Deliverable Phase 1 – Climate risk assessment

Advanced Risk assessment for ClimAte resilience Debates, Innovations and Actions in Dobrich (ARCADIA)

Bulgaria, Dobrich

HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk Assessment approach

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Document Information

Deliverable Title	Phase 1 – Climate risk assessment
Brief Description	The Dobrich municipality's climate risk assessment report zeroes in on flooding as the main hazard, using the CLIMAAX approach to thoroughly analyze key climate risks and vulnerabilities. The project team has created an assessment, using relevant data and as well as stakeholder feedback to suggest practical ways to improve flood risk management.
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5.0	...		Final version to be submitted

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Abbreviations and acronyms

Abbreviation / acronym	Description
CRA	Climate Risk Assessment
DRBD	Danube River Basin District
DRRP	Disaster Risk Reduction Program
NSI	National Statistical Institute
NIMH	National Institute of Meteorology and Hydrology

Executive summary

Motivation

This report presents the first phase of multi-risk assessment for Dobrich Municipality under the CLIMAAX project. It addresses the need for science-based climate risk evaluation in urban areas experiencing changing hydrological patterns. The document provides local decision-makers and stakeholders with a comprehensive analysis of river flooding hazards along the Dobrichka River, and offers essential insights for strategic adaptation planning and risk management.

Main Results and Findings

The assessment employed the CLIMAAX methodology and toolbox for river flood risk evaluation, utilizing historical hydrological data, regional climate projections under RCP4.5 and RCP8.5 scenarios (for 2030, 2050, and 2080 timeframes), and spatial infrastructure data. The analysis incorporated EURO-CORDEX climate simulations downscaled to Dobrich Municipality's geography, with particular attention to precise river channel and urban drainage system mapping.

Key actions undertaken during this phase included:

Selection and implementation of appropriate climate scenarios (RCP4.5 and RCP8.5)

Geospatial mapping of potential flood zones

Vulnerability assessment of infrastructure and population Quantification

of potential economic damages

The assessment revealed that the Dobrichka River has a highly variable flow regime, with the average annual discharge of 0.04 m³/s, potentially reaching 0.42 m³/s during extreme events. The analysis identifies the critical flood-prone urban zones around the Dobrichka River, where the modified river channel passes through densely built-up territories with limited infiltration capa. Climate projections indicate increasing flood frequency, with water depths reaching up to 2m for 10- year return period events and up to 5m for 500-year events under RCP4.5 and RCP8.5 scenarios, with a higher frequency of extreme events under RCP8.5. The results of the study reveal an exponential increase in the potential economic damage and the number of affected population with an increase in the flood recurrence period. According to preliminary calculations, in a 500-year flood, the financial losses reach 100 million. EUR, and over 12,000 people would be at risk.

Conclusions

The results of this initial river flood risk assessment for Dobrich Municipality provides a base for the regional climate adaptation planning on municipality scale. The results highlight the necessity for investments in river channel improvements, drainage system upgrades, and early warning mechanisms. Integration of these results into municipal disaster protection plans is essential for reducing vulnerability of urban infrastructure and population under changing climate conditions. The deliverable supports the broader CLIMAAX objective of developing harmonized, science-based climate risk assessments that enable European regions to enhance their climate resilience.

1 Introduction

1.1 Background

Figure 1-1 Location of the Dobrich Municipality

Dobrich Municipality, located in Bulgaria's Northeast Planning Region (NUTS2), covers 109.018 km², making it the smallest municipality in Dobrich District. The terrain is predominantly flat to slightly rolling, part of the Dobrudzha plateau, with elevations ranging from 191 to 350 meters above sea level. The northern parts are lower than the southern periphery, influencing the Dobrichka River's flow pattern.

The municipality experiences a moderate continental climate with an annual average temperature of 10.2°C. July is the warmest month (21.1°C). The precipitation is about 540 mm, concentrated primarily in May and June. Maximum daily rainfall can reach 205.16 mm under extreme conditions (0.1% probability). Northwestern winds dominate, occasionally reaching speeds of up to 20 m/s.

The Dobrichka River, a right tributary of the Suhata River within the Danube system, traverses the municipality. The river exhibits a highly variable hydrological regime characterized by long dry periods punctuated by short but potentially intense flood events.

Demographically, Dobrich has experienced significant fluctuations, growing substantially between 1946 and 1992 to approximately 125,000 inhabitants before declining to 87,361 by 2024 (National statistical Institute – NSI).

Economically, the municipality combines agricultural heritage with diverse industries, with food processing dominating the local economy (over 50% of industrial output), complemented by light industry and engineering sectors.

1.2 Main objectives of the project

The primary objective of the CLIMAAX project for Dobrich Municipality is to conduct a comprehensive and harmonized Climate Risk Assessment (CRA) specifically focused on river flooding hazards along the Dobrichka River. This assessment responds to the growing challenges of climate change in a region characterized by variable hydrological patterns and increasing extreme weather events.

Key objectives of the project for the Municipality include:

- Identifying and evaluating climate-related hazards specific to Dobrich Municipality through rigorous scientific analysis and modelling, particularly on flooding dynamics under various climate scenarios, strong winds, snowstorms, and droughts.
- Assessing the exposure and vulnerability of infrastructure and population to these hazards
- Engaging local stakeholders, including municipal authorities, businesses, community organizations, and citizens, in the CRA process to incorporate local knowledge and ensure community ownership of adaptation strategies
- Enhancing the technical capacity of local authorities through training and knowledge transfer, enabling them to independently conduct future assessments and implement effective climate risk management strategies
- Systematically assessing climate risks to develop adaptation strategies that mitigate impacts and enhance the resilience of communities and infrastructure.

The application of the CLIMAAX Handbook and toolbox provides Dobrich Municipality with several significant benefits:

- A structured methodological framework ensures that all critical aspects—from hazard identification to risk evaluation—are systematically addressed.
- Integration of local context and stakeholder input to produce relevant and actionable assessments
- Enhanced capacity to prioritize adaptation investments based on quantitative risk metrics
- Guidance for incorporating CRA findings into broader municipal planning processes, including urban development, infrastructure management, and emergency response systems
- Alignment with Bulgaria's national adaptation objectives and the broader EU climate adaptation initiatives, potentially unlocking access to additional funding and resources.
- Support for developing proactive approaches to climate resilience that can reduce future economic losses and safeguard public safety

Through this project, Dobrich Municipality aims to transform its approach to climate risk management from reactive emergency response to proactive, evidence-based adaptation planning that enhances urban resilience while protecting citizens, infrastructure, and economic assets. It will particularly focus on managing the unique challenges posed by the Dobrichka River system under changing climate conditions.

1.3 Project team

The CLIMAAX project for Dobrich Municipality involves a team that combines scientific expertise with local knowledge. The team includes: Project manager responsible for overall project management, control and reporting functions - Pavel Pavlov - deputy mayor; Financial expert - Petia Dimitrova; Environmental and climate expert - prof. Nelly Hristova (Climate, Atmosphere and Water Research Institute from the Bulgarian Academy of Science); Municipal expert responsible for data collection, communication activities, coordination of information with external services - Miroslava Raynova. A public procurement procedure will be carried out to support the municipality in the next stages of the project.

1.4 Outline of the document's structure

This document, adhering to the CLIMAAX Handbook's workflows, presents a climate risk assessment for Dobrich Municipality, focusing on river flooding hazards. It starts with Document Information and Contents, including the project name, table of contents, lists of maps, figures, tables, abbreviations, and acronyms, followed by an Executive Summary that concisely outlines the assessment's key findings, methodology, and conclusions for stakeholders like the municipal government and fire department.

The report then covers an Introduction detailing Dobrich's location, natural conditions, project objectives, implementation team, and document structure, before moving to Chapter 2: Climate Risk Assessment, Phase 1, which defines the assessment's objectives, explores the primary hazard of river flooding, analyzes its risks, evaluates their severity, urgency, and existing capacity, and describes monitoring and evaluation methods. It continues with Chapter 3: Conclusions, summarising key findings and risk implications for Dobrich, and Chapter 4: Progress Evaluation, setting the stage for future phases. Finally, Chapter 5: Supporting Documentation references additional materials, and Chapter 6: References lists sources, including academic literature, municipality reports, and Danube River Basin Management District documents (DRBD).

2 Climate risk assessment – phase 1

2.1 Scoping

2.1.1 Objectives

The Climate Risk Assessment (CRA) for Dobrich Municipality aims to quantify and assess the municipality's exposure and vulnerability to flood hazards of the Dobrichka River. This assessment is essential for the following:

- Understand the spatial distribution and magnitude of flood risks across different urban zones and critical infrastructure
- Analyse the variability of flood patterns under different climate scenarios (RCP4.5 and RCP8.5) and temporal horizons (2030, 2050, 2080)
- Evaluate the vulnerability of urban infrastructure, residential areas, and economic assets to varying flood intensities
- Enable evidence-based policy development and risk-informed decision-making for flood risk management
- Support the design of targeted adaptation strategies that reflect local hydrological conditions and urban development patterns.
- Foster awareness among municipal authorities, businesses, and residents regarding flood risks and adaptation measures
- Strengthen coordination between municipal departments, utility companies, and emergency services in flood risk management.

This scientific assessment, grounded in contemporary analytical methods, supports the EU Strategy for smarter, faster, and more systemic adaptation to climate change. The CLIMMAX project results will contribute to the development of effective regional policies and the adoption of nature-based solutions and actions to mitigate negative impacts on urban infrastructure and daily life of residents.

The expected outcomes: a) Integration of the results in the urban development plans; b) enhancing the capacity of municipal authorities and stakeholders and the coordination between them; c) developing risk-informed investment projects for infrastructure upgrades and flood protection measures. So, the climate risk assessment for Dobrich Municipality contributes to Bulgaria's national climate resilience goals and supports alignment with EU adaptation targets through the participatory approach embedded in the CLIMAAX methodology.

The limitations of the flood risk assessment are the data limitations (limited hydrometric data for the Dobrichka River—monthly discharges from 1952 to 1965), infrastructure data gaps (incomplete data on the condition of urban drainage systems), and municipal budget limitations, which may affect the implementation of recommended adaptation measures.

2.1.2 Context

Historical Assessment and Management of Climate Hazards. The assessment and management of climate hazards in Dobrich Municipality has historically been addressed through the municipal disaster protection framework established under the Disaster Protection Act. The municipality's competence is exercised through implementing the Municipal Disaster Protection Plan and other strategic documents, primarily the Municipal Integrated Development Plan (MIDP) 2021-2027. Before the CLIMAAX project, Dobrich's flood risk assessment was related in the Preliminary Flood Risk Assessment (2022-2027) by the Danube River Basin District. The city of

Dobrich has been designated as an Area of Significant Potential for Flood Risk (ASPFR) with code BG1_APSFR_DB100. The area encompasses the Dobrichka River and two of its right tributaries.

