
MERSİN-ADANA-GAZİANTEP HIGH STANDARD RAILWAY PROJECT

FLOOD RISK ASSESSMENT REPORT

NOVEMBER 2021

ANKARA



MERSİN-ADANA-GAZİANTEP HIGH STANDARD RAILWAY PROJECT

FLOOD RISK ASSESSMENT REPORT

version	Revision	Date	Prepared	Quality Management Officer	Proofreading	Controlling	Approving
Draft	A.0	November 2021	İsmail Ulusoy Environmental Engineer	Esra Okumuşoğlu Geological Engineer	Gill Cousins Environmental Biological	Günel Özenirler Environmental Engineer	Emre Kaya Environmental Engineer

REVISION CODES : A: DRAFT, B: FINAL DRAFT, C: FINAL

PROJE NO: 21 / 024

NOVEMBER 2021

CLIENT



REC Uluslararası İnşaat Yatırım Sanayi ve
Ticaret A.Ş.
Portakal Çiçeği Sok. No. 33 Yukarı Ayrancı
ÇANKAYA / ANKARA
☎: +90 (312) 441 31 41
☎: +90 (312) 442 59 48

CONSULTANT:



Tepe Prime İş Ve Yaşam Merkezi
Mustafa Kemal Mahallesi Dumlupınar
Bulvarı No: 266 B Blok Kat: 2 Daire: 38
Çankaya - Ankara / Türkiye
☎: +90 (312) 295 62 48
☎: +90 (312) 295 62 00

TABLE OF CONTENTS

	<u>Page</u>
Table of Contents	i
List of Tables	ii
List of Figures	ii
1. INTRODUCTION	1
2. PROJECT OVERVIEW	2
3. METHODOLOGY	3
3.1. Flood Risk Assessment	3
4. FLOOD RISK ASSESSMENT	6
4.1. Weather and Climate	6
4.1.1. Observed Temperature and Rainfall Trends	6
4.1.2. Rainfall Projections	9
4.2. Hydrogeology, Topography, and Water Bodies	10
4.3. Historical Extremes (Floods, storms, and Heavy Rainfalls)	13
4.4. Potential sources of flood risk	16
4.4.1. Surface Water	16
4.4.2. Groundwater	17
4.4.3. Artificial Sources	18
4.5. Floodplain	18
4.6. Flood Risk Maps	20
4.6.1. Detailed Risk Maps	27
4.6.2. Coastal Flooding	37
4.7. Summary of Key Project Flood Risks	37
5. FLOOD RISK MANAGEMENT STRATEGIES	39
5.1. Types of Flood Risks	39
5.2. Reporting Flooding	40
5.3. Running through Flood Water	41
5.4. Mitigation Measures	41
5.4.1. Monitoring	41
5.4.2. Flood Warning	42
5.5. Managing the Risks	42
5.6. To Do Lists	42
6. CONCLUSION	44

LIST OF TABLES

	<u>Page</u>
Table 3-1. WRF Physics Options.....	5
Table 4-1. The List of Water Bodies Crossing the Project Route	12
Table 4-2. Extreme events (flood, storm, and heavy rain) from 1975 to 2020	14
Table 4-3. The Bridges' Locations	27
Table 4-4. Definition of Likelihood	37
Table 4-5. Criteria for Magnitude of Change.....	38
Table 4-5. Significance Rating Matrix	38
Table 4-7. Significance Assessment.....	38

LIST OF FIGURES

Figure 1-1. Flood Risk Assessment Methodology Steps.....	1
Figure 2-1. The Project Location	2
Figure 3-1. Flood Risk Assessment Procedure.....	4
Figure 3-2. The Study Area	5
Figure 4-1. Average Temperature and Total Rainfall Values for Each Cities.	7
Figure 4-2. Rainfall Changes (%)	8
Figure 4-3. Total Rainy Days from October 2020 to September 2021.....	8
Figure 4-4. Projected Rainfall changes (RCP4.5) from 2021 to 2050.....	9
Figure 4-5. Projected Rainfall changes (RCP8.5) from 2021 to 2050.....	9
Figure 4-6. The Hydrological Structure (Aquifers).....	10
Figure 4-7. Water Bodies (Rivers and Lakes) Near the Project Areas.....	11
Figure 4-8. The Slope Distribution Map of Ceyhan River Basin (a), East Mediterranean River Basin (b), and Seyhan River Basin (c).....	12
Figure 4-9. Total Number of Floods and Heavy Rain Events	13
Figure 4-10. Flood Event on Ankara – Konya High Speed Railway	17
Figure 4-11. Types of Flood Damages from the Side of Railways	18
Figure 4-12. The Floodplain Areas	19
Figure 4-13. The Route Section 1.....	21
Figure 4-14. The Route Section 2.....	22
Figure 4-15. The Route Section 3.....	23
Figure 4-16. The Route Section 4.....	24
Figure 4-17. The Route Section 5.....	25
Figure 4-18. The Route Section 6.....	26
Figure 4-19. Typical Flood Damages of Bridge's Structure.....	27
Figure 4-20. The Bridge 1.....	28
Figure 4-21. The Bridge 2.....	29
Figure 4-22. The Bridge 3.....	30
Figure 4-23. The Bridge 4 – 5.....	31
Figure 4-24. The Bridge 6 – 7.....	32

Figure 4-25. The Bridge 8.....	33
Figure 4-26. The Bridge 9 – 10.....	34
Figure 4-27. The Bridge 11 – 12.....	35
Figure 4-28. The Bridge 13.....	36
Figure 4-29. Sea Level Rise under 1.5°C and 4°C Scenarios.....	37
Figure 5-1. An Example of Flood Impacts on the Railway System.....	40
Figure 5-1. Pumping Stations	43
Figure 5-2. Flood Barriers.....	43
Figure 5-3. Clearing the water channels near the railways	43

1. INTRODUCTION

In line with the agreement signed between The Republic of Turkey State Railways (TCDD) and REC International Construction Investment Industry and Trade Inc. under Rönesans Holding within the scope of the High Standard Railway Line Construction and Electromechanical Systems Installation Project, Mersin Gaziantep High Standard Train (286 km-long railway) is planned to be built between Mersin and Gaziantep (Başpınar). This will reduce the travel time by 1.5 hours, with high-standard passenger trains planned to run at a maximum speed of 200 km/h (120 mph) and freight trains at a speed of 80 – 120 km/h (49 – 74 mph).

In order to understand and evaluate the flood risks over the project areas, a Flood Risk Assessment (FRA) has been prepared. In preparing the FRA report, five steps have been followed (see. Figure 1-1).

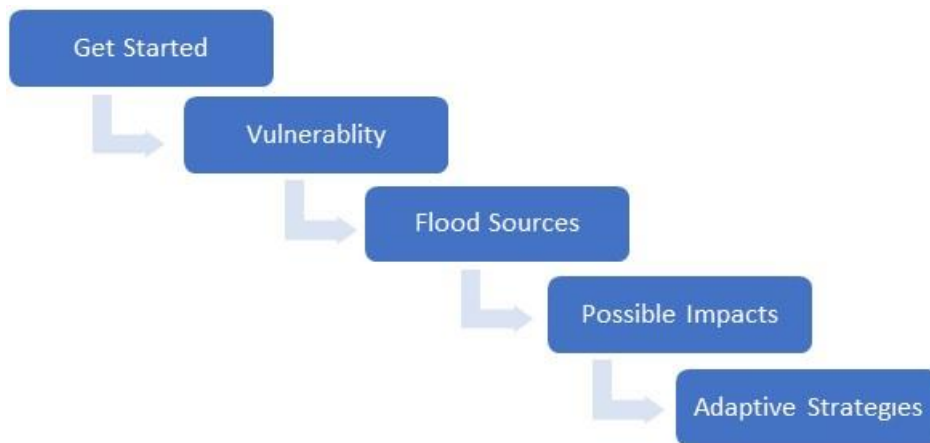


Figure 1-1. Flood Risk Assessment Methodology Steps

This FRA for the Mersin Gaziantep High Standard Train Project is organised into the following sections:

- **Chapter 1** : constitutes the introduction to FRA report
- **Chapter 2** : provides a brief overview of the project
- **Chapter 3** : describes the methodology for the analysis of FRA
- **Chapter 4** : gives the detail analysis of floods and the assessment of risks
- **Chapter 5** : focuses on the possible adaptation and mitigation measures
- **Chapter 6** : draws the conclusions of FRA.

2. PROJECT OVERVIEW

The 286 km-long High Standard Train Project will start from Mersin, and pass-through Tarsus, Adana, Incirlik, Toprakkale, Bahçe, Nurdağı, Başpınar stations, and last at Mustafa Yavuz Station. 78 km of this 286 km line is between Mersin and Adana, 79 km between Adana and Toprakkale, 56 km between Toprakkale and Bahçe, 17 km between Bahçe and Nurdağı and the last 56 km between Nurdağı and Başpınar is planned to be. The route of the Project mostly passes through agricultural areas and natural areas such as Nurdağı and Sof Mountain.

Project route and study area were shown in Figure 2-1.

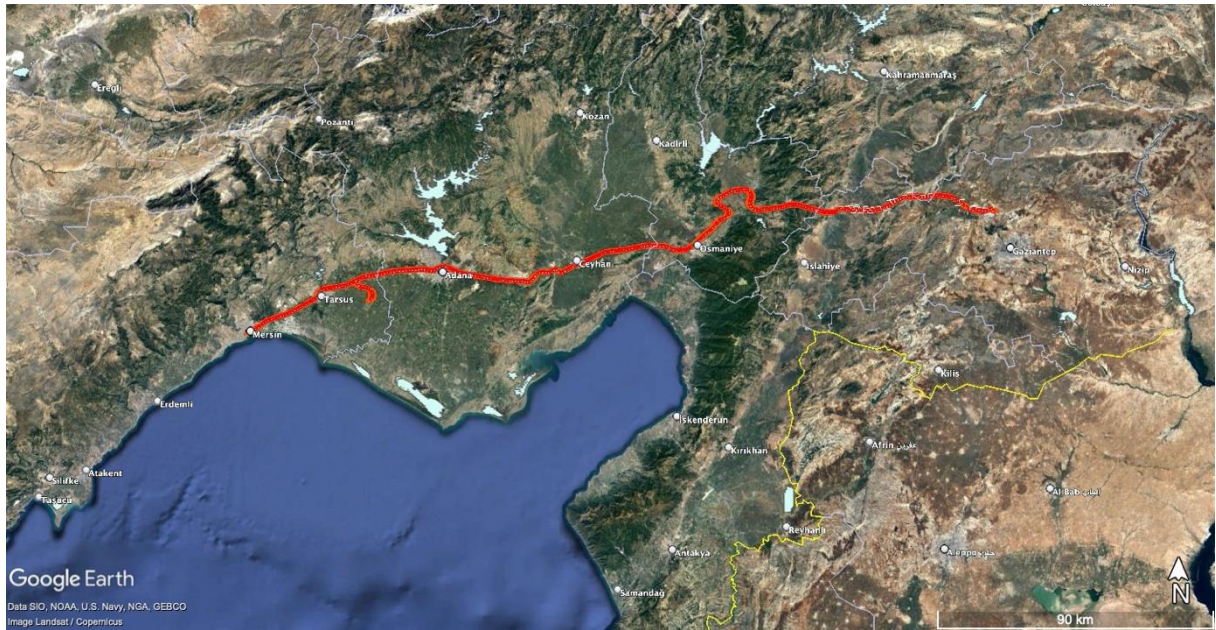


Figure 2-1. The Project Location

3. METHODOLOGY

3.1. Flood Risk Assessment

According to EU Directive (COM, 2006) for flood management, "flood risk" is the likelihood of a flood event together with the actual damage to human health and life, the environment and economic activity associated with that flood event. In this context flood risk can be considered as the actual threat, in other words the real source of flood hazard to the affected areas. The aims of the report are as follows:

- Identify the risks of flooding associated with the development of the rail line from all potential sources;
- Assess the impact that the proposed new and adapted rail infrastructure would have on these flood risks;
- Identify a strategy for managing surface water run-off;
- Seek to demonstrate that the overall flood risk can be reduced and/or managed through design or operational controls.

In the context of the preliminary evaluation of flood risk undertaken in the study area, the first stage requires the definition and identification of flood risk sources. A flood can be defined as a "temporary covering of land by water outside its normal confines". In the characterization of flood risk, the sources of flooding should be clearly identified at the outset to ensure that the consequences of the event can be properly evaluated. A linear railway system is subject to different types of flooding ranging from long duration but low intensity events to flash floods of very short duration but of high intensity and with often very different consequences.

The following main sources of flooding were highlighted during the risk identification stage:

- Watercourses
- Surface water runoff
- Coastal flooding
- Groundwater

These can be further divided into subgroups to include for the presence of debris in the flow and sediment transport for example. The following overall procedure (see. Figure 3-1) aims to form the basis for assessment and management of structures susceptible to flood risks.

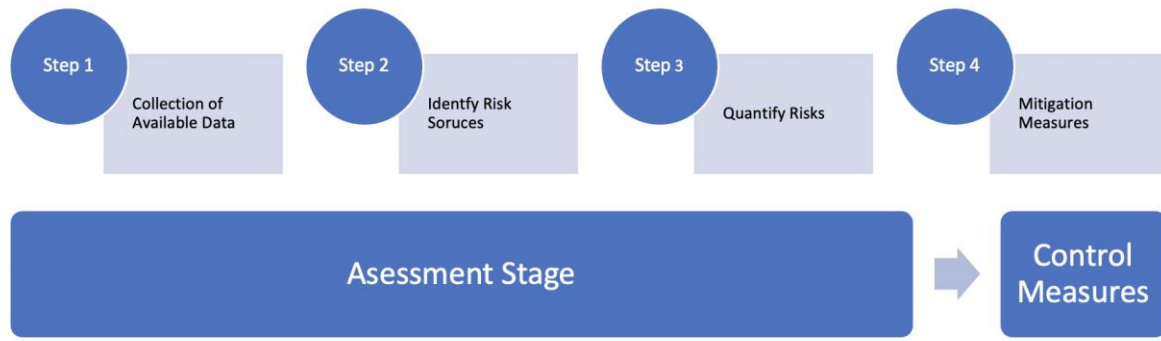


Figure 3-1. Flood Risk Assessment Procedure

Step 1 should be regarded as a desk-based assessment procedure where the aim is to collate all relevant information regarding the structure.

Step 2 is similarly a desk-based exercise, to identify all possible risk scenarios in need of further investigation.

Step 3 is an assessment of structures identified in Step 2 as being at potential risk and for which assessment on site is required. The assessment of risk comprises two levels of assessment, an initial assessment, and then where necessary, a more detailed level of assessment. This initial screening assessment followed by a more detailed in-depth quantitative assessment is aimed at better targeting resources on those structures requiring further investigation and assessment.

Following assessment and identification of High Priority Structures, the next step is to mitigate against the identified risk (Step 4). Mitigation may be in the form of physical scour protection works, physical restraints to water pressure, revised frequency of monitoring during flooding, or line closures at times of high risk.

As a part of flood risk assessments, extreme precipitation which will directly impact the flood events in the project areas have been obtained from the IPCC's CMIP5 RCP4.5 and RCP8.5 scenarios by using the Weather Research and Forecasting (WRF) model. WRF model is an open-source customizable regional numerical weather prediction model that is widely used by atmospheric scientist, with many physical and dynamic options. The WRF model is used for high resolution modelling of regional atmospheric phenomena, with inputs being geographical data, and meteorological data. In the analysis of changes in extreme events, changes above the 90th percentile were examined, and the working area used for the model is given in the Figure 3-2.

