UTILIZATION OF NUMERICAL WEATHER PREDICTION MODELS FOR FLOOD PLANNING AND OPERATIONAL STUDIES IN DATA-SCARCE BASINS

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

BY

OKAN ÇAĞRI BOZKURT

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
CIVIL ENGINEERING

SEPTEMBER 2020

Approval of the thesis:

UTILIZATION OF NUMERICAL WEATHER PREDICTION MODELS FOR FLOOD PLANNING AND OPERATIONAL STUDIES IN DATA-SCARCE BASINS

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ABSTRACT

UTILIZATION OF NUMERICAL WEATHER PREDICTION MODELS FOR FLOOD PLANNING AND OPERATIONAL STUDIES IN DATA-SCARCE BASINS

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September 2020, 178 pages

With the increasing rates of urbanization, floods have become a more critical problem day by day. Consequently, the perception arises that the flood control structures have become insufficient. Well-calibrated weather forecasting and hydrological models are important complementary tools to reduce the damage caused by floods. Such applications can yield results as useful as structural measures. In this study, the effects of the use of numerical weather forecasting and hydrological models on structural and non-structural based flood protection activities were examined. Lake Mogan basin in Ankara is chosen as the study area. In the analyses, the outputs of 2 different numerical weather forecast models (Weather Research Forecasting (WRF) and Transition Step Between ALadin and AROme (ALARO, ALR), which are used operationally by the Turkish State General Directorate of Meteorology (*Meteoroloji Genel Müdürlüğü*, MGM), were taken from the MGM for 6 different dates. The accuracy of the precipitation forecasts was measured by various statistical methods on a point and areal basis. The results obtained showed that the areal based forecasts give better results than the point-based forecasts. However, it has been observed that the parameters that the MGM uses to run the

WRF and ALR numerical weather models are not successful in predicting the convectional precipitation in this basin. There is no stream gauge station with a long-term measurement in the study area. Besides, in recent years, water transfer to the Mogan Lake basin has been provided by pipelines outside the basin, the exact amount and time of which cannot be determined precisely. For these reasons, the hydrological model constructed for the basin could be calibrated on an event-based basis with water level measurement values of Lake Mogan. Flood operation simulations have been carried out in 2 main scenarios. In the first scenario, it was assumed that Mogan Detention Pond, located upstream of Mogan Lake, is in operation, and the water level of Lake Mogan is at current operating values (973.42 m., value on 14.03.2016). In the second scenario, it was assumed that the detention pond is not built, and the normal operating level of the Lake Mogan is 972.00 m. as given in the planning reports of the State Hydraulic Works (*Devlet Su İşleri Genel Müdürlüğü*, DSİ). Under these two main scenarios, different cases have been created in which 50-, 100- and 500-year storms can occur, and the capacity of the canal located at the exit of Lake Mogan is taken as either 15 or 30 m^3/s. Precipitation forecasts of WRF and ALR models regarding 50, 100, and 500 years design hydrographs were created fictitiously using observed forecasts of the 14.03.2016 event. According to the results of the flood operation studies, it is seen that the 500-year flood reached 974,850 m. in the 1st scenario and 974,909 m. in the 2nd scenario in the most disadvantageous cases. These results are thought to contribute to decision-makers regarding structural and non-structural solution alternatives in flood planning studies.

Keywords: Lake Mogan, Numerical Weather Forecasts, Hydrological Modeling, Flood Planning, Decision Making

ÖZ

VERİ KITLIĞI OLAN HAVZALARDA TAŞKIN PLANLAMASI VE TAŞKIN İŞLETME ÇALIŞMALARI İÇİN SAYISAL HAVA TAHMİN MODELLERİNİN KULLANIMI

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Artan şehirleşme oranlarıyla beraber, taşkınlar günden güne daha önemli sorunlar haline gelmeye başlamıştır. Buna bağlı olarak da taşkın kontrol yapılarının yetersiz hale geldiği algısı ortaya çıkmaktadır. İyi kalibre edilmiş hava tahmin ve havza hidrolojik modelleri, taşkınların yaratacağı zararları azaltmak için birbirini tamamlayan önemli araçlardandır. Bu tip uygulamalar, yapısal önlemler kadar etkili sonuçlar verebilmektedir. Bu çalışmada meteorolojik ve hidrolojik modellerin kullanımının, yapısal ve işletme bazlı taşkın koruma faaliyetlerindeki etkisi incelenmiştir. Çalışma alanı olarak Ankara'daki Mogan Gölü havzası seçilmiştir. Analizlerde Meteoroloji Genel Müdürlüğü (MGM) tarafından operasyonel olarak kullanılan 2 farklı sayısal hava tahmin modelinin (Weather Research Forecasting (WRF) ve Transition Step Between ALadin and AROme (ALARO, ALR)) çıktıları, 6 farklı tarih için MGM'den alınarak kullanılmıştır. Yağış tahminlerinin doğruluğu çeşitli istatistiksel metotlarla, nokta ve alan bazlı olarak ölçülmüştür. Elde edilen sonuçlar, alansal dağılım ile elde edilen sonuçların, noktasal sonuçlara göre daha iyi sonuçlar verdiğini göstermiştir. Ancak MGM'nin WRF ve ALR sayısal hava modellerini çalıştırmak için kullandığı parametrelerin, bu havzadaki konveksiyonel yağışları tahmin etmekte başarılı olamadığı görülmüştür. Çalışma alanında uzun süreli kayıtları olan bir akım gözlem istasyonu bulunmamaktadır. Ayrıca son yıllarda Mogan Gölü havzasına, havza dışından boru hatları ile zamanı ve miktarı net olarak belirlenemeyen su takviyesi yapılmıştır. Bu nedenlerden dolayı havza için oluşturulan hidrolojik modelin kalibrasyonu olay bazlı olarak Mogan Gölü seviye ölçüm değerleri ile yapılmaya çalışılmıştır. Taşkın işletme çalışması simülasyonları, 2 ana senaryo çerçevesinde yapılmıştır. İlk senaryoda Mogan Gölünün membaında bulunan Mogan Sel Kapanın işletmede olduğu ve Mogan Gölü su seviyesinin de güncel işletme değerlerinde, (14.03.2016 tarihindeki 973.42 m. değeri) olduğu varsayılmıştır. 2. senaryoda ise sel kapanının inşa edilmemiş olduğu ve göl normal işletme seviyesinin de DSİ planlama raporlarında verildiği gibi 972.00 m. olacağı kabul edilmiştir. Bu iki ana senaryo altında, Mogan gölünün çıkışında yer alan kanalın kapasitesinin 15 ve 30 m^3/s olduğu; 50, 100 ve 500 yıllık yağışlarının oluştuğu farklı alt senaryolar oluşturulmuştur. WRF ve ALR modellerinin 50, 100 ve 500 yıllık tasarım hidrograflarına ilişkin yağış tahminleri 14.03.2016 olayının gözlemlenen tahminleri kullanılarak kurgusal olarak oluşturulmuştur. Elde edilen gerçek zamanlı taşkın işletme çalışması sonuçlara göre, 500 yıllık taşkının en dezavantajlı durumlarda, 1. Senaryoda 974.850 m., 2. Senaryoda ise 974.909 m. seviyelerine geldiği görülmüştür. Bu sonuçların, taşkın planlama çalışmalarında yapısal ve yapısal olmayan çözüm alternatiflerine ilişkin olarak karar vericilere katkı sağlayacağı düşünülmektedir.

Anahtar Kelimeler: Mogan Gölü Havzası, Sayısal Hava Tahminleri, Hidrolojik Modelleme, Taşkın Planlama, Karar Verme.

To humble beginnings

ACKNOWLEDGMENTS

I would like to express my deep gratitude and sincere thanks to my supervisor Assoc. Prof. Dr. Nuri Merzi for his encouragement, valuable contributions, guidance, and kindness throughout this research.

I also extend my grateful thanks to my co-supervisor Prof. Dr. Zuhal Akyürek and dissertation monitoring committee members Prof. Dr. İsmail Yücel and Assoc. Prof. Dr. Yakup Darama for their precious comments and advice which improved my work in crucial ways.

I would like to thank the Turkish State General Directorate of Meteorology and General Directorate of State Hydraulic Works for providing meteorological and hydrological datasets.

I am also very grateful to my employers Musa Çetinkaya and Kerim Orhon at SUİŞ Proje Engineering and Consulting Ltd. Co. for their understanding and support.

I would like to thank Ahmet Nazım Şahin and Çağrı Karaman for their valuable assistance during data processing.

Sincere thanks to my beloved family members, especially my dear mother, Sadiye, for her endless help and support. The love of my nieces Melis Su, Bilge Derin, and Melina Ada was always in my mind during this long study.

Last for this study, but not least for my life, I would like to express my gratitude to my dearest fiancée Meltem for her endless love, encouragement, understanding, and patience. I hope we rise from our humble beginnings to immeasurable happiness in life.

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ABBREVIATIONS

ALARO	: Transition Step Between ALadin and AROme
ALR	: Transition Step Between ALadin and AROme
APFM-WMO	: Associated Programme on Flood Management - World Meteorological Organization
ARW	: Advanced Research WRF
C	: Convective Type Precipitation of WRF Forecasts
CN	: Curve Number
Con	: Convective Type Precipitation of ALR Forecasts
CSI	: Critical Success Index
DEM	: Digital Elevation Model
DSİ	: General Directorate of State Hydraulic Works
EİEİ	: Electrical Work Investigation Administration
ESRL	: Earth System Research Laboratory
FAR	: False Alarm Ratio
GDPNA	: General Directorate of Protection of Natural Assets
Gec	: Non-Convective Type Precipitation of ALR Forecasts
HEC-HMS	: Hydrologic Engineering Center’s Hydrologic Modeling System
HS	: Heidke Skill Score
HSG	: Hydrological Soil Group
MAE	: Mean Absolute Error

METU	: Middle East Technical University
MGM	: Turkish State General Directorate of Meteorology
NC	: Non-Convective Type Precipitation of WRF Forecasts
NCAR	: National Center for Atmospheric Research
NCEP	: National Centers for Environmental Prediction
NMM	: Nonhydrostatic Mesoscale Model
NOAA	: National Oceanic and Atmospheric Administration
NRCS	: Natural Resources Conservation Service
NWP	: Numerical Weather Prediction
PC	: Proportion Correct
POD	: Probability of Detection
QPF	: Quantitative Precipitation Forecasts
RMSE	: Root Mean Square Error
SCS	: Soil Conservation Service
SD	: Standard Deviation
SEPA	: Special Environmental Protection Area
TS	: Threat Score
USACE	: Hydrologic Engineering Center within the United States Army Corps of Engineers
WMO	: World Meteorological Organization
WRF	: Weather Research and Forecasting
r	: Correlation

CHAPTER 1

INTRODUCTION

1.1 General

Floods are one of the most important natural disasters that affect human life and cause loss of property. It has been reported that floods caused 43.7% of climate-related and geophysical disasters between 1988 and 2017; as a result, more than two billion people were affected, approximately 142,000 people died, and $ 656 billion worth of financial losses were confronted (Wallemacq, 2018).

Flooding events occur due to a combination of meteorological, hydrological, and human factors. These factors are classified as follows (APFM, 2008):

> **Meteorological Factors:** Rainfall, cyclonic storms, small-scale storms, temperature, snowfall, and snowmelt
>
> **Hydrological Factors:** Soil moisture level, groundwater level prior to a storm, natural surface infiltration rate, presence of impervious cover, channel cross-sectional shape and roughness, presence or absence of overbank flow, channel network, synchronization of runoffs from various parts of the watershed, high tide impeding drainage
>
> **Human Factors:** Land-use changes, occupation of the flood plain obstructing flows, inefficiency or non-maintenance of infrastructure, too efficient drainage of upstream areas (increasing flood peaks), climate change effects, urban microclimate

According to seasonality, meteorological condition, location, temporal and spatial distribution, World Meteorological Organization (2011) classifies floods as follows (WMO, 2011; APFM, 2017):

Fluvial (riverine) floods: They are generally triggered by snowmelt or heavy rainfall in the upstream region. River levels increase slowly in a long period of time, and when flow capacities of the river are exceeded, spilling over river banks are started, and deltaic, flat slope regions remain inundated.

Flash floods: These types of floods occur in a small area, mainly due to heavy convective storms in a short duration. They are generally seen in areas where the terrain is steep. Discharges reach peak value quickly and also withdraw rapidly. They are more damaging than riverine floods.

Single Event Floods: This widespread type of flood occurs due to widespread heavy rainfalls, which last in several hours to few days associated with cyclonic disturbances, mid-latitude depressions, and storms. This type of flood has a single peak and longer duration than flash floods.

Multiple Event Floods: Due to more complex atmospheric conditions than single-event floods have, successive flood peaks that follow each other closely may occur. These kinds of floods are named multiple-event floods.

Seasonal Floods: As a result of seasonal regular precipitation patterns, some regions of the world are subjected to more inundated areas than the "normal" flooded times. Flooding lasts for a period of weeks in a basin-wide range. This type of flood is generally observed in regions where monsoonal type climate is effective.

Coastal Floods: This type of flooding occurs mainly for high winds coinciding with high tides and storm surges. River flow will be blocked due to the surge, and that will result in flooding in coastal zones. Tsunamis are also the cause of coastal floods with very high impact.

Estuarine Floods: This type of flood is mostly observed in deltaic areas of rivers along the coastal zones due to the interaction between the landward flow of saline water and the seaward flow of river water.

Snowmelt Floods: Regions where extensive snow accumulation exist, may be subject to snowmelt floods. The rapid temperature rises in the spring season, and heavy precipitation rates produce heavy meltwater runoff, which causes flooding in downstream areas.

Ice – and debris-jam Floods: If rapid seasonal melting is formed in snowy regions, ice masses may accumulate in rivers, which may form constrictions. The sudden break of those ice masses may cause flood waves like dam-break flows.

Urban Floods: This type of flood generally occurs in areas where impervious regions are dominant. Intense rainfall creates rapid runoff rates, and the capacity of the storm drainage system remains insufficient. Blocks and deposits in the storm drainage system are also important reasons for this type of flood. Ponds in low lying areas and overland flows over streets are formed due to those reasons.

As a result of different combinations of factors that contribute to flooding, urban floods are more likely seen anymore. Andjelkovic (2001) discusses the effects of urbanization more systematically (Figure 1-1). As building density increases, the rate of impervious structures also increases, and the existing drainage system may remain insufficient. With the additional effect of urban climate changes, runoff volume and flow velocity increase, which reduces the runoff travel time. As a result, peak runoff rates increase, and flood control problems are started to be observed.

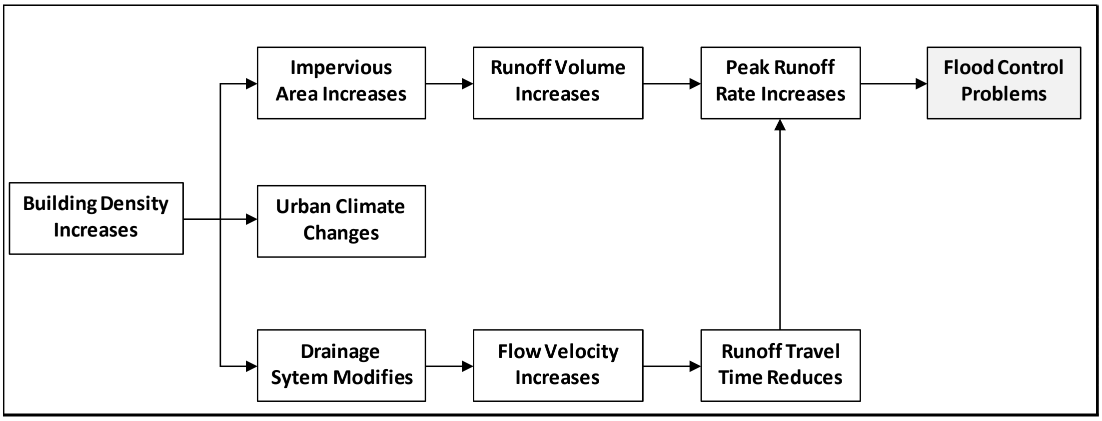

Figure 1-1. Hydrologic Impacts of Urbanization (Andjelkovic, 2001)

In order to prevent flooding events, structural and non-structural/operational based solutions are proposed. In structural based solutions, construction of new storage structures such as dams, ponds, dikes/levees, channel conveyance lines, change on river sections, and river bypasses are generally proposed. Constructing reservoirs with flood control purposes can be an effective solution, but the land-use of the reservoir is an essential limiting issue. Changing river sections, decreasing roughness may increase flow capacity; however, these changes may have environmental impacts in the reach and affect downstream sites by adding additional runoff rates. River deviation also has similar outcomes. Flow coming from sub-basins or tributaries should also be considered while constructing dikes or levees in order not to threaten downstream sites by additional peak discharges. Additionally, all of these solutions can be costly in most situations.

Levees along the rivers, stormwater drainage system, detention, and retention ponds are the main elements of the flood control structures in urban areas. Water control structures of the natural lakes can also be considered as an urban flood control structure. These types of structures are generally constructed for flood control; however, priorities of the local administrative officers may change over time, and these structures could be used for different objectives; these situations may be due to the gain of recreation areas and ecological reasons. This kind of priority changes may create problems in structural based solutions. Forecasts of the incoming flood must be available to operate multi-functional reservoirs for flood control (WMO, 2011).

Non-structural or operation-based solutions could be applied in combination with structural measures. Rehabilitation and effective use of existing flood control structures could also be suggested. These kinds of measures are obviously less expensive. Major measures can be listed as flood mapping/zoning, insurance policies, implementation of early warning, and flood forecasting systems. In order to minimize flood impacts, flood risk areas could be detected by working to obtain hazard maps. Spatial planning would be applied in high-risk regions. Flood insurance issue can be implemented in developed countries; however, it is not very common in the rest of the world.

Flood retention or detention ponds, lakes, and other reservoirs can play a crucial role in flood control. Forecasting meteorological events a few days in advance and operating control structures accordingly may be the most effective operation-based solution to prevent flood damages. However, these operations require well-organized forecasting algorithm and measurement instruments on the drainage basin.

In order to have an effective early warning and flood forecasting system, a series of issues should be worked in an organized manner. Having a numerical forecast system that can produce appropriate results on a temporal and spatial basis and the establishment of a well-distributed hydrometric station network is essential for this purpose.

Existence and accurate records of meteorological weather stations, rainfall estimates of radar stations, satellite images, and numerical weather model forecasts are highly important for conducting flood operation studies. Besides these, a well-suited hydrological watershed model is essential. A proactive operation scheme would be very beneficial in flood studies by using any type of rainfall forecasts in a hydrological model.

There are different numerical weather forecast models, and Weather Research and Forecasting (WRF) model is a common tool for weather predictions around the world. Transition Step Between ALadin and AROme (ALARO or ALR) model, appropriate for limited areas, is also used in Turkey for weather forecasting.

Forecast results of these models can be used as input values for hydrological models (rainfall-runoff models). Hydrological models have been developed over the years. The models can be classified according to their structure, spatial characterization, time basis, and equations used in the model. As expected, when the complexity is increased, input data requirements are also increased in hydrological models.

Accuracy of the result of rainfall-runoff models is generally measured with records of stream gauges. It is expected that runoff results of models should be consistent with the records of the gauges. Mostly past rainfall and streamflow gauges are used for calibration and validation of models. However, in ungauged or data-scarce basins, it becomes more difficult to calibrate and validate the models. Lake level measurements can be used in these situations as an alternative calibration parameter.

1.2 Problem Statement

Basins of Lake Mogan, Lake Eymir, and İncesu Detention Pond are subsequent parts of the same system; the Lake Mogan basin has the greatest watershed area with an area of 934 km^2. There are two small irrigation reservoirs in the upstream part of the basin, namely Dikilitaş and İkizce. Mogan Detention Pond exists on the mainstream, and the Lake Mogan takes place downstream of these structures; discharged water from this lake enters Lake Eymir. At the exit of the drainage area, İncesu Detention Pond exists, which is followed by a closed conduit. The discharged water is conveyed via this conduit and integrated into the city stormwater drainage system. Although the total drainage area of İncesu Detention Pond (1100 km^2) is approximately 1/3 of the drainage area of Ankara city, there is a scarcity of streamflow gauge and data; that situation creates difficulties in hydrological modeling studies.

Over recent past years, flooding events occurred in the basin. In order to prevent flooding damages, Mogan Detention Pond was constructed in 2015 upstream of Lake Mogan. However, it is still necessary to have a good flood operation scheme for the basin because of the importance of downstream regions and inadequate infrastructures. Although the normal operation level of Lake Mogan was determined as 972.00 m. in all planning reports of State Hydraulic Works (DSİ), the lake's operation level at the beginning of the flood was taken as 971.00 m in the planning report of Mogan Detention Pond. Furthermore, the operation level of Lake Mogan is generally kept relatively high. Besides these, the capacity of closed conduit at the exit of İncesu Detention Pond and the stormwater drainage system is limited; this situation creates problems in the city center when precipitation occurs even if at a moderate level. These circumstances reveal the need to re-evaluate the flood planning studies and propose a new flood operation algorithm for the basin.

1.3 Methodology and Objective

This study aims to use numerical weather forecasting models in flood planning and operation studies in an ungauged Lake Mogan basin by comparing the effectiveness of structural and non-structural intervention measures.

The general framework of the study can be seen in Figure 1-2. There are three main parts in the study. In the first part of the study, the precipitation outputs of two numerical weather forecasting models, WRF and ALR, were compared with the rain gauge station records for the selected events. Events with a relatively higher amount of daily or hourly precipitation and having different rainfall types were considered in comparisons. Totally six events were selected, and comparisons were performed by means of statistical scores in point and areal based analysis. The effect of lead times was also one of the main interests. Results of on the day, one day before, and two days before forecasts were compared with each other. In this way, it was tested how successful the General Directorate of Meteorology's parameter selections were while using numerical weather prediction methods in predicting different types of precipitation (convective and non-convective) in this basin. The relatively more successful precipitation forecast type was taken as a sample event in flood management studies.

In the second part of the study, a hydrological model of the catchment area was created. Hydrological modeling is heavily used in water resources engineering for various purposes, and their role in flood forecasting is inevitable. In this study, Hydrologic Modeling System (HEC-HMS) software was used for rainfall-runoff modeling. The study area is divided into subbasins, and characteristics are defined

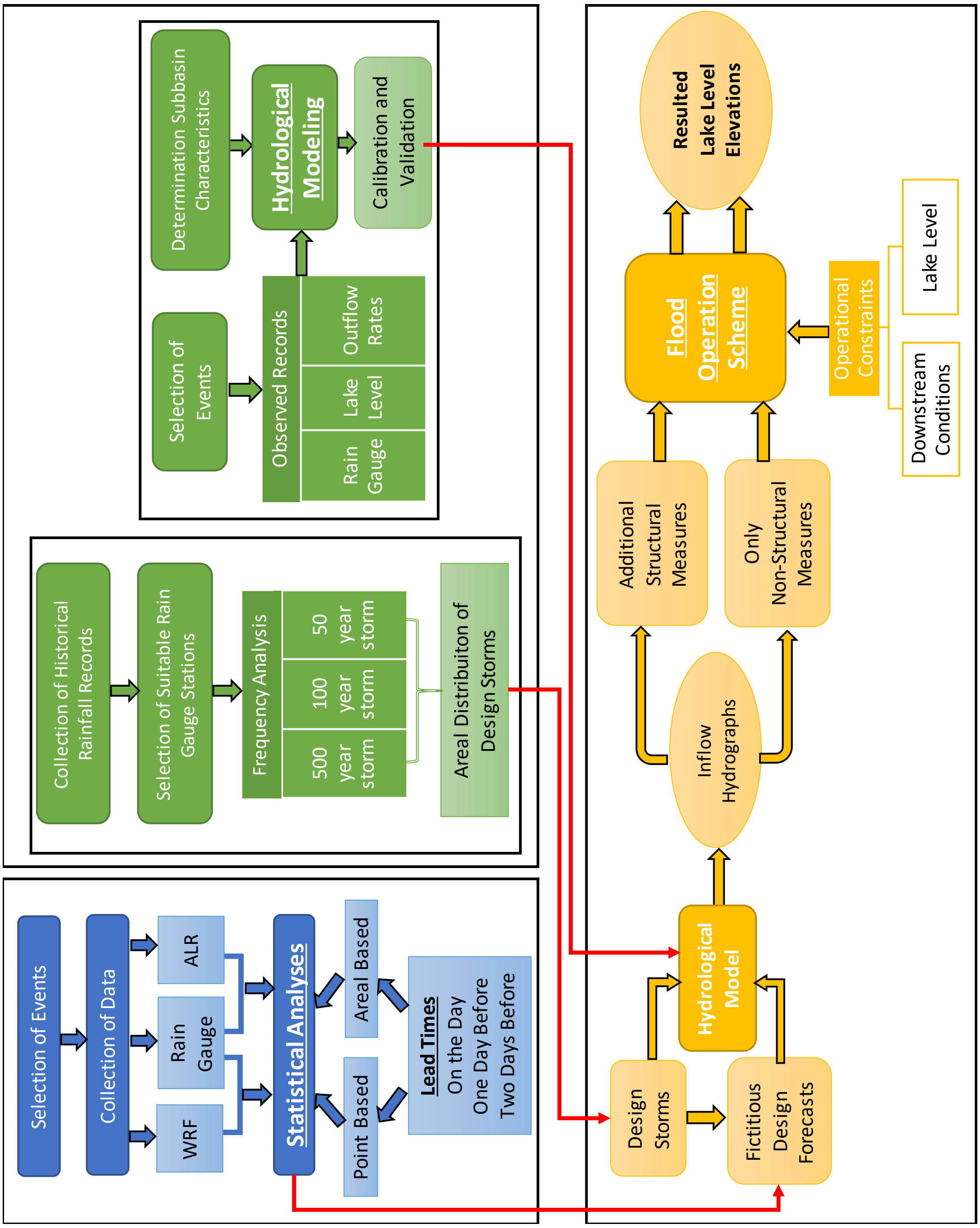

Figure 1-2. General Flowchart of Proposed Methodology

in the program. Events and corresponding data that can be used for validation and calibration in the basin were investigated. The study area is a data-scarce basin, and there is no streamflow data that can be used for modeling. Three events are selected for the calibration and validation of the model. Instead of streamflow records, measured water levels of Lake Mogan was used for calibration and validation. The model was run by making the spatial distribution of precipitation measured at the meteorology stations for the selected three events. A validated event-based hydrological model was used in flood planning and operation studies in the third part.

In the third part of the study, flood planning and operation studies were performed. The aim was to compare structural and non-structural alternative solutions by evaluating the situations with and without Mogan Detention Pond. The current / realized operating conditions of the lake and the operating conditions proposed in the planning reports of State Hydraulic Works (DSİ) were tested under 50, 100, and 500-year design storms. Since design storms need to be used in planning studies, the outputs of numerical weather prediction models were used indirectly at this stage. This is because it is almost impossible to find forecasting precipitation values that predict design storms. The precipitation values of the event, which gave relatively more successful statistical results by the models in the first stage of the study, were increased to design storm values, and fictitious precipitation forecast values were formed. Using these values in the hydrological model created in the second stage of the study, the flood volume that would come to Lake Mogan was calculated, and the required discharge amount to evacuate the forecasted amount of excess volume was estimated. These operations have been carried out for three successive lead times (on the day, one day before, and two days before). According to the resulted forecasting hydrographs, the amount of water to be released downstream was decided. The hydrological model was rerun by the predefined discharge rate and actual design storm values. This procedure was repeated for three lead times, and final results are compared in terms of the water level of Lake Mogan. The effectiveness of structural and non-structural measures was tried to be shown by these analyses.

1.4 Thesis Outline

Content of the subjects in the following chapters are given below:

In Chapter 2, an overview of the past studies conducted in the study area is given. Literature review on numerical weather predictions and hydrological modeling applications is presented.

In Chapter 3, a general description of the study area and available data are presented. Hydrometeorological characteristics, land use and soil data of subbasins, available lake water level observation data, records of rain gauge stations, and frequency analysis of those records are explained within the chapter.

In Chapter 4, the output of numerical weather prediction models is presented. Statistical analyses and accuracy of WRF and ALR model outputs are compared and discussed.

In Chapter 5, hydrological modeling in data-scarce basins is explained. Calibration and validation methods are discussed, and flood planning and operation studies are described. The proposed flood operation scheme and the result of this scheme for planning conditions are investigated.

In Chapter 6, the summary and conclusions of the study are presented.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Past Studies on Study Area

Çubuk, Hatip, and İncesu creeks are the main streams of Ankara. These three creeks come together inside the city center of Ankara, near Akköprü, and take the name of Ankara Creek. A general view of the catchment area of Ankara Creek is given in Figure 2-1. İzbırak (1978) states that all creeks of Ankara Creek are torrential type streams. These streams have irregular flow regimes (Ateş, 1985). Flow rates decrease, or streams will totally become dry when precipitation season ends or temperature increase; they start to increase again with the start of precipitation season and also the effects of snowmelt (Atalay, 2004).

In this study, the main focus is given to the drainage area of Lake Mogan on the upstream of İncesu Creek. However, the flow capacities of downstream facilities are also crucial for flood operation studies in Lake Mogan. Therefore, general information about downstream conditions is also given very briefly in the following sections.

A flooding event that causes maximum loss of life in Turkey took place in Ankara on Hatip Creek at 11.09.1957. According to official records, 169 people passed away, and severe economic losses occurred due to flooding (DSİ, 1963). Several flooding events occurred before and after that date, and in 1963, State Hydraulic Works (DSİ) prepared a planning report regarding flood threats for Ankara city. It was pointed out that studies conducted until that time were not cover the whole catchment area of Ankara; individual reports and works for different streams were prepared. However, as the upstream and downstream conditions of the facilities constructed were not met, sufficient benefit was not obtained from those studies. Several structural remedies on Çubuk, Hatip, Dikmen, and İncesu creeks were

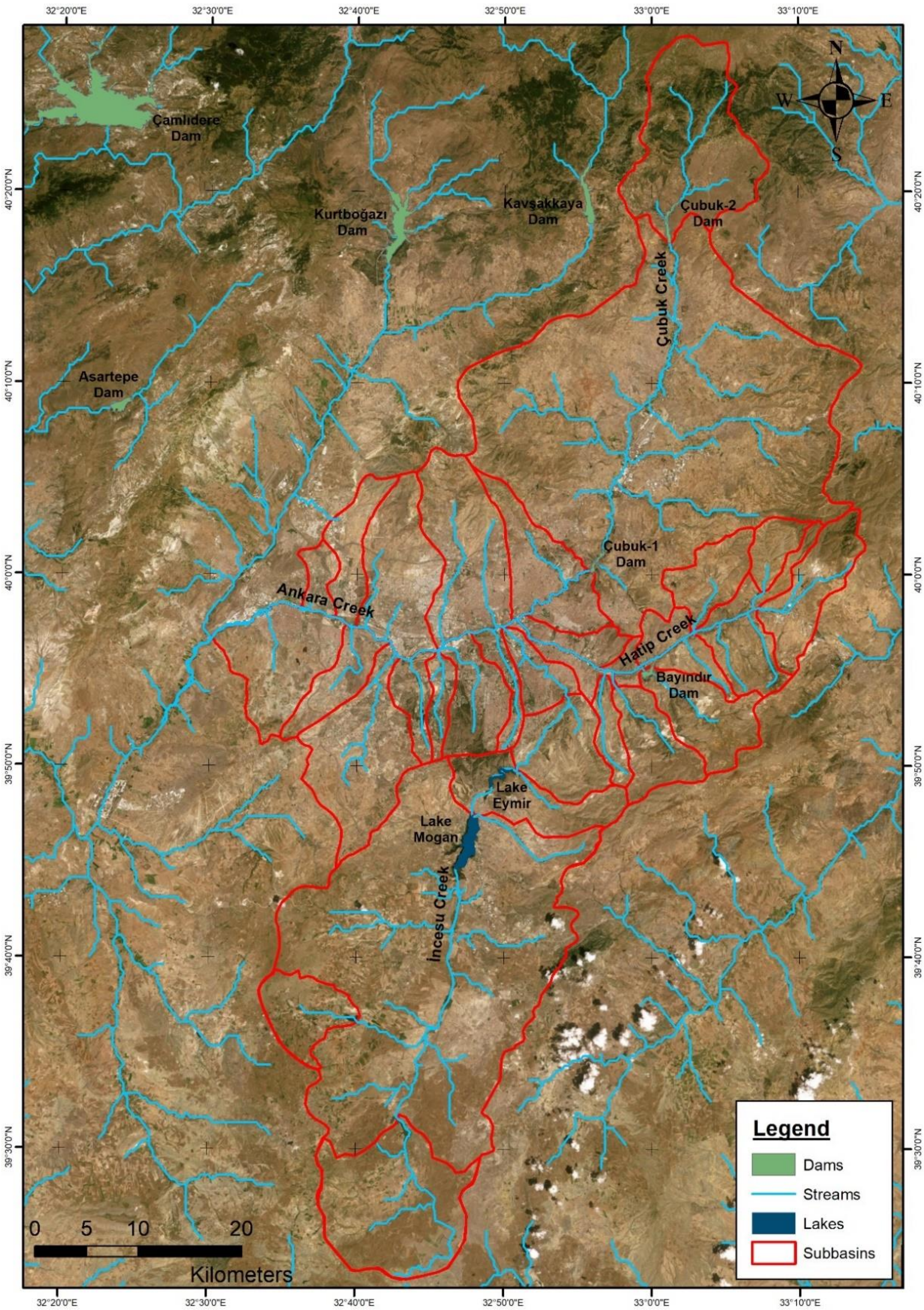

Figure 2-1. General View of Catchment Area of Ankara Creek

proposed together at a preliminary level within that report. İncesu Detention Pond, which was constructed at the downstream of Mogan and Eymir lakes on İncesu Creek was also proposed in that report. Application details of all projects were summarized in a report which was prepared for State Hydraulic Works in 1968 (Batukan, 1968). Since the sewage of neighboring living areas was flowing directly into the İncesu Creek, the stream section at the exit of the İncesu Detention Pond was closed in the next years.

Ankara Metropolitan Municipality asked METU to prepare a report on Mogan and Eymir lakes, and it was completed in 1995. That report is still the most inclusive report, which is prepared until today for the study area. Hydrological, meteorological, geological, hydrogeological, environmental, limnological, bathymetric, isotope, and some other properties of the basin were investigated, and solution methodologies were proposed in the report. The bathymetric map of the lakes was also updated, and flood operation studies using 12-hour rainfall duration for 100 and 500-year storms were also performed. While performing flood operation studies, the effects of two irrigation ponds, namely Dikilitaş and İkizce, were neglected. The normal operating level of Lake Mogan has been taken as 972,00 m as given in all planning reports of DSİ. The curve number of the region was taken as 75 for the whole basin.

Merzi and Aktaş (2000) investigated the flood hydrographs of three subbasins (Yavrucak, Başpınar, and Sukesen subbasins) of Lake Mogan. The average curve number of subbasins was calculated by using GIS tools and estimated around 86. They also tried to form the inundation map of the Lake Mogan using the results of studies conducted by METU in 1995.

DSİ had been prepared a flood planning report in 2008 (DSİ, 2008) and proposed Mogan Detention Pond on Çölovası Creek the upstream of Lake Mogan. Flood operation studies for the 500-year storm were performed by considering existing Dikilitaş and İkizce reservoirs, Mogan and Eymir Lakes, and İncesu Detention Pond. Bathymetric values of Lake Mogan was taken from the DSİ report prepared in 1994

(DSİ, 1994). The entire region's curve number was taken as 80, and the normal operation level of Lake Mogan is taken as 971.00 m at the beginning of the flooding event. The discharge capacity of downstream sections of İncesu Detention Pond, which is very important for flood operation studies, is given as 48-94 m^3/s. Based on this planning report, Mogan Detention Pond was built at the end of 2015, and it has been operated since then.

Bozkurt (2013) evaluated the operation performance of water control structures at Mogan and Eymir lakes and İncesu Detention Pond. The curve number of the study area was estimated by using soil and land use maps for all the subbasins. Canal capacity between Mogan and Eymir lakes (7, 15, and 30 m^3/s), the return period of design storm (50, 100, and 500 years), and operation level of Lake Mogan (972.00, 972.50, and 973.00 m.) were used for testing the different operational conditions of the system.

General Directorate of Ankara Water and Sewerage Administration stated that if the water discharged from the İncesu Detention Pond exceeds 16 m^3/s, problems occur in the downstream regions around the city center (ASKİ, 2013). Bozkurt et al. (2013) performed flood management studies by considering all existing and planned water control structures in the basin. They proposed four new detention ponds on side streams of İncesu Creek, located on the downstream region of Lake Eymir on İmrahor Valley. In this way, it was ensured that the maximum amount of water discharged from the İncesu Detention Pond was around 10 m^3/s.

In 2016, flood hazard maps of several streams in Ankara had been prepared by the DSİ. Flood inundation areas of the downstream region of Lake Mogan and Sukesen Creek were also determined in that study by using hydraulic modeling software (DSİ, 2016). The normal operation level of Lake Mogan was taken as 972.50 m; the discharge capacity of the canal between Mogan and Eymir lakes was determined as 13-15 m^3/s, and the safe discharge capacity of İncesu Detention Pond was taken as 48 m^3/s throughout the studies.

General Directorate of Water Management (SYGM) prepared a report regarding flood measures for the Sakarya Basin in 2018 (SYGM, 2018). Based on the result of studies conducted by DSİ in 2016, SYGM proposed to open the closed sections of İncesu Creek beginning at the exit of İncesu Detention Pond. İdali Özden (2020) studied the criteria for stream daylighting for the closed rivers and showed that flood susceptible streams are generally overlapped with the closed streams of Ankara.

In addition to flood studies, many studies have been carried out regarding biological, ecological, groundwater, and water potential in the region throughout the years. Since the data collected in these studies and the analyses made can also be used in future interdisciplinary studies, some of them are briefly mentioned below.

In 1988, Gölbaşı Municipality prepared a breeding project against pollution on Lake Mogan (Gölbaşı Municipality, 1988). Due to pollution on Lake Mogan, a limnological study report (DSİ, 1993) and recovery planning report (DSİ, 1994) were prepared by DSİ in 1993 and 1994, respectively.

Mogan and Eymir lakes environmental convention was held in 1995 by Gölbaşı Municipality. Various issues, including water resources, pollution, ecological, biological, erosion, land planning, special environmental protection plan, recreational use, birdlife, bottom mud, and rehabilitation suggestions, were addressed at the congress, including international participants, and 33 papers were presented.

Abolished Electrical Work Investigation Administration (*Elektrik İşleri Etüt İdaresi*, EİEİ) had prepared two reports in 2001 and 2005 regarding hydrometeorological characteristics of the Mogan and Eymir lakes basin. The water budget of the basin had been examined by using the records collected between 1999 and 2004. Water quality measurement studies were also done in the scope of those studies.

Yağbasan and Yazıcıgil (2009) studied to quantify groundwater components in Mogan and Eymir lakes and concluded that groundwater inflows and outflows have the lowest contribution to the overall lakes' budget. In other studies, Yağbasan and

Yazıcıgil (2012) and Yağbasan et al. (2017) pointed out the importance of management of lakes in the future by considering the effect of climate change. They investigated the effects of climate change under different scenarios, and it was concluded that small but long-term changes in precipitation regime and temperature could cause significant decreases in water levels and even drying of Lake Mogan and Lake Eymir. Yağbasan et al. (2020) studied the trends of monthly lake levels and hydrometeorological variables in Mogan and Eymir lakes. They tried to find a relationship between evaporation, precipitation, evaporation, humidity, wind speed, cloud cover, radiation, and water levels in those two lakes. Apaydın and Ocaklıoğlu (2020) studied the water budget of Mogan and Eymir lakes. They claimed that if Lake Mogan had been kept in natural conditions in the last 50 years, it would dry up completely once and shrunk in considerable amounts several times.

A group of researchers calculated unit nutrient pollution loads for Lake Mogan basin during wet periods within 2007-2010 years based on the data obtained from the monitoring station on Yavrucak creek. (Özcan et al., 2016; Özcan et al., 2017a) By using the same data, Özcan et al. (2017b) applied Soil and Water Assessment (SWAT) model to evaluate the effectiveness of agricultural management practices by considering a reduction in pollution loads.

Limnological surveys, sources of pollution, water quality, the concentration of contaminants on sediments and water on Lake Mogan has also been studied by various researchers (Beklioğlu et al. 2017; Akkoyunlu and Karaaslan, 2015; Karakoç et al. 2003; Topçu et al. 2018; Coppens et al. 2016; Sanal and Demir, 2018, Benzer et al. 2015, Mangit and Yerli, 2010).

2.2 Literature Review on Numerical Weather Predictions

Accurate estimation of hydrological data is essential to provide valuable information for water resources management in different sectors (Estevez et al., 2020) and precipitation is one of the primary hydrometeorological drivers for flood simulation and operational flood forecasting (Singh and Woolhiser, 2002). Numerical weather prediction (NWP) models provide beneficial precipitation estimations that can be used in hydrological modeling for river flow forecasting and flood warning (Nasrollahi et al., 2012; Ran et al., 2018). They can significantly increase lead times for flood warnings when used in combination with hydrological models (Banihabib et al., 2015). In this way, more extensive and proactive measures can be taken for heavy rainfall events in flood management operations (Lin et al., 2005).

Benjamin et al. (2018) divided the evolution of weather forecasting into four eras of 20-30 years, starting from 1919. Those periods are classified as follows: i) "Era 1" (1919 – 1939: maps only; observations and extrapolation/advection techniques); ii) "Era 2" (1939 – 1956: increasing science understanding; application especially to aviation; birth of computers); "Era 3" (1956 – 1985: the advent of NWP and dawn of remote sensing); and "Era 4" (1985 – 2018: weather forecasting, and especially NWP, mature and penetrate virtually all areas of human activity). Within era 4, especially after the emergence of ensemble forecasting, the use of numerical weather predictions has been increased considerably in hydrological models.

Over the years, the use of atmospheric models has been expanded, and the performance of the various models has been compared by different researchers considering the different locations and different conditions. Damrath et al. (2000) studied the verification of two numerical weather prediction models, the EuropaModell (EM) and the Deutschland-Modell (DM), of the German Weather Services by using existing seven-year data. Frei et al. (2003) tried to evaluate and compare five regional European climate models (ARPEGE, CHRM, HadRM, HIRHAM, and REMO) on daily basis records of 6400 rain gauge stations in the 1979-1993 period for the Alpine region where the study area covers 1100 × 700 km^2 domain. Kaufmann et al. (2003) performed an evaluation of rainfall records of Swiss Model (SM) in Switzerland by using the available eight-year data. Richard et al. (2003) evaluated the four mesoscale forecasting models which are used by operationally in Switzerland (Swiss Model, SM), Canada (MC2), Italy (Bolam3) and France (Meso-NH) for heavy precipitation events occurred in Toce Ticino (Italy) or

Ammer (Germany) catchments. Habets et al. (2004) studied the utilization of precipitation forecasts of ARPEGE and ALADIN models for streamflow prediction on the Rhone basin in France. Fall et al. (2006) investigated the MM5 and WRF model performance to predict the heavy rainfalls in Senegal by considering the event that occurred on 9-11 January 2002, and they conclude that those models can become a part of regional hazard mitigation planning. Roy Bhowmik et al. (2007) evaluated the performance of the numerical weather prediction model of India Meteorological Department for 2001 and 2003 years over the monsoon region. Mölders (2008) studied the suitability of the WRF model to predict June 2005 “fire weather” for interior Alaska. Pressure, precipitation, shortwave downward radiation, temperature, relative humidity, and wind parameters, which are fire risk-relevant meteorological parameters, are evaluated based on the model results and meteorological observations. The precipitation performance of the WRF model, which is formed for the study, is found as comparable to other mesoscale atmospheric models for midlatitudes. Ghile and Schulze (2010) compared the precipitation forecasts of CCAM, UM, and NCEP-MRF models over the Mgeni catchment in South Africa for the selected four events. Shresta et al. (2012) evaluated the performance of four Australian Numerical Weather Prediction models (ACCESS-G, ACCESS-R, ACCESS-A, and ACCESS-VT) for the short-term streamflow forecasting over the Ovens catchment in Australia between 2010 and 2011. Yucel (2015) investigated the performance of the WRF model for simulation of flash flooding events that occurred in the Ayamama Basin in İstanbul during 7-12 September 2009. Toros et al. (2018) evaluated the success of the HARMONIE, High Resolution Limited Area Model (HIRLAM) and WRF models for the severe precipitation events that occurred on 8-9 September 2009 and cause flash floods in İstanbul. Ran et al. (2018) compared the precipitation forecasts of three models [European Centre for Medium-Range Weather Forecasts (ECMWF); the U.K. Meteorological Office (UKMO); and the China Meteorological Administration (CMA)] on Linxian and Jiuzhaigou basins in China for the flood season during 2011-2013. Özkaya and Akyürek (2019a) compared weather radar data, Hydro-Estimator satellite rainfall product, and WRF model precipitation data in physics-based distributed WRF-Hydro hydrological model in the Terme basin of eastern Black Sea Region in Samsun, Turkey. Khalki et al. (2020) evaluated AROME, ALADIN, used by the Directorate of National Meteorology in Morocco, and WRF models for prediction of selected flood events in the Rheraya and Ourika basins during the 2013-2016 period.

Accurate precipitation forecasting is a very challenging issue due to the nonlinear and dynamic characteristics of precipitation (Liu et al., 2019). Therefore, they contain a high level of uncertainty (Crochemore et al., 2016; Moghim and Bras, 2017; Jabbari and Bae, 2018), and improvement of predictions is still one of the greatest challenges of the researchers (Estevez et al., 2020). Since most of the general circulation models have coarse resolutions and generally use hydrostatic equations, they may become inadequate in local atmospheric forecasts, especially for extreme rainfall analysis (Chawla, 2018). Because of this situation, mesoscale (medium-sized) atmospheric models that have finer resolutions are widely used in weather forecasting all around the world. In Turkey, the General Directorate of Meteorology also uses two mesoscale atmospheric models, the Weather Research and Forecasting (WRF) and ALARO - ALR (Transition step between ALADIN and AROME), for operational purposes.

The Weather Research and Forecasting (WRF) model is one of the widely used mesoscale numerical weather prediction (NWP) system, which is designed for operational and research applications. There is a huge amount of studies for WRF models in the literature that investigate the use and success of the model due to its good performance (Morroni et al., 2017). It has a wide physics and two dynamic solvers options, i.e., the Advanced Research WRF (ARW) and Nonhydrostatic Mesoscale Model (NMM), for simulations. It is developed under the collaboration of the National Oceanic and Atmospheric Administration’s (NOAA) National Centers for Environmental Prediction (NCEP) and Earth System Research Laboratory (ESRL), National Center for Atmospheric Research’s (NCAR) Mesoscale and Microscale Meteorology (MMM) Division, the Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma, the Department of

Defense’s Air Force Weather Agency (AFWA) and Naval Research Laboratory (NRL) and the Federal Aviation Administration (FAA) of United States Departments of Transportation. (Skamarock et al., 2008). The Advanced Research WRF-ARW solver is developed at NCAR mainly for research, while the WRF-NMM solver is developed at NCEP for operational usage (Skamarock et al., 2008, Karadavut, 2014).

Initial conditions, resolution, and configuration of model parameters highly influence the performance of the WRF model (Kyrza et al., 2013), and parameter sensitivity of model physics is generally dependent on local conditions (Di et al., 2015). Therefore, the parametrization of numerical weather prediction models for different regions and seasons is widely researched in the scientific community for different purposes. For instance, Calvetti and Filho (2014) used different initial conditions and model physics to improve hourly WRF forecasts for the thirty-two rainfall events between 2005 and 2010, which is modeled for the Igacu River Basin in Southern Brazil. Verification studies are carried out by using the Brier skill score, MSE, RMSE, and correlation. Moreover, Yücel and Önen (2014) studied the effect of data assimilation techniques in the WRF model with different parameterizations to capture heavy rainfall events in the western Black Sea Region. Precipitation derived from the WRF model with and without data assimilation are compared with the gauge precipitation records by evaluating RMSE, R, and bias for hourly based values, where categorical skill scores are also evaluated for daily values. Cassola et al. (2015) sought to find the best parametrization scheme of the WRF model to predict severe rainfall events that occurred over the Liguria region in Italy between October 2010 and November 2011 by considering three different case studies. Müller et al. (2016) studied WRF model performance by considering precipitation and 2-m temperature parameters. Evaluation is based on simulations at 15-km grid spacing over La Plata basin in southern South America for the period from 1 August 2012 to 3 July 2014. Observed station data is compared with the nearest grid point of forecasted points. Results of WRF model precipitation values are evaluated in terms of occurrence/nonoccurrence of daily events by using categorical skill scores (PC, POD, FAR, HSS, BIAS score). Morroni et al. (2018) analyzed an ensemble of microphysics schemes of the WRF forecasting model operated by the Chilean Weather Agency by using three rainfall events between 2015 and 2017. Rogelis and Werner (2018) tested the configuration of the WRF model that is used by the hydro-meteorological agency of Colombia, IDEAM, to see the utilization of the model outputs for flood early warning systems in tropical mountainous catchments. Chawla et al. (2018) also studied the effect of different processes in WRF model configuration to forecast extreme rainfall events by computing MAE and RMSE on a daily basis period over the Ganga Basin in India around the Himalayas. Rodrigo et al. (2018) used a combined score approach to evaluate the overall performance of heavy rainfall forecast results of the WRF model in Sri Lanka to identify the best model configuration by using PC, POD, TS, FAR, and Pearson correlation coefficient. Lastly, Pilatin (2020) studied the best configuration options of the WRF model over two different regions of Turkey by using four different rainfall events in the study area in different seasons. More examples of such studies can easily be found in the literature.

The lead time of operational flood forecasting is very critical for flood alert and flood risk reduction operations, and it is impossible to extend the lead time of flood forecasting just by using rain gauge observations (Yao et al., 2019). It has been widely recognized that the lead time of flood forecasting can be increased by using the precipitation forecasts derived from numerical weather prediction models (Chao et al., 2018; Todini, 2017; Zhang et al., 2016). Shrestha et al. (2012) stated that success in forecasting decreases with longer lead times and increases with rising precipitation accumulation periods. The latest numerical weather forecast model could provide 1–15-day quantitative precipitation forecasting products in grid format (Ahlgrimm et al., 2016; Li et al., 2017). Besides the above studies related to model configuration and initial conditions, Jee and Kim (2017) tried to see the effects of domain size and lead time of the WRF model for a heavy rainfall event in Seoul in South Korea, where localized heavy rainfalls caused flash floods. In order to evaluate forecast performance, POD, FAR, and ETS values are calculated by considering the 0.5 mm/h threshold value and correlation coefficient, BIAS, and RMSE parameters are calculated on an hourly and daily basis. There are also other studies testing the capability of the WRF precipitation to increase the lead time of flood forecasting, and warning has also been tested in recent studies (i.e., Berezowski & Chybicki, 2018; Zhou et al., 2017).

ALARO - ALR (Transition step between ALADIN and AROME) model is another mesoscale weather prediction model developed by *Aire Limitée Adaptation Dynamique Développement International* consortium. It also has non-hydrostatic and hydrostatic versions with 4.5 km horizontal resolution, and it takes boundary and initial conditions from the global ARPEGE model, which is developed by Meteo-France.

Research studies for the ALR model remain limited compared to the WRF model. In Turkey, the ALR model is also used by the General Directorate of Meteorology for operational services. Karadavut (2014) studied WRF and ALR models to compare actual pressure, temperature, precipitation, and wind magnitude parameters with records of 361 automated meteorological observation stations over Turkey for January and July months in the 2009-2013 period. Durmuş (2016) analyzed the precipitation forecast of ALR and WRF models for the flooding event at Hopa, Artvin, on 24 August 2015 by considering 24-hour cumulative rainfall amount.

It is seen that numerical weather prediction models are used heavily in weather forecasting. As a general result, these studies showed that more complex microphysics parameterizations resulted in better precipitation forecast values.

In this study, WRF and ALR model precipitation data are selected to evaluate their performance for the selected events in the study area. Forecast results are directly taken from the Turkish State General Directorate of Meteorology (MGM). Model parameters that are used in WRF and ALR simulations by MGM are given in Table 2-1.

Table 2-1. Summary of WRF and ALR Configurations

Model	WRF 3.3.1	ALR
Grid Size	649 x 430	709 x 439
Grid Resolution	4.5 km	4.5 km
Number of Vertical Layers	46	60
Microphysics	WSM5 - WRF Single 5–class Scheme	3MT
Cumulus	Kain-Fritsch Scheme	Xu-Randal
Radiation (Longwave)	RRTM Longwave Scheme	ACRANEB (New Geleyn)
Radiation (Shortwave)	Dudhia Shortwave Scheme	
Land Surface Layer	Unified Noah Land Surface Model	ISBA
Boundary Layer	Yonsei University Scheme (YSU)	Geleyn

2.3 Literature Review on Hydrological Modeling

Hydrology is defined as earth science, which deals with the circulation of water between the earth and atmosphere, which is defined as a hydrologic cycle. All the processes that govern the movement of water over and under the land surface, physical and chemical properties during the hydrologic cycle and its reaction with the environment are subject to hydrology science.

Chow (1964) divided and defined the historical development of this science into a series of periods under the influence of Meinzer (1942) as follows:

1) Period of Speculation (Ancient Times - 1400): Although this period was mainly speculated with erroneous concepts by many philosophers; great hydraulic works like Arabian wells, Roman aqueducts, irrigation projects at Egypt and Mesopotamia were constructed during this period.
2) Period of Observation (1400 - 1600): Based on observations, the hydrologic cycle was started to be understood during this period.

3) Period of Measurement (1600 - 1700): Correct conclusions on observed hydrologic phenomena were begun by measurements in the 17th century.
4) Period of Experimentation (1700 - 1800): By performing hydraulic experiments, hydrologic studies were moved to a quantitative basis.
5) Period of Modernization (1800 - 1900): During this era, several governmental agencies were started to be founded. Experimental studies were moved to a more modern level by the development of measuring instruments and the development of many flow formulas.
6) Period of Empiricism (1900 - 1930): Lots of empirical formulas were proposed to solve the practical problems of engineers during this period.
7) Period of Rationalization (1930 - 1950): Instead of empirical analyses, rational analyses were started to solve hydrologic problems.
8) Period of Theorization (1950 - date): theoretical approaches have been started to be used by the 1950s. Mathematical analyses of rational hydrologic principles have been started to deal. Complicated hydraulic equations can be solved by employing high-tech computers and software.

After Chow's grouping periods in hydrology, many scientists have been studying problems in hydrology, and new periods may be offered to the science community for the years later than the 1950s based on those studies.

Plate (2009) stated that today's hydrologists' purposes are lay on two different bases. The first one is a better understanding of nature, and the second one is providing analytical tools for helping engineers and decision-makers to overcome management problems and produce better designs. In parallel to this standpoint, 230 scientists all over the World identified 23 unsolved problems in 6 groups for hydrology science as a result of collaborative studies in 2019 (Blösh et al., 2019). Those groups are defined as time variability and change, space variability and scaling, the variability of extremes, measurements and data, interfaces with society, and modeling methods.