Problem Definition and Regional Context. The main problem that the CLIMMAX project is trying to address is a scientifically based assessment of flood risk on the municipality level. This is important because there are no targeted climate adaptation strategies and effective management measures for climate change on this scale.

Governance Context. The governance framework for climate risk assessment in Dobrich Municipality operates within multiple layers of legal and policy frameworks: a) Bulgaria's National Climate Change Adaptation Strategy and Action Plan (a policy framework for climate adaptation activities); b) The Northeast Planning Region's development strategies; c) The Municipal Integrated Development Plan (MIDP) 2021-2027; d) various sectoral regulations (for the govern water management, urban planning, and infrastructure development with implications). The municipality operates within resource constraints typical of Bulgarian local governments, with limited dedicated funding for climate adaptation measures and heavy reliance on national and EU funding mechanisms for major infrastructure investments.

Relevant Sectors that could be affected by climate change. Several key sectors in Dobrich Municipality are vulnerable to climate change impacts, especially those related to flood risks. First, these are the residential and public buildings near the Dobrichka River. The other vulnerable sector is the industrial zone "Sever" (The Northern Industrial Zone), with many production facilities, warehouses, and offices. The public services (the hospital and medical centres, schools, and emergency services) and the urban Infrastructure (roads, bridges, drainage system) are also vulnerable. The municipality's role as a transportation hub makes road and rail networks particularly critical for regional connectivity.

External Influences. Two external factors influence the context of flood risk management in Dobrich Municipality. The first external Influence is the land use and infrastructure development in the Dobrichka River catchment area and the overflow of the two dams that are outside the municipal boundaries (micro dams "Plachi Dol-1" with a volume of 239,000 m^3 and "Plachi Dol-2" with a volume of 149,000 m^3). The second type of external Influence is the regional climate initiatives for climate adaptation (including the CLIMAAX project itself), the EU Policy on flood risk management, and national funding programs.

Potential Adaptation Interventions. Based on the assessment objectives, several categories of adaptation interventions can contribute to meeting the municipality's flood risk management goals. One such intervention is upgrading urban drainage systems. Just as important is river channel management, enhancing riparian vegetation along the low riverbanks of the Dobrichka River. The next intervention is the flood monitoring and warning system. Not least are enhancing public awareness and coordination with neighboring municipalities.

2.1.3 Participation and risk ownership

Two main groups may be affected by flooding, as was seen in 2014, as they are located in the path of the river - firstly, these are neighborhoods inhabited by a socially disadvantaged population, which builds illegal structures along the river, and secondly, these are local small and medium-sized enterprises located in the northern industrial zone, also built in the intended flood zone of the river. Another vulnerable area is the old quarter of the city, completely built up with houses, which is in the lower part of the city and where there are the relevant educational and health institutions, which may suffer.

The ownership of various risks that may affect the population of the city of Dobrich is regulated by a number of planning and strategic documents adopted by the Municipal Council, such as:

- Disaster Risk Reduction Program (DRRP) on the territory of the Municipality of Dobrich for the period 2021–2025;
- Disaster Protection Plan of the Municipality of Dobrich from 2019;
- Plan for evacuation and/or dispersal in the event of a disaster of the population, animals and material values from the Municipality of Dobrich – 2015.

The key stakeholders for the project include

Competent authoritities: the municipal administration and council of Dobrich Municipality, the Regional Directorate for Fire Safety and Protection of the Population; Regional Environment and Water Inspectorate; the National Institute of Metrology and Hydrology; Regional Directorate of Forestry; Regional Health Inspectorate; Danube River Basin Directorate; Water Supply and Sanitation entity.

Community Members: Residents, community leaders, local NGOs, universities in the region and professional high schools.

Businesses and Industry: Private sector entities, including businesses, industries of properties exposed to floods or exposed to the snow and ice accumulation in the winter and the risk of accidents and road closures.

Vulnerable population, including low-income communities, marginalized groups who are often disproportionately affected by climate change impacts with special attention to the vulnerable groups living in low-lying areas with inadequate drainage exposed to flooding, residents in periphery areas where housing structures who may be less resistant to strong winds, commuters exposed to the snow and ice accumulation in the winter and the risk of accidents and road closures.

The project activities designed to communicate the outputs contributed to the visibility of the project before the journalists and the general public. A press conference took place on January 23, 2025 and it was covered by the local media and publications on the municipality's website. The first meeting with stakeholders to present the report on the implementation and adaptation of climate change risk assessment tools was held on March 28, 2025. Participants in the event were representatives of the Dobrich Municipality, the Dobrich rural municipality, Regional Administration, Regional Information Center - Dobrich, Fire Safety and Population Protection Agency,

2.2 Risk Exploration

2.2.1 Screen risks (selection of main hazards)

Climate-Related Hazards and Potential Risks. The climate hazards and potential climate risks for the Dobrich Municipality are as follows:

- River floods lead to street flooding, infrastructure damage, impose risk to life and personal property and disruption of public transportation.
- Heavy rainfall, leading to street flooding, infrastructure damage, disruption of public transportation.
- Urban heatwaves (temperatures above 35 °C) in the summer months are risky for older people, children, and people with chronic conditions.
- Windstorms: Stormy northeast winds cause material damage, fallen trees, and public transportation disruption, as well as risk of falling objects, electricity cuts, falling of billboard and street signs.
- Heavy snowfall and blizzards: Ice and snow accumulation disrupt roads and power supply, and disruption of public transportation, social services, access to educational institutions.

Current Hazard Situation or where does the hazard occur? The most significant risk of flooding comes from the Dobricka River and dams, which periodically overflow their banks. Urban areas are vulnerable during heavy rainfall and flooding, typical for peripheral regions with poor drainage systems. Autumn and winter storm systems regularly cause infrastructure damage, affecting buildings, transportation networks, and utility systems.

Who is affected? The most affected are the residents (especially older adults, children, and people with chronic diseases) during heat waves, the infrastructure (buildings, roads, and facilities) during floods and storms, and the public services during droughts.
The hazards are observed/expected in the area of Dobrich municipality are flooding, strong winds, heat waves, and droughts have been observed in the region. According to forecast data, the intensity of these hazards is expected to increase in the future. Accordingly, the hazards will you cover in the risk assessment are river floods, heavy rainfall, urban heatwaves, windstorms and heavy snowfall and blizzards.

The project will apply the experience of the experts in assessing flood risks, especially those caused by intense rainfall. The assessment will include historical data on past events and preliminary evaluations of Dobrich's city's vulnerability to flooding. Additional data from hydrometeorological monitoring (from the National Institute of Meteorology and Hydrology, Bulgaria), such as daily temperature, precipitation, snow and snow cover, wind speed, and daily discharges (for the Dobrichka River) will be needed.

2.2.2 Workflow selection

Based on the hazard screening analysis and the specific vulnerabilities identified for Dobrich Municipality, the following CLIMAAX risk assessment workflow has been selected for detailed implementation:

2.2.2.1 Workflow #1 River Flooding

Workflow Selection Rationale: The river flooding workflow has been prioritized due to the Dobrichka River's significant flood risks and its documented historical impacts on the municipality, particularly the 2014 flooding event.

Relevant Vulnerable Groups: Socially disadvantaged groups residing along the river, which have limited resources for flood preparedness and recovery; Elderly populations and individuals with mobility limitations who face challenges during evacuation; Residents in low-lying neighbourhoods with inadequate drainage infrastructure, particularly in the historic old quarter of the city; School children and healthcare facility users in institutions located within potential flood zones.

Exposed Areas and Assets: Housing developments near the Dobrichka River; small and medium enterprises in the northern industrial zone and commercial establishments in the city center; transportation networks and utility systems; historic buildings and cultural sites in the old quarter.

Specific Vulnerabilities: Aging urban drainage systems with insufficient capacity for extreme precipitation events; Limited resources for flood monitoring and early warning systems; Concentration of small businesses and industrial activities in flood-prone zones.

Socio-Economic Development Assumptions: Population Trends: The population of Dobrich decline from the 2024 baseline of 87,361 residents continues; the population is ageing, with implications for vulnerability and adaptive capacity. Sectoral Vulnerability Analysis: The residential, commercial, and public services sectors are facing potential revenue losses and recovery costs.

2.2.3 Choose Scenario

Climate Change Scenario Selection: For Dobrich Municipality's River flooding assessment, the following climate scenarios have been selected based on their relevance to regional hydrological patterns and alignment with European climate projection frameworks:

- RCP4.5 or a moderate climate change scenario with stabilized greenhouse gas concentrations by mid-century;
- RCP8.5 or the high-emission scenario with increased greenhouse gas concentrations throughout the 21st century. This scenario serves as an upper-bound estimate for climate change impacts.

There are three temporal Horizons: Short-term (2030), 5-10 years; medium-term (2050), 20-30 years; and long-term (2080), which provides insights for long-term strategic planning and major infrastructure decisions (50+ years). These temporal horizons enable evaluating how flood risks may evolve, supporting both immediate decision-making and long-term strategic planning for Dobrich Municipality. The flood risk assessment is based also on inundation maps showing flood zones for return periods of 10, 50, 100, and 500 years, along with empirical data and graphical representations of potential economic damages and population evacuation requirements for these flood scenarios. This may include short-term (e.g., 5 years), medium-term (e.g., 20-30 years) and long-term (e.g., 50-100 years).

Which scenarios available in the workflows are useful for your region? RCP4.5 and RCP8.5

2.3 Risk Analysis

2.3.1 Workflow #1 Flood

Table 2-1 Data overview workflow #1

Hazard data	***Vulnerability data***	***Exposure data***	***Risk output***
River flood hazard maps for 1980	Population and river flood maps with a 10-year and a 500-year return period	Population exposed to flood risk at different recurrence periods	Assessment of damage and vulnerability of infrastructure to floods
Flood extent and depth maps for difference return period	Damage (million euros) to buildings in river floods with a 10-year and a 500-year return period	Maps and data of the population that needs to be evacuated during river floods with a 10-year and a 500-year return period	Assessment of the flood risk with different recurrence rates for the infrastructure and for the population

2.3.1.1 Hazard assessment

Flood map (baseline scenario 1980 and recurrence rate 1 in 250 years)

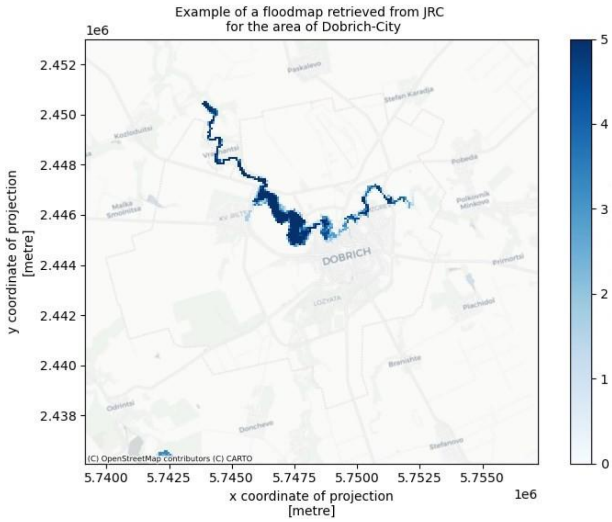


Figure 2-1 Flooding retrieved from JRC for the area of Dobrich City

The 1980 flood map with a probability of 1 in 250 years shows minimum flood depths in Dobrich municipality ranging from -0.10 m to 0.10 m, suggesting a very shallow flood confined to a narrow corridor along the Dobrichka River (Figure 2-1). The limited extent of the flood (only along the river banks) is realistic, as the flat terrain and the lack of large tributaries limit the spread of water. The affected areas are mainly in the central part of the city, while neighborhoods such as "Riltsi" and "Pobeda" remain unaffected. The negative values (-0.025 to -0.100 m) likely reflect topographic depressions or limitations in modeling, which is typical of older models based on 1980 data. The insignificant depths are realistic for this period but likely underestimate the risk, as the 1980 models did not account for future climate change and increased urbanization.