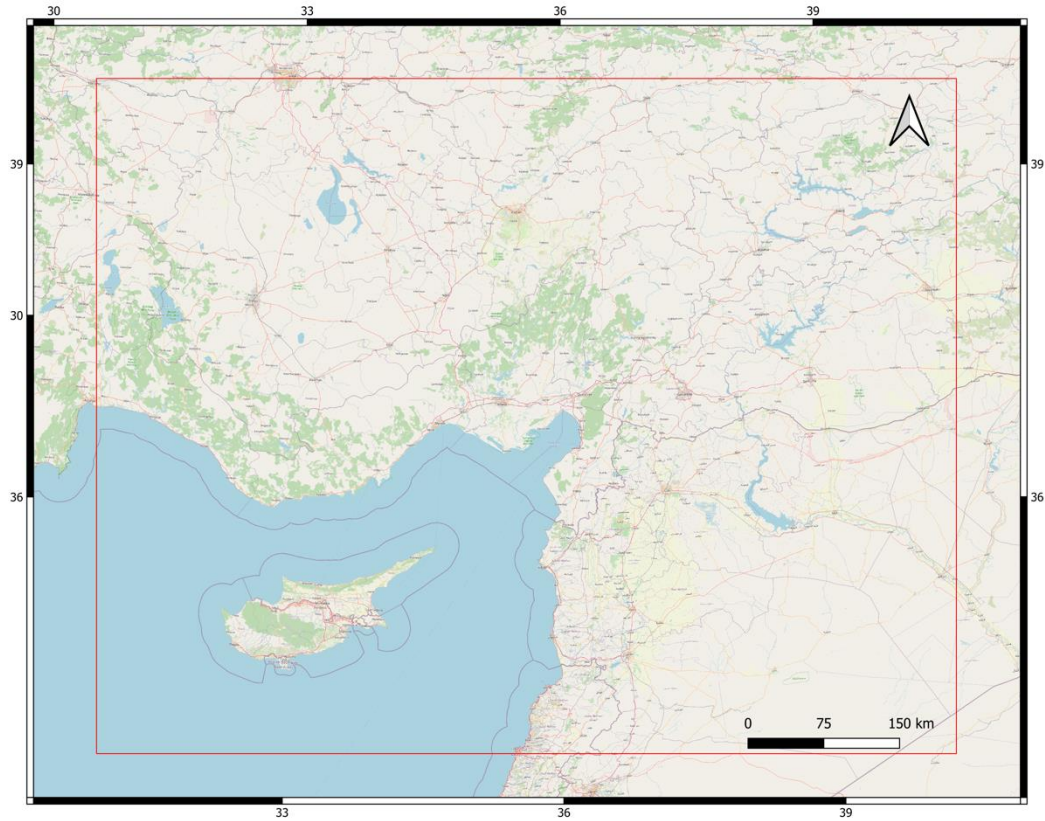


Figure 3-2. The Study Area

WRF version 4.3 was run at 20 km resolution to produce more detailed climate projections. CMIP5 RCP4.5 as the optimistic scenario and CMIP5 RCP8.5 data as the pessimistic scenario were used as meteorological data for the WRF model. The model was operated for 40 years between 2011-2050. Future climate projection change expectations are determined according to the period 2011-2020. The physics options used for the model are given in the Table 3-1.

Table 3-1. WRF Physics Options

Physics Options	Outer Domain
Microphysics	New Thompson
Cumulus Parameterization	Tiedtke
Longwave Radiation	RRTMG
Shortwave Radiation	RRTMG
Planetary Boundary layer	MYJ
Surface Layer	Eta
Land Surface	NOAH

4. FLOOD RISK ASSESSMENT

Flooding can have significant direct and indirect negative effects on a railway network affecting both infrastructure and rail operations. Such impacts include the delaying or cancelling of train services, damage to railway structures or the implementation of costly maintenance and monitoring programs to ensure the safety and performance of the railway system. Identifying sections of railway line at risk from flooding allows appropriate actions to be targeted at specific areas and contributes to an effective asset management plan.

The railway network is exposed to many forms of flooding and the management of flood risk is the responsibility of the owner and/ or operator. In all forms of risk management, a procedure for understanding the risks affecting the system being studied is required, which can often require several stages to fully appreciate the sources and consequences of the different types of risk.

4.1. Weather and Climate

Turkey lies between latitudes 36-42°N and adjacent to the Mediterranean Sea and so might be expected to have a Mediterranean climate which does apply to the southern coastal areas where the project will be operated. In summer-time period, southern coastal areas are mostly dry and sunny. In general, Turkey is warm or hot in summer and cold or very cold in winter. However, coasts are much milder in winter than inland, especially the south and west coasts.

4.1.1. Observed Temperature and Rainfall Trends

In the project area, Figure 4-1 shows how monthly temperature averages and total rainfall values have changed since 1970 (1986 for Osmaniye). This illustrates a warming trend in the project area through the year of 1970-2018 by about 1°C. Additionally, it is noted that there is warming by about 2°C over the years in Mersin. The annual total rainfall values, do not indicate any rainfall changes, but in detail, there has been an increase in extremes reaching 1000mms since 1990s.

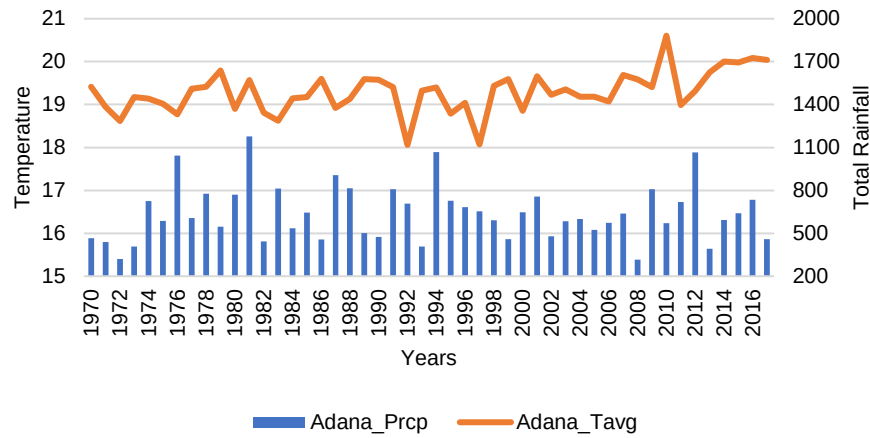
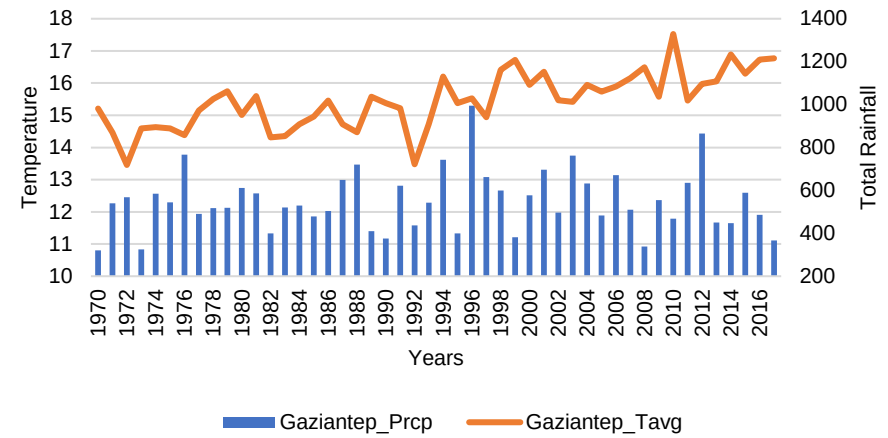
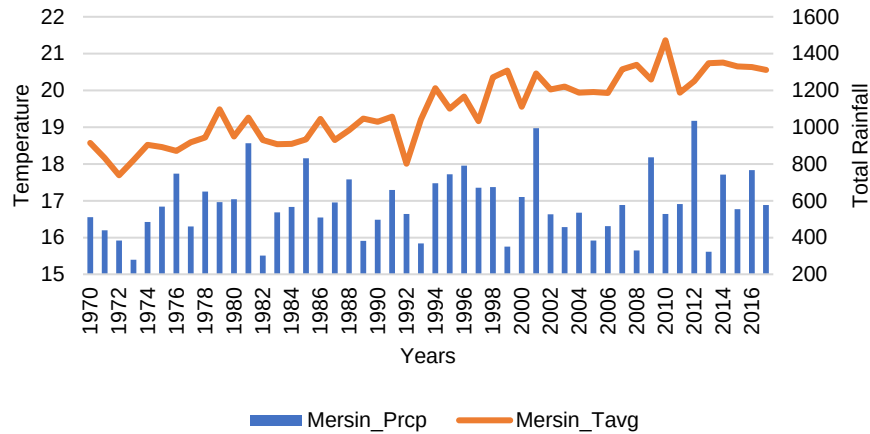
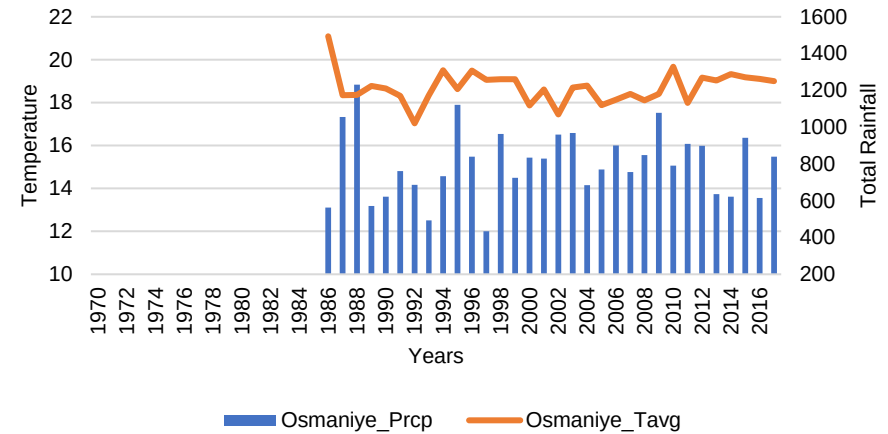


Figure 4-1. Average Temperature and Total Rainfall Values¹ for Each Cities.

As Osmaniye meteorological station was established in 1986, it was not possible to obtain observations before 1986.

¹ Please note that the axis max and min values are different.

As the Project is in the south-east of Turkey, the location is characterised as dry and does not receive consistent annual precipitation. Turkey was under very dry period in 2020, and many places faced problems for drinking water reservoir levels. Figure 4-2 shows how the precipitation over Turkey changed in 2020 autumn (a) and January 2021(b). In January 2021, Turkey mean areal precipitation in January 2021 was 93.8 mm, which is 43 % above from 1981-2010's normal (65.8mm). For seasonal changes (Autumn) in 2020 compared to long-term averages, Turkey's rainfall was below the long-term areal precipitation means. The differences between 2020 and the long-term averages in the project location was about -60% (TSMS, 2021b).

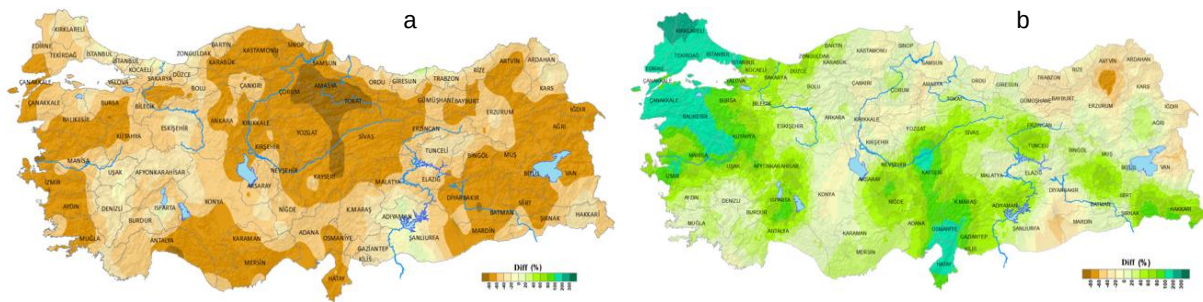


Figure 4-2. Rainfall Changes (%)

When considering the number of rainy days (October 2020 to September 2021), the project area is not located in the wettest Turkish areas, but the route passes through Osmaniye, where over 100 rainy days were observed (see. Figure 4-3).

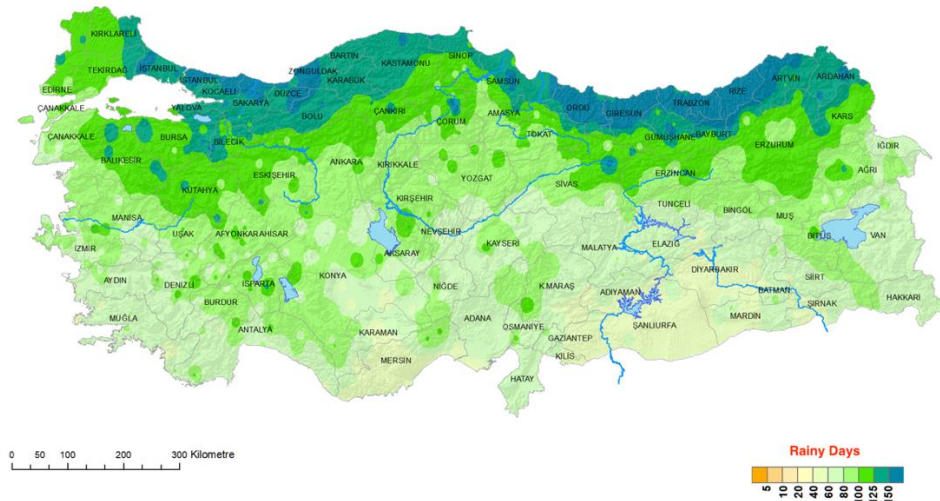


Figure 4-3. Total Rainy Days from October 2020 to September 2021

4.1.2. Rainfall Projections

According to CMIP5 model outputs (see. Figure 4-4 and Figure 4-5), it is expected that rainfall will increase by 25-50% near the project areas under the RCP 4.5 scenario; however, there will be increase and decrease by 25% under the high emission scenario (RCP8.5).

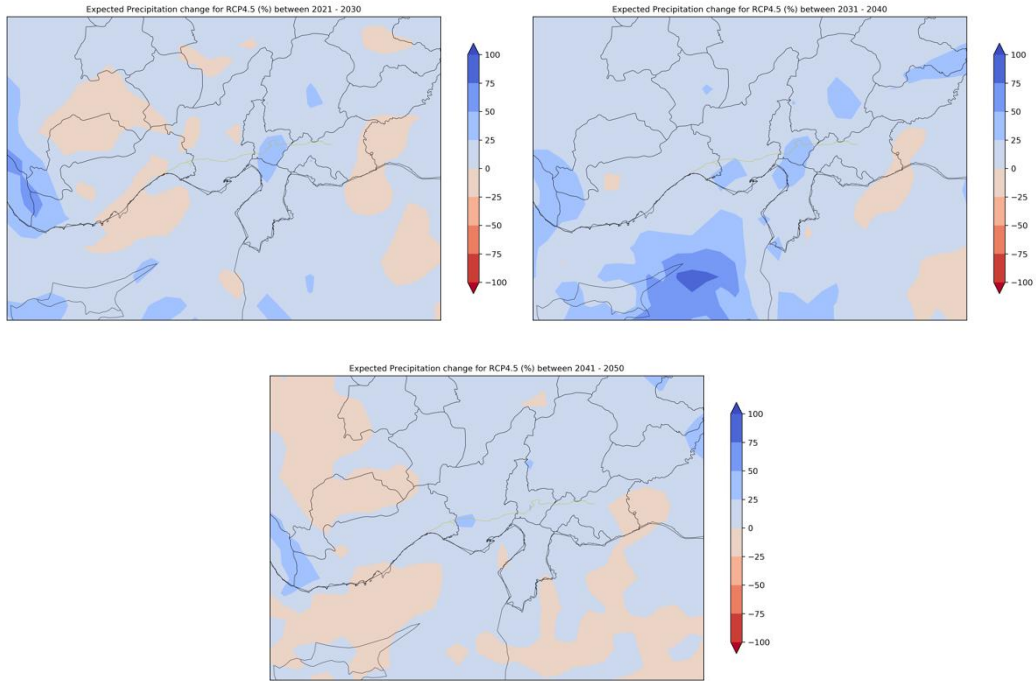


Figure 4-4. Projected Rainfall changes (RCP4.5) from 2021 to 2050

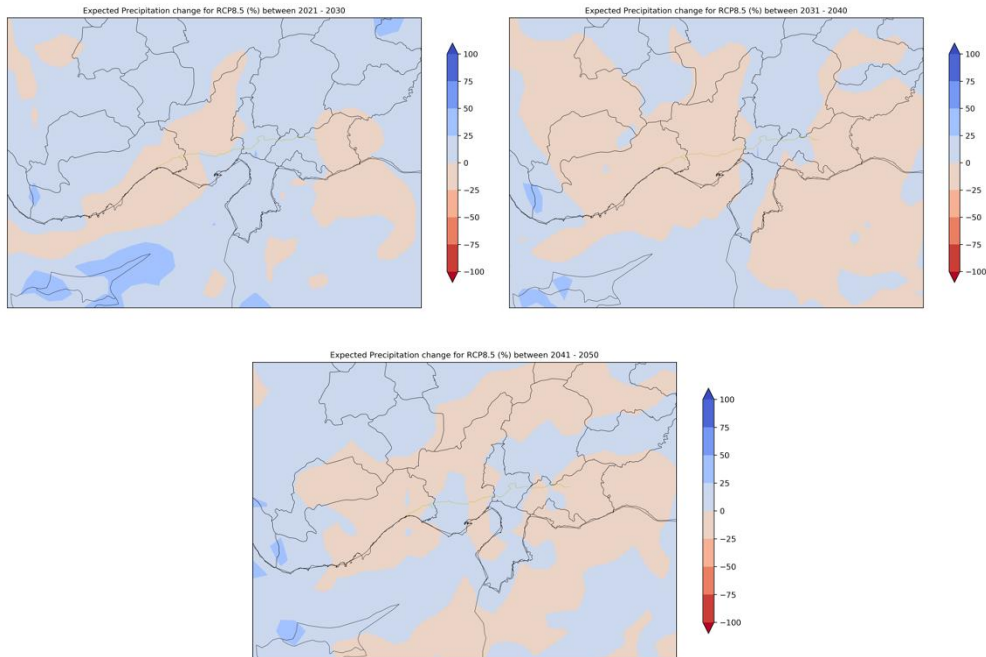


Figure 4-5. Projected Rainfall changes (RCP8.5) from 2021 to 2050

4.2. Hydrogeology, Topography, and Water Bodies

The project route is located in the Çukurova plain, which is in the southern part of the Neogene Adana Basin lying in the intersection region of the Arabia, Africa, and Anatolia Plates. It is bounded by the Ecemis Fault Zone in the North-West, and by the Karataş Fault Zone along the structural high formed by the Misis mountain range in the South-East. The entire area is characterized by intense seismicity, including destructive earthquakes, as documented by historical records.