Modeling in hydrology has been one of the major challenging issues for engineers through the years due to the heterogeneous distribution of model components and the lack of continuous data. Moradkhani and Sorooshian (2009) defined the hydrological model as a simplified representation of a real-world system. While simplifying the real catchment system, the main purpose is predicting system behavior under different hydrometeorological conditions. In order to estimate those system responses, various methods may be applied by using various parameters. Parameters related to climate, land use, hydrometeorology, and soil characteristics with their temporal and spatial features are integrated within the models. Those models would be used for watershed management, flood mitigation, groundwater monitoring, reservoir operation, and they have become extremely crucial for water resources management (Dwarakish and Ganasri, 2015). Especially in ungauged or poorly gauged catchments, modeling studies would present highly appreciated outcomes to the engineers and decision-makers.

With the development of computer technology in the 1960s, hydrological modeling also began to gain momentum. After Crawford and Linsey (1966) introduced the Stanford Watershed Model (SWM), which virtually models the entire hydrological cycle, a wide range of models has been developed (Singh and Woolhiser, 2002).

The World Meteorological Organization published three reports in 1975, 1986, and 1992 to make a comparison among hydrological models. The first one dealt with conceptual models that were used in operational hydrological forecasting, the theme of the second one was the snowmelt runoff, and the content of the third one was streamflow forecasting in real-time. Besides these studies, Singh and Frevert (2005) stated that the Bureau of Reclamation in the USA prepared an inventory of 64 watersheds which are classified in 4 groups in 1991; Singh (1995) made a summary for 26 watershed model from around the world; Wurbs (1998) made a list of generalized hydrologic models in seven categories, and Singh and Frevert (2002a, 2002b) made an edition of two books one for small watersheds and one for large watersheds which contain totally 38 models.

A number of review studies about hydrologic modeling can be found in the literature easily. Pechlivanidis et al. (2011), Jajarmizadeh et al. (2012), Devia et al. (2015), Dwarakish and Ganasri (2015) are some recent examples from those studies. Classification of models is generally being done on the basis of certain basic criteria.

Based on model structure or simulation, algorithm models would be classified as a metric or empirical, conceptual, and physic-based. Metric models are valid within their boundaries, and they are primarily based on observations. Unit hydrograph, artificial neural network, and fuzzy logic methods are examples of this type of model. Semi-empirical equations are used in conceptual models, and the value of model variables is determined not only from field studies but also from the calibration of the model (Devia et al., 2015). In physic-based (mechanistic) models, the flow of water is calculated based on governing equations of motion (Pechlivanidis et al., 2011). According to spatial representation, lumped, distributed, and semi-distributed models would be considered. In lumped models, the whole watershed area is assumed to be homogenous, and all parameters are averaged over the catchment. Whereas in distributed models, all parameters would be considered on a unit or grid base, and model parameters are defined as a function of space. In semi-distributed models, hydrologically similar areas are modeled as a single unit. Time-based models would be divided into two as event-based and continuous based models. In event-based models, a single specific event for a short time interval is simulated, while in continuous models, simulation is performed on a longer time interval. Based on governing equations, deterministic and stochastic models come into the picture. Deterministic models produce the same results with a set of known parameters. Whereas in stochastic models, results are in the form of statistical/probabilistic outputs.

By considering these different kinds of models, several studies are carried on that which model will yield more consistent results with observed discharges. If more detailed results are needed, more complicated models like fully distributed or physically based models may be required (Elfert & Bormann, 2010). However, it is stated that complex modeling may not always provide better results, and the best model is the one that presents more accurate results to reality according to the needs of purposes by using the least parameters with simple model complexity (Devia et al., 2015). In many cases, required data may not be in the continuous form or may not exist or not at all, so generally, the type of model is chosen according to the availability of data (Singh and Woolhiser, 2002).

For flood management practices, hydrological modeling could be used both for planning and operating purposes. In the planning phase, inundation areas and water levels can be determined by using the results of models based on historical data, and necessary precautions can be taken. Whereas for the operation phase, models are generally used as a forecasting tool in operational studies. Releasing water for the anticipation of incoming floods and taking predetermined actions to prevent or reduce flood damages could be achieved by means of hydrological models (Plate, 2009). In this study, hydrological modeling is also used for this purpose by using daily lake level measurements of Lake Mogan.

CHAPTER 3

GENERAL DESCRIPTION OF STUDY AREA

3.1 Description of Study Area

İncesu Creek is composed of approximately one-third of the 3300 km^2 drainage area of Ankara Creek. Lake Mogan, Lake Eymir, and İncesu Detention Pond are the main elements of İncesu Creek. There is a 934 km^2 drainage area at the upstream part of Lake Mogan. A sub basin area between Lake Mogan and Lake Eymir is 42 km^2, whereas it is 98 km^2 between Lake Eymir and İncesu Detention Pond. İmrahor Valley starts at the exit of Lake Eymir. Creek follows an irregular pattern through the valley and reaches Incesu Detention Pond, which was constructed in 1965. The height of this pond is 12 m., and it is followed by a closed conduit through the city center, which is merged then with Çubuk and Hatip creeks at around the Akköprü District of Ankara. The capacity of the closed conduit is given as high as 94 m^3/s in past reports (DSİ, 2008); however, the current capacity is so much lower, according to municipality authorities (ASKİ, 2013).

In this study, the main focus is given to the drainage area of Lake Mogan. Lake has a nearly 934 km^2 catchment area. ASTER GDEM (Advanced Spaceborn Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM)) is used for basin processing issues in the GIS environment. In the upstream part of the basin, there are two small irrigation reservoirs, namely Dikilitaş and İkizce. Mogan Detention Pond takes place at the downstream part of these reservoirs on the mainstream; it is upstream of Lake Mogan.

Dikilitaş Reservoir, which is the most upstream structure on the basin, was constructed on Sarıkaya Creek in 1987. The height of the body is 20 m. and thalweg elevation is 1031 m. Active storage volume and the annual average water budget of the reservoir are given as 9 hm^3 and 1.24 hm^3, respectively (DSİ, 2008). The drainage area of this reservoir is calculated as 169 km^2.

İkizce Reservoir, which has 15 m in height, was constructed on Mencilen Creek at the 1054-meter thalweg elevation in 1976. Active storage volume and the annual average water budget of the reservoir are given as 1.10 hm^3 and 1.27 $hm^{3,}$ respectively (DSİ, 2008). The drainage area of this reservoir is calculated as 52 km^2.

Mogan Detention Pond is constructed in 2015 on Çölovası Creek, which is the mainstream feeding Lake Mogan. The Detention pond is located on 7 km upstream of the lake. The height of the pond is 10 m, and the drainage area is 542 km^2, which also includes drainage areas of Dikilitaş and İkizce reservoirs. The subarea between these reservoirs and the detention pond is calculated as 321 km^2. Thalweg and spillway crest elevations of the detention pond are 982.00 m. and 990.85 m. respectively. The maximum storage volume of the detention pond is calculated from the elevation-area curve of the reservoir, which is given in the report that had been prepared by DSİ in 2008, and it is found as 34.4 hm^3. Bozkurt et al. (2013) stated that a 500-year storm could be stored in this reservoir without releasing any water from the sluiceway; maximum water elevation would be equal to 988.53 m. in that case, which is below spillway crest elevation.

Çölovası Creek comes together with Yavrucak and Başpınar creeks at the downstream part of Mogan Detention Pond. The region where Çölovası Creek enters the Lake Mogan is known as Çökek Marsh. There are seven small subbasins that are defined in the reports of State Hydraulic Works (DSİ, 2008) on the left and right sides of Lake Mogan. Bağırsak, Gölcük, Tatlım, and Burcupınar subbasins exist on the left-hand side, İğdeli, Kepir, and Sukesen subbasins exist on the right-hand side of Lake Mogan. Among these subbasins, only the Sukesen subbasin creek has a well-defined stream bed. All other creeks are in the form of an intermittent (ephemeral) stream. These streams become almost invisible, with very low slopes on the wet zone area of Lake Mogan.

According to EİEİ (2005) report, the contribution of these side-streams to Lake Mogan is very limited. It is stated that based on data collected between 1999 and

2004, 80 (in dry years) to 93 (in wet years) percent of streamflows entering to the Lake Mogan is coming from Çölovası Creek on Çökek Marsh, and the contribution of Sukesen Creek was reported as 5-6 percent.

The general layout of the study area can be seen in Figure 3-1. Some of the geomorphological characteristics of all of these subbasins are given in Table 3-1.

Table 3-1. Some of the Geomorphological Characteristics of Subbasins

Subbasin Name	Area (km^2)	Elevation (m)			Average Slope (%)
		Min.	Max.	Mean	
İkizce Reservoir	51.99	1051	1398	1189	4.42
Dikilitaş Reservoir	168.91	1026	1432	1156	4.71
Mogan Detention Pond	321.00	975	1437	1087	4.46
Upstream of Lake Mogan	249.53	975	1506	1123	5.22
Sukesen Creek	32.54	975	1708	1257	9.59
Kepir Creek	8.39	975	1157	1047	4.33
İğdeli Creek	17.91	975	1511	1163	6.64
Bağırsak Creek	9.73	975	1270	1115	6.21
Gölcük Creek	22.75	975	1269	1102	5.00
Tatlım Creek	14.14	975	1252	1077	4.96
Burcupınar Creek	12.59	975	1272	1075	5.15
Whole Mogan Basin	933.72	975	1708	1118	4.98

Lake Mogan is a shallow alluvial lake that is produced by the deposition of alluvial material from Sukesen Creek (METU, 1995; Yağbasan&Yazıcıgil, 2012). The surface area of the lake changes with respect to water level and the elevation of the deepest point is given as 969.00 m. The length and width of the lake are about 6 and 1 km, respectively. Information about the surface area, water level, and volume of Lake Mogan is given in Table 3-2. The elevation-storage relationship of Lake Mogan is given in Table 3-3.

Table 3-2. Basic Characteristics of Lake Mogan

Characteristics	Minimum	Normal	Maximum
Water Level (m)	971	972	973.25
Volume (hm^3)	6.20	11.63	20.19
Area (km^2)	4.77	6.07	7.72

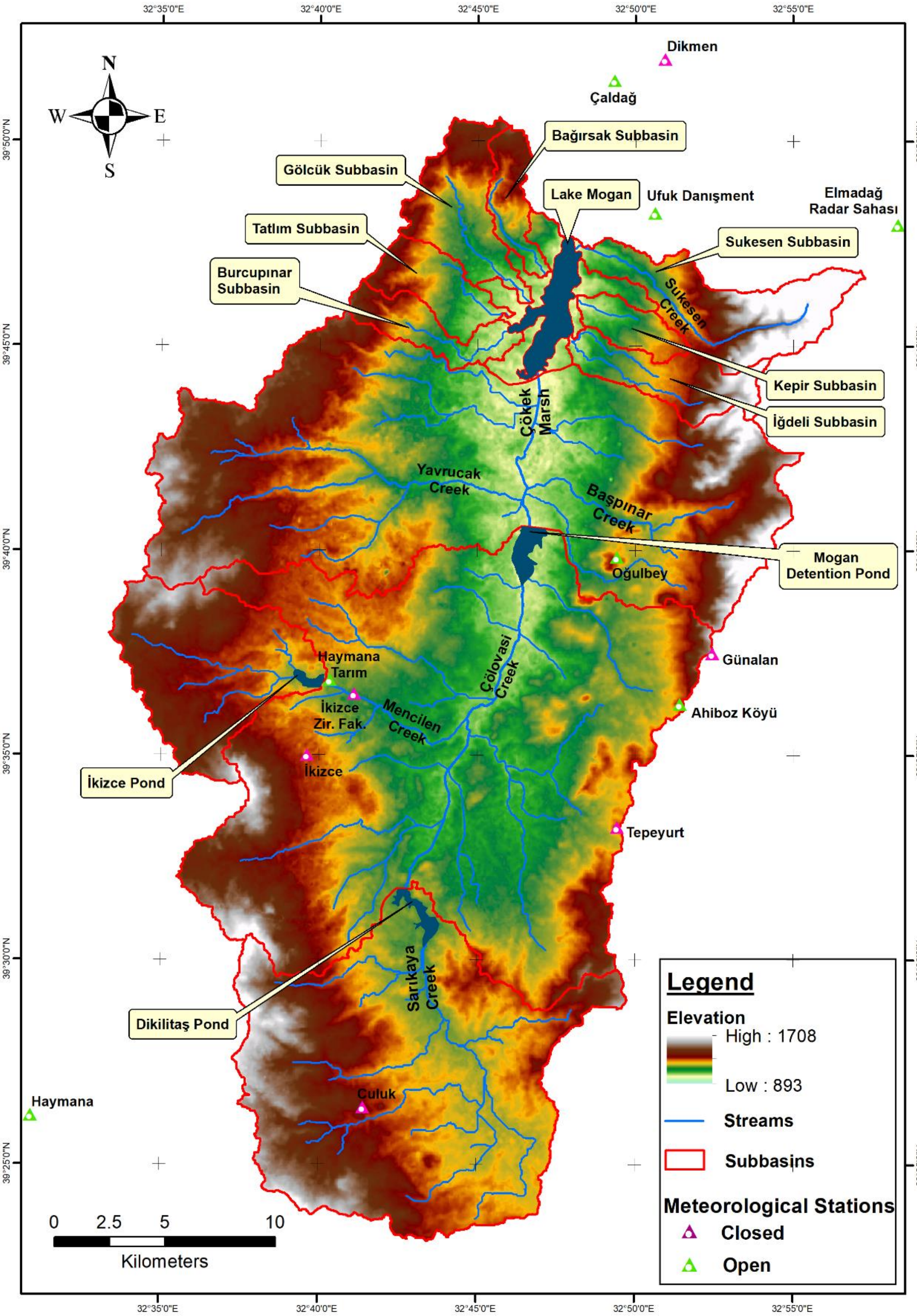

Figure 3-1. General Layout of the Study Area

Table 3-3. Elevation-Storage Relationship of Lake Mogan (METU, 1995)

Elevation (m)	Volume (hm^3)	Elevation (m)	Volume (hm^3)
971.00	6.20	973.75	24.24
972.00	11.63	974.00	26.43
972.50	14.82	974.25	28.70
973.00	18.32	974.50	31.06
973.25	20.19	974.75	32.42
973.50	22.16	975.00	34.94

During the studies performed by METU until 1995, the bathymetric maps of Lake Mogan for the years 1968, 1990, and 1995 were compared. It was determined that between 1968-1990 and 1968-1995, 4.5 hm^3 and 6.4 hm^3 volume loss (sediment accumulation) occurred on Lake Mogan, respectively (METU, 1995). 2.7 hm^3 sediment was cleaned from the bottom of the lake within the scope of sediment cleaning works carried out by the Ministry of Environment and Urbanization between 2016-2018 (web1). The current bathymetry map could not be obtained within the scope of this study.

At the exit of Lake Mogan, there exists a water control structure that is composed of two vertical sluice gates. The width and base elevation of each of these sluice gates is 3.25 m. and 971.00 m, respectively. The water control structure is followed by a lined canal through 1.4 km, and discharged water is conveyed to the wet zone area of Lake Eymir, which is also a shallow alluvial lake.

An area of 245 km^2, including some regions of Mogan and Eymir lakes' basin, was declared as a special environmental protection area (SEPA) by the decision of the Council of Ministers in 1990, and it is forbidden to make any construction in the area without special permission. There are 18 SEPA all over Turkey, and this region is crucial for the survival of numerous species of plants and animals. The marsh area of the region is used by the 227 bird species for shelter, breeding, and accommodation (web2). However, it is stated that built-up areas have been increasing, and agricultural areas and open spaces have been decreasing in the zone since the declaration of SEPA (Tüdeş et al., 2015).

3.2 Soil Data

In order to establish a rainfall-runoff relationship, soil parameters are used throughout the years. Measured infiltrometer, runoff, and rainfall data had been used to assign hydrologic soil groups (Mussgrave, 1955). Soil Conservation Service (now Natural Resources Conservation Service, NRCS) defined criteria to assign four hydrologic soil groups by using depth of water-impermeable layer, depth to the high water table, saturated hydraulic conductivity (K_{sat}) of the least transmissive layer in depth range, and K_{sat} depth range (NRCS, 2009). General characteristics of these hydrologic soil groups are given in Table 3-4. The slope of the soil surface is not taken into account while assigning these hydrologic soil groups.

Table 3-4 General Characteristics of Hydrologic Soil Groups

Hydrologic Soil Groups	**Explanation**	**General Form**
A	Have low runoff potential when thoroughly wet	Have less than 10% clay, more than 90% sand or gravel, and have gravel and sand textures.
B	Have moderately low runoff potential when thoroughly wet.	Have 10-20% clay and 50-90 percent sand and have loam sand or sandy loam textures.
C	Have moderately high runoff potential when thoroughly wet.	Have 20-40% clay and less than 50 percent sand and have loam textures.
D	Have high runoff potential when thoroughly wet.	Have more than 40% clay, less than 50 percent sand, and have clayey textures.

In this study, erosion rate and depth of soil maps and great soil group map of the study area, which are obtained from 1/25000 scale national soil database, are used in order to determine the hydrological soil group of the basin. It is seen that majority of the area is composed of brown soil. Soil depths are generally in deep and moderately deep levels. Water erosion is not high across the basin. These three soil maps are used to establish hydrologic soil maps according to the given criteria given in Table 3-5. It is found that the most of the area has a type B hydrological soil group.

Table 3-5 Determination of Hydrologic Soil Group

Classification of Great Soil Groups (GSG)		
Symbol	**Explanation**	**Value**
CE	Chestnut Color Soil	1
K	Colluvial Soil	2
X	Basaltic Soil	2
A	Allvuial Soil	1
B	Brown Soil	1
N	Lime-Free Brown Forest Soil	1
D	Reddish Maroon Soil	1
F	Reddish Brown Soil	1
Y	High Mountain Pasture Lands	1
M	Brown Forest Soil	1
U	Lime-Free Brown Soil	1
G	Grey Brown Podzolic Soil	1
H	Hydromorphic Alluvial Soil	2
O	Organic Soil	1
P	Red Yellow Podzolic Soil	1
C	Saline-Alkali and Saline Alkali Melange Soil	2

Classification of Soil Depths (SD)	
Explanation	**Value**
Deep (+ 90 cm)	1
Moderately Deep (90 - 50 cm)	2
Shallow (50 - 20 cm)	3
Very Shallow (20 - 0 cm)	4
Lithologic	5

Classification of Erosion Level (EL)	
Explanation	**Value**
None or Very Little Water Erosion	1
Moderate Water Erosion	2
Intensive Water Erosion	3
Very Intensive Water Erosion	4

Determination of Hydrological Soil Group (HSG)			
HSG	**Value**		
	GSG	**Depth**	**Erosion**
A	2	-	3-4
B	1	1-2	1-2
C	1	3-4-5	1-2-3
D	Other Cases		

Soil Conservation Service (USDA, 1972) introduces the curve number (CN) (a conceptual parameter) approach to estimate direct runoff generation from rainfall. By using hydrologic soil groups and various land use/land cover information, a series of curve numbers were assigned by also considering antecedent soil moisture conditions. Based on the total 5-day antecedent rainfall amount and season (growing or dormant), three types of soil moisture condition are defined, which are type 1 (dry condition), type 2 (normal condition), and type 3 (wet condition). CN values for normal antecedent moisture conditions were assigned empirically from rainfall-runoff measurements. These values have been obtained generally from small agricultural watersheds where the slope has a limited effect on the infiltration process. Since steep slopes cause a reduction in infiltration and an increase in surface runoff, it is accepted that CN values that are generated by SCS are appropriate for watershed slopes around 5% (Savvidou, E. et al., 2016). In this study, average watershed slopes are also calculated as around 5%, and it is acceptable to use the CN approach in hydrological modeling. In order to generate curve numbers for the study area, land use data is obtained from Corine (Coordination of Information on the Environment) 2018 maps. According to these maps, the basin is mainly composed of agricultural areas (more than 85% of the area). By using standard curve number tables given in the literature (USDA, 1972; Chow, V.T. et al., 1988; Hoogan, 1989), curve numbers are assigned to every Corine layer for four different hydrologic soil groups. Those assigned numbers were also calibrated within the hydrologic modeling studies. Those numbers can be observed in Table 3-6. The average curve number for the whole basin is calculated around 76. Great soil group, erosion rate and depth of soil, hydrological soil groups, Corine, and curve number maps of the study area can be seen between Figure 3-2 and Figure 3-7.

Table 3-6 Determination of Hydrologic Soil Group

Corine Code	Explanation	A	B	C	D
111	Continuous urban fabric	77	86	91	94
112	Discontinuous urban fabric	76	85	90	93
121	Industrial or commercial units	77	86	91	94
122	Road and rail networks and associated land	77	86	91	94
123	Port areas	77	86	91	94
124	Airports	77	86	91	94
131	Mineral extraction sites	77	86	91	94
132	Dump sites	77	86	91	94
133	Construction sites	77	86	91	94
141	Green urban areas	74	83	88	91
142	Sport and leisure facilities	76	85	90	93
211	Non-irrigated arable land	63	74	79	84
212	Permanently irrigated land	64	75	80	85
213	Rice fields	65	77	85	89
221	Vineyards	30	60	73	79
222	Fruit trees and berry plantations	30	60	73	79
223	Olive groves	30	60	73	79
231	Pastures	39	68	78	83
241	Annual crops associated with permanent crops	45	72	82	86
242	Complex cultivation patterns	30	61	72	78
243	Land principally occupied by agriculture, with	56	72	80	85
244	Agro-forestry areas	40	65	77	83
311	Broad-leaved forest	38	52	62	70
312	Coniferous forest	38	52	62	70
313	Mixed forest	38	52	62	70
321	Natural grasslands	39	57	71	77
322	Moors and heathland	39	57	71	77
323	Sclerophyllous vegetation	39	57	71	77
324	Transitional woodland-shrub	39	57	71	77
331	Beaches, dunes, sands	56	73	82	86
332	Bare rocks	98	98	98	98
333	Sparsely vegetated areas	58	75	84	88
334	Burnt areas	77	86	91	94
411	Inland marshes	77	86	91	94
412	Peat bogs	77	86	91	94
421	Salt marshes	77	86	91	94
422	Salines	77	86	91	94
423	Intertidal flats	77	86	91	94
511	Water courses	100	100	100	100
512	Water bodies	100	100	100	100
521	Coastal lagoons	100	100	100	100
522	Estuaries	100	100	100	100
523	Sea and ocean	100	100	100	100

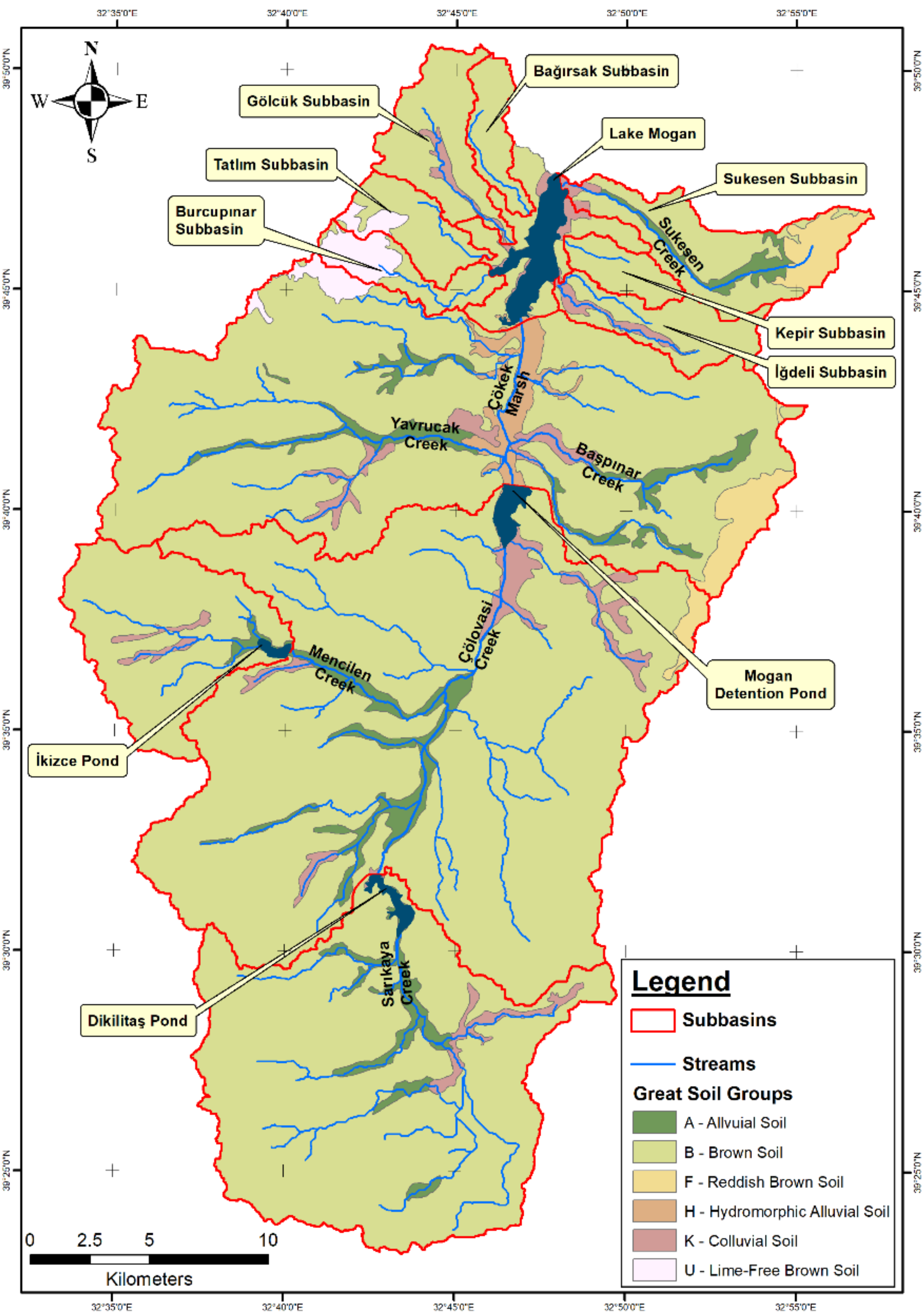

Figure 3-2. Great Soil Group Map of the Study Area

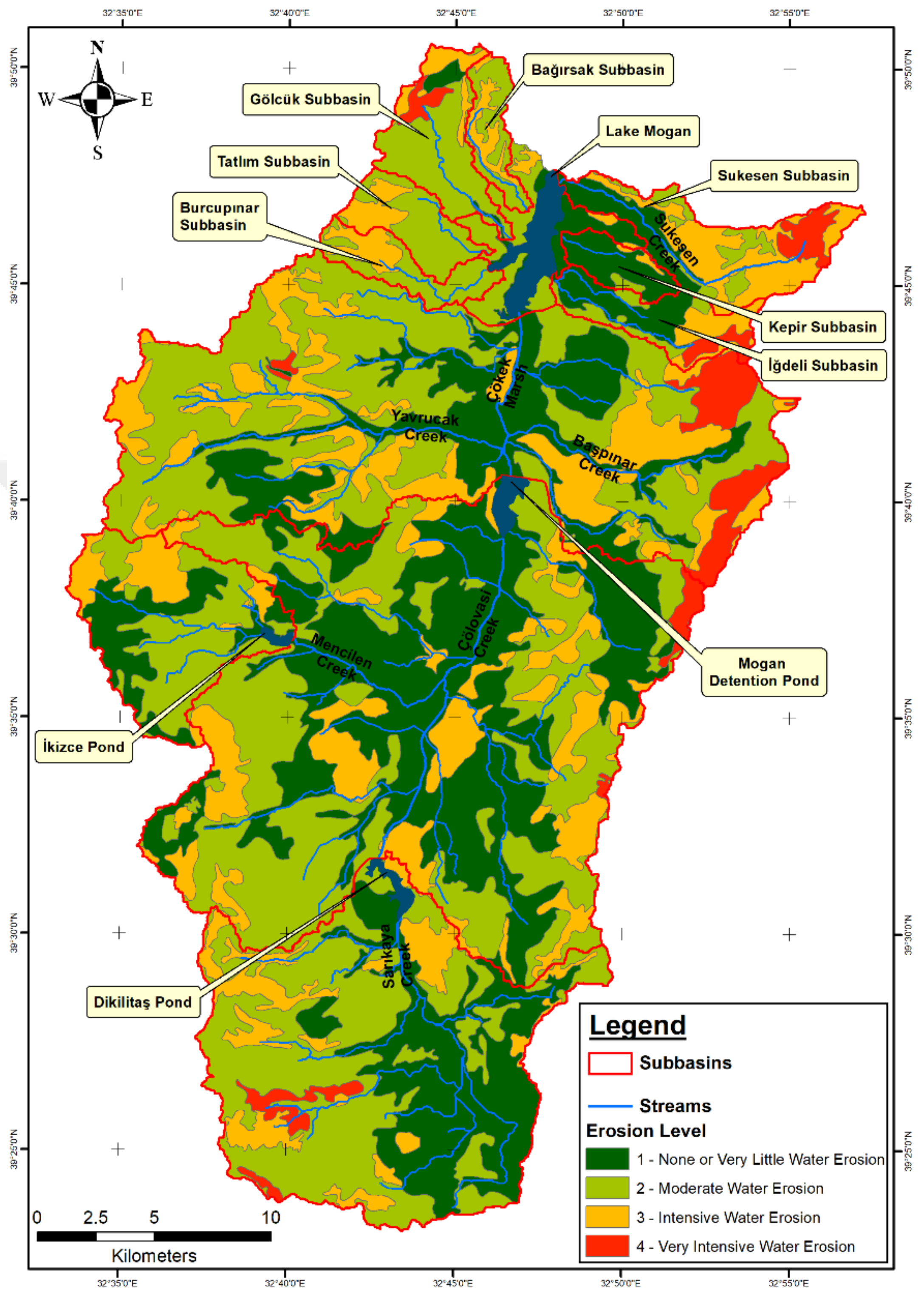

Figure 3-3. Erosion Level Map of the Study Area

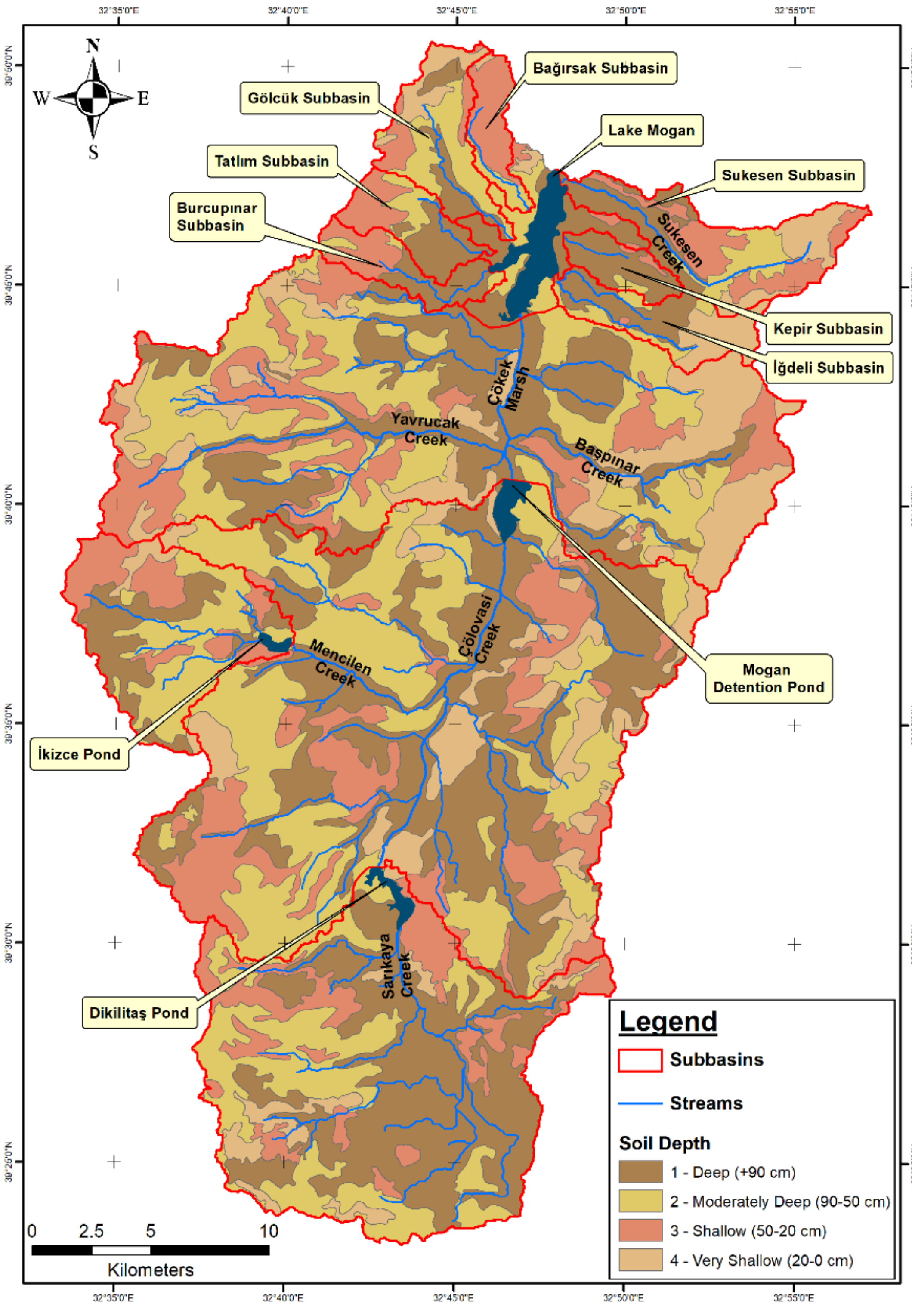

Figure 3-4. Soil Depth Map of the Study Area

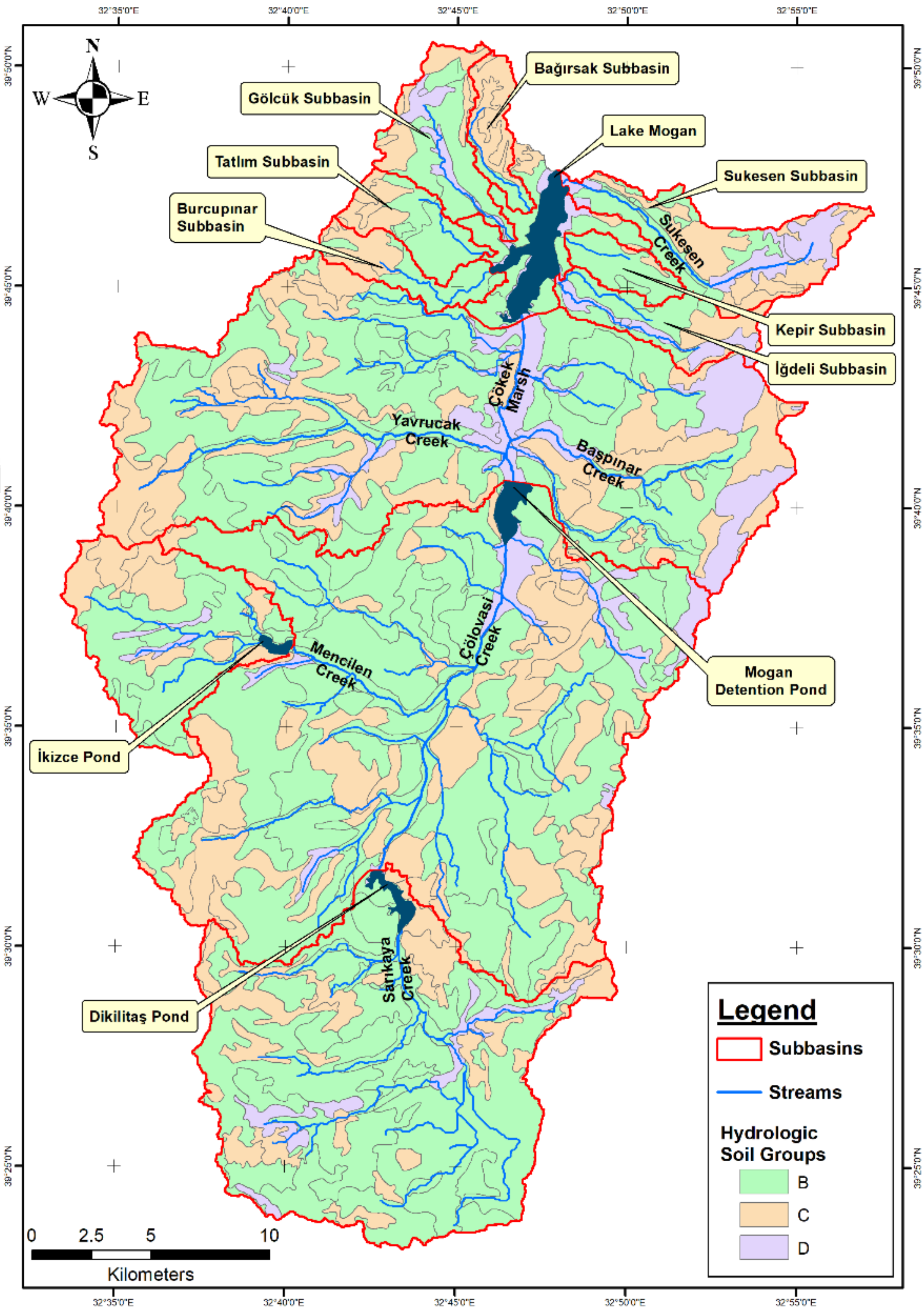

Figure 3-5. Hydrologic Soil Group Map of the Study Area

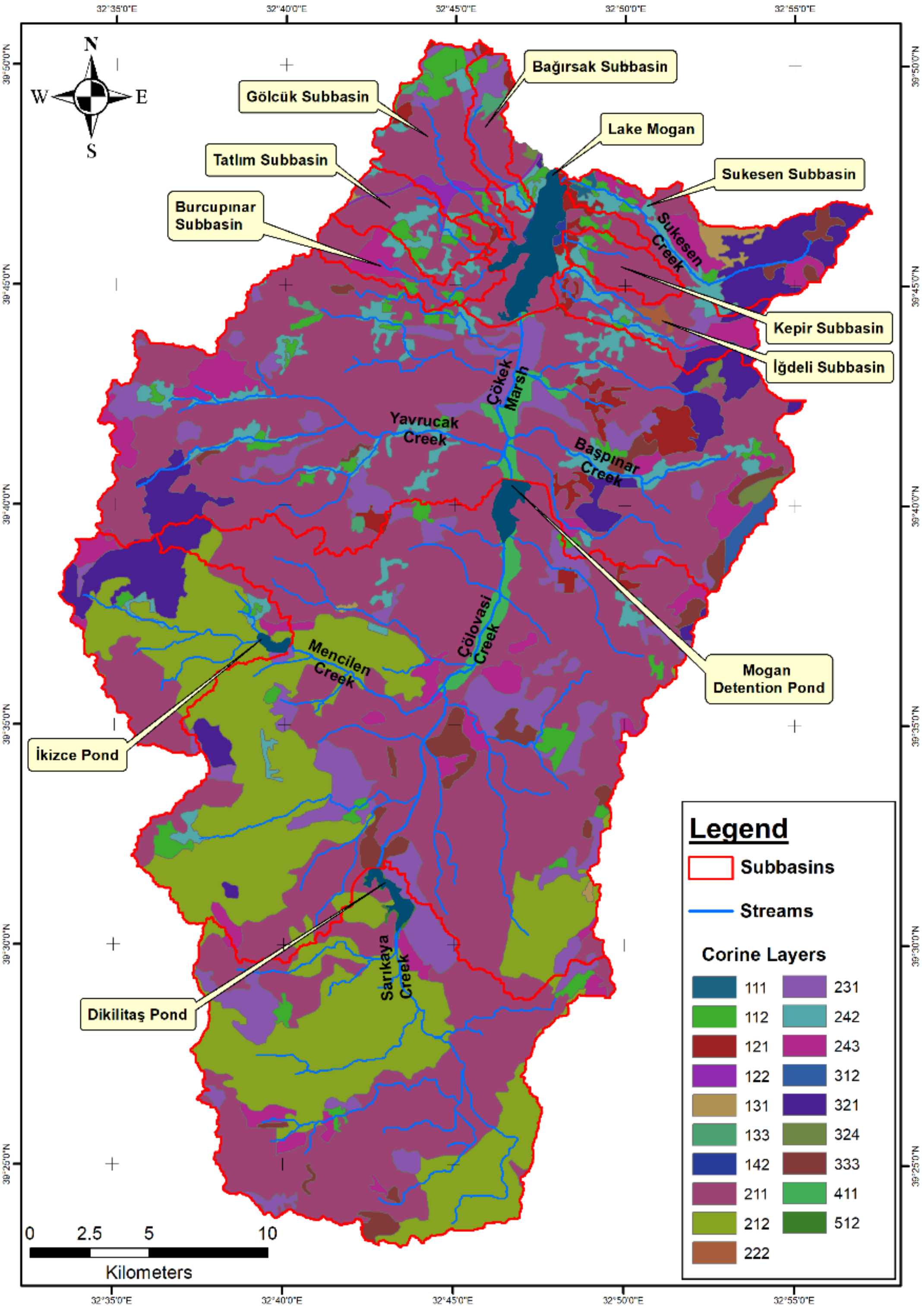

Figure 3-6. Corine Land Use Map of the Study Area

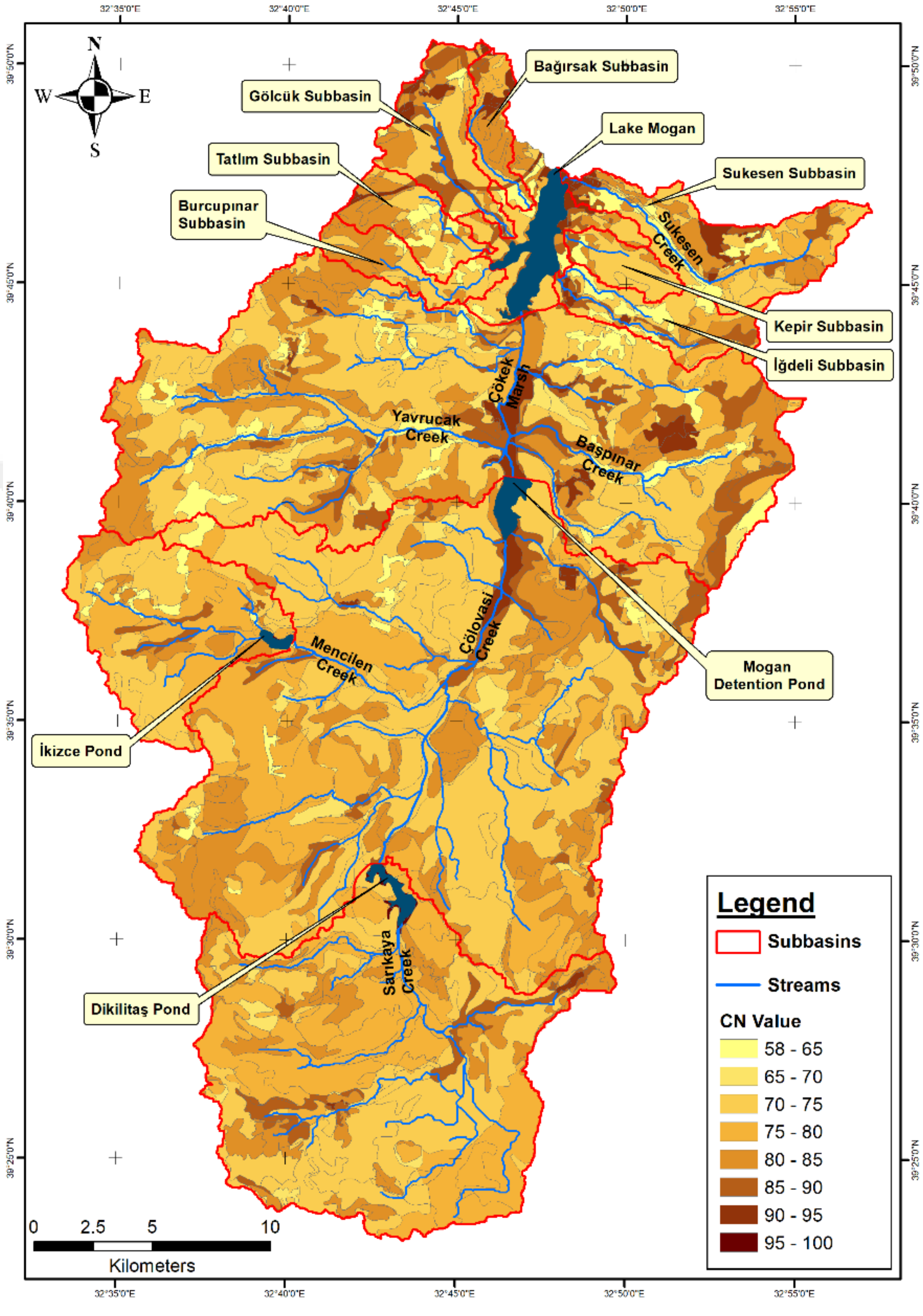

Figure 3-7. Curve Number Map of the Study Area

3.3 Rainfall Data

Required minimum densities of hydrometeorological stations depend on different geographic and climatic zones. Spatial and temporal variations of rainfall, relation with and location of streamflow gauges, the population density of the area, economic circumstances also affect the density of hydrometeorological stations network. World Meteorological Organization has defined basics characteristics of general hydrometeorological network density. For precipitation measurement, it is advised to have at least one recording station per 10-20 km^2 in urban areas and at least one non-recording station per 575 km^2 for interior plains unless any other zonal special requirements will not exist (WMO, 2008).

The current meteorological station network of the study area can be seen in Figure 3-1. All of the precipitation records that belong to the meteorological stations in Ankara for the period between 1970 and 2019 were supplied by the General Directorate of Meteorology for this study. Some of the stations do not operate currently, and some of the closed stations have recently been reopened in the immediate vicinity of the previous locations. Operation periods of stations in the study area are given in Table 3-7.

Table 3-7. Operations Periods of Meteorological Stations in Study Area

Station Name	**Status**	**Data Period**
Ahiboz Köyü	Open	2015 - Present
Culuk	Closed	1999 - 2004
Çaldağ	Open	2014 - Present
Dikmen	Closed	1966 – 1991 (1970 is missing)
Elmadağ-Radar	Open	2007 - Present
Günalan (DSİ)	Closed	1972 - 2005
Haymana KK	Closed	1957 - 1990
Haymana	Open	2014 - Present
Haymana Tarım	Open	2007 - Present
Haymana Yenice	Closed	1986 - 1995
Haymana Yenice Bld.	Open	2016 - Present
İkizce	Closed	1966 - 2004
İkizce Zir. Fak.	Closed	1931-1938, 1956-1973, 1975-1982, 1984-1987
Tepeyurt	Closed	1999 - 2001, 2004
Ufuk Danişment	Open	2007 - Present
Yağlıpınar Köyü	Open	2019 - Present

In order to be able to make judgements about the amounts of individual rainfalls, probability distribution analyses were carried out for the stations. By using the maximum daily precipitation records of each year, probable maximum daily rainfall amounts of different return periods were calculated by using the spreadsheet prepared by DSİ. Result sheets of calculations are given in Appendix A. Before starting calculations, the records of stations in close proximity were united to obtain a longer data period. The summary of the results can be seen in Table 3-8.

Table 3-8. Frequency Analysis of Selected Stations in Study Area

Stations	**Number of Years**	**Frequency Type**	**Return Period**		
			50yr (mm)	**100yr (mm)**	**500yr (mm)**
Ufuk Danişment	13	Pearson Type-3	75.47	85.06	103.99
Dikmen + Çaldağ	31	Gumbel	59.06	65.19	79.34
Elmadağ Radar	13	Pearson Type-3	59.47	63.17	70.10
Günalan (DSİ) + Ahiboz	39	Log-Pearson Type-3	63.18	71.39	90.07
Haymana KK + Haymana	26	Log-Pearson Type-3	51.18	54.15	59.85
İkizce + Haymana Tarım	52	Log-Pearson Type-3	60.93	70.06	91.57
Haymana Yenice + Haymana Yenice Bld.	14	Gumbel	69.66	77.22	94.67

After these analyses, days that have precipitation of more than 40 mm, which is around 5-10 year daily total amount of rainfall, were selected. Besides daily precipitation records of climate stations, precipitation records higher than the 10 mm/hour of automated stations are also investigated. Lastly, days that have non-convective precipitation types are investigated in order to analyze the success of numerical weather prediction models in different rainfall types, although they have a less total amount of precipitation than 40 mm. Among these events, six of them, which occurred after 2013, are selected since weather forecasting models of the Turkish State General Directorate of Meteorology (MGM) are available after 2013. Finally, the results of weather forecasting models (WRF, ALR) of those six events are provided from the MGM. Those dates are given in Table 3-9.

Table 3-9. Dates of Selected Events

27.9.2014	11.8.2015	18.12.2017
29.5.2015	14.3.2016	20.5.2018

Areal distribution of precipitation is of considerable interest for flood analysis (Tarpanelli et al., 2012). Accurate estimation of the spatial distribution of precipitation is crucial in hydrological modeling and planning and management of water resources (Woldemeskel et al., 2013). There are various spatial interpolation techniques that have been employed in different fields such as the nearest neighbor, Thiessen polygons, inverse distance weighting, geographically weighted regression, global polynomial, local polynomial, trend surface analysis, radial basic function, Kriging, and so on (Chen and Liu, 2012). In this study, the inverse distance weighted (IDW) method was used to obtain the areal distribution of 50-, 100-, and 500-year storms. The obtained results are given in Table 3-10, and areal figures can be seen in Appendix B.

Table 3-10. Areal Precipitation Amount of Subbasins for Design Storms (mm)

Subbasin Name	**50-year (mm)**	**100-year (mm)**	**500-year (mm)**
İkizce Reservoir	61.05	69.40	88.57
Dikilitaş Reservoir	62.18	69.20	84.74
Sukesen Creek	68.73	76.23	90.76
Kepir Creek	71.08	79.55	96.07
İğdeli Creek	68.50	76.41	92.05
Bağırsak Creek	69.30	77.23	92.05
Gölcük Creek	68.08	75.85	90.64
Tatlım Creek	67.07	74.92	90.46
Burcupinar Creek	66.49	74.39	90.32
Upstream of Lake Mogan (Area between the lake and the pond)	64.12	72.17	89.58
Mogan Detention Pond (Except Dikilitaş and İkizce Reservoirs)	62.17	70.34	88.82
Whole Mogan Basin	63.60	71.50	88.73

3.4 Streamflow and Lake Observation Data

Although the Lake Mogan basin is one of the important drainage areas of Ankara Creek, available streamflow data is not much and does not cover long time periods. Middle East Technical University (METU), State Hydraulic Works (DSİ), and the abolished Electrical Work Investigation Administration (EİEİ) had operated several streamflow gauges in the past, but they were all closed more than ten years ago. Furthermore, records of gauges operated by DSİ are not available.

Lake level measurements in Lake Mogan were also done by the General Directorate of Protection of Natural Assets (GDPNA) on a monthly basis between 1996 and 2011. These records can be seen in Figure 3-8.

Discharged water from controlled gates of Lake Mogan and lake level measurements on a daily basis performed by State Hydraulic Works between 2013 and 2018 years are given in Figure 3-9.

As shown in the given figures, the lake's operating level has been kept well above the 972.00 m. level almost all the time. In addition, the amount of water released from the lake is extremely low, a maximum 2.75 m^3/s of water was discharged.