Potential for river floods, based on a 2018 base scenario and recurrence rates of 1 in 10, 1 in 50, and 1 in 100 years

In a flood with a recurrence period of 1 in 10 years, the height of the water layer varies from 0 to approximately 2.0 m, with the highest values (1.5–2.0 m) being recorded in the southern part of Dobrich, near the river. The majority of the flooded areas exhibit depths ranging from 0.5 to 1.5 m. The central and northern parts of the city appear to be less affected, with depths below 0.5 m or no flooding. In an extreme event with a recurrence period of 1 in 50 years, the water level reaches approximately 3.0 m in the southern parts of Dobrich, resulting in a broader flood extent compared to the 10-year scenario. The zones with depths between 1.5 and 2.5 m expand towards the southeastern and eastern parts, while the central parts remain with depths below 1.0 m. The flood covers a large area, including the southern, southeastern and partly eastern regions of Dobrich. The center and northern parts are still less affected, but the risk increases (Figure 2-2).

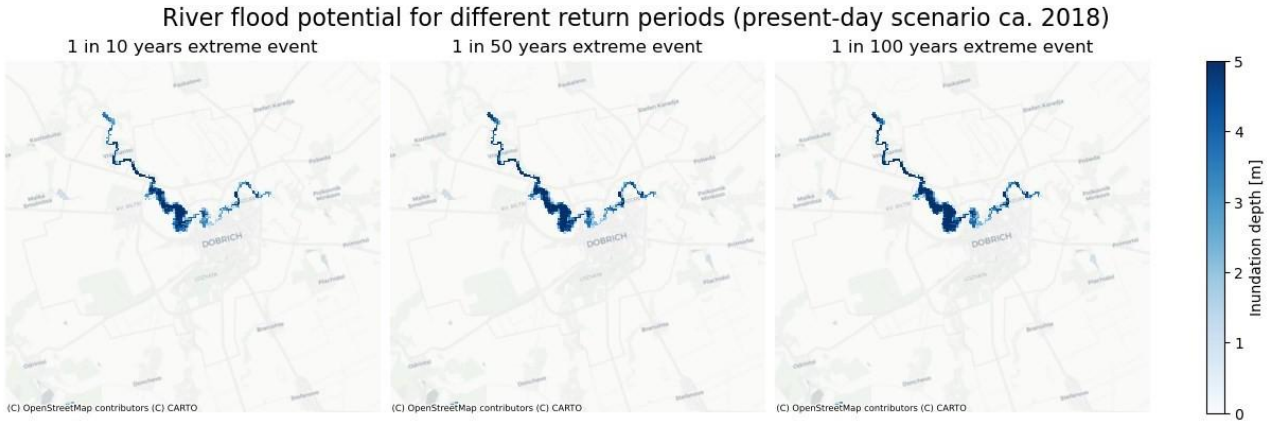


Figure 2-2 River flood potential for a return period of 10, 50 and 100 years (2018 script)

A flood with a recurrence frequency of once every 100 years has a water table height of up to 4.0 m – significantly higher compared to the 1980 baseline scenario. Zones with depths between 2.0 and 3.0 m expand towards the eastern and southeastern parts, while the central parts already show depths of 0.5–1.5 m. The flood covers a large part of the southern, southeastern and eastern regions and also begins to affect the central parts of Dobrich. The northern parts remain the least affected. This scenario is realistic, considering the increased intensity of precipitation and the rise in impermeable surfaces (asphalt, concrete) between 1980 and 2018, which reduces precipitation infiltration and increases surface runoff. This explains the broader scope and higher depths of the flood in the city center. The 2018 models likely utilize more recent climate data and more sophisticated hydrological models, which explains the higher depths compared to those in 1980.

Depths of 4.0 m are possible during extreme rainfall events, especially if the Dobrich River overflows and water accumulates in low-lying areas in the city center. Historical flood data in Dobrich, such as that from 2014, shows that heavy rainfall can cause significant flooding, although not as deep. This scenario is realistic but may represent a worst-case scenario if combined with other factors such as clogged drainage systems or simultaneous rainfall across the entire catchment area.

Flood potential in the 1980 baseline scenario and a recurrence rate of 1 in 250 years

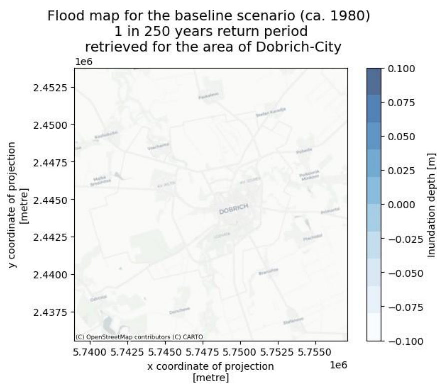


Figure 2-3 Flood map for the baseline scenario (ca.1980) 1 in 250 years return period

Floods in the 1980 baseline scenario and a recurrence rate of 1 in 250 years show a water table height of 0.00 to 0.10 m, which is consistent with the hydrological characteristics of the Dobrich River. In 1980, precipitation in the region was less intense compared to today's conditions. The limited extent of the flood, confined to the riverbanks, is realistic, as the flat terrain and the absence of large tributaries restrict the flood's spread. The center of Dobrich is most affected, as the Dobrich River runs through the city's central parts, and the dense construction (even in 1980) likely increases surface runoff from precipitation. Neighborhoods such as "Riltsi" and "Pobeda" remain unaffected, which is consistent with their higher elevation and greater distance from the river (Figure 2-3).

Flood potential under RCP4.5 and RCP8.5 scenarios (2030, 2050, 2080, 1 in 250 years

The flood potential in Dobrich under RCP4.5 (moderate emissions) and RCP8.5 (high emissions) scenarios for 2030, 2050, and 2080, with a 1-in-250-year event, indicates increasing risks over time. In the RCP4.5 scenario, water table heights rise from 0–0.4 m in 2030, with the highest values (0.3–0.4 m) in southern and southeastern parts, to 0.5 m by 2050, slightly expanding flood zones, and reach 0.6 m by 2080, with depths of 0.3–0.5 m extending to southeastern and eastern areas. However, the central and northern parts remain minimally affected (Figure 2-4).

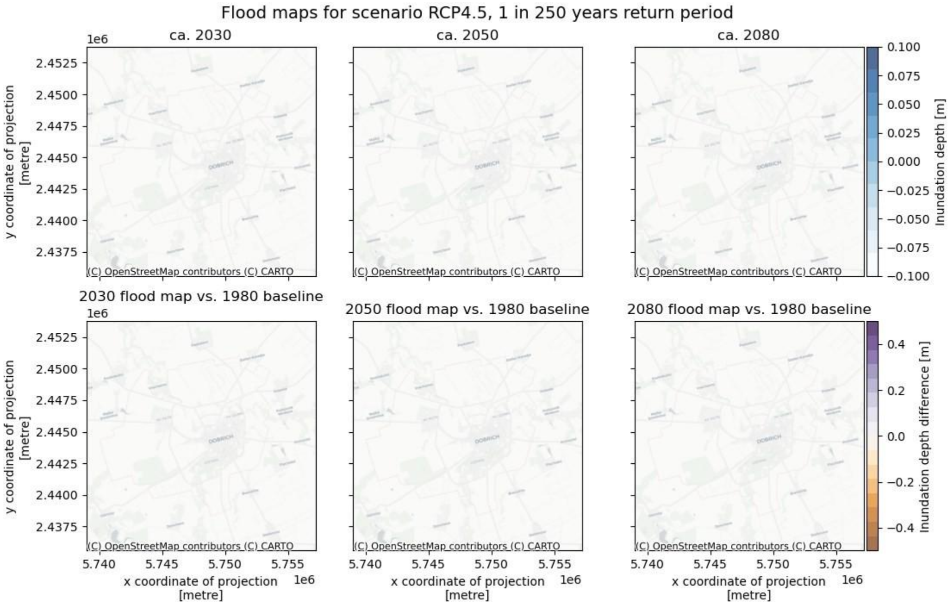


Figure 2-4 Flood maps for RCP4.5 scenario, 1 in 250-year return period (relative to 1980)

Under RCP8.5, flooding is more extensive, starting with water heights of 0.4 m in 2030, peaking at 0.3–0.4 m near the river and affecting southern and southeastern parts, then rising to 0.5 m in 2050 with slight expansion eastward, and reaching 0.6 m by 2080, with depths of 0.3–0.5 m in southeastern and eastern parts and 0.1–0.2 m in some central areas (Figure 2-5).

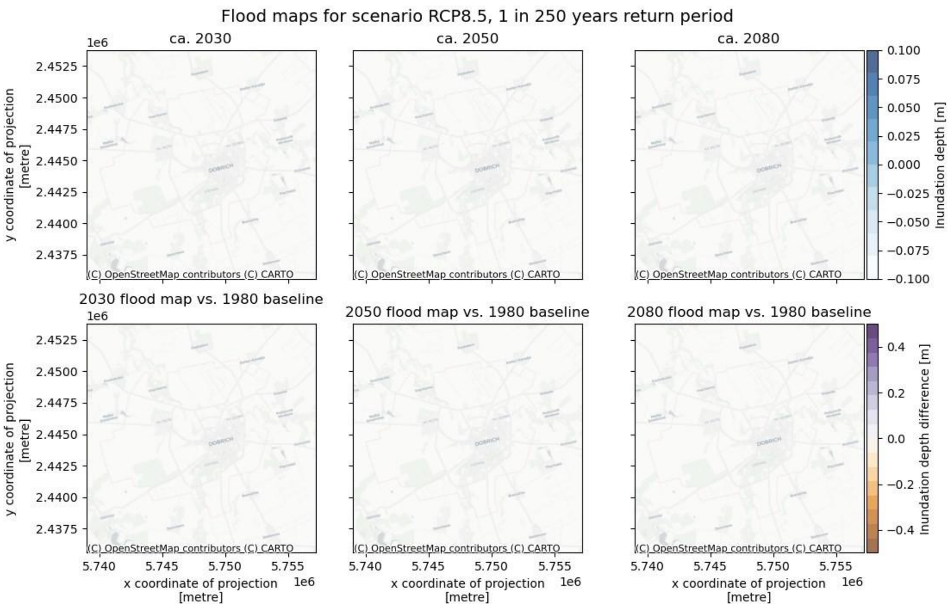


Figure 2-5 Flood maps for RCP8.5 scenario, 1 in 250-year return period (relative to 1980)

Both scenarios show a gradual increase in flood depths over time, with southern and southeastern parts being the most vulnerable, though RCP8.5 exhibits slightly broader flooding. Compared to the 2018 scenario (1-in-100 years, 4.0–5.0 m), these projections appear less severe, suggesting potential underestimation of risks, particularly in RCP8.5, as climate change may lead to more extreme flooding not fully captured by these models.

