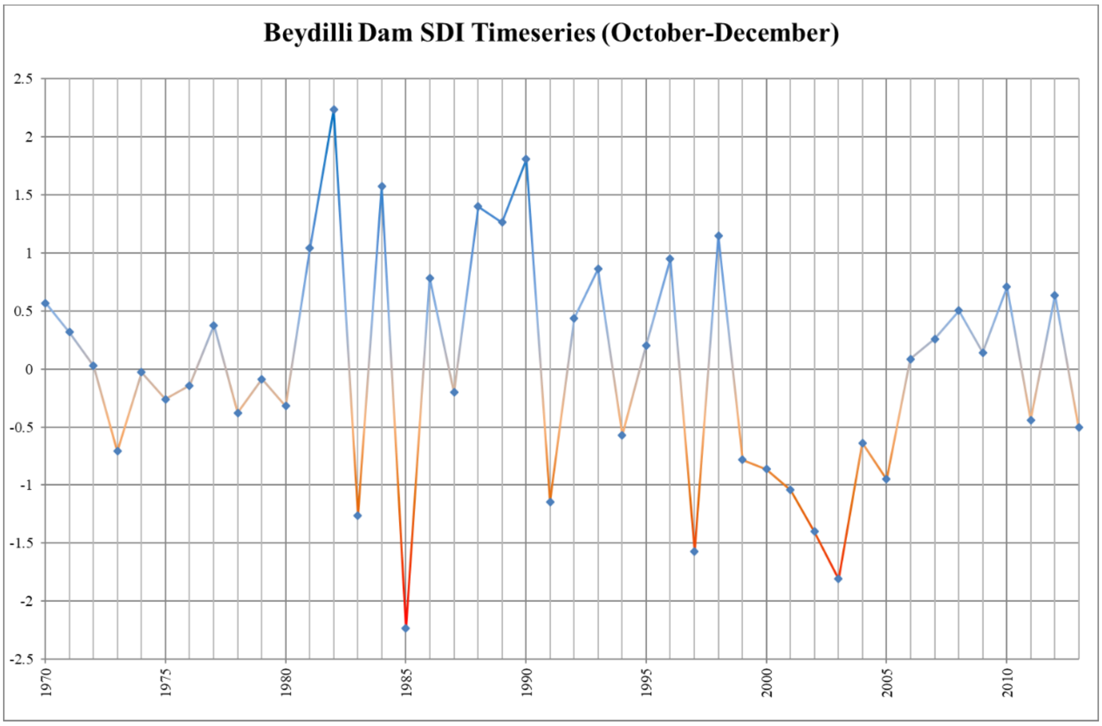


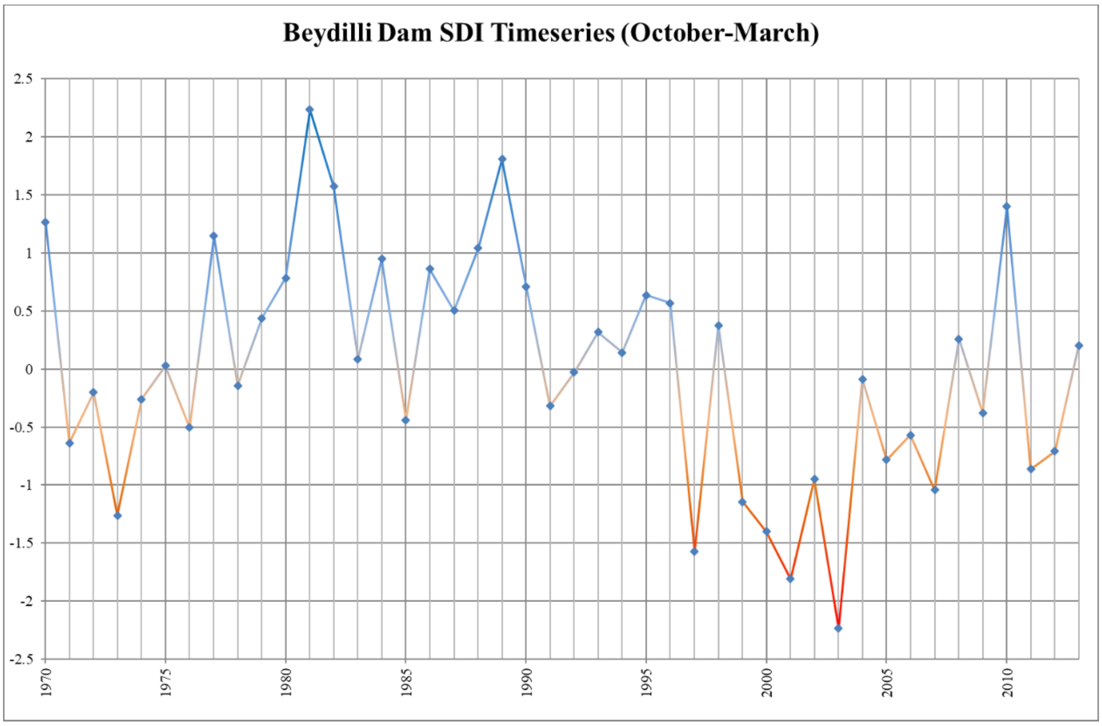

Pusat-Özen Dam SDI Timeseries (October-December)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1970
1975
1980
1985
1990
1995
2000
2005