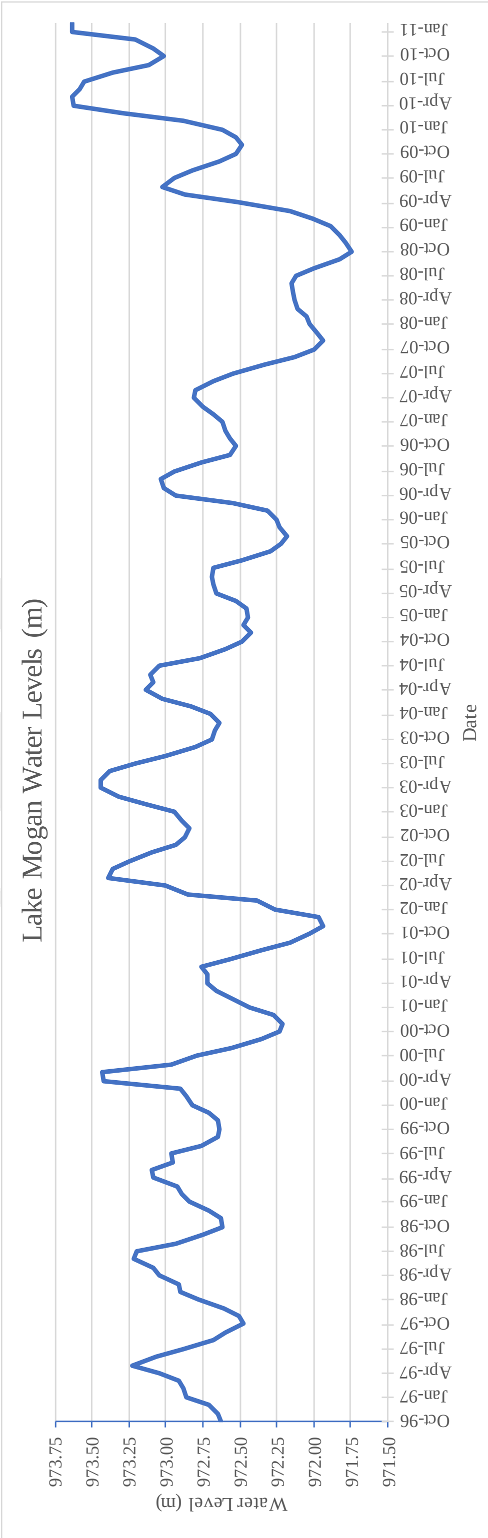

Figure 3-8. Water Level and Discharged Water Amounts of Lake Mogan between 1996 and 2011

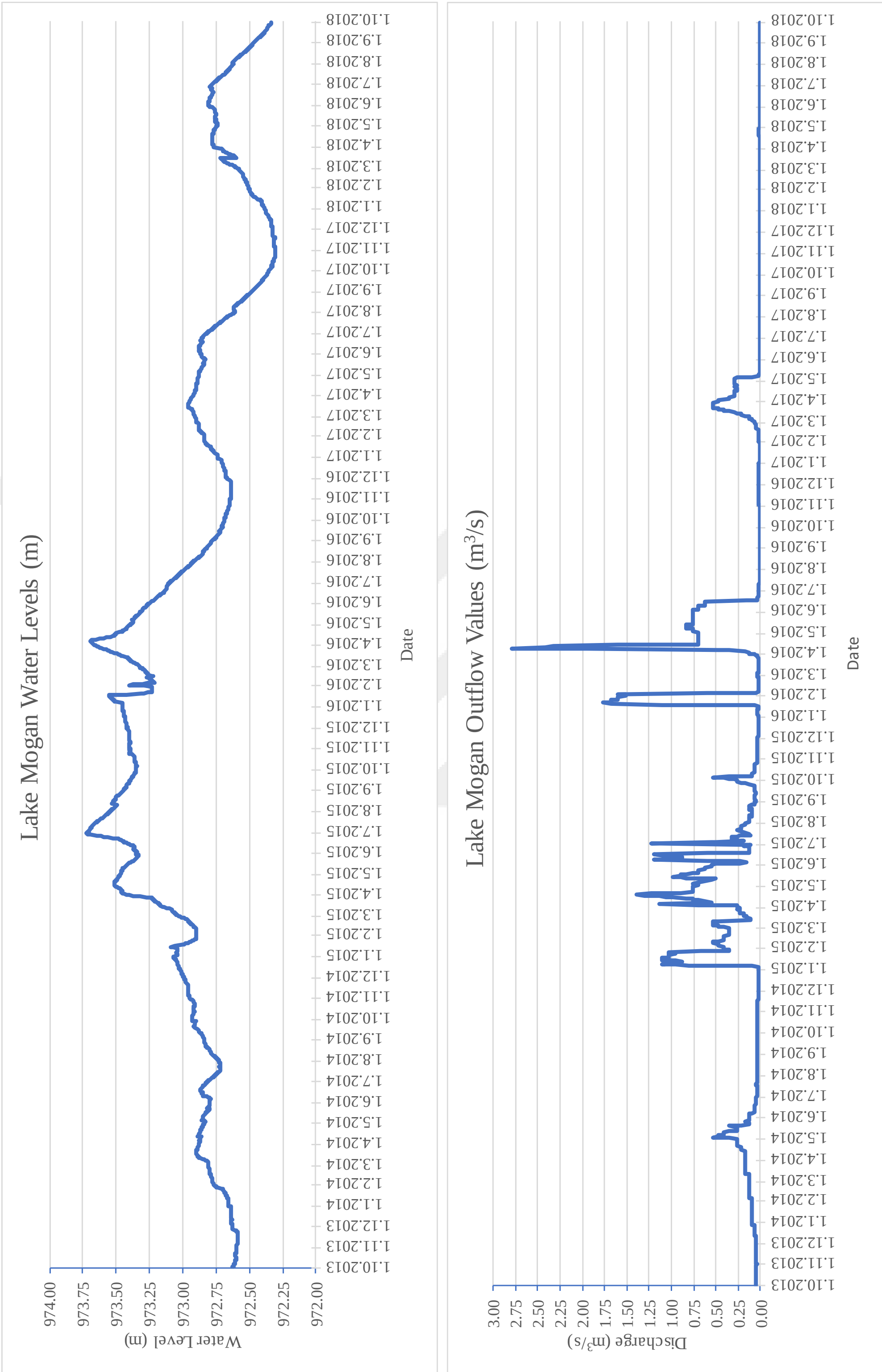

Figure 3-9. Water Level and Discharged Water Amounts of Lake Mogan between 2013 and 2018

CHAPTER 4

PRECIPITATION FORECASTS AND STATISTICAL ANALYSES

4.1 General

Numerical weather forecasting models are increasingly being used for decision support in water management (Müller, 2016), as also stated in Chapter 2. In Turkey, the General Directorate of Meteorology also uses numerical models for operational purposes. The relationships between forecast values and corresponding observations are always measured, and the quality of forecasts is examined for a variety of reasons. These reasons were categorized as administrative, scientific, and economic purposes by Brier and Allen (1951). Wilks (2011) made also pointed out these aspects as follows. Administrative authorities may examine trends of forecast performance over time, and forecast improvement for different lead times and locations can be compared. Those comparisons allow us to see the performance of the forecaster and forecasting system. Forecast values for an event from different sources can also be compared. Studying strengths and deficiencies or weaknesses in a set of forecasts will lead to better forecasts in the next times by applying methodological improvements scientifically. Economic aspects for forecast verification are also lie in better decision making. Enterprises gathering information from forecasted events desire to maximize their gains or institutes wants to prevent damages due to atmospheric events by taking some early precautions. Knowing the reliability or sufficiency of the forecast is also essential from this point of view.

Quantitative precipitation forecasts (QPF) also have an important role in determining the potential for flooding events, especially for urban catchments on short time intervals; however, decision-makers are unwilling to devise to make an action based on forecasts whose quality is less or unknown (Rossa et al. 2008).

As explained above, verification or validation of forecasts is an essential part of work for reliable action plans. Since precipitation forecasts have a large variability both in space and in time, localization and timing of the events and precipitation intensity are the potential error fields (Habets et al., 2004). In order to reduce these kinds of errors, researchers have been studied both verification techniques and developing well-suited numerical forecast models by applying various alternatives. There are a number of papers and textbooks (Wilks, 2011; Von Storch and Zwiers, 2003; Mudelsee, 2013) that explain the general framework and details about the verification of precipitation methods in atmospheric science.

Parameters that are used for verification are defined as skill scores. Traditional verification methods are generally broad into two groups as qualitatively or categorical skills and quantitative skills. These skill scores will be explained below parts.

4.1.1 Categorical Skill Scores

Categorical forecasts are generally done in two or more classes, like below normal, around normal, and above normal, which are clearly stated according to priori defined threshold values (Von Storch and Zwiers, 2003). The contingency table is heavily used in atmospheric science in terms of occurrence and non-occurrence of events for the verification of yes/no forecasts (Wilks, 2011). Four possible combination of forecasts (occurrence/non-occurrence) and observations (occurrence/non-occurrence) are identified in 2x2 contingency table (Table 4-1). These possible combinations are classified as a hit (N_1), where an event is observed and forecasted; miss (N_2), where an event is observed but not forecasted; false alarm (N_3), where an event is not observed but forecasted; and correct rejection (N_4) where an event is not observed and not forecasted. N_T is denoted as the total number of forecasts. Categorical skill scores are calculated based on these parameters. Since the dimensionality of 2x2 contingency table is 3 ($2 \times 2 - 1 = 3$), forecast performance should be expressed at least with three parameters (Wilks, 2011). The most widely used parameters that are associated with 2x2 contingency table are given below.

Table 4-1. Contingency Table

Event	Observed	Not observed
Forecasted	N_1 (hit)	N_3 (false alarm)
Not forecasted	N_2 (miss)	N_4 (correct rejection)

Proportion Correct (PC)

Proportion correct is a measure of accuracy, and it is the ratio of summation of hits and correct rejections to the total forecast number (N_T). In perfect forecasts, N_2 and N_3 values will be equal to 0. In other words, all of the occurrence and non-occurrence of events will be forecasted without any misses or false alarms. The worst and the best scores are zero and one, respectively. This parameter is found to be misleading, especially in the case of rare events (Mölders, 2008).

$$PC = \frac{N_1 + N_4}{N_T} \tag{4.1}$$

Threat Score (TS)

Threat score (TS) or critical success index (CSI) is also a measure of accuracy. It is found to be useful when a forecasted event is less frequently occurs than nonoccurrence. The number of hits is divided by the summation of hits, false alarms, and misses. The worst and the best scores are zero and one, respectively.

$$TS = CSI = \frac{N_1}{N_1 + N_2 + N_3} \tag{4.2}$$

BIAS

It is the ratio of forecasted events (hits + false alarms) to the observed events (hits + misses). The perfect score for bias is 1, and it can take values between zero and infinity. A value greater than 1 shows that event was forecasted more times than the observed situations, which is called as overforecasting. The opposite situation is referred to as underforecasting where an event is observed more than forecasted.

$$BS = \frac{N_1 + N_3}{N_1 + N_2} \tag{4.3}$$

False Alarm Ratio (FAR)

It is the fraction of events that are predicted to occur but actually do not occur. Since this value is negatively oriented, smaller values are preferable. The worst and the best scores are one and zero, respectively.

$$FAR = \frac{N_3}{N_1 + N_3} \tag{4.4}$$

Probability of Detection (POD)

It is defined as the ratio of the number of hits (correct forecasts) to the number of total events that occur. It is also known as hit rate. The worst and the best scores are zero and one, respectively.

$$POD = \frac{N_1}{N_1 + N_2} \tag{4.5}$$

Heidke Skill Score

It measures the fraction of true forecasts after eliminating forecasts that would be true by random chance (Mölders, 2008). For the perfect forecast, it is equal to 1, for the random chance, it is 0, and for worse than random chance, it has negative values.

$$HS = \frac{2\,(N_1 N_4 - N_2 N_3)}{(N_1 + N_2)\,(N_2 + N_4) + (N_1 + N_3)\,(N_3 + N_4)} \tag{4.6}$$

A summary of these scores can be seen in Table 4-2. In addition to these scores, there are also more scores described in literature like Brier skill score, Peirce skill score, Clayton skill score, Gilbert Skill score, extreme dependency score, symmetric extreme dependency score, and so on.

Table 4-2. Summary of Categorical Skill Scores

Skill Scores	Equation	Definition	Range
Proportion Correct	$PC = \frac{N_1 + N_4}{N_T}$	Fraction of correct forecasts	0-1, with 1 being a perfect score
Threat Score	$TS = CSI = \frac{N_1}{N_1 + N_2 + N_3}$	Fraction of hits over total forecast except correct rejection	0-1, with 1 being a perfect score
Bias Score	$BS = \frac{N_1 + N_3}{N_1 + N_2}$	Ratio of forecasted events to the observed events	(-∞) – (∞)
False Alarm Ratio	$FAR = \frac{N_3}{N_1 + N_3}$	Fraction of forecasted positive events that actually did not occur	0-1, with 0 being a perfect score
Probability of Detection	$POD = \frac{N_1}{N_1 + N_2}$	Ratio of hits over total observed events	0-1, with 1 being a perfect score
Heidke Skill Score	$HS = \frac{a}{b + c}$ $a = 2\,(N_1N_4 - N_2N_3)$ $b = (N_1 + N_2)\,(N_2 + N_4)$ $c = (N_1 + N_3)\,(N_3 + N_4)$	Number of correct forecasts which not occur by chance	(-1) – (1)

4.1.2 Quantitative Skill Scores

Correlation

Pearson correlation coefficient is one of the most widely used statistical parameters that is used in natural sciences and estimates the degree of a linear relationship

(Mudelsee, 2010). It takes values between -1 and +1; where the value 0 shows no positive or negative linear relationship between the variables. It is sensitive to extreme values of the variables, i.e., statistical outliers (DEFRA, 2013).

$$r = \frac{\sum_i (x_i - \bar{x})\,(y_i - \bar{y})^2}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}} \tag{4.7}$$

Variance

Variance (σ^2) is a measurement of the spread between numbers in a data set. It measures how far each number in the set is from the mean and is calculated by taking the sum of the squares of differences between the individual observations and the mean and dividing by the number of observations in the set minus one.

$$\sigma^2 = \frac{\sum_i (x_i - \bar{x})^2}{n-1} \tag{4.8}$$

Standard Deviation

It is a measure of the amount of variation or dispersion of a set of values and is calculated as the square root of the variance for a statistical population.

$$\sigma = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{n-1}} \tag{4.9}$$

Mean Absolute Error (MAE)

It is used to estimate the closeness of (observed and forecasted) data pairs. It is calculated by taking the absolute difference of observed and predicted data values corresponding to the same time step and dividing by the number of observations. Therefore, it is always positive, and small values are preferable.

$$MAE = \frac{1}{n} \sum_i \left| x_{obs,i} - x_{for,i} \right| \tag{4.10}$$

Root Mean Square Error

The Root Mean Square Error (RMSE) is very commonly used as a measure of the overall performance of the model and calculated as the square root of the mean squared difference between forecasted and observed values for a given time period.

$$RMSE = \sqrt{\frac{\sum_i \left(x_{obs,i} - x_{for,i}\right)^2}{n}} \tag{4.11}$$

Mean Bias

The difference between any forecasted and observed value is named as bias, and correspondingly, mean bias is the average of the differences between the forecasted and observed data pairs in the domain.

$$Bias = \frac{1}{n} \sum_i \left(x_{obs,i} - x_{for,i}\right) \tag{4.12}$$

4.2 Comparison of Rainfall Forecasts

In order to compare the success of two weather forecasting models, namely WRF and ALR, quantitative and categorical statistical parameters are used. For quantitative analyses, Pearson correlations (r), root mean square errors (RMSE), and biases are calculated. On the other hand, for categorical statistical analyses, proportion correct (PC), threat score (TS), bias, false alarm ratio (FAR), probability of detection (POD), and Heidke skill scores are calculated by using 0.25 mm/hr threshold value.

Statistical analyses were carried out for three lead times; on the day, one day before, and two days before times on a point and areal basis.

In point-based analyses, four different meteorological observation stations are used. Three of these stations are currently operating in the study area. These stations are Gölbaşı Ufuk Danışment, Haymana Tarım, and Elmadağ Radar stations. In addition to these stations, Ankara station is selected to see the precipitation and forecast patterns to analyze statistical measurements outside the study area. Convective and non-convective type of precipitation forecasts are given for every grid point at the result files of WRF and ALR models. These forecast results are also given separately in statistical analysis tables. “C” and “Con” stands for convective type precipitation, “NC” and “Gec” stands for the non-convective type of precipitation. Averages of the nearest grid points to stations are used in statistical analyses.

In areal-based analyses, the study area is divided into 11 subbasins, and average weighted precipitation values are calculated by using the inverse distance weighted (IDW) method for every hour time step.

All these analyses are carried out for selected six different case events. Results are given in graphs and tables. The most distinguished statistical results of every point and areal analyses are explained in subsequent sections for every event, and general evaluation is given in the last subsection. Some of the categorical scores cannot be calculated due to zero value in the denominator, and these values are specified as “N.A.”.

4.2.1 27.09.2014 Event

Precipitation gauge records, WRF and ALR forecasts for Ankara, Ufuk Danışment, Elmadağ Radar, and Haymana Tarım stations for the 27.09.2014 event are given between Figure 4-1 and Figure 4-4. Areal distribution of actual precipitation and forecast values are given in Figure 4-5. Calculated statistics based on point and areal forecasts are given between Table 4-3 and Table 4-5.

For Ankara station, ALR forecasts are a bit better than WRF forecasts. Cumulative precipitation values are quite overestimated in WRF forecasts, r and RMSE statistics are better in ALR forecasts for on the day and one day before the forecast sets. However, r values are quite low for both WRF and ALR. Categorical statistics show better results compared to quantitative statistics. The results of the ALR forecast are again better than WRF forecasts.

For Gölbaşı-Ufuk Danişment Station forecast values are too underestimated for ALR forecasts and cumulative precipitation values are quite good for WRF forecast, especially for on the day and one day before forecast sets. However, r and RMSE values do not show that much satisfaction. On the other hand, categorical skills are better in ALR forecasts.

For Elmadağ Radar Station, the best total precipitation value was seen in one day before ALR forecast with a 0.43 correlation score. Other forecast results show overestimated values with low correlation and high RMSE scores. Similar to the results of Gölbaşı Ufuk Danişment station, categorical skills are again better in ALR forecasts.

For Haymana Tarım Station, on the day and one day before WRF forecasts are similar to each other with overestimated total precipitation values, while on the day ALR forecast a bit better than those with underestimated total precipitation value.

In general, two days before ALR forecasts are quite unsatisfactory when compared to other ones in point-based analyses. Correlation and RMSE statistics are not adequate for all precipitation sets. Categorical statistics seem more meaningful for both types, while they are generally better for ALR forecasts.

In an areal-based analysis, two days before ALR forecasts are again quite unsatisfactory, which is normal when point-based forecasts are considered. Cumulative precipitation values are seen around 1 mm for all points and basins. While one day before ALR forecasts are closer to gauge records than WRF forecasts, categorical skills are also better for on the day and one day before ALR forecasts for all subbasins.

In the Sukesen sub-basin, one day before ALR forecasts have a 0.03 correlation coefficient, but the total precipitation value is closer to gauge records than WRF forecasts.

In Kepir, Bağırsak, Gölcük, Tatlım, and Burcupınar subbasins, on the day WRF forecasts are closer to gauge records (less BIAS values) with higher correlation coefficient and but also with high RMSE. One day before ALR forecasts have higher correlation coefficients, less RMSE, and better bias scores with underestimated total precipitation values.

In the İğdeli subbasin, the cumulative precipitation value of on the day ALR forecast has a very small BIAS value but again with a very low correlation coefficient.

In the İkizce subbasin on the day ALR forecast is underestimated, but its Bias score is close to zero, and its correlation coefficient is higher with lower RMSE for on the day forecasts. One day before ALR forecasts have less bias and correlation scores with overestimated total precipitation values.

In the Dikilitaş subbasin, both WRF and ALR forecasts are overestimated. On the day ALR forecasts have a bit better scores than WRF forecasts, and one day before forecasts have similar bias scores while WRF forecasts have a higher correlation with lesser RMSE.

For upstream of Lake Mogan, correlation values are higher in WRF forecasts, bias scores are better in ALR forecasts. RMSE values are higher in on the day WRF and one day before ALR forecasts.

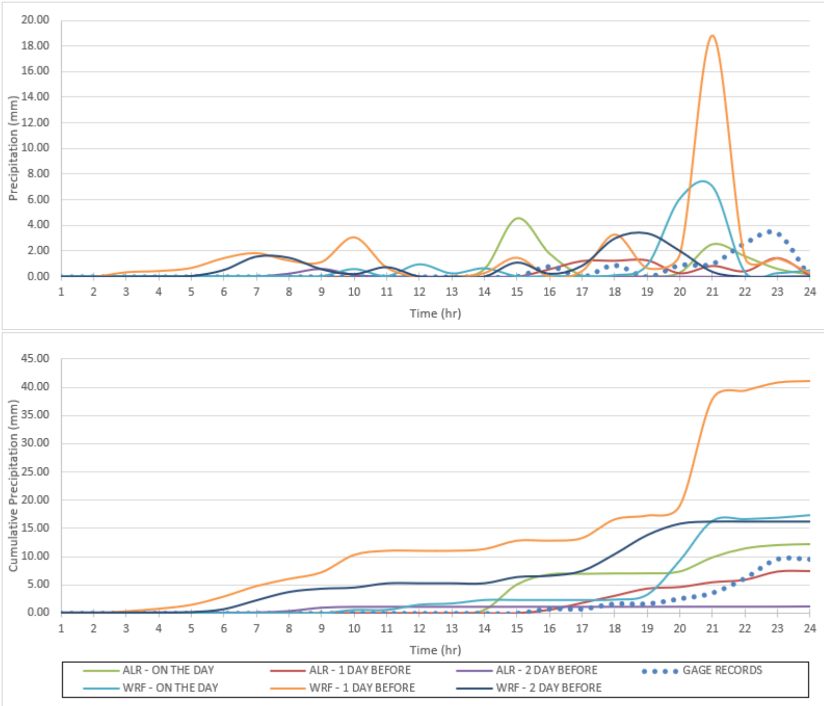

Figure 4-1. Precipitation Records and Forecast Values of 27.09.2014 Event for Ankara Station

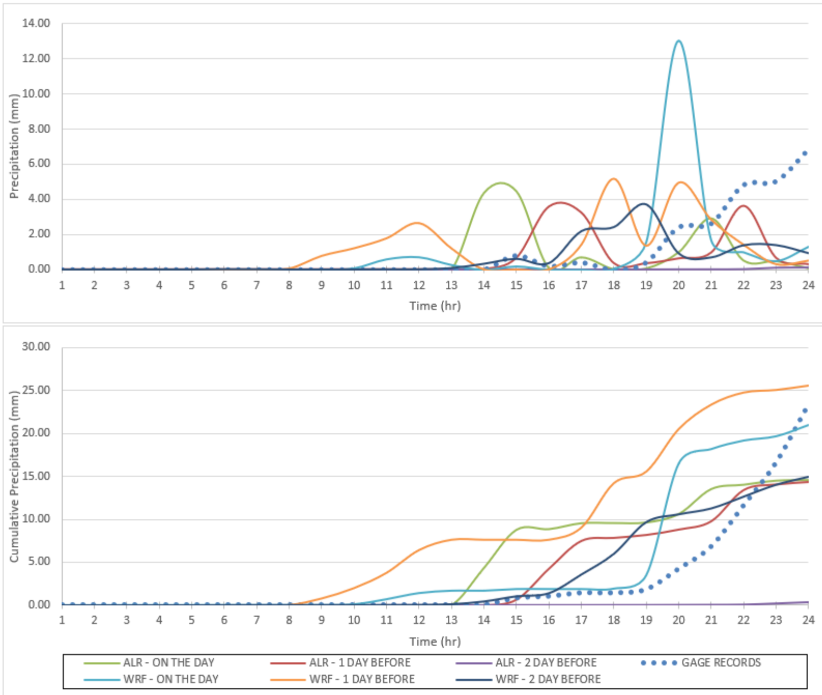

Figure 4-2. Precipitation Records and Forecast Values of 27.09.2014 Event for Ufuk Danışment Station

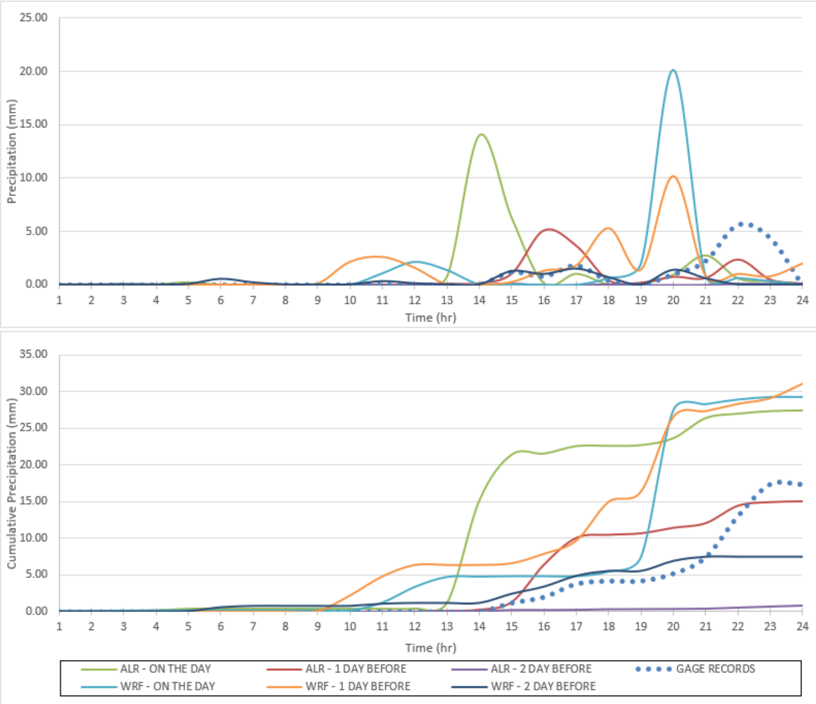

Figure 4-3. Precipitation Records and Forecast Values of 27.09.2014 Event for Elmadağ Radar Station

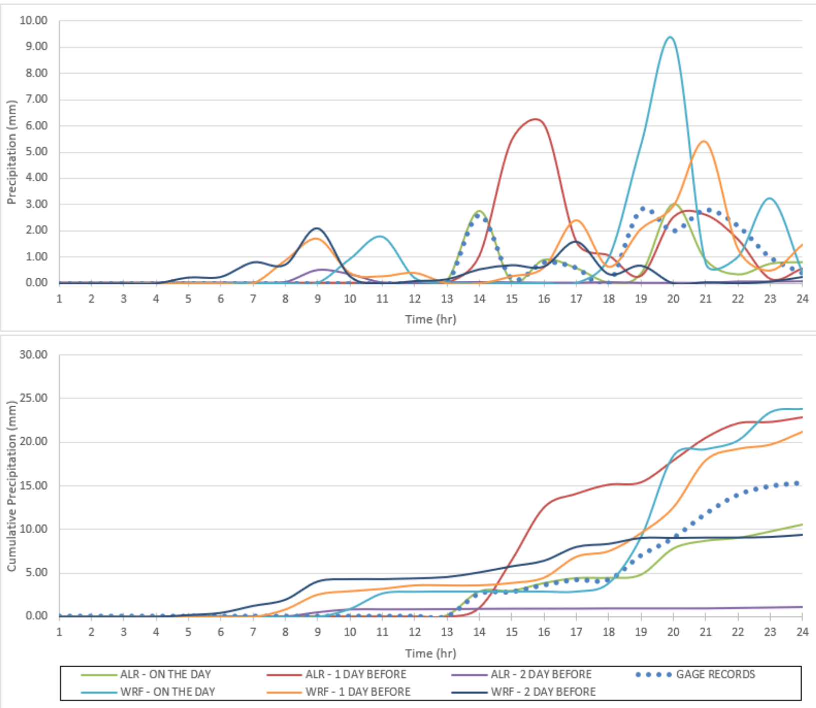

Figure 4-4. Precipitation Records and Forecast Values of 27.09.2014 Event for Haymana Tarım Station

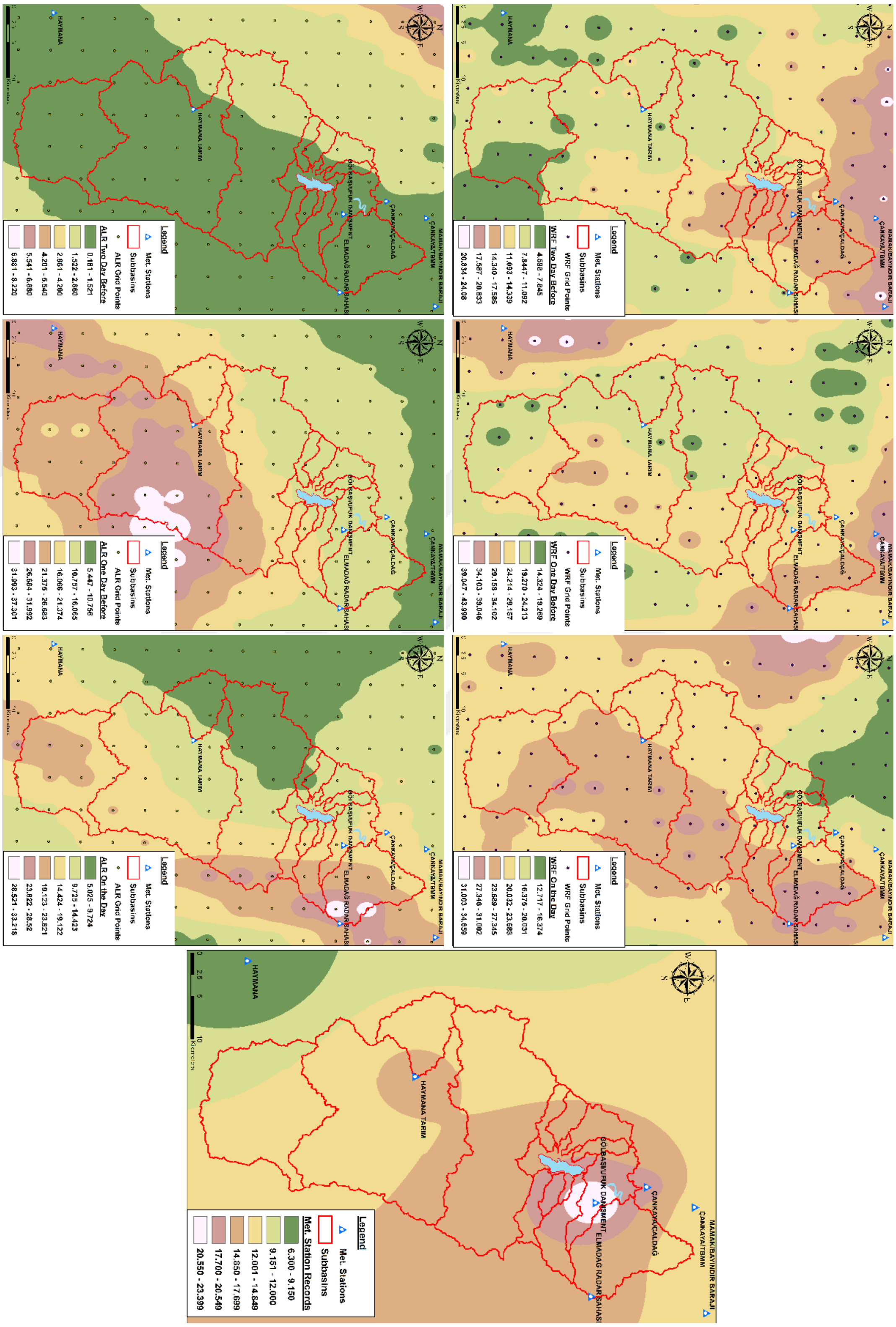

Figure 4-5. Areal Distribution of Actual Precipitation and Forecast Values of 27.09.2014 Event

Table 4-3. Statistical Scores of Forecasts on Point Basis for 27.09.2014 Event

Quantitative Scores

Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			C	NC	Total	r	RMSE	Bias	Con	Gec	Total	r	RMSE	Bias
ANKARA	9.60	On the Day	4.57	12.76	17.33	0.20	1.84	0.32	3.60	8.69	12.29	0.25	1.19	0.11
		1 Day Before	23.42	17.68	41.10	0.21	3.83	1.31	1.21	6.17	7.38	0.57	0.71	-0.09
		2 Days Before	13.50	2.69	16.19	-0.07	1.35	0.27	0.00	1.14	1.14	-0.15	0.96	-0.35
GOLBASI-UFUK DANİŞMENT	23.40	On the Day	5.41	15.64	21.05	0.28	2.75	-0.10	2.94	11.67	14.61	0.08	2.23	-0.37
		1 Day Before	18.67	6.87	25.53	0.11	2.26	0.09	2.50	11.86	14.36	0.30	1.92	-0.38
		2 Days Before	13.79	1.22	15.01	0.28	1.88	-0.35	0.01	0.30	0.31	0.86	2.09	-0.96
ELMADAG-RADAR	17.40	On the Day	7.05	22.30	29.35	0.04	4.21	0.50	16.19	11.22	27.41	0.01	3.32	0.42
		1 Day Before	21.25	9.92	31.17	0.07	2.63	0.57	2.19	12.87	15.06	0.43	1.45	-0.10
		2 Days Before	6.75	0.75	7.51	0.15	1.50	-0.41	0.08	0.77	0.85	0.65	1.56	-0.69
HAYMANA TARIM	15.40	On the Day	8.39	15.41	23.80	0.51	1.85	0.35	1.85	8.69	10.54	0.67	0.77	-0.20
		1 Day Before	17.57	3.67	21.24	0.64	1.02	0.24	8.01	14.90	22.91	0.30	1.68	0.31
		2 Days Before	8.69	0.69	9.37	-0.07	1.18	-0.25	0.65	0.46	1.11	-0.17	1.18	-0.60

Categorical Scores

Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
ANKARA	9.60	On the Day	0.67	0.27	1.33	0.63	0.50	0.20	0.88	0.63	1.17	0.29	0.83	0.68
		1 Day Before	0.38	0.25	3.17	0.74	0.83	0.03	0.92	0.75	1.33	0.25	1.00	0.80
		2 Days Before	0.54	0.21	1.83	0.73	0.50	0.04	0.67	0.00	0.33	1.00	0.00	-0.14
GOLBASI-UFUK DANİŞMENT	23.40	On the Day	0.79	0.55	1.13	0.33	0.75	0.55	0.88	0.67	0.88	0.14	0.75	0.71
		1 Day Before	0.71	0.50	1.63	0.46	0.88	0.43	0.92	0.80	1.25	0.20	1.00	0.82
		2 Days Before	0.88	0.73	1.38	0.27	1.00	0.74	0.67	0.00	0.00	N.A.	0.00	0.00
ELMADAG-RADAR	17.40	On the Day	0.71	0.42	1.13	0.44	0.63	0.36	0.83	0.60	1.00	0.25	0.75	0.63
		1 Day Before	0.75	0.54	1.50	0.42	0.88	0.50	1.00	1.00	1.00	0.00	1.00	1.00
		2 Days Before	0.83	0.60	1.00	0.25	0.75	0.63	0.67	0.00	0.00	N.A.	0.00	0.00
HAYMANA TARIM	15.40	On the Day	0.75	0.50	1.00	0.33	0.67	0.47	1.00	1.00	1.00	0.00	1.00	1.00
		1 Day Before	0.67	0.50	1.67	0.47	0.89	0.37	0.88	0.73	1.11	0.20	0.89	0.74
		2 Days Before	0.54	0.27	1.11	0.60	0.44	0.04	0.54	0.00	0.22	1.00	0.00	-0.16

Table 4-4. Quantitative Statistical Scores of Forecasts on Areal Basis for 27.09.2014 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)				ALR Forecast (IDW)			
			Total	r	RMSE	Bias	Total	r	RMSE	Bias
Ikizce Pond	13.80	On the Day	22.84	0.58	1.51	0.38	9.01	0.63	0.67	-0.20
		1 Day Before	21.62	0.65	1.21	0.33	19.78	0.36	0.25	0.25
		2 Days Before	10.11	-0.25	1.10	-0.15	1.65	-0.24	0.99	-0.51
Dikilitas Pond	12.44	On the Day	23.32	0.29	2.48	0.45	18.57	0.32	1.28	0.26
		1 Day Before	22.90	0.43	1.11	0.44	22.81	0.25	1.91	0.43
		2 Days Before	8.44	0.53	0.63	-0.17	0.90	0.63	0.83	-0.48
Sukesen Creek	18.69	On the Day	24.50	0.20	2.90	0.24	20.16	0.03	2.41	0.06
		1 Day Before	27.49	0.13	1.94	0.37	16.39	0.34	1.51	-0.10
		2 Days Before	13.98	0.07	1.52	-0.20	0.46	0.79	1.55	-0.76
Kepir Creek	19.15	On the Day	22.58	0.27	2.52	0.14	14.57	0.08	1.90	-0.19
		1 Day Before	25.93	0.16	1.83	0.28	16.29	0.37	1.52	-0.12
		2 Days Before	15.60	0.19	1.51	-0.15	0.36	0.60	1.62	-0.78
Igdeli Creek	17.80	On the Day	24.08	0.24	2.63	0.26	17.44	0.05	2.15	-0.02
		1 Day Before	26.39	0.15	1.76	0.36	18.26	0.35	1.53	0.02
		2 Days Before	15.21	0.08	1.46	-0.11	0.38	0.72	1.47	-0.73
Bagirsak Creek	16.87	On the Day	16.63	0.35	1.69	-0.01	12.88	0.21	1.50	-0.17
		1 Day Before	24.23	0.27	1.56	0.31	13.24	0.64	0.98	-0.15
		2 Days Before	12.15	0.23	1.29	-0.20	1.32	-0.11	1.43	-0.65
Gölcük Creek	15.81	On the Day	17.05	0.36	1.55	0.05	12.81	0.20	1.50	-0.12
		1 Day Before	24.10	0.29	1.43	0.35	13.38	0.70	0.83	-0.10
		2 Days Before	11.97	0.21	1.20	-0.16	1.78	-0.15	1.34	-0.58
Tatlim Creek	15.45	On the Day	19.37	0.37	1.63	0.16	10.23	0.27	1.19	-0.22
		1 Day Before	24.37	0.30	1.31	0.37	13.73	0.63	0.88	-0.07
		2 Days Before	10.50	0.13	1.18	-0.21	1.64	-0.14	1.27	-0.58
Burcupinar Creek	15.34	On the Day	20.53	0.37	1.70	0.22	9.60	0.32	1.10	-0.24
		1 Day Before	24.57	0.31	1.26	0.38	14.16	0.58	0.92	-0.05
		2 Days Before	9.35	0.05	1.19	-0.25	1.59	-0.14	1.24	-0.57
Upstream of Lake Mogan	15.10	On the Day	23.78	0.39	1.92	0.36	12.50	0.28	1.25	-0.11
		1 Day Before	23.44	0.42	1.13	0.35	18.81	0.39	1.31	0.15
		2 Days Before	11.01	0.03	1.08	-0.17	1.14	-0.11	1.13	-0.58
Mogan Detention Pond	14.43	On the Day	25.15	0.50	2.09	0.45	14.57	0.46	1.10	0.01
		1 Day Before	25.67	0.49	1.20	0.47	27.28	0.26	2.24	0.54
		2 Days Before	10.08	0.14	0.88	-0.18	0.65	0.34	0.99	-0.57

Table 4-5. Categorical Statistical Scores of Forecasts on Areal Basis for 27.09.2014 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)						ALR Forecast (IDW)					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
Ikizce Pond	13.80	On the Day	0.67	0.43	1.00	0.40	0.60	0.31	0.96	0.90	0.90	0.00	0.90	0.91
		1 Day Before	0.67	0.50	1.40	0.43	0.80	0.35	0.92	0.818	1.00	0.10	0.90	0.83
		2 Days Before	0.50	0.20	0.80	0.63	0.30	-0.06	0.54	0.00	0.10	1.00	0.00	-0.08
Dikilitas Pond	12.44	On the Day	0.63	0.40	0.91	0.40	0.55	0.24	1.00	1.00	1.00	0.00	1.00	1.00
		1 Day Before	0.71	0.56	1.27	0.36	0.82	0.42	0.92	0.83	1.00	0.09	0.91	0.83
		2 Days Before	0.92	0.85	1.18	0.15	1.00	0.83	0.54	0.00	0.00	N.A.	0.00	0.00
Sukesen Creek	18.69	On the Day	0.67	0.38	1.00	0.44	0.56	0.29	0.83	0.60	0.78	0.14	0.67	0.63
		1 Day Before	0.71	0.53	1.56	0.43	0.89	0.44	0.92	0.82	1.22	0.18	1.00	0.83
		2 Days Before	0.83	0.69	1.44	0.31	1.00	0.67	0.63	0.00	0.00	N.A.	0.00	0.00
Kepir Creek	19.15	On the Day	0.67	0.43	1.22	0.45	0.67	0.32	0.83	0.60	0.78	0.14	0.67	0.63
		1 Day Before	0.67	0.47	1.44	0.46	0.78	0.35	0.96	0.90	1.11	0.10	1.00	0.91
		2 Days Before	0.79	0.64	1.56	0.36	1.00	0.60	0.63	0.00	0.00	N.A.	0.00	0.00
Igdeli Creek	17.80	On the Day	0.71	0.46	1.11	0.40	0.67	0.39	0.83	0.60	0.78	0.14	0.67	0.63
		1 Day Before	0.71	0.53	1.56	0.43	0.89	0.44	0.92	0.82	1.22	0.18	1.00	0.83
		2 Days Before	0.75	0.60	1.67	0.40	1.00	0.53	0.63	0.00	0.00	N.A.	0.00	0.00
Bagirsak Creek	16.87	On the Day	0.67	0.38	1.00	0.44	0.56	0.29	0.88	0.7	0.889	0.13	0.78	0.73
		1 Day Before	0.71	0.53	1.56	0.43	0.89	0.44	0.96	0.9	1.111	0.10	1.00	0.91
		2 Days Before	0.83	0.67	1.22	0.27	0.89	0.66	0.54	0.00	0.22	1.00	0.00	-0.16
Gölcük Creek	15.81	On the Day	0.71	0.46	1.11	0.40	0.67	0.39	0.92	0.80	1.00	0.11	0.89	0.82
		1 Day Before	0.67	0.50	1.67	0.47	0.89	0.37	0.96	0.90	1.11	0.10	1.00	0.91
		2 Days Before	0.79	0.62	1.33	0.33	0.89	0.58	0.54	0.00	0.22	1.00	0.00	-0.16
Tatlim Creek	15.45	On the Day	0.67	0.43	1.00	0.40	0.60	0.31	0.96	0.90	0.90	0.00	0.90	0.91
		1 Day Before	0.71	0.56	1.50	0.40	0.90	0.44	0.92	0.82	1.00	0.10	0.90	0.83
		2 Days Before	0.83	0.67	1.00	0.20	0.80	0.66	0.50	0.00	0.20	1.00	0.00	-0.16
Burcupinar Creek	15.34	On the Day	0.67	0.43	1.00	0.40	0.60	0.31	0.96	0.90	0.90	0.00	0.90	0.91
		1 Day Before	0.67	0.50	1.40	0.43	0.80	0.35	0.92	0.82	1.00	0.10	0.90	0.83
		2 Days Before	0.83	0.67	1.00	0.20	0.80	0.66	0.50	0.00	0.20	1.00	0.00	-0.16
Upstream of Lake Mogan	15.10	On the Day	0.63	0.40	1.10	0.45	0.60	0.24	0.96	0.90	0.90	0.00	0.90	0.91
		1 Day Before	0.71	0.59	1.70	0.41	1.00	0.45	0.96	0.91	1.10	0.09	1.00	0.92
		2 Days Before	0.67	0.47	1.20	0.42	0.70	0.33	0.54	0.00	0.10	1.00	0.00	-0.08
Mogan Detention Pond	14.43	On the Day	0.67	0.43	1.00	0.40	0.60	0.31	0.92	0.82	1.00	0.10	0.90	0.83
		1 Day Before	0.67	0.50	1.40	0.43	0.80	0.35	0.96	0.91	1.10	0.09	1.00	0.92
		2 Days Before	0.58	0.38	1.20	0.50	0.60	0.17	0.58	0.00	0.00	N.A.	0.00	0.00

4.2.2 29.05.2015 Event

Precipitation gauge records, WRF and ALR forecasts for Ankara, Ufuk Danışment, Elmadağ Radar, and Haymana Tarım stations for the 29.05.2015 event are given between Figure 4-6 and Figure 4-9. Areal distribution of actual precipitation and forecast values are given in Figure 4-10. Calculated statistics based on point and areal forecasts are given between Table 4-6 and Table 4-8.

For Ankara Station, one day before WRF and ALR forecasts are quite overestimated with low correlation values. Two days before WRF and ALR forecasts and on the day ALR forecasts also give high total precipitation values with poor correlations and RMSE values. The best result for this station is achieved by on the day WRF forecast in terms of total precipitation value, but the correlation coefficient is almost zero. Categorical skill scores of WRF and ALR forecasts are quite unsatisfactory.

For Gölbaşı-Ufuk Danişment Station, all WRF forecasts are quite underestimated with high RMSE values. In terms of total precipitation value, ALR forecasts produce much better results. One day before ALR forecast gives close results to the station record. Other ALR forecasts are better than WRF forecasts but still underestimated significantly. ALR forecasts give similar results in categorical statistics, and they are a bit better than WRF forecasts.

For Elmadağ-Radar station, all forecasts, especially ALR ones, produce highly overestimated results. On the day and one day before WRF and ALR forecasts produce close results in themselves. Two days before forecasts are better than other forecasts but still overestimated. Categorical skill scores are also unacceptably bad.

For Haymana Tarım station, results are better than Elmadağ-Radar station's but not good enough. On the day forecasts are overestimated with low correlation values. The best forecast result is obtained from two days before ALR forecast with a 0.01 bias score but with a 0.14 correlation. The best correlation score is obtained from one day before WRF forecast. Categorical scores of ALR forecasts seem better than the WRF forecasts.

In areal analyses, two days before WRF forecasts are quite underestimated for this event. On the other hand, two days before ALR forecasts seem reasonable in terms of total precipitation value, but correlation coefficients are not as good as them.

In Sukesen, Kepir, and İğdeli subbasins, on the day and one day before WRF forecasts are resulted in underestimated total precipitation value with low correlation, whereas on the day and one day before ALR forecasts resulted with overestimated total precipitation value with higher correlation. Categorical skill scores of WRF and ALR forecasts are close to each other, but ALR values are slightly better than WRF values.

In Bağırsak and Gölcük subbasins, on the day WRF and ALR forecasts resulted in reasonable total precipitation values. The correlation coefficients on ALR forecasts are better than WRF's. One day before WRF forecasts also produced reasonable total precipitation values with some overestimation and low correlation. However, one day before ALR forecast produce a fairly high total precipitation value with a correlation of about 0.50. The majority of categorical scores are better in ALR forecasts, whereas two days before WRF forecasts a bit better than ALR forecasts.

In Tatlım and Burcupınar subbasins, on the day ALR forecasts are again resulted in reasonable total precipitation values, whereas WRF forecasts produce higher precipitation values with lower correlation coefficients. Between one day before forecasts, ALR has a better correlation coefficient, WRF has a better estimate, but both of the models result in overestimated total precipitation values. Categorical scores are close to each other.

For the İkizce subbasin, one day before WRF forecast result with a bit high total precipitation value and good correlation coefficient. On the day WRF and ALR forecasts result in overestimated total precipitation and low correlation coefficients. Two days before ALR forecast has a good correlation score but underestimated total precipitation value. Categorical scores are better in WRF only in on the day forecasts.

For the Dikilitaş subbasin, on the day WRF forecast with highly overestimated total precipitation value. One day before WRF forecast has also overestimated value where two days before forecast has underestimated total precipitation values. ALR forecasts result in almost 30 percent underestimated total precipitation values. For categorical estimates, proportion correct, threat score, probability of detection, and Heidke scores are better in WRF forecasts, whereas bias and false alarm ratio scores are better in ALR forecasts.

For upstream of Lake Mogan, on the day and one day before ALR forecasts result with slightly high total precipitation values with around 0.50 correlation values. One day before WRF forecast also has a slightly high total precipitation value but with a low correlation value. On the day WRF forecast produced an overestimated value with low correlation, while two days before WRF forecast produced an underestimated value with a higher correlation. On the day and one day before WRF and ALR forecasts are close to each other, but two days before ALR forecast a bit better than WRF forecasts.

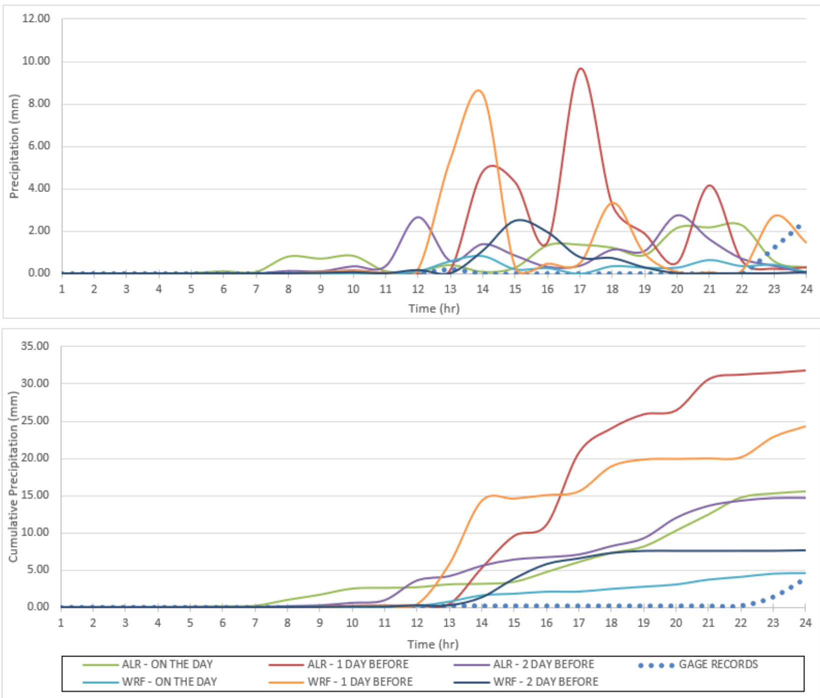

Figure 4-6. Precipitation Records and Forecast Values of 29.05.2015 Event for Ankara Station

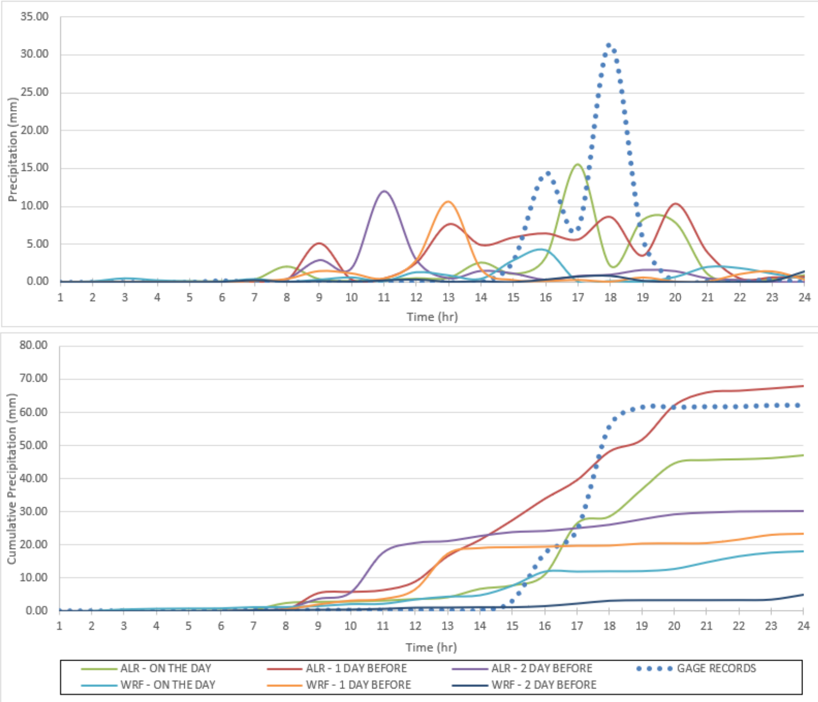

Figure 4-7. Precipitation Records and Forecast Values of 29.05.2015 Event for Ufuk Danışment Station

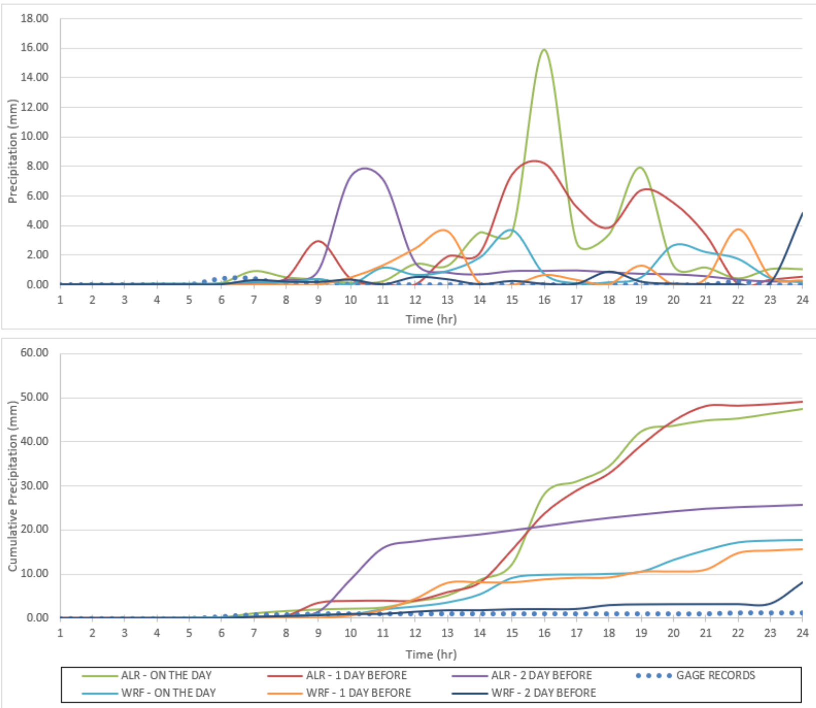

Figure 4-8. Precipitation Records and Forecast Values of 29.05.2015 Event for Elmadağ Radar Station

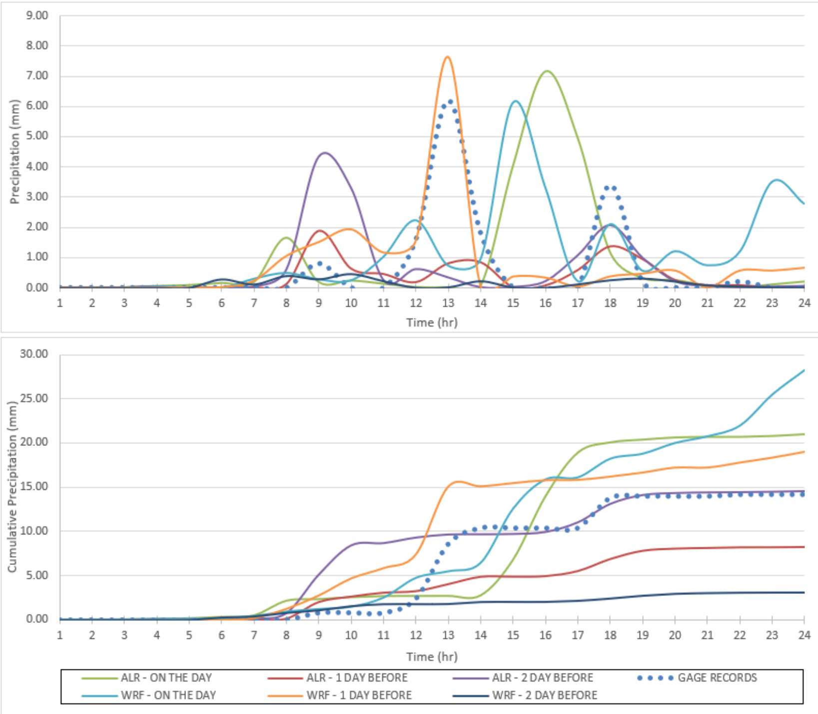

Figure 4-9. Precipitation Records and Forecast Values of 29.05.2015 Event for Haymana Tarım Station

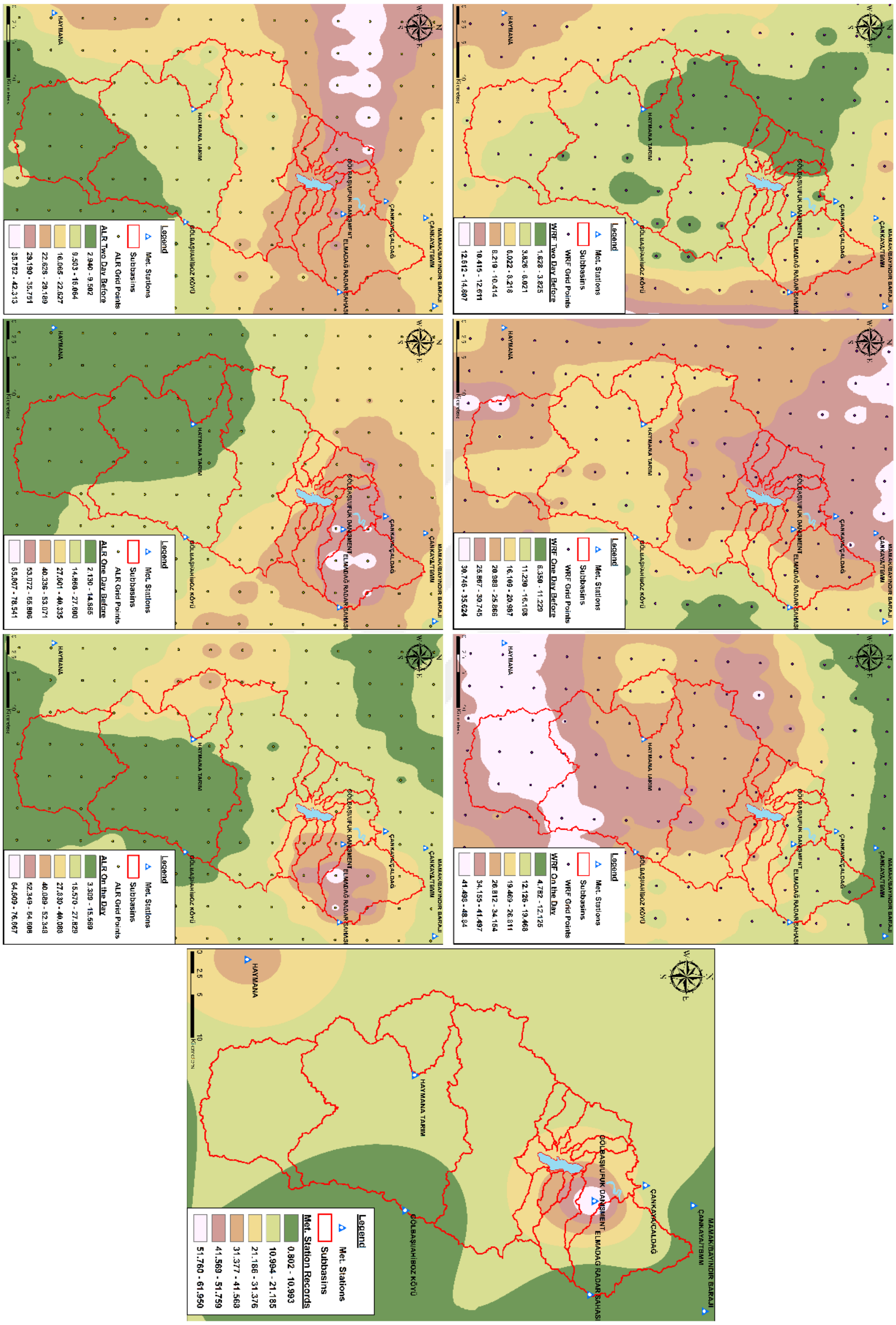

Figure 4-10. Areal Distribution of Actual Precipitation and Forecast Values of 29.05.2015 Event