The Çukurova plain, surrounded by the Misis Mountains in the East and the Tauride Mountain belt in the North and West, is formed by the Taurus, Seyhan and Ceyhan rivers. The detail hydrological structure over the project areas was shown in figure Figure 4-6.



Figure 4-6. The Hydrological Structure (Aquifers)

The details maps of the rivers and lakes can be found in Figure 4-7. It is noted that, on the Mersin-Gaziantep project route, the train passes over the two main rivers; the Seyhan and Ceyhan, which are two important water resources between Adana and Toprakkale. There are also 10 streams where there will be crossing sections, and all rivers and streams are given in Table 4-1.

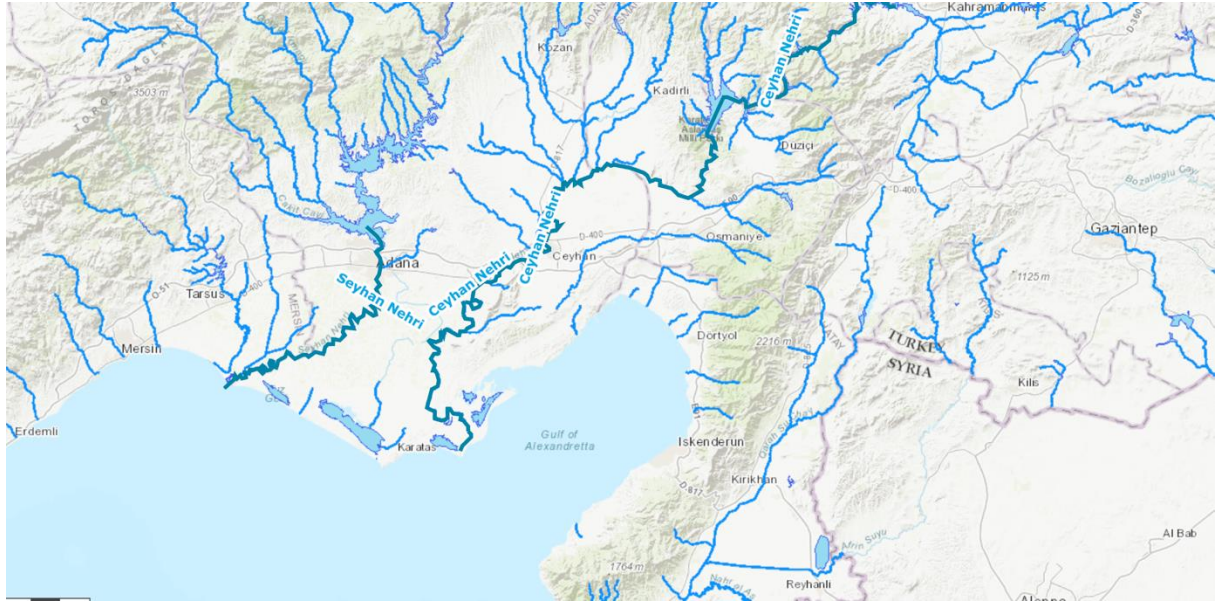


Figure 4-7. Water Bodies (Rivers and Lakes) Near the Project Areas

The Seyhan River flows into the Seyhan dam lake immediately after the Çatalan Dam and mixed Körkün Water and Çakıt Waters from the right shore of the Seyhan dam lake. The annual average flow measured at the station 1820 with a precipitation area of 1440.8 km² operated on Körkün Water is 405 hm³/year, and the annual average flow measured at the station 1828 with a precipitation area of 1896.9 km² operated on Çakıt Water is 343 hm³/year. After that, the Seyhan River enters the Seyhan Regulator and continues its southward flow and discharges into the Mediterranean.

The Ceyhan River is one of Çukurova's main sources of life and its length is about 509 km. The Ceyhan River, which originates from Pınarbaşı at 3 km southeast of Elbistan and passes through the middle of Elbistan, is one of the largest rivers in the Mediterranean Region. It forms a wide delta in Çukurova and discharges into the Iskenderun Bay in the Mediterranean. Its main tributaries are Söğütlü, Hurman, Göksun, Cave Eye, Firniz, Tekir, Körsu and Aksu Streams. Ceyhan River generally passes through deep valleys within the borders of Kahramanmaraş province. Many of these valleys have been dammed.

Table 4-1. The List of Water Bodies Crossing the Project Route

No	Name	Water Type
1	Deliçay	River
2	Tarsus	Stream
3	Kuşkun	Stream
4	Koca	Stream
5	Seyhan	River
6	Sarıçam	Stream
7	Ceyhan	River
8	Yarpuz	Stream
9	Akçasu	Stream
10	Bekdemir	Stream
11	Horuçay	Stream
12	Aksu	Stream

The slope distribution map of the project area (see. Figure 4-8) highlights that the rail route will pass through areas of higher slopes, especially in the Ceyhan River Basin. Even if the train railways are constructed in lower slope, it is highly important for surface runoff which will impact directly flood occurrence.

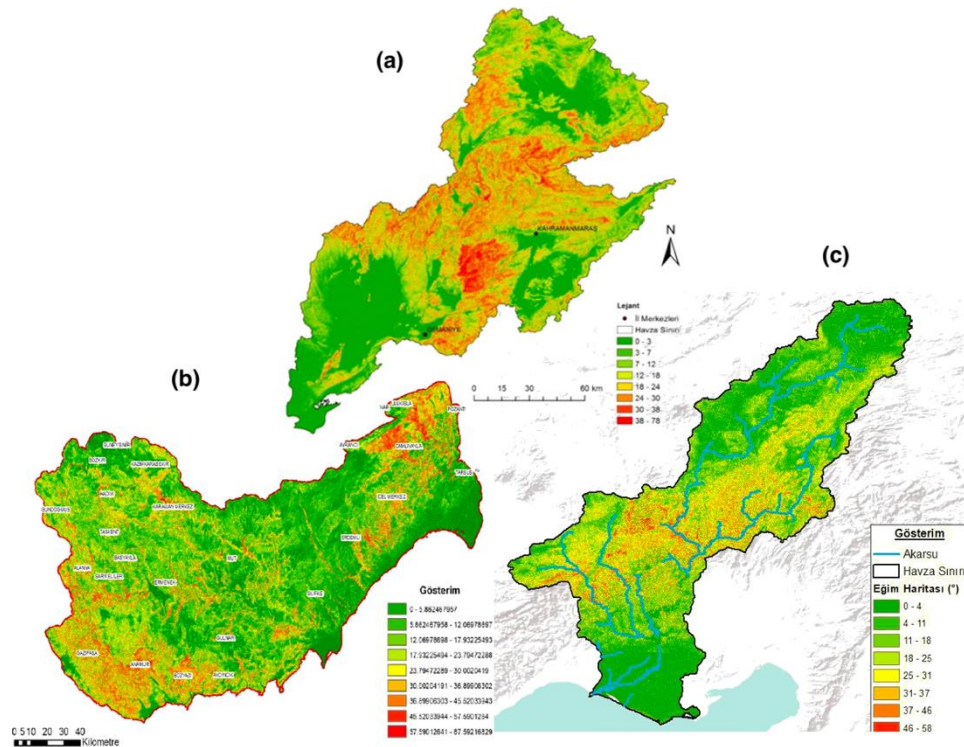


Figure 4-8. The Slope Distribution Map of Ceyhan River Basin (a), East Mediterranean River Basin (b), and Seyhan River Basin (c)

4.3. Historical Extremes (Floods, storms, and Heavy Rainfalls)

Extreme events (floods, storms, and heavy rainfalls) near the project area from 1975 to 2020 were obtained from four different meteorological stations (Adana, Osmaniye, Ceyhan, and Mersin) operated by TSMS. As seen in Table 4-2, floods and heavy rainfalls were observed frequently near the project area.

Figure 4-9 shows how the number of floods and heavy rains have changed yearly, with the total number of floods and heavy rainfalls increasing since 1975, especially after 2006s. Due to gap in the data, 2020 is not fully completed, and 2020 events were lower than other years. This shows that the project needs to be papered for flood events. These extreme events were observed mostly in May and June.

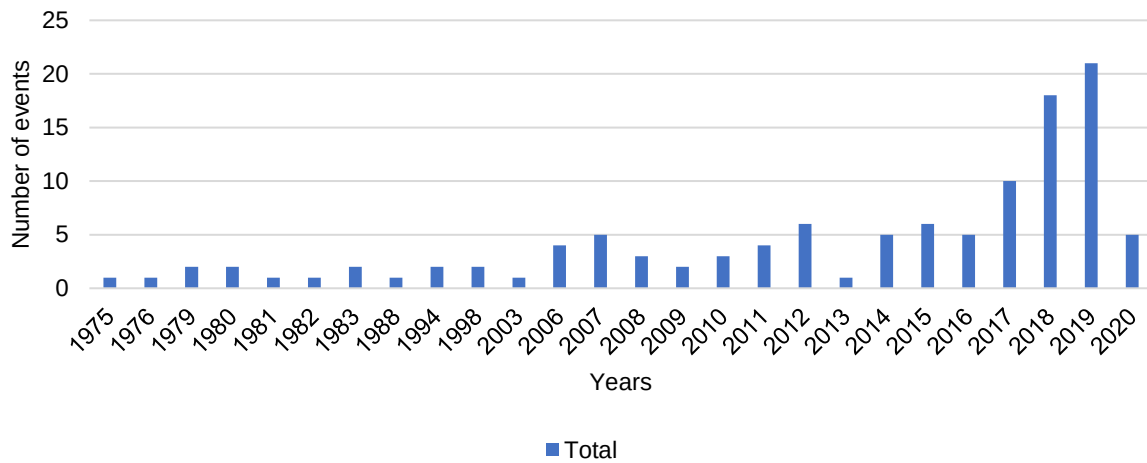


Figure 4-9. Total Number of Floods and Heavy Rain Events

Table 4-2. Extreme events (flood, storm, and heavy rain) from 1975 to 2020

Date	Location	City	Extremes	Date	Location	City	Extremes	Date	Location	City	Extremes
12/05/1975	Adana	Adana	Rain and flood	26/10/2006	Ceyhan	Adana	Rain and flood	20/11/2011	Osmaniye	Osmaniye	Rain and flood
23/04/1976	Adana	Adana	Rain, flood, and hail	04/11/2006	Osmaniye	Osmaniye	Rain and flood	03/05/2012	Adana	Adana	Rain and flood
17/05/1979	Osmaniye	Osmaniye	Rain and flood	28/03/2007	Mersin	Mersin	Rain and flood	21/05/2012	Adana	Adana	Rain and flood
02/11/1979	Osmaniye	Osmaniye	Rain and flood	08/04/2007	Adana	Adana	Rain and flood	03/10/2012	Mersin	Mersin	Rain and flood
27/03/1980	Adana	Adana	Rain and flood	29/04/2007	Ceyhan	Adana	Rain and flood	25/10/2012	Osmaniye	Osmaniye	Rain and flood
02/04/1980	Adana	Adana	Rain and flood	11/11/2007	Mersin	Mersin	Rain and flood	09/11/2012	Mersin	Mersin	Rain and flood
15/06/1981	Adana	Adana	Rain, flood, and storm	06/12/2007	Mersin	Mersin	Rain and flood	10/12/2012	Mersin	Mersin	Rain and flood
17/05/1982	Osmaniye	Osmaniye	Rain, flood, and hail	09/05/2008	Adana	Adana	Rain and flood	19/07/2013	Adana	Adana	Flood in urban areas at high attitudes
23/05/1983	Osmaniye	Osmaniye	Rain and flood	22/11/2008	Ceyhan	Adana	Rain and flood	03/03/2014	Mersin	Mersin	Heavy rain and flood
30/05/1983	Adana	Adana	Rain and flood	23/11/2008	Osmaniye	Osmaniye	Rain and flood	24/05/2014	Osmaniye	Osmaniye	Heavy rain and flood
10/10/1988	Adana	Adana	Rain, flood, and storm	04/11/2009	Osmaniye	Osmaniye	Rain and flood	06/06/2014	Adana	Adana	Heavy rain and flood
03/01/1994	Adana	Adana	Rain and flood	12/12/2009	Mersin	Mersin	Rain and flood	27/09/2014	Mersin	Mersin	Heavy rain and flood
18/11/1994	Adana	Adana	Rain and flood	17/03/2010	Osmaniye	Osmaniye	Heavy rain and flood	25/11/2014	Mersin	Mersin	Heavy rain and flood
06/07/1998	Mersin	Mersin	Rain and flood	26/03/2010	Osmaniye	Osmaniye	Heavy rain and flood	05/01/2015	Osmaniye	Osmaniye	Heavy rain and flood
24/12/1998	Mersin	Mersin	Rain and flood	28/03/2010	Osmaniye	Osmaniye	Heavy rain and flood	21/04/2015	Osmaniye	Osmaniye	Heavy rain and flood
16/12/2003	Ceyhan	Adana	Rain and flood	10/04/2011	Osmaniye	Osmaniye	Rain and flood	26/06/2015	Osmaniye	Osmaniye	Heavy rain and flood
19/10/2006	Osmaniye	Osmaniye	Rain and flood	11/04/2011	Osmaniye	Osmaniye	Rain and flood	26/06/2015	Osmaniye	Osmaniye	Heavy rain and flood
26/10/2006	Adana	Adana	Rain and flood	11/06/2011	Osmaniye	Osmaniye	Rain and flood	21/09/2015	Adana	Adana	Heavy rain and flood

Date	Location	City	Extremes	Date	Location	City	Extremes	Date	Location	City	Extremes
Date	Location	City	Extremes	Date	Location	City	Extremes	Date	Location	City	Extremes
29/10/2015	Osmaniye	Osmaniye	Heavy rain and flood	10/04/2018	Osmaniye	Osmaniye	Heavy rain and flood	09/04/2019	Osmaniye	Osmaniye	Heavy rain and flood
28/04/2016	Osmaniye	Osmaniye	Heavy rain and flood	30/05/2018	Osmaniye	Osmaniye	Heavy rain and flood	09/04/2019	Osmaniye	Osmaniye	Heavy rain and flood
24/05/2016	Osmaniye	Osmaniye	Heavy rain and flood	13/06/2018	Adana	Adana	Heavy rain and flood	17/04/2019	Adana	Adana	Heavy rain and flood
29/05/2016	Adana	Adana	Heavy rain and flood	17/06/2018	Mersin	Mersin	Heavy rain and flood	14/06/2019	Osmaniye	Osmaniye	Heavy rain and flood
30/06/2016	Adana	Adana	Heavy rain and flood	17/06/2018	Mersin	Mersin	Heavy rain and flood	18/06/2019	Mersin	Mersin	Heavy rain and flood
29/12/2016	Mersin	Mersin	Heavy rain and flood	21/06/2018	Mersin	Mersin	Heavy rain and flood	18/06/2019	Mersin	Mersin	Heavy rain and flood
02/03/2017	Mersin	Mersin	Heavy rain and flood	20/07/2018	Osmaniye	Osmaniye	Heavy rain and flood	18/06/2019	Osmaniye	Osmaniye	Heavy rain and flood
07/04/2017	Adana	Adana	Heavy rain and flood	08/09/2018	Mersin	Mersin	Heavy rain and flood	20/06/2019	Mersin	Mersin	Heavy rain and flood
07/05/2017	Osmaniye	Osmaniye	Heavy rain and flood	24/10/2018	Adana	Adana	Heavy rain and flood	20/06/2019	Mersin	Mersin	Heavy rain and flood
20/05/2017	Osmaniye	Osmaniye	Heavy rain and flood	25/10/2018	Osmaniye	Osmaniye	Heavy rain and flood	20/06/2019	Mersin	Mersin	Heavy rain and flood
20/05/2017	Osmaniye	Osmaniye	Heavy rain and flood	29/11/2018	Mersin	Mersin	Heavy rain and flood	12/07/2019	Osmaniye	Osmaniye	Heavy rain and flood
01/06/2017	Osmaniye	Osmaniye	Heavy rain and flood	06/12/2018	Mersin	Mersin	Heavy rain and flood	15/09/2019	Mersin	Mersin	Heavy rain and flood
14/06/2017	Adana	Adana	Heavy rain and flood	18/12/2018	Mersin	Mersin	Heavy rain and flood	20/10/2019	Osmaniye	Osmaniye	Heavy rain and flood
06/09/2017	Mersin	Mersin	Heavy rain and flood	26/12/2018	Adana	Adana	Heavy rain and flood	23/12/2019	Adana	Adana	Heavy rain and flood
05/11/2017	Mersin	Mersin	Heavy rain and flood	04/01/2019	Adana	Adana	Heavy rain and flood	30/12/2019	Mersin	Mersin	Heavy rain and flood
19/11/2017	Mersin	Mersin	Heavy rain and flood	04/01/2019	Osmaniye	Osmaniye	Heavy rain and flood	07/01/2020	Mersin	Mersin	Heavy rain and flood
03/01/2018	Adana	Adana	Heavy rain and flood	05/01/2019	Osmaniye	Osmaniye	Heavy rain and flood	06/02/2020	Mersin	Mersin	Heavy rain and flood
04/01/2018	Mersin	Mersin	Heavy rain and flood	14/01/2019	Adana	Adana	Heavy rain and flood	18/06/2020	Mersin	Mersin	Heavy rain and flood

4.4. Potential sources of flood risk

Factors causing floods are; the type of precipitation, its distribution over time, in other words, its intensity, duration, changes over time, and the time elapsed after the previous precipitation and the distribution of precipitation within the basin can be listed as meteorological factors. Depending on the type, geological factors such as the permeability rate of the ground and the degree of water saturation, and physiographic factors such as the geometry, length, area, and slope of the basin also play a role in flood formation. On the other hand, factors such as the type of vegetation and its distribution in the basin, the area covered, its height, the growth rate as well as the status of settlement areas, the presence of roads and similar infrastructures, and the way the soil is used determine the state of the flow. These factors are not independent of each other and interact with each other. In addition, over a long time period, these factors are changed by natural events, humans and animals. For this reason, the flow that emerges under the influence of these different factors varies from precipitation to precipitation, from basin to basin, from point to point in the same basin.