2010


Pusat-Özen Dam SDI Timeseries (October-March)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1970
1975
1980
1985
1990
1995
2000
2005
2010


Pusat-Özen Dam SDI Timeseries (October-June)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1970
1975
1980
1985
1990
1995
2000
2005
2010


Pusat-Özen Dam SDI Timeseries (October-September)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1970
1975
1980
1985
1990
1995
2000
2005
2010


Beydilli Dam SDI Timeseries (October-December)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1970
1975
1980
1985
1990
1995
2000
2005
2010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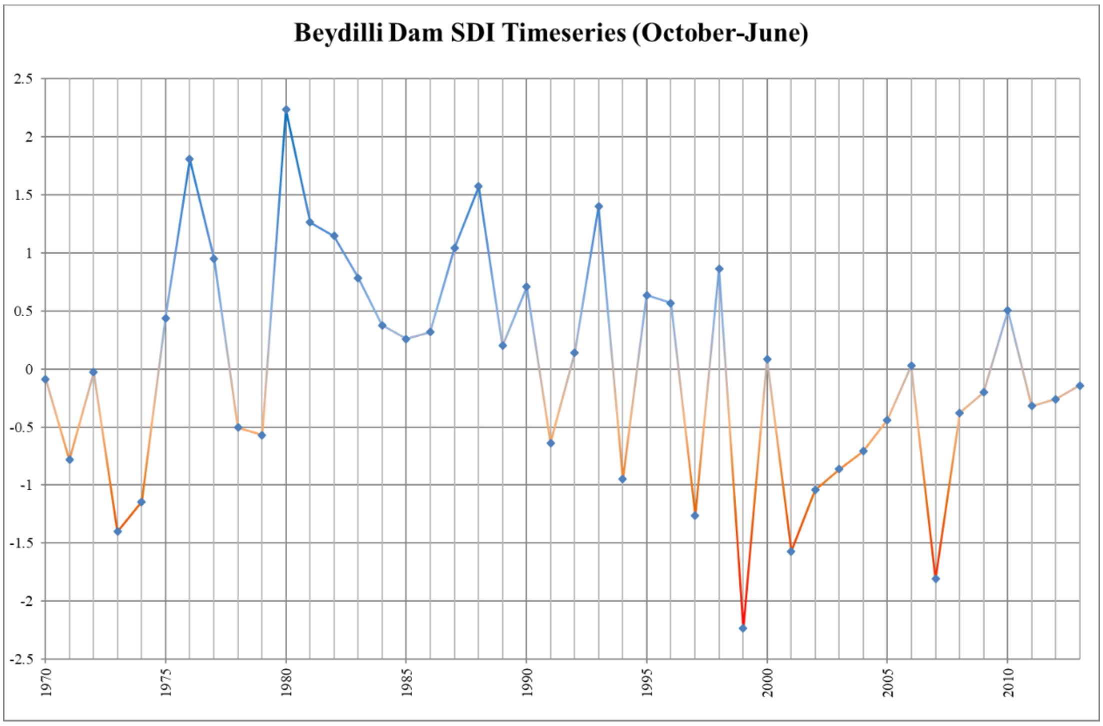