Floods with different recurrence periods

A) The 10-year return flood map shows flood depths of up to about 2.0 m. The highest levels (1.0–2.0 m) are recorded in the central part of Dobrich, along the Dobrichka River. The majority of the affected areas show water table heights below 1.0 m. The extent of the flood is relatively small, which is consistent with the more frequent return period (1 in 10 years) and the limited flow of the Dobrichka River (Figure 2-6).

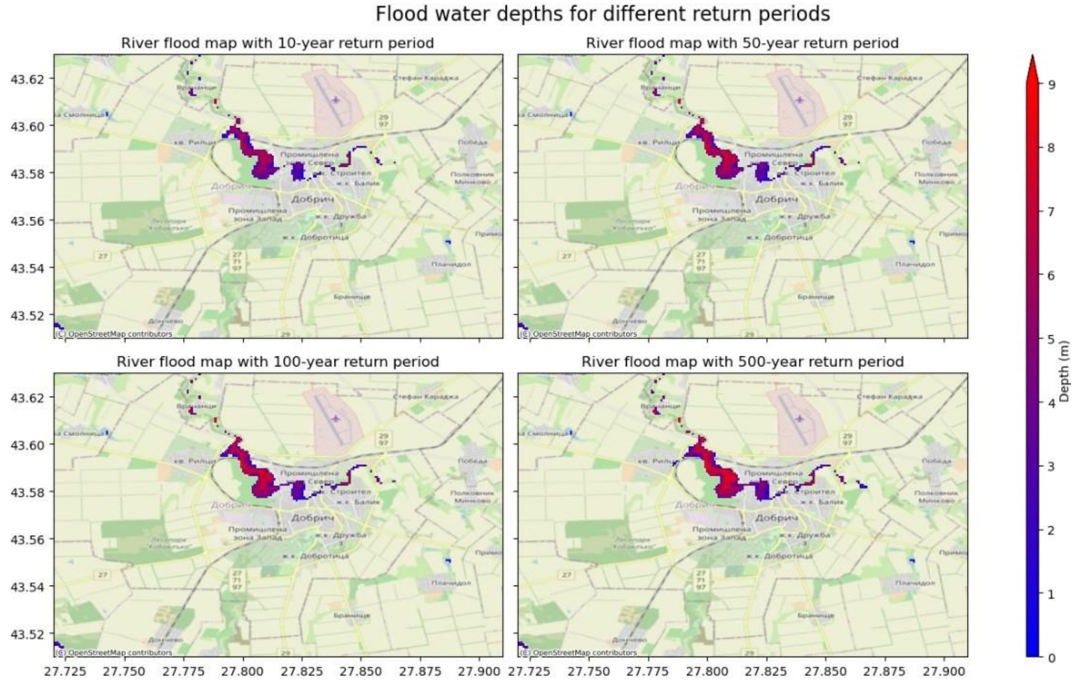


Figure 2-6 Flood water depths for different return periods

B) The 50-year return period flood map shows an increase in flood depths, ranging from 0 m to around 3.0 m. The highest depths (2.0–3.0 m) are in the centre of Dobrich, along the Dobrichka River, with more significant flooding compared to the 10-year scenario. Flooding is still concentrated in the city centre, but the extent is wider, affecting most of the central districts. The central parts exhibit water table heights ranging from 1.0 to 2.0 m, while the Industrial Zone "Sever" is below 1.0 m. The extent of flooding increases compared to the 10-year scenario, as expected, given that the 50-year return period implies more extreme precipitation and higher peak runoff.

C) The 100-year flood map shows flooding with water table heights of up to 4.0 m in the most affected areas. Most of the central regions show depths between 3.0 and 4.0 m. The flooding covers a wider part of the city center, where water table heights reach 2.0–3.0 m. The industrial zone "Sever" is more affected than in the previous scenarios, with depths ranging from 1.0 to 2.0 m. The surrounding areas, such as "Riltsi" and "Pobeda", experience minimal flooding, with levels below 0.5 m. The extent of the flooding is significantly more significant compared to the 10- and 50-year scenarios, which is consistent with the rarer and more extreme return period (1 in 100 years).

Comparative insights suggest RCP4.5 and RCP8.5 scenarios may underestimate risks, as local factors like drainage and urbanization are not fully reflected in climate models.

2.3.1.2 Risk assessment

Flood Exposure Assessment for Dobrich Municipality

Exposure is a key component in flood risk assessment and refers to the extent to which people, buildings, infrastructure and economic assets are located in areas at risk of flooding.

· Exposure of buildings and infrastructure: assesses the number and type of buildings, their construction, and flood resistance. The assessment depends on the location and degree of impact under different flood scenarios.

· Population exposure: the number of people living or working in vulnerable areas, which depends on population density, socio-economic factors, and people's mobility. Vulnerable groups, such as children, the elderly, and people with disabilities, are at a higher risk.

· Exposure of economic assets: related to the value of affected industries, businesses and agricultural areas; depends on the possibilities for rapid recovery after a flood.

Exposure of buildings to floods and material damage

The map displays a range of building types in Dobrich without categorizing them into primary categories (residential, commercial, industrial): Residential – apartments, houses, detached houses, semi-detached houses; Commercial: commercial buildings, offices, retail stores, supermarkets; Industrial: industrial buildings (industrial); Public: churches (church), hospitals (hospital), schools (school), government buildings (government), stadiums (stadium), synagogues (synagogue), and train stations (train station) (Figure 2-7).

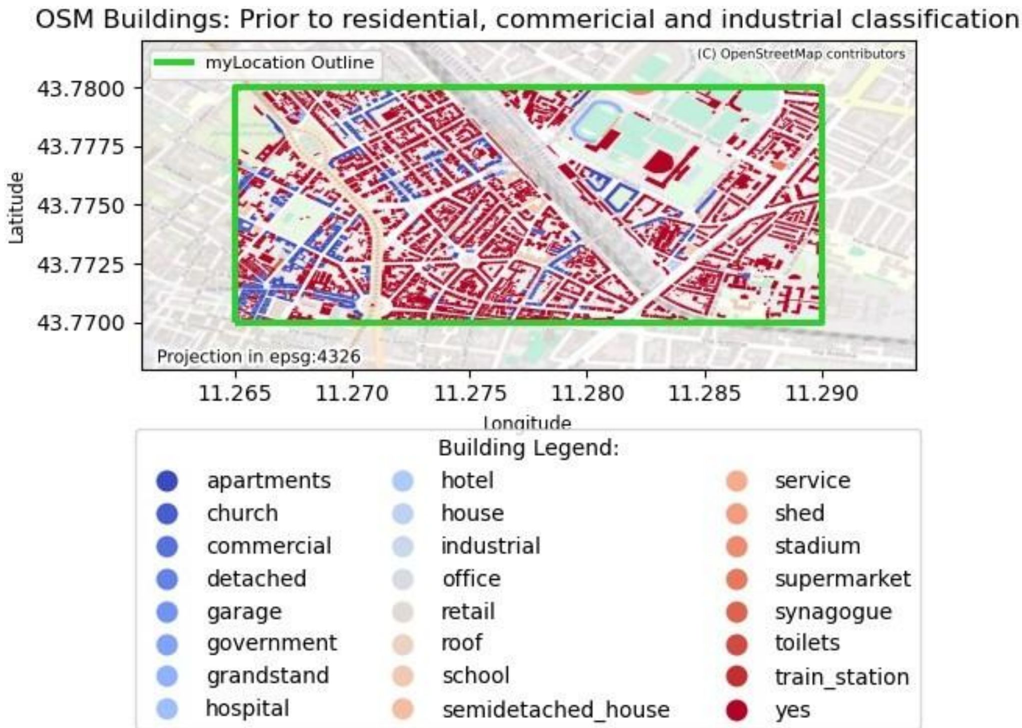


Figure 2-7 Buildings before the classification of residential, commercial and industrial buildings

The map of classified buildings, categorised into four groups, reveals a predominance of commercial and residential buildings in the central and southern parts of the city, making them highly vulnerable due to the highest floodwater levels at all scenarios (Fig. 2-8).

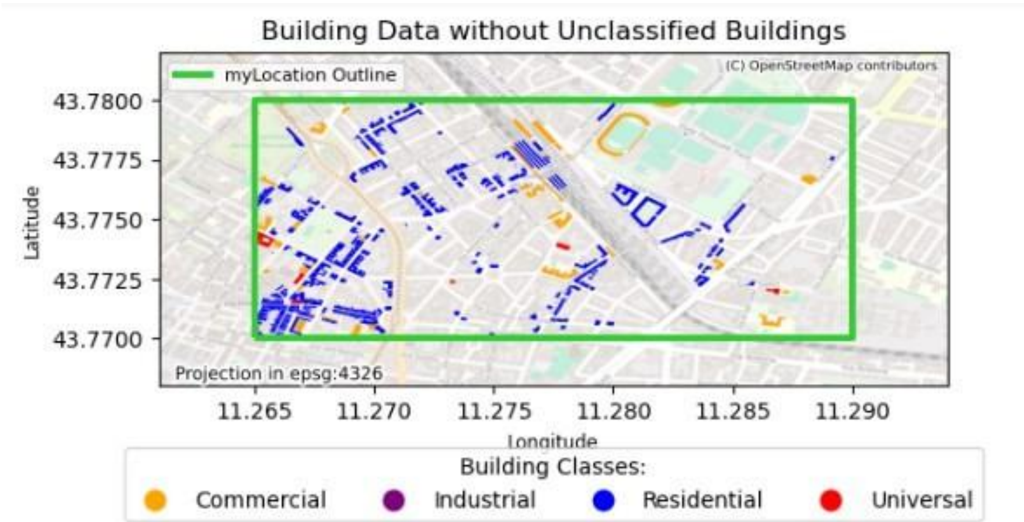


Figure 2-8 The classification of buildings into four main categories

Universal buildings are distributed evenly throughout the region, but are particularly visible in the center and southern parts (Figure 2-9).