4.4.1. Surface Water

Surface water flooding typically occurs when intense rainfall is unable to infiltrate into the ground or enter a drainage system such as a watercourse or sewer, resulting in localised flooding due to overland flow or backing up of floodwaters. Flooding events are typically of short duration (unless there is a drainage system blockage) but can be severe. Any rain falling on the site or adjacent areas may flood the surface for a time before entering the on-site watercourses, lakes or off-site collection systems.

On 3rd of July, after rainfalls in Konya and surrounding provinces, the flood waters damaged a part of the Ankara-Konya YHT line, and the services were stopped by the traffic control centre as soon as the damage was detected. The culverts on the line were inundated, and overflowed and the rails were flooded, leading to the TCDD cancelling the Ankara-Istanbul-Konya train services. The detailed rainfall for the 3rd of July, show little rainfall over the flooded area (red point in the Figure 4-10), with most rainfall in the surrounding areas causing the flooding.

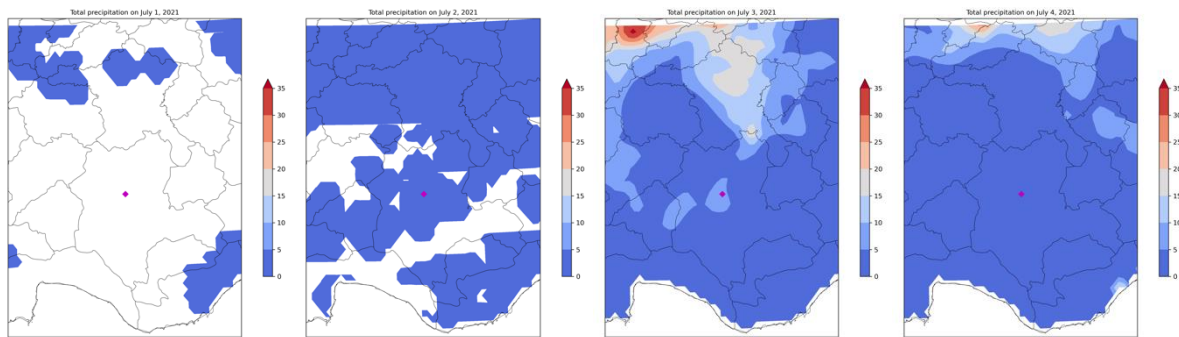


Figure 4-10. Flood Event on Ankara – Konya High Speed Railway

4.4.2. Groundwater

Groundwater flooding occurs when water contained within permeable soils and/or bedrock rises to a level that exceeds the ground surface elevation. It usually persists for an extended period due to the volume of the source and the slow changes in groundwater relative to surface water but is often relatively shallow. Flooding occurs in low-lying areas or at the boundaries between permeable and impermeable soil or bedrock types. The British Geological Survey (BGS) publishes a dataset identifying the level of susceptibility to groundwater flooding from permeable superficial deposits or bedrock, which is used to assess the risk of groundwater flooding. The bedrock geology at the site is unproductive, however, there are superficial aquifers in close proximity to the rail line.

Drainage and Sewer Systems

A risk of flooding may arise from failure or blockage of surface water drainage and sewer systems. This risk generally only arises from surrounding roads and housing developments and is associated with the predicted risk of flooding from surface water. The details groundwater sampling results were given in the Project ESIA report. Consequently, there is not currently any risk of flooding from this source.

4.4.3. Artificial Sources

Reservoir failure and overtopping, failure or overtopping of navigable waterbodies, and failure of water mains constitute the primary means of flooding from artificial sources. There are no known upstream reservoirs or canals in the vicinity of the rail line, nor currently any known water supply infrastructure on, or near the rail line.

4.5. Floodplain

A floodplain (or floodplain) is a generally flat area of land next to a river or stream. It stretches from the banks of the river to the outer edges of the valley. floodplains are natural flooding outlets for rivers. People, agriculture, and businesses on floodplains are always at some risk. Heavy rains can swell the river and force it to break its banks, drowning wide swaths of land as the floodplain can be unable to efficiently absorb the river's excess water or dissipate its energy.

Managing development of floodplains is a critical responsibility for regional and urban planners. The benefits of floodplains, including prime agricultural land and desirable housing locations, must be balanced with the personal and economic threats posed by floods.

Depending on the flood event, flood may have impacts on grounds, rails, and even contact lines. The impacts of high discharges in floodplain were given in Figure 4-11.

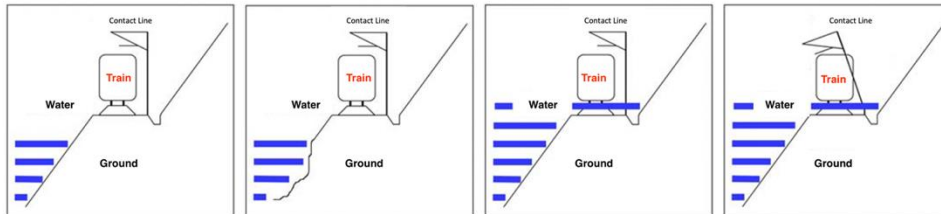


Figure 4-11. Types of Flood Damages from the Side of Railways

In the Mersin Gaziantep High Standard Train Project, there are some sections where the train passes through floodplain. Those areas were given in Figure 4-12, and need to be noted for the risks of floodplain.

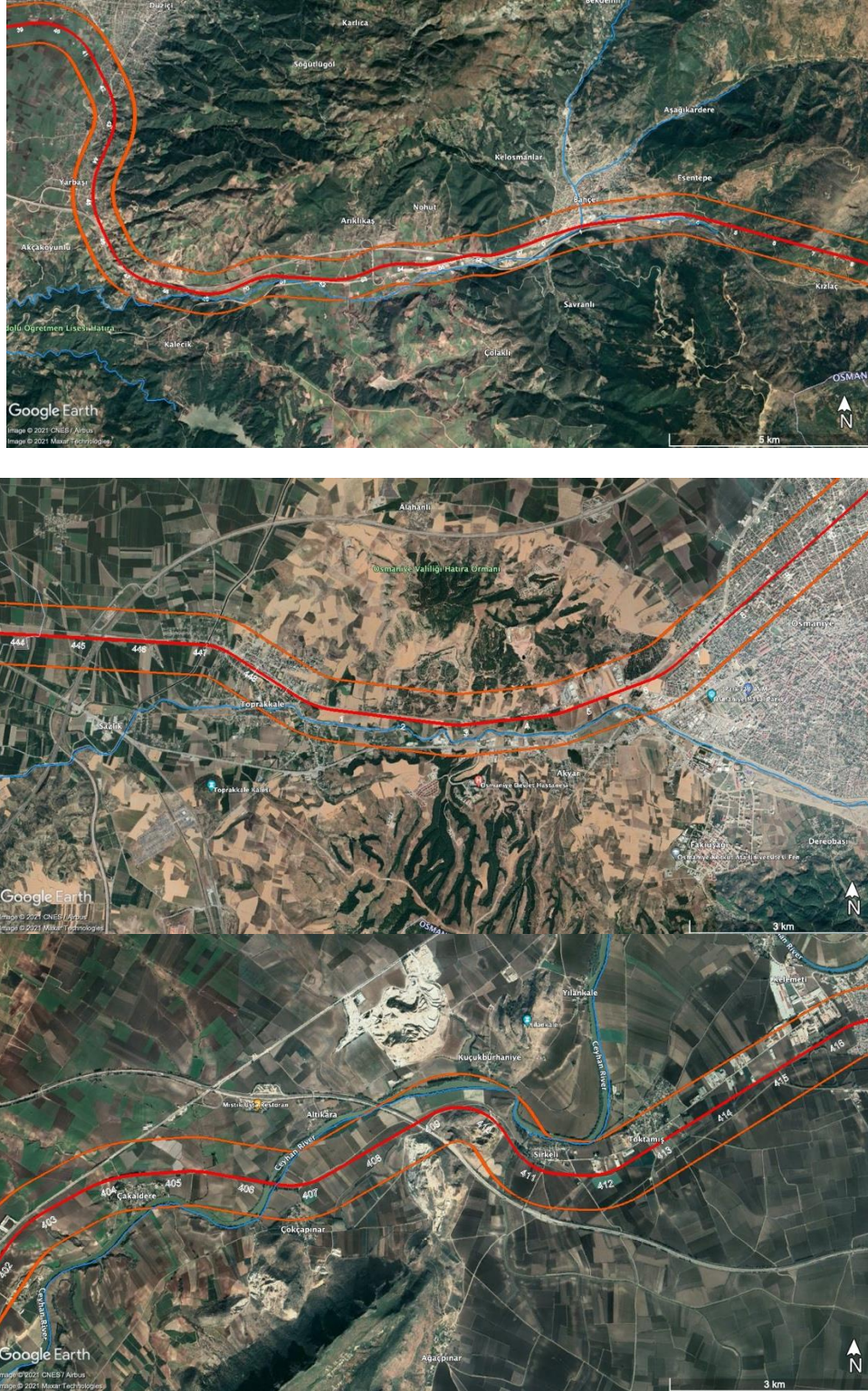


Figure 4-12. The Floodplain Areas

4.6. Flood Risk Maps

The flood maps provide a detailed picture of flood risk for a range of flood event scenarios including climate change, and are the essential tools for land use planning in flood-prone areas. The flood maps support planning and emergency response and allow the authorities to be prepared for possible flood events. The basic criteria for mapping are usually chosen according to flood return periods. Flood risk maps were obtained from the Turkish Flood Management Portal for the maximum flood discharges with return periods of 50 years. In order to look at the flood risks, the project route was divided into six sections, and risk maps were generated for each section.

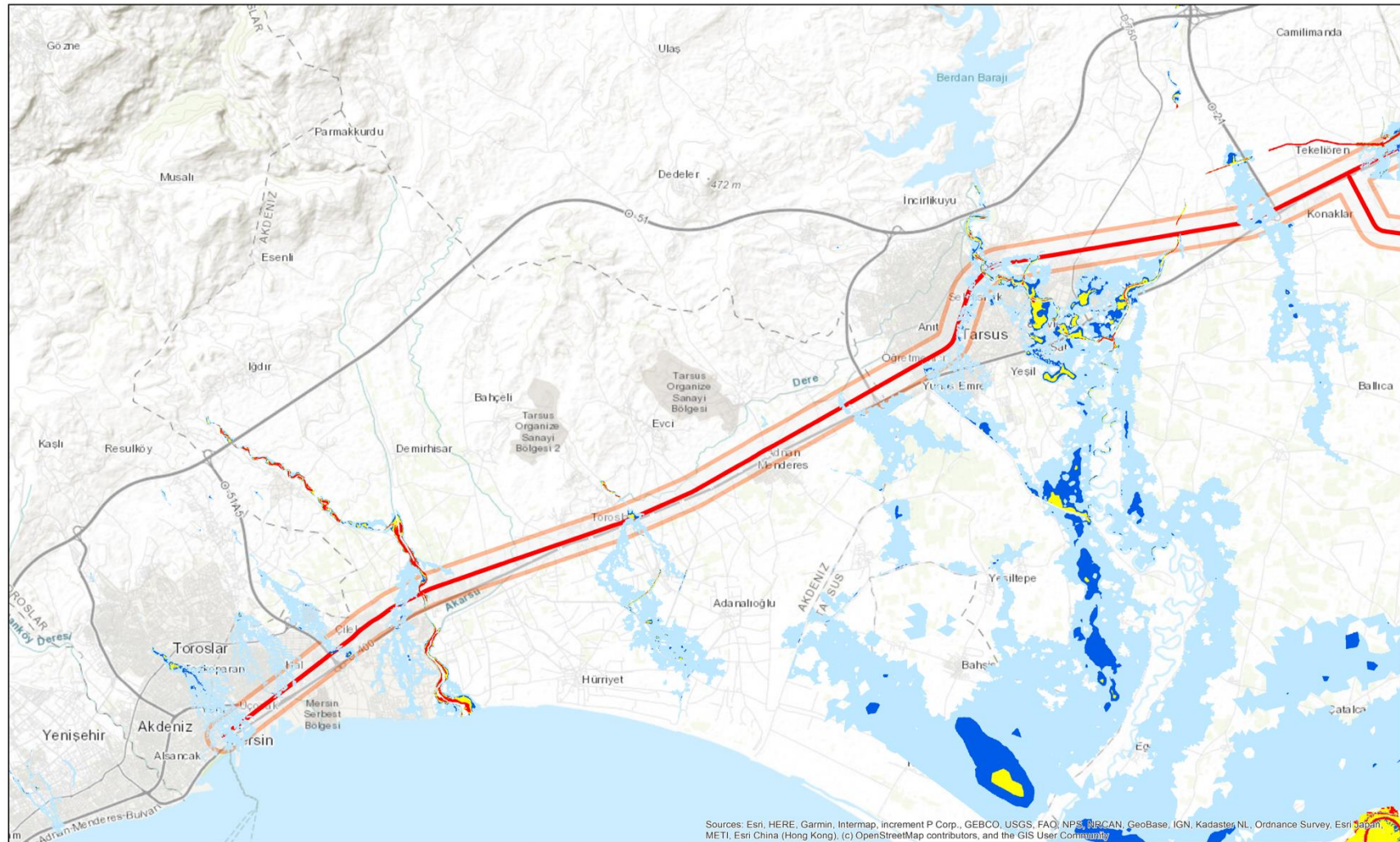
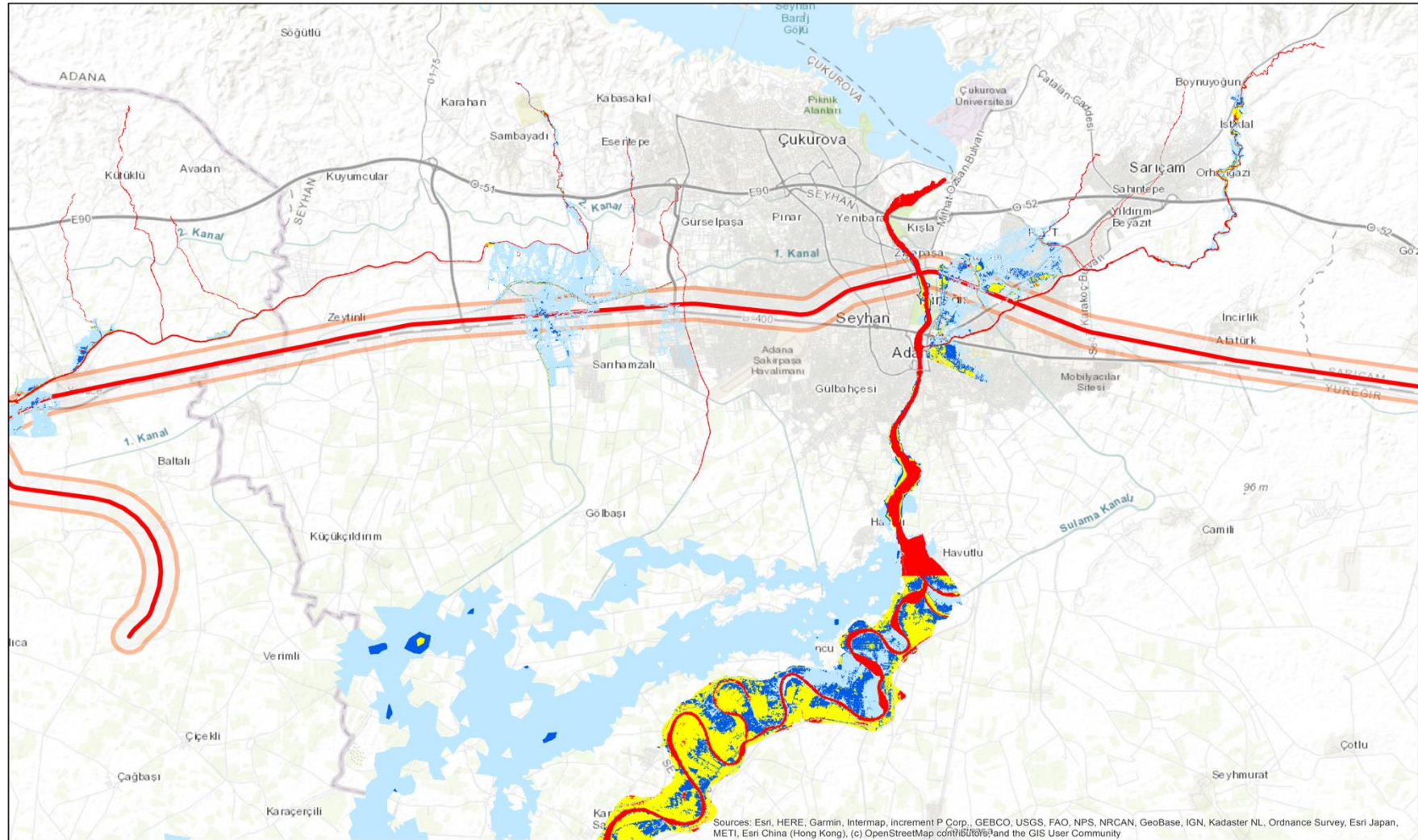