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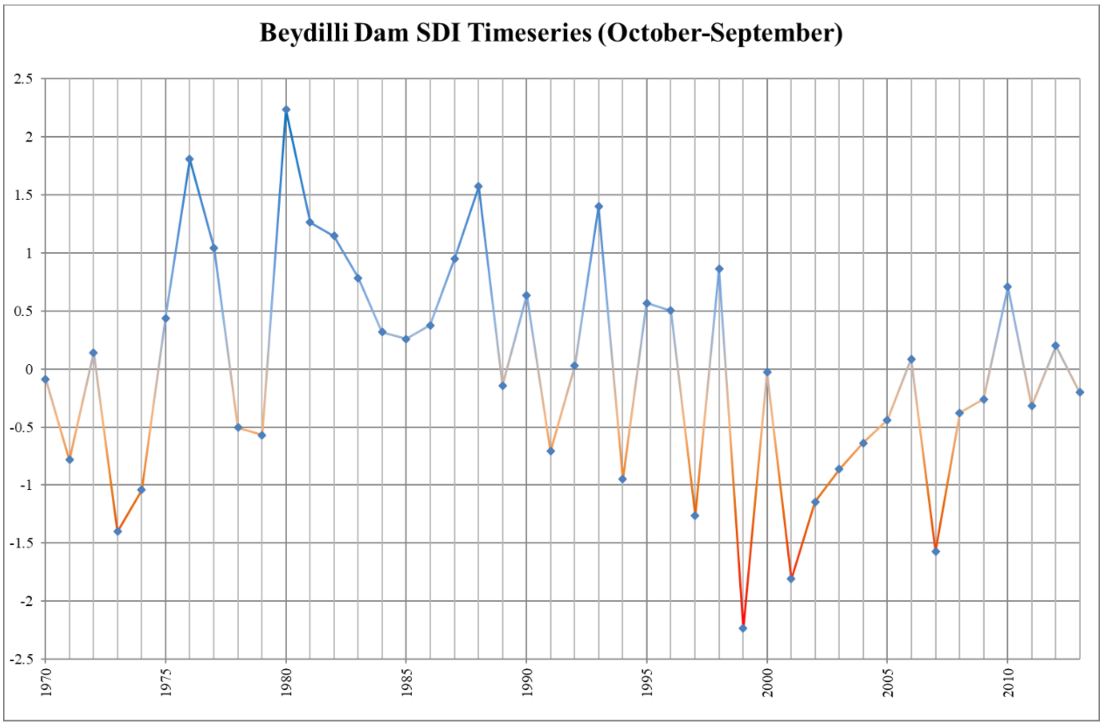
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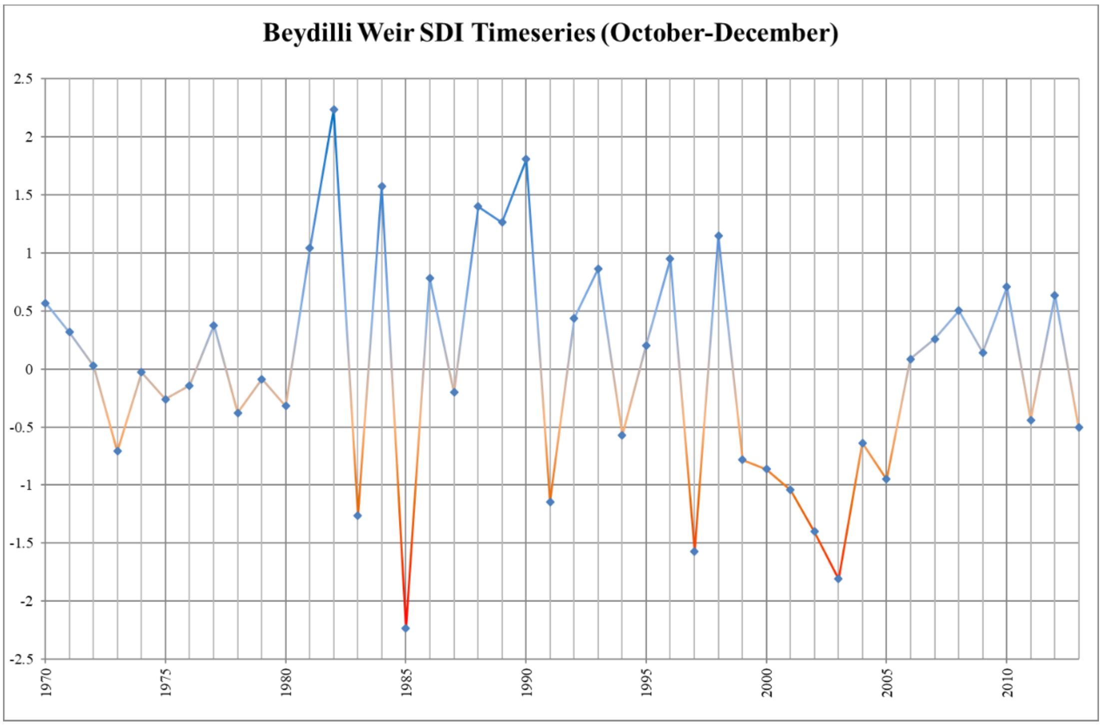