Table 4-6. Statistical Scores of Forecasts on Point Basis for 29.05.2015 Event

Quantitative Scores														
Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			C	NC	Total	r	RMSE	Bias	Con	Gec	Total	r	RMSE	Bias
ANKARA	3.90	On the Day	3.20	1.36	4.56	0.02	0.59	0.03	5.60	10.02	15.62	-0.12	1.08	0.49
		1 Day Before	4.24	20.07	24.32	0.15	2.19	0.85	22.53	9.23	31.76	-0.13	2.70	1.16
		2 Days Before	7.21	0.45	7.66	-0.13	0.91	0.16	4.61	10.11	14.72	-0.18	1.12	0.45
GOLBASI-UFUK DANİŞMENT	62.20	On the Day	5.91	12.10	18.01	0.16	7.00	-1.84	33.20	13.82	47.02	0.25	6.89	-0.63
		1 Day Before	5.60	17.63	23.23	-0.14	7.63	-1.62	51.02	16.82	67.85	0.51	5.91	0.24
		2 Days Before	3.48	1.49	4.97	0.44	7.11	-2.38	17.65	12.54	30.19	-0.06	7.50	-1.33
ELMADAG-RADAR	1.20	On the Day	8.40	9.25	17.65	-0.13	1.21	0.69	34.04	13.44	47.49	-0.18	3.93	1.93
		1 Day Before	5.89	9.84	15.73	0.00	1.25	0.61	27.11	22.10	49.20	-0.25	3.34	2.00
		2 Days Before	2.61	5.47	8.08	-0.09	1.02	0.29	7.99	17.70	25.69	-0.18	2.18	1.02
HAYMANA TARIM	14.20	On the Day	7.50	20.74	28.24	0.02	2.10	0.58	14.55	6.41	20.95	-0.13	2.45	0.28
		1 Day Before	7.12	11.90	19.02	0.79	0.97	0.20	2.90	5.31	8.21	0.49	1.28	-0.25
		2 Days Before	2.45	0.65	3.10	-0.03	1.50	-0.46	9.23	5.29	14.52	0.14	1.66	0.01

Categorical Scores														
Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
ANKARA	3.90	On the Day	0.63	0.10	4.50	0.89	0.50	0.05	0.50	0.14	7.00	0.86	1.00	0.12
		1 Day Before	0.71	0.22	4.50	0.78	1.00	0.26	0.58	0.09	5.00	0.90	0.50	0.03
		2 Days Before	0.67	0.00	3.00	1.00	0.00	-0.14	0.42	0.07	7.00	0.93	0.50	-0.02
GOLBASI-UFUK DANİŞMENT	62.20	On the Day	0.42	0.18	2.33	0.79	0.50	-0.08	0.58	0.38	2.67	0.63	1.00	0.29
		1 Day Before	0.54	0.27	2.17	0.69	0.67	0.12	0.54	0.35	2.83	0.65	1.00	0.24
		2 Days Before	0.79	0.38	0.83	0.40	0.50	0.41	0.50	0.29	2.67	0.69	0.83	0.14
ELMADAG-RADAR	1.20	On the Day	0.42	0.00	6.00	1.00	0.00	-0.17	0.29	0.06	8.50	0.94	0.50	-0.05
		1 Day Before	0.46	0.00	5.50	1.00	0.00	-0.16	0.33	0.00	7.00	1.00	0.00	-0.17
		2 Days Before	0.75	0.14	3.00	0.83	0.50	0.14	0.25	0.00	8.00	1.00	0.00	-0.17
HAYMANA TARIM	14.20	On the Day	0.50	0.29	3.40	0.71	1.00	0.20	0.63	0.10	1.20	0.83	0.20	-0.06
		1 Day Before	0.54	0.27	2.80	0.71	0.80	0.16	0.79	0.44	1.60	0.50	0.80	0.48
		2 Days Before	0.71	0.22	1.20	0.67	0.40	0.18	0.75	0.40	1.80	0.56	0.80	0.41

Table 4-7. Quantitative Statistical Scores of Forecasts on Areal Basis for 29.05.2015 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)				ALR Forecast (IDW)			
			Total	r	RMSE	Bias	Total	r	RMSE	Bias
Ikizce Pond	15.84	On the Day	26.67	0.29	1.51	0.45	32.33	-0.01	3.01	0.69
		1 Day Before	19.24	0.72	0.85	0.14	8.895	0.62	-0.29	-0.29
		2 Days Before	4.77	0.05	1.15	-0.46	15.60	0.28	1.31	-0.01
Dikilitas Pond	14.64	On the Day	42.94	0.29	2.56	1.18	9.81	0.02	0.99	-0.20
		1 Day Before	21.81	0.40	1.16	0.30	10.10	0.45	0.76	-0.19
		2 Days Before	6.01	0.20	0.77	-0.36	7.53	0.32	0.76	-0.30
Sukesen Creek	31.29	On the Day	22.51	-0.05	3.37	-0.37	46.64	0.50	3.03	0.64
		1 Day Before	19.13	-0.11	3.74	-0.51	50.25	0.51	2.96	0.79
		2 Days Before	5.39	0.24	3.27	-1.08	25.53	-0.02	3.73	-0.24
Kepir Creek	37.51	On the Day	26.17	0.03	3.95	-0.47	41.35	0.42	3.63	0.16
		1 Day Before	23.34	-0.13	4.56	-0.59	44.25	0.52	3.29	0.28
		2 Days Before	5.12	0.55	3.88	-1.35	26.54	-0.02	4.33	-0.46
Igdeli Creek	28.41	On the Day	26.34	-0.04	3.01	-0.09	35.19	0.48	2.55	0.28
		1 Day Before	21.14	-0.10	3.51	-0.30	41.98	0.45	2.72	0.57
		2 Days Before	4.87	0.45	2.82	-0.98	24.49	0.01	3.31	-0.16
Bagirsak Creek	24.98	On the Day	20.51	0.21	2.27	-0.19	26.89	0.60	1.86	0.08
		1 Day Before	28.24	-0.14	3.44	0.14	48.77	0.54	2.33	0.99
		2 Days Before	3.34	0.75	2.28	-0.90	29.49	-0.09	2.97	0.19
Gölcük Creek	21.60	On the Day	23.02	0.21	1.97	0.06	24.02	0.65	1.49	0.10
		1 Day Before	28.29	-0.13	3.12	0.28	45.98	0.50	2.21	1.02
		2 Days Before	3.13	0.82	1.87	-0.77	31.99	-0.10	2.75	0.43
Tatlim Creek	20.76	On the Day	28.95	0.24	2.03	0.34	22.79	0.59	1.52	0.08
		1 Day Before	27.26	-0.09	2.97	0.27	34.42	0.45	1.85	0.57
		2 Days Before	3.22	0.83	1.76	-0.73	27.70	-0.07	2.50	0.29
Burcupinar Creek	20.34	On the Day	31.35	0.25	2.11	0.46	21.92	0.57	1.49	0.07
		1 Day Before	26.78	-0.06	2.93	0.27	29.45	0.42	1.74	0.38
		2 Days Before	3.42	0.79	1.68	-0.70	24.77	-0.03	2.27	0.18
Upstream of Lake Mogan	16.70	On the Day	31.05	0.14	1.70	0.60	20.12	0.53	1.14	0.14
		1 Day Before	22.78	0.16	2.11	0.25	23.33	0.44	1.24	0.28
		2 Days Before	3.83	0.50	1.25	-0.54	19.13	0.18	1.47	0.10
Mogan Detention Pond	12.38	On the Day	35.73	0.39	1.60	0.97	13.21	0.18	1.05	0.03
		1 Day Before	19.63	0.51	1.20	0.30	13.66	0.58	0.68	0.05
		2 Days Before	4.42	0.06	0.85	-0.33	11.79	0.25	0.99	-0.02

Table 4-8. Categorical Statistical Scores of Forecasts on Areal Basis for 29.05.2015 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)						ALR Forecast (IDW)					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
Ikizce Pond	15.84	On the Day	0.79	0.71	1.23	0.25	0.92	0.57	0.63	0.47	0.92	0.33	0.62	0.25
		1 Day Before	0.71	0.59	1.08	0.29	0.77	0.41	0.83	0.71	0.85	0.09	0.77	0.67
		2 Days Before	0.50	0.25	0.54	0.43	0.31	0.03	0.75	0.60	0.85	0.18	0.69	0.50
Dikilitas Pond	14.64	On the Day	0.88	0.82	1.07	0.13	0.93	0.73	0.63	0.47	0.67	0.20	0.53	0.28
		1 Day Before	0.79	0.69	0.80	0.08	0.73	0.58	0.67	0.47	0.47	0.00	0.47	0.40
		2 Days Before	0.50	0.33	0.60	0.33	0.40	0.06	0.54	0.31	0.40	0.17	0.33	0.19
Sukesen Creek	31.29	On the Day	0.33	0.16	2.14	0.80	0.43	-0.21	0.58	0.41	2.43	0.59	1.00	0.29
		1 Day Before	0.67	0.43	1.86	0.54	0.86	0.36	0.58	0.41	2.43	0.59	1.00	0.29
		2 Days Before	0.83	0.50	0.71	0.20	0.57	0.56	0.46	0.28	2.29	0.69	0.71	0.05
Kepir Creek	37.51	On the Day	0.38	0.21	2.29	0.75	0.57	-0.10	0.67	0.47	2.14	0.53	1.00	0.40
		1 Day Before	0.50	0.25	1.86	0.69	0.57	0.03	0.63	0.44	2.29	0.56	1.00	0.34
		2 Days Before	0.88	0.63	0.86	0.17	0.71	0.68	0.50	0.29	2.14	0.67	0.71	0.09
Igdeli Creek	28.41	On the Day	0.50	0.37	2.25	0.61	0.88	0.14	0.71	0.53	1.88	0.47	1.00	0.46
		1 Day Before	0.58	0.38	1.75	0.57	0.75	0.21	0.71	0.53	1.88	0.47	1.00	0.46
		2 Days Before	0.79	0.50	0.88	0.29	0.63	0.52	0.54	0.35	1.88	0.60	0.75	0.15
Bagirsak Creek	24.98	On the Day	0.54	0.31	1.63	0.62	0.63	0.11	0.67	0.467	1.75	0.50	0.88	0.37
		1 Day Before	0.63	0.40	1.63	0.54	0.75	0.27	0.71	0.533	1.875	0.47	1.00	0.46
		2 Days Before	0.75	0.40	0.75	0.33	0.50	0.40	0.58	0.38	1.75	0.57	0.75	0.21
Gölcük Creek	21.60	On the Day	0.50	0.29	1.75	0.64	0.63	0.05	0.67	0.43	1.50	0.50	0.75	0.33
		1 Day Before	0.54	0.31	1.63	0.62	0.63	0.11	0.71	0.53	1.88	0.47	1.00	0.46
		2 Days Before	0.75	0.40	0.75	0.33	0.50	0.40	0.63	0.44	1.88	0.53	0.88	0.31
Tatlim Creek	20.76	On the Day	0.42	0.30	1.89	0.65	0.67	-0.06	0.63	0.36	1.11	0.50	0.56	0.22
		1 Day Before	0.63	0.44	1.56	0.50	0.78	0.28	0.67	0.50	1.67	0.47	0.89	0.37
		2 Days Before	0.75	0.40	0.56	0.20	0.44	0.41	0.63	0.44	1.56	0.50	0.78	0.28
Burcupinar Creek	20.34	On the Day	0.50	0.40	1.80	0.56	0.80	0.08	0.58	0.33	1.00	0.50	0.50	0.14
		1 Day Before	0.67	0.50	1.40	0.43	0.80	0.35	0.67	0.50	1.40	0.43	0.80	0.35
		2 Days Before	0.71	0.36	0.50	0.20	0.40	0.35	0.63	0.44	1.30	0.46	0.70	0.26
Upstream of Lake Mogan	16.70	On the Day	0.75	0.67	1.50	0.33	1.00	0.50	0.71	0.56	1.08	0.31	0.75	0.42
		1 Day Before	0.75	0.63	1.17	0.29	0.83	0.50	0.75	0.65	1.33	0.31	0.92	0.50
		2 Days Before	0.63	0.36	0.58	0.29	0.42	0.25	0.79	0.64	0.92	0.18	0.75	0.58
Mogan Detention Pond	12.38	On the Day	0.79	0.71	1.42	0.29	1.00	0.58	0.58	0.38	0.83	0.40	0.50	0.17
		1 Day Before	0.71	0.59	1.25	0.33	0.83	0.42	0.79	0.67	1.08	0.23	0.83	0.58
		2 Days Before	0.63	0.44	0.92	0.36	0.58	0.25	0.83	0.69	0.83	0.10	0.75	0.67

4.2.3 11.08.2015 Event

Precipitation gauge records, WRF and ALR forecasts for Ankara, Ufuk Danışment, Elmadağ Radar, and Haymana Tarım stations for the 11.08.2015 event are given between Figure 4-11 and Figure 4-14. The areal distribution of actual precipitation and forecast values are given in Figure 4-15. Calculated statistics based on point and areal forecasts are given between Table 4-9 and Table 4-11.

For Ankara Station, the total precipitation gauge record is 1.10 mm. The closest forecast result is seen in one day before WRF forecast with a value of 0.76 mm total precipitation but with a correlation of around zero.

For Gölbaşı-Ufuk Danışment Station, the best forecast result is seen in on the day WRF forecast; however, even that forecast is quite underestimated, and the correlation coefficient is too low. Although some categorical skills seem to have good scores, all other forecasts are very unsatisfactory.

For Elmadağ-Radar Station, one the day WRF forecasts are similar to those for Gölbaşı Ufuk Danışment Station. However, at this time, the total precipitation value is so close to the gauge record, whereas correlation and RMSE values are still low. The results of categorical skills are also similar to those for Gölbaşı Ufuk Danışment Station.

For Haymana Tarım Sation, the total precipitation gauge record is 1.40 mm. However, on the day WRF and ALR forecasts are around 28 and 15 mm, respectively, which are too overestimated, and correlation is around zero for both forecasts. One and two days before forecasts are not that much worse, but statistical scores seem unsatisfactory overall.

On an areal basis, in all sub-basins except the İkizce sub-basin, the total precipitation value was calculated between 15 and 26 mm. In all those subbasins, WRF total precipitation value was calculated around 2-4 mm for every lead time, one and two days before ALR forecasts were resulted in around 0.5 mm total precipitation value.

On the day ALR forecasts for the subbasins Bağırsak, Gölcük, Tatlım, and Burcupınar (which are on the left side of Lake Mogan) produced a bit higher but still underestimated total precipitation values. For Sukesen, Kepir, and İğdeli subbasins, the total precipitation value of one the day ALR forecasts are also around 3 mm. In general, the correlation values of all those forecasts are below zero.

For the İkizce subbasin, the total precipitation value was calculated as 6.88. All WRF forecasts resulted in around 4 mm total precipitation value and with a low correlation coefficient. Only on the day ALR forecasts produce overestimated total precipitation value in this event with -0.08 correlation and 2.08 RMSE values.

For the Dikilitaş subbasin, WRF forecasts are calculated as 4-7 mm with negative bias and low correlation values. On the other hand, the result of ALR forecasts worse than the WRF's ones with around 1 mm total precipitation values.

For Mogan Detention Pond and upstream of Lake Mogan subbasins, on the day ALR forecasts are better than others; however, they are still underestimated with low correlation and RMSE values.

Except for PC scores, categorical scores are found to be also unsatisfactory for all subbasins.

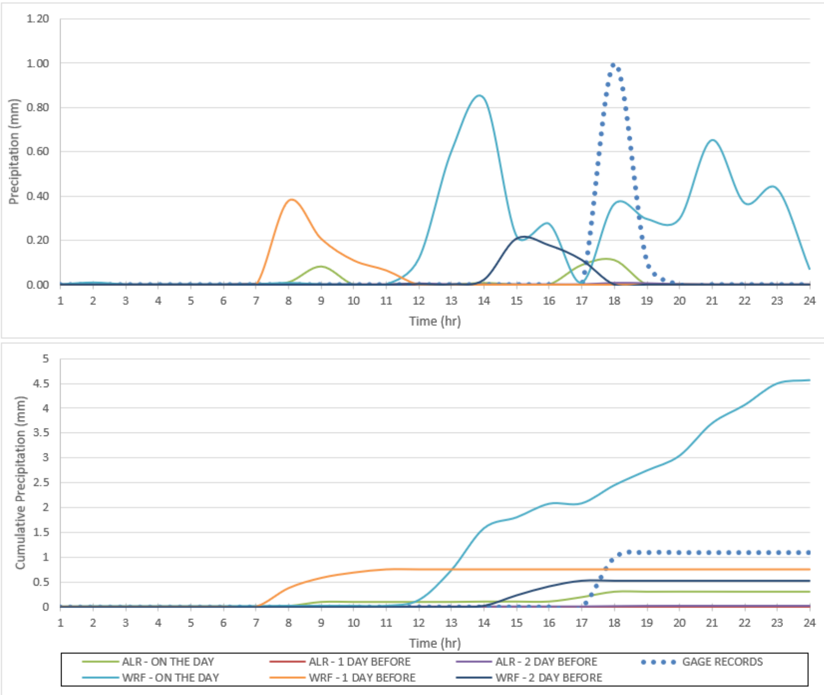

Figure 4-11. Precipitation Records and Forecast Values of 11.08.2015 Event for Ankara Station

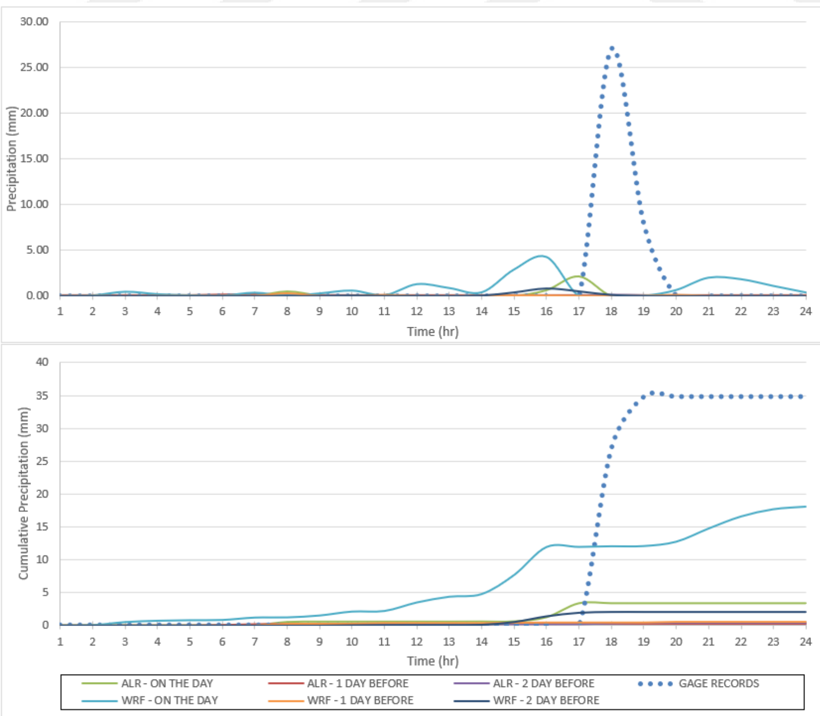

Figure 4-12. Precipitation Records and Forecast Values of 11.08.2015 Event for Ufuk Danışment Station

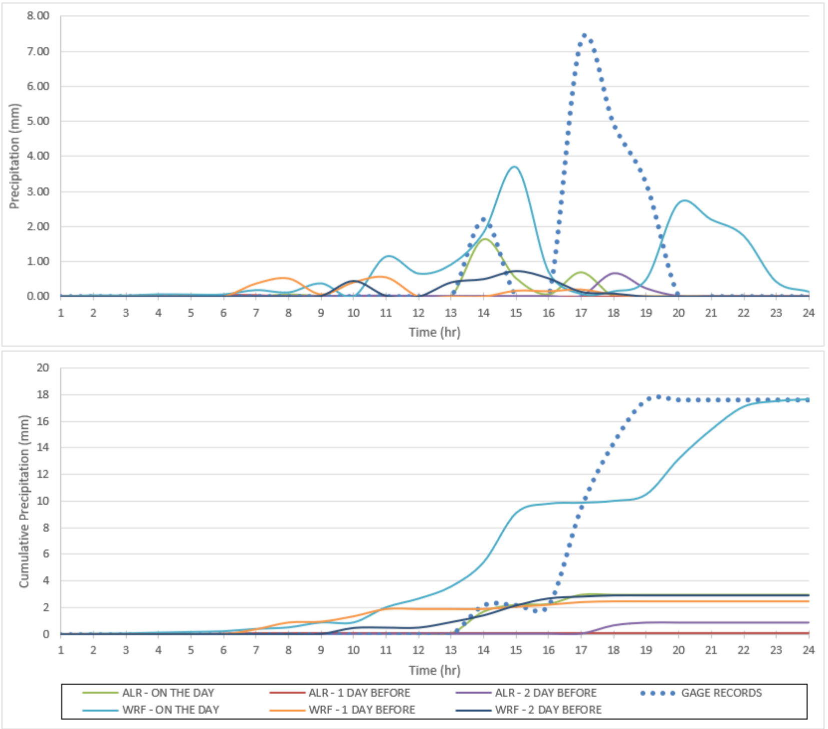

Figure 4-13. Precipitation Records and Forecast Values of 11.08.2015 Event for Elmadağ Radar Station

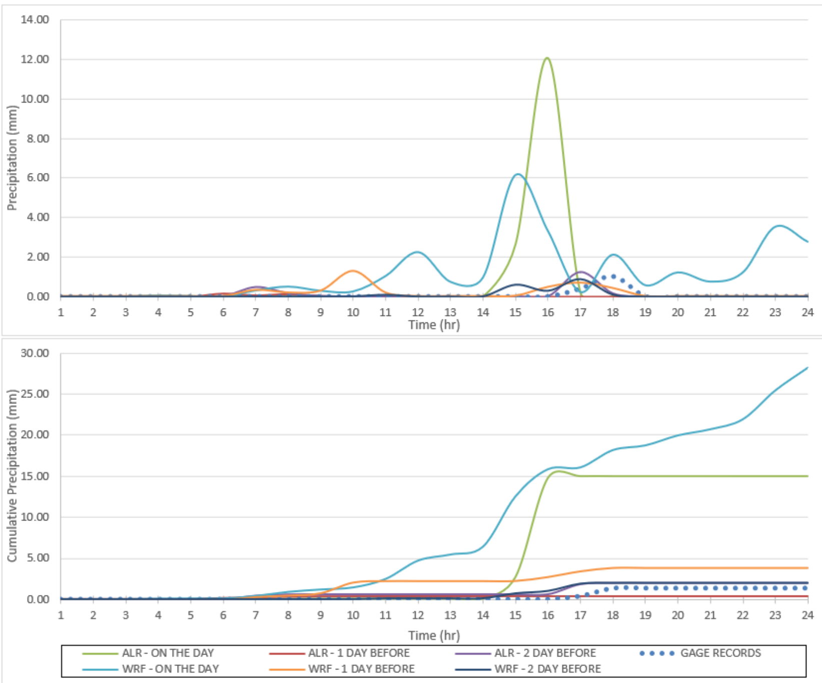

Figure 4-14. Precipitation Records and Forecast Values of 11.08.2015 Event for Haymana Tarım Station

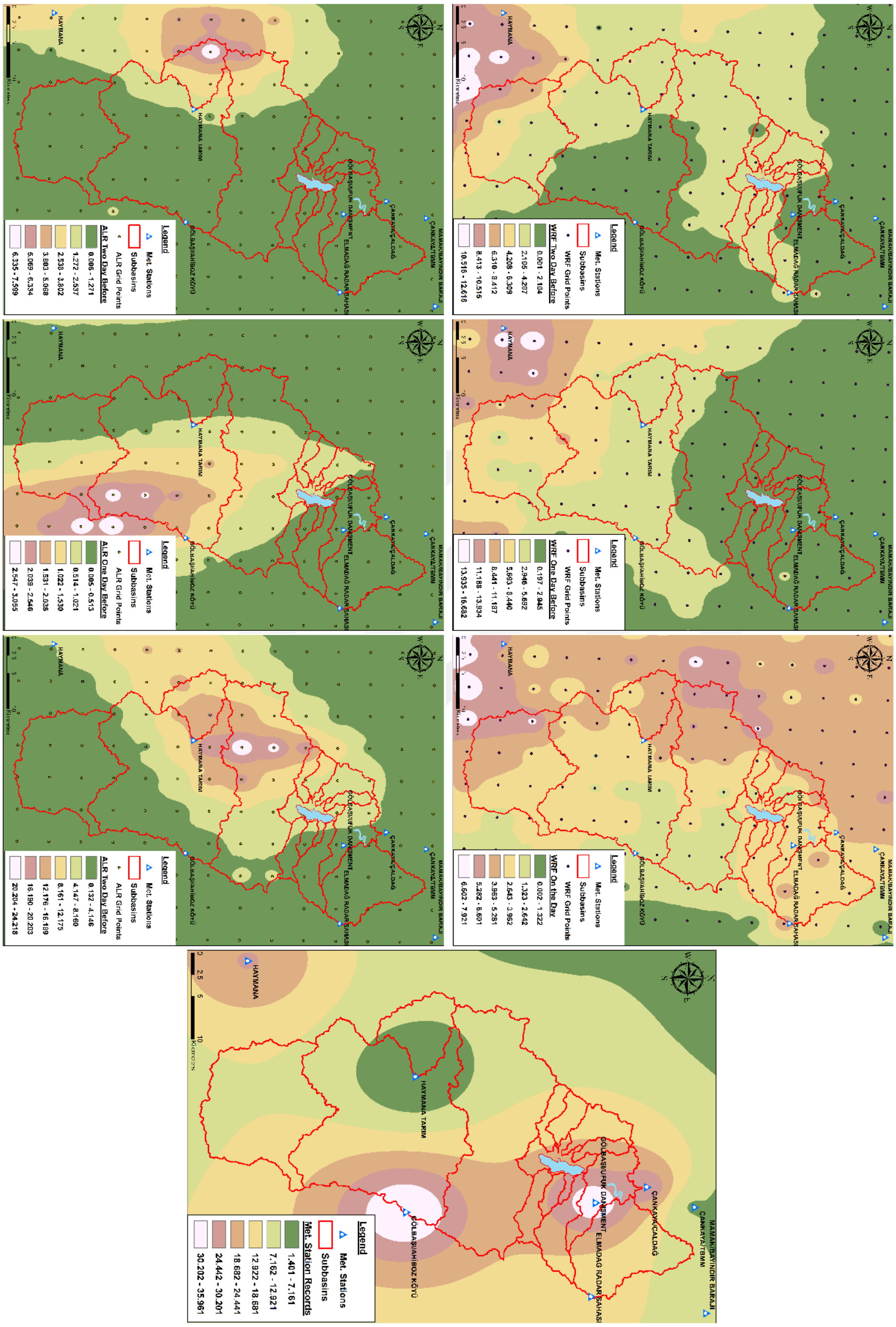

Figure 4-15. Areal Distribution of Actual Precipitation and Forecast Values of 11.08.2015 Event

Table 4-9. Statistical Scores of Forecasts on Point Basis for 11.08.2015 Event

Quantitative Scores														
Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			C	NC	Total	r	RMSE	Bias	Con	Gec	Total	r	RMSE	Bias
ANKARA	1.10	On the Day	3.20	1.36	4.56	0.16	0.32	0.14	0.01	0.29	0.301	0.65	0.18	-0.03
		1 Day Before	0.76	0.00	0.76	-0.08	0.22	-0.01	0.00	0.00	0.004	-0.05	0.21	-0.05
		2 Days Before	0.52	0.00	0.52	-0.09	0.21	-0.02	0.01	0.02	0.023	0.74	0.20	-0.04
GOLBASI-UFUK DANİŞMENT	34.80	On the Day	5.91	12.10	18.01	-0.17	5.86	-0.70	0.38	2.95	3.33	-0.08	5.75	-1.31
		1 Day Before	0.45	0.00	0.45	-0.11	5.74	-1.43	0.01	0.19	0.203	-0.10	5.74	-1.44
		2 Days Before	1.98	0.00	1.98	0.01	5.72	-1.37	0.02	0.32	0.345	0.53	5.71	-1.44
ELMADAG-RADAR	17.60	On the Day	8.40	9.25	17.65	-0.15	2.18	0.00	1.92	1.06	2.983	0.41	1.81	-0.61
		1 Day Before	2.48	0.00	2.48	-0.01	1.93	-0.63	0.00	0.06	0.06	-0.13	1.96	-0.73
		2 Days Before	2.89	0.00	2.89	0.04	1.92	-0.61	0.27	0.63	0.901	0.55	1.88	-0.70
HAYMANA TARIM	1.40	On the Day	7.50	20.74	28.24	0.07	1.85	1.12	9.80	5.16	14.96	-0.06	2.53	0.57
		1 Day Before	3.84	0.00	3.84	0.30	0.33	0.10	0.03	0.36	0.395	-0.11	0.22	-0.04
		2 Days Before	2.02	0.00	2.02	0.31	0.25	0.03	0.67	1.37	2.04	0.40	0.26	0.03
Categorical Scores														
Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
ANKARA	1.10	On the Day	0.67	0.11	9.00	0.89	1.00	0.14	0.96	0.00	0.00	N.A.	0.00	0.00
		1 Day Before	0.92	0.00	1.00	1.00	0.00	-0.04	0.96	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.96	0.00	0.00	N.A.	0.00	0.00	0.96	0.00	0.00	N.A.	0.00	0.00
GOLBASI-UFUK DANİŞMENT	34.80	On the Day	0.33	0.00	7.00	1.00	0.00	-0.17	0.79	0.00	1.50	1.00	0.00	-0.11
		1 Day Before	0.92	0.00	0.00	N.A.	0.00	0.00	0.92	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.79	0.00	1.50	1.00	0.00	-0.11	0.92	0.00	0.00	N.A.	0.00	0.00
ELMADAG-RADAR	17.60	On the Day	0.50	0.14	3.00	0.83	0.50	0.00	0.88	0.40	0.75	0.33	0.50	0.50
		1 Day Before	0.67	0.00	1.00	1.00	0.00	-0.20	0.83	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.71	0.13	1.25	0.80	0.25	0.05	0.88	0.25	0.25	0.00	0.25	0.36
HAYMANA TARIM	1.40	On the Day	0.29	0.06	8.50	0.94	0.50	-0.05	0.83	0.00	1.00	1.00	0.00	-0.09
		1 Day Before	0.83	0.33	3.00	0.67	1.00	0.43	0.92	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.88	0.25	1.50	0.67	0.50	0.33	0.92	0.33	1.00	0.50	0.50	0.45

Table 4-10. Quantitative Statistical Scores of Forecasts on Areal Basis for 11.08.2015 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)				ALR Forecast (IDW)			
			Total	r	RMSE	Bias	Total	r	RMSE	Bias
Ikizce Pond	6.88	On the Day	4.24	-0.12	1.07	-0.11	12.67	-0.08	2.08	0.24
		1 Day Before	4.45	0.15	0.99	-0.10	0.20	-0.10	-0.28	-0.28
		2 Days Before	3.18	0.20	0.98	-0.15	4.18	0.24	1.03	-0.11
Dikilitas Pond	14.81	On the Day	4.20	-0.07	2.19	-0.44	0.78	-0.08	2.18	-0.58
		1 Day Before	6.91	0.15	2.10	-0.33	0.84	-0.12	2.18	-0.58
		2 Days Before	4.94	-0.09	2.17	-0.41	0.26	-0.03	2.18	-0.61
Sukesen Creek	24.40	On the Day	3.11	-0.09	3.62	-0.89	3.34	-0.01	3.62	-0.88
		1 Day Before	1.40	-0.19	3.63	-0.96	0.25	-0.12	3.63	-1.01
		2 Days Before	2.26	-0.05	3.62	-0.92	0.45	0.81	3.59	-1.00
Kepir Creek	26.29	On the Day	2.89	-0.10	4.16	-0.98	3.78	-0.05	4.17	-0.94
		1 Day Before	1.09	-0.13	4.16	-1.05	0.43	-0.12	4.16	-1.08
		2 Days Before	2.36	-0.06	4.16	-1.00	0.45	0.13	4.15	-1.08
Igdeli Creek	23.64	On the Day	2.68	-0.08	3.58	-0.87	4.07	-0.03	3.58	-0.82
		1 Day Before	1.66	-0.15	3.59	-0.92	0.44	-0.12	3.59	-0.97
		2 Days Before	2.33	-0.06	3.59	-0.89	0.46	0.19	3.57	-0.97
Bagirsak Creek	21.45	On the Day	3.06	-0.09	3.42	-0.77	5.63	-0.05	3.48	-0.66
		1 Day Before	1.31	-0.13	3.43	-0.84	0.48	-0.12	3.43	-0.87
		2 Days Before	2.54	0.01	3.41	-0.79	0.56	0.20	3.41	-0.87
Gölcük Creek	18.70	On the Day	3.56	-0.10	2.96	-0.63	6.91	-0.04	3.06	-0.49
		1 Day Before	1.44	-0.14	2.95	-0.72	0.62	-0.12	2.95	-0.75
		2 Days Before	2.52	0.06	2.92	-0.67	0.65	0.24	2.93	-0.75
Tatlim Creek	17.73	On the Day	3.47	-0.09	2.76	-0.59	8.55	-0.03	2.97	-0.38
		1 Day Before	1.54	-0.14	2.76	-0.67	0.73	-0.12	2.76	-0.71
		2 Days Before	2.44	0.05	2.73	-0.64	0.70	0.26	2.73	-0.71
Burcupinar Creek	17.26	On the Day	3.17	-0.08	2.66	-0.59	10.41	-0.03	3.04	-0.29
		1 Day Before	1.61	-0.13	2.66	-0.65	0.73	-0.12	2.66	-0.69
		2 Days Before	2.22	0.01	2.65	-0.63	0.72	0.29	2.63	-0.69
Upstream of Lake Mogan	16.77	On the Day	3.54	-0.07	2.48	-0.55	10.15	-0.04	2.89	-0.28
		1 Day Before	2.59	-0.02	2.46	-0.59	0.67	-0.13	2.48	-0.67
		2 Days Before	2.45	0.06	2.45	-0.60	1.27	0.46	2.42	-0.65
Mogan Detention Pond	15.27	On the Day	3.19	-0.03	2.23	-0.50	6.19	-0.06	2.43	-0.38
		1 Day Before	5.03	0.12	2.18	-0.43	1.20	-0.12	2.24	-0.59
		2 Days Before	2.20	0.11	2.20	-0.54	1.00	0.20	2.21	-0.59

Table 4-11. Quantitative Statistical Scores of Forecasts on Areal Basis for 11.08.2015 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)						ALR Forecast (IDW)					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
Ikizce Pond	6.88	On the Day	0.63	0.00	2.00	1.00	0.00	-0.20	0.79	0.00	0.67	1.00	0.00	-0.11
		1 Day Before	0.71	0.22	2.67	0.75	0.67	0.22	0.88	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.88	0.40	1.33	0.50	0.67	0.50	0.88	0.40	1.33	0.50	0.67	0.50
Dikilitas Pond	14.81	On the Day	0.71	0.13	2.00	0.83	0.33	0.07	0.79	0.00	0.67	1.00	0.00	-0.11
		1 Day Before	0.75	0.25	2.33	0.71	0.67	0.27	0.79	0.00	0.67	1.00	0.00	-0.11
		2 Days Before	0.63	0.10	2.67	0.88	0.33	0.00	0.88	0.00	0.00	N.A.	0.00	0.00
Sukesen Creek	24.40	On the Day	0.71	0.22	1.75	0.71	0.50	0.19	0.83	0.33	1.00	0.50	0.50	0.40
		1 Day Before	0.83	0.00	0.00	N.A.	0.00	0.00	0.83	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.79	0.17	0.75	0.67	0.25	0.17	0.83	0.00	0.00	N.A.	0.00	0.00
Kepir Creek	26.29	On the Day	0.79	0.17	1.33	0.75	0.33	0.17	0.83	0.20	1.00	0.67	0.33	0.24
		1 Day Before	0.88	0.00	0.00	N.A.	0.00	0.00	0.88	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.83	0.20	1.00	0.67	0.33	0.24	0.83	0.00	0.33	1.00	0.00	-0.07
Igdeli Creek	23.64	On the Day	0.75	0.00	1.00	1.00	0.00	-0.14	0.79	0.17	1.33	0.75	0.33	0.17
		1 Day Before	0.83	0.00	0.33	1.00	0.00	-0.07	0.88	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.83	0.20	1.00	0.67	0.33	0.24	0.83	0.00	0.33	1.00	0.00	-0.07
Bagirsak Creek	21.45	On the Day	0.71	0.00	1.33	1.00	0.00	-0.17	0.88	0.25	0.67	0.50	0.33	0.33
		1 Day Before	0.75	0.00	1.00	1.00	0.00	-0.14	0.88	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.83	0.20	1.00	0.67	0.33	0.24	0.83	0.00	0.33	1.00	0.00	-0.07
Gölcük Creek	18.70	On the Day	0.71	0.00	1.33	1.00	0.00	-0.17	0.88	0.25	0.67	0.50	0.33	0.33
		1 Day Before	0.79	0.00	0.67	1.00	0.00	-0.11	0.88	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.83	0.20	1.00	0.67	0.33	0.24	0.83	0.00	0.33	1.00	0.00	-0.07
Tatlim Creek	17.73	On the Day	0.71	0.00	1.33	1.00	0.00	-0.17	0.88	0.25	0.67	0.50	0.33	0.33
		1 Day Before	0.79	0.00	0.67	1.00	0.00	-0.11	0.83	0.00	0.33	1.00	0.00	-0.07
		2 Days Before	0.83	0.20	1.00	0.67	0.33	0.24	0.83	0.00	0.33	1.00	0.00	-0.07
Burcupinar Creek	17.26	On the Day	0.71	0.00	1.33	1.00	0.00	-0.17	0.88	0.25	0.67	0.50	0.33	0.33
		1 Day Before	0.79	0.00	0.67	1.00	0.00	-0.11	0.83	0.00	0.33	1.00	0.00	-0.07
		2 Days Before	0.83	0.20	1.00	0.67	0.33	0.24	0.83	0.00	0.33	1.00	0.00	-0.07
Upstream of Lake Mogan	16.77	On the Day	0.67	0.00	1.67	1.00	0.00	-0.19	0.79	0.17	1.33	0.75	0.33	0.17
		1 Day Before	0.75	0.14	1.67	0.80	0.33	0.11	0.88	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.83	0.20	1.00	0.67	0.33	0.24	0.88	0.25	0.67	0.50	0.33	0.33
Mogan Detention Pond	15.27	On the Day	0.71	0.00	1.33	1.00	0.00	-0.17	0.83	0.20	1.00	0.67	0.33	0.24
		1 Day Before	0.75	0.25	2.33	0.71	0.67	0.27	0.79	0.00	0.67	1.00	0.00	-0.11
		2 Days Before	0.83	0.20	1.00	0.67	0.33	0.24	0.88	0.25	0.67	0.50	0.33	0.33

4.2.4 14.03.2016 Event

Precipitation gauge records, WRF and ALR forecasts for Ankara, Ufuk Danışment, Elmadağ Radar, and Haymana Tarım stations for the 14.03.2016 event are given between Figure 4-16 and Figure 4-19. The areal distribution of actual precipitation and forecast values are given in Figure 4-20. Calculated statistics based on point and areal forecasts are given between Table 4-12 and Table 4-14.

For Ankara Station, the total precipitation gauge record is 11.30 mm. The total precipitation value of on the day WRF and ALR forecasts are 10.00 and 15.00 mm, with a correlation value of 0.90 and 0.78, respectively. Categorical scores are close to each other and quite satisfactory. One day before WRF forecast is underestimated with -0.27 bias and 0.07 correlation values, whereas one day before ALR forecast resulted in an overestimated total precipitation value with 0.52 bias and 0.41 correlation. Categorical scores are again close to each other, but the result of ALR's are a bit better. Two days before ALR forecast is underestimated with -0.34 bias and 0.65 correlation, whereas WRF forecast resulted in zero precipitation rate. Therefore categorical scores are also better in ALR forecast.

For Gölbaşı Ufuk Danışment Station, the total precipitation gauge record is 25.20 mm. On the day and one day before WRF forecasts resulted in around 12 mm total precipitation and -0.50 bias values. On the other side, on the day ALR forecast resulted in 19.00 mm total precipitation and 0.83 correlation values. One day before ALR forecast is better in terms of total precipitation value with a value of 23.84 mm, but the correlation is worse than on the day forecast. Between two days before forecasts ALR forecast is better in total precipitation value, but they are all significantly underestimated. For on the day forecasts, both WRF and ALR have quite satisfactory categorical scores. Categorical scores of one and two days before ALR forecats are better than WRF ones, and they are at a reasonable level.

For Elmadağ Radar Station, the total precipitation gauge record is 18.00 mm. On the day WRF and one day before ALR forecasts are quite close to gauge records with

19.46 and 18.35 mm total precipitation values, respectively. On the day ALR forecasts are also reasonable with 13.89 mm total precipitation and 0.77 correlation values. One day before WRF forecast is also acceptable with a value of 14.99 mm total precipitation; however, the correlation value is around zero. Two days before WRF forecast is quite underestimated, while the ALR forecast is not that low. Categorical scores of on the day and one day before WRF and ALR forecasts are close to each other, and they are at a reasonable level. Two days before ALR foracast also has satisfactory categorical scores, and they are a bit better than the WRF ones.

For Haymana Tarım Station, the total precipitation gauge record is 21.80 mm. On the day WRF nad ALR forecasts have 29.24 and 24.10 mm. total precipitation values with 0.92 correlation value. One and two days before ALR forecasts are much better with 18 and 14.82 mm total precipitation values than WRF's ones with 6.63 and 2.54 mm. Categorical skill scores are also seen better in ALR forecasts.

In areal basis, the total precipitation value of on the day and one day before ALR forecasts are quite close to gauge records with high correlation, low RMSE, and bias values in all subbasins. Although WRF forecasts become better with reducing lead time, they are not as good as ALR forecasts, and two days before forecasts are too far from the gauge records. Correlation of on the day WRF and ALR forecasts are close to each other and around 0.90. Categorical scores of on the day WRF and ALR forecasts are close to each other, and results are quite good. One and two days before ALR forecasts are not as good as on the day forecasts, but they are still well enough, while the results of WRF forecasts are at a moderate level.

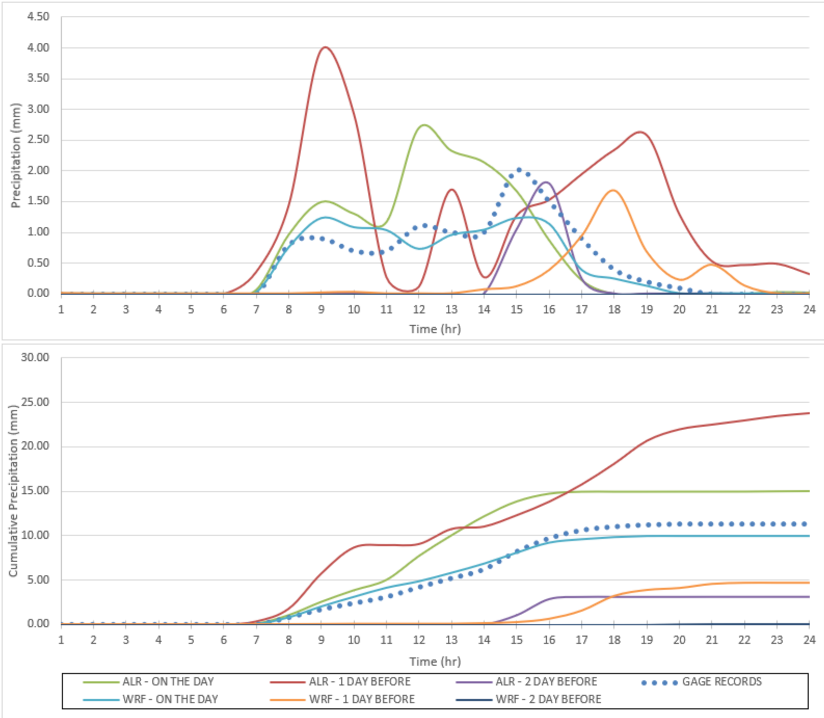

Figure 4-16. Precipitation Records and Forecast Values of 14.03.2016 Event for Ankara Station

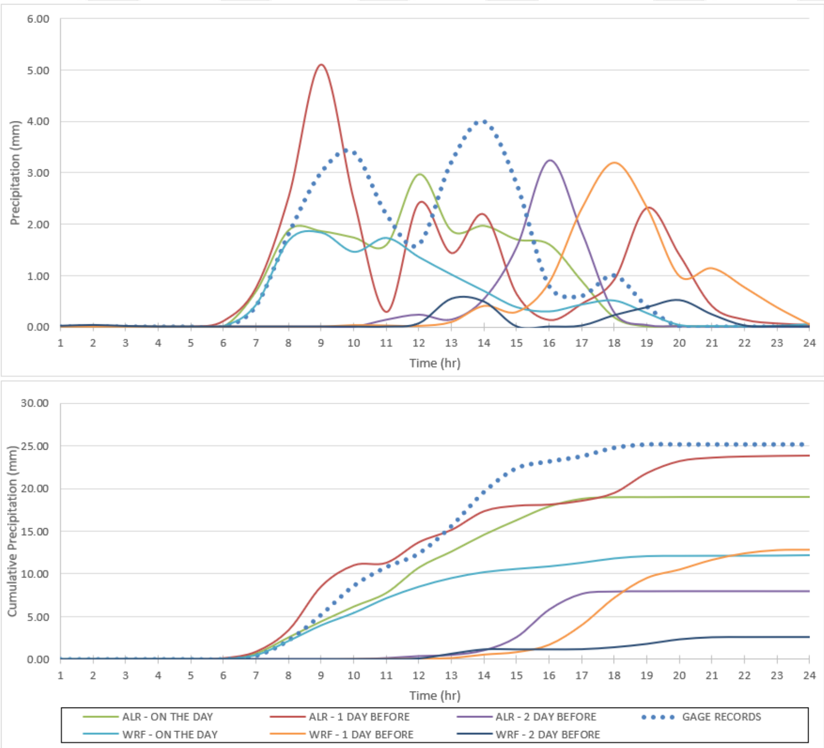

Figure 4-17. Precipitation Records and Forecast Values of 14.03.2016 Event for Ufuk Danışment Station

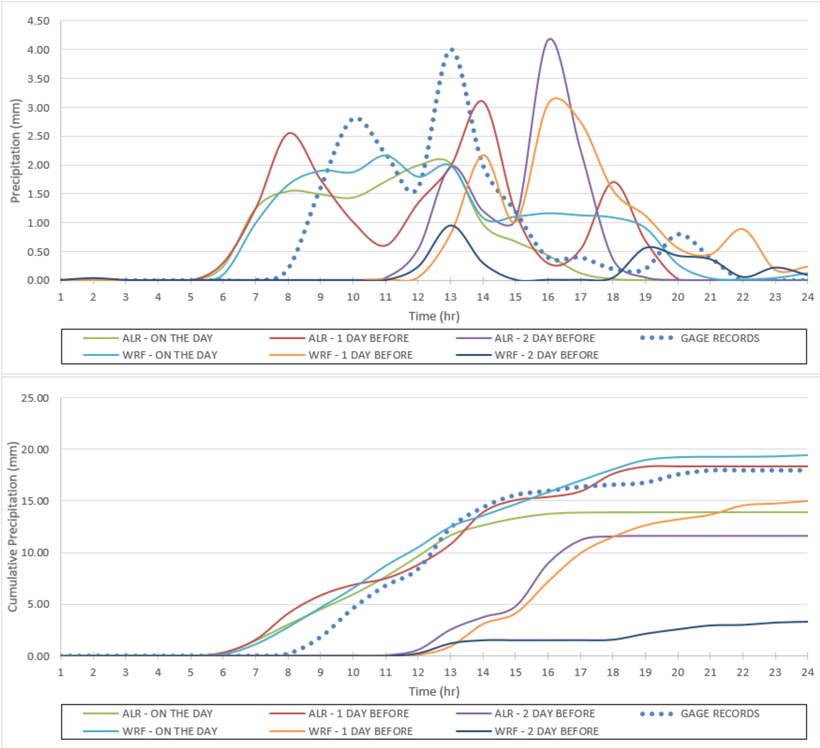

Figure 4-18. Precipitation Records and Forecast Values of 14.03.2016 Event for Elmadağ Radar Station

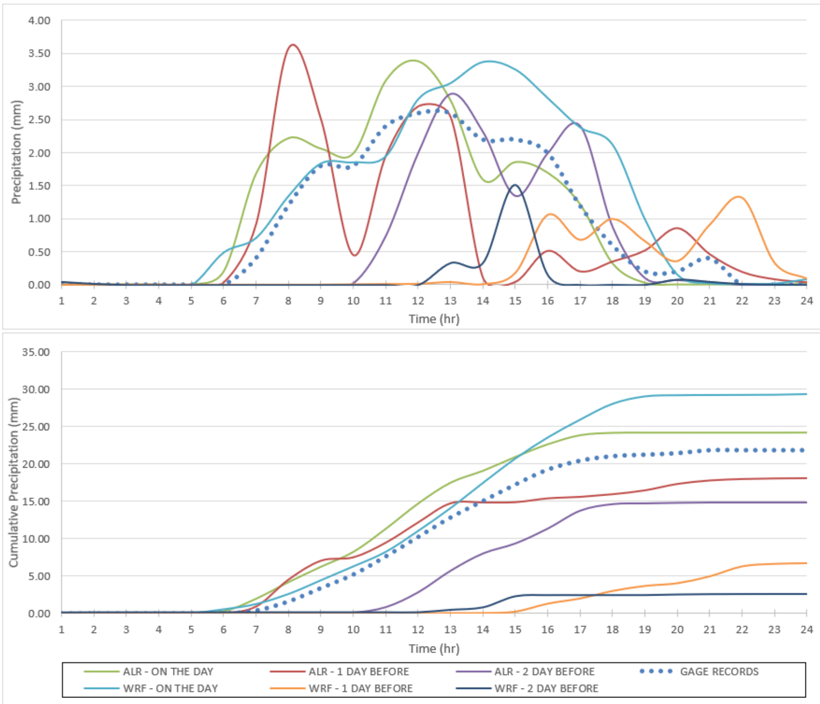

Figure 4-19. Precipitation Records and Forecast Values of 14.03.2016 Event for Haymana Tarım Station

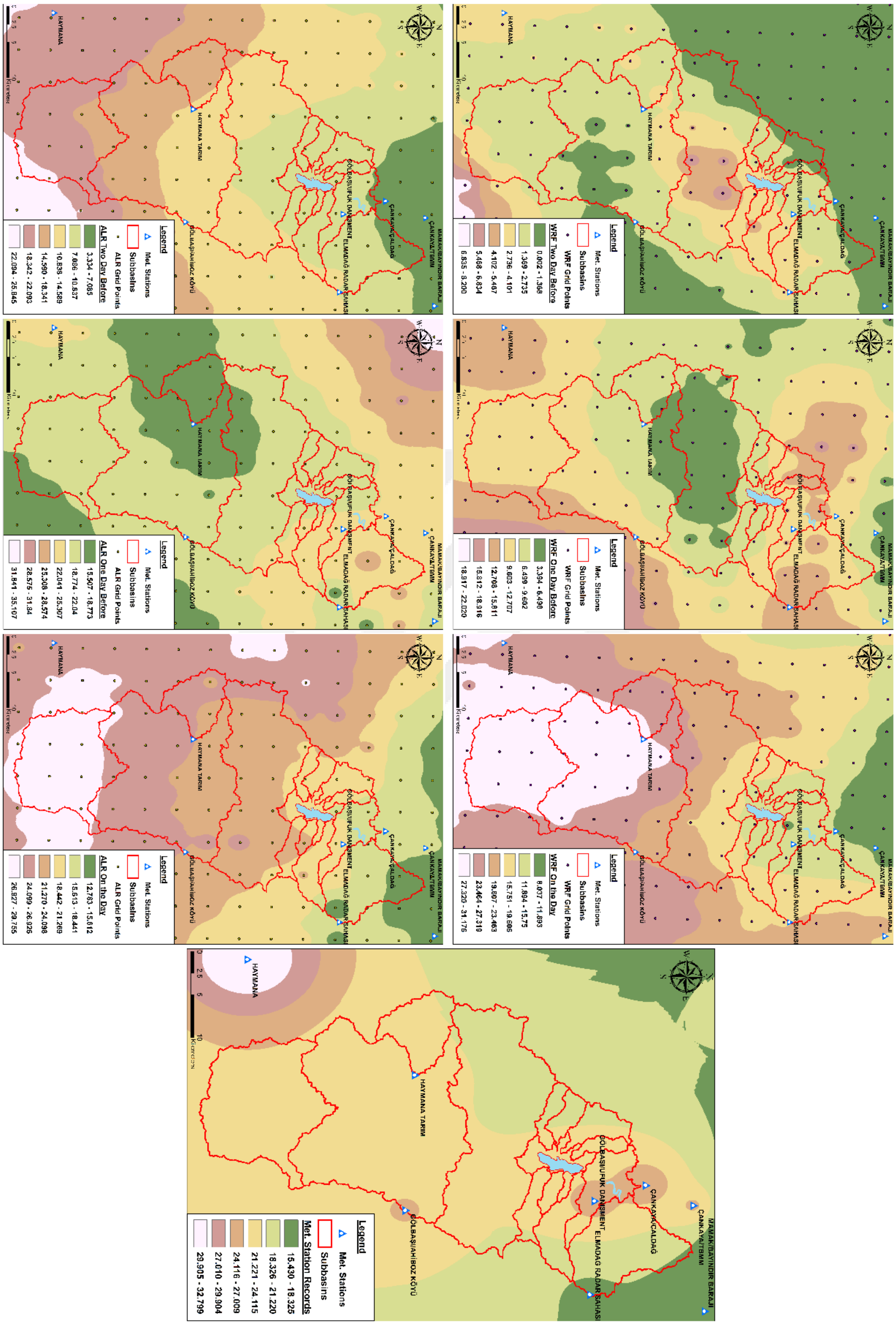

Figure 4-20. Areal Distribution of Actual Precipitation and Forecast Values of 14.03.2016 Event

