Frisco1

S čezmejnim sodelovanjem do zmanjšanja poplavne ogroženosti

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PROJEKT FRISCO1

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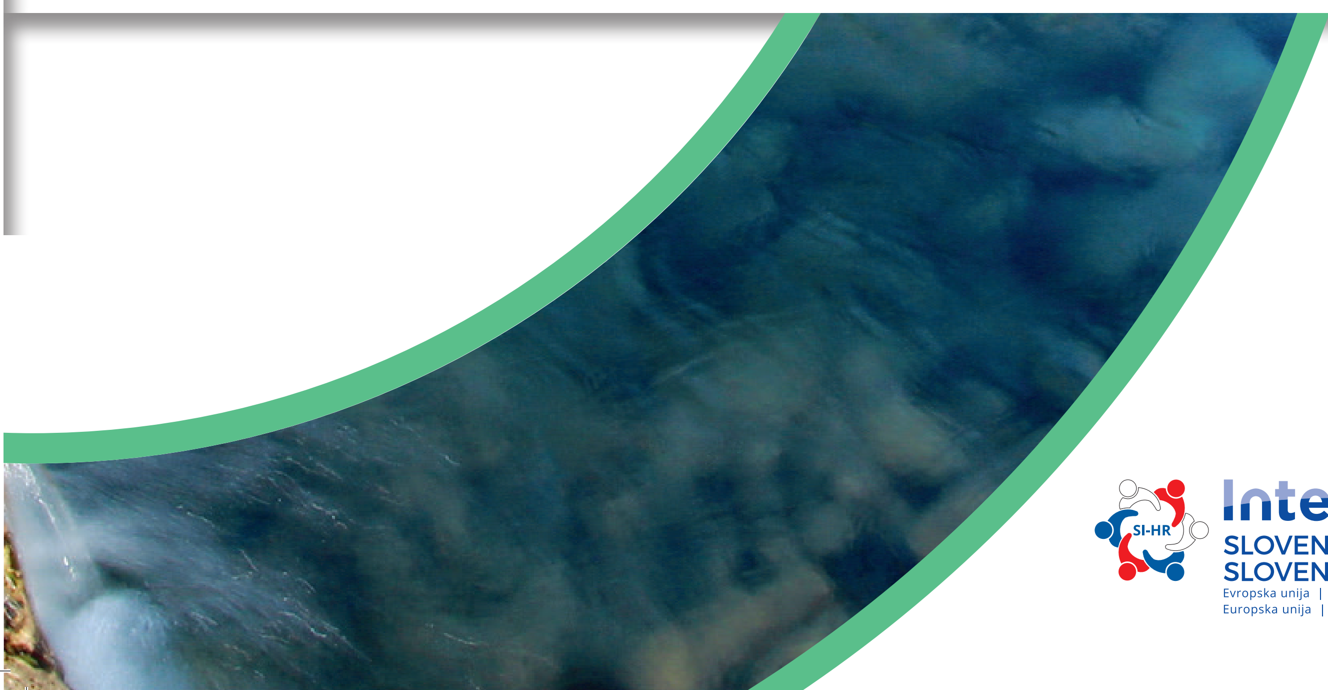
CROSS-BORDER HARMONIZED COMPREHENSIVE FLOOD RISK REDUCTION STUDY FOR THE DRAGONJA RIVER BASIN

abstract



SI-HR

Interreg

SLOVENIJA – HRVAŠKA

SLOVENIJA – HRVATSKA

Evropska unija | Evropski sklad za regionalni razvoj

Europska unija | Europski fond za regionalni razvoj

INTERREG V-A Slovenia–Croatia 2014–2020 Cooperation Programme

Project:

FRISCO 1 – Cross-border Harmonised Slovenian-Croatian Flood Risk Reduction – Non-structural Measures

Objective:

Project FRISCO1 – Technical assistance in the elaboration of a comprehensive flood risk reduction study carried out for the cross-border Dragonja river basin

Documentation type:

CROSS-BORDER HARMONIZED COMPREHENSIVE FLOOD RISK REDUCTION STUDY FOR THE DRAGONJA RIVER BASIN

ABSTRACT

June 2019

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1 INTRODUCTORY PRESENTATION OF THE FRISCO 1 PROJECT

The FRISCO1 project is a strategic project aimed at reducing flood risk in the basins of the Dragonja, Kolpa, Sotla and Bregana rivers and parts of the Drava and Mura river basins, which is implemented in the framework of the INTERREG V-A Slovenia–Croatia Cooperation Programme. The INTERREG V-A Slovenia–Croatia Cooperation Programme text is the main document that represents the framework for cross-border cooperation between Slovenia and Croatia in the 2014–2020 financial perspective. The purpose of cross-border cooperation is to overcome the common challenges that both countries have jointly recognised in the border area, while also taking advantage of untapped growth potentials and strengthening the process of cooperation for the overall harmonious development of the European Union.

FRISCO1 substantially examines the non-structural measures for flood risk reduction and the improvement of flood risk management system. The improved, cross-border harmonized flood risk mapping and the elaboration/improvement of cross-border flood forecasting models will provide the necessary expertise and documentation for the proposal and selection of harmonised structural cross-border flood risk reduction measures that would be carried out in the second phase of the FRISCO project, i.e. through the FRISCO2 project implemented in the basins of the Kolpa, Sotla, Drava and Mura.

The FRISCO1 project partners:

- Croatian Waters (CW, Croatian: Hrvatske vode) as the leading partner,
- Ministry of the Environment and Spatial Planning of the Republic of Slovenia (MESP, Slovenian: ministrstvo za okolje in prostor Republike Slovenije),
- Slovenian Environment Agency (SEA, Slovenian: Agencija Republike Slovenije za okolje),
- Slovenian Water Agency (SWA, Slovenian: Direkcija Republike Slovenije za vode),
- National Protection and Rescue Directorate (NPRD, Croatian: Državna uprava za zaštitu i spašavanje),
- Meteorological and Hydrological Service (MHS, Slovenian: Državni hidrometeorološki zavod),
- Institute for Hydraulic Research (IHR, Slovenian: Inštitut za hidravlične raziskave),
- Administration for Civil Protection and Disaster Relief (ACPDR, Slovenian: Uprava Republike Slovenije za zaščito in reševanje).