Figure 4-13. The Route Section 1

**Figure 4-14.** The Route Section 2

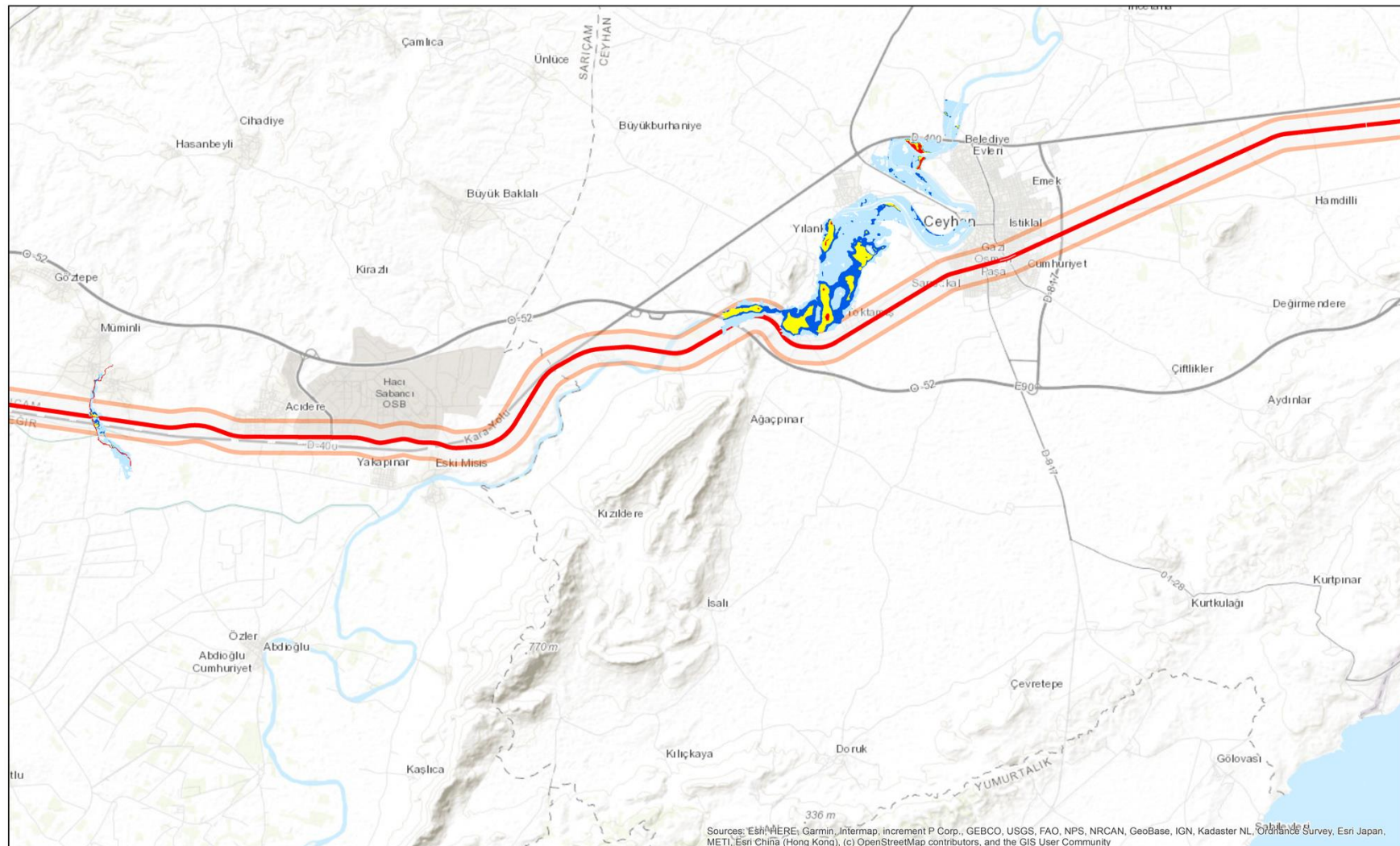


Figure 4-15. The Route Section 3

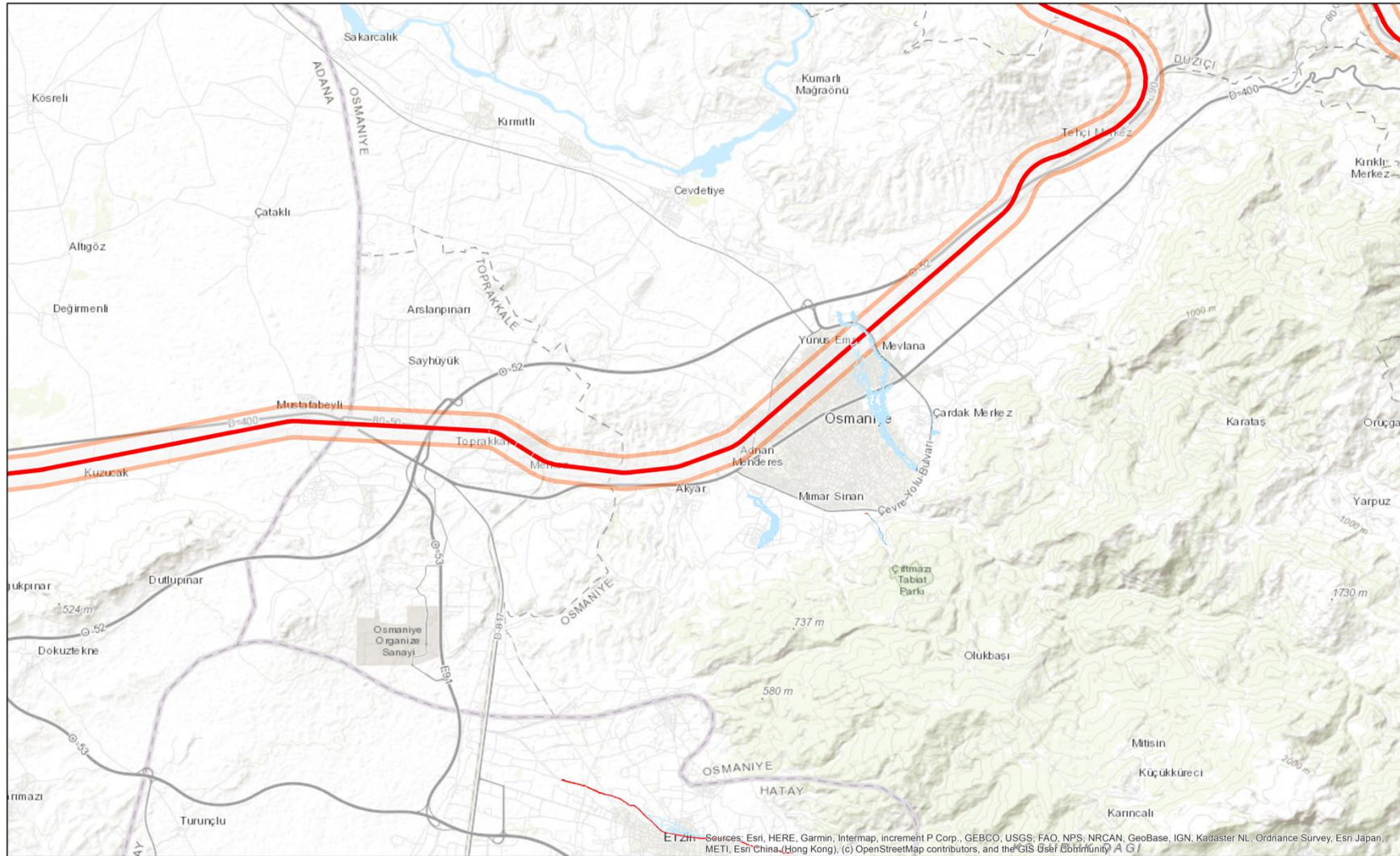
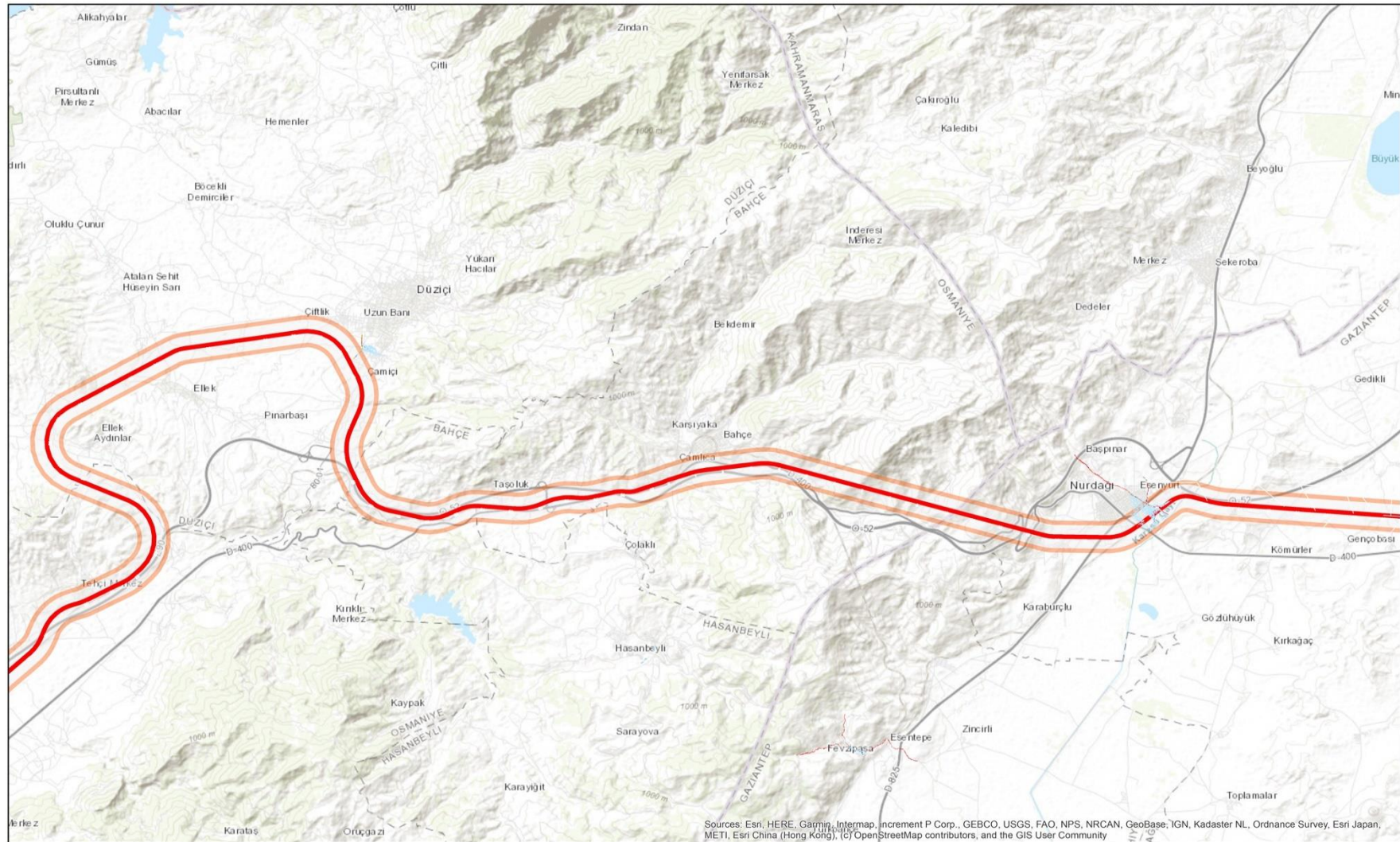


Figure 4-16. The Route Section 4

**Figure 4-17.** The Route Section 5

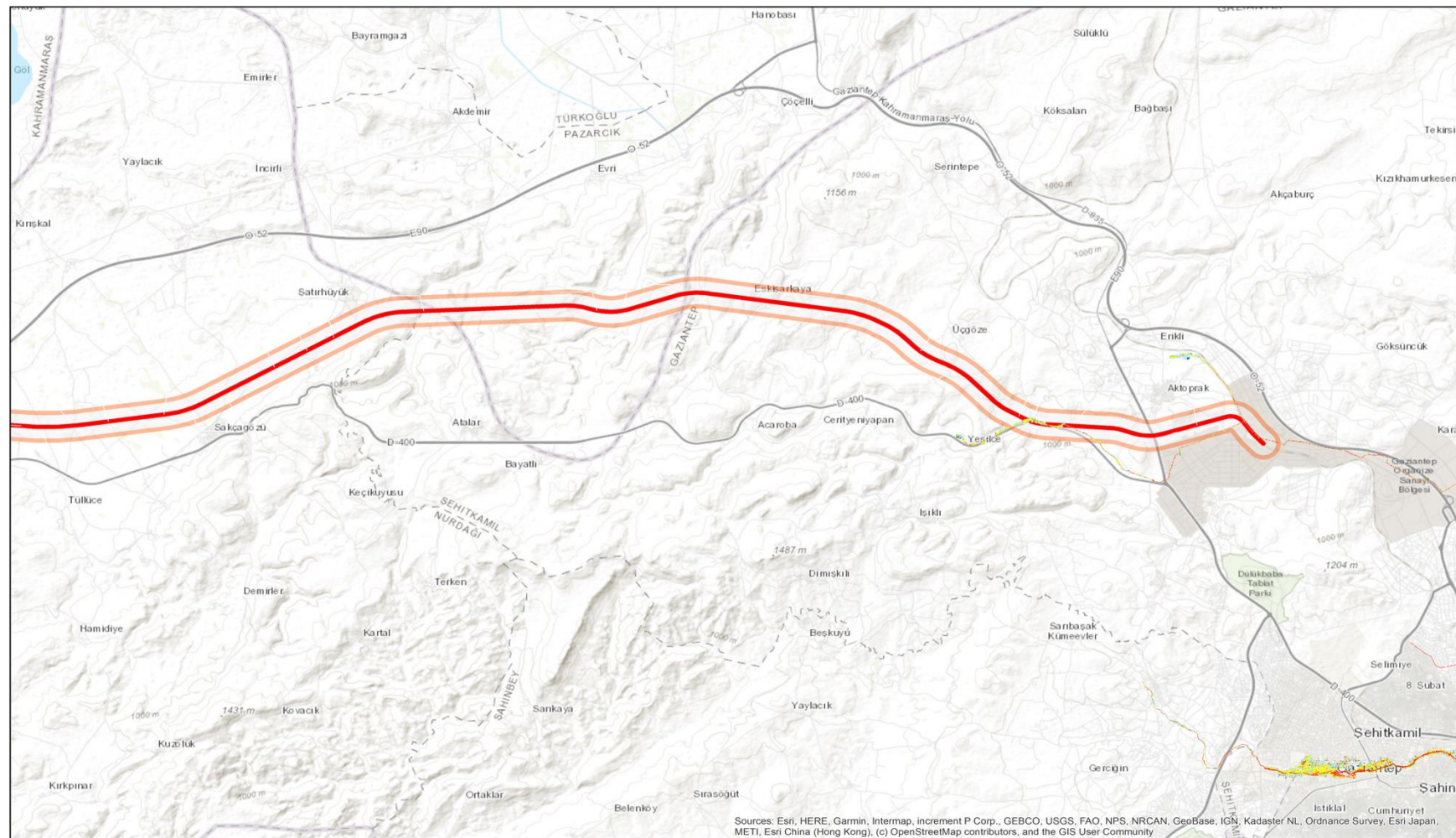


Figure 4-18. The Route Section 6

4.6.1. Detailed Risk Maps

After overall examining the flood risk (Q50) for each route sections which gives the main understanding of risks on the project, risks on specific locations (bridges) where the train passes through the rivers, lakes, and streams etc needs to be evaluated in detail. The bridges' locations were given in Table 4-3. All risks maps over the important locations were given below (see. Figure 4-20 to Figure 4-28).