Table 4-12. Statistical Scores of Forecasts on Point Basis for 14.03.2016 Event

Quantitative Scores														
Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			C	NC	Total	r	RMSE	Bias	Con	Gec	Total	r	RMSE	Bias
ANKARA	11.30	On the Day	0.00	10.00	10.00	0.90	0.25	-0.05	2.26	12.75	15.00	0.78	0.57	0.15
		1 Day Before	0.03	4.70	4.73	0.07	0.72	-0.27	1.91	21.92	23.83	0.41	1.12	0.52
		2 Days Before	0.00	0.00	0.00	-0.23	0.73	-0.47	0.82	2.28	3.10	0.65	0.55	-0.34
GOLBASI-UFUK DANİŞMENT	25.20	On the Day	0.00	12.24	12.24	0.76	1.07	-0.54	2.05	16.95	19.00	0.83	0.79	-0.26
		1 Day Before	0.03	12.80	12.83	-0.16	1.76	-0.52	4.18	19.66	23.84	0.65	1.07	-0.06
		2 Days Before	0.82	1.73	2.55	0.26	1.58	-0.94	4.13	3.88	8.008	0.13	1.60	-0.72
ELMADAG-RADAR	18.00	On the Day	0.00	19.46	19.46	0.75	0.70	0.06	0.96	12.94	13.89	0.77	0.70	-0.17
		1 Day Before	0.00	14.99	14.99	0.06	1.35	-0.13	4.34	14.00	18.35	0.54	0.95	0.01
		2 Days Before	0.72	2.55	3.27	0.50	1.14	-0.61	4.91	6.72	11.64	0.25	1.28	-0.27
HAYMANA TARIM	21.80	On the Day	0.00	29.24	29.24	0.92	0.59	0.31	2.00	22.10	24.1	0.92	0.45	0.10
		1 Day Before	0.00	6.63	6.63	-0.14	1.28	-0.63	7.36	10.64	18.00	0.58	0.94	-0.16
		2 Days Before	0.39	2.16	2.54	0.41	1.21	-0.80	1.05	13.77	14.82	0.74	0.75	-0.29

Categorical Scores														
Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
ANKARA	11.30	On the Day	0.96	0.91	0.91	0.00	0.91	0.92	0.92	0.82	0.82	0.00	0.82	0.83
		1 Day Before	0.58	0.23	0.45	0.40	0.27	0.12	0.67	0.56	1.55	0.41	0.91	0.36
		2 Days Before	0.54	0.00	0.00	N.A.	0.00	0.00	0.63	0.18	0.18	0.00	0.18	0.19
GOLBASI-UFUK DANİŞMENT	25.20	On the Day	1.00	1.00	1.00	0.00	1.00	1.00	0.92	0.85	0.85	0.00	0.85	0.83
		1 Day Before	0.54	0.35	0.77	0.40	0.46	0.10	0.88	0.80	1.08	0.14	0.92	0.75
		2 Days Before	0.54	0.21	0.31	0.25	0.23	0.13	0.67	0.38	0.38	0.00	0.38	0.36
ELMADAG-RADAR	18.00	On the Day	0.79	0.67	1.27	0.29	0.91	0.59	0.79	0.62	0.91	0.20	0.73	0.58
		1 Day Before	0.71	0.50	0.91	0.30	0.64	0.41	0.71	0.56	1.27	0.36	0.82	0.42
		2 Days Before	0.67	0.33	0.45	0.20	0.36	0.30	0.75	0.50	0.64	0.14	0.55	0.48
HAYMANA TARIM	21.80	On the Day	0.88	0.80	1.08	0.14	0.92	0.75	0.96	0.92	0.92	0.00	0.92	0.92
		1 Day Before	0.46	0.24	0.62	0.50	0.31	-0.05	0.79	0.67	0.92	0.17	0.77	0.58
		2 Days Before	0.58	0.23	0.23	0.00	0.23	0.22	0.79	0.62	0.62	0.00	0.62	0.59

Table 4-13. Quantitative Statistical Scores of Forecasts on Areal Basis for 14.03.2016 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)				ALR Forecast (IDW)			
			Total	r	RMSE	Bias	Total	r	RMSE	Bias
Ikizce Pond	22.36	On the Day	25.66	0.93	0.40	0.14	24.34	0.95	0.34	0.08
		1 Day Before	7.39	-0.02	1.27	-0.62	18.23	0.66	-0.17	-0.17
		2 Days Before	2.49	0.41	1.23	-0.83	16.01	0.71	0.81	-0.26
Dikilitas Pond	23.61	On the Day	29.48	0.91	0.52	0.24	27.57	0.93	0.49	0.17
		1 Day Before	11.80	-0.11	1.34	-0.49	19.86	0.72	0.79	-0.16
		2 Days Before	2.37	0.02	1.36	-0.89	19.65	0.70	0.82	-0.16
Sukesen Creek	22.28	On the Day	15.87	0.89	0.60	-0.27	20.13	0.87	0.54	-0.09
		1 Day Before	10.37	0.13	1.26	-0.50	22.46	0.71	0.81	0.01
		2 Days Before	3.47	0.55	1.22	-0.78	9.97	0.31	1.22	-0.51
Kepir Creek	23.32	On the Day	14.29	0.89	0.70	-0.38	21.33	0.88	0.54	-0.08
		1 Day Before	8.44	-0.01	1.39	-0.62	22.02	0.61	0.99	-0.05
		2 Days Before	3.75	0.53	1.26	-0.82	9.29	0.33	1.25	-0.58
Igdeli Creek	22.44	On the Day	16.36	0.93	0.50	-0.25	21.51	0.87	0.52	-0.04
		1 Day Before	7.74	0.20	1.21	-0.61	21.91	0.62	0.93	-0.02
		2 Days Before	3.79	0.55	1.18	-0.78	10.20	0.44	1.10	-0.51
Bagirsak Creek	22.78	On the Day	13.55	0.78	0.77	-0.38	18.90	0.88	0.52	-0.16
		1 Day Before	13.06	-0.05	1.48	-0.41	21.15	0.59	0.93	-0.07
		2 Days Before	1.48	0.33	1.35	-0.89	8.04	0.43	1.16	-0.61
Gölcük Creek	21.99	On the Day	14.79	0.83	0.66	-0.30	19.64	0.88	0.50	-0.10
		1 Day Before	12.65	-0.03	1.41	-0.39	20.83	0.59	0.91	-0.05
		2 Days Before	1.33	0.37	1.30	-0.86	8.66	0.45	1.10	-0.56
Tatlim Creek	21.76	On the Day	16.27	0.88	0.55	-0.23	20.37	0.89	0.46	-0.06
		1 Day Before	9.82	-0.02	1.32	-0.50	20.41	0.54	0.96	-0.06
		2 Days Before	1.82	0.45	1.24	-0.83	9.28	0.44	1.09	-0.52
Burcupinar Creek	21.68	On the Day	16.63	0.90	0.51	-0.21	20.71	0.90	0.44	-0.04
		1 Day Before	8.03	-0.02	1.28	-0.57	20.02	0.53	0.96	-0.07
		2 Days Before	2.11	0.45	1.21	-0.82	9.59	0.44	1.07	-0.50
Upstream of Lake Mogan	22.11	On the Day	20.92	0.97	0.26	-0.05	22.70	0.92	0.42	0.02
		1 Day Before	6.15	0.18	1.19	-0.67	19.78	0.57	0.93	-0.10
		2 Days Before	2.88	0.50	1.19	-0.80	11.45	0.63	0.90	-0.44
Mogan Detention Pond	22.87	On the Day	27.16	0.96	0.38	0.18	24.78	0.91	0.47	0.08
		1 Day Before	9.35	-0.06	1.28	-0.56	19.17	0.53	0.99	-0.15
		2 Days Before	1.94	0.41	1.31	-0.87	14.87	0.81	0.69	-0.33

Table 4-14. Quantitative Statistical Scores of Forecasts on Areal Basis for 14.03.2016 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)						ALR Forecast (IDW)					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
Ikizce Pond	22.36	On the Day	0.88	0.80	1.08	0.14	0.92	0.75	0.92	0.86	1.00	0.08	0.92	0.83
		1 Day Before	0.54	0.31	0.62	0.38	0.38	0.11	0.79	0.67	0.92	0.17	0.77	0.58
		2 Days Before	0.58	0.23	0.23	0.00	0.23	0.22	0.79	0.62	0.62	0.00	0.62	0.59
Dikilitas Pond	23.61	On the Day	0.92	0.87	1.15	0.13	1.00	0.83	0.96	0.93	1.08	0.07	1.00	0.92
		1 Day Before	0.50	0.33	0.85	0.45	0.46	0.01	0.79	0.69	1.08	0.21	0.85	0.58
		2 Days Before	0.50	0.14	0.23	0.33	0.15	0.06	0.83	0.71	0.85	0.09	0.77	0.67
Sukesen Creek	22.28	On the Day	1.00	1.00	1.00	0.00	1.00	1.00	0.96	0.92	0.92	0.00	0.92	0.92
		1 Day Before	0.63	0.44	0.77	0.30	0.54	0.26	0.88	0.80	1.08	0.14	0.92	0.75
		2 Days Before	0.54	0.21	0.31	0.25	0.23	0.13	0.79	0.62	0.62	0.00	0.62	0.59
Kepir Creek	23.32	On the Day	0.92	0.85	0.85	0.00	0.85	0.83	0.92	0.85	0.85	0.00	0.85	0.83
		1 Day Before	0.58	0.38	0.69	0.33	0.46	0.18	0.88	0.80	1.08	0.14	0.92	0.75
		2 Days Before	0.54	0.15	0.15	0.00	0.15	0.14	0.79	0.62	0.62	0.00	0.62	0.59
Igdeli Creek	22.44	On the Day	0.92	0.85	0.85	0.00	0.85	0.83	0.96	0.92	0.92	0.00	0.92	0.92
		1 Day Before	0.63	0.44	0.77	0.30	0.54	0.26	0.83	0.73	1.00	0.15	0.85	0.66
		2 Days Before	0.58	0.23	0.23	0.00	0.23	0.22	0.79	0.62	0.62	0.00	0.62	0.59
Bagirsak Creek	22.78	On the Day	0.96	0.92	0.92	0.00	0.92	0.92	0.92	0.846	0.85	0.00	0.85	0.83
		1 Day Before	0.58	0.38	0.69	0.33	0.46	0.18	0.92	0.867	1.15	0.13	1.00	0.83
		2 Days Before	0.46	0.07	0.15	0.50	0.08	-0.01	0.63	0.31	0.31	0.00	0.31	0.29
Gölcük Creek	21.99	On the Day	0.96	0.92	0.92	0.00	0.92	0.92	0.92	0.85	0.85	0.00	0.85	0.83
		1 Day Before	0.58	0.38	0.69	0.33	0.46	0.18	0.92	0.87	1.15	0.13	1.00	0.83
		2 Days Before	0.50	0.08	0.08	0.00	0.08	0.07	0.63	0.31	0.31	0.00	0.31	0.29
Tatlim Creek	21.76	On the Day	0.96	0.92	0.92	0.00	0.92	0.92	0.92	0.85	0.85	0.00	0.85	0.83
		1 Day Before	0.54	0.31	0.62	0.38	0.38	0.11	0.79	0.69	1.08	0.21	0.85	0.58
		2 Days Before	0.50	0.08	0.08	0.00	0.08	0.07	0.71	0.46	0.46	0.00	0.46	0.44
Burcupinar Creek	21.68	On the Day	1.00	1.00	1.00	0.00	1.00	1.00	0.92	0.85	0.85	0.00	0.85	0.83
		1 Day Before	0.50	0.25	0.54	0.43	0.31	0.03	0.79	0.69	1.08	0.21	0.85	0.58
		2 Days Before	0.54	0.15	0.15	0.00	0.15	0.14	0.75	0.54	0.54	0.00	0.54	0.52
Upstream of Lake Mogan	22.11	On the Day	0.92	0.86	1.00	0.08	0.92	0.83	0.96	0.92	0.92	0.00	0.92	0.92
		1 Day Before	0.58	0.38	0.69	0.33	0.46	0.18	0.83	0.73	1.00	0.15	0.85	0.66
		2 Days Before	0.58	0.23	0.23	0.00	0.23	0.22	0.83	0.69	0.69	0.00	0.69	0.67
Mogan Detention Pond	22.87	On the Day	0.96	0.93	1.08	0.07	1.00	0.92	0.92	0.86	1.00	0.08	0.92	0.83
		1 Day Before	0.50	0.29	0.69	0.44	0.38	0.02	0.79	0.69	1.08	0.21	0.85	0.58
		2 Days Before	0.54	0.15	0.15	0.00	0.15	0.14	0.83	0.69	0.69	0.00	0.69	0.67

4.2.5 18.12.2017 Event

Precipitation gauge records, WRF and ALR forecasts for Ankara, Ufuk Danışment, Elmadağ Radar, and Haymana Tarım stations for the 18.12.2017 event are given between Figure 4-21 and Figure 4-24. The areal distribution of actual precipitation and forecast values are given in Figure 4-25. Calculated statistics based on point and areal forecasts are given between Table 4-15 and Table 4-17.

Gauge records of Ankara, Ufuk Danişment, Elmadağ Radar, and Haymana Tarım stations are 8.30, 4.80, 7.20, and 4.80 mm, respectively. Among WRF forecasts, on the day and two days before forecasts resulted in quite overestimated total precipitation while one day before forecast resulted in underestimated values. Although the correlation of on the day forecasts is not too bad, total precipitation values are quite high. The result of ALR forecasts become more overestimated with decreasing lead time for Ankara Station. On the other hand, the overestimation of ALR forecasts is decreasing with a decreasing lead time for Elmadağ-Radar Station. Forecast for Ufuk Danışiment and Haymana Tarım stations are in the same order for all lead times. Similar to WRF forecasts, all ALR forecasts have also resulted in overestimated total precipitation values (less than WRF's) with low correlation values. Results of categorical scores of WRF and ALR forecasts are generally close to each other. However, on the day and two days before WRF and one day before ALR forecasts are a bit better than other forecasts for all stations.

Similar to point-based analyses, all ALR forecasts, except two days before ALR forecast for the Dikilitaş subbasin, and on the day and two days before WRF forecasts resulted in quite overestimated total precipitation values for all subbasins. While subbasins' average total precipitation values are around 6-7 mm, forecast results are between 13-33 mm. Interestingly, one day before WRF forecast resulted in much better total precipitation values. Correlation coefficients of on the day WRF forecasts are generally better and at a well-enough level when others are considered. Categorical skill scores of on the day and two days before WRF forecasts and one day before ALR forecasts are better in general for all subbasins.

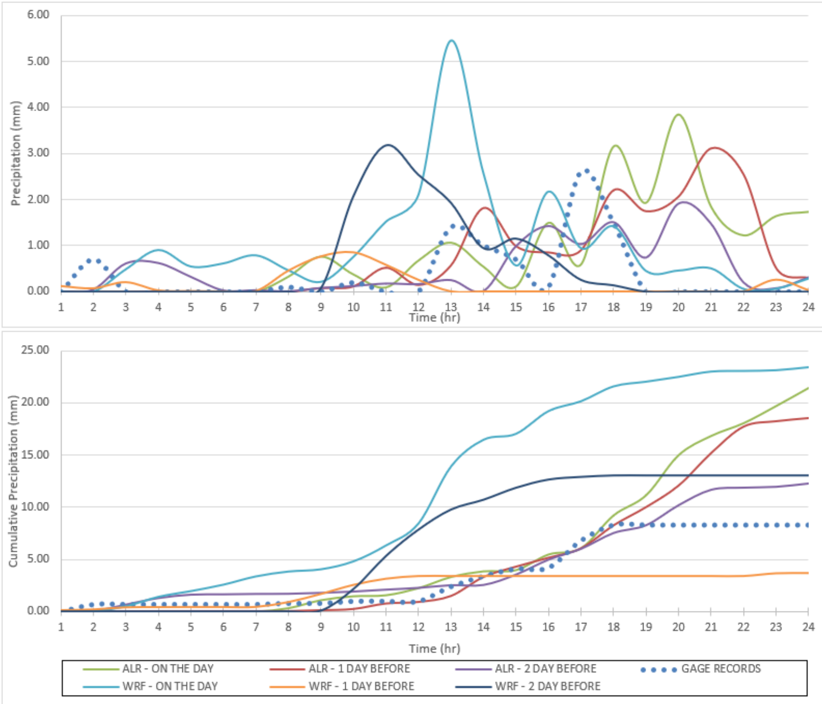

Figure 4-21. Precipitation Records and Forecast Values of 18.12.2017 Event for Ankara Station

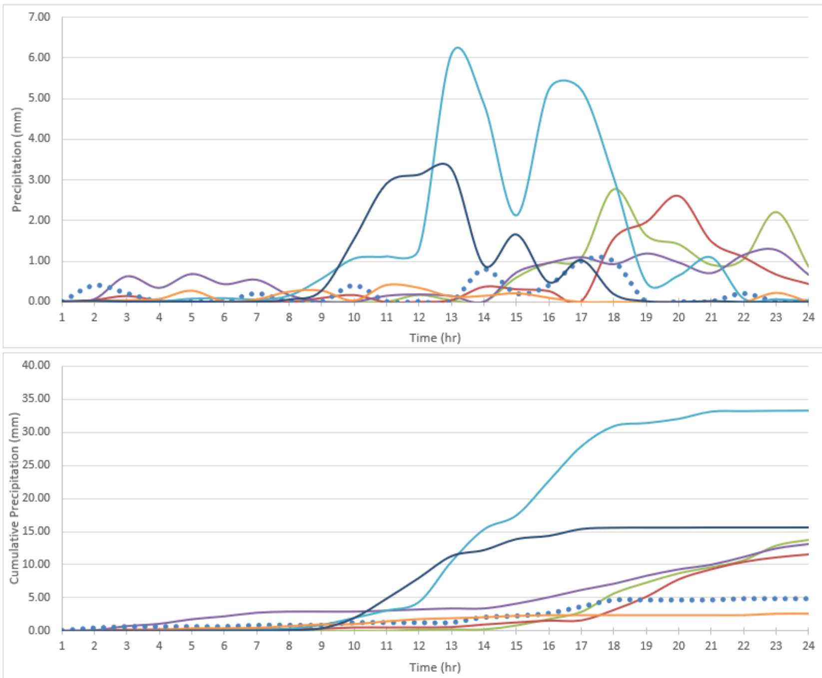

Figure 4-22. Precipitation Records and Forecast Values of 18.12.2017 Event for Ufuk Danışment Station

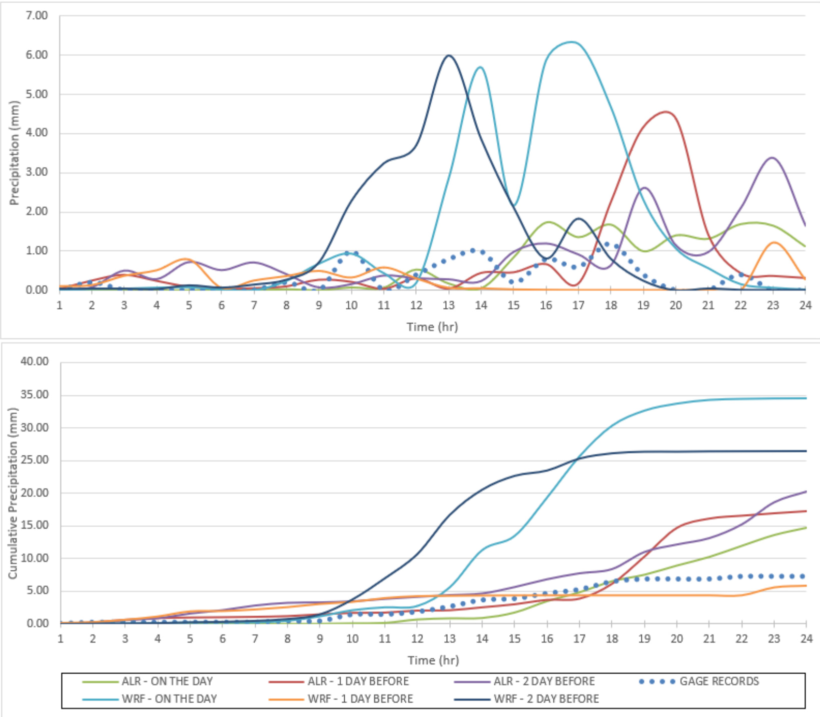

Figure 4-23. Precipitation Records and Forecast Values of 18.12.2017 Event for Elmadağ Radar Station

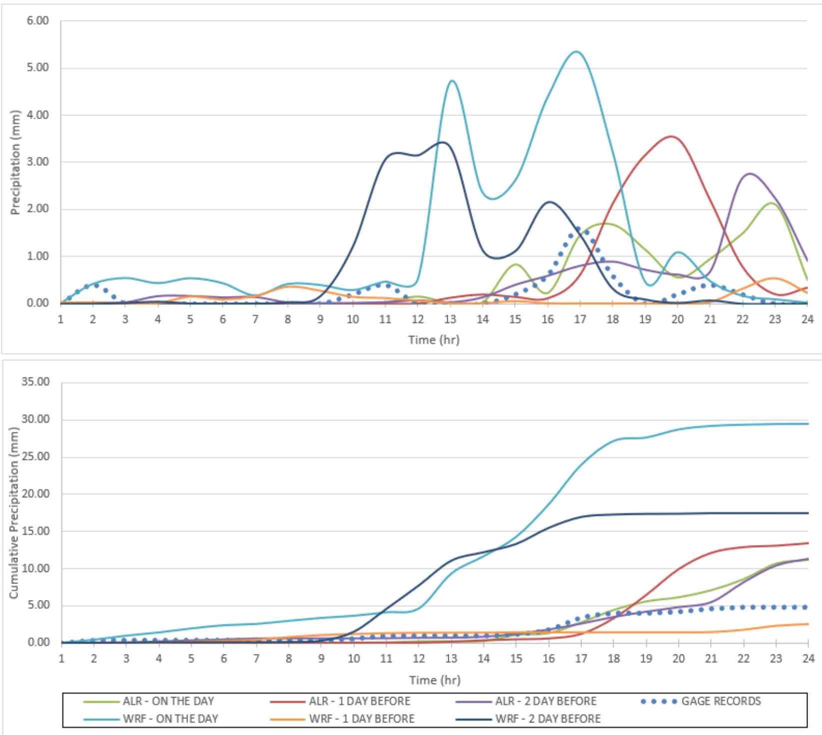

Figure 4-24. Precipitation Records and Forecast Values of 18.12.2017 Event for Haymana Tarım Station

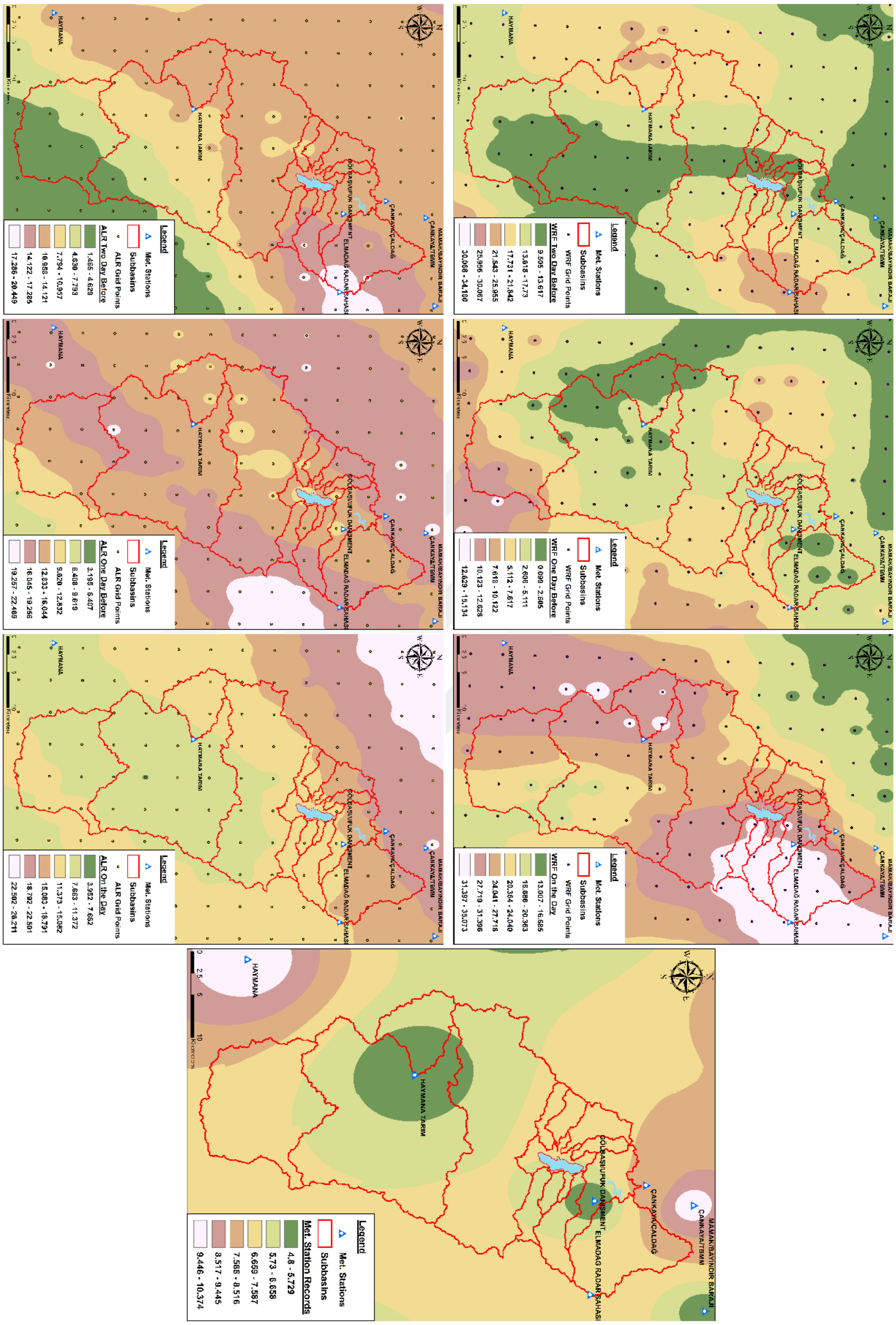

Figure 4-25. Areal Distribution of Actual Precipitation and Forecast Values of 18.12.2017 Event

Table 4-15. Statistical Scores of Forecasts on Point Basis for 18.12.2017 Event

Quantitative Scores														
Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			C	NC	Total	r	RMSE	Bias	Con	Gec	Total	r	RMSE	Bias
ANKARA	8.30	On the Day	4.51	18.88	23.39	0.42	1.24	0.63	5.92	15.56	21.48	0.08	1.29	0.55
		1 Day Before	3.06	0.59	3.64	-0.25	0.78	-0.19	7.27	11.28	18.55	0.18	1.12	0.43
		2 Days Before	0.00	13.08	13.08	0.09	1.10	0.20	6.39	5.85	12.23	0.23	0.78	0.16
GOLBASI-UFUK DANİŞMENT	4.80	On the Day	0.28	33.06	33.34	0.59	2.13	1.19	6.21	7.54	13.75	0.31	0.83	0.37
		1 Day Before	1.53	1.13	2.66	-0.30	0.38	-0.09	3.49	7.99	11.48	0.02	0.82	0.28
		2 Days Before	0.00	15.60	15.60	0.00	1.18	0.45	7.48	5.63	13.11	0.14	0.60	0.35
ELMADAG-RADAR	7.20	On the Day	0.22	34.27	34.49	0.76	2.10	1.14	5.68	9.08	14.76	0.24	0.77	0.31
		1 Day Before	1.95	3.86	5.82	-0.41	0.58	-0.06	6.12	11.17	17.29	0.09	1.27	0.42
		2 Days Before	0.00	26.49	26.49	0.53	1.64	0.80	7.02	13.25	20.27	-0.12	1.10	0.54
HAYMANA TARIM	4.80	On the Day	3.27	26.24	29.52	0.64	1.72	1.03	6.77	4.39	11.15	0.41	0.65	0.26
		1 Day Before	1.20	1.31	2.51	-0.29	0.42	-0.10	4.55	8.90	13.46	0.16	1.09	0.36
		2 Days Before	0.04	17.40	17.43	0.22	1.19	0.53	6.63	4.65	11.28	0.16	0.76	0.27

Categorical Scores														
Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
ANKARA	8.30	On the Day	0.38	0.25	3.17	0.74	0.83	0.03	0.46	0.24	2.50	0.73	0.67	0.04
		1 Day Before	0.50	0.00	1.00	1.00	0.00	-0.33	0.63	0.36	2.17	0.62	0.83	0.28
		2 Days Before	0.75	0.40	1.33	0.50	0.67	0.40	0.58	0.29	2.00	0.67	0.67	0.17
GOLBASI-UFUK DANİŞMENT	4.80	On the Day	0.63	0.36	2.17	0.62	0.83	0.28	0.58	0.23	1.67	0.70	0.50	0.09
		1 Day Before	0.54	0.00	0.83	1.00	0.00	-0.29	0.58	0.23	1.67	0.70	0.50	0.09
		2 Days Before	0.71	0.36	1.50	0.56	0.67	0.33	0.38	0.17	2.50	0.80	0.50	-0.11
ELMADAG-RADAR	7.20	On the Day	0.71	0.50	1.33	0.42	0.78	0.42	0.67	0.43	1.22	0.45	0.67	0.32
		1 Day Before	0.38	0.12	1.11	0.80	0.22	-0.30	0.54	0.35	1.56	0.57	0.67	0.12
		2 Days Before	0.75	0.54	1.22	0.36	0.78	0.49	0.42	0.33	2.11	0.63	0.78	-0.02
HAYMANA TARIM	4.80	On the Day	0.46	0.32	3.17	0.68	1.00	0.16	0.63	0.25	1.50	0.67	0.50	0.14
		1 Day Before	0.58	0.00	0.67	1.00	0.00	-0.25	0.71	0.30	1.17	0.57	0.50	0.26
		2 Days Before	0.71	0.36	1.50	0.56	0.67	0.33	0.67	0.33	1.67	0.60	0.67	0.27

Table 4-16. Quantitative Statistical Scores of Forecasts on Areal Basis for 18.12.2017 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)				ALR Forecast (IDW)			
			Total	r	RMSE	Bias	Total	r	RMSE	Bias
Ikizce Pond	5.62	On the Day	30.43	0.67	1.73	1.03	12.22	0.47	0.65	0.28
		1 Day Before	2.21	-0.34	0.45	-0.14	13.33	0.21	0.32	0.32
		2 Days Before	21.06	0.23	1.38	0.64	11.78	0.33	0.59	0.26
Dikilitas Pond	6.98	On the Day	24.60	0.60	1.39	0.73	10.80	-0.08	0.92	0.16
		1 Day Before	7.02	-0.10	0.55	0.00	14.85	0.13	0.98	0.33
		2 Days Before	13.83	0.72	0.59	0.29	4.77	-0.06	0.50	-0.09
Sukesen Creek	6.32	On the Day	32.98	0.82	1.96	1.11	13.92	0.27	0.76	0.32
		1 Day Before	5.22	-0.44	0.50	-0.05	16.13	-0.01	1.24	0.41
		2 Days Before	19.83	0.29	1.27	0.56	15.36	-0.12	0.87	0.38
Kepir Creek	6.14	On the Day	31.84	0.75	1.93	1.07	13.29	0.32	0.76	0.30
		1 Day Before	4.86	-0.42	0.50	-0.05	13.92	-0.01	1.09	0.32
		2 Days Before	15.87	0.15	1.08	0.41	13.76	-0.04	0.77	0.32
Igdeli Creek	6.46	On the Day	31.88	0.82	1.90	1.06	12.60	0.28	0.70	0.26
		1 Day Before	5.58	-0.46	0.53	-0.04	15.51	-0.02	1.26	0.38
		2 Days Before	17.55	0.25	1.10	0.46	13.83	-0.11	0.85	0.31
Bagirsak Creek	7.22	On the Day	26.30	0.52	1.52	0.79	16.7	0.25	0.92	0.39
		1 Day Before	4.81	-0.17	0.58	-0.10	15.53	0.09	1.03	0.35
		2 Days Before	13.50	0.06	1.06	0.26	12.58	0.23	0.60	0.22
Gölcük Creek	7.32	On the Day	24.75	0.47	1.43	0.73	17.22	0.27	0.92	0.41
		1 Day Before	5.03	-0.20	0.57	-0.10	16.56	0.11	1.09	0.39
		2 Days Before	14.14	0.08	1.09	0.28	12.46	0.27	0.60	0.21
Tatlim Creek	7.05	On the Day	24.92	0.54	1.41	0.74	14.98	0.31	0.82	0.33
		1 Day Before	5.28	-0.35	0.56	-0.07	14.83	0.08	1.04	0.32
		2 Days Before	14.28	0.11	1.04	0.30	11.48	0.29	0.54	0.18
Burcupinar Creek	6.88	On the Day	24.99	0.58	1.41	0.75	14.01	0.33	0.77	0.30
		1 Day Before	5.51	-0.44	0.55	-0.06	14.23	0.07	1.02	0.31
		2 Days Before	14.03	0.12	1.00	0.30	11.26	0.29	0.52	0.18
Upstream of Lake Mogan	6.41	On the Day	27.44	0.78	1.43	0.88	12.09	0.36	0.63	0.24
		1 Day Before	5.07	-0.53	0.49	-0.06	14.75	0.07	1.12	0.35
		2 Days Before	16.34	0.22	1.02	0.41	11.66	0.08	0.63	0.22
Mogan Detention Pond	5.98	On the Day	25.47	0.73	1.40	0.81	9.91	0.21	0.58	0.16
		1 Day Before	3.65	-0.34	0.44	-0.10	15.53	0.10	1.19	0.40
		2 Days Before	14.13	0.46	0.79	0.34	8.88	-0.03	0.69	0.12

Table 4-17. Quantitative Statistical Scores of Forecasts on Areal Basis for 18.12.2017 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)						ALR Forecast (IDW)					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
Ikizce Pond	5.62	On the Day	0.50	0.33	2.43	0.65	0.86	0.15	0.63	0.31	1.43	0.60	0.57	0.19
		1 Day Before	0.54	0.00	0.57	1.00	0.00	-0.27	0.54	0.21	1.43	0.70	0.43	0.01
		2 Days Before	0.71	0.42	1.43	0.50	0.71	0.37	0.63	0.36	1.71	0.58	0.71	0.25
Dikilitas Pond	6.98	On the Day	0.67	0.43	1.22	0.45	0.67	0.32	0.63	0.31	0.89	0.50	0.44	0.18
		1 Day Before	0.46	0.19	1.11	0.70	0.33	-0.13	0.63	0.36	1.11	0.50	0.56	0.22
		2 Days Before	0.83	0.67	1.22	0.27	0.89	0.66	0.54	0.21	0.89	0.63	0.33	0.00
Sukesen Creek	6.32	On the Day	0.71	0.50	1.63	0.46	0.88	0.43	0.54	0.27	1.38	0.64	0.50	0.06
		1 Day Before	0.33	0.06	1.25	0.90	0.13	-0.41	0.58	0.29	1.25	0.60	0.50	0.12
		2 Days Before	0.83	0.64	1.25	0.30	0.88	0.65	0.42	0.22	1.75	0.71	0.50	-0.11
Kepir Creek	6.14	On the Day	0.71	0.50	1.63	0.46	0.88	0.43	0.58	0.29	1.25	0.60	0.50	0.12
		1 Day Before	0.33	0.06	1.25	0.90	0.13	-0.41	0.58	0.29	1.25	0.60	0.50	0.12
		2 Days Before	0.79	0.55	1.13	0.33	0.75	0.55	0.42	0.22	1.75	0.71	0.50	-0.11
Igdeli Creek	6.46	On the Day	0.71	0.50	1.63	0.46	0.88	0.43	0.54	0.27	1.38	0.64	0.50	0.06
		1 Day Before	0.33	0.06	1.25	0.90	0.13	-0.41	0.54	0.21	1.13	0.67	0.38	0.00
		2 Days Before	0.83	0.64	1.25	0.30	0.88	0.65	0.46	0.24	1.63	0.69	0.50	-0.05
Bagirsak Creek	7.22	On the Day	0.75	0.54	1.50	0.42	0.88	0.50	0.58	0.33	1.5	0.58	0.63	0.17
		1 Day Before	0.58	0.17	0.75	0.67	0.25	0.00	0.63	0.40	1.63	0.54	0.75	0.27
		2 Days Before	0.79	0.55	1.13	0.33	0.75	0.55	0.38	0.25	2.13	0.71	0.63	-0.10
Gölcük Creek	7.32	On the Day	0.75	0.54	1.50	0.42	0.88	0.50	0.63	0.40	1.63	0.54	0.75	0.27
		1 Day Before	0.58	0.17	0.75	0.67	0.25	0.00	0.63	0.40	1.63	0.54	0.75	0.27
		2 Days Before	0.83	0.64	1.25	0.30	0.88	0.65	0.38	0.25	2.13	0.71	0.63	-0.10
Tatlim Creek	7.05	On the Day	0.71	0.46	1.71	0.50	0.86	0.42	0.63	0.36	1.71	0.58	0.71	0.25
		1 Day Before	0.42	0.00	1.00	1.00	0.00	-0.41	0.67	0.38	1.57	0.55	0.71	0.31
		2 Days Before	0.75	0.45	1.29	0.44	0.71	0.44	0.38	0.21	2.29	0.75	0.57	-0.10
Burcupinar Creek	6.88	On the Day	0.71	0.46	1.71	0.50	0.86	0.42	0.63	0.36	1.71	0.58	0.71	0.25
		1 Day Before	0.38	0.00	1.14	1.00	0.00	-0.45	0.63	0.31	1.43	0.60	0.57	0.19
		2 Days Before	0.71	0.42	1.43	0.50	0.71	0.37	0.38	0.21	2.29	0.75	0.57	-0.10
Upstream of Lake Mogan	6.41	On the Day	0.63	0.44	1.88	0.53	0.88	0.31	0.54	0.27	1.38	0.64	0.50	0.06
		1 Day Before	0.42	0.13	1.25	0.80	0.25	-0.24	0.54	0.21	1.13	0.67	0.38	0.00
		2 Days Before	0.83	0.64	1.25	0.30	0.88	0.65	0.46	0.24	1.63	0.69	0.50	-0.05
Mogan Detention Pond	5.98	On the Day	0.75	0.50	1.25	0.40	0.75	0.47	0.58	0.33	1.50	0.58	0.63	0.17
		1 Day Before	0.54	0.08	0.63	0.80	0.13	-0.14	0.58	0.23	1.00	0.63	0.38	0.06
		2 Days Before	0.79	0.55	1.13	0.33	0.75	0.55	0.63	0.31	1.13	0.56	0.50	0.18

4.2.6 20.05.2018 Event

Precipitation gauge records, WRF and ALR forecasts for Ankara, Ufuk Danışment, Elmadağ Radar, and Haymana Tarım stations for the 20.05.2018 event are given between Figure 4-26 and Figure 4-29. The areal distribution of actual precipitation and forecast values are given in Figure 4-30. Calculated statistics based on point and areal forecasts are given between Table 4-18 and Table 4-20.

For Ankara Station, the total precipitation gauge record is 7.70 mm, and on the day ALR forecast is 7.81 mm, which is quite good, but the correlation coefficient is 0.58. Among other forecasts, two days before WRF forecast is overestimated with 0.27 bias value, and the rest are underestimated with around -0.20 bias value. Categorical scores are close to each other, and they are better in on the day ALR, one and two days before WRF forecasts.

For Gölbaşı Ufuk Danişment Station gauge record is 19.20 mm; however, the highest total precipitation value is 3.87 mm, which belongs one day before WRF forecasts, and the best correlation value is seen in on the day WRF forecast with a value of 0.73. Categorical scores are better in WRF forecasts.

For Elmadağ Radar Station, two days before WRF forecast is so close to the total precipitation value but with low correlation. On the day WRF forecast also remains underestimated with a -0.22 bias value, but it is a bit better than the remaining ones. One day before WRF and all ALR forecasts underestimated with around -0.50 bias value and low correlations.

The Haymana Tarım Station gauge record is 5.20 mm, and on the day WRF forecast produced 4.64 mm total precipitation value with 0.20 correlation and 0.78 RMSE values. This is the best result among other forecasts for this station. Two days before WRF forecasts were resulted in an overestimated total precipitation value while other forecasts underestimated with around -0.17 bias value. Among categorical scores, PC and BS scores are better in ALR forecasts, and the rest is better in WRF forecasts.

For Sukesen, Kepir, and İğdeli subbasins, the average total precipitation values are around 13 mm. However, none of the forecasts could result in close values. All of them have around -0.50 bias score and 1.50 mm RMSE. Categorical skill scores are partially better in WRF forecasts.

For Bağırsak, Gölcük, Tatlım, and Burcupınar subbasins, the average of total precipitation gauge records is about 10 mm. On the day WRF and ALR forecasts have around 5 and 4 mm total precipitation and around 0.65 and 0.25 correlation values, respectively. Two days before WRF forecasts are better than any other forecasts in terms of total precipitation. The remaining forecasts do not have satisfactory values. Among categorical scores, TS, POD, and Heidke scores are better in WRF, while PC, BS, and FAR scores are better in ALR forecasts.

For İkizce, Dikilitaş, and Mogan Detention Pond subbasins, total precipitation records are around 6 mm, and on the day WRF forecasts are close to that value with around -0.02 bias value. Two days before WRF forecasts resulted in 8-9 mm total precipitation and low correlation values, while one day before WRF forecasts resulted in around 1 mm total precipitation value. ALR forecasts also have very poor results with negative biases and low correlation values. Among categorical skill scores, PC and BS are seem better in ALR forecasts, and rests are close to each other.

For upstream of Lake Mogan, the average total precipitation value is 8.22 mm. The closest forecast is seen in two days before WRF forecast with a 6.01 mm total precipitation value. On the day WRF and ALR forecasts have around 5 and 3 mm total precipitation values, and the rests have even lower values. Categorical scores are close to each other, but ALR scores are a little better than WRF scores.

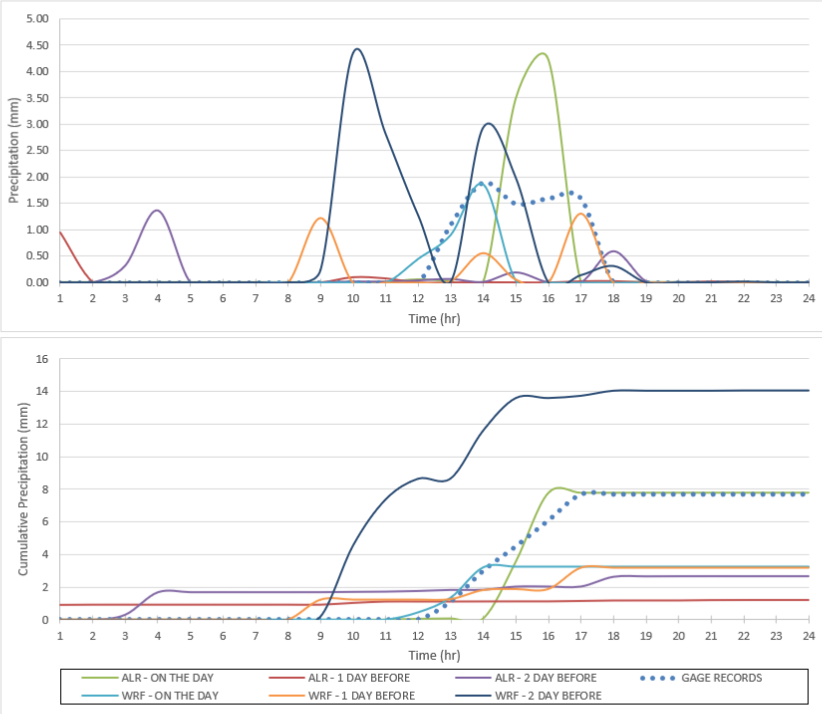

Figure 4-26. Precipitation Records and Forecast Values of 20.05.2018 Event for Ankara Station

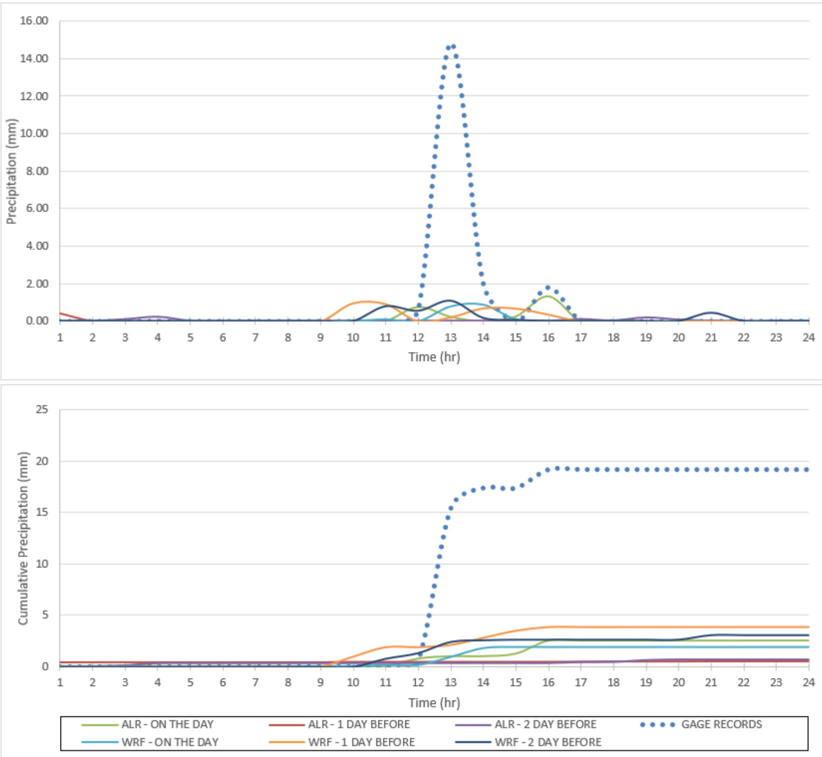

Figure 4-27. Precipitation Records and Forecast Values of 20.05.2018 Event for Ufuk Danışment Station

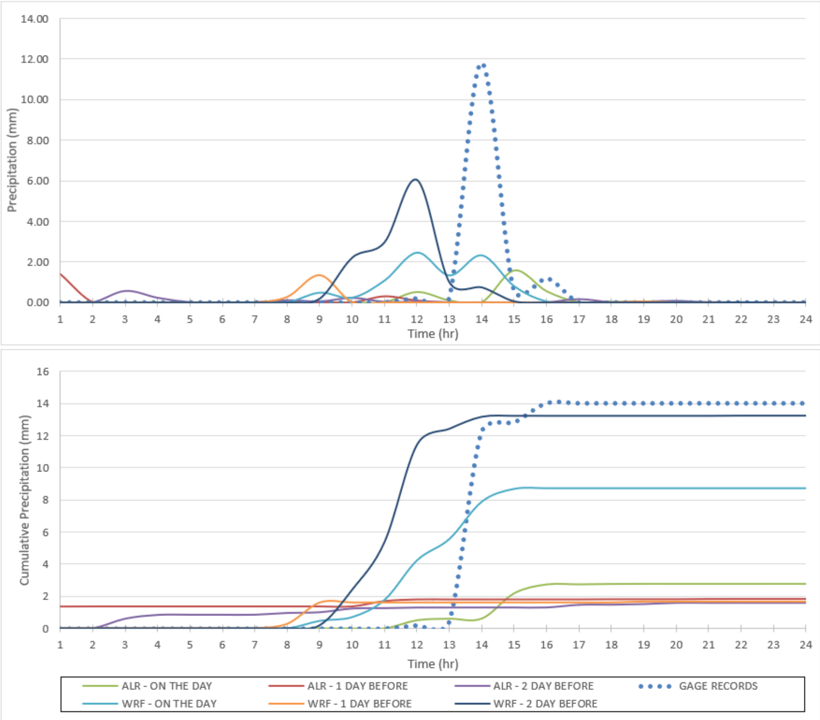

Figure 4-28. Precipitation Records and Forecast Values of 20.05.2018 Event for Elmadağ Radar Station

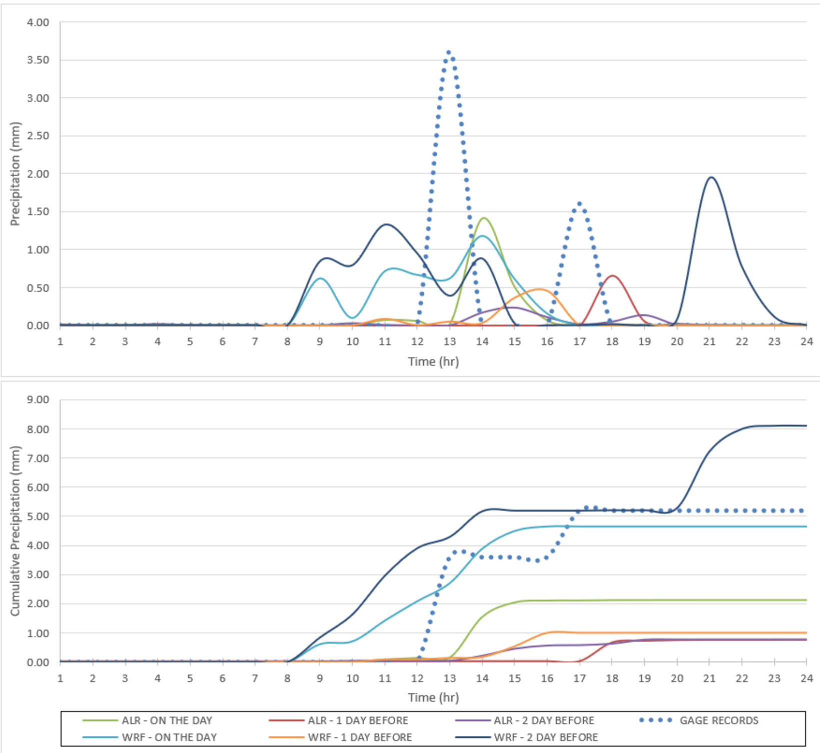

Figure 4-29. Precipitation Records and Forecast Values of 20.05.2018 Event for Haymana Tarım Station

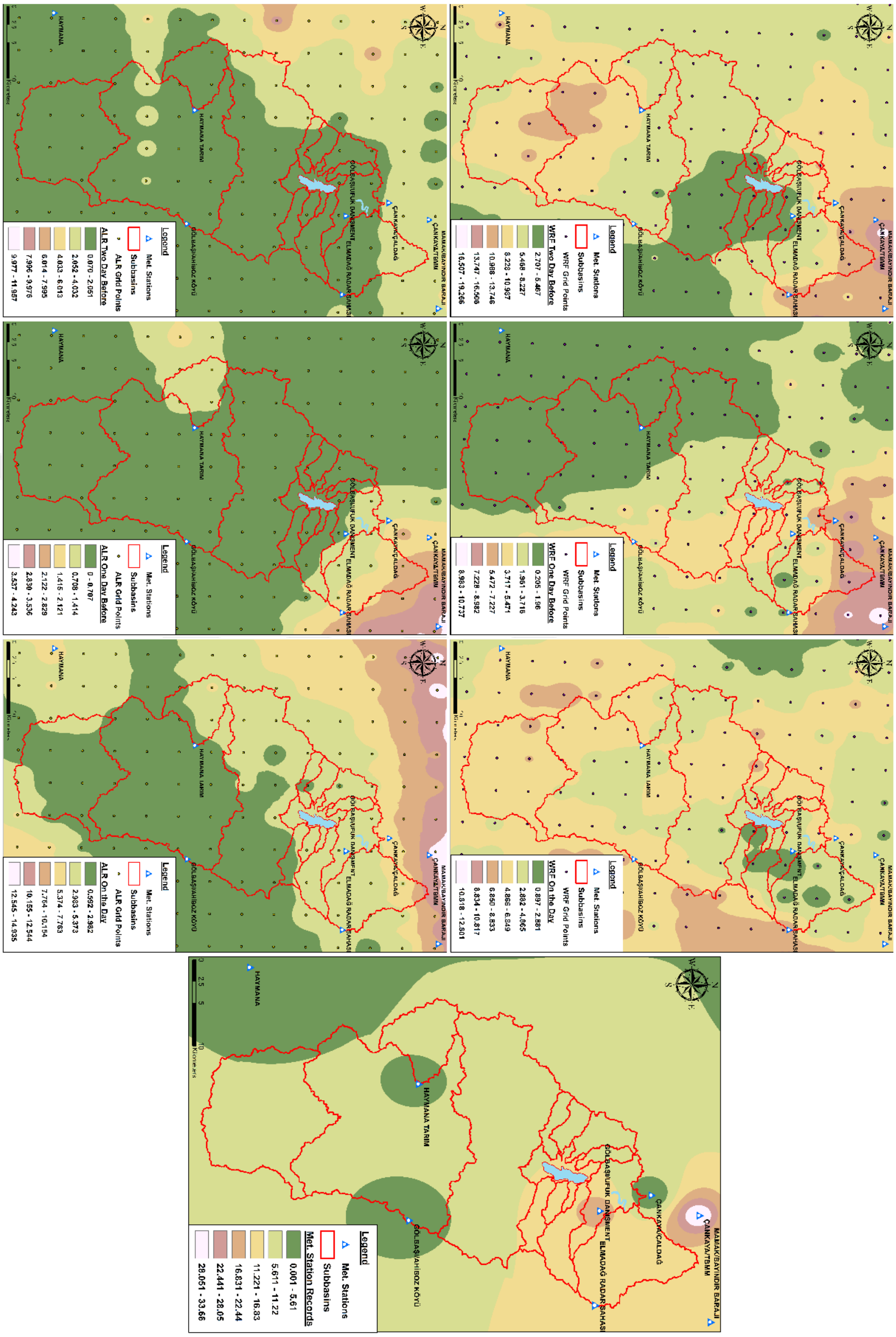

Figure 4-30. Areal Distribution of Actual Precipitation and Forecast Values of 20.05.2018 Event