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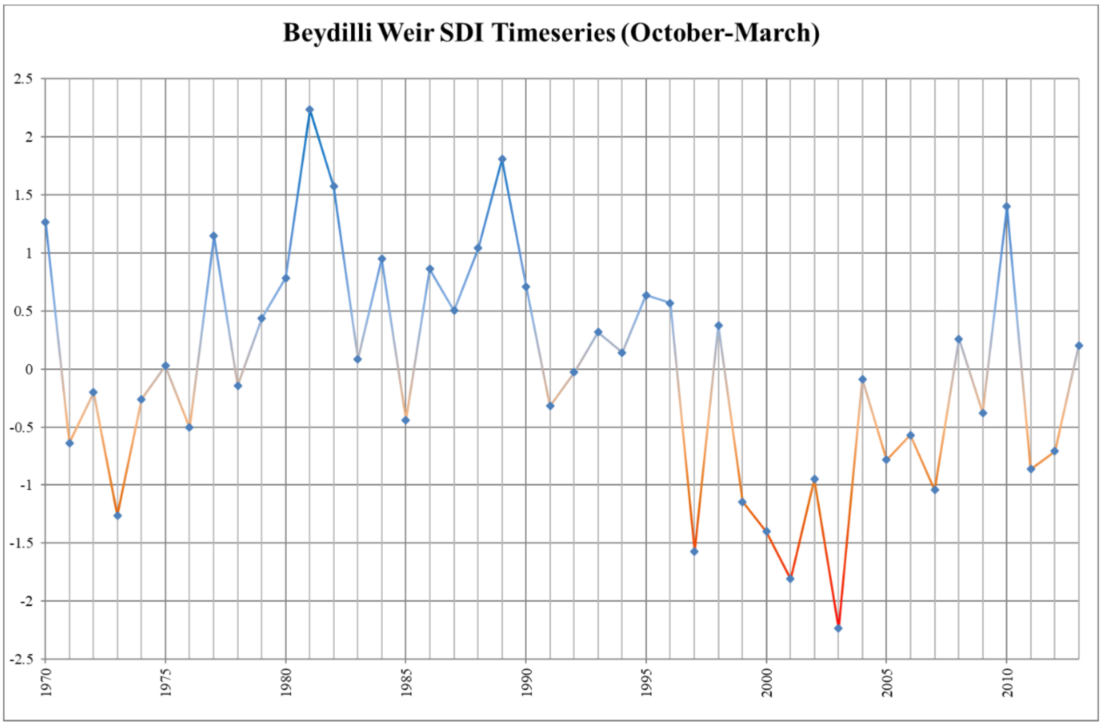
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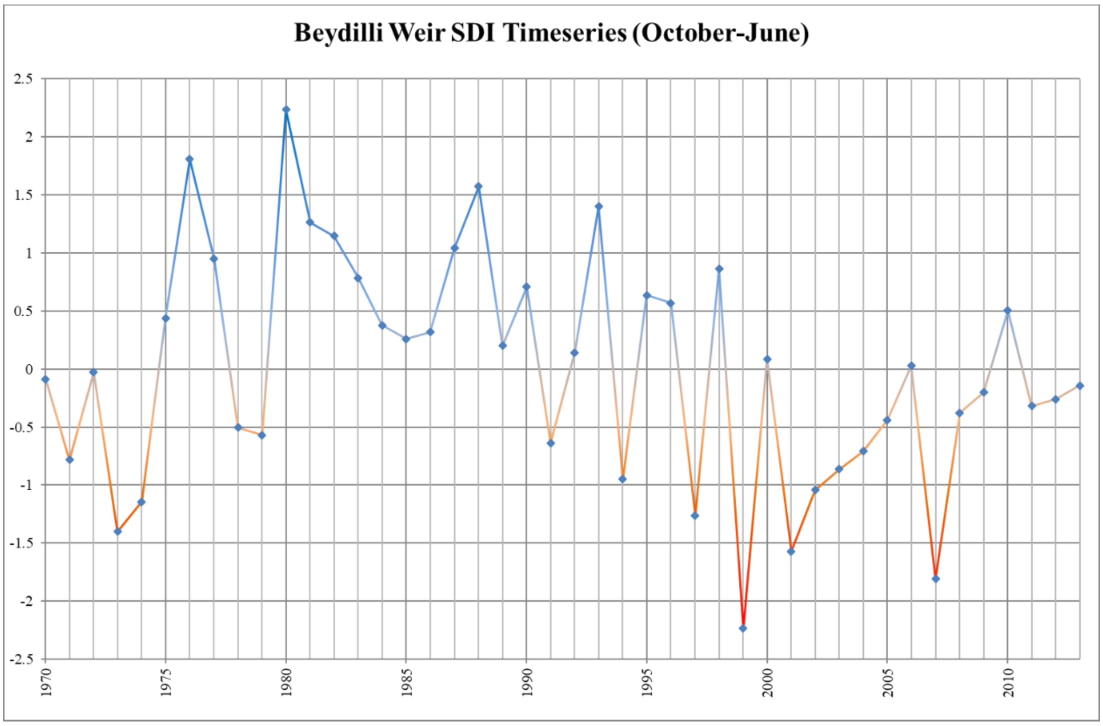
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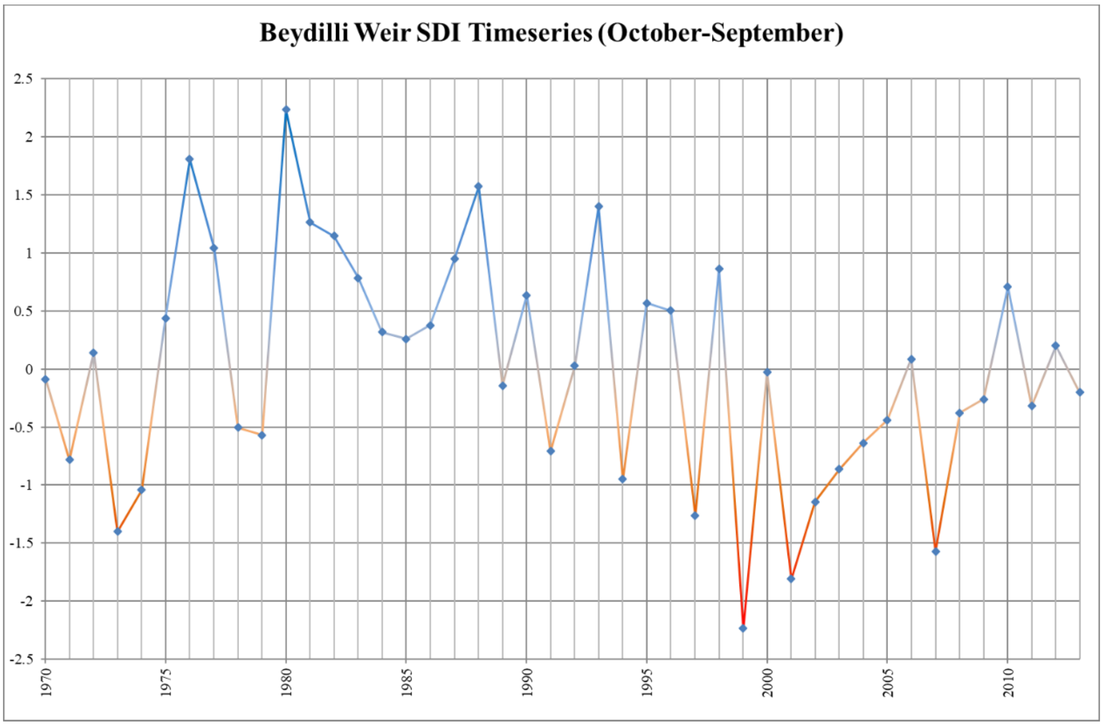