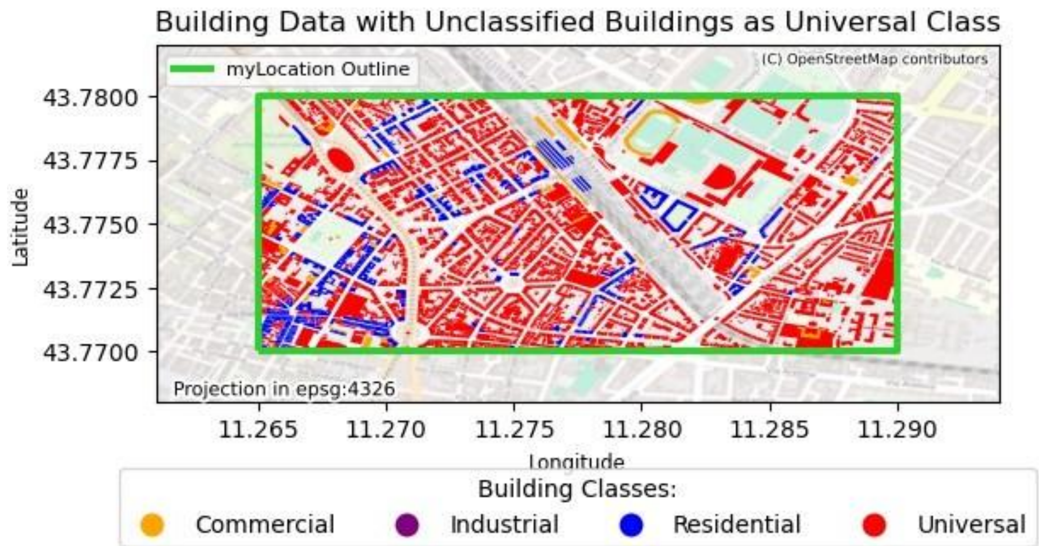


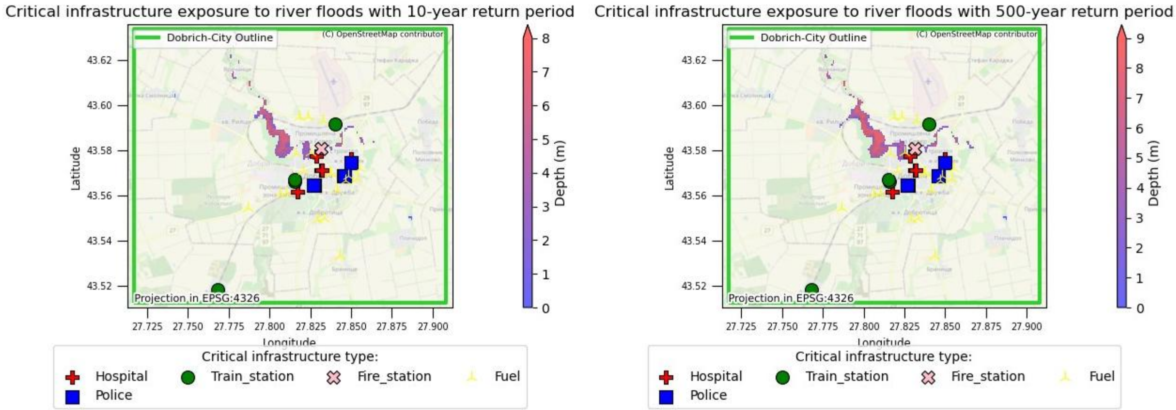
Figure 2-9 Buildings Data with Unclassified Buildings as Universal Class

Including unclassified buildings as a universal class provides a more complete picture of risk, as it takes into account all buildings in the area, even those with an unclear function.

Exposure of key infrastructure in Dobrich Municipality.

When assessing exposure to floods of varying frequency, a scale from 1 to 3 is applied as follows: m depth zones or are not affected; 2 (medium): The objects are in zones with a depth of 2–4 m, with moderate impact; 3 (high):

The objects are located in areas with depths exceeding 4.0 m, resulting in high impact. The municipality's critical infrastructure is located with varying degrees of exposure to flood with a probability of occurrence in 10 years and in 500 years. In both return periods, the hospital, fire station and police station have a high degree of exposure, and the railway station – a medium degree. In the 500 years, almost all critical infrastructure in Dobrich is exposed to significant flood depths, with the hospital, fire station and police stations in zones with a depth of 7.0–9.0 m, and the railway station - in a zone with a depth of 3.0–6.0 m (Figure 2-10). This significantly increases the risk to the functioning of critical infrastructure during extreme flooding.



a) b)

Figure 2-10 Exposure of critical infrastructure to river floods with a 10-year (a) and a 500-year return period (b)

The overall assessment in both analyzed cases remains high (Table 2-1).

Table 2-2 Assessment of the exposure of critical infrastructure to floods in the Municipality of Dobrich City

Recurrence period	***Type objects***	***Flood depth (m)***	***Exposure (1–3)***
10-year period	hospital, fire station, police stations	6.0–8.0	3 (high)
	stations	2.0–.0	2 (medium)
Overall rating		**3 (high)**	
500-year period	hospital, fire station, police stations	7.0–9.0	3 (high)
	stations	3.0–6.0 m	3 (high)
Overall rating		**3 (high)**	

Material damage to buildings during floods

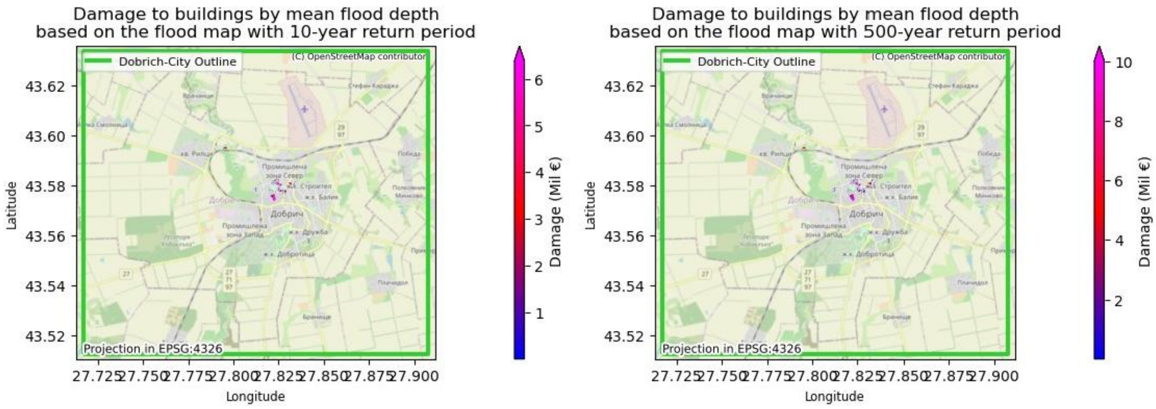
The damage caused to buildings is determined based on the depth of the flood to which the buildings are exposed, using the following assumed values: CPI2010 = World Bank Consumer Price Index for 2010; CPI2022 = Consumer Price Index for 2022 for the respective country (most recent available value).

Damage classes:

- Options include residential, commercial, industrial, agricultural, cultural, transportation, and general purpose.

- In the standard code, agricultural, cultural, and transport buildings, as well as unclassified buildings, are designated as universal.

The damage function is based on polynomial functions fitted to the JRC depth-damage curves. The standard code applies a combined damage function based on the JRC depth-damage values for residential, commercial and industrial buildings. The damage to buildings in the Dobrich municipality has been calculated in millions of euros in the four separate categories under different scenarios. Damage to buildings in a 10-year flood recurrence period (calculated based on the average flood depth) ranges between 4.0 and 6.0 million euros and is concentrated in the central parts of Dobrich, especially around the Dobrichka River (Figure 2-11).

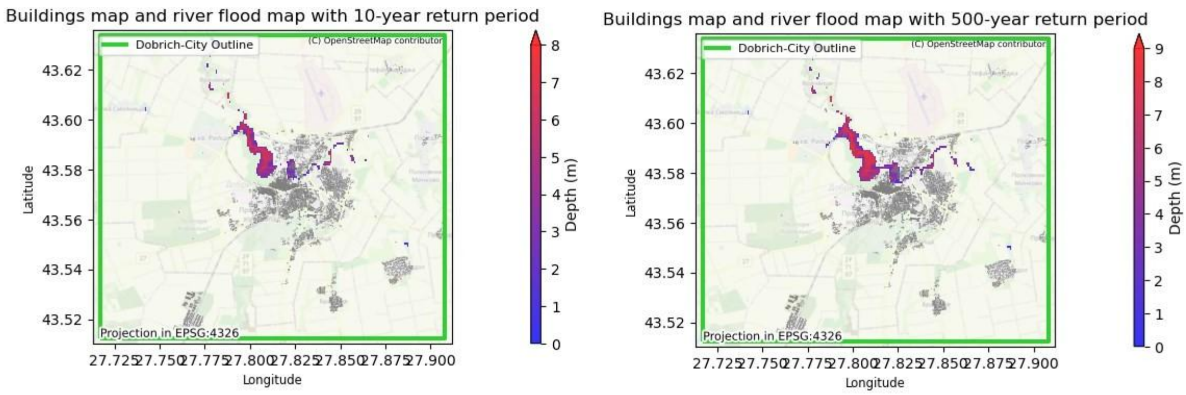


a) b)

Figure 2-11 Damage (million euros) to buildings in river floods with a 10-year (a) and a 500-year return period (b))

Damage to residential buildings and commercial properties located near the river is estimated at between 2.0 and 4.0 million euros. Economic damage in a 500-year flood recurrence period increases to 8–10 million euros in central areas and to 4–8 million euros in neighboring regions, with a larger area of flooded land.

Additional information is provided by the maps of buildings and river floods with a 10-500-year return period and the graph showing the expected damage to buildings based on the average flood depth and building locations (Figure 2-12). In the 10 years, many buildings in the central areas are affected by depths of 6.0–8.0 m, in the 500 years the depth increases to 7.0–9.0 m, and the flooding also affects peripheral areas.



a) b)

Figure 2-12 Map of buildings and river floods with a 10-year (a) and a 500-year return period (b)

The data from the graph show an increase in damage with increasing return period, which is expected because less frequent floods (e.g., 500-year period) are more intense and cause greater flood depths. The increase in damage is relatively linear but with a slight slowdown after the 100-year period. This may indicate that after a certain threshold (e.g., 100 years), further increases in flood depth do not lead to a proportional increase in damage, probably because most buildings are already severely affected (Figure 2-13).