Table 4-18. Statistical Scores of Forecasts on Point Basis for 20.05.2018 Event

Quantitative Scores

Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			C	NC	Total	r	RMSE	Bias	Con	Gec	Total	r	RMSE	Bias
ANKARA	7.70	On the Day	2.68	0.56	3.25	0.57	0.56	-0.19	3.15	4.66	7.808	0.58	0.87	0.00
		1 Day Before	3.17	0.00	3.17	0.41	0.62	-0.19	0.00	1.21	1.213	-0.12	0.74	-0.27
		2 Days Before	9.42	4.68	14.10	0.24	1.22	0.27	1.12	1.53	2.652	-0.11	0.76	-0.21
GOLBASI-UFUK DANİŞMENT	19.20	On the Day	1.89	0.00	1.89	0.73	2.90	-0.72	0.83	1.74	2.574	0.20	3.00	-0.69
		1 Day Before	3.87	0.00	3.87	0.10	3.02	-0.64	0.04	0.49	0.531	-0.07	3.07	-0.78
		2 Days Before	2.21	0.89	3.11	0.71	2.85	-0.67	0.05	0.70	0.742	-0.12	3.07	-0.77
ELMADAG-RADAR	14.00	On the Day	8.73	0.00	8.74	0.59	2.03	-0.22	1.23	1.52	2.756	0.01	2.42	-0.47
		1 Day Before	1.65	0.00	1.65	-0.06	2.44	-0.51	0.96	0.84	1.804	-0.07	2.44	-0.51
		2 Days Before	7.82	5.42	13.24	0.03	2.68	-0.03	0.77	0.79	1.559	-0.12	2.43	-0.52
HAYMANA TARIM	5.20	On the Day	4.63	0.01	4.64	0.20	0.78	-0.02	1.05	1.08	2.14	-0.07	0.86	-0.13
		1 Day Before	1.00	0.00	1.00	-0.02	0.80	-0.17	0.08	0.68	0.764	-0.07	0.81	-0.18
		2 Days Before	5.81	2.31	8.12	-0.04	0.96	0.12	0.04	0.72	0.759	-0.12	0.81	-0.19

Categorical Scores

Station	Gage Record	Forecast Time	WRF Forecast						ALR Forecast					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
ANKARA	7.70	On the Day	0.83	0.33	0.60	0.33	0.40	0.41	0.88	0.40	0.40	0.00	0.40	0.51
		1 Day Before	0.83	0.33	0.60	0.33	0.40	0.41	0.75	0.00	0.20	1.00	0.00	-0.07
		2 Days Before	0.71	0.22	1.20	0.67	0.40	0.18	0.67	0.00	0.60	1.00	0.00	-0.19
GOLBASI-UFUK DANİŞMENT	19.20	On the Day	0.92	0.50	0.50	0.00	0.50	0.63	0.88	0.40	0.75	0.33	0.50	0.50
		1 Day Before	0.79	0.29	1.25	0.60	0.50	0.32	0.79	0.00	0.25	1.00	0.00	-0.07
		2 Days Before	0.83	0.33	1.00	0.50	0.50	0.40	0.83	0.00	0.00	N.A.	0.00	0.00
ELMADAG-RADAR	14.00	On the Day	0.79	0.29	2.00	0.67	0.67	0.33	0.92	0.50	1.00	0.33	0.67	0.62
		1 Day Before	0.79	0.00	0.67	1.00	0.00	-0.11	0.79	0.00	0.67	1.00	0.00	-0.11
		2 Days Before	0.75	0.14	1.67	0.80	0.33	0.11	0.83	0.00	0.33	1.00	0.00	-0.07
HAYMANA TARIM	5.20	On the Day	0.75	0.14	3.00	0.83	0.50	0.14	0.83	0.00	1.00	1.00	0.00	-0.09
		1 Day Before	0.83	0.00	1.00	1.00	0.00	-0.09	0.88	0.00	0.50	1.00	0.00	-0.06
		2 Days Before	0.67	0.11	4.00	0.88	0.50	0.08	0.92	0.00	0.00	N.A.	0.00	0.00

Table 4-19. Quantitative Statistical Scores of Forecasts on Areal Basis for 20.05.2018 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)				ALR Forecast (IDW)			
			Total	r	RMSE	Bias	Total	r	RMSE	Bias
Ikizce Pond	5.83	On the Day	5.28	0.35	0.62	-0.02	2.30	0.20	0.66	-0.15
		1 Day Before	0.79	0.16	0.67	-0.21	0.87	-0.07	-0.21	-0.21
		2 Days Before	8.04	0.05	0.85	0.09	1.28	0.11	0.67	-0.19
Dikilitas Pond	6.48	On the Day	5.90	0.64	0.50	-0.02	3.72	0.76	0.45	-0.12
		1 Day Before	0.94	0.51	0.67	-0.23	0.05	-0.11	0.71	-0.27
		2 Days Before	9.48	0.25	0.80	0.12	0.37	0.25	0.69	-0.25
Sukesen Creek	14.15	On the Day	3.65	0.56	1.55	-0.44	3.01	0.16	1.70	-0.46
		1 Day Before	3.73	0.11	1.70	-0.43	0.63	-0.10	1.76	-0.56
		2 Days Before	5.67	0.43	1.55	-0.35	0.97	-0.14	1.75	-0.55
Kepir Creek	13.91	On the Day	2.62	0.38	1.76	-0.47	3.46	0.16	1.82	-0.44
		1 Day Before	4.42	0.19	1.80	-0.40	0.37	-0.10	1.88	-0.56
		2 Days Before	4.22	0.50	1.70	-0.40	0.90	-0.11	1.88	-0.54
Igdeli Creek	12.44	On the Day	3.32	0.42	1.38	-0.38	3.05	0.20	1.46	-0.39
		1 Day Before	4.39	0.15	1.46	-0.34	0.35	-0.11	1.52	-0.50
		2 Days Before	4.60	0.49	1.34	-0.33	0.84	-0.12	1.52	-0.48
Bagirsak Creek	10.52	On the Day	5.03	0.68	0.99	-0.23	4.33	0.23	1.24	-0.26
		1 Day Before	2.62	0.10	1.26	-0.33	0.52	-0.12	1.30	-0.42
		2 Days Before	8.18	0.59	1.00	-0.10	1.50	-0.10	1.30	-0.38
Gölcük Creek	10.15	On the Day	5.19	0.67	0.90	-0.21	4.91	0.27	1.13	-0.22
		1 Day Before	2.48	0.17	1.14	-0.32	0.30	-0.13	1.19	-0.41
		2 Days Before	8.33	0.57	0.92	-0.08	1.63	-0.09	1.19	-0.36
Tatlim Creek	9.86	On the Day	5.27	0.60	0.90	-0.19	4.56	0.28	1.06	-0.22
		1 Day Before	2.60	0.14	1.09	-0.30	0.18	-0.14	1.13	-0.40
		2 Days Before	6.97	0.53	0.91	-0.12	1.65	-0.08	1.14	-0.34
Burcupinar Creek	9.64	On the Day	5.62	0.60	0.86	-0.17	4.18	0.27	1.02	-0.23
		1 Day Before	2.61	0.07	1.08	-0.29	0.16	-0.15	1.10	-0.39
		2 Days Before	6.42	0.47	0.91	-0.13	1.70	-0.07	1.11	-0.33
Upstream of Lake Mogan	8.22	On the Day	4.92	0.53	0.72	-0.14	3.22	0.25	0.84	-0.21
		1 Day Before	2.64	0.14	0.86	-0.23	0.22	-0.17	0.90	-0.33
		2 Days Before	6.01	0.38	0.78	-0.09	1.45	-0.02	0.90	-0.28
Mogan Detention Pond	5.97	On the Day	5.21	0.72	0.41	-0.03	3.43	0.48	0.55	-0.11
		1 Day Before	1.79	0.34	0.59	-0.17	0.28	-0.11	0.64	-0.24
		2 Days Before	8.63	0.17	0.74	0.11	1.30	0.25	0.60	-0.19

Table 4-20. Quantitative Statistical Scores of Forecasts on Areal Basis for 20.05.2018 Event

Subbasin	Gage Record (IDW)	Forecast Time	WRF Forecast (IDW)						ALR Forecast (IDW)					
			PC	TS	BS	FAR	POD	Heidke	PC	TS	BS	FAR	POD	Heidke
Ikizce Pond	5.83	On the Day	0.75	0.33	1.40	0.57	0.60	0.34	0.88	0.40	0.40	0.00	0.40	0.51
		1 Day Before	0.83	0.20	0.20	0.00	0.20	0.28	0.75	0.00	0.20	1.00	0.00	-0.07
		2 Days Before	0.63	0.18	1.60	0.75	0.40	0.07	0.79	0.17	0.40	0.50	0.20	0.19
Dikilitas Pond	6.48	On the Day	0.75	0.33	1.40	0.57	0.60	0.34	0.83	0.33	0.60	0.33	0.40	0.41
		1 Day Before	0.79	0.00	0.00	N.A.	0.00	0.00	0.79	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.67	0.20	1.40	0.71	0.40	0.12	0.79	0.00	0.00	N.A.	0.00	0.00
Sukesen Creek	14.15	On the Day	0.92	0.67	1.00	0.20	0.80	0.75	0.92	0.60	0.60	0.00	0.60	0.70
		1 Day Before	0.71	0.13	0.80	0.75	0.20	0.05	0.75	0.00	0.20	1.00	0.00	-0.07
		2 Days Before	0.83	0.43	1.00	0.40	0.60	0.49	0.71	0.00	0.40	1.00	0.00	-0.14
Kepir Creek	13.91	On the Day	0.92	0.60	0.60	0.00	0.60	0.70	0.88	0.50	0.80	0.25	0.60	0.59
		1 Day Before	0.79	0.38	1.20	0.50	0.60	0.41	0.79	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.83	0.43	1.00	0.40	0.60	0.49	0.75	0.00	0.20	1.00	0.00	-0.07
Igdeli Creek	12.44	On the Day	0.88	0.50	0.50	0.00	0.50	0.60	0.88	0.50	0.50	0.00	0.50	0.60
		1 Day Before	0.71	0.22	0.83	0.60	0.33	0.18	0.75	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.75	0.25	0.67	0.50	0.33	0.25	0.71	0.00	0.17	1.00	0.00	-0.08
Bagirsak Creek	10.52	On the Day	0.88	0.50	0.80	0.25	0.60	0.59	0.83	0.33	0.60	0.33	0.40	0.41
		1 Day Before	0.71	0.13	0.80	0.75	0.20	0.05	0.79	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.67	0.20	1.40	0.71	0.40	0.12	0.75	0.14	0.60	0.67	0.20	0.11
Gölcük Creek	10.15	On the Day	0.79	0.38	1.20	0.50	0.60	0.41	0.88	0.40	0.40	0.00	0.40	0.51
		1 Day Before	0.71	0.13	0.80	0.75	0.20	0.05	0.79	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.67	0.20	1.40	0.71	0.40	0.12	0.75	0.14	0.60	0.67	0.20	0.11
Tatlim Creek	9.86	On the Day	0.79	0.38	1.20	0.50	0.60	0.41	0.79	0.29	0.80	0.50	0.40	0.32
		1 Day Before	0.75	0.25	1.00	0.60	0.40	0.24	0.79	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.67	0.20	1.40	0.71	0.40	0.12	0.79	0.17	0.40	0.50	0.20	0.19
Burcupinar Creek	9.64	On the Day	0.79	0.38	1.20	0.50	0.60	0.41	0.79	0.29	0.80	0.50	0.40	0.32
		1 Day Before	0.71	0.13	0.80	0.75	0.20	0.05	0.79	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.71	0.22	1.20	0.67	0.40	0.18	0.79	0.17	0.40	0.50	0.20	0.19
Upstream of Lake Mogan	8.22	On the Day	0.71	0.22	1.20	0.67	0.40	0.18	0.79	0.29	0.80	0.50	0.40	0.32
		1 Day Before	0.75	0.25	1.00	0.60	0.40	0.24	0.79	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.63	0.10	1.20	0.83	0.20	-0.06	0.79	0.17	0.40	0.50	0.20	0.19
Mogan Detention Pond	5.97	On the Day	0.75	0.33	1.40	0.57	0.60	0.34	0.79	0.29	0.80	0.50	0.40	0.32
		1 Day Before	0.79	0.17	0.40	0.50	0.20	0.19	0.79	0.00	0.00	N.A.	0.00	0.00
		2 Days Before	0.63	0.18	1.60	0.75	0.40	0.07	0.88	0.40	0.40	0.00	0.40	0.51

4.2.7 General Evaluation of Model Results

Statistical results of six different events are summarized one by one in former sections. In general, it is seen that the results of areal analyses are a little more successful than the results of point-based analyses. In general, total precipitation values are closer to the gauge records, correlation scores are relatively higher, and RMSE values are smaller in areal based values. Most of the categorical scores of the areal analyses were found better, if not as much as the quantitative scores.

The threshold value for categorical statistical scores is selected as 0.25 mm/hr. By applying different values and different time frames, i.e., 1 mm/3hr, 3 mm/6hr, etc., the success of categorical scores can be examined deeply. Even in unsatisfactory forecasts, the proportion correct (PC) score can be found as well enough in some cases for this threshold value.

As seen clearly, the forecast results of the 14.03.2016 event are much better than any other events, which are all in the form of convective type. Both in point and areal based statistical scores show quite satisfactory results, especially on the day and one day before ALR forecasts produce remarkably good outputs.

Except for the 14.03.2016 event, there is no general tendency about the goodness of fits of numerical forecasts. WRF and ALR forecasts are almost equally unsatisfactory. While some statistical parameters were found to be better in the WRF forecast for an event, the same statistical parameters could be better in the ALR forecast in another event.

The failure of convective precipitation forecast indicates that the parameters of numerical weather forecasting models are not appropriately selected for this region. This situation indicates that the choice of parameter configurations needs to be reconsidered both for WRF and ALR models. On the other hand, non-convective precipitation is expected according to the forecast of WRF and ALR models for the 18.12.2017 event. However, expectations did not realize, and forecasts became too overestimated. This situation raises doubts for the predictions of non-convective precipitation types and shows the effect of seasonality on model configurations. Pilatin (2020) has also pointed out the impact of seasonality on model performance.

CHAPTER 5

HYDROLOGICAL MODELLING AND FLOOD OPERATION STUDIES

5.1 Hydrologic Modeling and Their Application in Data Scarce Basins

Hydrological models have crucial importance in assisting the water resources practices through their ability to facilitate the comprehension of physical processes realizing within the watershed (Cirilo et al., 2020).

The real hydrologic system's behavior can be closely imitated with the simulated models to see watersheds' responses (Koriche et al., 2012). Moreover, filling the discontinuities in records, predicting the system response to change in the basins, and evaluating management alternatives can be achieved by hydrological models (Harnett et al., 2007). Model results can be used for planning activities (effects of climate or land-use changes), designing or evaluating the performance of structures or issues for water quality management (construction of wetlands, detention and retention ponds, riparian buffers, etc.) (Daggupati et al., 2015). The benefits of models also have vital importance for flood forecasting works (Kong et al., 2019). Several studies have been performed to show the role of models in flood inundation problems (Prosdocimi et al., 2015; Karamage et al., 2017).

As stated briefly in Chapter 2, there are various types of hydrological models according to simulation algorithm (metric or empirical, conceptual, physic-based), spatial representation (lumped, distributed, semi distributed), time base (event-based, continuous based), and governing equations of hydrologic processes (deterministic, stochastic). Selection of the appropriate model should be performed based on the available data and the purpose of the model. A successful hydrological model can be established by maintaining the balance between model complexity and available data (Wheater, 2002).

According to Beven (1989), equations used in physics-based models are based on homogeneous systems with small-scale basins. Thus, those types of models can be preferable for small-sized catchments, where hydrological characteristics are not varied too much and under control (Bergström, 1991). The utilization of physics-based models can be useful regarding knowledge of the hydrological cycle; however, a simpler type of models such as conceptual ones found as sufficient for operational purposes (Perrin et al., 2001). Especially for data-scarce basins, conceptual models for streamflow simulations are preferable due to their less amount of data requirement and operational ease (Hansen et al., 2007; de Vos et al., 2010; Li et al., 2013; Mendez & Calvo-Valverde, 2016). Furthermore, Aubert et al. (2003) pointed out that they are suitable for real-time prediction over medium-scale basins and resulted in similar outputs with physics-based models for operational situations. Vansteenkiste et al. (2014) make a study to compare three lumped conceptual and two distributed physic-based models. They concluded that due to the less number of parameters, lumped models resulted in more accurate calibration.

The aridity of the regions may also affect the choice and success of the hydrological models. Poncelet et al. (2017) and Parajka et al. (2013) stated that an increase in aridity results in poor model performance. The basins' rainfall-runoff processes can be changed due to the long humid periods over time. Due to the spatiotemporal variability of precipitation, hydrological parameters' values may be required to be modified (Pilgrim et al., 1988). Because of those effects, getting satisfactory results from hydrological models in semi-arid basins is still a tricky task. (Huang et al., 2016). Al-Qurashi et al. (2008) summarize the other aspects of difficulties in hydrological modeling in arid and semi-arid zones studied in the literature as follows: Lack of data on rainfall, streamflow, soil properties, and initial conditions (Grayson et al., 1992; Nouh, 2006); seasonality of vegetation and estimation of evaporation (Hughes, 1995), complex channel morphology (Costelloe et al., 2006); loss thresholds associated with the over-bank flow (Knighton and Nanson, 1994; Lange, 2005).

It should also be noted that the improvement in water resources management cannot be sustained with improved models in the absence of improved data (Silberstein, 2006). Measured or recorded data should not be thought of as free of uncertainties and errors. On the other hand, data scarcity and over-parametrization may create a prediction uncertainty in modeling (Skaugen et al., 2015; Beven, 2006), so models that need fewer data stand out in ungauged or poorly gauged regions. However, rainfall-runoff modeling is still challenging in data-scarce areas despite the improvement undertaken in recent years (Cirilo et al., 2020). Because calibration and validation are fundamental processes in rainfall-runoff models (Daggupati, 2015), and they are generally performed with continuous streamflow data. In the absence of these data, difficulties arise while simulating system behavior in a model. Because of the relatively higher costs of streamflow gauges compared to the other type of hydrometeorological (i.e., rainfall, water level, and evaporation) gauges, available continuous streamflow data is still limited across the world (Akanegbu et al., 2017; Atieh et al., 2017).

Various researches for streamflow estimation in ungauged basins have been widely performed to overcome this data scarcity problem (Peng et al., 2019). There are several studies show that instead of continuous flow records, a few measurements can be enough to constrain modeling parameters (Pool et al., 2019; Rojas-Serna et al., 2016; Viviroli and Seibert, 2015; Seibert and McDonnell, 2015; Seibert and Beven, 2009). Etter et al. (2020) and van Meerveld et al. (2017) also stated that continuous water level or water level class records of streams can also be used to perform calibration analyses. Reynolds et al. (2020) stated that in the case of some daily observational data, they could be used in the calibration of hydrological models, and those calibrated parameters could be used together with the rainfall forecasts to predict the floods at sub-daily resolutions. Sun et al. (2012) used satellite radar altimetric observations of river water levels to calibrate the model. They found that even without any streamflow records, the hydrological model can produce reasonable streamflow estimations.

Another popular approach to overcome the data-scarcity problem is regionalization, i.e., converting calibrated parameters from gauged catchments to ungauged catchments (Blöschl et al., 2013; Yang et al., 2018). Regionalization analysis is performed based on hydrological similarity by considering runoff-generation, land use, and watershed characteristics, and so on. There are various approaches to convert calibrated values to ungauged basins: i) spatial proximity (Vandewiele et al.,1991; Kokkonen et al. 2003; Merz and Blöschla, 2004); ii) regression analysis between modeling parameters and watershed characteristics (Abdulla and Lettenmaier,1997; Seibert, 1999; Bastola et al., 2008; Xu, 1999, Merz and Blöschl 2004); iii) regional calibration (Fernandez et al. 2000, Szolgay et al. 2003); iv) parameter averaging in a group of similar gauged basins (Goswami et al. 2007, Yang et al. 2019). However, Sivapalan et al. (2003) pointed out that considerable difficulties exist for regionalization processes due to the dependency on available gauged catchments, the uncertainty of the hydrological model, and lack of understanding of the basin heterogeneity.

Another approach used for rainfall-runoff modeling in the data-scarce basin is using water level measurement of lakes. Vehvilainen and Huttunen (2001) studied lake water levels in hydrological models for real-time monitoring in Finland. Lindstörm (2016) used water level measurements of 42 lakes in Sweden for model calibration instead of streamflow records. He stated that even without any streamflow data, water level measurements are very useful for the calibration of rainfall-runoff models. Furthermore, there are additional advantages to use water level measurements. Firstly, there is no need for a discharge rating curve, which may include estimation errors. Secondly, water level measurements are easier and cheaper compared to discharge measurements. From this perspective, having lake level measurements can provide beneficial contributions to hydrological modeling studies, especially in data-scarce areas.

5.2 Hydrologic Modeling Study in Lake Mogan Basin with HEC-HMS

Hydrologic Modeling System (HEC-HMS) is a software developed by the US Army Corps of Engineers (USACE) to perform simulation of precipitation-infiltration-runoff processes. The results of software could be used directly or in accordance with other computer programs for water budget studies of watersheds, urban drainage, flood management practices, and so on (Scharffenberg, 2016). Hydrological modeling studies in this study is also carried out by using HEC-HMS software.

The program includes traditional hydrologic analysis tools like event-based infiltration calculation, unit hydrographs, and routing procedures. Besides event-based simulations, continuous-based simulations could be applied by defining parameters related to evapotranspiration, snowmelt, and soil moisture accounting.

All mathematical models in the software are empirical based, uncoupled, deterministic type, and use time stationary (constant) parameters. Initial and boundary conditions and model parameters are assumed to be exactly known. Long-term changes that occurred due to human activities and natural processes in the watershed are not taken into account in the models.

HEC-HMS software contains two main components: the basin model and the meteorological model. Watershed characteristics are represented by defining precipitation loss (infiltration), canopy, surface, transform, and baseflow methods in the basin model. Elements that can be used for watershed representation are subbasin, reach, reservoir, junction, diversion, source, and sink. Meteorological parameters could be defined by precipitation, evapotranspiration, shortwave, longwave, and snowmelt methods in the meteorological model. Available modeling methods for these parameters are given in Table 5-1. Among loss methods of basin model initial and constant, SCS curve number, Smith Parlange, Green Ampt, and exponential methods could be used for event modeling, whereas one- layer deficit constant could be used for simple continuous modeling, and three-layer soil moisture accounting could be used for complex continuous modeling (Scharffenberg, 2016).

Table 5-1. Available Modeling Methods in HEC-HMS Software

Basin Model Components and Available Modelling Methods

Methods for Subbasins

Canopy	Surface	Loss Rate	Transform	Baseflow
◦ Dynamic ◦ Simple ◦ Gridded Simple	◦ Simple ◦ Gridded Simple	◦ Deficit and Constant ◦ Gridded Deficit Constant ◦ Exponential ◦ Green and Ampt ◦ Gridded Green and Ampt ◦ Initial and Constant ◦ SCS Curve Number ◦ Gridded SCS Curve Number ◦ Smith Parlange ◦ Soil Moisture Accounting ◦ Gridded Soil Moisture Accounting	◦ Clark Unit Hydrograph ◦ Kinematic Wave ◦ ModClark ◦ SCS Unit Hydrograph ◦ Snyder Unit Hydrograph ◦ User Specified S-Graph ◦ User Specified Unit Hydrograph	◦ Bounded Recession ◦ Constant Monthly ◦ Linear Reservoir ◦ Nonlinear Boussinesq ◦ Recession

Methods for Reaches		Methods for Reservoirs		Methods for Diversions	Methods for Sources
Routing	**Gain/Loss**	**Outflow**	**Storage**	**Divert Method**	**Flow Method**
◦ Kinematic Wave ◦ Lag ◦ Modified Puls ◦ Muskingum ◦ Muskingum-Cunge ◦ Straddle Stagger	◦ Constant ◦ Percolation	◦ Outflow Curve ◦ Outflow Structure ◦ Specified Release	◦ Elevation-Area ◦ Elevation-Storage	◦ Constnat Flow ◦ Inflow Function ◦ Lateral Weir ◦ Pump Station ◦ Specified Flow	◦ Constant ◦ Discharge Gage

Meteorological Model Components and Available Modelling Methods

Shortwave	Longwave	Preciptation	Evapotranspiration	Snowmelt
◦ Bristow Campbell ◦ FAO56 ◦ Gridded Shortwave ◦ Specified Pyranograph	◦ FAO56 ◦ Gridded Longwave ◦ Satterlund ◦ Specified Pyranograph	◦ Frequency Storm ◦ Gage Weights ◦ Gridded Precipitation ◦ HMR52 Storm ◦ Inverse Distance ◦ SCS Storm ◦ Specified Hyetograph ◦ Standard Project Storm	◦ Annual Evapotranspiration ◦ Gridded Penman Monteith ◦ Gridded Priestley Taylor ◦ Month Average ◦ Penman Monteith ◦ Priestley Taylor ◦ Specified Evapotranspiration	◦ Gridded Temperature Index ◦ Temperature Index

Precipitation, discharge, and stage values records can be defined in the time-series data manager. Storage-discharge, elevation-storage, and elevation-discharge relations are also defined in the paired-data manager in the software.

5.3 Parameters Defined for Lake Mogan Basin in Hydrological Model

5.3.1 General Constraints

As stated in previous sections, available continuous data is very limited in Lake Mogan Basin. Lake level records exist on a monthly basis between 1996 and 2011. Daily lake level and controlled discharged water records are available since the beginning of the 2013 water year. However, unfortunately, there is no available continuous record regarding streamflows that feed Lake Mogan. There exist only some instantaneous records which are not appropriate to use in hydrological modeling.

Ankara Metropolitan Municipality made a water transfer from Kızılırmak River via a pipeline system which conveys water from Kesikköprü Dam to İvedik Water Treatment Plant in order not to allow to lowering the water level in Lake Mogan at spring/summer months between 2014 and 2018 years. The effect of this action can be seen in the unnatural rise of lake levels in those time zones. However, the exact duration of water transfer and the amount of daily discharged water could not be obtained. Apaydın and Ocaklıoğlu (2020) stated that 2.87 hm^3 and 2.38 hm^3 water recharged to Lake Mogan between July and October in 2014 and 2015, respectively.

In addition to the scarcity of hydrometeorological data, the absence of such operational data creates an essential disadvantage for modeling studies. Predetermined curve number (CN) values, lake level, lake outflow records, lake storage-elevation data, and precipitation records are the only parameters that can be used in hydrological modeling. Because of these limitations, long-term simulations could not be performed, and event-based simulations were preferred to validate the hydrological model. While selecting dates for event-based modeling, times in autumn and spring months were chosen in order to avoid the effect of water transfer and the impact of snow-melt. Precipitation records of rain gauges were distributed by the inverse distance weighted method over the basin.

5.3.2 Event Base Simulations

While performing event-based simulations, a semi-distributed, deterministic model was created and used in HEC-HMS software. All subbasins which are described in Chapter-2 were defined in the model (Figure 5-1). It is assumed that there was no outflow from Dikilitaş and İkizce reservoirs and Mogan Detention Pond to the main streams that could have an effect on water elevations of Lake Mogan. It was also stated before that due to a technical problem, stored water at Mogan Detention Pond could not be discharged until October 2019.

SCS curve number (CN), SCS unit hydrograph, and simple canopy methods were used for loss, transform, and canopy methods. Curve number values of subbasins were estimated by using weighted average values, which were calculated and given in Chapter 2. Those parameters that are defined for subbasins are given in Table 5-2.

Because of the absence of streamflow records, observed daily lake level measurements is the only calibration and validation parameter. Three events are selected by considering the aforementioned general constraints. Results of simulations on Lake Mogan could be seen in Table 5-3. Obtained lake level results are seemed to be compatible with the observed values. As expected, the contribution of side subbasins to total inflows of Lake Mogan remained very limited. The majority of the inflows were due to precipitation, which directly fell into the lake surface. Lake level changes can be seen in Figure 5-2.

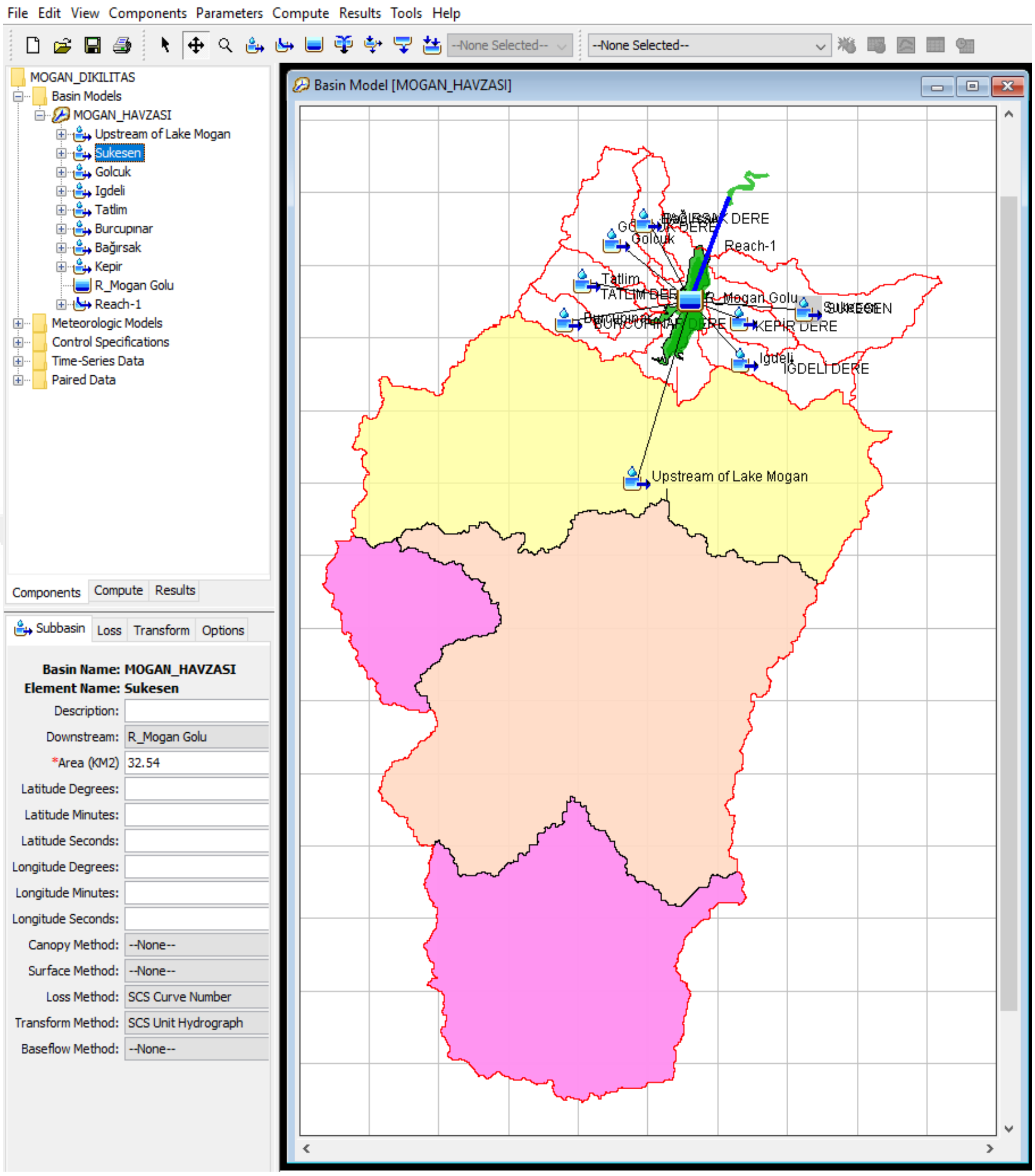

Figure 5-1. General View of HEC-HMS Model

Table 5-2. Hydrological Modeling Parameters for Subbasins

Subbasin Name	Area (km^2)	CN	Lag Time (min)	Canopy - Max. Storage (mm)
Sukesen Creek	32.54	74.98	170	5
Kepir Creek	8.39	75.17	100	5
Igdeli Creek	17.91	74.34	136	5
Bağırsak Creek	9.73	78.09	100	5
Gölcük Creek	22.75	78.70	120	5
Tatlim Creek	14.14	74.90	176	5
Burcupinar Creek	12.59	75.83	130	5
Upstream of Lake Mogan *for the dates before the end of 2015	570.00	75.96	400	5
Upstream of Lake Mogan	249.53	75.80	250	5

Table 5-3. Result of Event-Based Simulations of Hydrological Model

	Date	Outflow Discharge (m^3/s)	Observed Lake Level (m)	Simulated Lake Level (m)
Event 1	11.4.2014	0.174	972.860	972.860
	12.4.2014	0.174	972.890	972.891
Event 2	22.10.2015	0.073	973.370	973.370
	25.10.2015	0.073	973.400	973.395
Event 3	14.3.2016	0.020	973.420	973.420
	15.3.2016	0.020	973.460	973.460

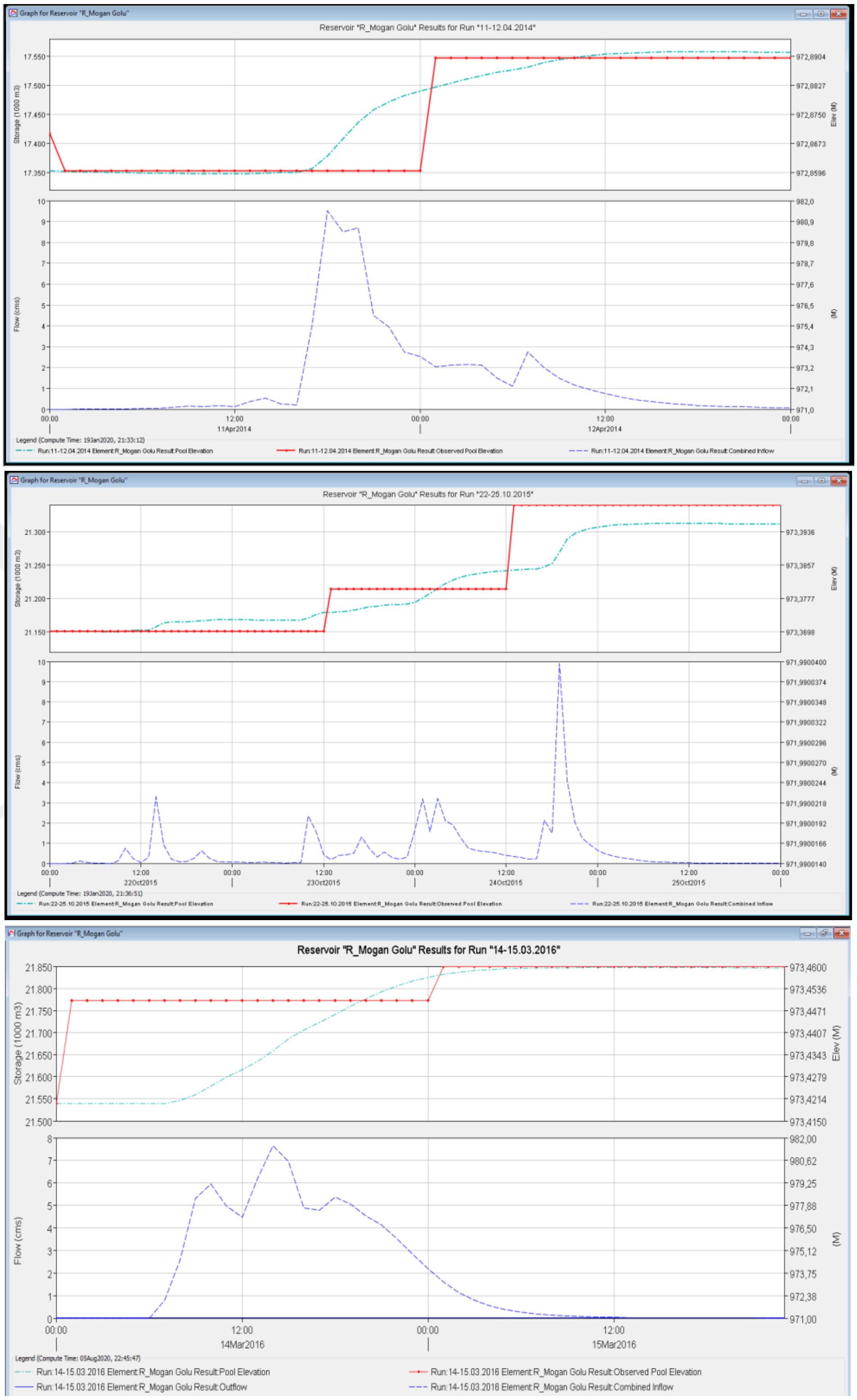

Figure 5-2. Result of Event-Based Simulations of Hydrological Model for Lake Mogan

5.4 Flood Planning and Operation Studies

5.4.1 Operational Scheme and Operational Constraints

Early response against upcoming flooding events is the most important issue in flood management. Therefore, forecasts of meteorological models should be used as soon as possible in flood management and early warning systems. In this study, available 72-hour forecast values of WRF and ALR models were used to propose a flood operation scheme in Lake Mogan. By using forecasted precipitation values and a created hydrological model, forecasted streamflows are determined. In order to evacuate the lake for upcoming heavy precipitation, a simple algorithm is generated. A tabular form for this algorithm is given in Table 5-4.

Table 5-4. Tabular Form of Water Evacuation Algorithm

Normal Storage Volume = S_n

Time Step	Time	Inflow (m^3/s)	Storage (m^3)	Elevation (m)	Excess Storage (m^3)	Required Ouflow (m^3/s)
1	01:00	I_1	S_1	H_1	S_1 - S_n	(S_1 - S_n) / 1
2	02:00	I_2	S_2	H_2	S_2 - S_n	(S_2 - S_n) / 2
3	03:00	I_3	S_3	H_3	S_3 - S_n	(S_3 - S_n) / 3
4	04:00	I_4	S_4	H_4	S_4 - S_n	(S_4 - S_n) / 4
…	…	…	…	…	…	…
…	…	…	…	…	…	…
i	i:00	I_i	S_i	H_i	S_i	(S_i - S_n) / i
i+1	i+1:00	I_{i+1}	S_{i+1}	H_{1+i}	S_{i+1}	(S_{i+1} - S_n) / i+1
…	…	…	…	…	…	…
…	…	…	…	…	…	…
72	72:00	I_{72}	S_{72}	H_{72}	S_{72}	(S_{72} - S_n) / 72

In this algorithm, forecasted precipitation values are used as an input for the hydrological model, and forecasted inflow to the lake is estimated. Excess storage volume, which is calculated according to predefined or desired operation levels due to forecasted inflow, is calculated. Required outflow rate (Q_i) in order to evacuate the forecasted amount of excess storage until time "i" is estimated. The maximum amount of outflow rate is started to be discharged at the beginning of the first-time step until the next precipitation forecasts are obtained. The procedure is repeated whenever new forecasts are available. If the required outflow rate will be higher than the downstream discharge capacity, the decisionmaker should compare damage levels of upstream and downstream of the control point and decide on the outflow amount. According to the given decision, early warning precautions should be taken. Since there is a 24-hour time interval between the precipitation forecasts provided for this study, the proposed methodology could be performed on a daily basis. More frequent forecasts increase the effectiveness of the proposed scheme and reduce the error due to overestimated or underestimated forecast values of different lead times.

Social facilities around Lake Mogan are placed at 973.75 m., and damage level begins with that altitude. In case of flooding, high damages would be occurred by reaching the level of 974.25 m, which is the crest elevation of the levee of Lake Mogan. After this level, water starts to propagate into the downstream areas and cause damages at the downstream parts of Lake Mogan. According to the report prepared by DSİ in 2008, it was estimated that a flood reaching a level of 975,00 m in Lake Mogan would cause a loss of approximately 65 million TL (according to 2008-unit prices) in housing, trade, industry, education, and infrastructure facilities between the Mogan and Eymir lakes.

The discharge capacity of Lake Mogan is given as 30 m^3/s in planning reports of DSİ. However, the current capacity is reduced up to 15-16 m^3/s due to downstream conditions (ASKİ, 2013).

Since more up-to-date data could not be obtained, the values in the volume-elevation table (Table 3-3) given by METU (1995) were used in the operation studies. Operational studies have been carried out considering all the above constraints.

5.4.2 Need for Fictitious Design Forecasts

The designs of the flood control structures are made according to the design hydrographs of long return periods (i.e., 100-year, 500-year storms). Therefore, precipitation data sets of long return periods are required to compare the use of structural and non-structural measures, which are the main purpose of the study, in flood planning studies. However, precipitation records of subbasins were relatively too small for this purpose. For this reason, it was necessary to establish a link between the design storm values with measured and forecasted precipitation values, which were created on the basis of subbasins. Forecast values of design storms were created fictitiously by using observed forecast values.

Gallus and Segal (2004) show that as the amount of precipitation that occurs increases, model predictions become more likely. In this study, it is assumed that fictitious rainfalls can be predicted with the same success rate of the real event.

Since the forecast successes in the non-convective type of precipitation are found to be much better, the proposed algorithm is used by using forecast values of the 14.03.2016 event. The hourly distribution of 50-, 100-, and 500-year storms were created separately for each sub-basin by using the hourly distribution of precipitation values of the 14.03.2016 event. The ratio between the areal values of 14.03.2016 event and design storm values were calculated. The obtained value is multiplied by the forecast values of on the day, one day before, and two days before WRF and ALR forecasts to obtain 50-, 100- and 500-year fictitious forecast values.

The calculations for the Sukesen sub-basin are given as an example in Table 5.5. The values obtained for all sub-basins are given in the Appendix C.

Table 5-5. An Example Calculation for Obtaining Fictitious Design Forecasts

Sukesen Subbasin			On the Day		One Day Before		Two Days Before	
Hours	Areal Values of		Areal WRF Forecasts for		Areal WRF forecasts for		Areal WRF Forecasts for	
	14.3.2016 Event	500-year Storm	14.3.2016 Event	500-year Storm	14.3.2016 Event	500-year Storm	14.3.2016 Event	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.002	0.009	0.040	0.161
01:00	0.000	0.000	0.000	0.000	0.002	0.009	0.021	0.087
…	…	…	…	…	…	…	…	…
09:00	2.605	10.608	1.588	6.467	0.017	0.070	0.000	0.000
10:00	1.990	8.105	1.954	7.960	0.023	0.092	0.000	0.000
11:00	1.684	6.859	1.921	7.825	0.035	0.143	0.060	0.244
12:00	3.001	12.225	2.051	8.352	0.354	1.440	0.961	3.915
…	…	…	…	…	…	…	…	…
22:00	0.003	0.014	0.017	0.067	0.180	0.734	0.044	0.178
23:00	0.000	0.000	0.068	0.275	0.104	0.425	0.010	0.040
Total	22.282	90.756	15.871	64.642	10.372	42.246	3.468	14.126
Ratio	4.073		4.073		4.073		4.073	

5.4.3 Flood Operation Studies for the Selected Fictitious Design Storm Forecasts

Flood operation study simulations were carried out in 2 main scenarios by considering constraints given in the above sections. Fictitious design forecasts created for the 14.03.2016 event is used in the analyses. In the first scenario, it was assumed that the Mogan Detention Pond, located upstream of Lake Mogan, is in operation, and the water level of Lake Mogan is at current operating values (973.42 m., value on 14.03.2016). It is assumed that no outflow is discharged from Mogan Detention Pond to downstream areas (Drainage area contributing the Lake Mogan from Çölovası Creek is taken as 250 km^2). In the second scenario, it was assumed that the detention pond is not built, and the normal operating level of the Lake Mogan is taken 972.00 m. as given in planning reports of the State Hydraulic Works (DSİ). It is assumed that no outflow is discharged from Dikilitaş and İkizce Reservoirs to the downstream areas (Drainage area contributing the Lake Mogan from Çölovası Creek is taken as 570 km^2). Under these two main scenarios, different cases were created in which 50-, 100- and 500-year storms can occur, and the capacity of the canal located at the exit of Lake Mogan can be either 15 or 30 m^3/s.

The hydrological model is run for the first fictitious forecast values, and the post-calculated discharge rate is obtained. In the second step, the hydrological model is run with the proposed outflow rate obtained in the first step and fictitious gauge records of design storms for the day 12.03.2016. Since the next forecast values are available after 24-hour, the lake level at the end of 24 hours is taken as the initial lake level for the third and the fourth run (In real-time applications, initial lake levels would be taken as actual values). The third run is simulated by one-day before fictitious forecasts, and a new proposed outflow rate is obtained. That outflow rate and fictitious gauge records of design storms for the day 13.03.2016 are used for the fourth simulation. The lake level, which is obtained by the fourth run at the end of 24 hours, is taken as the initial lake level for the fifth and the sixth run. In the fifth simulation, fictitious on the day forecast values of the event are used, and the last proposed outflow rate is obtained. In the last simulation, fictitious gauge records of design storms for the day 14.03.2016 are simulated by the last proposed outflow rate.

Summary of the results of this flood operation algorithm are given in Table 5-6 and Table 5-7. The results given in the tables are colored to highlight the damage level created according to the lake water elevations. In both main scenarios, it is seen that the water level in the lake reached 974.85 - 974.90, which is a very high damage level. However, it is clearly seen that damage levels are generally lower in the 2nd scenario, where planning conditions are tested. This situation shows how important canal capacity and lake operation levels are in flood planning studies.

Table 5-6. Result of Operation Studies – Scenario 1

Lake Level:	973.75 m.	974.25 m.
No Damage	Moderate Damage	High Damage

Date	Fictitious Forecast Model	Canal Capacity (m^3/s)	Return Period (year)	Initial Lake Level (m)	$Q_{required}$ (m^3/s)	$Q_{outflow}$ (m^3/s)	Maximum Lake Level (m)
12.3.2016	WRF	15	50	973.420	0.357	0.357	973.420
13.3.2016	WRF	15	50	973.416	2.806	2.806	973.416
14.3.2016	WRF	15	50	973.385	53.385	15.000	974.088
12.3.2016	ALR	15	50	973.420	3.740	3.740	973.420
13.3.2016	ALR	15	50	973.379	30.992	15.000	973.379
14.3.2016	ALR	15	50	973.213	62.069	15.000	973.938
12.3.2016	WRF	15	100	973.420	0.400	0.400	973.420
13.3.2016	WRF	15	100	973.416	3.780	3.780	973.416
14.3.2016	WRF	15	100	973.374	69.383	15.000	974.296
12.3.2016	ALR	15	100	973.420	5.436	5.436	973.420
13.3.2016	ALR	15	100	973.360	39.376	15.000	973.360
14.3.2016	ALR	15	100	973.193	82.921	15.000	974.143
12.3.2016	WRF	15	500	973.420	0.485	0.485	973.420
13.3.2016	WRF	15	500	973.415	6.464	6.464	973.415
14.3.2016	WRF	15	500	973.344	106.552	15.000	974.850
12.3.2016	ALR	15	500	973.420	9.878	9.878	973.420
13.3.2016	ALR	15	500	973.312	58.300	15.000	973.312
14.3.2016	ALR	15	500	973.142	130.093	15.000	974.651
12.3.2016	WRF	30	50	973.420	0.357	0.357	973.420
13.3.2016	WRF	30	50	973.416	2.806	2.806	973.416
14.3.2016	WRF	30	50	973.385	53.385	30.000	973.930
12.3.2016	ALR	30	50	973.420	3.740	3.740	973.420
13.3.2016	ALR	30	50	973.379	30.992	30.000	973.379
14.3.2016	ALR	30	50	973.039	46.163	30.000	973.621
12.3.2016	WRF	30	100	973.420	0.400	0.400	973.420
13.3.2016	WRF	30	100	973.416	3.780	3.780	973.416
14.3.2016	WRF	30	100	973.374	69.383	30.000	974.138
12.3.2016	ALR	30	100	973.420	5.436	5.436	973.420
13.3.2016	ALR	30	100	973.360	39.376	30.000	973.360
14.3.2016	ALR	30	100	973.020	66.691	30.000	973.835
12.3.2016	WRF	30	500	973.420	0.485	0.485	973.420
13.3.2016	WRF	30	500	973.415	6.464	6.464	973.415
14.3.2016	WRF	30	500	973.344	106.552	30.000	974.660
12.3.2016	ALR	30	500	973.420	9.878	9.878	973.420
13.3.2016	ALR	30	500	973.312	58.300	30.000	973.312
14.3.2016	ALR	30	500	972.966	113.729	30.000	974.291

Table 5-7. Result of Operation Studies – Scenario 2

Lake Level:	973.75 m.	974.25 m.
No Damage	Moderate Damage	High Damage

Date	Fictitious Forecast Model	Canal Capacity (m^3/s)	Return Period (year)	Initial Lake Level (m)	$Q_{required}$ (m^3/s)	$Q_{outflow}$ (m^3/s)	Maximum Lake Level (m)
12.3.2016	WRF	15	50	972.000	0.375	0.375	972.000
13.3.2016	WRF	15	50	971.994	2.863	2.863	971.994
14.3.2016	WRF	15	50	971.951	88.192	15.000	973.535
12.3.2016	ALR	15	50	972.000	6.408	6.408	972.000
13.3.2016	ALR	15	50	971.904	47.394	15.000	971.904
14.3.2016	ALR	15	50	971.679	103.253	15.000	973.338
12.3.2016	WRF	15	100	972.000	0.422	0.422	972.000
13.3.2016	WRF	15	100	971.993	3.879	3.879	971.993
14.3.2016	WRF	15	100	971.935	114.687	15.000	973.945
12.3.2016	ALR	15	100	972.000	9.443	9.443	972.000
13.3.2016	ALR	15	100	971.858	60.779	15.000	971.858
14.3.2016	ALR	15	100	971.663	134.942	15.000	973.746
12.3.2016	WRF	15	500	972.000	0.513	0.513	972.000
13.3.2016	WRF	15	500	971.992	7.108	7.108	971.992
14.3.2016	WRF	15	500	971.886	176.862	15.000	974.909
12.3.2016	ALR	15	500	972.000	17.473	15.000	972.000
13.3.2016	ALR	15	500	971.775	92.812	15.000	971.775
14.3.2016	ALR	15	500	971.550	208.654	15.000	974.689
12.3.2016	WRF	30	50	972.000	0.375	0.375	972.000
13.3.2016	WRF	30	50	971.993	2.863	2.863	971.993
14.3.2016	WRF	30	50	971.951	88.192	30.000	973.305
12.3.2016	ALR	30	50	972.000	6.408	6.408	972.000
13.3.2016	ALR	30	50	971.904	47.394	30.000	971.904
14.3.2016	ALR	30	50	971.448	89.682	30.000	972.920
12.3.2016	WRF	30	100	972.000	0.422	0.422	972.000
13.3.2016	WRF	30	100	971.993	3.879	3.879	971.993
14.3.2016	WRF	30	100	971.935	114.687	30.000	973.730
12.3.2016	ALR	30	100	972.000	9.443	9.443	972.000
13.3.2016	ALR	30	100	971.858	60.779	30.000	971.858
14.3.2016	ALR	30	100	971.396	121.096	30.000	973.357
12.3.2016	WRF	30	500	972.000	0.513	0.513	972.000
13.3.2016	WRF	30	500	971.992	7.108	7.108	971.992
14.3.2016	WRF	30	500	971.886	176.862	30.000	974.683
12.3.2016	ALR	30	500	972.000	17.473	17.473	972.000
13.3.2016	ALR	30	500	971.738	91.733	30.000	971.738
14.3.2016	ALR	30	500	971.260	194.059	30.000	974.241

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 Summary

Operational usage of numerical weather forecasting models has increased around the world over the years. The output of these models can be used for various purposes in water management. Turkish State General Directorate of Meteorology (MGM) also uses WRF and ALR models operationally. Outputs of these models were obtained from the MGM for the selected six events in the study area. It is aimed to investigate the utilization of numerical weather forecasting models in flood planning and operation studies in an ungauged Lake Mogan basin by comparing the effectiveness of structural and non-structural intervention measures.

The selection of parameters in the configuration of numerical weather forecasting models is the most important issue to get accurate forecast results with actual records. Researchers have been striving to find the best parameter combination for their area of interest. Quantitative and categorical statistical skill scores are widely used to evaluate the performance of numerical weather forecasting models. In this study, Pearson correlations (r), root mean square errors (RMSE), and bias scores are used for quantitative analyses; proportion correct (PC), threat score (TS), bias, false alarm ratio (FAR), probability of detection (POD) and Heidke skill scores are used for categorical analyses. These analyses were performed for three consecutive lead time with a 24-hour interval.

Statistical analyses were completed both for point-based and areal-based. Point-based analyses were conducted for the grids which are close to the meteorological stations, and areal analyses were conducted for subbasins in the study area. In this study, areal-based values were created by using the inverse distance weighted (IDW) technique. Instead of this method, kriging, geographically weighted regression, and natural neighbor methods may also be used. Future studies can investigate which areal interpolation method yields a more accurate spatial and temporal distribution. In any case, analyses should produce more reliable results than the Thyssen polygon method, which is still used operationally in Turkey.

Statistical results showed that the areal-based forecasts make more accurate estimates than the point-based forecasts. However, forecasts of convective type precipitations resulted in poor statistical scores. Statistical analysis has shown that forecasting models are not sufficiently successful for the selected events. Except for the 14.03.2016 event, all WRF and ALR models' forecasts for all events were found to be quite unsatisfactory. The results of forecasts for the non-convective type of storm (event on 14.03.2016) were found to be much better than convective types. It is also recognized that the results of ALR models are better than WRF models for non-convective storms in this study area.

In this study, the most challenging issue was the failure to obtain appropriate longitudinal streamflow records data. Hydrological modeling techniques have developed over the years, and lumped models have started to be replaced by distributed models. However, more complex models need more sophisticated types of data such as temperature, radiation, or groundwater parameters in addition to precipitation. It is not true to claim that more complex models always produce better results, but detailed outputs could be obtained by those models. The success of simulation, calibration, and validation processes of hydrological modeling also depends on the availability of past data. Because of the absence of streamflow records in the study area, the semi-distributed hydrological model constructed in this study was tried to be validated by water elevations of Lake Mogan. These studies have resulted in satisfactory results.

Flood control structures are designed according to the hydrographs of long return periods of precipitation (i.e., 100-year, 500-year storms). Since it is almost impossible to find forecasting precipitation values that predict design storms, fictitious rainfall forecasts were produced in order to examine the utilization of numerical weather forecasting models in flood planning studies.These fictitious rainfall forecasts were created by using the forecast data of the precipitation event experienced on 14.03.2016.

In this study, the proposed operational conditions of Lake Mogan in planning reports of DSİ are compared with current operational conditions for the 14.03.2016 event. The event on 14.03.2016 was chosen among selected six events because the numerical weather forecast methods gave more successful results. In current conditions, Mogan Detention Pond is taken as operational, and it is assumed that there is no water discharged downstream, and this means that the drainage area contributing to the lake from Çölovası Creek is 250 km^2. Furthermore, the water level of Lake Mogan is taken to be at the same level as 14.03.2016 (973.42 m.). By contrast, for the cases of conditions given in planning reports of DSİ, the water level of Lake Mogan is taken as 972.00 m, and the drainage area contributing to the lake from Çölovası Creek is taken as 570 km^2. These two main scenarios are tested with different return periods (50-, 100- and 500-year storms) and different discharge capacities (15 m^3/s and 30 m^3/s) by using fictitious forecast results of WRF and ALR models.

When the results for the cases of conditions given in planning reports are analyzed, it is seen that the 50-year storm does not create any flooding damages in any case. The 100-year storm also does not create damage if fictitious ALR forecasts are used in the hydrological model or fictitious WRF forecasts are used with 30 m^3/s discharge capacity. In the case of a 500-year storm, using fictitious ALR forecasts in the hydrological model for the cases of 30 m^3/s discharge capacity results in moderate level damage. In all other cases, high levels of damage occur.