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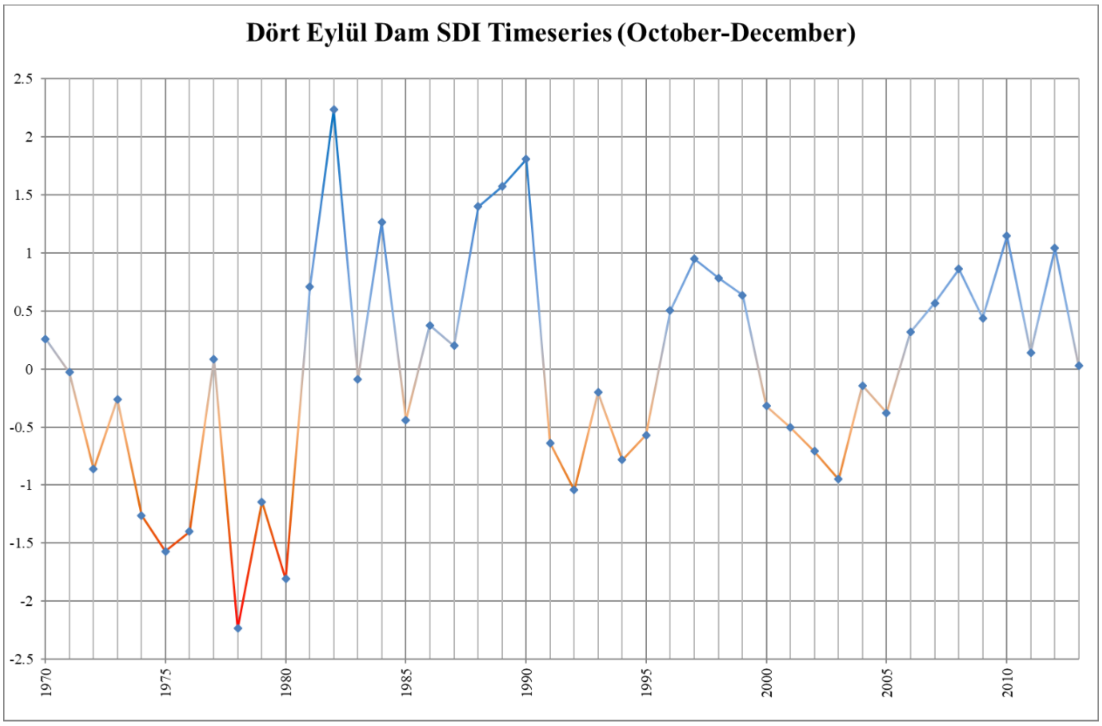
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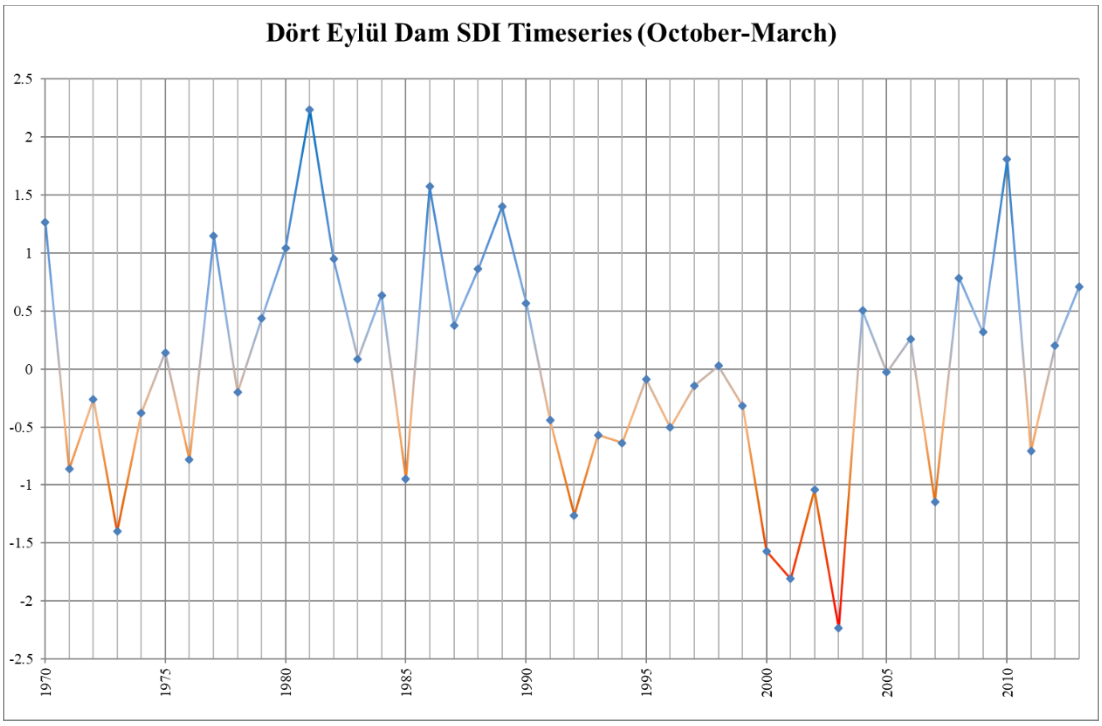