The FRISCO1 project consists of the following ten work packages:

M Project Management

C Project promotion

T1 Kolpa common tools, models, maps and projects

T2 Sotla common tools, models, maps and projects

T3 Drava common tools, models, maps and projects

T4 Mura common tools, models, maps and projects

T5 Dragonja common tools, models, maps and projects

T6 Bregana common tools, models, maps and projects

T7 Flood warning and alerting systems

T8 Activities For Raising Awareness and Comprehensive Concept and Programme Management – for the Flood Risk Reduction/Flood Relief Project

In the T5 Dragonja work package, the common tools, models, maps and projects comprise the following activities:

T5.1 Development of common tool 1 (Flood risk database)

T5.2 Development of common tool 2 (Target area study)

T5.3 Development of common model 1 (Improved hydraulic model)

T5.4 Development of common model 2 (Improved predictive model)

T5.5 Development of common map 1 (Improved flood hazard map)

T5.6 Development of common map 2 (Improved flood risk map)

T5.7 Preparation of construction projects

The planned activities and results are interconnected.

In accordance with the project application, the results of the FRISCO1 project are as follows:

- Improved databases for flood risk management
- Cross-border studies of comprehensive flood risk management
- Improved hydrological and hydraulic models
- An improved flood forecasting model
- Improved and cross-border harmonised flood hazard and risk maps
- Joint projects (preparation of project and other documentation)
- Early warning system (upgrade of the prognostic and warning alarm system)
- Raising public awareness in flood risk and institutional strengthening of the flood risk management system

The main objective of the T5.2 Common tool 2 is "A study of cross-border harmonised reduction in flood risk for the Dragonja river basin".

2 CROSS-BORDER STUDY OF COMPREHENSIVE FLOOD RISK MANAGEMENT OF THE DRAGONJA RIVER

2.1 THE PROGRAMME

INTERREG V-A Slovenia–Croatia 2014–2020 Cooperation Programme

2.2 THE PROJECT

FRISCO 1 – Cross-border Harmonised Slovenian-Croatian Flood Risk Reduction – Non-structural Measures

2.3 THE SUBJECT

The FRISCO1 project – Technical assistance in the elaboration of a comprehensive study in the flood risk reduction for the Dragonja cross-border basin

2.4 THE SPONSOR

THE REPUBLIC OF SLOVENIA,
Slovenian Water Agency (Slovenian: Direkcija Republike Slovenije za vode)
Hajdrihova ulica 28c, SI-1000 Ljubljana

2.5 THE CONTRACTOR

Lead Partner:

IZVO-R, projektiranje in inženiring d.o.o.
Pot za Brdom 102, SI-1000 Ljubljana

Responsible task manager:
Rok Fazarinc, M.Sc., B.Sc. Civil Engineer

Partners:

Water Science Institute (Slovenian: Inštitut za vodarstvo, d.o.o.)
Hajdrihova ulica 28a, SI-1000 Ljubljana

Water Management Bureau Maribor (Slovenian: Vodnogospodarski biro Maribor d.o.o.)
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HIDROSVET d.o.o.
Kidričeva ulica 25, SI-3000 Celje

DHD, d.o.o.
Praprotnikova ulica 37, SI-2000 Maribor

SL-Consult, d.o.o.
Dunajska cesta 122, SI-1000 Ljubljana

2.6 THE TASK MONITORING AND MANAGEMENT

One of the objectives of the FRISCO1 project is a cross-border study in flood risk reduction for the Dragonja area, which was carried out by a professionally qualified contractor selected through a public procurement process. The contract was officially carried out by the Slovenian Water Agency, but the study was also monitored in accordance with the project assignment by the leading structure of the FRISCO1 project, which comprises multiple project management groups and working groups:

- The Sotla Working Group (WG)
- The Project Management Team (PMT)
- The Strategic Management Team (SMT)
- The Quality Management Team (QMT)
- The Project Communication Team (PCT)
- The Expert Panel (EXP)

The study was managed by the Dragonja Working Group (WG), which comprised the representatives of project partners. The leader of the working group was Mrs. Zorka Sotlar (DRSV) and the co-leader was Mr. Vanja Rački (CW).

2.7 THE PURPOSE AND OBJECTIVES OF THE STUDY

The cross-border study carried out for flood risk reduction in the Dragonja river basin contains an analysis of the existing situation and alternative solutions as well as the identification and justification of flood risk reduction measures in the relevant area, including the identification of key natural water retention areas and an analysis of potential green infrastructure measures, which is based on hydrological, hydraulic and technical economic analyses. The elaborated study serves as a support tool for decision makers and as an informative tool for all stakeholders. The proposed optimal flood risk management programme in the study is divided into measures that are feasible in the short term and could be implemented during the current implementation period of the European flood directive (2016–2021) as well as measures that could be implemented later.

2.8 THE PURPOSE AND OBJECTIVE OF THE SUMMARY OF THE CROSS-BORDER HARMONISED STUDY IN FLOOD RISK REDUCTION OF THE DRAGONJA

Below is a summary of the Cross-Border Coordinated Study of the Comprehensive Flood Risk Management for the Dragonja River, which contains summaries of key content and the results of the study.

The summary is an integral part of the T5.2 Development of Common Tool 2 (Target Area Study).

3 SUMMARY OF CROSS-BORDER HARMONISED STUDY IN FLOOD RISK REDUCTION OF THE DRAGONJA

3.1 ANALYSIS OF THE CURRENT SITUATION

3.1.1 COLLECTION AND ANALYSIS OF EXISTING DATA

For the purpose of the study, the available existing data was collected, reviewed and analysed, with quality control of the relevant data carried out at the same time. The data obtained from Slovenia and Croatia was then analysed by individual sets. The available project documentation, which had previously been created for the Dragonja river area, was analysed and reviewed.

3.1.2 DESCRIPTION OF THE CURRENT SITUATION

3.1.2.1 General description of the Dragonja river basin

The Dragonja river basin area is part of the Gulf of Piran watershed. It covers 95.6 km^2 and has 18 right and 13 left tributaries. Its stream is approximately 27 km long and the altitude difference between the highest point and the sea level is 460 m. The Dragonja valley is very sparsely inhabited – in the central and upper part of the valley, there are mostly individual commercial buildings and remnants of old mills, which were later converted into commercial and residential buildings. The upper part of the valley (above the inflow of Pinjevec brook) features no major agricultural areas and only wild vegetation is present here, but the agricultural surfaces become substantially more extensive down the stream. These mostly comprise vineyards, olive groves and fields with various crops.

In its upper and middle parts, the Dragonja is a torrential river marked by the dynamic processes of erosion, displacement and deposition of sediments, and a strong influence on the river's bottom and surrounding area. The hilly area of the Dragonja basin features wide and flat ridges on which almost all settlements were developed, while the narrow valleys of its tributaries are almost uninhabited, except for the lower part of the basin.

The side erosion and the typical flat form of gravel in the middle part of the Dragonja

The lower area of the mid-section is more subdued. The erosion processes are shown only as lateral erosion of the valley floor. The banks are overgrown and agricultural land spreads along the river.