It is expected that flood damages will be decreased by constructing an additional water control structure. However, since the operational water level of Lake Mogan is changed, adding Mogan Detention Pond to the flood control system does not result in less amount of damage. As also stated by WMO (2009), it is thought that the presence of a detention pond may create a false sense of security, which leads to a higher operational level in Lake Mogan. Only in one case, using fictitious ALR forecasts with 30 m^3/s discharge capacity for the 50-year storm does not result in any damages. Other cases for 50-year storms, and 100-year storms except using fictitious WRF forecasts with 15 m^3/s discharge capacity result in a moderate level of damages. 500-year storms result in a high level of damages in all of the cases.

6.2 Conclusions

According to records, it is seen that losses of life and damage due to flooding events have increased in recent years and may continue to increase in the future. However, given the population density and the level of investment in flood plains, this protection can only be achieved at the expense of high cost and generally to refuse the efficient use of flood-prone lands. The integrated flood management (IFM) approach has been tried to be applied around the world for a while. WMO (2009) considered this approach within the Integrated Water Resources Management as minimizing losses of life and damage to property while maximizing the efficient use of floodplain areas. The main aim of this approach is to reduce the flood risks to an appropriate level of social, environmental, and economic costs within the current legal obligations. It is very reasonable to consider the harmful effects of floods while coping with floods. However, it should be kept in mind that flood hazards also have beneficial impacts on nature. Therefore, IFM studies should consider both the negative and positive effects of floods by sustaining social awareness. Besides the technical issues, an optimal combination of structural and non-structural measures considering social, economic, and environmental aspects are investigated in the IFM approach. While conventional flood management only deals with defensive practices (i.e., structural measures), structural and non-structural interventions are analyzed with those aspects to give guidance to the decision-makers.

From a technical point of view, in order to fight against floods, well-organized flood operation systems containing meteorological forecasts, hydrological models, operation algorithms, and early warning systems should be employed in flood management. An operation algorithm should be formed by considering all possible physical and economic constraints. The importance of downstream and upstream inundation areas, operation levels, and discharge capacity of existing water control structures should be the main elements of the proposed algorithm. In case of unavoidable flooding, an early warning should be provided for predetermined possible inundation areas to reduce flooding damages. In this general framework, every single process has crucial importance in preventing flooding events. Meteorological, hydrological, and human factors should be deeply investigated, and necessary precautions should be taken for flood management.

Many flood forecasting systems around the world are based on observed actual rainfall measurements, and therefore, the lead time of these systems is generally short for small basins (Banihabib and Arabi, 2016). However, the use of numerical weather forecasting methods is increasingly common. In this study, it is seen that the performance of forecast models with the configurations that the MGM used are better for the non-convective type of precipitations for the study area. On the day WRF, on the day and one day before ALR forecasts of 14.03.2016 event are found to be satisfactory. However, it is known that the Turkish State General Directorate of Meteorology uses only one model configurations for WRF and ALR models for the whole of Turkey. Pilatin (2020) has also stated that using only one model configuration for the WRF model does not produce reliable forecasts for all regions and all the seasons. There are various researches regarding the best model configurations in the literature, which is also given in Chapter 2. In future studies, the selection of model parameters should be reconsidered, and more appropriate configurations should be specified to report more accurate forecast results for this region. Improving the results of forecast models would significantly increase the effectiveness of water management applications. Longer-term and more frequent forecasts will increase the efficiency of flood control operations with a well-configured meteorological model.

Threats of meteorological factors like rainfall amounts, snowmelt-temperature relations should be studied by past data as well as real-time observations for effective flood management. Historical records related to precipitation and streamflow gauges are essential data sources for hydrological modeling. The lack of such data creates reliability problems in hydrological applications. Many researchers have tried to overcome problems of hydrological modeling in ungauged or poorly gauged basins. Nevertheless, network density should be increased especially for the urban areas in any case. In order to create more sophisticated models, streamflow gauges should be established in the basin. The tentative location of proposed streamflow gauges can be seen in Figure 6-1. It would be very beneficial to record streamflows on those streams. Collecting groundwater observations would also be beneficial for hydrological modeling studies.

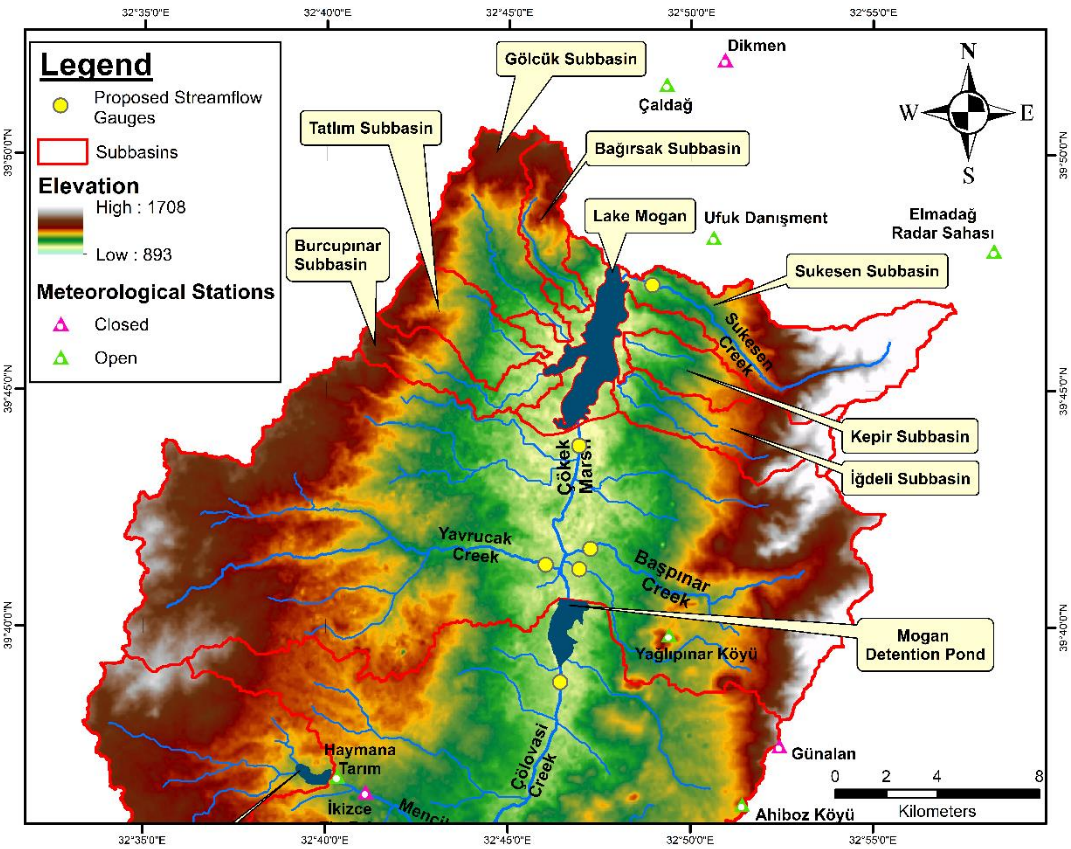

Figure 6-1. Location of Proposed Streamflow Gauges

Because of the absence of streamflow records, hydrological modeling studies are calibrated with lake level measurements in this study. While it is common practice to use streamflow records in hydrological modeling applications, using water level records can have an additional advantage. It involves no extrapolation of the rating curve and makes use of the real measurements of water levels and not discharge modeled via an estimated rating curve (Lindström, 2016). Due to the high variability and skewness of discharge values, calibration may also be easier while using water level data (Sorooshian & Gupta 1995).

In addition to establishing the proposed flow monitoring stations in the study area, the flood operation studies can be made much more functional with some additional issues. Released water from Dikilitaş and İkizce reservoirs and Mogan Detention Pond should also be recorded for flood operations and hydrological modeling. Another important issue is the amount and duration of water transferred from Kesikköprü Dam to Mogan Lake. Without knowing the exact amount and time of the water transfer, hydrological models yield unrealistic results. Radar data of Elmadağ Radar Station may also be very beneficial for flood management studies. Özkaya and Akyürek (2019b) have studied radar data in a data-scarce basin in Samsun, Turkey, for flood studies. Similar studies can be conducted for this area as the use of nowcasting products in flood operation studies. On the other hand, coupling numerical weather forecasting and hydrological models have a great potential to improve flood management works (Li et al., 2017; Yücel et al., 2015). Including all these issues described above, a flood management plan can be created for the basin, as shown in Figure 6-2.

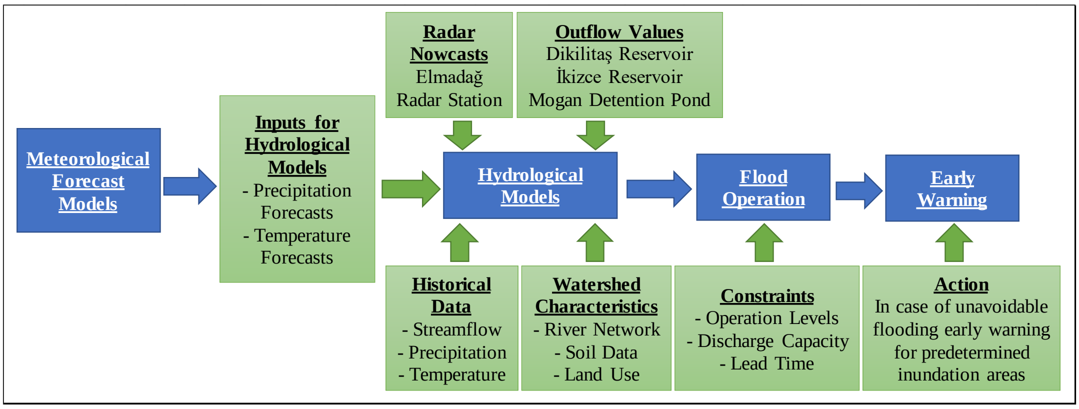

Figure 6-2. General Flowchart of Flood Management Plan for Study Area

Every single item in flood management requires detailed analysis and pre-defined action plans ready at all times. Engineering studies should be conducted with technological improvements to reduce flooding events. Public institutions should continuously review their water control structures and improve their capabilities. The flood management system should be operated by considering the upstream-downstream relationship and environmental concerns. Released water should not cause flooding in downstream areas, and stored water should not make inundation in upstream areas. If these two conditions cannot be satisfied at the same time, early warnings should be made to members of the public who are potentially threatened by flooding. There are some deficiencies and unknowns in the study area. The capacity of the canal between Mogan and Eymir lakes, the discharge capacity of Lake Eymir, and İncesu Creek and capacity of the closed conduit at the exit of İncesu Detention Pond and city storm-water system are problematic issues for flood operation studies in this area. If these unknowns can be cleared, an effective flood management system can be established in the basin. It is also crucial that the gates in Mogan and Eymir lakes should also be operated flexibly. Currently, these gates can be opened and closed with the help of heavy construction equipments.

It is also important to update the bathymetric map of the Lake Mogan. Due to the sedimentation, the lake's active storage volume may have decreased in recent years, and sediment cleaning works were carried out by the Ministry of Environment and Urbanization between 2016-2018. Since recent bathymetric map values could not be obtained, studies were conducted with outdated values of the Lake Mogan.

As the planning conditions were tested, the studies here were performed with fictitious forecasts of design storms. However, as a result, the proposed flood management algorithm can also be used on an operational basis. Sufficient flood control structures have now been built to protect the lake periphery and downstream city areas from flooding. However, such an algorithm is still needed due to the high operation levels of the lake and insufficient infrastructures. In addition, in the planning report of the Mogan Detention Pond, the operation level of Lake Mogan was taken as 971.00 m, which is very low. These situations necessitate additional studies in terms of flood planning in the region.

In order to prevent flooding events in the region, lead times should be as long as possible. Due to the false alarm of longer lead time meteorological forecasts, unexpected water losses may occur in the lake. On the other hand, during the flood operation studies, the amount of pre-released water discharge could be increased by a certain amount if forecasted precipitations generally remain underestimated. This would also lead to unexpected water losses in the reservoir. By considering biological requirements, minimum operation levels should also be considered in flood management studies to prevent ecological life in the lake.

Decision-makers should carry out planning and operational activities by taking into account the technical, social, environmental, and economic aspects of floods. In this study, it has been shown that operational-based solutions can be as successful as structural-based solutions. It is also understood that in order for structural-based solutions to be successful, it is necessary to adhere to operational policies strictly. Additionally, non-structural solutions are generally more economical than structural based solutions in flood operation studies. The agricultural land in the reservoir area of the Mogan Detention Pond has also become unusable, which creates a prolonged economic loss. Therefore, decision-makers should consider these issues during the planning stage of flood control projects.

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APPENDICES

A. Result Sheets of Probable Maximum Daily Rainfall Amounts Calculations (DSİ Spreadsheet)

UFUK DANİŞMENT METEOROLOJİ İSTASYONU
GÜNLÜK MAKSİMUM YAĞIŞLARININ EKSTREM DAĞILIM HESABI

Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %
1	2007	18.40	12.20	7.14										
2	2008	12.20	17.20	14.29										
3	2009	17.20	17.80	21.43										
4	2010	40.00	18.00	28.57										
5	2011	18.00	18.40	35.71										
6	2012	17.80	19.40	42.86										
7	2013	24.20	24.20	50.00										
8	2014	30.60	27.40	57.14										
9	2015	65.80	30.60	64.29										
10	2016	61.80	31.20	71.43										
11	2017	31.20	40.00	78.57										
12	2018	19.40	61.80	85.71										
13	2019	27.40	65.80	92.86										

Dağılım Tipi	2	5	10	25	50	100	200	500	Kabul Edilen
Normal Dağılım	29.54	43.81	51.28	59.24	64.38	69.00	73.22	78.31	
Log-Normal (2 Parametreli)	25.62	40.14	50.77	65.24	76.68	88.69	101.28	118.87	
Log-Normal (3 Parametreli)	26.55	41.65	51.67	64.37	73.85	83.35	92.92	105.74	
Pearson Tip-3 (Gama Tip-3)	25.71	41.49	52.21	65.65	75.47	85.06	94.53	103.99	*******
Log-Pearson Tip-3	24.60	38.91	51.07	70.09	87.21	107.24	130.64	159.15	
Gumbel	27.15	46.43	59.20	75.33	87.29	99.17	111.00	126.62	

DAĞILIMLARIN İSTATİSTİK PARAMETRELERİ

Yıl Sayısı	13
Lineer Çarpıklık Katsayısı	1.40401
Logaritmik Çarpıklık Katsayısı	0.65362
Lineer Ortalama	29.53846
Lineer Standart Sapma	16.96258
Logaritmik Ortalama	1.41484
Logaritmik Standart Sapma	0.22046

DAĞILIM TİPLERİNİN SİMİRNOV-KOLMOGOROV TESTİNE GÖRE SONUÇLARI

Dağılım Tipi	Teorik P	Amprik P	Maksimum P Δmax	P deki Gözlem Değeri	Anlamlılık Yüzdeleri				
					0.80	0.85	0.90	0.95	0.99
Normal Dağılım	0.539	0.714	**0.175**	31.2	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (2 Parametreli)	0.699	0.429	**0.127**	19.4	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (3 Parametreli)	0.698	0.429	**0.126**	19.4	Kabul	Kabul	Kabul	Kabul	Kabul
Pearson Tip-3 (Gama Tip-3)	0.316	0.429	**0.113**	19.4	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Pearson Tip-3	0.312	0.429	**0.116**	19.4	Kabul	Kabul	Kabul	Kabul	Kabul
Gumbel	0.288	0.143	**0.145**	17.2	Kabul	Kabul	Kabul	Kabul	Kabul

DİKMEN + ÇALDAĞ METEOROLOJİ İSTASYONU
GÜNLÜK MAKSİMUM YAĞIŞLARININ EKSTREM DAĞILIM HESABI

Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %
1	1966	25.20	17.90	3.13	27	1992		42.5	84.38	53	2018	50.0		
2	1967	19.20	18.20	6.25	28	1993		43.2	87.50	54	2019	21.4		
3	1968	30.30	19.20	9.38	29	1994		45.8	90.63					
4	1969	36.00	19.40	12.50	30	1995		47.4	93.75					
5	1970		20.20	15.63	31	1996		50.0	96.88					
6	1971	22.70	20.60	18.75	32	1997								
7	1972	21.40	20.90	21.88	33	1998								
8	1973	19.40	21.40	25.00	34	1999								
9	1974	45.80	21.40	28.13	35	2000								
10	1975	27.80	21.40	31.25	36	2001								
11	1976	43.20	22.30	34.38	37	2002								
12	1977	22.30	22.70	37.50	38	2003								
13	1978	20.20	24.90	40.63	39	2004								
14	1979	21.40	25.20	43.75	40	2005								
15	1980	20.60	25.30	46.88	41	2006								
16	1981	47.40	27.10	50.00	42	2007								
17	1982	42.30	27.80	53.13	43	2008								
18	1983	28.30	28.30	56.25	44	2009								
19	1984	18.20	29.10	59.38	45	2010								
20	1985	38.90	30.30	62.50	46	2011								
21	1986	17.90	31.60	65.63	47	2012								
22	1987	35.00	35.00	68.75	48	2013								
23	1988	25.30	36.00	71.88	49	2014	31.6							
24	1989	39.90	38.90	75.00	50	2015	29.1							
25	1990	42.50	39.90	78.13	51	2016	27.1							
26	1991	24.90	42.30	81.25	52	2017	20.9							

Dağılım Tipi	2	5	10	25	50	100	200	500	Kabul Edilen
Normal Dağılım	29.55	37.79	42.10	46.69	49.65	52.32	54.76	57.69	
Log-Normal (2 Parametreli)	28.06	36.81	42.42	49.36	54.42	59.42	64.38	70.92	
Log-Normal (3 Parametreli)	28.56	37.27	42.47	48.57	52.82	56.89	60.81	65.81	
Pearson Tip-3 (Gama Tip-3)	28.47	37.31	42.59	48.73	52.98	57.00	60.84	64.68	
Log-Pearson Tip-3	27.59	36.51	42.72	50.93	57.33	63.95	70.88	78.55	
Gumbel	28.06	38.00	44.58	52.90	59.06	65.19	71.29	79.34	*******

DAĞILIMLARIN İSTATİSTİK PARAMETRELERİ

Yıl Sayısı	31
Lineer Çarpıklık Katsayısı	0.67113
Logaritmik Çarpıklık Katsayısı	0.34659
Lineer Ortalama	29.55484
Lineer Standart Sapma	9.78658
Logaritmik Ortalama	1.44873
Logaritmik Standart Sapma	0.13857

DAĞILIM TİPLERİNİN SİMİRNOV-KOLMOGOROV TESTİNE GÖRE SONUÇLARI

Dağılım Tipi	Teorik P	Amprik P	Maksimum P Δmax	P deki Gözlem Değeri	Anlamlılık Yüzdeleri 0.80	0.85	0.90	0.95	0.99
Normal Dağılım	0.668	0.469	**0.137**	25.3	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (2 Parametreli)	0.744	0.375	**0.119**	22.7	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (3 Parametreli)	0.746	0.375	**0.121**	22.7	Kabul	Kabul	Kabul	Kabul	Kabul
Pearson Tip-3 (Gama Tip-3)	0.263	0.375	**0.112**	22.7	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Pearson Tip-3	0.200	0.313	**0.112**	21.4	Kabul	Kabul	Kabul	Kabul	Kabul
Gumbel	0.279	0.375	**0.096**	22.7	Kabul	Kabul	Kabul	Kabul	Kabul

ELMADAĞ RADAR METEOROLOJİ İSTASYONU
GÜNLÜK MAKSİMUM YAĞIŞLARININ EKSTREM DAĞILIM HESABI

Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %
1	2007	15.40	15.40	7.14										
2	2008	27.00	25.20	14.29										
3	2009	46.40	27.00	21.43										
4	2010	43.20	27.20	28.57										
5	2011	27.80	27.80	35.71										
6	2012	56.40	30.40	42.86										
7	2013	30.40	32.60	50.00										
8	2014	27.20	34.00	57.14										
9	2015	45.60	41.60	64.29										
10	2016	34.00	43.20	71.43										
11	2017	41.60	45.60	78.57										
12	2018	32.60	46.40	85.71										
13	2019	25.20	56.40	92.86										

Dağılım Tipi	2	5	10	25	50	100	200	500	Kabul Edilen
Normal Dağılım	34.83	44.23	49.14	54.38	57.76	60.80	63.58	66.93	
Log-Normal (2 Parametreli)	33.17	43.15	49.52	57.35	63.04	68.65	74.20	81.50	
Log-Normal (3 Parametreli)	34.36	44.04	49.39	55.33	59.28	62.93	66.33	70.54	
Pearson Tip-3 (Gama Tip-3)	34.29	44.03	49.44	55.45	59.47	63.17	66.63	70.10	*******
Log-Pearson Tip-3	34.21	44.37	49.93	55.93	59.79	63.21	66.29	69.51	
Gumbel	33.26	45.95	54.35	64.97	72.84	80.66	88.45	98.72	

DAĞILIMLARIN İSTATİSTİK PARAMETRELERİ

Yıl Sayısı	13
Lineer Çarpıklık Katsayısı	0.29224
Logaritmik Çarpıklık Katsayısı	-0.58328
Lineer Ortalama	34.83077
Lineer Standart Sapma	11.16359
Logaritmik Ortalama	1.51983
Logaritmik Standart Sapma	0.14847

DAĞILIM TİPLERİNİN SİMİRNOV-KOLMOGOROV TESTİNE GÖRE SONUÇLARI

Dağılım Tipi	Teorik P	Amprik P	Maksimum P Δmax	P deki Gözlem Değeri	Anlamlılık Yüzdeleri 0.80	0.85	0.90	0.95	0.99
Normal Dağılım	0.530	0.571	**0.101**	34.0	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (2 Parametreli)	0.766	0.643	**0.123**	41.6	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (3 Parametreli)	0.737	0.643	**0.094**	41.6	Kabul	Kabul	Kabul	Kabul	Kabul
Pearson Tip-3 (Gama Tip-3)	0.725	0.643	**0.082**	41.6	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Pearson Tip-3	0.726	0.643	**0.083**	41.6	Kabul	Kabul	Kabul	Kabul	Kabul
Gumbel	0.241	0.143	**0.098**	25.2	Kabul	Kabul	Kabul	Kabul	Kabul

GÜNALAN + AHİBOZ METEOROLOJİ İSTASYONU
GÜNLÜK MAKSİMUM YAĞIŞLARININ EKSTREM DAĞILIM HESABI

Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %
1	1972	30.40	19.40	2.50	27	1998	27.30	34.5	67.50					
2	1973	19.40	19.60	5.00	28	1999	34.50	35.1	70.00					
3	1974	40.80	19.90	7.50	29	2000	32.00	35.5	72.50					
4	1975	19.90	20.50	10.00	30	2001	26.00	39.6	75.00					
5	1976	25.20	21.20	12.50	31	2002	44.50	40.8	77.50					
6	1977	44.00	21.50	15.00	32	2003	26.50	42.2	80.00					
7	1978	24.50	22.60	17.50	33	2004	24.3	43.6	82.50					
8	1979	25.10	23.90	20.00	34	2005	21.5	44.0	85.00					
9	1980	50.70	24.30	22.50	35	2006	25.0	44.5	87.50					
10	1981	26.50	24.50	25.00	36	2007	29.0	45.2	90.00					
11	1982	39.60	24.70	27.50	37	2008		50.7	92.50					
12	1983	45.20	25.00	30.00	38	2009		56.3	95.00					
13	1984	23.90	25.00	32.50	39	2010		66.2	97.50					
14	1985	66.20	25.10	35.00	40	2011								
15	1986	19.60	25.20	37.50	41	2012								
16	1987	42.20	26.00	40.00	42	2013								
17	1988	27.00	26.50	42.50	43	2014								
18	1989	35.10	26.50	45.00	44	2015								
19	1990	34.30	27.00	47.50	45	2016	24.7							
20	1991	22.60	27.30	50.00	46	2017	21.2							
21	1992		29.00	52.50	47	2018	20.5							
22	1993	34.20	30.40	55.00	48	2019	56.3							
23	1994	35.50	32.00	57.50										
24	1995	32.20	32.20	60.00										
25	1996	25.00	34.20	62.50										
26	1997	43.60	34.30	65.00										

Dağılım Tipi	2	5	10	25	50	100	200	500	Kabul Edilen
Normal Dağılım	31.95	41.09	45.87	50.97	54.26	57.22	59.92	63.18	
Log-Normal (2 Parametreli)	30.25	39.96	46.22	53.98	59.66	65.29	70.89	78.29	
Log-Normal (3 Parametreli)	30.09	39.78	46.15	54.19	60.14	66.10	72.08	80.05	
Pearson Tip-3 (Gama Tip-3)	29.77	39.85	46.50	54.70	60.62	66.39	72.03	77.67	
Log-Pearson Tip-3	29.50	39.01	45.94	55.50	63.18	71.39	80.19	90.07	*******
Gumbel	30.27	41.08	48.23	57.28	63.98	70.64	77.28	86.03	

DAĞILIMLARIN İSTATİSTİK PARAMETRELERİ

Yıl Sayısı	39
Lineer Çarpıklık Katsayısı	1.23407
Logaritmik Çarpıklık Katsayısı	0.58382
Lineer Ortalama	31.94872
Lineer Standart Sapma	10.86297
Logaritmik Ortalama	1.48289
Logaritmik Standart Sapma	0.13512

DAĞILIM TİPLERİNİN SİMİRNOV-KOLMOGOROV TESTİNE GÖRE SONUÇLARI

Dağılım Tipi	Teorik P	Amprik P	Maksimum P Δmax	P deki Gözlem Değeri	Anlamlılık Yüzdeleri				
					0.80	0.85	0.90	0.95	0.99
Normal Dağılım	0.666	0.500	**0.166**	27.3	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (2 Parametreli)	0.622	0.500	**0.122**	27.3	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (3 Parametreli)	0.618	0.500	**0.118**	27.3	Kabul	Kabul	Kabul	Kabul	Kabul
Pearson Tip-3 (Gama Tip-3)	0.394	0.500	**0.106**	27.3	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Pearson Tip-3	0.402	0.500	**0.098**	27.3	Kabul	Kabul	Kabul	Kabul	Kabul
Gumbel	0.388	0.500	**0.112**	27.3	Kabul	Kabul	Kabul	Kabul	Kabul

HAYMANA KK + HAYMANA METEOROLOJİ İSTASYONU
GÜNLÜK MAKSİMUM YAĞIŞLARININ EKSTREM DAĞILIM HESABI

Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %
1	1957	28.00	17.70	3.70	27	1983	22.40			53	2009			
2	1958		19.00	7.41	28	1984				54	2010			
3	1959	31.20	21.50	11.11	29	1985				55	2011			
4	1960	43.90	22.10	14.81	30	1986				56	2012			
5	1961		22.40	18.52	31	1987	35.10			57	2013			
6	1962		25.20	22.22	32	1988	42.30			58	2014	35.4		
7	1963	28.30	27.10	25.93	33	1989				59	2015	38.7		
8	1964	39.30	27.30	29.63	34	1990	47.7			60	2016	33.8		
9	1965		28.00	33.33	35	1991				61	2017	41.9		
10	1966		28.30	37.04	36	1992				62	2018	34.8		
11	1967	19.00	28.40	40.74	37	1993				63	2019	31.5		
12	1968	31.20	31.20	44.44	38	1994								
13	1969		31.20	48.15	39	1995								
14	1970	21.50	31.40	51.85	40	1996								
15	1971	31.40	31.50	55.56	41	1997								
16	1972	27.10	33.80	59.26	42	1998								
17	1973	25.20	34.80	62.96	43	1999								
18	1974	22.10	35.10	66.67	44	2000								
19	1975	28.40	35.40	70.37	45	2001								
20	1976	45.40	38.70	74.07	46	2002								
21	1977	17.70	39.30	77.78	47	2003								
22	1978		41.90	81.48	48	2004								
23	1979		42.30	85.19	49	2005								
24	1980	27.30	43.90	88.89	50	2006								
25	1981		45.40	92.59	51	2007								
26	1982		47.70	96.30	52	2008								

Dağılım Tipi	2	5	10	25	50	100	200	500	Kabul Edilen
Normal Dağılım	31.95	38.91	42.55	46.44	48.95	51.20	53.26	55.74	
Log-Normal (2 Parametreli)	30.92	38.32	42.87	48.32	52.20	55.96	59.62	64.36	
Log-Normal (3 Parametreli)	31.72	38.83	42.68	46.89	49.66	52.20	54.54	57.41	
Pearson Tip-3 (Gama Tip-3)	31.71	38.83	42.69	46.92	49.70	52.24	54.60	56.96	
Log-Pearson Tip-3	31.34	38.86	43.14	47.95	51.18	54.15	56.93	59.85	*******
Gumbel	30.70	39.26	44.92	52.08	57.39	62.67	67.92	74.85	

DAĞILIMLARIN İSTATİSTİK PARAMETRELERİ

Yıl Sayısı	26
Lineer Çarpıklık Katsayısı	0.17231
Logaritmik Çarpıklık Katsayısı	-0.32327
Lineer Ortalama	31.94615
Lineer Standart Sapma	8.27745
Logaritmik Ortalama	1.48976
Logaritmik Standart Sapma	0.11687

DAĞILIM TİPLERİNİN SİMİRNOV-KOLMOGOROV TESTİNE GÖRE SONUÇLARI

Dağılım Tipi	Teorik P	Amprik P	Maksimum P Δmax	P deki Gözlem Değeri	Anlamlılık Yüzdeleri 0.80	0.85	0.90	0.95	0.99
Normal Dağılım	0.522	0.556	**0.077**	31.5	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (2 Parametreli)	0.897	0.185	**0.082**	22.4	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (3 Parametreli)	0.884	0.815	**0.069**	41.9	Kabul	Kabul	Kabul	Kabul	Kabul
Pearson Tip-3 (Gama Tip-3)	0.491	0.556	**0.065**	31.5	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Pearson Tip-3	0.124	0.185	**0.061**	22.4	Kabul	Kabul	Kabul	Kabul	Kabul
Gumbel	0.523	0.444	**0.078**	31.2	Kabul	Kabul	Kabul	Kabul	Kabul

İKİZCE + HAYMANA TARIM METEOROLOJİ İSTASYONU
GÜNLÜK MAKSİMUM YAĞIŞLARININ EKSTREM DAĞILIM HESABI

Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %
1	1966	21.90	16.00	1.89	27	1992	16.70	27.1	50.94	53	2018	35.4		
2	1967	16.00	16.60	3.77	28	1993	23.60	27.2	52.83	54	2019	21.6		
3	1968	31.00	16.70	5.66	29	1994	30.90	28.0	54.72					
4	1969	47.50	17.70	7.55	30	1995	36.00	28.0	56.60					
5	1970	78.00	18.00	9.43	31	1996	20.50	29.1	58.49					
6	1971	22.50	19.00	11.32	32	1997	26.20	29.3	60.38					
7	1972	17.70	19.80	13.21	33	1998	29.9	29.9	62.26					
8	1973	19.00	20.00	15.09	34	1999	29.1	30.0	64.15					
9	1974	16.60	20.50	16.98	35	2000	22.8	30.9	66.04					
10	1975	28.00	21.10	18.87	36	2001	39.4	31.0	67.92					
11	1976	44.90	21.20	20.75	37	2002	38.4	32.0	69.81					
12	1977	21.40	21.20	22.64	38	2003	23.2	32.5	71.70					
13	1978	22.40	21.40	24.53	39	2004	20.0	33.4	73.58					
14	1979	21.10	21.60	26.42	40	2005		35.0	75.47					
15	1980	37.50	21.90	28.30	41	2006		35.4	77.36					
16	1981	27.10	22.40	30.19	42	2007	22.6	36.0	79.25					
17	1982	53.20	22.50	32.08	43	2008	21.2	37.5	81.13					
18	1983	23.30	22.60	33.96	44	2009	28.0	38.4	83.02					
19	1984	21.20	22.80	35.85	45	2010	46.6	38.4	84.91					
20	1985	26.10	22.80	37.74	46	2011	25.2	39.4	86.79					
21	1986	33.40	23.20	39.62	47	2012	18.0	39.7	88.68					
22	1987	38.40	23.30	41.51	48	2013	19.8	44.9	90.57					
23	1988	29.30	23.60	43.40	49	2014	27.2	46.6	92.45					
24	1989	32.00	25.20	45.28	50	2015	32.5	47.5	94.34					
25	1990	39.70	26.10	47.17	51	2016	22.8	53.2	96.23					
26	1991	35.00	26.20	49.06	52	2017	30.0	78.0	98.11					

Dağılım Tipi	2	5	10	25	50	100	200	500	Kabul Edilen
Normal Dağılım	29.07	38.42	43.30	48.51	51.87	54.90	57.66	60.99	
Log-Normal (2 Parametreli)	27.16	37.05	43.58	51.82	57.94	64.07	70.23	78.45	
Log-Normal (3 Parametreli)	26.47	35.95	42.92	52.45	60.02	67.98	76.35	88.07	
Pearson Tip-3 (Gama Tip-3)	25.64	35.80	43.51	53.73	61.46	69.20	76.94	84.68	
Log-Pearson Tip-3	26.37	35.56	42.58	52.60	60.93	70.06	80.10	91.57	*******
Gumbel	27.33	38.14	45.30	54.34	61.05	67.71	74.35	83.10	

DAĞILIMLARIN İSTATİSTİK PARAMETRELERİ

Yıl Sayısı	52
Lineer Çarpıklık Katsayısı	2.01834
Logaritmik Çarpıklık Katsayısı	0.73548
Lineer Ortalama	29.07308
Lineer Standart Sapma	11.10116
Logaritmik Ortalama	1.43855
Logaritmik Standart Sapma	0.14290

DAĞILIM TİPLERİNİN SİMİRNOV-KOLMOGOROV TESTİNE GÖRE SONUÇLARI

Dağılım Tipi	Teorik P	Amprik P	Maksimum P Δmax	P deki Gözlem Değeri	Anlamlılık Yüzdeleri				
					0.80	0.85	0.90	0.95	0.99
Normal Dağılım	0.689	0.434	**0.123**	23.6	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (2 Parametreli)	0.648	0.434	**0.082**	23.6	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (3 Parametreli)	0.639	0.434	**0.073**	23.6	Kabul	Kabul	Kabul	Kabul	Kabul
Pearson Tip-3 (Gama Tip-3)	0.500	0.094	**0.406**	18.0	Ret	Ret	Ret	Ret	Ret
Log-Pearson Tip-3	0.362	0.434	**0.072**	23.6	Kabul	Kabul	Kabul	Kabul	Kabul
Gumbel	0.217	0.132	**0.085**	19.8	Kabul	Kabul	Kabul	Kabul	Kabul

HAYMANA YENİCE + HAYMANA YENİCE BLD. METEOROLOJİ İSTASYONU
GÜNLÜK MAKSİMUM YAĞIŞLARININ EKSTREM DAĞILIM HESABI

Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %	Sıra No	Yıllar	X Değerleri mm	Sıralı X mm	m/(N+1) %
1	1986	19.10	19.10	6.67	27	2012								
2	1987	48.30	21.10	13.33	28	2013								
3	1988	21.90	21.90	20.00	29	2014								
4	1989	22.80	22.10	26.67	30	2015								
5	1990	43.50	22.80	33.33	31	2016	22.10							
6	1991	49.40	28.80	40.00	32	2017	28.80							
7	1992	37.90	31.40	46.67	33	2018	34.1							
8	1993	21.10	33.70	53.33	34	2019	33.7							
9	1994	47.50	34.10	60.00										
10	1995	31.40	37.90	66.67										
11	1996		43.50	73.33										
12	1997		47.50	80.00										
13	1998		48.30	86.67										
14	1999		49.40	93.33										
15	2000													
16	2001													
17	2002													
18	2003													
19	2004													
20	2005													
21	2006													
22	2007													
23	2008													
24	2009													
25	2010													
26	2011													

Dağılım Tipi	2	5	10	25	50	100	200	500	Kabul Edilen
Normal Dağılım	32.97	42.16	46.97	52.09	55.40	58.38	61.09	64.37	
Log-Normal (2 Parametreli)	31.30	41.06	47.33	55.07	60.72	66.30	71.83	79.13	
Log-Normal (3 Parametreli)	32.50	41.98	47.22	53.04	56.92	60.50	63.84	67.97	
Pearson Tip-3 (Gama Tip-3)	32.44	41.97	47.26	53.15	57.09	60.71	64.11	67.50	
Log-Pearson Tip-3	31.33	41.60	48.22	56.41	62.42	68.34	74.27	80.71	
Gumbel	31.42	43.68	51.80	62.06	69.66	77.22	84.74	94.67	*******

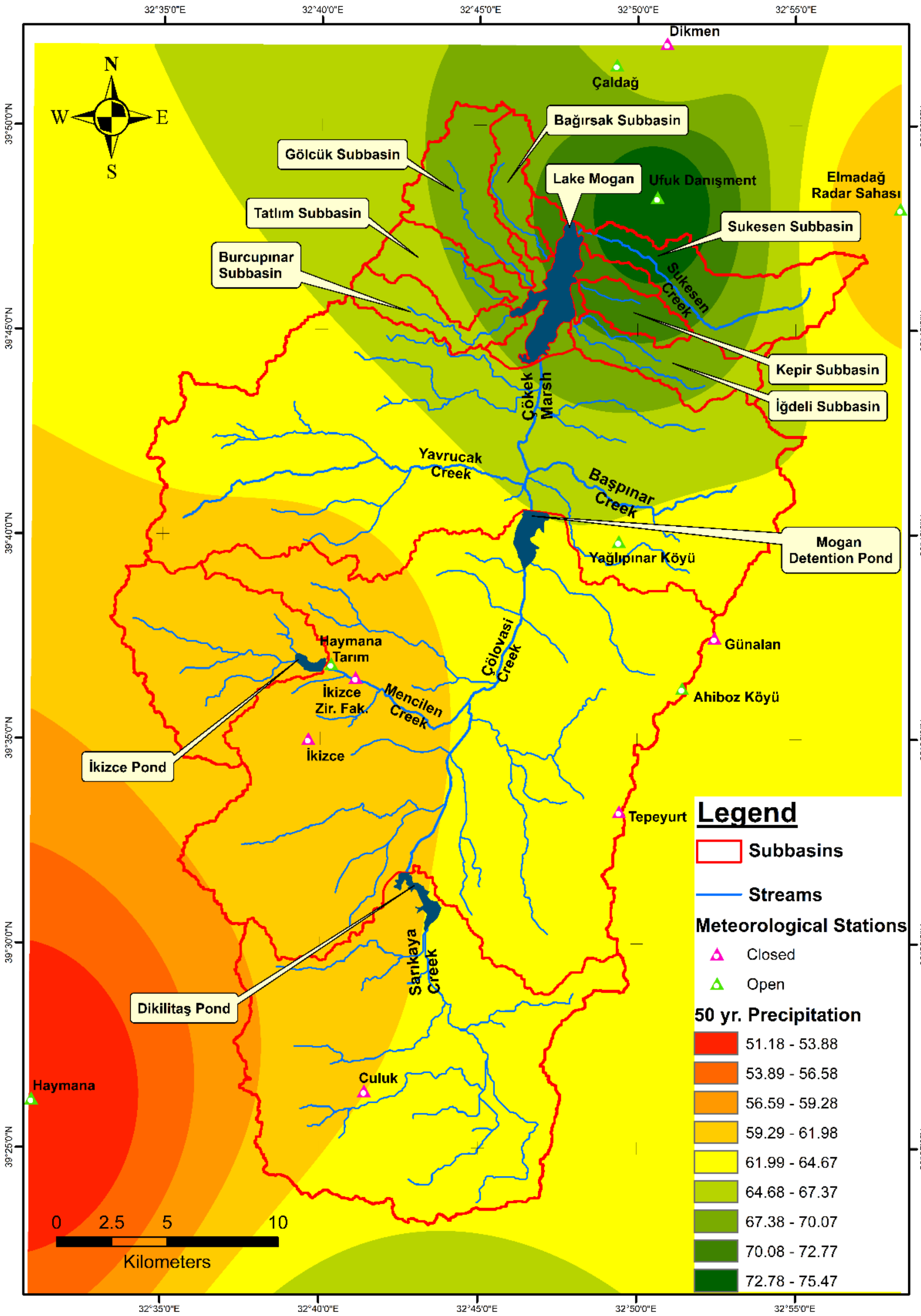
DAĞILIMLARIN İSTATİSTİK PARAMETRELERİ

Yıl Sayısı	14
Lineer Çarpıklık Katsayısı	0.29481
Logaritmik Çarpıklık Katsayısı	-0.01866
Lineer Ortalama	32.97143
Lineer Standart Sapma	10.92044
Logaritmik Ortalama	1.49545
Logaritmik Standart Sapma	0.14672

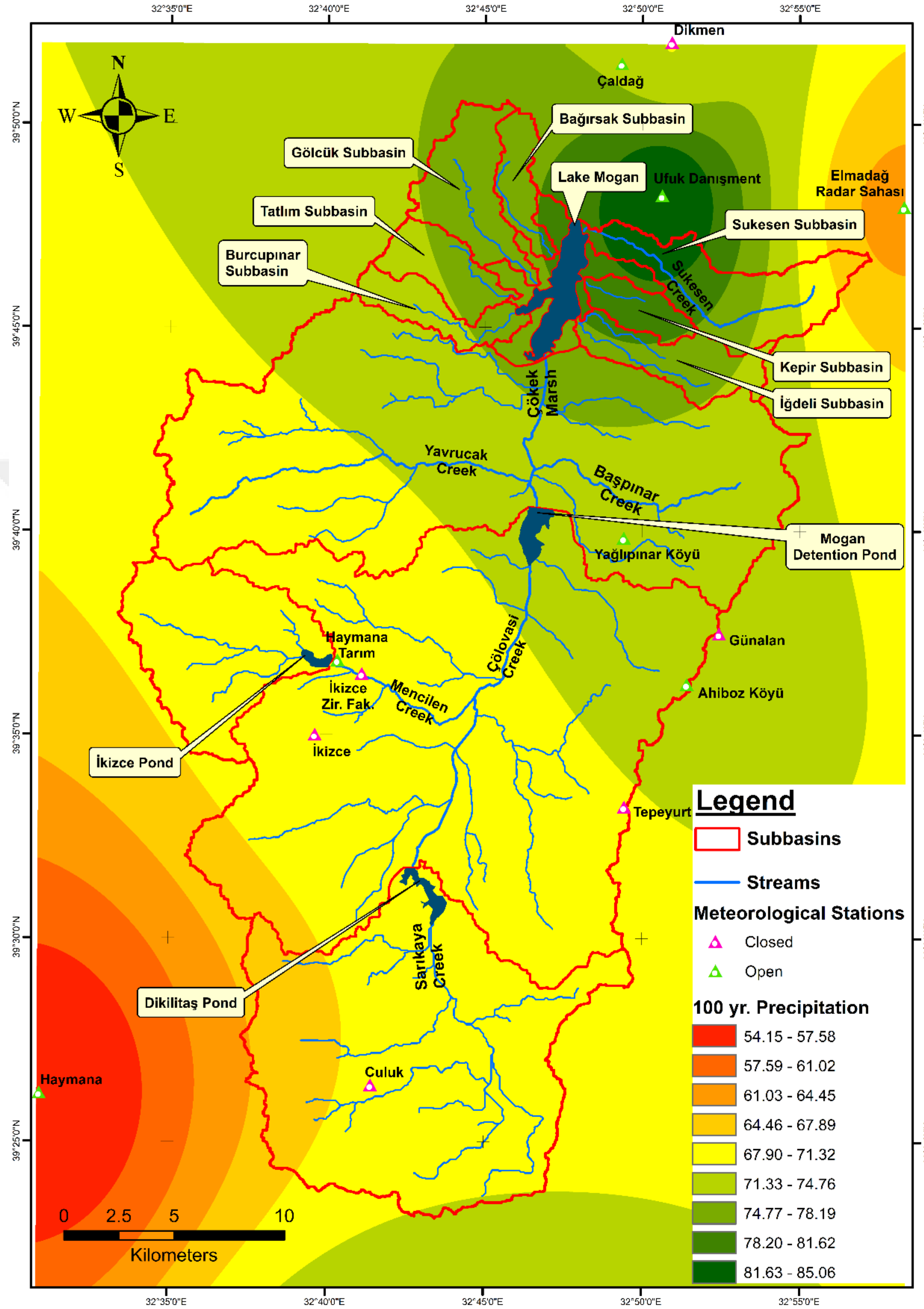
DAĞILIM TİPLERİNİN SİMİRNOV-KOLMOGOROV TESTİNE GÖRE SONUÇLARI

Dağılım Tipi	Teorik P	Amprik P	Maksimum P Δmax	P deki Gözlem Değeri	Anlamlılık Yüzdeleri				
					0.80	0.85	0.90	0.95	0.99
Normal Dağılım	0.824	0.333	**0.158**	22.8	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (2 Parametreli)	0.837	0.333	**0.170**	22.8	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Normal (3 Parametreli)	0.824	0.333	**0.157**	22.8	Kabul	Kabul	Kabul	Kabul	Kabul
Pearson Tip-3 (Gama Tip-3)	0.180	0.333	**0.153**	22.8	Kabul	Kabul	Kabul	Kabul	Kabul
Log-Pearson Tip-3	0.178	0.333	**0.155**	22.8	Kabul	Kabul	Kabul	Kabul	Kabul
Gumbel	0.215	0.333	**0.118**	22.8	Kabul	Kabul	Kabul	Kabul	Kabul

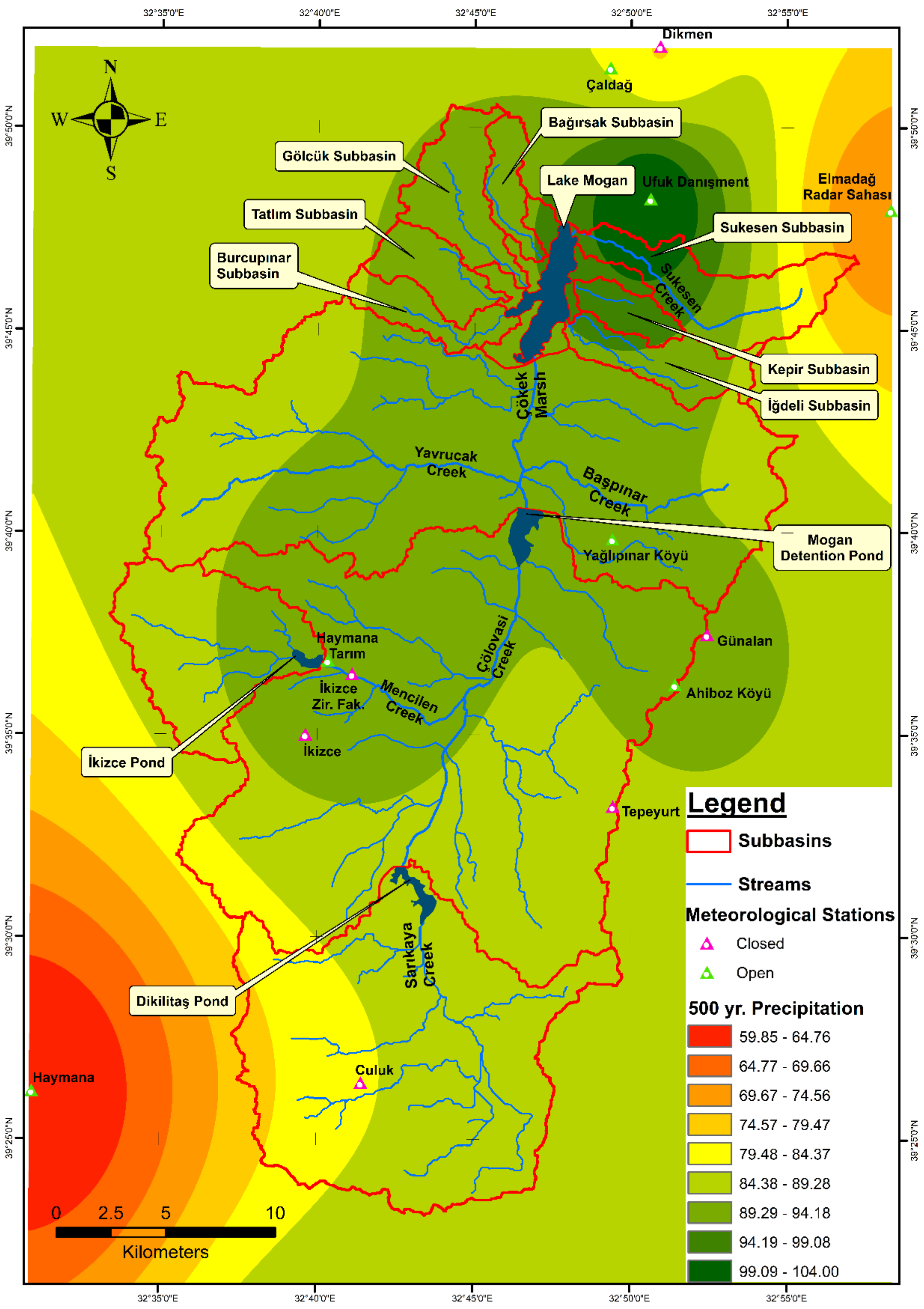
B. Areal Distribution of Design Storms



Areal Distribution of 50-year Design Storm



Areal Distribution of 100-year Design Storm



Areal Distribution of 500-year Design Storm

C. Fictitious WRF and ALR Forecasts of Design Storms for Subbasins

Sukesen Subbasin				
	Areal Values of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.001	0.002	0.002	0.002
06:00	0.354	1.090	1.209	1.440
07:00	1.232	3.799	4.213	5.016
08:00	2.375	7.326	8.126	9.674
09:00	2.605	8.033	8.910	10.608
10:00	1.990	6.138	6.808	8.105
11:00	1.684	5.194	5.761	6.859
12:00	3.001	9.258	10.268	12.225
13:00	3.170	9.776	10.844	12.910
14:00	2.353	7.257	8.049	9.583
15:00	1.051	3.242	3.596	4.282
16:00	0.938	2.893	3.209	3.820
17:00	0.863	2.661	2.952	3.514
18:00	0.369	1.137	1.261	1.502
19:00	0.191	0.589	0.653	0.777
20:00	0.105	0.322	0.358	0.426
21:00	0.000	0.000	0.000	0.000
22:00	0.003	0.010	0.012	0.014
23:00	0.000	0.000	0.000	0.000
Total	22.282	68.728	76.231	90.756
Ratio		3.084	3.421	4.073

On the Day				
	Areal WRF Forecasts for			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.154	0.473	0.525	0.625
06:00	0.899	2.772	3.075	3.660
07:00	1.438	4.434	4.918	5.855
08:00	1.734	5.349	5.933	7.063
09:00	1.588	4.897	5.432	6.467
10:00	1.954	6.028	6.686	7.960
11:00	1.921	5.926	6.573	7.825
12:00	2.051	6.325	7.015	8.352
13:00	1.383	4.266	4.732	5.634
14:00	0.933	2.878	3.192	3.800
15:00	0.597	1.840	2.041	2.430
16:00	0.360	1.111	1.232	1.467
17:00	0.419	1.292	1.433	1.707
18:00	0.288	0.889	0.986	1.173
19:00	0.053	0.162	0.180	0.214
20:00	0.010	0.032	0.035	0.042
21:00	0.006	0.019	0.021	0.024
22:00	0.017	0.051	0.056	0.067
23:00	0.068	0.208	0.231	0.275
Total	15.871	48.952	54.296	64.642
Ratio		3.084	3.421	4.073

One Day Before				
	Areal WRF forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.002	0.007	0.008	0.009
01:00	0.002	0.007	0.008	0.009
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000
06:00	0.000	0.000	0.000	0.000
07:00	0.000	0.000	0.000	0.000
08:00	0.000	0.000	0.000	0.000
09:00	0.017	0.053	0.059	0.070
10:00	0.023	0.069	0.077	0.092
11:00	0.035	0.109	0.120	0.143
12:00	0.354	1.091	1.210	1.440
13:00	1.119	3.451	3.828	4.558
14:00	0.665	2.050	2.274	2.707
15:00	1.322	4.077	4.522	5.384
16:00	1.694	5.226	5.796	6.900
17:00	1.833	5.654	6.271	7.466
18:00	1.294	3.992	4.427	5.271
19:00	0.568	1.751	1.943	2.313
20:00	0.640	1.972	2.188	2.605
21:00	0.520	1.605	1.780	2.120
22:00	0.180	0.556	0.616	0.734
23:00	0.104	0.322	0.357	0.425
Total	10.372	31.993	35.485	42.246
Ratio		3.084	3.421	4.073

Two Days Before				
	Areal WRF Forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.040	0.122	0.135	0.161
01:00	0.021	0.066	0.073	0.087
02:00	0.003	0.008	0.009	0.011
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000
06:00	0.000	0.000	0.000	0.000
07:00	0.000	0.000	0.000	0.000
08:00	0.000	0.000	0.000	0.000
09:00	0.000	0.000	0.000	0.000
10:00	0.000	0.000	0.000	0.000
11:00	0.060	0.185	0.205	0.244
12:00	0.961	2.965	3.288	3.915
13:00	1.301	4.013	4.451	5.299
14:00	0.122	0.377	0.418	0.497
15:00	0.001	0.003	0.003	0.004
16:00	0.008	0.025	0.028	0.033
17:00	0.083	0.257	0.285	0.340
18:00	0.300	0.925	1.026	1.222
19:00	0.330	1.016	1.127	1.342
20:00	0.160	0.495	0.549	0.653
21:00	0.024	0.075	0.083	0.099
22:00	0.044	0.134	0.149	0.178
23:00	0.010	0.031	0.034	0.040
Total	3.468	10.697	11.865	14.126
Ratio		3.084	3.421	4.073

Sukesen Subbasin				
	Areal Values of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.001	0.002	0.002	0.002
06:00	0.354	1.090	1.209	1.440
07:00	1.232	3.799	4.213	5.016
08:00	2.375	7.326	8.126	9.674
09:00	2.605	8.033	8.910	10.608
10:00	1.990	6.138	6.808	8.105
11:00	1.684	5.194	5.761	6.859
12:00	3.001	9.258	10.268	12.225
13:00	3.170	9.776	10.844	12.910
14:00	2.353	7.257	8.049	9.583
15:00	1.051	3.242	3.596	4.282
16:00	0.938	2.893	3.209	3.820
17:00	0.863	2.661	2.952	3.514
18:00	0.369	1.137	1.261	1.502
19:00	0.191	0.589	0.653	0.777
20:00	0.105	0.322	0.358	0.426
21:00	0.000	0.000	0.000	0.000
22:00	0.003	0.010	0.012	0.014
23:00	0.000	0.000	0.000	0.000
Total	22.282	68.728	76.231	90.756
Ratio		3.084	3.421	4.073