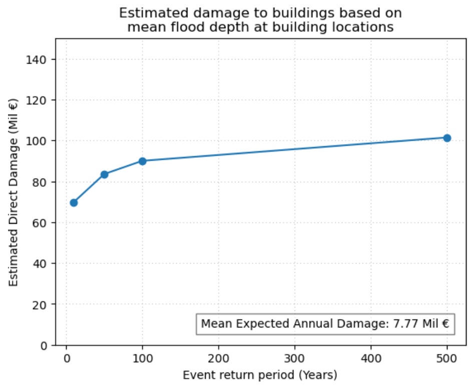


Figure 2-13 Expected damage to buildings based on average flood depth and building

These damages are approximately as follows:

- 10-year period: around €60 million
- 50-year period: around €80 million
- 100-year period: around €90 million
- 500-year period: around €110 million

The average expected annual damage is € 7.77 million. This average value represents the expected damage over one year, considering all possible floods (with varying recurrence periods) and their associated probabilities. This value is helpful for long-term risk assessment and planning of protection measures.

The data provided (beyond those from the maps) on economic damage from floods with different recurrence periods show that residential buildings have the largest share in total financial damage, unlike industrial buildings (Table 2-3). These values differ slightly from those in previous maps (€70 million for the 10-year period and €115 million for the 500-year period), which is likely due to variations in the methods used for estimation.

Table 2-3 Expected damage (million €) to building classes in floods with different recurrence rates

Building class	***Recurrence period***			
	10-year-old	***50-year-old***	***100-year-old***	***500-year-old***
Residential	49.18	74.83	85.87	107.38
Commercial	2.83	4.46	5.37	6.27
Industrial	0.0	0.0	0.0	0.0
Universal	6.20	9.65	11.37	13.40
Total	**58.23**	**88.95**	**102.63**	**127.06**

The degree of vulnerability ranges from low to high (Table 2-4).

Table 2-4 Assessment of damage and vulnerability of infrastructure to floods in Dobrich Municipality

Recurrence period	***Type buildings***	***Damages (million euros)***	***Flood depth (m)***	***Vulnerability (1–3)***
10-year period	Residential	49.19	6–8	3 (high)
	Commercial	2.84	6–8; 2–4	2 (medium)
	Industrial	0.0	0–2	1 (low)
	Universal	6.21	6–8; 0–2	2 (medium)
General vulnerability		**58.24**	**3 (high)**	
500-year period	Residential	107.39	7–9; 1–3	3 (high)
	Commercial	6.27	7–9 ; 3–6;	2 (medium)
	Industrial	0.0	1–3	1 (low)

Recurrence period	Type buildings	Damages (million euros)	Flood depth (m)	Vulnerability (1–3)
	Universal	13.41	7–9;1–3	3 (high)
General vulnerability		**127.07**	**3 (high)**	

The damage of 49.19 million euros is substantial due to the significant damage to residential buildings, in contrast to commercial buildings, which are also located in the central area but are fewer in number. The damage of 6.21 million euros is moderate: some of the universal buildings are in the center, exposed to high depths. Industrial buildings are assessed with a low degree of vulnerability.

The lack of damage (0.0 million euros) is unusual, as the depths in the periphery reach 1.0–3.0 m over the 500 years. This may be due to the higher resilience of industrial buildings, the lower value of these buildings in the damage assessment, or error or omission in the data.

Exposure and vulnerability of the population of Dobrich municipality to floods

The population density in the town of Dobrich ranges from 0 to approximately 300 people, with the highest density (over 200 people) in the central parts of the region. The peripheral parts show lower density (under 50 people) (Figure 2-14).

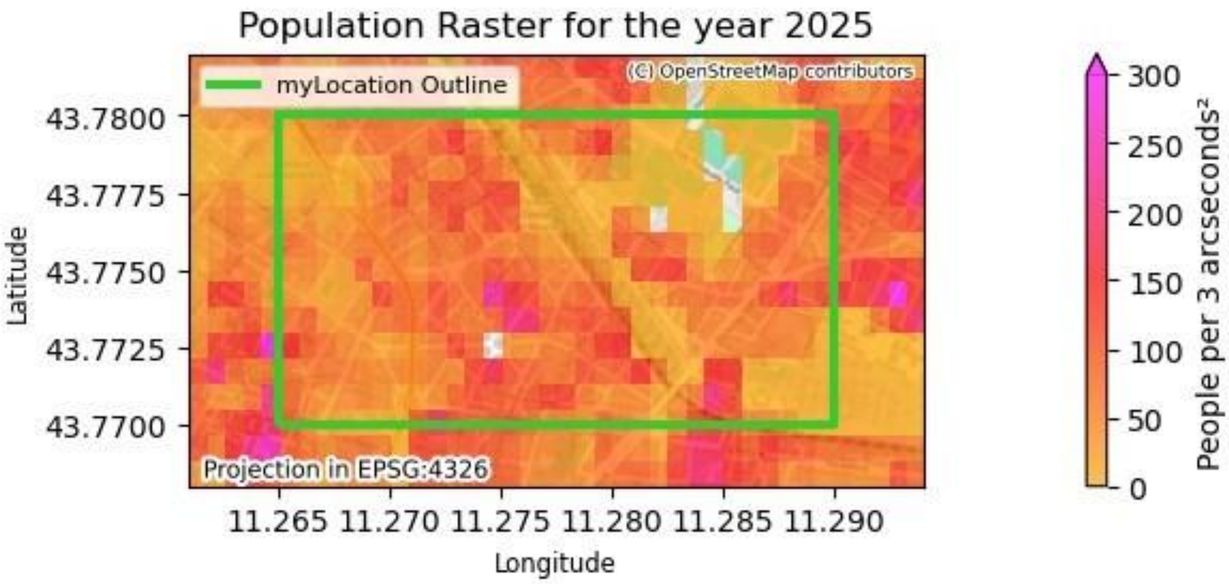


Figure 2-14 Population density map 2025

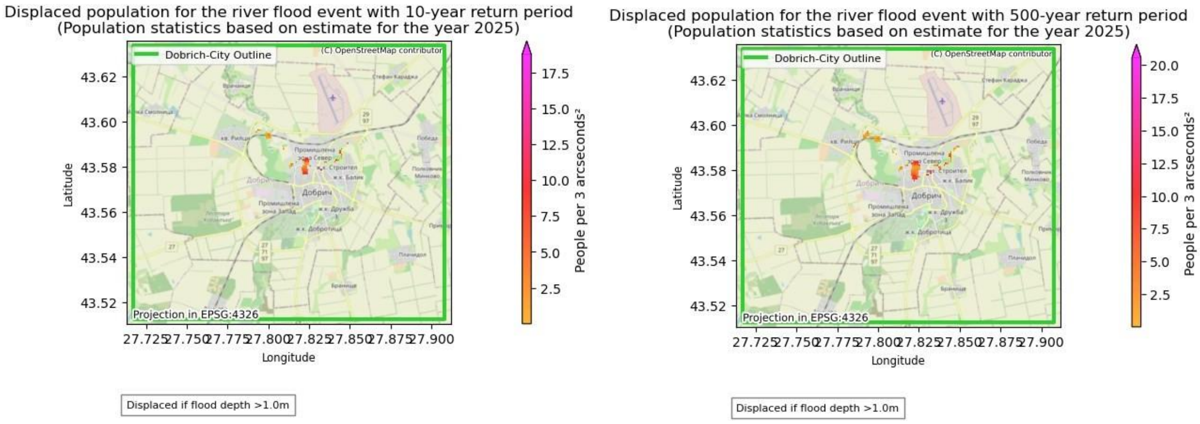
The population exposure to flooding is calculated based on a population projection for 2025 and refers to areas where the flood depth is greater than 0.0 m. The population density exposed is expressed as the number of people per 3.0 arcseconds (approximately 90 m x 90 m at this latitude). The initial information refers to the number of people exposed to flood risk and the number of people who must be evacuated in the event of a river flood.

The sources of information – table, maps and graph- give significant differences in both indicators. According to the table provided, the population exposed to flood risk is between 9344 and 12,290 people (Table 2-5).

Table 2-5 Number of populations exposed to flood risk

Recurrence period (years)	Exposed population (number)
10	9344
50	10,072
100	10,085
500	12,290

According to the map data, the number of people exposed to flood risk is ~30,000 people with a 10-year recurrence period and ~50,000 people with a 10-year recurrence period (Figure 2- 15).



a) b)

Figure 2-15 Population and river flood maps with a 10-year (a) and a 500-year return period (b)

The data from the graph provides the following information: 10-year period: ~900 people; 50-year period: ~950 people; 100-year period: ~1000 people; 500-year period: ~1200 people (Figure 2- 16).

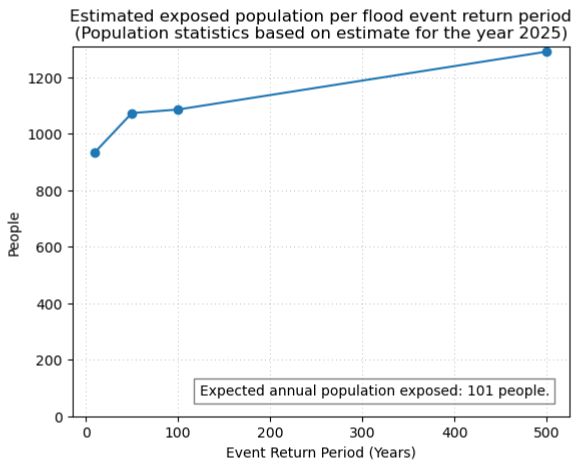


Figure 2-16 Population exposed to flood risk at different recurrence

The values in the graph are significantly lower than those in the table: for the 10 years, 900 people (graph) vs. 9,344 people (table), representing a difference of approximately 10 times; for the 500 years, 1,200 people (graph) vs. 12,290 people, again representing a difference of roughly 10 times. The data in the graph lead to a much lower exposure (1 – low), which would significantly reduce the risk assessment. However, these values seem unusually low compared to the previous maps and table, which show a much higher number exposed to flood risk. Since the graph does not provide additional context (e.g., an explanation of the methodology), the analysis proceeds with the data in the table.

The criteria for assessing population exposure (1 to 3) are as follows (Table 2-6):

- 1 (low): less than 10% of the population is at risk, flood depth less than 1.0 m
- 2 (medium): 10–30% of the population is at risk, depth 1.0–3.0 m
- 3 (high): Over 30% of the population is exposed to danger, with depths exceeding 3.0 m.