The agricultural surfaces with irrigation ditches between the Dragonja and Sečovlje

The Dragonja valley is at risk of flooding. The floodplains are mostly cultivated for agriculture, while the settlements are located at the edge of the valley and are largely found outside the Dragonja flood zone. In order to examine this problem, the Dragonja river basin was analysed as part of a comprehensive study for the Dragonja river basin.

3.1.2.2 <u>Area of the Dragonja river basin relevant for the FRISCO 1 project</u>

The study area comprises the Dragonja river between its source and the Sečovlje International border crossing. The study and hydraulic modelling area does not comprise the airport and the salt pans, which is why only solutions aimed at reducing the flooding of agricultural land and the possible implementation of local measures for the protection of individual facilities were considered.

An overview map of the area in line with the project assignment

3.1.2.3 *Geographical description of the relevant area*

The source of the Dragonja river is located near the village of Popetre in the municipality of Koper. The river formed its basin in flysch hills. Only a small part, which lies predominantly on the Croatian side, is composed of limestone. The altitudes range from 0 to 487 m and the average drop in the upper stream is about 2.5%, while standing at 0.75% in the middle stream (from Pinjevec brook to Argila brook) and 0.2% in the lower, regulated stream. The landscape mostly consists of forests and bushes, while some agricultural areas can be found near the settlements.

3.1.2.4 *The water environment*

The Dragonja river basin covers an area of 95.6 km^2. The source of the river is near the village of Popetre in the municipality of Koper. It has 18 right and 13 left tributaries, with the largest of them being a right tributary named Pinjevec brook (Rokava brook) and Argila brook, a left tributary. Other tributaries are torrential and mostly dry during summer. The river formed its basin in flysch hills. Only a small part, which lies predominantly on the Croatian side, is made of limestone. The altitudes range from 0 to 487 m and the average drop in the upper stream is about 2.5%, while it is 0.75% in the middle stream (from Pinjevec brook to Argila brook) and 0.2% in the lower, regulated stream. The landscape mostly consists of forests and bushes, while some agricultural areas can be found near the settlements.

3.1.3 THE HYDROLOGICAL ANALYSIS

3.1.3.1 *Description of starting points and used data*

For the purpose of a hydrological analysis of the Dragonja river basin, the topographic data for the entire basin was used in creating the digital relief model (DRM 12.5 m), while a DRM 1 m (LIDAR) was also used for the Slovenian part of the river basin. The existing land use data includes the CORINE Land Cover (CLC) map of the entire river basin and the agricultural land use map (GERK, for the Slovenian part of the river basin only). The pedological map was only available for the Slovenian part of the basin. The existing hydrographical data covers a channel network, hydrographical areas (only for the Slovenian part of the basin), locations of meteorological and hydrometric stations, and precipitation and flow measurements at these stations.

3.1.3.2 *Analysis of the quality in obtained data*

Considering that DRM 1 m is available only for the Slovenian part of the basin, DRM 12.5 m was used to determine the courses of divides and streams.

For the purposes of determining the drainage potential of the soil, data on the rate of infiltration and soil texture was used. In assessing both of the two parameters, a pedological map was used, which is available only for the Slovenian part of the Dragonja river basin.

There are several meteorological stations located in the Dragonja river basin and its nearby surroundings, both on the Slovenian and the Croatian side. For the purpose of this study, six stations were selected based on the delimitation of the Dragonja river basin and the Thiessen polygons, with a more than 20-year series of daily precipitation measurements collected between 1956 and 2016. These stations are Dekani, Dragonja, Koštabona, Kubed, Movraž and Momjan. All except for the last one are located on the Slovenian side of the basin. Extreme rainfall with shorter duration was determined by stretching to return periods for extreme precipitation at the Portorož airport station. For the purposes of calibration of the hydrological model as per the 2010 event, hourly and half-hourly precipitation measurements were also used.

There are two hydrological stations in the lower part of the basin: Podkaštel (SLO) and Plovanija (HR), where flowing around the station was detected during high flows. When the water is extremely high, the Dragonja river flows onto roads and existing inundation surfaces, which means that a part of the flow is not included in the cross-section of the hydrometric station. As a result, the flow curve of these hydrological stations at higher flows is underestimated.

For the purpose of the hydrological model calibration for the event that took place in September 2010, in addition to the Koper weather station, for which half-hourly precipitation data was available, hourly precipitation measurements were used from the stations of Krkavče and Truške, which operated in the area as part of the SIGMA project (Community Initiative Programme INTERREG III A Slovenia–Italy). The calculated flows were compared with the results of a previous hydrological study (IZVO-R, 2012), which analysed the extreme event of 2010 in addition to determining the value of the Dragonja high waters in the cross-section of the Dragonja border crossing with a return period of 10, 100 and 500 years.

3.1.3.3 Setting up a hydrological model

The RiverFlow2D (Hydronia LLC, 2017) model was used for hydrological modelling of the Dragonja river. The model is based on a triangular network that can be arbitrarily condensed. Consequently, the triangular elements are of different sizes. In this case, the minimum surface area of the triangular element was 0.75 m^2, the average area was 90.50 m^2 and the maximum surface area was 5,940.55 m^2. The RiverFlow2D calculation is usually performed using the final volume method, with a single height for each triangular element based on the topography (in this case DMR 12.5 m).

The normal level was used for the outflow and the location of the lower boundary criterion was not affected by the results of the model due to the appropriate distance from the evaluation site of the outflow hydrogram. The selected values of the roughness coefficient ranged between 0.06 (valley bottom) and 0.2 (in forest areas). The value of 0.08 was chosen as the coefficient of roughness in the river channel.

In order to calculate precipitation losses, the SCS method was used, by means of which the surplus of surface drainage was estimated as a function of the drainage potential, the preliminary humidity of the soil and the use of the soil.