On the Day				
	Areal ALR Forecasts for			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.003	0.009	0.010	0.012
04:00	0.000	0.000	0.000	0.000
05:00	0.181	0.558	0.619	0.737
06:00	1.425	4.395	4.875	5.804
07:00	2.138	6.594	7.314	8.708
08:00	1.787	5.512	6.114	7.278
09:00	1.863	5.746	6.374	7.588
10:00	2.287	7.054	7.824	9.315
11:00	2.292	7.069	7.841	9.335
12:00	2.275	7.017	7.783	9.266
13:00	1.842	5.682	6.302	7.502
14:00	1.447	4.463	4.950	5.894
15:00	1.431	4.414	4.896	5.828
16:00	0.812	2.505	2.778	3.307
17:00	0.270	0.833	0.924	1.100
18:00	0.050	0.154	0.171	0.204
19:00	0.016	0.049	0.055	0.065
20:00	0.005	0.015	0.017	0.020
21:00	0.000	0.000	0.000	0.000
22:00	0.002	0.006	0.007	0.008
23:00	0.003	0.009	0.010	0.012
Total	20.129	62.086	68.864	81.986
Ratio		3.084	3.421	4.073

One Day Before				
	Areal ALR forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.239	0.737	0.818	0.973
06:00	1.127	3.476	3.856	4.590
07:00	2.842	8.766	9.723	11.575
08:00	3.588	11.067	12.275	14.614
09:00	2.206	6.804	7.547	8.985
10:00	0.428	1.320	1.464	1.743
11:00	2.199	6.783	7.523	8.957
12:00	1.894	5.842	6.480	7.714
13:00	2.734	8.433	9.353	11.136
14:00	0.560	1.727	1.916	2.281
15:00	0.181	0.558	0.619	0.737
16:00	0.359	1.107	1.228	1.462
17:00	0.951	2.933	3.254	3.873
18:00	1.674	5.163	5.727	6.818
19:00	1.012	3.121	3.462	4.122
20:00	0.309	0.953	1.057	1.259
21:00	0.090	0.278	0.308	0.367
22:00	0.040	0.123	0.137	0.163
23:00	0.025	0.077	0.086	0.102
Total	22.458	69.270	76.832	91.472
Ratio		3.084	3.421	4.073

Two Days Before				
	Areal ALR Forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000
06:00	0.000	0.000	0.000	0.000
07:00	0.000	0.000	0.000	0.000
08:00	0.000	0.000	0.000	0.000
09:00	0.005	0.015	0.017	0.020
10:00	0.409	1.262	1.399	1.666
11:00	0.613	1.891	2.097	2.497
12:00	0.740	2.282	2.532	3.014
13:00	0.800	2.468	2.737	3.258
14:00	1.223	3.772	4.184	4.981
15:00	3.161	9.750	10.814	12.875
16:00	2.120	6.539	7.253	8.635
17:00	0.619	1.909	2.118	2.521
18:00	0.172	0.531	0.588	0.701
19:00	0.086	0.265	0.294	0.350
20:00	0.021	0.065	0.072	0.086
21:00	0.001	0.003	0.003	0.004
22:00	0.000	0.000	0.000	0.000
23:00	0.000	0.000	0.000	0.000
Total	9.970	30.752	34.109	40.608
Ratio		3.084	3.421	4.073

	Kepir Subbasin				On the Day				One Day Before				Two Days Before			
	Areal Values of				Areal WRF Forecasts for				Areal WRF forecasts of				Areal WRF Forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.005	0.006	0.007	0.057	0.174	0.195	0.235
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.022	0.066	0.074	0.089
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.016	0.018	0.022
03:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000	0.099	0.301	0.337	0.407	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
06:00	0.431	1.328	1.473	1.754	0.758	2.312	2.587	3.124	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
07:00	1.421	4.383	4.862	5.788	1.384	4.220	4.723	5.704	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
08:00	2.602	8.026	8.902	10.598	1.782	5.431	6.078	7.341	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
09:00	2.669	8.231	9.130	10.870	1.493	4.552	5.094	6.152	0.022	0.067	0.075	0.090	0.000	0.000	0.000	0.000
10:00	1.968	6.071	6.734	8.017	1.797	5.476	6.129	7.402	0.024	0.074	0.083	0.100	0.000	0.000	0.000	0.000
11:00	1.700	5.243	5.815	6.923	1.710	5.213	5.835	7.047	0.016	0.049	0.055	0.066	0.029	0.087	0.098	0.118
12:00	2.861	8.826	9.789	11.655	1.753	5.342	5.979	7.221	0.148	0.450	0.503	0.608	0.613	1.869	2.091	2.526
13:00	3.376	10.414	11.551	13.752	1.422	4.334	4.850	5.857	0.505	1.538	1.721	2.079	2.128	6.485	7.258	8.765
14:00	2.571	7.930	8.796	10.472	0.956	2.913	3.260	3.938	0.502	1.530	1.712	2.067	0.239	0.728	0.814	0.983
15:00	1.162	3.583	3.974	4.731	0.384	1.171	1.310	1.583	0.613	1.869	2.091	2.526	0.001	0.003	0.003	0.004
16:00	1.024	3.157	3.502	4.169	0.223	0.681	0.762	0.920	1.088	3.316	3.711	4.482	0.009	0.026	0.029	0.035
17:00	0.982	3.029	3.360	4.000	0.308	0.938	1.049	1.267	1.951	5.948	6.657	8.040	0.103	0.315	0.352	0.426
18:00	0.407	1.255	1.392	1.657	0.137	0.417	0.467	0.564	1.646	5.018	5.616	6.782	0.193	0.587	0.657	0.794
19:00	0.088	0.271	0.301	0.358	0.013	0.040	0.045	0.054	0.616	1.877	2.101	2.537	0.241	0.735	0.822	0.993
20:00	0.054	0.167	0.185	0.220	0.010	0.030	0.034	0.041	0.632	1.926	2.156	2.603	0.097	0.294	0.330	0.398
21:00	0.000	0.000	0.000	0.000	0.004	0.012	0.013	0.016	0.417	1.272	1.424	1.720	0.009	0.027	0.030	0.036
22:00	0.003	0.008	0.009	0.010	0.009	0.027	0.030	0.036	0.206	0.627	0.702	0.848	0.008	0.024	0.027	0.033
23:00	0.000	0.000	0.000	0.000	0.048	0.146	0.164	0.198	0.052	0.157	0.176	0.212	0.002	0.006	0.006	0.008
Total	23.318	71.080	79.553	96.072	14.289	43.556	48.748	58.870	8.439	25.724	28.790	34.769	3.754	11.442	12.806	15.465
Ratio		3.048	3.412	4.120		3.048	3.412	4.120		3.048	3.412	4.120		3.048	3.412	4.120

	Kepir Subbasin				On the Day				One Day Before				Two Days Before			
	Areal Values of				Areal ALR Forecasts for				Areal ALR forecasts of				Areal ALR Forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000	0.001	0.003	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000	0.085	0.259	0.290	0.350	0.142	0.433	0.484	0.585	0.000	0.000	0.000	0.000
06:00	0.431	1.328	1.473	1.754	1.320	4.024	4.503	5.438	0.776	2.365	2.647	3.197	0.000	0.000	0.000	0.000
07:00	1.421	4.383	4.862	5.788	2.322	7.078	7.922	9.567	2.829	8.624	9.651	11.656	0.000	0.000	0.000	0.000
08:00	2.602	8.026	8.902	10.598	1.881	5.734	6.417	7.750	4.270	13.016	14.568	17.593	0.000	0.000	0.000	0.000
09:00	2.669	8.231	9.130	10.870	2.049	6.246	6.990	8.442	2.276	6.938	7.765	9.377	0.004	0.012	0.014	0.016
10:00	1.968	6.071	6.734	8.017	2.656	8.096	9.061	10.943	0.292	0.890	0.996	1.203	0.486	1.481	1.658	2.002
11:00	1.700	5.243	5.815	6.923	2.333	7.112	7.959	9.612	2.467	7.520	8.416	10.164	0.574	1.750	1.958	2.365
12:00	2.861	8.826	9.789	11.655	2.399	7.313	8.184	9.884	1.490	4.542	5.083	6.139	0.578	1.762	1.972	2.381
13:00	3.376	10.414	11.551	13.752	2.087	6.362	7.120	8.599	1.938	5.908	6.612	7.985	0.661	2.015	2.255	2.723
14:00	2.571	7.930	8.796	10.472	1.641	5.002	5.598	6.761	0.311	0.948	1.061	1.281	1.324	4.036	4.517	5.455
15:00	1.162	3.583	3.974	4.731	1.440	4.390	4.913	5.933	0.145	0.442	0.495	0.597	2.755	8.398	9.399	11.351
16:00	1.024	3.157	3.502	4.169	0.815	2.484	2.780	3.358	0.285	0.869	0.972	1.174	2.031	6.191	6.929	8.368
17:00	0.982	3.029	3.360	4.000	0.247	0.753	0.843	1.018	0.585	1.783	1.996	2.410	0.584	1.780	1.992	2.406
18:00	0.407	1.255	1.392	1.657	0.025	0.076	0.085	0.103	1.788	5.450	6.100	7.367	0.172	0.524	0.587	0.709
19:00	0.088	0.271	0.301	0.358	0.012	0.037	0.041	0.049	1.587	4.838	5.414	6.539	0.104	0.317	0.355	0.428
20:00	0.054	0.167	0.185	0.220	0.006	0.018	0.020	0.025	0.533	1.625	1.818	2.196	0.013	0.040	0.044	0.054
21:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.166	0.506	0.566	0.684	0.000	0.000	0.000	0.000
22:00	0.003	0.008	0.009	0.010	0.005	0.015	0.017	0.021	0.083	0.253	0.283	0.342	0.000	0.000	0.000	0.000
23:00	0.000	0.000	0.000	0.000	0.005	0.015	0.017	0.021	0.057	0.174	0.194	0.235	0.000	0.000	0.000	0.000
Total	23.318	71.080	79.553	96.072	21.329	65.017	72.766	87.876	22.020	67.123	75.124	90.723	9.286	28.306	31.680	38.259
Ratio		3.048	3.412	4.120		3.048	3.412	4.120		3.048	3.412	4.120		3.048	3.412	4.120

	İğdeli Subbasin				On the Day				One Day Before				Two Days Before			
Hours	Areal Values of				Areal WRF Forecasts for				Areal WRF forecasts of				Areal WRF Forecasts of			
	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.001	0.003	0.004	0.005	0.079	0.242	0.270	0.325
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.004	0.005	0.018	0.054	0.060	0.073
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.008	0.009	0.011
03:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000	0.195	0.596	0.665	0.801	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
06:00	0.413	1.275	1.414	1.684	0.878	2.681	2.990	3.603	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
07:00	1.253	3.865	4.287	5.103	1.262	3.853	4.298	5.178	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
08:00	2.291	7.065	7.836	9.329	1.673	5.106	5.696	6.862	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
09:00	2.387	7.361	8.165	9.721	1.516	4.628	5.161	6.218	0.015	0.044	0.049	0.059	0.000	0.000	0.000	0.000
10:00	1.943	5.992	6.646	7.913	1.864	5.690	6.347	7.647	0.025	0.075	0.084	0.101	0.000	0.000	0.000	0.000
11:00	1.799	5.548	6.154	7.327	1.992	6.080	6.781	8.170	0.033	0.100	0.111	0.134	0.031	0.093	0.104	0.125
12:00	2.830	8.727	9.680	11.525	2.256	6.885	7.680	9.253	0.273	0.834	0.930	1.121	0.614	1.875	2.092	2.520
13:00	3.107	9.584	10.630	12.655	1.918	5.853	6.529	7.866	0.866	2.643	2.948	3.551	2.095	6.395	7.133	8.593
14:00	2.432	7.501	8.320	9.905	1.389	4.238	4.727	5.695	0.718	2.191	2.444	2.944	0.397	1.211	1.351	1.628
15:00	1.338	4.125	4.576	5.448	0.726	2.215	2.470	2.976	0.855	2.610	2.911	3.507	0.002	0.007	0.008	0.009
16:00	1.124	3.467	3.846	4.578	0.206	0.629	0.701	0.845	0.905	2.763	3.082	3.713	0.005	0.016	0.018	0.022
17:00	0.912	2.814	3.121	3.716	0.255	0.779	0.869	1.047	1.419	4.331	4.831	5.820	0.067	0.206	0.229	0.276
18:00	0.398	1.227	1.361	1.621	0.142	0.435	0.485	0.584	1.169	3.567	3.979	4.794	0.174	0.531	0.592	0.714
19:00	0.132	0.407	0.451	0.537	0.018	0.055	0.062	0.074	0.450	1.373	1.532	1.845	0.195	0.596	0.665	0.801
20:00	0.081	0.250	0.277	0.330	0.007	0.020	0.023	0.027	0.458	1.397	1.558	1.877	0.077	0.236	0.263	0.317
21:00	0.000	0.000	0.000	0.000	0.003	0.008	0.009	0.011	0.342	1.045	1.165	1.404	0.010	0.032	0.035	0.043
22:00	0.004	0.011	0.012	0.015	0.010	0.031	0.035	0.042	0.147	0.449	0.501	0.603	0.014	0.044	0.049	0.059
23:00	0.000	0.000	0.000	0.000	0.054	0.164	0.182	0.220	0.066	0.200	0.223	0.269	0.005	0.015	0.017	0.021
Total	22.442	68.502	76.407	92.052	16.363	49.948	55.712	67.120	7.741	23.630	26.357	31.754	3.788	11.561	12.895	15.536
Ratio		3.052	3.405	4.102		3.052	3.405	4.102		3.052	3.405	4.102		3.052	3.405	4.102

	İğdeli Subbasin				On the Day				One Day Before				Two Days Before			
Hours	Areal Values of				Areal ALR Forecasts for				Areal ALR forecasts of				Areal ALR Forecasts of			
	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000	0.002	0.006	0.007	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000	0.198	0.604	0.674	0.812	0.190	0.580	0.647	0.779	0.000	0.000	0.000	0.000
06:00	0.413	1.275	1.414	1.684	1.662	5.073	5.659	6.817	0.958	2.924	3.262	3.930	0.000	0.000	0.000	0.000
07:00	1.253	3.865	4.287	5.103	2.290	6.990	7.797	9.393	3.032	9.255	10.323	12.437	0.000	0.000	0.000	0.000
08:00	2.291	7.065	7.836	9.329	1.831	5.589	6.234	7.510	3.723	11.364	12.676	15.271	0.000	0.000	0.000	0.000
09:00	2.387	7.361	8.165	9.721	2.007	6.126	6.833	8.232	2.305	7.036	7.848	9.455	0.013	0.040	0.044	0.053
10:00	1.943	5.992	6.646	7.913	2.607	7.958	8.876	10.693	0.332	1.013	1.130	1.362	0.609	1.859	2.073	2.498
11:00	1.799	5.548	6.154	7.327	2.364	7.216	8.049	9.697	2.401	7.329	8.175	9.849	0.760	2.320	2.588	3.117
12:00	2.830	8.727	9.680	11.525	2.431	7.421	8.277	9.972	1.869	5.705	6.363	7.666	0.833	2.543	2.836	3.417
13:00	3.107	9.584	10.630	12.655	2.037	6.218	6.935	8.355	2.100	6.410	7.150	8.614	0.827	2.524	2.816	3.392
14:00	2.432	7.501	8.320	9.905	1.491	4.551	5.076	6.116	0.264	0.806	0.899	1.083	1.221	3.727	4.157	5.008
15:00	1.338	4.125	4.576	5.448	1.408	4.298	4.794	5.775	0.137	0.418	0.466	0.562	2.665	8.135	9.073	10.931
16:00	1.124	3.467	3.846	4.578	0.796	2.430	2.710	3.265	0.250	0.763	0.851	1.025	2.158	6.587	7.347	8.852
17:00	0.912	2.814	3.121	3.716	0.292	0.891	0.994	1.198	0.580	1.770	1.975	2.379	0.728	2.222	2.479	2.986
18:00	0.398	1.227	1.361	1.621	0.065	0.198	0.221	0.267	1.553	4.740	5.287	6.370	0.218	0.665	0.742	0.894
19:00	0.132	0.407	0.451	0.537	0.018	0.055	0.061	0.074	1.437	4.386	4.893	5.894	0.133	0.406	0.453	0.546
20:00	0.081	0.250	0.277	0.330	0.005	0.015	0.017	0.021	0.509	1.554	1.733	2.088	0.029	0.089	0.099	0.119
21:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.157	0.479	0.535	0.644	0.000	0.000	0.000	0.000
22:00	0.004	0.011	0.012	0.015	0.003	0.009	0.010	0.012	0.069	0.211	0.235	0.283	0.000	0.000	0.000	0.000
23:00	0.000	0.000	0.000	0.000	0.003	0.009	0.010	0.012	0.046	0.140	0.157	0.189	0.000	0.000	0.000	0.000
Total	22.442	68.502	76.407	92.052	21.510	65.658	73.235	88.231	21.912	66.885	74.603	89.879	10.194	31.117	34.707	41.814
Ratio		3.052	3.405	4.102		3.052	3.405	4.102		3.052	3.405	4.102		3.052	3.405	4.102

Hours	Gölcük Subbasin Areal Values of				On the Day Areal WRF Forecasts for				One Day Before Areal WRF forecasts of				Two Days Before Areal WRF Forecasts of			
	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.062	0.193	0.215	0.257	0.004	0.011	0.012	0.014
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.013	0.014	0.017
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.021	0.023	0.028
03:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000	0.020	0.061	0.068	0.081	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
06:00	0.454	1.401	1.554	1.850	0.844	2.611	2.909	3.477	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
07:00	1.187	3.660	4.059	4.833	2.107	6.522	7.267	8.684	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
08:00	2.635	8.127	9.014	10.732	1.653	5.116	5.701	6.812	0.004	0.013	0.014	0.017	0.000	0.000	0.000	0.000
09:00	2.299	7.092	7.866	9.365	1.429	4.423	4.929	5.889	0.007	0.021	0.024	0.028	0.000	0.000	0.000	0.000
10:00	1.702	5.249	5.822	6.932	1.754	5.429	6.049	7.228	0.041	0.127	0.142	0.169	0.000	0.001	0.001	0.001
11:00	1.680	5.181	5.747	6.842	1.317	4.076	4.542	5.427	0.021	0.066	0.073	0.088	0.031	0.097	0.108	0.129
12:00	2.410	7.434	8.245	9.816	0.960	2.972	3.311	3.957	0.070	0.216	0.240	0.287	0.148	0.457	0.509	0.608
13:00	2.897	8.936	9.911	11.800	1.302	4.030	4.491	5.366	0.319	0.987	1.100	1.314	0.456	1.410	1.571	1.878
14:00	2.429	7.493	8.311	9.895	1.018	3.150	3.510	4.194	0.894	2.768	3.085	3.686	0.077	0.237	0.264	0.315
15:00	1.365	4.211	4.671	5.561	0.687	2.127	2.370	2.831	0.454	1.404	1.565	1.870	0.000	0.000	0.000	0.000
16:00	1.338	4.126	4.576	5.448	0.741	2.295	2.557	3.056	1.891	5.853	6.522	7.793	0.036	0.110	0.123	0.147
17:00	0.993	3.064	3.398	4.046	0.574	1.777	1.980	2.366	2.907	8.997	10.025	11.979	0.103	0.319	0.356	0.425
18:00	0.408	1.259	1.396	1.662	0.209	0.647	0.721	0.861	2.955	9.147	10.192	12.178	0.156	0.483	0.538	0.643
19:00	0.118	0.365	0.405	0.482	0.029	0.089	0.099	0.119	1.429	4.422	4.927	5.888	0.240	0.743	0.828	0.990
20:00	0.073	0.226	0.251	0.299	0.072	0.223	0.249	0.298	1.002	3.102	3.457	4.131	0.071	0.220	0.245	0.293
21:00	0.000	0.000	0.000	0.000	0.014	0.042	0.047	0.056	0.507	1.570	1.749	2.090	0.002	0.006	0.007	0.008
22:00	0.003	0.008	0.009	0.011	0.024	0.073	0.082	0.098	0.088	0.273	0.304	0.364	0.000	0.001	0.001	0.001
23:00	0.000	0.000	0.000	0.000	0.039	0.119	0.133	0.159	0.004	0.014	0.015	0.018	0.000	0.000	0.000	0.000
Total	21.992	68.077	75.853	90.639	14.790	45.784	51.015	60.959	12.655	39.173	43.648	52.157	1.334	4.129	4.601	5.497
Ratio		3.096	3.449	4.122		3.096	3.449	4.122		3.096	3.449	4.122		3.096	3.449	4.122

Hours	Gölcük Subbasin Areal Values of				On the Day Areal ALR Forecasts for				One Day Before Areal ALR forecasts of				Two Days Before Areal ALR Forecasts of			
	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000	0.002	0.006	0.007	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000	0.038	0.118	0.131	0.157	0.047	0.145	0.162	0.194	0.000	0.000	0.000	0.000
06:00	0.454	1.401	1.554	1.850	0.614	1.901	2.118	2.531	0.447	1.384	1.542	1.842	0.000	0.000	0.000	0.000
07:00	1.187	3.660	4.059	4.833	1.629	5.043	5.619	6.714	2.233	6.912	7.702	9.203	0.000	0.000	0.000	0.000
08:00	2.635	8.127	9.014	10.732	1.677	5.191	5.784	6.912	3.854	11.930	13.293	15.884	0.000	0.000	0.000	0.000
09:00	2.299	7.092	7.866	9.365	1.749	5.414	6.033	7.209	1.565	4.845	5.398	6.450	0.000	0.000	0.000	0.000
10:00	1.702	5.249	5.822	6.932	2.189	6.776	7.550	9.022	0.418	1.294	1.442	1.723	0.061	0.189	0.210	0.251
11:00	1.680	5.181	5.747	6.842	2.777	8.596	9.578	11.445	2.399	7.426	8.275	9.888	0.107	0.331	0.369	0.441
12:00	2.410	7.434	8.245	9.816	2.776	8.593	9.575	11.441	0.764	2.365	2.635	3.149	0.186	0.576	0.642	0.767
13:00	2.897	8.936	9.911	11.800	1.884	5.832	6.498	7.765	1.765	5.464	6.088	7.274	1.084	3.356	3.739	4.468
14:00	2.429	7.493	8.311	9.895	1.729	5.352	5.964	7.126	0.406	1.257	1.400	1.673	2.842	8.798	9.803	11.713
15:00	1.365	4.211	4.671	5.561	1.590	4.922	5.484	6.553	0.353	1.093	1.218	1.455	2.398	7.423	8.271	9.883
16:00	1.338	4.126	4.576	5.448	0.612	1.894	2.111	2.522	0.676	2.093	2.332	2.786	1.585	4.906	5.467	6.533
17:00	0.993	3.064	3.398	4.046	0.155	0.480	0.535	0.639	1.501	4.646	5.177	6.186	0.234	0.724	0.807	0.964
18:00	0.408	1.259	1.396	1.662	0.030	0.093	0.103	0.124	2.203	6.820	7.599	9.080	0.068	0.210	0.235	0.280
19:00	0.118	0.365	0.405	0.482	0.019	0.059	0.066	0.078	1.242	3.845	4.284	5.119	0.089	0.276	0.307	0.367
20:00	0.073	0.226	0.251	0.299	0.012	0.037	0.041	0.049	0.442	1.368	1.525	1.822	0.004	0.012	0.014	0.016
21:00	0.000	0.000	0.000	0.000	0.008	0.025	0.028	0.033	0.225	0.697	0.776	0.927	0.002	0.006	0.007	0.008
22:00	0.003	0.008	0.009	0.011	0.029	0.090	0.100	0.120	0.174	0.539	0.600	0.717	0.000	0.000	0.000	0.000
23:00	0.000	0.000	0.000	0.000	0.120	0.371	0.414	0.495	0.118	0.365	0.407	0.486	0.000	0.000	0.000	0.000
Total	21.992	68.077	75.853	90.639	19.639	60.794	67.739	80.943	20.832	64.487	71.853	85.860	8.660	26.808	29.870	35.692
Ratio		3.096	3.449	4.122		3.096	3.449	4.122		3.096	3.449	4.122		3.096	3.449	4.122

	Burcupınar Subbasin				On the Day				One Day Before				Two Days Before			
	Areal Values of				Areal WRF Forecasts for				Areal WRF forecasts of				Areal WRF Forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.025	0.075	0.084	0.102	0.007	0.020	0.022	0.027
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.033	0.037	0.045
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.004	0.005
03:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000	0.042	0.128	0.144	0.175	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
06:00	0.407	1.255	1.392	1.657	1.199	3.676	4.113	4.994	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
07:00	1.175	3.625	4.020	4.786	1.726	5.294	5.923	7.192	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
08:00	2.441	7.528	8.349	9.940	1.798	5.513	6.167	7.488	0.001	0.002	0.002	0.002	0.000	0.000	0.000	0.000
09:00	2.302	7.099	7.874	9.374	1.502	4.605	5.152	6.255	0.002	0.006	0.007	0.008	0.000	0.000	0.000	0.000
10:00	1.802	5.558	6.165	7.339	1.908	5.851	6.546	7.948	0.028	0.086	0.096	0.117	0.000	0.000	0.000	0.000
11:00	1.829	5.641	6.257	7.450	1.529	4.689	5.246	6.369	0.013	0.040	0.045	0.054	0.006	0.017	0.020	0.024
12:00	2.475	7.635	8.468	10.082	1.196	3.667	4.102	4.981	0.064	0.197	0.221	0.268	0.156	0.477	0.533	0.648
13:00	2.743	8.460	9.384	11.172	1.748	5.360	5.996	7.280	0.151	0.462	0.517	0.628	1.341	4.114	4.602	5.588
14:00	2.325	7.173	7.956	9.471	1.483	4.547	5.087	6.176	1.192	3.655	4.089	4.964	0.272	0.835	0.935	1.135
15:00	1.480	4.565	5.063	6.028	0.786	2.410	2.696	3.273	0.230	0.705	0.789	0.958	0.000	0.001	0.001	0.001
16:00	1.249	3.853	4.274	5.088	0.628	1.925	2.154	2.615	0.622	1.907	2.134	2.591	0.009	0.028	0.031	0.037
17:00	0.861	2.656	2.946	3.507	0.658	2.018	2.257	2.741	1.813	5.559	6.219	7.552	0.041	0.126	0.141	0.171
18:00	0.367	1.130	1.254	1.493	0.255	0.783	0.876	1.064	2.066	6.334	7.086	8.604	0.091	0.278	0.310	0.377
19:00	0.123	0.381	0.422	0.503	0.032	0.097	0.109	0.132	0.796	2.440	2.730	3.315	0.130	0.400	0.447	0.543
20:00	0.101	0.311	0.345	0.410	0.065	0.201	0.224	0.272	0.533	1.633	1.827	2.219	0.044	0.136	0.152	0.185
21:00	0.000	0.000	0.000	0.000	0.004	0.011	0.013	0.015	0.408	1.251	1.399	1.699	0.001	0.004	0.004	0.005
22:00	0.003	0.008	0.009	0.010	0.015	0.046	0.051	0.062	0.086	0.263	0.294	0.357	0.000	0.001	0.001	0.002
23:00	0.000	0.000	0.000	0.000	0.062	0.190	0.213	0.258	0.005	0.016	0.018	0.022	0.000	0.000	0.000	0.000
Total	21.682	66.492	74.387	90.321	16.634	51.011	57.068	69.292	8.032	24.633	27.558	33.461	2.111	6.473	7.242	8.793
Ratio		3.067	3.431	4.166		3.067	3.431	4.166		3.067	3.431	4.166		3.067	3.431	4.166

	Burcupınar Subbasin				On the Day				One Day Before				Two Days Before			
	Areal Values of				Areal ALR Forecasts for				Areal ALR forecasts of				Areal ALR Forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000	0.001	0.003	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000	0.061	0.187	0.209	0.254	0.054	0.166	0.185	0.225	0.000	0.000	0.000	0.000
06:00	0.407	1.255	1.392	1.657	0.825	2.530	2.830	3.437	0.484	1.484	1.661	2.016	0.000	0.000	0.000	0.000
07:00	1.175	3.625	4.020	4.786	1.958	6.005	6.718	8.157	2.692	8.256	9.236	11.214	0.000	0.000	0.000	0.000
08:00	2.441	7.528	8.349	9.940	1.857	5.695	6.371	7.736	3.486	10.691	11.960	14.522	0.000	0.000	0.000	0.000
09:00	2.302	7.099	7.874	9.374	1.891	5.799	6.488	7.877	1.425	4.370	4.889	5.936	0.001	0.003	0.003	0.004
10:00	1.802	5.558	6.165	7.339	2.589	7.940	8.882	10.785	0.416	1.276	1.427	1.733	0.153	0.469	0.525	0.637
11:00	1.829	5.641	6.257	7.450	2.775	8.510	9.521	11.560	2.880	8.832	9.881	11.997	0.308	0.945	1.057	1.283
12:00	2.475	7.635	8.468	10.082	2.459	7.541	8.436	10.244	1.006	3.085	3.451	4.191	0.513	1.573	1.760	2.137
13:00	2.743	8.460	9.384	11.172	2.031	6.228	6.968	8.461	1.557	4.775	5.342	6.486	0.738	2.263	2.532	3.074
14:00	2.325	7.173	7.956	9.471	1.670	5.121	5.729	6.957	0.114	0.350	0.391	0.475	2.482	7.612	8.515	10.339
15:00	1.480	4.565	5.063	6.028	1.597	4.898	5.479	6.653	0.182	0.558	0.624	0.758	2.459	7.541	8.436	10.244
16:00	1.249	3.853	4.274	5.088	0.670	2.055	2.299	2.791	0.390	1.196	1.338	1.625	2.021	6.198	6.934	8.419
17:00	0.861	2.656	2.946	3.507	0.167	0.512	0.573	0.696	0.947	2.904	3.249	3.945	0.504	1.546	1.729	2.100
18:00	0.367	1.130	1.254	1.493	0.021	0.064	0.072	0.087	1.800	5.520	6.175	7.498	0.191	0.586	0.655	0.796
19:00	0.123	0.381	0.422	0.503	0.011	0.034	0.038	0.046	1.410	4.324	4.837	5.874	0.191	0.586	0.655	0.796
20:00	0.101	0.311	0.345	0.410	0.009	0.028	0.031	0.037	0.565	1.733	1.938	2.354	0.024	0.074	0.082	0.100
21:00	0.000	0.000	0.000	0.000	0.008	0.025	0.027	0.033	0.272	0.834	0.933	1.133	0.000	0.000	0.000	0.000
22:00	0.003	0.008	0.009	0.010	0.026	0.080	0.089	0.108	0.208	0.638	0.714	0.866	0.000	0.000	0.000	0.000
23:00	0.000	0.000	0.000	0.000	0.086	0.264	0.295	0.358	0.133	0.408	0.456	0.554	0.000	0.000	0.000	0.000
Total	21.682	66.492	74.387	90.321	20.712	63.518	71.059	86.281	20.021	61.399	68.689	83.402	9.585	29.394	32.885	39.929
Ratio		3.067	3.431	4.166		3.067	3.431	4.166		3.067	3.431	4.166		3.067	3.431	4.166

	Bağırsak Subbasin				On the Day				One Day Before				Two Days Before			
	Areal Values of				Areal WRF Forecasts for				Areal WRF forecasts of				Areal WRF Forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.108	0.120	0.143	0.005	0.014	0.016	0.019
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.014	0.016	0.019
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.022	0.025	0.029
03:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000	0.013	0.041	0.045	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
06:00	0.517	1.596	1.770	2.107	0.718	2.185	2.435	2.903	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
07:00	1.269	3.915	4.343	5.170	2.180	6.630	7.388	8.806	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
08:00	2.732	8.426	9.346	11.127	1.693	5.149	5.739	6.840	0.002	0.007	0.008	0.010	0.000	0.000	0.000	0.000
09:00	2.366	7.298	8.095	9.637	1.436	4.367	4.867	5.801	0.007	0.022	0.025	0.029	0.000	0.000	0.000	0.000
10:00	1.742	5.374	5.960	7.096	1.672	5.086	5.668	6.756	0.044	0.134	0.149	0.178	0.000	0.000	0.000	0.000
11:00	1.670	5.150	5.712	6.801	1.247	3.793	4.226	5.038	0.026	0.080	0.089	0.106	0.029	0.087	0.097	0.116
12:00	2.518	7.766	8.614	10.255	0.854	2.596	2.893	3.449	0.074	0.226	0.252	0.301	0.199	0.605	0.674	0.804
13:00	3.062	9.444	10.475	12.471	1.073	3.263	3.636	4.334	0.329	1.000	1.114	1.328	0.411	1.250	1.393	1.660
14:00	2.538	7.827	8.681	10.335	0.813	2.473	2.756	3.285	0.644	1.959	2.183	2.602	0.058	0.176	0.196	0.233
15:00	1.298	4.003	4.440	5.286	0.481	1.462	1.629	1.942	0.485	1.476	1.645	1.961	0.000	0.000	0.000	0.000
16:00	1.351	4.167	4.622	5.502	0.594	1.808	2.015	2.402	2.031	6.177	6.884	8.205	0.041	0.123	0.138	0.164
17:00	1.097	3.384	3.753	4.468	0.491	1.492	1.663	1.982	3.084	9.382	10.455	12.462	0.147	0.447	0.499	0.594
18:00	0.440	1.357	1.506	1.793	0.164	0.498	0.555	0.661	3.045	9.262	10.322	12.303	0.201	0.612	0.682	0.812
19:00	0.114	0.352	0.391	0.465	0.021	0.063	0.071	0.084	1.471	4.473	4.985	5.942	0.291	0.885	0.986	1.175
20:00	0.067	0.207	0.230	0.274	0.054	0.165	0.183	0.219	1.084	3.298	3.676	4.381	0.088	0.267	0.298	0.355
21:00	0.000	0.000	0.000	0.000	0.014	0.041	0.046	0.055	0.574	1.745	1.945	2.318	0.003	0.010	0.011	0.013
22:00	0.003	0.008	0.009	0.011	0.018	0.053	0.059	0.071	0.113	0.344	0.384	0.457	0.000	0.001	0.001	0.001
23:00	0.000	0.000	0.000	0.000	0.017	0.051	0.057	0.068	0.005	0.016	0.017	0.021	0.000	0.000	0.000	0.000
Total	22.784	69.300	77.227	92.052	13.551	41.216	45.931	54.748	13.055	39.710	44.252	52.747	1.484	4.514	5.030	5.996
Ratio		3.042	3.390	4.040		3.042	3.390	4.040		3.042	3.390	4.040		3.042	3.390	4.040

	Bağırsak Subbasin				On the Day				One Day Before				Two Days Before			
	Areal Values of				Areal ALR Forecasts for				Areal ALR forecasts of				Areal ALR Forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000	0.001	0.003	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000	0.024	0.073	0.081	0.097	0.058	0.176	0.197	0.234	0.000	0.000	0.000	0.000
06:00	0.517	1.596	1.770	2.107	0.621	1.889	2.105	2.509	0.507	1.542	1.719	2.048	0.000	0.000	0.000	0.000
07:00	1.269	3.915	4.343	5.170	1.692	5.146	5.735	6.836	2.230	6.783	7.559	9.010	0.000	0.000	0.000	0.000
08:00	2.732	8.426	9.346	11.127	1.690	5.140	5.728	6.828	3.963	12.054	13.433	16.011	0.000	0.000	0.000	0.000
09:00	2.366	7.298	8.095	9.637	1.758	5.347	5.959	7.103	1.609	4.894	5.454	6.501	0.000	0.000	0.000	0.000
10:00	1.742	5.374	5.960	7.096	2.107	6.409	7.142	8.513	0.338	1.028	1.146	1.366	0.082	0.249	0.278	0.331
11:00	1.670	5.150	5.712	6.801	2.560	7.787	8.677	10.343	2.135	6.494	7.237	8.626	0.127	0.386	0.430	0.513
12:00	2.518	7.766	8.614	10.255	2.456	7.470	8.325	9.923	0.857	2.607	2.905	3.462	0.185	0.563	0.627	0.747
13:00	3.062	9.444	10.475	12.471	1.826	5.554	6.189	7.377	1.625	4.943	5.508	6.565	0.938	2.853	3.179	3.790
14:00	2.538	7.827	8.681	10.335	1.698	5.165	5.756	6.860	0.538	1.636	1.824	2.174	2.408	7.324	8.162	9.729
15:00	1.298	4.003	4.440	5.286	1.539	4.681	5.217	6.218	0.370	1.125	1.254	1.495	2.445	7.437	8.288	9.878
16:00	1.351	4.167	4.622	5.502	0.648	1.971	2.196	2.618	0.776	2.360	2.630	3.135	1.521	4.626	5.156	6.145
17:00	1.097	3.384	3.753	4.468	0.148	0.450	0.502	0.598	1.431	4.353	4.851	5.782	0.224	0.681	0.759	0.905
18:00	0.440	1.357	1.506	1.793	0.018	0.055	0.061	0.073	2.329	7.084	7.894	9.410	0.055	0.167	0.186	0.222
19:00	0.114	0.352	0.391	0.465	0.016	0.049	0.054	0.065	1.394	4.240	4.725	5.632	0.053	0.161	0.180	0.214
20:00	0.067	0.207	0.230	0.274	0.009	0.027	0.031	0.036	0.488	1.484	1.654	1.972	0.003	0.009	0.010	0.012
21:00	0.000	0.000	0.000	0.000	0.004	0.012	0.014	0.016	0.226	0.687	0.766	0.913	0.001	0.003	0.003	0.004
22:00	0.003	0.008	0.009	0.011	0.017	0.052	0.058	0.069	0.164	0.499	0.556	0.663	0.000	0.000	0.000	0.000
23:00	0.000	0.000	0.000	0.000	0.073	0.222	0.247	0.295	0.116	0.353	0.393	0.469	0.000	0.000	0.000	0.000
Total	22.784	69.300	77.227	92.052	18.905	57.502	64.080	76.381	21.154	64.343	71.703	85.467	8.042	24.461	27.259	32.492
Ratio		3.042	3.390	4.040		3.042	3.390	4.040		3.042	3.390	4.040		3.042	3.390	4.040

Hours	Tatlım Subbasin: Areal Values of 14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000
06:00	0.417	1.285	1.426	1.697
07:00	1.175	3.623	4.019	4.785
08:00	2.514	7.755	8.601	10.240
09:00	2.308	7.119	7.896	9.401
10:00	1.764	5.439	6.033	7.183
11:00	1.761	5.432	6.025	7.173
12:00	2.442	7.533	8.356	9.948
13:00	2.800	8.637	9.580	11.405
14:00	2.360	7.280	8.075	9.614
15:00	1.440	4.443	4.928	5.867
16:00	1.276	3.934	4.364	5.195
17:00	0.904	2.789	3.093	3.682
18:00	0.380	1.171	1.299	1.546
19:00	0.122	0.377	0.418	0.497
20:00	0.090	0.278	0.308	0.367
21:00	0.000	0.000	0.000	0.000
22:00	0.003	0.009	0.010	0.012
23:00	0.000	0.000	0.000	0.000
Total	21.756	67.069	74.920	90.459
Ratio		3.083	3.444	4.158

Hours	On the Day: Areal WRF Forecasts for 14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.036	0.109	0.122	0.148
06:00	1.077	3.320	3.708	4.478
07:00	1.874	5.778	6.454	7.793
08:00	1.737	5.354	5.981	7.221
09:00	1.479	4.559	5.093	6.149
10:00	1.864	5.745	6.417	7.748
11:00	1.457	4.491	5.017	6.058
12:00	1.155	3.562	3.979	4.804
13:00	1.648	5.081	5.675	6.853
14:00	1.347	4.151	4.637	5.599
15:00	0.798	2.459	2.746	3.316
16:00	0.717	2.210	2.469	2.981
17:00	0.649	2.001	2.235	2.699
18:00	0.246	0.758	0.847	1.023
19:00	0.033	0.101	0.113	0.137
20:00	0.074	0.229	0.256	0.309
21:00	0.007	0.022	0.024	0.030
22:00	0.019	0.057	0.064	0.077
23:00	0.058	0.178	0.199	0.241
Total	16.273	50.167	56.039	67.663
Ratio		3.083	3.444	4.158

Hours	One Day Before: Areal WRF forecasts of 14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.046	0.141	0.157	0.190
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000
06:00	0.000	0.000	0.000	0.000
07:00	0.000	0.000	0.000	0.000
08:00	0.002	0.005	0.006	0.007
09:00	0.003	0.008	0.009	0.011
10:00	0.033	0.101	0.113	0.136
11:00	0.015	0.045	0.050	0.060
12:00	0.068	0.210	0.234	0.283
13:00	0.206	0.636	0.710	0.857
14:00	1.158	3.569	3.987	4.814
15:00	0.300	0.923	1.031	1.245
16:00	1.071	3.300	3.687	4.451
17:00	2.242	6.912	7.721	9.322
18:00	2.424	7.474	8.348	10.080
19:00	1.034	3.187	3.560	4.298
20:00	0.693	2.137	2.387	2.882
21:00	0.436	1.344	1.502	1.813
22:00	0.086	0.266	0.298	0.359
23:00	0.005	0.016	0.018	0.022
Total	9.820	30.273	33.816	40.830
Ratio		3.083	3.444	4.158

Hours	Two Days Before: Areal WRF Forecasts of 14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.006	0.018	0.020	0.024
01:00	0.008	0.026	0.029	0.035
02:00	0.003	0.009	0.010	0.012
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000
06:00	0.000	0.000	0.000	0.000
07:00	0.000	0.000	0.000	0.000
08:00	0.000	0.000	0.000	0.000
09:00	0.000	0.000	0.000	0.000
10:00	0.000	0.000	0.000	0.000
11:00	0.011	0.033	0.037	0.044
12:00	0.152	0.470	0.525	0.634
13:00	1.017	3.135	3.503	4.229
14:00	0.208	0.641	0.716	0.865
15:00	0.000	0.000	0.000	0.000
16:00	0.018	0.054	0.061	0.073
17:00	0.058	0.179	0.200	0.242
18:00	0.111	0.343	0.384	0.463
19:00	0.171	0.526	0.587	0.709
20:00	0.054	0.168	0.187	0.226
21:00	0.001	0.004	0.004	0.005
22:00	0.000	0.001	0.001	0.001
23:00	0.000	0.000	0.000	0.000
Total	1.819	5.607	6.263	7.562
Ratio		3.083	3.444	4.158

Hours	Tatlım Subbasin: Areal Values of 14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000
06:00	0.417	1.285	1.426	1.697
07:00	1.175	3.623	4.019	4.785
08:00	2.514	7.755	8.601	10.240
09:00	2.308	7.119	7.896	9.401
10:00	1.764	5.439	6.033	7.183
11:00	1.761	5.432	6.025	7.173
12:00	2.442	7.533	8.356	9.948
13:00	2.800	8.637	9.580	11.405
14:00	2.360	7.280	8.075	9.614
15:00	1.440	4.443	4.928	5.867
16:00	1.276	3.934	4.364	5.195
17:00	0.904	2.789	3.093	3.682
18:00	0.380	1.171	1.299	1.546
19:00	0.122	0.377	0.418	0.497
20:00	0.090	0.278	0.308	0.367
21:00	0.000	0.000	0.000	0.000
22:00	0.003	0.009	0.010	0.012
23:00	0.000	0.000	0.000	0.000
Total	21.756	67.069	74.920	90.459
Ratio		3.083	3.444	4.158

Hours	On the Day: Areal ALR Forecasts for 14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.001	0.003	0.003	0.004
04:00	0.000	0.000	0.000	0.000
05:00	0.047	0.145	0.162	0.195
06:00	0.716	2.207	2.466	2.977
07:00	1.831	5.645	6.305	7.613
08:00	1.803	5.558	6.209	7.497
09:00	1.849	5.700	6.367	7.688
10:00	2.467	7.605	8.495	10.257
11:00	2.823	8.703	9.721	11.738
12:00	2.576	7.941	8.871	10.711
13:00	1.969	6.070	6.780	8.187
14:00	1.691	5.213	5.823	7.031
15:00	1.593	4.911	5.486	6.623
16:00	0.646	1.991	2.225	2.686
17:00	0.160	0.493	0.551	0.665
18:00	0.025	0.077	0.086	0.104
19:00	0.015	0.046	0.052	0.062
20:00	0.011	0.034	0.038	0.046
21:00	0.011	0.034	0.038	0.046
22:00	0.031	0.096	0.107	0.129
23:00	0.102	0.314	0.351	0.424
Total	20.367	62.787	70.136	84.683
Ratio		3.083	3.444	4.158

Hours	One Day Before: Areal ALR forecasts of 14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.046	0.142	0.158	0.191
06:00	0.456	1.406	1.570	1.896
07:00	2.537	7.821	8.736	10.548
08:00	3.604	11.110	12.411	14.985
09:00	1.458	4.495	5.021	6.062
10:00	0.403	1.242	1.388	1.676
11:00	2.751	8.481	9.473	11.438
12:00	0.846	2.608	2.913	3.518
13:00	1.674	5.161	5.765	6.960
14:00	0.180	0.555	0.620	0.748
15:00	0.219	0.675	0.754	0.911
16:00	0.474	1.461	1.632	1.971
17:00	1.124	3.465	3.871	4.673
18:00	2.013	6.206	6.932	8.370
19:00	1.416	4.365	4.876	5.888
20:00	0.556	1.714	1.915	2.312
21:00	0.285	0.879	0.981	1.185
22:00	0.225	0.694	0.775	0.936
23:00	0.146	0.450	0.503	0.607
Total	20.413	62.929	70.295	84.874
Ratio		3.083	3.444	4.158

Hours	Two Days Before: Areal ALR Forecasts of 14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000
05:00	0.000	0.000	0.000	0.000
06:00	0.000	0.000	0.000	0.000
07:00	0.000	0.000	0.000	0.000
08:00	0.000	0.000	0.000	0.000
09:00	0.115	0.355	0.396	0.478
10:00	0.220	0.678	0.758	0.915
11:00	0.369	1.138	1.271	1.534
12:00	0.824	2.540	2.838	3.426
13:00	2.678	8.256	9.222	11.135
14:00	2.472	7.621	8.513	10.278
15:00	1.879	5.793	6.471	7.813
16:00	0.406	1.252	1.398	1.688
17:00	0.146	0.450	0.503	0.607
18:00	0.155	0.478	0.534	0.644
19:00	0.014	0.043	0.048	0.058
20:00	0.000	0.000	0.000	0.000
21:00	0.000	0.000	0.000	0.000
22:00	0.000	0.000	0.000	0.000
23:00	0.000	0.000	0.000	0.000
Total	9.278	28.602	31.950	38.577
Ratio		3.083	3.444	4.158

	Upstream of Lake Mogan				On the Day				One Day Before				Two Days Before			
	Areal Values of				Areal WRF Forecasts for				Areal WRF forecasts of				Areal WRF Forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.035	0.039	0.049	0.062	0.179	0.201	0.250
01:00	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.002	0.016	0.045	0.051	0.063
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.002
03:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.265	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.001	0.001	0.001	1.158	0.769	0.866	1.075	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
06:00	0.474	1.462	1.622	1.931	1.272	3.358	3.780	4.692	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
07:00	1.232	3.799	4.213	5.016	1.705	3.690	4.153	5.154	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
08:00	2.012	6.206	6.884	8.196	1.523	4.944	5.564	6.906	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000
09:00	2.087	6.437	7.140	8.500	1.938	4.418	4.972	6.171	0.004	0.010	0.012	0.015	0.000	0.000	0.000	0.000
10:00	2.013	6.208	6.886	8.198	2.112	5.620	6.326	7.852	0.021	0.061	0.069	0.085	0.000	0.000	0.000	0.000
11:00	2.237	6.900	7.653	9.111	2.233	6.126	6.895	8.558	0.043	0.126	0.142	0.176	0.008	0.023	0.026	0.032
12:00	2.722	8.395	9.312	11.086	2.749	6.475	7.288	9.046	0.141	0.409	0.460	0.571	0.305	0.886	0.997	1.237
13:00	2.542	7.840	8.696	10.353	2.456	7.974	8.975	11.140	0.421	1.221	1.375	1.706	1.454	4.216	4.745	5.890
14:00	2.257	6.961	7.721	9.192	1.719	7.122	8.016	9.950	1.088	3.154	3.550	4.406	0.841	2.440	2.746	3.409
15:00	1.857	5.729	6.354	7.565	0.887	4.985	5.611	6.964	0.766	2.222	2.501	3.105	0.020	0.057	0.064	0.080
16:00	1.301	4.014	4.452	5.300	0.522	2.574	2.897	3.596	0.441	1.280	1.441	1.788	0.003	0.010	0.011	0.014
17:00	0.749	2.310	2.562	3.051	0.212	1.515	1.705	2.116	0.860	2.493	2.806	3.483	0.017	0.050	0.056	0.069
18:00	0.348	1.073	1.190	1.417	0.040	0.615	0.692	0.859	0.879	2.549	2.869	3.561	0.051	0.147	0.165	0.205
19:00	0.130	0.402	0.446	0.531	0.022	0.116	0.130	0.162	0.349	1.013	1.141	1.416	0.059	0.171	0.193	0.239
20:00	0.144	0.445	0.494	0.588	0.005	0.064	0.071	0.089	0.448	1.301	1.464	1.817	0.029	0.084	0.094	0.117
21:00	0.000	0.000	0.000	0.000	0.027	0.013	0.015	0.019	0.502	1.455	1.638	2.033	0.008	0.022	0.025	0.031
22:00	0.002	0.006	0.007	0.008	0.075	0.077	0.087	0.108	0.133	0.387	0.435	0.540	0.008	0.023	0.026	0.032
23:00	0.000	0.000	0.000	0.000	0.000	0.218	0.245	0.304	0.038	0.111	0.125	0.155	0.004	0.013	0.014	0.018
Total	22.108	64.120	72.168	89.578	20.919	60.672	68.288	84.762	6.147	17.829	20.067	24.908	2.885	8.367	9.417	11.689
Ratio		2.900	3.264	4.052		2.900	3.264	4.052		2.900	3.264	4.052		2.900	3.264	4.052

	Upstream of Lake Mogan				On the Day				One Day Before				Two Days Before			
	Areal Values of				Areal ALR Forecasts for				Areal ALR forecasts of				Areal ALR Forecasts of			
Hours	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm	14.3.2016 Event	50-year Storm	100-year Storm	500-year Storm
00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
01:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
02:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
03:00	0.000	0.000	0.000	0.000	0.026	0.075	0.085	0.105	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
04:00	0.000	0.000	0.000	0.000	0.001	0.003	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
05:00	0.000	0.001	0.001	0.001	0.230	0.667	0.751	0.932	0.090	0.261	0.294	0.365	0.000	0.000	0.000	0.000
06:00	0.474	1.462	1.622	1.931	1.525	4.423	4.978	6.179	0.740	2.146	2.416	2.998	0.000	0.000	0.000	0.000
07:00	1.232	3.799	4.213	5.016	2.204	6.392	7.195	8.930	3.225	9.354	10.528	13.067	0.000	0.000	0.000	0.000
08:00	2.012	6.206	6.884	8.196	1.927	5.589	6.290	7.808	3.108	9.014	10.146	12.593	0.000	0.000	0.000	0.000
09:00	2.087	6.437	7.140	8.500	2.055	5.960	6.708	8.327	1.526	4.426	4.981	6.183	0.021	0.061	0.069	0.085
10:00	2.013	6.208	6.886	8.198	2.787	8.083	9.098	11.293	0.635	1.842	2.073	2.573	0.408	1.183	1.332	1.653
11:00	2.237	6.900	7.653	9.111	2.742	7.953	8.951	11.110	2.774	8.046	9.055	11.240	0.963	2.793	3.144	3.902
12:00	2.722	8.395	9.312	11.086	2.461	7.138	8.034	9.972	2.242	6.503	7.319	9.084	1.438	4.171	4.694	5.827
13:00	2.542	7.840	8.696	10.353	2.198	6.375	7.175	8.906	1.080	3.132	3.526	4.376	1.149	3.332	3.751	4.656
14:00	2.257	6.961	7.721	9.192	1.629	4.725	5.318	6.601	0.087	0.252	0.284	0.353	1.682	4.878	5.491	6.815
15:00	1.857	5.729	6.354	7.565	1.575	4.568	5.141	6.382	0.203	0.589	0.663	0.823	2.270	6.584	7.410	9.198
16:00	1.301	4.014	4.452	5.300	0.848	2.459	2.768	3.436	0.268	0.777	0.875	1.086	2.272	6.590	7.417	9.206
17:00	0.749	2.310	2.562	3.051	0.287	0.832	0.937	1.163	0.545	1.581	1.779	2.208	0.761	2.207	2.484	3.084
18:00	0.348	1.073	1.190	1.417	0.092	0.267	0.300	0.373	1.099	3.187	3.588	4.453	0.252	0.731	0.823	1.021
19:00	0.130	0.402	0.446	0.531	0.031	0.090	0.101	0.126	1.271	3.686	4.149	5.150	0.187	0.542	0.610	0.758
20:00	0.144	0.445	0.494	0.588	0.017	0.049	0.055	0.069	0.533	1.546	1.740	2.160	0.045	0.131	0.147	0.182
21:00	0.000	0.000	0.000	0.000	0.013	0.038	0.042	0.053	0.202	0.586	0.659	0.818	0.000	0.000	0.000	0.000
22:00	0.002	0.006	0.007	0.008	0.017	0.049	0.055	0.069	0.099	0.287	0.323	0.401	0.000	0.000	0.000	0.000
23:00	0.000	0.000	0.000	0.000	0.038	0.110	0.124	0.154	0.056	0.162	0.183	0.227	0.000	0.000	0.000	0.000
Total	22.108	64.120	72.168	89.578	22.703	65.846	74.112	91.991	19.783	57.377	64.580	80.159	11.448	33.203	37.371	46.386
Ratio		2.900	3.264	4.052		2.900	3.264	4.052		2.900	3.264	4.052		2.900	3.264	4.052

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Bozkurt, Okan Çağrı
Nationality: Turkish (TC)

EDUCATION

Degree	Institution	Year of Graduation
MS	METU Civil Engineering	2013
BS	METU Civil Engineering	2009
High School	Atatürk High School, Ankara	2003

WORK EXPERIENCE

Year	Place	Enrollment
2011-Present	SUİŞ Proje Engineering and Consulting Ltd. Co.	Civil Engineer
2009-2011	Ankara Branch of Chamber of Civil Engineers	Civil Engineer

FOREIGN LANGUAGES

English

PUBLICATIONS

1. Tuncok, I. K., Bozkurt, O. C., Integrated Basin Management – Case Study on Konya Closed Basin. (Original Title in Turkish: Bütüncül Havza Yönetimi: Konya Kapalı Havzası Örneği). 4th Water Structures Symposium (4. Su Yapıları Sempozyumu), Turkish Chamber of Civil Engineers 2015, Antalya.

2. Bozkurt, O. C., Merzi, N., Akyurek, Z. Considerations on Lake Mogan Floods (Original Title in Turkish: Mogan Gölü Taşkınları Üzerine Değerlendirmeler). 3rd Water Structures Symposium (3. Su Yapıları Sempozyumu), Turkish Chamber of Civil Engineers 2013, Ankara.

3. Bozkurt, O. C., Merzi, N., Akyurek, Z. Evaluation of the Flood Performance of Water Control Structures of Mogan and Eymir Lakes and Incesu Detention Pond (Original Title in Turkish: Mogan ve Eymir Gölleri Su Kontrol Yapıları İle İncesu Sel Kapanının Taşkın Performansının Değerlendirmesi). 3rd National Flood Symposium (3. Ulusal Taşkın Sempozyumu), General Directorate of State Hydraulics Works, 2013, İstanbul.

4. Bozkurt, Okan Çağrı, Master Thesis, Operation of The Water Control Structures, 2013, Middle East Technical University.