Table 4-3. The Bridges' Locations

Bridge	Lat	Lon
Bridge 1	36.84361	34.701487
Bridge 2	36.934439	34.893734
Bridge 3	36.945691	34.960253
Bridge 4	36.968252	35.03103
Bridge 5	36.946556	35.029994
Bridge 6	37.007304	35.334748
Bridge 7	36.998935	35.367901
Bridge 8	36.992691	35.705433
Bridge 9	37.125686	36.302002
Bridge 10	37.128301	36.305614
Bridge 11	37.190376	36.571316
Bridge 12	37.190891	36.57428
Bridge 13	37.176164	36.844027

In these locations risk will be especially on the bridge's columns, as flooding caused by a short but very severe precipitation due to changes in climatic conditions, changes in the rainfall-runoff relationship and in the amount of runoff due to changes in land cover (LC) and land use (LU) in the basin, occurrence of hydroelectric power plants or dams, sand and gravel withdrawal from streams affect stream discharges will have direct or indirect impacts on bridges. Types of damages were given in Figure 4-19.

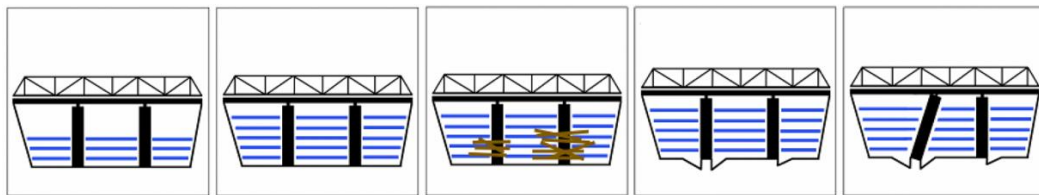


Figure 4-19. Typical Flood Damages of Bridge's Structure

In this regard, bridges may be faced to long closures depending on the level of flood destruction, and any materials such as log jams etc. need to be removed to be avoid from further damages.

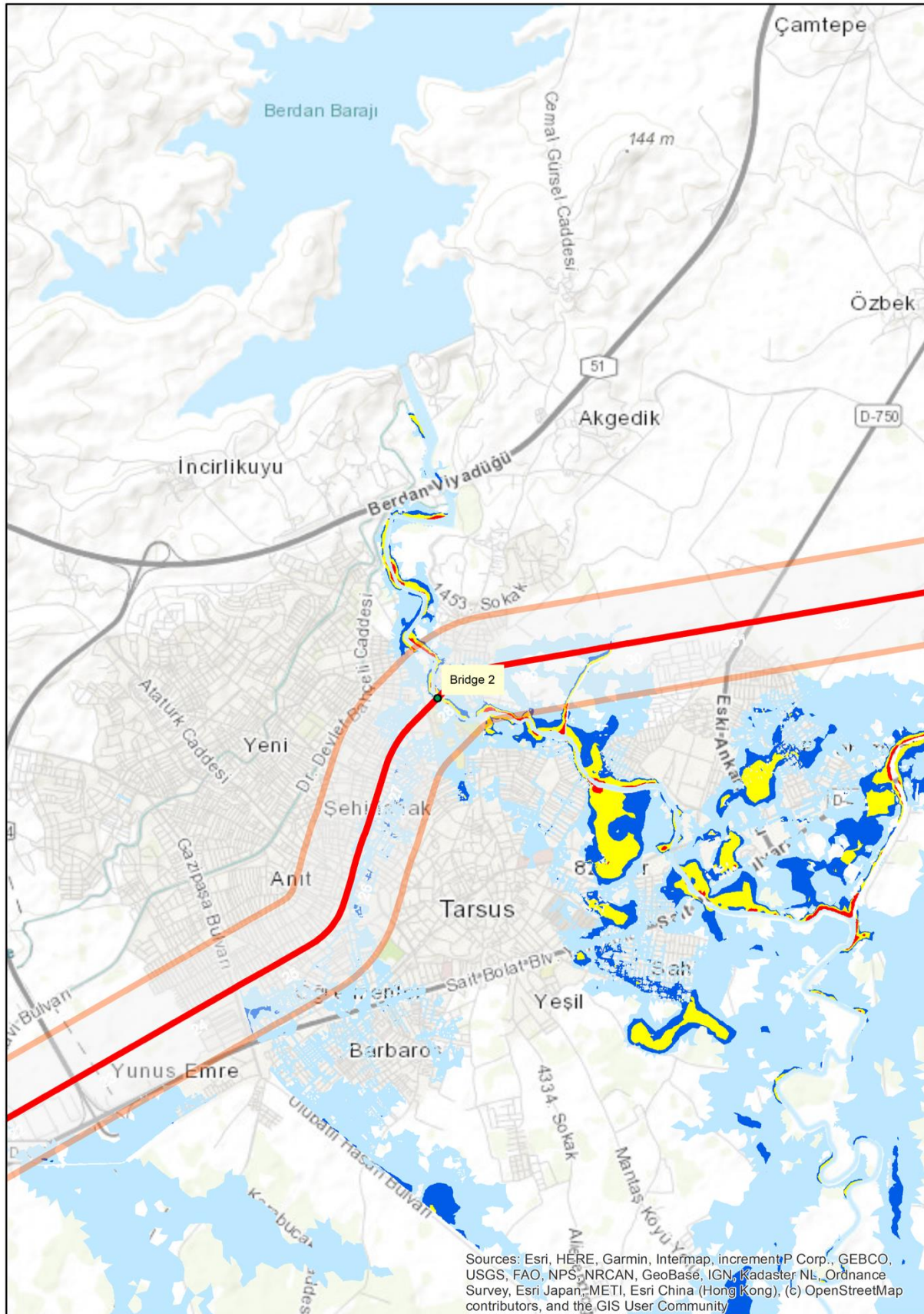
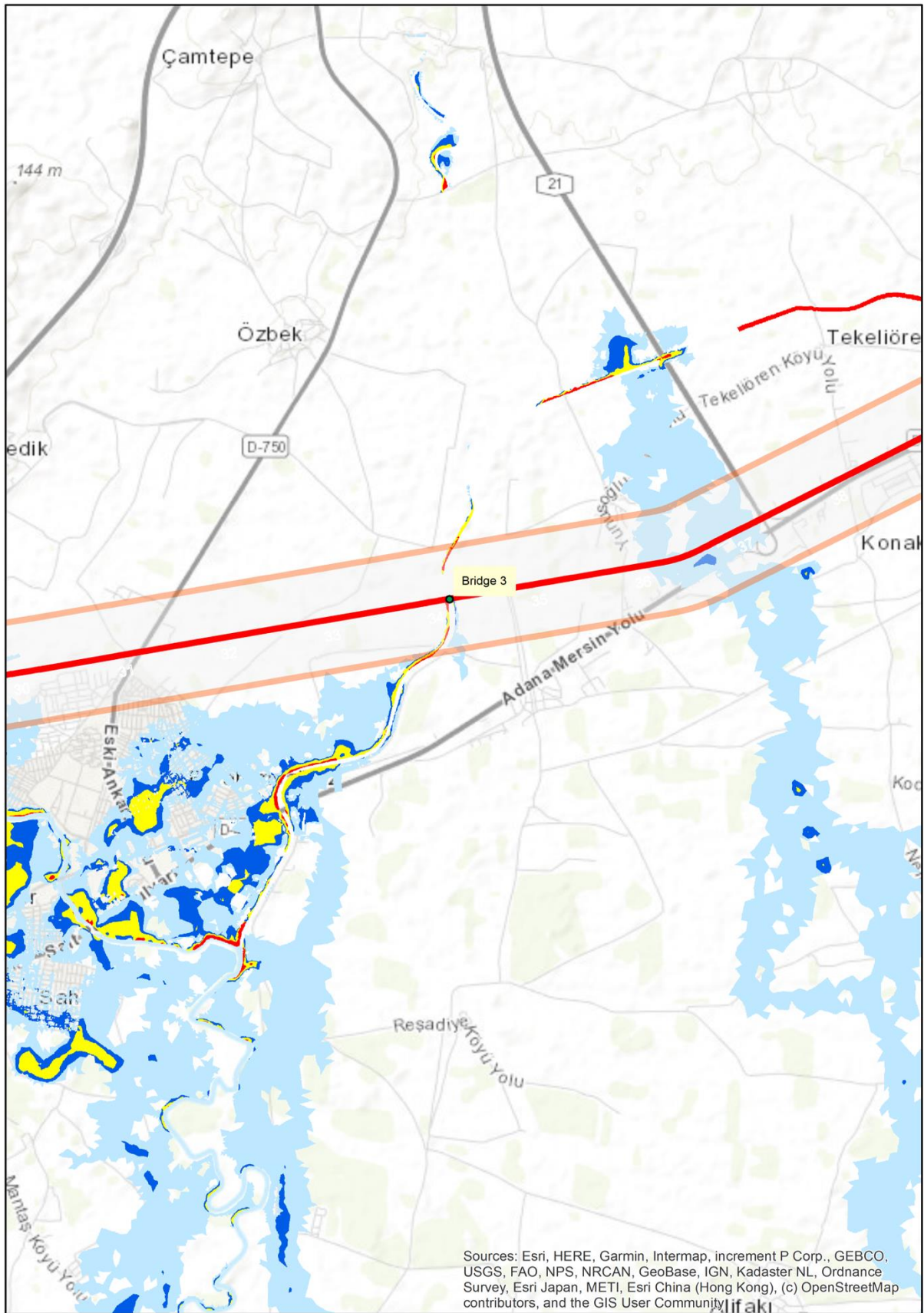
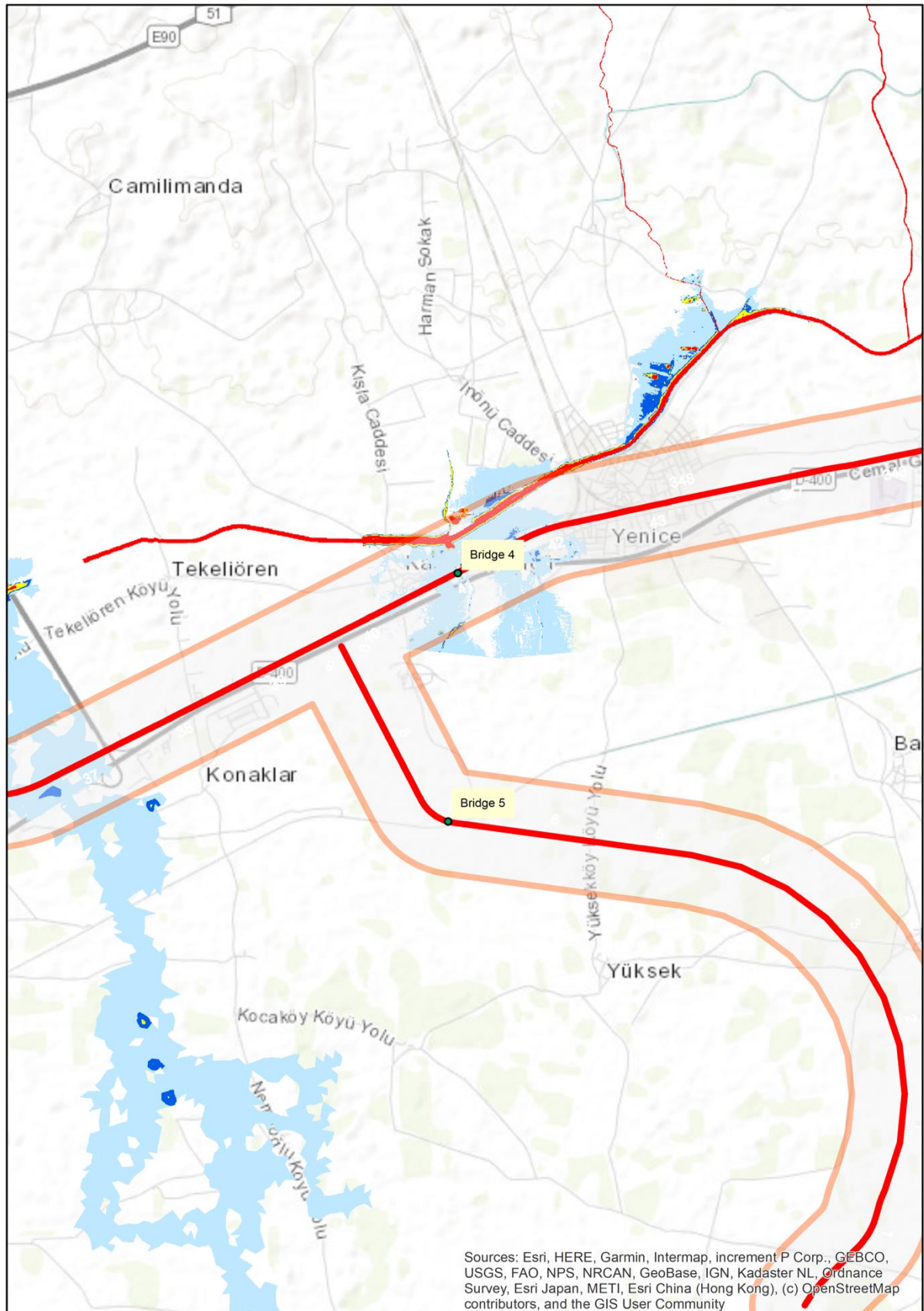