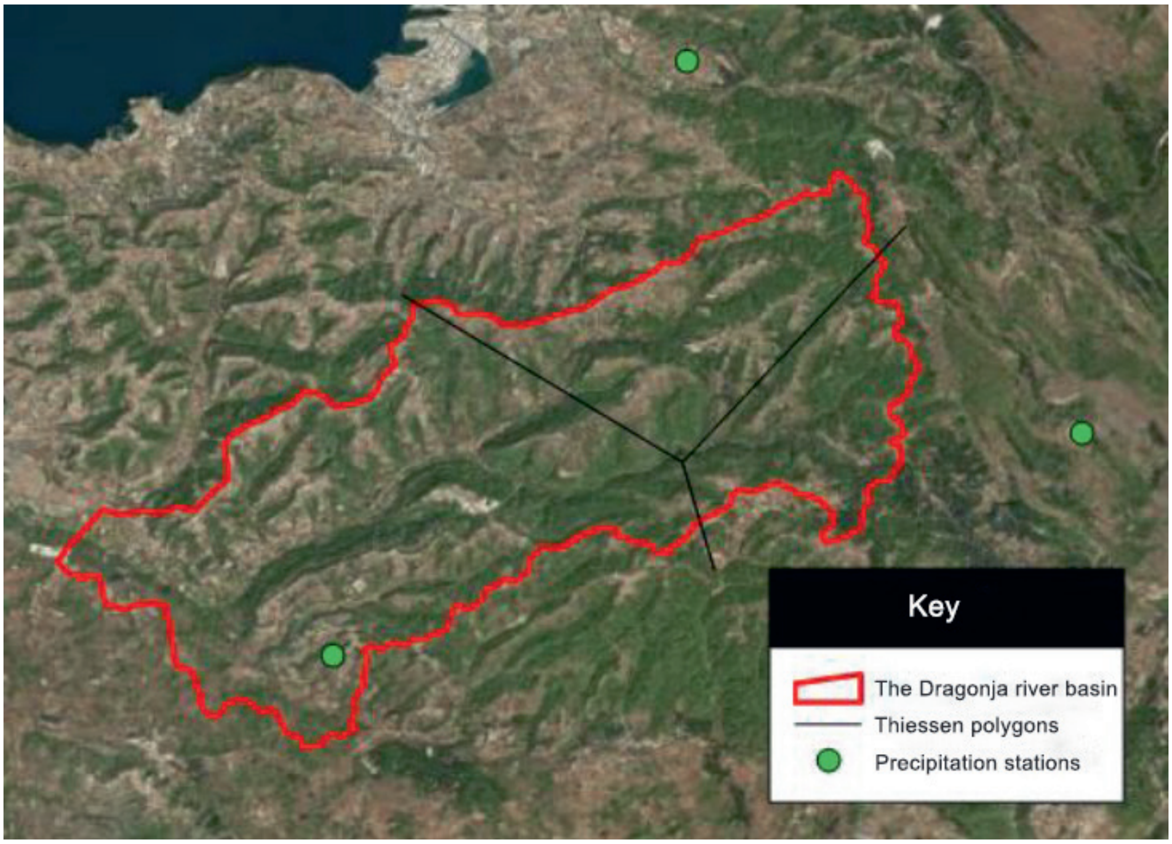
The drainage potential depends on the prevailing soil type, which was determined for the entire Slovenia in a project named *Projection of Water Quantities for Irrigation in Slovenia (CRP Competitiveness of Slovenia 2006–2013, 2012)*. The results of this project were used to determine the drainage potential in the Slovenian part of the Dragonja river basin. Since the ground in the Croatian section of the river basin consists of clay and loam (Glavan, 2011), which are characterised by a high to moderate drainage potential with a low water infiltration rate, the drainage potential C was predicted for almost the entire area.

The values of the CN coefficient were determined with the use of a USACE (US Army Corps of Engineers, 2000) table, in which CN measurements depend on land use, runoff potential and hydrological conditions. The average CN value for the entire Dragonja river basin is 69.7 when taking into account good hydrological conditions, 72.96 when taking into account average hydrological conditions, and 77.27 for bad hydrological conditions.

3.1.3.4 Precipitation analysis

From the point of determining the precipitation with different periods of return, the stations with the longest set of measurements and arrays in the last decade (including 2010) are the most important. For the purpose of this study, three stations, i.e. Dekani, Momjan and Movraž, were selected based on the delimitation of the Dragonja river basin and the Thiessen polygons, which had a more than 20-year series of daily precipitation measurements between 1956 and 2016, including the year 2010.

According to the formed Thiessen polygons, the Dragonja river basin is covered by the Momjan station in 61% of the surface, while the Dekani station covers 24% and Movraž covers 15%. The Momjan station is located on the Croatian side of the river basin, while the Dekani and Movraž stations are located on the Slovenian side of the river basin.



The locations of analysed precipitation stations

Since the selected stations do not have any values recorded for return periods in extreme precipitation, the archive data on maximum daily precipitation amounts for each year were examined. For each of these stations, a statistical analysis of data on maximum daily precipitation quantities in a particular year was carried out by using the Gumble method with the help of the FreqPlot programme. The results of the analysis are extreme daily values of precipitation with 10, 25, 50, 100 and 500-year return periods. Extreme precipitation with a 1,000-year return period was determined by extrapolation.

Since the extreme values of precipitation in lower intensities could not be statistically evaluated, the lower intensity precipitation values were stretched to the values from the previous study of 2012 titled Hydrological Analysis of the High Water of the Dragonja within the area of the Dragonja border crossing.

Because of the size of the basin, the reduction factor, which basically depends on the size of the basin and the duration of precipitation, needed to be taken into account when determining the projected precipitation values. As a result, the entire Dragonja river basin was divided into two parts, i.e. the upper stream area of the Pinjevec brook (up to the "upstream of the Pinjevec brook″ profile, with a catchment area of over 30 km^2) with influence on the upper stream area extending from the "upstream of the Pinjevec brook" cross-section, where the reduction factors were not considered, and the lower stream of the Dragonja river basin extending from the "downstream of the Pinjevec brook" cross-section with reduction factors belonging to the mean value between the two surfaces related to the cross-sections of "downstream of the Pinjevec brook" and "downstream of Argila". The size of this area is 70.85 km^2. For the purposes of hydrological calculations, a constant distribution of precipitation was used.

Time	**Return period (years)**						
min	**hrs**	**10**	**25**	**50**	**100**	**500**	**1,000**
60	1	57	68	76	84	102	112
90	1.5	70	83	93	104	126	138
120	2	75	91	103	115	141	156
180	3	81	97	110	122	150	165
240	4	85	102	115	128	157	172
300	5	88	106	119	133	162	178
360	6	92	110	123	137	167	183
540	9	99	119	133	147	178	196
720	12	106	126	140	155	188	206
900	15	111	132	147	162	196	214
1080	18	116	137	153	168	203	222
1440	24	125	147	163	179	216	236

The return periods of extreme precipitation (in mm) determined for the part of the Dragonja river basin above the "above the Pinjevec brook" cross-section – surface-weighted values based on surface values obtained from the Thiessen polygons

Time	**Return period (years)**						
min	**hrs**	**10**	**25**	**50**	**100**	**500**	**1,000**
60	1	49	59	66	73	89	97
90	1.5	62	74	83	92	111	122
120	2	68	82	93	104	127	140
180	3	75	91	102	114	139	153
240	4	80	96	108	121	147	162
300	5	84	101	114	126	154	169
360	6	88	106	118	132	160	176
540	9	96	114	128	141	172	188
720	12	102	121	135	150	181	198
900	15	108	127	142	157	190	207
1080	18	113	133	148	163	197	215
1440	24	122	144	159	175	211	230

The recovery periods for extreme precipitation (in mm) determined for the part of the Dragonja river basin stretching from the "downstream of the Pinjevec brook" profile and down the stream, with the reduction factors belonging to the average surface of the cross-sections called "downstream of the Pinjevec brook" and "downstream of Argila", which is 70.85 km^2, with the surface weighted values based on surfaces having been obtained from the Thiessen polygons method.