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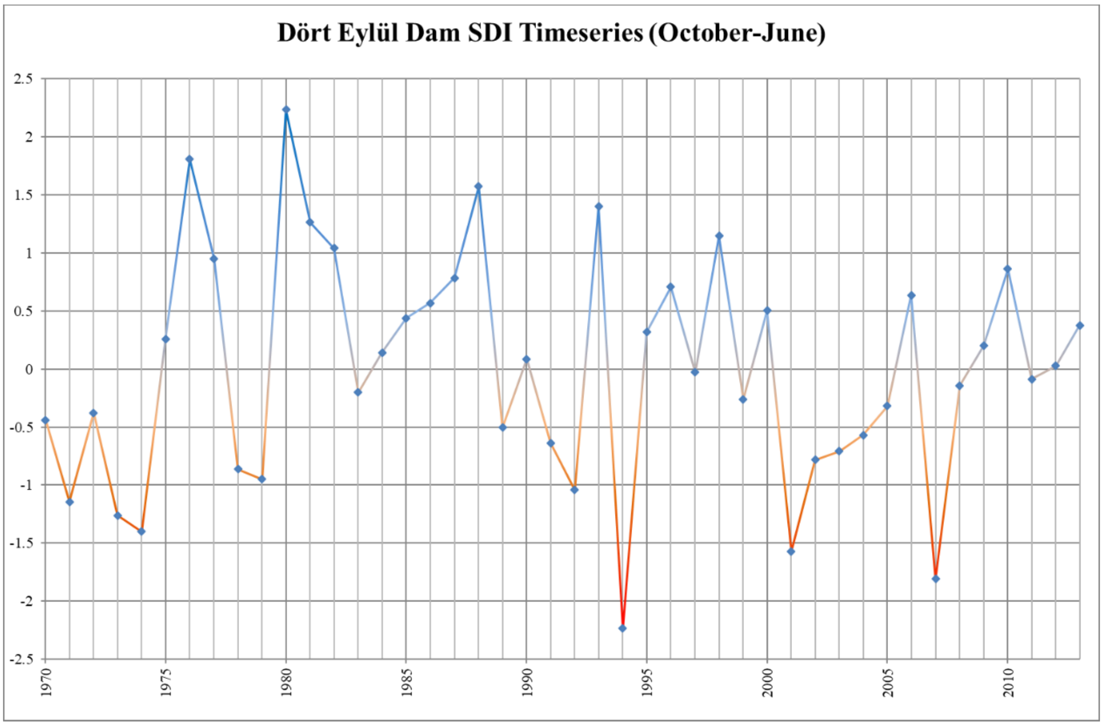
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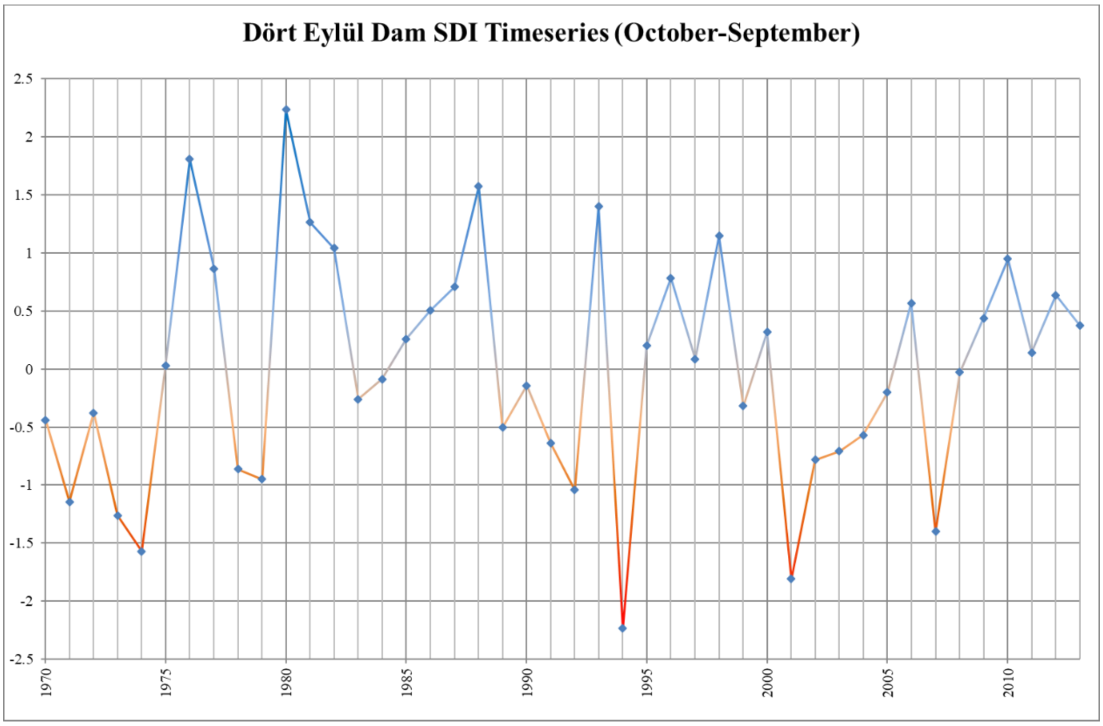
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