Figure 4-21. The Bridge 2

**Figure 4-22.** The Bridge 3

**Figure 4-23.** The Bridge 4 – 5

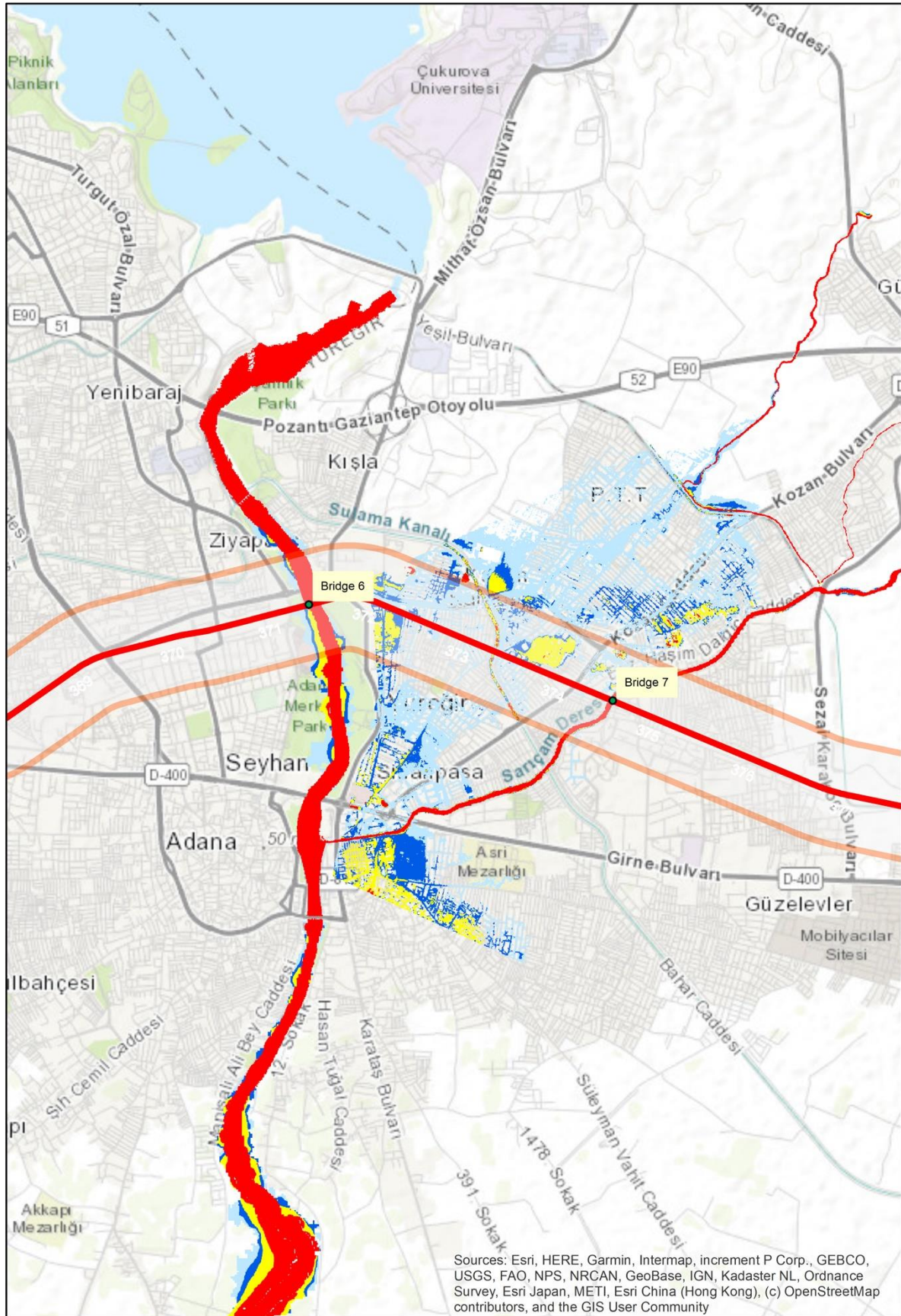
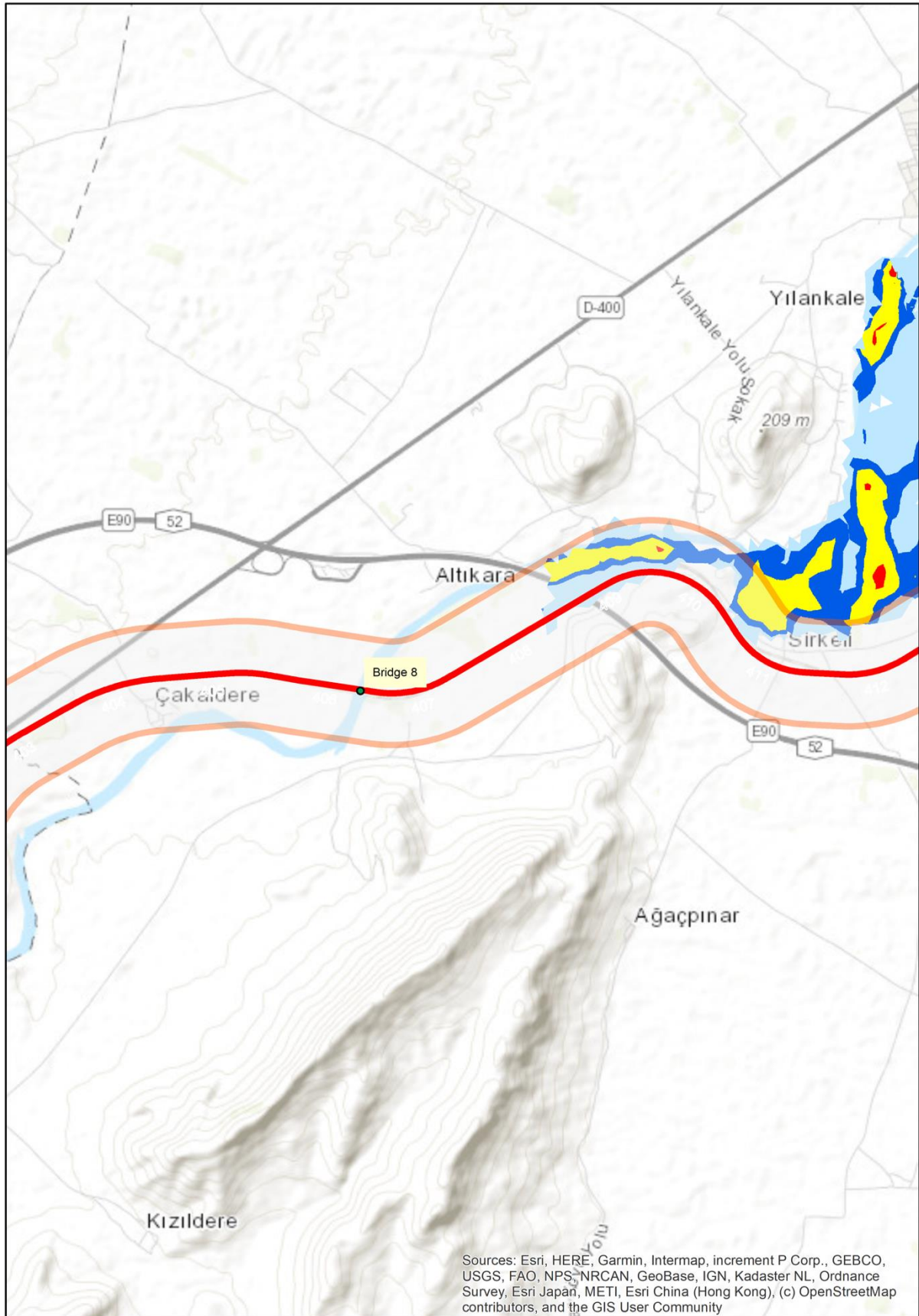
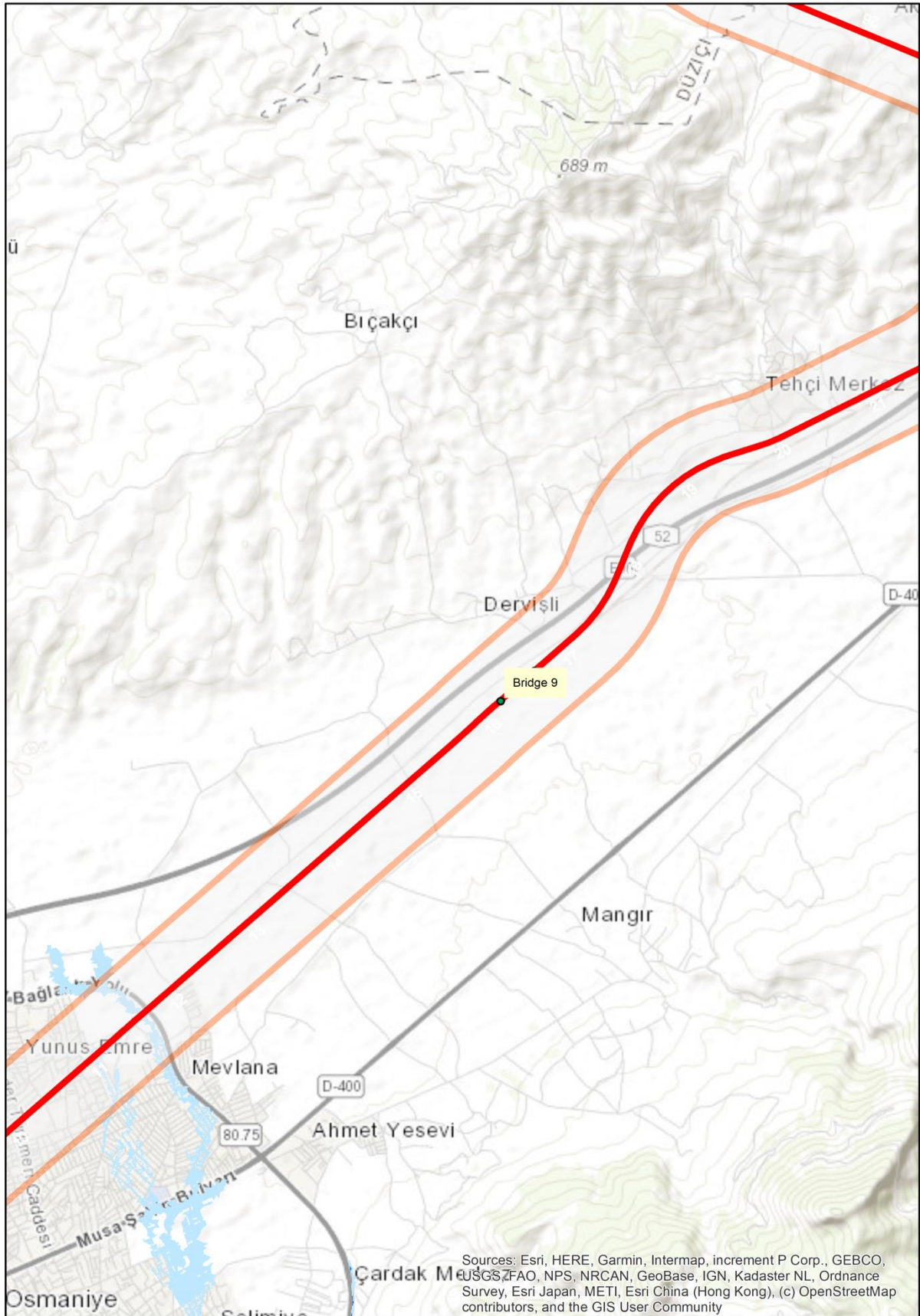
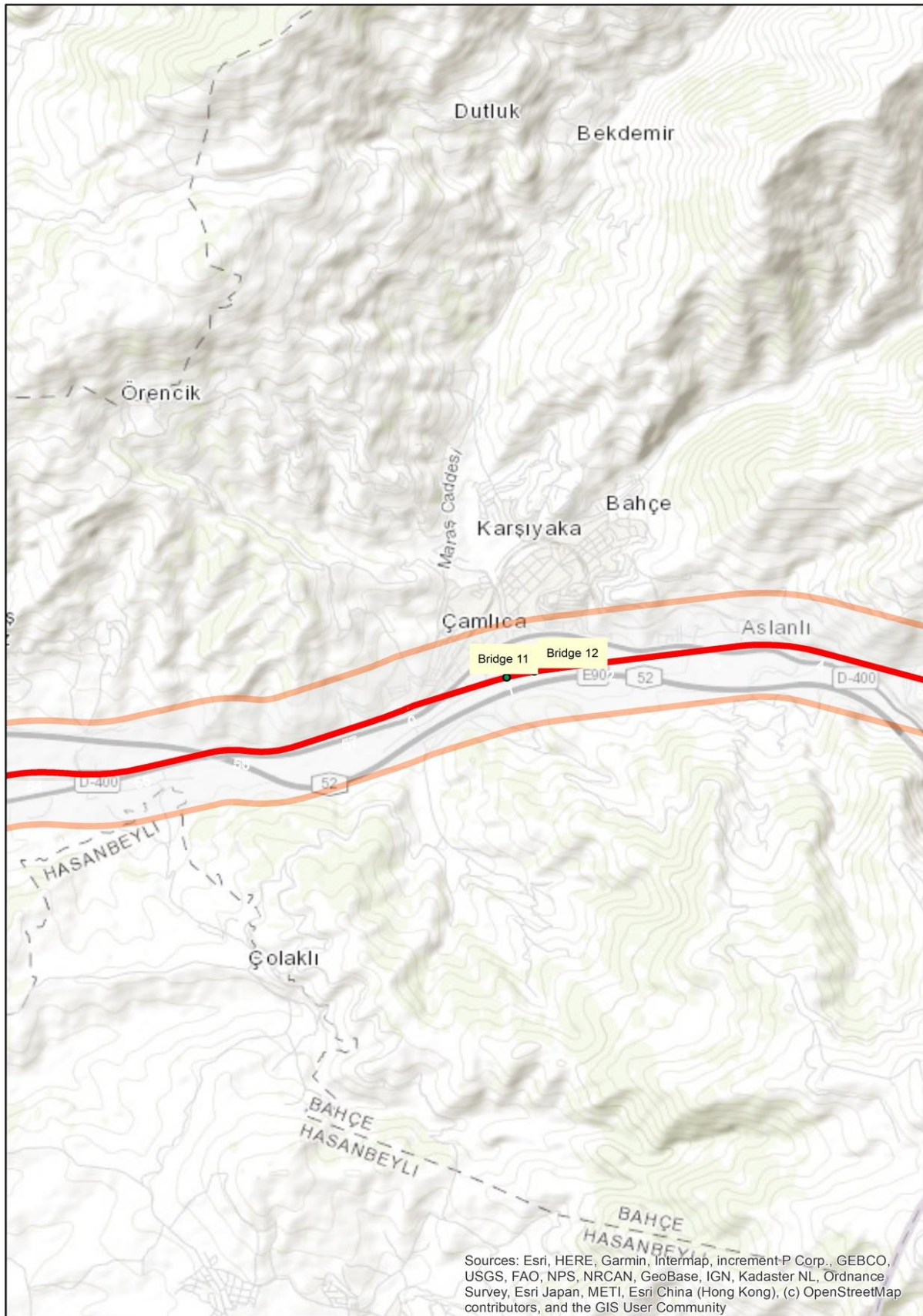
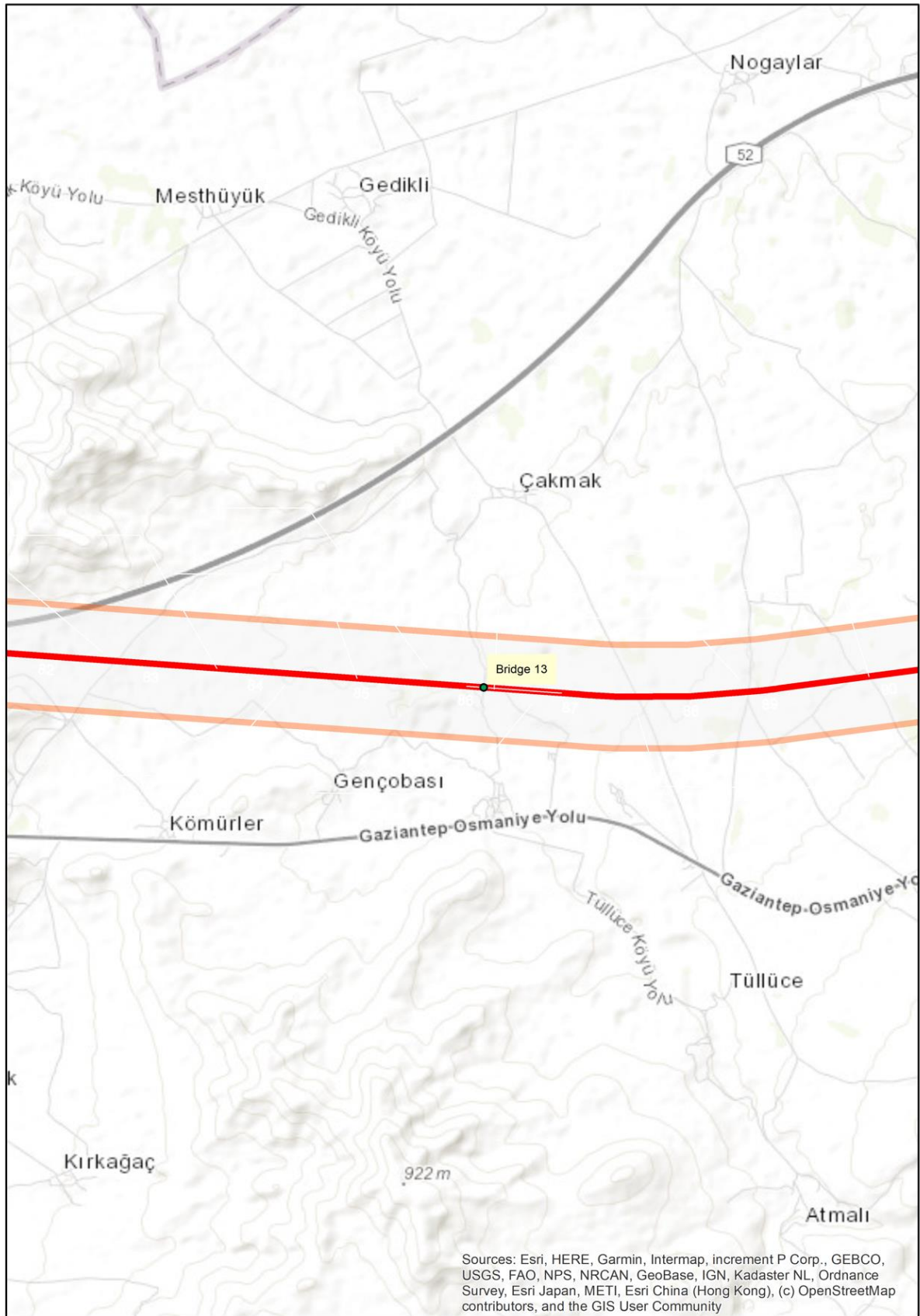


Figure 4-24. The Bridge 6 – 7

**Figure 4-25. The Bridge 8**

**Figure 4-26.** The Bridge 9 – 10

**Figure 4-27.** The Bridge 11 – 12

**Figure 4-28.** The Bridge 13

4.6.2. Coastal Flooding

Changing sea levels are affecting human activities in coastal areas. Rising sea level inundates low-lying wetlands and dry land, erodes shorelines, and contributes to coastal flooding. Higher sea level also makes coastal infrastructure more vulnerable to damage from storms.