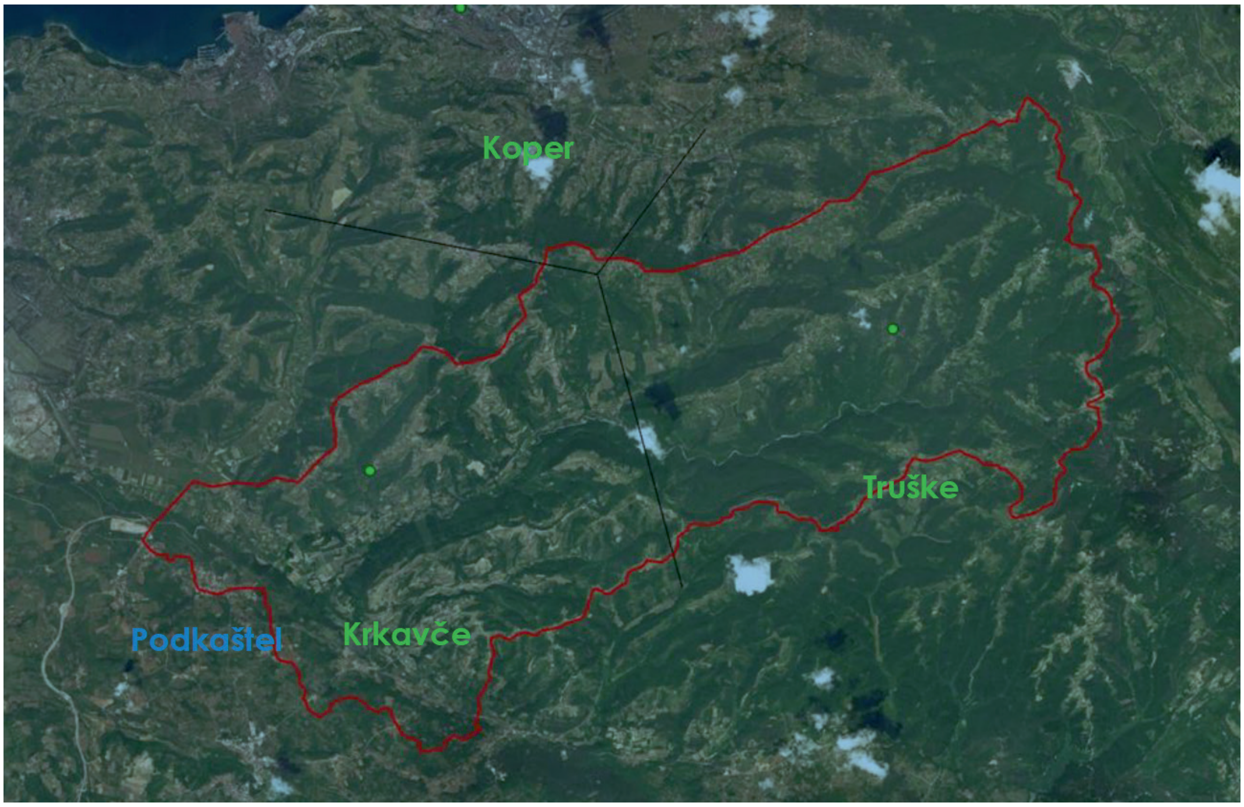
3.1.3.5 Calibration of the hydrological model

For the calibration of the hydrological model, a precipitation event which took place in September 2010 was selected. The closest weather stations are found at the Portorož airport and in Koper. Most of the precipitation at the Portorož airport station fell as downpours from the afternoon of 18 September until the morning of 19 September, with a 25-year return period for the two-day sum of precipitation (152 mm).

In the Dragonja river basin area, the stations of Truške and Krkavče were installed as part of the international SIGMA (INTERREG III A Slovenia–Italy Community Initiative Programme) project. The Truške station is located in the upper part and the Krkavče station is found in the lower part of the Dragonja river basin. At the Truške station, the two-day amount of precipitation for the respective event was recorded at 204 mm, while at the Krkavče station the value was 238 mm. The two-day amount of precipitation, measured on 18 and 19 September 2010, was also checked at the surrounding meteorological stations which record daily precipitation measurements. At the Movraž station, the measurement result was 171 mm, at the Dekani station it was 198 mm, while the number at the Momjan station stood at 207 mm.

Two hydrometric stations, i.e. Podkaštel and Plovanija (CRO), are located in the Dragonja river basin, but both are problematic because of the water flowing around them at times of high discharges.

Based on the analysis of the Dragonja river basin by means of the Thiessen polygons, the quantities of hourly precipitation measured at the stations of Krkavče and Truške and half-hour precipitation measured at the Koper station were used for the model calibration and validation. Considering that the event that took place in September 2010 comprised several successive events, the model was calibrated to a 12-hour event that took place between 6 pm on 18 September and 6 am on 19 September. For this event, a return period between 25 and 30 years (Truške) and 100 and 500 years (Krkavče) was estimated. A 15-hour event that took place on 18 September between 3 am and 6 pm, was used for the validation. The return period of precipitation at the stations of Truške and Krkavče was estimated to be shorter than 10 years.



Location of precipitation stations used in the model calibration

Within the calibration, good, average and poor hydrological conditions were verified. Since the precipitation event occurred after a prior period of rain, the hydrological conditions in the basin ranged from average to poor.

In the validation, good hydrological conditions were taken into account, since there was no rain during the three hours right before the event and the initial flow of the Dragonja was only 0.2 m^3/s.

3.1.3.6 Results of hydrological modelling

The calibrated (and validated) hydrological model evaluates high water values with a return period of 10, 25, 50, 100, 500 and 1,000 years for 37 profiles along the Dragonja river and for four profiles of its tributaries. The hydrological calculations were made by using the RiverFlow2D tool for different precipitation times, in order to find the most inconvenient precipitation event at the locations of selected profiles in terms of the flow. The 24-hour event was considered as the most inconvenient precipitation event in terms of volumes at all locations.

The calculated flow is comparable with the estimated maximum flow of the Dragonja river from September 2010 (314 m^3/s, taking into account poor hydrological conditions), which suggests that the flood event had a return period of approx. 100 years.

The results/flood waves are evaluated by using the entire/unreduced precipitation amount in cross-sections 1–23 and a reduced precipitation amount in cross-sections 23–41. Up to the cross-section 23 (up to the final inflow, which represents the difference between the flood waves from cross-sections 22 and 23), the flood waves are used as a result of the entire (unreduced) precipitation amount. From the cross-section 23 onwards (beginning with the inflow of Pinjevec brook – the difference between flood waves from cross-sections 24 and 23), flood waves with reduced precipitation are used. In this case, we get more intense downpours in the upper part of the basin. Slightly less intense downpours are considered for the lower part of the basin (including the Pinjevec brook basin).