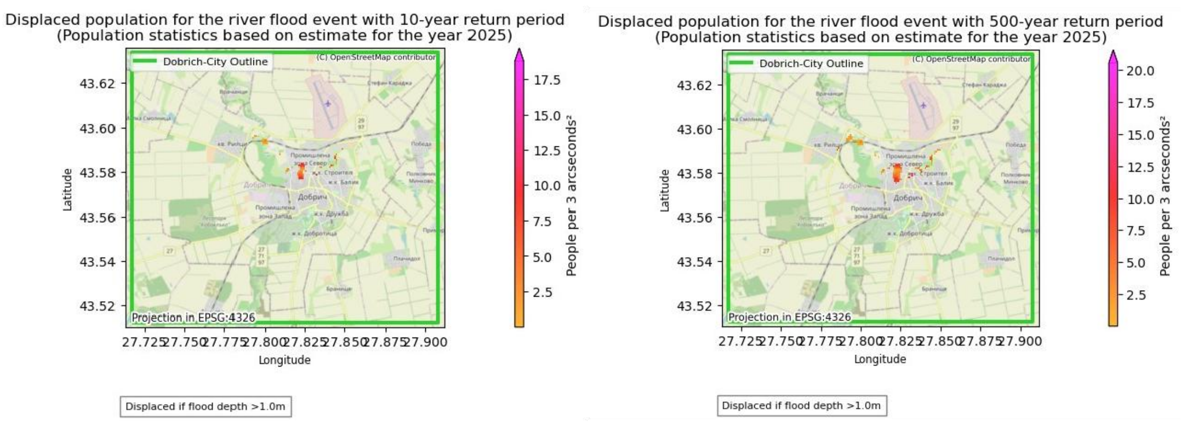
With these criteria and a population of 87,361 people in Dobrich in 2024, the following results are obtained for the number of people exposed to the risk of flooding with different recurrence rates:

Table 2-6 Number of populations exposed to flood risk in different recurrence period (years)

Recurrence period	***Number of populations at risk***	***Percentage of population***	***Flood depth (m)***	***Exposure (1–3)***
10-year-old	9344	10.70	6–8 ;0–2	2 (medium)
50-year-old	10,072	11.53	~6–8	2 (medium)
100-year-old	10,085	11.54	~6–8	2 (medium)
500-year-old	12,290	14.07	7–9 ; 1–3	2 (medium)

Population vulnerability refers to the extent to which people can be affected by flooding – i.e. how easily they can suffer physical, social or economic harm. Since there is no data on vulnerability (e.g. age structure, health status, income), the number of evacuees is used as a proxy indicator: a high number of evacuees suggests high vulnerability, as the flood has had a significant impact on their homes and lives.

The maps for the displaced population (Displaced Population) for river floods with a 10-year and 500-year return period present this indicator through a color scale ranging from 0 to 17.5 people per 3 arches for the 10 years and from 0 to 20 people per 3 arches for the 500 years. The maps note the evacuated population in areas with a flood depth of more than 1.0 m. The most significant number of evacuees is projected to be in the central parts of the city, where the flood is deepest in both scenarios, followed by the neighboring urban areas (Figure 2- 17).



a) b)

Figure 2-17 Maps of the population that needs to be evacuated during river floods with a 10-year (a) and a 500-year return period (b)

An idea of the number of evacuees in the event of a flood with different probability of occurrence is given by the graph based on the population for 2025 (Figure 2-18).

10-year period: ~700 people

50-year period: ~750 people

100-year period: ~800 people

500-year period: ~900 people

The average annual number of people evacuated during floods is 76.

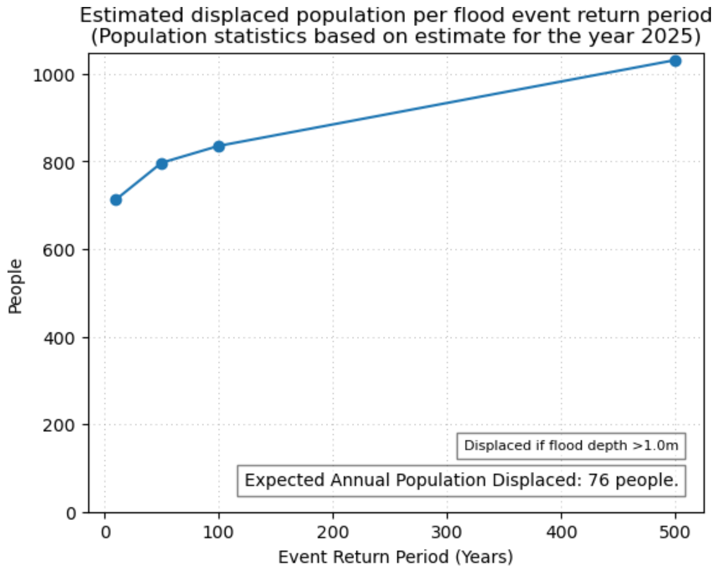


Figure 2-18 Expected number of evacuated populations for different flood recurrence periods

To assess the vulnerability of the population to floods with different recurrence rates, the relative share of evacuees (as indicated by the graph data) among the total population exposed to flood risk (as shown in the table data) is calculated. The relative share of the population that must be evacuated (of the population exposed to risk) is between 7.49% for a flood with a probability of occurrence once in 10 years and 7.32% for a flood with a probability of occurrence once in 500-years (Table 2-7).

Table 2-7 Number of populations that needs to be evacuated

Period of repeatability	***Population at risk***		***Population to be evacuated***		***Evacuated vs. at risk (%)***
	Number	***% of total population***	***Number***	***% of total number***	
10-year-old	9344	10.70	700	0.80	7.49
500-year-old	12290	14.07	900	1.03	7.32

The combination of the physical and social vulnerability of the population gives grounds for introducing the following criteria:

Physical vulnerability:

- Depth over 3.0 m: Rating 3 (high), as it poses a direct risk to life.
- Depth 1.0–3.0 m: Rating 2 (medium).
- Depth below 1.0 m: Rating 1 (low).

Social vulnerability (based on displaced population):

- Over 50% of those exposed are displaced: score 3 (high).

- 20–50% of those exposed are displaced: score 2 (medium).
- Less than 20% of those exposed are displaced: score 1 (low).

In the case of overall vulnerability (the average of the two assessments), priority is given to physical vulnerability if it is higher, as it directly affects life and health.

This approach yields the following estimates:

10-year recurrence period:	500-year recurrence period:
• Physical vulnerability: Depth 6–8 m near river → score 3 (high).	Physical vulnerability: Depth 7–9 m near river → score 3 (high)
Social vulnerability: 7.49% of those exposed are displaced. → Score 1 (low).	Social vulnerability: 7.32% of those exposed are displaced. → Score 1 (low).
Overall vulnerability: → 3 (high).	Overall vulnerability: 3 (high)

The final assessment of the flood risk for the population is determined by the three indicators: average risk in the event of a flood with a recurrence rate of once every 10 years

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

The flood risk severity in Dobrich shows depths of 6–8 m in central areas and 0–2 m in peripheral areas for a 10-year return period, exposing 9,344 individuals (10.7% of population) with annual economic damages of 46.15 million EUR, while a 500-year scenario increases depths to 7–9 m centrally and 1–3 m peripherally, affecting 12,290 individuals (14.1% of population). Risk severity is assessed as medium to high for population (rated 2–3) and high for buildings (rated 3), with per-building damages of 6–12 million EUR and potential evacuees of 700 (10-year) and 900 (500-year). Key observations highlight central areas' vulnerability, a population density of 15–20 per 3-arcsecond cell, and a significant risk increase from 10- to 500-year scenarios, supported by historical flooding events, concluding that floods pose a severe climate risk for Dobrich across various return periods.

The flooding poses a severe climate risk for Dobrich. The current models reveal significant hazard across different return periods.

Major Risks for Dobrich Region. The major risks for the Dobrich region stem from river flooding, the primary climate-related hazard driven by increased precipitation intensity, climate change effects, and urbanization reducing water infiltration, posing high vulnerability to critical infrastructure like hospitals, emergency services, transportation networks, and utility systems. This results in annual economic damages of 46.15 million EUR, potential building damages of 6-12 million EUR per event, and risks to local businesses, while exposing 9,344 people (10.7% of population) in a 10-year scenario and 12,290 (14.1%) in a 500-year scenario, with vulnerable groups at highest risk. Severity assessment indicates flood depths from 0–2.0 m to 7.0-9.0 m, escalating risk with longer return periods, high population density in central areas, potential for catastrophic infrastructure damage, and a medium to high climate risk rating (2-3).

Severity of Flood Risk: Historical and Current Trends.The historical context of Dobrich reveals limited flood data, with minimal flooding (0-0.10 m depths) in the 1980 baseline and a significant 2014 event highlighting rainfall impacts, while current trends show a marked increase in flood potential from

1980 to 2018, driven by climate change-induced intense precipitation, urbanization, and rising impermeable surfaces reducing water infiltration. Potential impacts include escalating flood depths of 6-8 m in central areas for a 10-year scenario and 7-9 m for a 500-year scenario, with population exposure rising to 9,344 people (10.7%) and 12,290 people (14.1%) respectively, alongside annual economic damages of 46.15 million EUR and high risk to critical infrastructure. Severity indicators rate climate risk as medium to high (2–3), with potential for catastrophic infrastructure damage and expanding flood zones over longer return periods, projecting a continued risk increase with more frequent and intense flooding, possibly underestimating extreme events in current models.

2.4.2 Urgency

Timing of Major Impact: The timing of major flood impacts in Dobrich includes immediate risks within the next 10-20 years, short-term scenarios for 10-year and 50-year return periods, and long-term critical scenarios for 100-year and 500-year return periods, necessitating urgent actions such as infrastructure interventions like riverbed corrections, modernization of drainage facilities, and upgrading flood resilience of critical infrastructure, alongside preparedness measures including a comprehensive early warning system, community education, emergency response training, and detailed evacuation plans. The hazard is sudden-onset with rapid inundation potential, triggered by intense precipitation, river overflow, and rapid surface runoff, with urgency evaluation indicating possible flood escalation within hours, potential for catastrophic flooding, increasing risk due to climate change, and immediate threats to critical infrastructure, recommending a timeline of immediate (0–5 years) development of early warning systems, short-term (5–10 years) infrastructure modifications, and medium-term (10–20 years) comprehensive flood management strategy.

2.4.3 Capacity

Current Risk Management Measures

The municipality of Dobrich currently employs several measures to manage flood risks effectively. These include the construction of hydrotechnical facilities, the establishment of early warning systems to monitor high water levels, and the installation of video surveillance along the Dobrichka River to enhance monitoring capabilities. Additionally, spatial territory planning is utilized to mitigate flood impacts, while annual cleaning of river beds and ravines helps maintain natural drainage. Preventive measures and population education programs are also in place to increase community awareness and preparedness.

Opportunities for Risk Management

Financial Opportunities: There are significant financial opportunities to bolster flood risk management in Dobrich. The municipality can attract national and EU funding to support flood mitigation projects, potentially leading to lower insurance premiums for residents and businesses. These initiatives can also generate jobs through the development of sustainable drainage systems, retention basins, and river restoration projects, while stimulating local business growth.

Social Opportunities: Social opportunities play a crucial role in enhancing flood resilience. Improving disaster preparedness through the development of early warning systems and conducting awareness campaigns can empower the community. Encouraging public participation in decision-making fosters a sense of ownership, while reducing community stress and the potential for displacement during flood events.

Human Capital Development: Investing in human capital is essential for long-term risk management. Building the capacity of local authorities, training engineers and emergency responders, and enhancing expertise in hydrology, urban planning, and climate adaptation are key steps. Facilitating knowledge transfer among professionals will further strengthen the municipality's ability to address flood challenges.