As relative sea level rises due to climate change, one of the most noticeable consequences is an increase in coastal flooding. Flooding typically occurs during seasonal high tides (“king tides”) and storms that push water toward the shore. In recent years, however, coastal cities are increasingly flooding on days with less extreme tides or little wind, even on sunny days. Floods are happening more often as rising sea level reduces the gap between average sea level and the height of the land.

How the sea level will change by the end of this century under 1.5°C and 4°C Scenarios were given in Figure 4-29. According to sea level rise map below, it is not expected to the route will be under the flood threat. However, as Mersin Station of the railway will be very close to coastal areas, it is important to follow the regulations from the government and local authorities.



Figure 4-29. Sea Level Rise under 1.5°C and 4°C Scenarios

4.7. Summary of Key Project Flood Risks

To determine the effects of these risks on the project, significance of effects was defined. In order to determine significance, likelihood and magnitude of change was considered. Likelihood description are given in Table 4-4 and magnitude criteria are given in Table 4-5.

Table 4-4. Definition of Likelihood

Measure of Likelihood	Description
Very Low	The event may occur once during the lifetime of the project.
Low	The event occurs occasionally during the lifetime of the project, e.g., once in 60 years.
Medium	The event occurs limited times during the lifetime of the project, e.g., approximately once every 15 years.
High	The event occurs several times during the lifetime of the project, e.g., approximately once every five years.
Very High	The event occurs multiple times during the lifetime of the project, e.g., usually annually.

Table 4-5. Criteria for Magnitude of Change

Magnitude	Criteria
Negligible	No infrastructure damage
Low	Localised infrastructure or asset disruption. No permanent damage, minor restoration work required:
Medium	Limited infrastructure or asset damage and loss of service with damage recoverable by maintenance or minor repair
High	Permanent damage and complete loss of service

Likelihood and magnitude were combined to assess significance of the effects. Assessment is qualitative and based on expert judgement. Significance matrix is shown in Table.

Table 4-6. Significance Rating Matrix

Likelihood	Magnitude			
	Negligible	Low	Medium	High
Very Low	Not significant	Not significant	Not significant	Significant
Low	Not significant	Not significant	Not significant	Significant
Medium	Not significant	Not significant	Significant	Significant
High	Not significant	Not significant	Significant	Significant
Very High	Not significant	Significant	Significant	Significant

The potential physical impacts, proposed mitigation measures and residual impact significances are summarized in Table 4-7.

Table 4-7. Significance Assessment

Project Component	Flood Likelihood	Magnitude	Significance	Design Measures
Bridge 1	High	Low	Not significant	No action required. Project designed for high flow capacity (Q500). Project components in accordance with material standards.
Bridge 2	High	Low	Not significant	No action required. Project designed for high flow capacity (Q500). Project components in accordance with material standards.
Bridge 3	High	Negligible	Not significant	No action required. Project designed for high flow capacity (Q500). Project components in accordance with material standards.
Bridge 4	High	Negligible	Not significant	No action required. Project designed for high flow capacity (Q500). Project components in accordance with material standards.
Bridge 5	Low	Low	Not significant	No action required.
Bridge 6	High	Low	Not significant	No action required. Project designed for high flow capacity (Q500). Project components in accordance with material standards.
Bridge 7	High	Negligible	Not significant	No action required. Project designed for high flow capacity (Q500). Project components in accordance with material standards.
Bridge 8	Low	Low	Not significant	No action required.
Bridge 9	Low	Low	Not significant	No action required.
Bridge 10	Low	Low	Not significant	No action required.
Bridge 11	Low	Low	Not significant	No action required.
Bridge 12	Low	Low	Not significant	No action required.
Bridge 13	Low	Low	Not significant	No action required.

5. FLOOD RISK MANAGEMENT STRATEGIES

The risk of damage and disruption because of flooded track is a problem for railways the world over. The main actors include the driver, signaller, and operations control (the Network Rail Route Control Manager). The procedures are split into two sections, those that govern the reporting of flooding and those for running through floodwater.

5.1. Types of Flood Risks

Flood water in particular can pose problems on the railway. Water blocking the lines, as well as debris, silt and mud making its way onto the track, are only part of it. The lasting damage that flood water can cause to infrastructure can lead to ongoing repair work that takes days, weeks or even months. Some examples of the flood risks on the railways system were given in Figure 5-1.

Flood water can wash away ballast – the bed of stones that supports the railway sleepers. Such ‘washouts can make the line unsafe until it has been re-laid.

Points and signalling equipment rely on intricate wiring and power supplies, which are extremely vulnerable to failure during flooding, and need replacing before services can run again. If the track has a live conductor rail, flooding can cause a short circuit.

Sometimes flood water doesn’t stop trains running, but if water levels rise above the rails, trains have to reduce their speed to prevent damage to the train, which in turn can cause delays.

Heavy rain can overwhelm the drainage systems on the railway, known as culverts, and make flooding more likely.

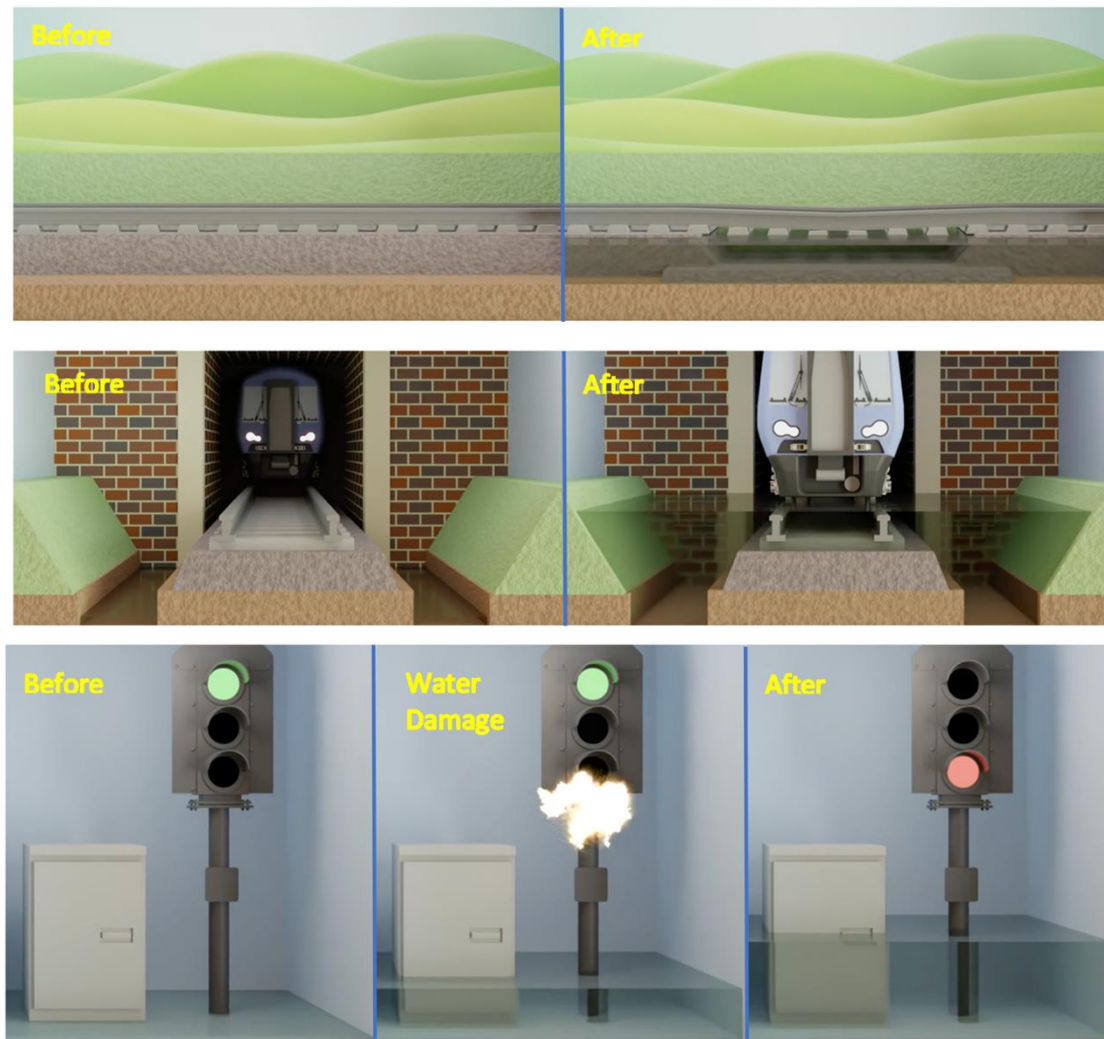


Figure 5-1. An Example of Flood Impacts on the Railway System

5.2. Reporting Flooding

Drivers must report any floodwater with the potential to affect the passage of trains to the signaller, who in turn must report it to operations control immediately. The following information should be included as relevant:

- Has ballast been dislodged by the floodwater?
- Is the floodwater moving? If so, is it likely to dislodge ballast?
- If the floodwater is not moving, at what depth is it relative to the railhead? Is it:
 - Below the bottom of the railhead;
 - Below the top of the railhead;
 - Above the level of the railhead.

Where vehicles have been stabled in or passed through floodwater that is above the level of the bottom of the axle box, the driver must arrange for operations control to be notified.

5.3. Running through Flood Water

Trains may be allowed to move through floodwater if the floodwater is not moving and the ballast is unlikely to be dislodged or if the ballast has not been dislodged. Permitted movement speeds are based on the depth of the floodwater relative to the railhead:

- If floodwater is below the bottom of the railhead, trains are permitted to continue normally;
- If floodwater is no deeper than the top of the railhead, then trains may be allowed to proceed at a maximum speed of 5 mph.

Train movements through floodwater that is above the top of the railhead are not permitted except under instruction from Operations Control.

5.4. Mitigation Measures

Any identified flood risk to a railway structure that is considered to be unacceptable (either because it is likely or the are substantial) requires a mitigation measure. A mitigation measure may comprise physical works, flood warning/monitoring, improvement the structure management procedures or a combination of all three.

5.4.1. Monitoring

Monitoring can be very cost-effective and quick to implement (at least when compared to physical protection). An important distinction needs to be made between monitoring for operational response/mitigation purposes and for data collection. The former requires a very demanding level of reliability, which is difficult to achieve given the exposed environment any monitoring device will be subject to. The latter is desirable as it will allow future fine-tuning of management responses.

General constraints on monitoring are:

- All devices involving electronics (the majority) require a power source, which is difficult to provide in remote locations. Alternative battery supplies require regular maintenance.
- The devices may be in place for considerable lengths of time (years or decades) before a significant flood occurs.
- The resources needed to maintain monitoring equipment and download data (even where telemetry is used) are specialist and considerable. Sub-contract maintenance contracts may be difficult due to the safety requirements of working on the operational railway.
- It is often not possible to distinguish equipment failure from a flood event.

For the above reasons, monitoring on its own cannot be considered a sufficiently robust mitigation measure to change the priority rating of a structure. However, it can form a useful input into the Flood Plan.

5.4.2. Flood Warning

In Turkey, river and tidal flood warnings are provided by Turkish Met Office. These warnings are based on a mixture of river level/ tide gauge monitors and also forecasting using numerical models. The warnings are freely available to the public and the railway industry via the Turkish Met Office websites.

5.5. Managing the Risks

The infrastructure controller shall have procedures in place to receive all appropriate river and coastal flood warnings issued by the relevant authorities. The infrastructure controller shall maintain a list of national, regional and area offices of the relevant authorities.

All decisions made and actions taken to meet the requirements of flood risks shall be recorded. Records shall be retained for the lifetime of the structure.

The infrastructure controller shall ensure that the responsibilities of all persons engaged in managing the risk from water action at a structure are clearly defined in writing and understood by those persons. The skill, expertise and training of the persons carrying out the duties shall be related to the nature of the structure and the nature of the risk from water action.

5.6. To Do Lists

In order to reduce the effects of flooding and prevent delays:

- Monitor the weather – check the flood warning from the Turkish Met Office or responsible authorities.
- Send adequately trained people and equipment to the risk areas so as to act quickly.
- Where suitable deploy flood defence systems, including barriers with a membrane that seals to prevent water getting through, and inflatable barriers filled with water.
- Clear out branches, leaves and debris in ditches, culverts, and other drainage systems which might reduce or prevent effective water runoff.
- Build pumping stations in flood-prone locations at sensitive essential infrastructure to enable flood water to be , quickly pumped away when needed.

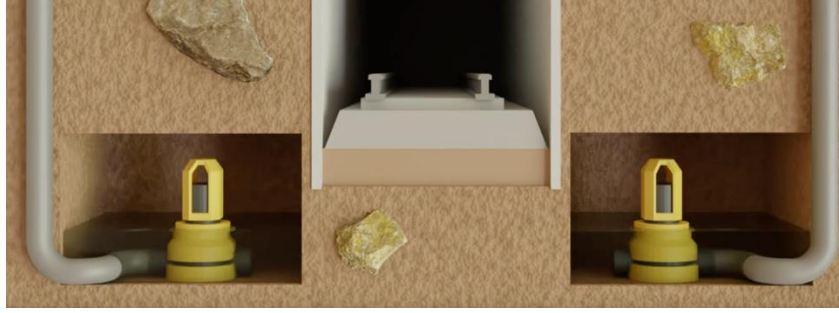


Figure 5-2. Pumping Stations

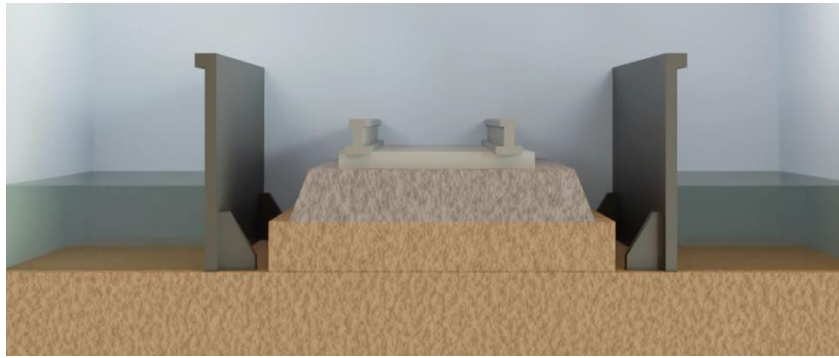


Figure 5-3. Flood Barriers



Figure 5-4. Clearing the water channels near the railways

6. CONCLUSION

This report provides a summary of the methods and information used to perform a flood risk assessment, specifically tailored to the project of Mersin Gaziantep High Standard Train. This followed the six steps defined in Chapter 1, and utilised the WRF model, to provide high resolution outputs, to evaluate the projected rainfall and extreme rainfall changes

Monthly temperature averages and total rainfall values have been changing since 1970 (1986 for Osmaniye), and there is warming trend in the project area through the year of 1970-2018 by about 1°C. There has also been an increase in extreme events reaching 1000mms since 1990s. Although the majority of the project area is not located in heavy rainfall areas, the route passes through Osmaniye, where over 100 rainy days were observed. According to CMIP5 model outputs, it is expected that rainfall and extreme rainfalls will increase by 25-50% near the project areas under the RCP 4.5 and RCP 8.5 scenario. Floods and heavy rainfalls were observed frequently near the project area, and the total number of floods and heavy rainfalls have been increased since 1975, especially after 2006s. One of the main flood risk will be from the surface water flooding typically occurring when intense rainfall is unable to infiltrate into the ground or enter a drainage system such as a watercourse or sewer, resulting in localised flooding due to overland flow or backing up of floodwaters. There are also some places where the railway passes through floodplain and those areas should be noted for the floodplain risks. No groundwater flooding risks have been identified. Bridges along the route have been identified as most sensitive to potential flood damage, with the potential for long closure times depending on the level of flood destruction. Overall coastal flooding risks are not considered to be significant, however as Mersin Station of the railway will be very close to coastal areas, it is important to follow the regulations from the government and local authorities for the coastal flooding.

Potential mitigation measures and possible actions have been evaluated, which include management and physical measures. The main responsible parties for the management of risk will include the driver, signaller, and operations controller, and the procedures are split into two sections, those that govern the reporting of flooding and those for running through floodwater. Railway operations should follow the flood warnings provided by Turkish Met Office. The infrastructure controller shall have procedures in place to receive all appropriate river and coastal flood warnings issued by the relevant authorities. The infrastructure controller shall maintain a list of national, regional and area offices of the relevant authorities. All decisions made and actions taken to meet the requirements of flood risks shall be recorded. Records shall be retained for the lifetime of the structure.