For the purpose of a more in-depth analysis of the main and also the largest Dragonja tributary, i.e. the Pinjevec brook, the cross-section 24 includes flood waves as a consequence of unreduced precipitation. If flood waves between profiles 23 and 24 (with unreduced precipitation used in both cases) are subtracted, we get the most unfavourable flood wave values for the Pinjevec brook, which can be used to analyse possible measures for the Pinjevec brook basin. For other complementary waves, the use of flood waves obtained by using reduced precipitation values was recommended. This means that more intense downpours can be taken into consideration for the Pinjevec brook basin and downpours that are less intense can be taken into consideration for the other parts of the basin.

3.1.4 HYDRAULIC ANALYSIS

The results and conclusions of the Cross-border harmonised flood risk reduction study for the Dragonja cross-border river basin are based on the use of tools supplied by the sponsor to the contractor: the hydraulic model of the Mura river (model created by the Institute for Hydraulic Research) and bilaterally harmonised methodologies. The first phase of the study describes the Dragonja flooding issues at the level of expert opinion and the second phase describes it on the basis of a hydraulic model.

3.1.5 ANALYSIS OF FLOOD RISK

The assessment of flood risk serves as the basis for the optimisation of measures as well as financial and economic analysis. The basis for the definition of flood damages for the FRISCO1 project was the methodology from "The Basis for the Bilateral Methodology of Economic Assessment of Flood Damage on Cross-border Basins, Huizinga Methodology with Parameters for the FRISCO1 Project" (University of Zagreb). This methodology defines a limited set of damage categories, which on average account for 80% of the total damage in all EU countries concerned. The method covers the assessment of damage to (1) residential buildings, (2) commercial buildings, (3) industrial buildings, (4) roads, and (5) agricultural facilities.

For the area that was the subject of the FRISCO project, the number of affected residents was analysed based on the Central Population Register of the Republic of Slovenia (data from 2018). There are 14 buildings with a house number each, found in the area of influence with a 1000-year return period. One inhabited building is located upstream from the Dragonja border crossing and is not shown in the figure. 66 persons (on both sides of the Dragonja) live permanently or temporarily in the above-mentioned buildings. If a flooding analysis with a 100-year return period is carried out, the number decreases to 14 persons. All individuals are protected in case the measures get implemented, which means that the number decreases to zero if the measures are in fact implemented (reservoir, both options have the same impact on the 100-year return period) and this is why the effects can be considered the most beneficial under this criterion.

This is given that there are not enough inhabitants in the area to even assess the positive effects on the environment, there are also no other factors (treatment plants, factories etc.). The effects are either insignificant or non-existent. According to the definition under the environment (5) and population (1) criteria, the solution is designated as 4 – Appropriate with regard to the impact of flood events on the health of people and the environment.

3.2 DESIGN AND ANALYSIS OF ALTERNATIVE SOLUTIONS

3.2.1 DESIGN OF ALTERNATIVE SOLUTIONS

The area analyses highlighted an important fact: in the pursuit of the FRISCO project objectives (reduction of flood risk in the Dragonja valley), the greatest problem is posed by the area that was selected for the project, because it ends just above the area that would require the most complex consideration as it features the greatest damage potential. The area in question consists of the Sečovlje salt pans, which is one of the most important places of Slovenian cultural heritage, and the Portorož airport. The financial damage caused by flooding of the salt pans is difficult to evaluate, since in addition to the loss of income from salt production, some elements (buildings, landscaping etc.) that are of great cultural, natural and historical importance could be damaged. The most vital and delicate buildings as well as the main part of the infrastructure lie in the NW part of the airport, where the risk of flooding is

lower. Some parts of the settlements of Dragonja, Sečovlje and Mlini are also endangered, albeit to a lesser extent.
The Dragonja valley is very sparsely populated. The central and upper part of the valley features mainly individual commercial buildings and several remains of old mills, which have been converted into commercial and residential buildings. The upper part of the Dragonja valley (above the Pinjevec brook inflow) features are no major agricultural areas and only wild vegetation is present, while the number of agricultural lands substantially increases below the Pinjevec brook. These mostly comprise vineyards, olive groves and fields with various crops and vegetables.

3.2.1.1 Structural measures for flood risk reduction

The search for possibilities of flood risk reduction in the Dragonja valley was carried out in phases. In general, there are four possible approaches for improving flood safety through structural measures: increasing the water flow of river channels, protecting the floodplains with flood-control embankments, retaining excess water in the catchment area above the vulnerable areas, and a combination of different types of measures.

The Dragonja valley represents an important natural asset, since practically the entire channel section above the Dragonja settlement represents wild nature and the surrounding plains are either used as agricultural land or are covered in forest and shrubs in the upper part. Any structural regulation of the river channel and the channelling of water into the primary riverbed would be unacceptable from an environmental point of view and inconsistent with water directives that attempt to conserve the natural overflow areas and keep as much water in the basin as possible.

Furthermore, a construction of embankments along the riverbed would represent a huge intervention into the environment, as they would be positioned at certain distance from the main river channel (the average water flow of the main riverbed is 10–40% Q100, which means that the secondary riverbed between the embankments would need to be significantly larger), which would significantly reduce the proportion of agricultural land. The construction of embankments would also degrade the natural environment between the Dragonja settlement and the Pinjevec brook confluence. This approach would therefore be unacceptable in view of the described impact.

Another option would be to retain flood water in the basin. When we examined the possibilities for retention, the first phase was focused only on the technical aspects – the available locations according to current use and morphology of the area. The proximity of the areas protected by the measure is also important in determining the locations of reservoirs. In principle, the measures carried out at remote locations have less impact than those carried out closer to the threatened areas. Hydrologically speaking, the closer the location of the implemented measure, a larger portion of the drainage basin it covers, so it has greater influence on the water regime of the protected area.

3.2.1.2 Technical options for the construction of reservoirs

In accordance with this reasoning, we looked for locations of reservoirs that would be closest to the assets that require protection. As stated previously, agricultural land is the most vulnerable element (according to the objectives of the project). In the Dragonja river valley, a limited amount of agricultural land stretches all the way to the Pinjevec brook confluence. For this reason, the first logical selection in terms of location was the river channel section upstream from the bridge over the Dragonja above the Pinjevec brook confluence. The reservoir (code ZD-1A) barrier could be constructed approximately 250 m up the stream, from the mentioned bridge. The valley floor upstream from the Pinjevec brook is practically uninhabited, which is why the construction of a reservoir at this location would be the simplest and least problematic option in terms of impact on the surrounding infrastructure and buildings.