Physical Infrastructure Improvements: Upgrading physical infrastructure offers substantial opportunities for flood risk reduction. Modernizing municipal infrastructure, implementing digital flood monitoring tools, enhancing urban resilience, and installing real-time monitoring sensors will improve the ability to detect and respond to flood threats effectively.

Natural Environment Opportunities: Leveraging the natural environment provides sustainable solutions for flood management. Ecosystem restoration, enhancing biodiversity, supporting groundwater recharge, creating permeable surfaces, implementing forestation projects, and developing green roof technologies can mitigate flood risks while promoting environmental health.

Conclusion: Addressing flood risks in Dobrich Municipality through these measures can yield multiple benefits, including attracting financial investments, fostering stronger social cohesion, improving infrastructure, enhancing local expertise, and delivering significant environmental advantages. Collectively, these efforts enable the building of a more resilient and sustainable future for the region.

2.5 Preliminary Monitoring and Evaluation

Key Learnings from First-Phase Climate Risk Assessment. The assessment reveals that the current municipal infrastructure in Dobrich lacks resilience against extreme rainfall, with significant flood risks identified across various return periods, underscoring the need for comprehensive drainage system improvements and the importance of precise flood mapping and risk assessment.

Stakeholder Feedback and Engagement. The preliminary climate risk assessment for Dobrich Municipality sparked valuable discussions with local stakeholders. The administration expresses concern about infrastructure vulnerability and stresses the urgent need for investments in drainage systems to mitigate flood risks. Firefighters point out inaccuracies in the 1-in-500-year floodplain mapping and emphasize the need for more precise risk assessments to enhance preparedness. Hydrology and Urban Planning Experts recommend exploring riverbed of Dobrichka River and its two tributaries widening, creating buffer zones near riverbanks, and developing comprehensive flood mitigation strategies to address the identified risks effectively. Community representatives showed mixed awareness, highlighting the need for targeted education and clear communication. Collaborative feedback favored a proactive, holistic approach combining technical expertise, community involvement, and forward-looking strategies.

Data and Resource Gaps. Available data includes reports from the National Institute of Meteorology and Hydrology (NIMH) and historical flood event records, such as the June 2014 flood. More detailed climate and rainfall data, along with precise heavy rainfall measurements, are required. Granular land use mapping and a detailed infrastructure vulnerability assessment are essential. A comprehensive population profile and identification of vulnerable groups are necessary for targeted planning.

Recommended Next Steps. Collaborate with NIMH for enhanced data collection, engage financial and insurance institutions, integrate GIS-based flood mapping into municipal planning, develop a more comprehensive risk assessment methodology, and expand stakeholder engagement to improve outcomes.

Potential Stakeholders for Future Iterations. Key stakeholders include national meteorological agencies, climate research institutions, insurance companies, local community representatives, emergency services, and urban planning experts to support future assessments. The competencies and research needs encompass advanced hydrological modeling, climate change impact assessment, urban resilience planning, and community adaptation strategies to strengthen flood risk management.

3 Conclusions Phase 1- Climate risk assessment

The first phase of climate risk assessment for Dobrich Municipality reveals flood risk, characterized by increasing hazards across different temporal and climate scenarios. Flood risks demonstrate a dramatic progression from historical baseline (1980) through current conditions to projected future scenarios, with flood depths and extent expanding significantly. Climate scenarios (RCP4.5 and RCP8.5) further illustrate potential changes, with water levels gradually increasing from 0-0.4 m in 2030 to 0.6 m by 2080, though these models may potentially underestimate local risk factors. Comparative analysis of 10-year and 500-year flood scenarios shows a stark increase in potential impact: economic damages are projected to rise from 60 to 100 million euros, population exposure from 9,300 to 12,290 people, and potential evacuations from 700 to 900 individuals. Threatened areas are concentrated around the Dobrich River and low-lying urban zones with high concentrations of residential, commercial, and industrial infrastructure.

Key challenges

The climate risk assessment for Dobrich Municipality encountered several methodological challenges: incomplete historical flood records; variations in data collection methods across different time periods; potential underestimation of local risk factors in climate scenarios; uncertainties in long-term precipitation and flood projections; limited resolution in flood extent and depth mapping.

The other challenges are the lack of detailed economic loss quantification, limited integration of hydrological, meteorological, and urban planning data. These challenges highlight the complexity of comprehensive climate risk assessment and underscore the need for continued research, improved data collection methods, and more sophisticated modeling techniques.

Climate scenarios suggest that while flood extents remain limited in RCP4.5 and RCP8.5 projections, local factors such as drainage systems, urbanization, and precipitation patterns may create additional risks not fully captured by current models. Institutional and technical capacity assessments revealed both strengths and significant gaps in current climate adaptation strategies.

Recommendations for future phases include enhancing hydrological monitoring, developing comprehensive economic impact models, conducting in-depth social vulnerability analyses, and creating targeted mitigation strategies.

The research underscores an urgent need for comprehensive, multi-faceted climate adaptation approaches in Dobrich Municipality, emphasizing proactive risk management and resilience building in the face of increasing flood hazards.

4 Progress evaluation and contribution to future phases

Connection Between Deliverable, Outputs, and Future Project Phases

The initial phase of the climate risk assessment for Dobrich Municipality focused specifically on river flood hazards, establishing a critical foundation for comprehensive climate resilience planning. This Deliverable Report concludes Phase 1, providing a detailed analysis of flood risks through the CLIMAAX methodology and toolbox, specifically tailored to Dobrich's unique urban and hydrological context. The current phase has successfully:

- Mapped flood risks for different return periods (10, 50, 100, and 500 years)
- Analyzed climate scenarios (RCP4.5 and RCP8.5)
- Assessed infrastructure and population vulnerability
- Identified key challenges in flood risk management

Upcoming project phases will build upon these foundational insights to:

- Expand Risk Understanding
- Deepen the analysis of flood-related vulnerabilities
- Develop more precise economic impact assessments
- Create detailed social vulnerability mapping
- Transform risk assessment into concrete adaptation strategies
- Integrate findings into municipal strategic documents
- Develop targeted flood mitigation and resilience plans
- Conduct workshops to validate and expand research findings
- Engage local communities, businesses, and institutional stakeholders
- Build collaborative approaches to climate risk management
- Translate research insights into practical, implementable solutions
- Support local policy development
- Enhance Dobrich Municipality's long-term climate adaptation capabilities

The project will transition from methodology testing to strategic implementation, aiming to provide Dobrich with a robust, evidence-based approach to managing and mitigating flood risks.

Table 4-1 Overview key performance indicators

Key performance indicators	***Progress***
1 report on the application and adaptation of the CLIMAAX framework published	Submitted
5000 residents, key local and regional authorities, and stakeholders reached through local and national media, incl. social media channels. *(accumulative, by the end of the project)*	To date, more than 100 individuals, key local and regional authorities and stakeholders, have attended the project's kick-off events, as well as more than 215 others reached out through local and national media, and 150 visitors through social media channels.
Kick-off meeting	The kick-off meeting took place after selection of all team members and the issuance of a mayor's order in January 2025. At the event, the project and team

Key performance indicators	***Progress***
	members were presented to representatives of regional and municipal administrations, as well as to other institutions related to climate change and the risks to society that it leads to.
1 workshop with stakeholders	The workshop presentation of the report to municipal officials, representatives of other administrations, who were previously familiarized with the report and participated in a discussion on the results of the application of the methodological framework. /and non-governmental organizations related to climate change and the risks to society that it leads to. In the process of work, feedback was received through a pre-prepared survey.
At least 5 local or national NGOs and 20 local community members involved in the workshops with stakeholders	In process of implementation.

Table 4-2 Overview milestones

Milestones	***Progress***
M1 *Kick-off meeting of the project team with municipal and external experts*	The kick-off meeting took place after the election of all team members and the issuance of a mayor's order in January 2025. At the event, the project and team members were presented to representatives of regional and municipal administrations, as well as to other institutions related to climate change and the risks to society that it leads to.
M2: Press conference to announce the project and its goals	The media presentation of the project took place a week after the team's kick-off meeting. The event was broadcast in real time on one of the local electronic media outlets, and after the event, publications were made in four such outlets, one regional print publication, as well as on the municipality's website.
M3: Completion of the workshop on the application and adaptation of the CLIMAAX framework	The workshop consisted of a presentation of the report to municipal officials, representatives of other administrations, and participated in a discussion on the results of the application of the methodological framework.

5 Supporting documentation

- Main Report (PDF)
- Visual Outputs (infographics, maps, charts)
- Communication Outputs (Press release, media)

- https://pronewsdobrich.bg/analiz-na-riska-za-dobrich-ot-klimatichnite-promeni-predstoi-da- se-izvarshi-po-proekt-p557351?fbclid=IwY2xjawIIZoJleHRuA2FlbQIxMAABHTer9Hi_d- fYG3UH-r2kmCZ4KvW-fQcL- VUxenlCcYHjniY8q4EDhclimA_aem_uWFPCeulC0NUXpwUf2SkeA

- https://www.dobrichonline.com/novini/86313/obshchina-dobrich-zapochna-rabota-po-proekt-arkadiya-razshirena-otsenka-na-riska-chrez-debati-inovatsii-i-deystviya-za- klimatichna-ustoychivost-v-dobrich?fbclid=IwY2xjawIIZqRleHRuA2FlbQIxMQABHeYS8iUpI0Q84btiWlTOJt3nGLyj3jlLzqtMs933Y1M1coLxFu75dgieXA_aem_8lb2finT7L6eAkgJKrdapg

- https://dobrudjabg.com/novina/na-jivo-predstavqne-na-proekt-arkadiq-v-obshtina-grad-dobrich/102538?fbclid=IwY2xjawIIZtJleHRuA2FlbQIxMQABHbfuo9wsIh3AhOTAhIu9OQVu1vd1iHwHl5oOw_e8bkaMtIJvgfH5h107rw_aem_m_9c9gZ8aIJSifCAfhttps://www.

- *https://www.dobrich.bg/bg/novini/proekt-arkadiya-razshirena-otsenka-na-riska-chrez-debati- inovatsii-i-deystviya-za-klimatichna-ustoychivost-v-dobrich*

- *https://www.youtube.com/ watch?v=B w9dvfjjvU&t=33s* -

- *https://www.dobrich.bg/bg/novini/rabotna-sreshta-za-predstavyane-na-doklad-po-proekt-arkadiya-se-provede-v-dobrich*

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The Changing Climate of Bulgaria – Data and Analyses. Edited by Prof. Tanya Marinova and Assoc. Prof. Liliya Bocheva. National Institute of Meteorology and Hydrology, Sofia, 2023. [In Bulgarian]. Available at: https://www.meteo.bg/meteo7/sites/storm.cfd.meteo.bg.meteo7/files/kniga_klim_promeni_23-12-2023_KM_ff.pdf

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