The volume of the Dragonja 100-year short-period flood wave for the section of the river upstream from the Pinjevec brook (F=31 km^2) is up to 1.6 million m^3, while the volume of the 24-hour event is over 2.1 million m^3. The volume of the short-period wave for the 500-year event is up to 2.1 million m^3 and the volume of the long-term wave is over 2.8 million m^3. Given the fact that the reservoir is quite a long way upstream from the protected area, it is assumed that the outflow from the reservoir would need to be completely closed in the event of high water. As the first starting point for the projected volume of the reservoir, the value of 2.6 million m^3 was chosen. For the project volume of ~2.6 million m^3, the project level would need to be 103 m a.s.l., while the depth of the water at maximum capacity would exceed 20 metres in the lowest reaches, whereby 29.4 hectares of land would be flooded and the water would extend 1.5 km upstream of the barrier. There are no residential structures in the flooded area, nor is there any other infrastructure (except for the forest trail).

At the site in question, it would be possible to construct a significantly larger reservoir (code ZD-1B) with an elevation of 110 m a.s.l. and a volume of 4.7 million m^3. In this case, 39.6 hectares of land would be flooded, the maximum depth at maximum capacity would be 27 m, and the water would reach up to 1.9 km upstream of the barrier. The reservoir in question could be used for two purposes. Because of the agricultural activities in the Dragonja valley and the fact that its climate is optimal for cultivating different crops, part of the reservoir area could be used for retaining water to be used for the irrigation of lower-lying agricultural land.

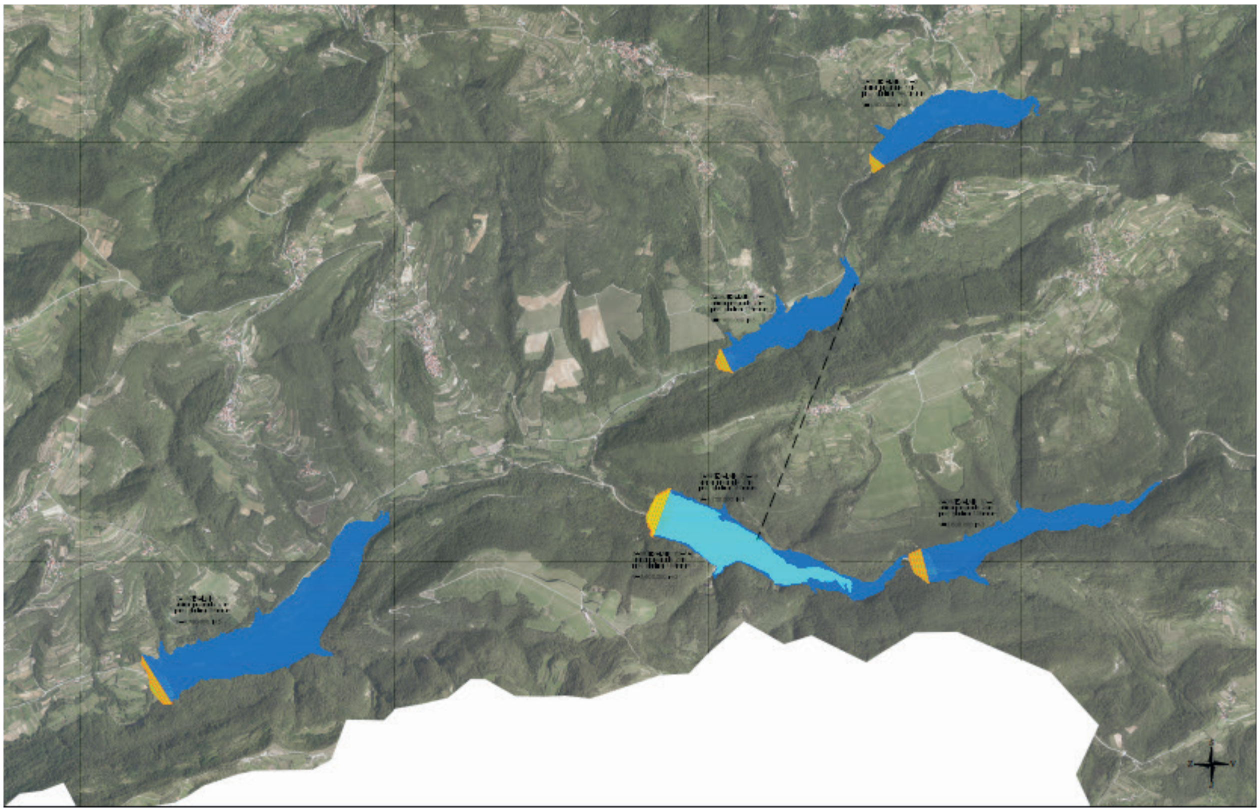
Another option, which is less likely to be implemented and economically less feasible, is that the ZD-1B reservoir would retain also the high water from the Pinjevec brook, which would flow into the reservoir through a two-kilometre tunnel with a diameter of approximately 4 metres. The construction of a reservoir on the Dragonja would have a relatively small effect on conditions in the lower part of the Dragonja valley (downstream of the Dragonja border crossing) relative to the share of the drainage basin (approx. 1/3), which is why high water of the Pinjevec brook (F=20 km^2) would also need to be retained. The confluence of the Pinjevec brook and Dragonja represents over 55% (F=52 km^2) of the entire surface of the river basin (F=93 km^2).

A connecting tunnel of a smaller diameter could also be constructed in case of the ZD-1B reservoir for the purpose of irrigation. Through it, excess water from the Pinjevec brook basin would be diverted for accumulation, and it would also have a positive effect during high water events. In this case, the Pinjevec brook flood reservoir could be much smaller.

Another possible location for the construction of a reservoir (code ZD-2) in the Dragonja valley would be at a slightly higher location, south of the Labor settlement (downstream from a tributary by the name of Martinjski kanal). A reservoir constructed at the elevation of 136 m a.s.l. would flood 27 hectares of land and could retain up to 2.6 m m^3 of water, while its area of influence would stretch 1.8 km upstream. The expected depth at the deepest section would be over 24 m. There is no infrastructure or buildings present other than a power line that runs over the central reservoir area.

The accumulation of high water on the Pinjevec brook would be possible at two locations. The first (code ZP-1) possible location of the barrier is found south from the top of the Jeplenca hill and a village named Župančiči. A reservoir constructed at the elevation of 114 m a.s.l. could retain 1.4 million m^3 of water. It would flood 20 hectares of land, its maximum depth would be 19 metres and its area of influence would stretch to 1.2 km upstream from the barrier. There are two buildings found in the area of the reservoir influence, but neither has a house number. A short section (45 m and 100 m) of the Babiči–Župančiči road would be flooded, while the local Župančiči–Dragonja valley road would be flooded in its entirety. Due to the construction of the barrier embankment, the local road would need to be relocated within the broader area of the barrier. It would not be essential for the other sections of the road to be usable during flooding, since the affected areas can be accessed via other roads.

The second potential location for the reservoir embankment built on the Pinjevec brook (code ZP-2) is found at the throat downstream from the Barcovač brook confluence (south of the Rojci settlement). If the water level was activated at the elevation of 144.5 m a.s.l., the reservoir could hold 1.4 million m^3 of water. 25 hectares of surface would be flooded and the flooding would stretch 1.3 km into the catchment area upstream from the barrier. The area of the reservoir influence features a power line and a building without a house number. A 600-metre section of the Babiči–Župančiči road and a 220-metre section of the Babiči–Boršt road would be flooded. Overflowing on these roads would not be critical, as access to all nearby settlements would be possible via other roads. Regardless of the fact that the flooding of the roads would be conditionally acceptable, part of the road in the area of the barrier embankment of would need to be relocated to the crown level and connected to the existing road both upstream and downstream with a suitable slope grade.



Possible locations of reservoirs

Most of the aforementioned retention options include the construction of a reservoir in the basins of the Pinjevec brook and Dragonja. The construction of two reservoirs could be avoided by constructing a connecting tunnel between the valleys of the Pinjevec brook and the Dragonja river or by constructing a reservoir below their confluence. The area below the confluence features less agricultural lands, whereby agriculture is also less intensive and a significant part of the plain is covered by wild trees and bushes. For this reason, the part of the valley below Puče and Skorušica on the Croatian side of the border was identified as the last possible area for the construction of the reservoir. Due to the presence of agricultural land, the reservoir (code ZDS) is planned as a dry flood reservoir. At the project water level of 58 m a.s.l. and the maximum depth of 19 m, 61 hectares of land are flooded, the flood reaches 2.1 km upstream of the barrier and the retained volume is 4.7 million m^3. There are five buildings within the area of influence, of which two have house numbers (Puče 95 and Krkavče 120). A local road, which would also be flooded, would need to be relocated to higher ground due to the construction of the reservoir embankment.

3.2.1.3 A set of possible technical solutions

A summary of the possible reservoir solutions and their basic characteristics is presented in the table below

	reservoir name	proj. level	avg. max. H of embankment	max. water depth	max. flood surface	max. V	notes
		[a.s.l.]	[m]	[m]	[ha]	[in million m^3]	
1	ZD-1A	103	20	20	29.4	2.6	buildings and infrastructure not affected
2	ZD-1B	110	27	27	39.6	4.7	dual purpose; the option of connecting the Pinjevec brook waters
3	ZD-2	136	24	24	27	2.6	a power line in the area of influence
4	ZP-1	114	21	19	20	1.4	two buildings affected, relocation of a local road
5	ZP-2	144.5	18	17	25	1.4	a power line in the area of influence, one building affected, relocation of a local road
6	ZDS	58	21	19	61	4.7	five buildings affected, relocation of a local road

Depending on the need for retention on the Dragonja and Pinjevec brook, the following combinations of reservoirs can be defined:

	combination	joint volume [M m^3]:	notes
1	ZD-1A + ZP-1	4	
2	ZD-1B	4.7	an underground water tunnel from the Pinjevec brook
3	ZD-1B + ZP-1 *	5.0-5.5	multi-purpose reservoir; inflow from a small tunnel, a smaller reservoir on the Pinjevec brook would still be needed
4	ZD-1A + ZP-2	4	
5	ZD-2 + ZP-1	4	
6	ZD-2 + ZP-2	4	
7	ZDS	4.7	

As part of the search for alternative solutions, the existing documentation was reviewed, especially the Water Management Basis for the Dragonja River Basin and Drnica Brook (Water Management Institute of Ljubljana, 2000), in which no comprehensive measures were included to reduce the flood risk of the area.

3.2.1.4 <u>Environmental restrictions in space</u>

In the previous chapters, the technical aspects of a possible construction of dry and dual-purpose flood reservoirs was presented. Regardless of the spatial possibilities available in the Dragonja valley, it is also necessary to recognise and consider the key and unavoidable fact that the valley is an important natural asset and has several local and global protection regimes in place.

In those areas or in their immediate vicinity, where the reservoirs in question would be constructed (the barrier and the area of influence of the reservoir), the following natural assets (with accompanying restrictions) are located:

a) Natural asset (feature): **Vruja Waterfall**,

b) Natural asset (caves): **Buža pod Hrpeljci**, a cave with a vertical shaft and several levels, a sloping cave

c) **Natura 2000 (Slovenian Istria)**: the Dragonja valley above the Dragonja border crossing is designated as a Natura 2000 site. All possible reservoir locations are found within the Natura 2000 sites, which are in this case limited exclusively to the territory of the Republic of Slovenia. The ZP-1 and ZDS reservoirs are located entirely within the Natura 2000 sites. With ZD-1, only a part of the reservoir on the Croatian side of the border is located outside of the Natura 2000 area. With ZD-2, a part of the barrier and a small part of the reservoir on the Croatian side of the border would be located outside of the Natura 2000 area. With ZP-2, only the barrier and a small part of the reservoir would be placed within the Natura 2000 area.

d) Natural asset: **the Dragonja**. Due to its rare animal and plant species, exceptional geomorphological forms, fossils and other special features, the Dragonja channel is, along with its tributaries, designated as a natural asset practically from its source to the estuary. All proposed reservoirs are located within the area of the natural asset.

e) Natural asset: **the Dragonja – waterfall and rocks at Škrline**.

f) Natural asset: **Dragonja – the dry meadow at Fermov mlin** (grassland along the Dragonja, with typical flora).

g) Natural asset: **Fermov mlin – flysch walls above the Dragonja**.

h) Natural asset: **Pasjok**, a stream with waterfalls – left tributary of the Dragonja, downstream from Topolovec.

i) Natural asset: **Vruja**, a stream with waterfalls – left tributary of the Dragonja, downstream from Topolovec. The tributary flows into the Dragonja in the area of the reservoir, but the waters from the reservoir do not flow into the valley.

j) Ecologically important areas: **the Dragonja river basin** (applies to the area within the Republic of Slovenia). All proposed reservoirs are located within the subject area.

k) Forest reserve: **Krkavška komunela**. The forest reserve is located on the left bank of the Dragonja near the settlement of Krkavče.

In view of (mostly) natural assets found in the Dragonja valley and of the fact that some variants of the reservoirs would be located in the protected areas, it can be concluded that the construction of reservoirs would significantly affect the protected areas. The highest number of natural assets is included in the ZD-1 reservoir area.

The least problematic option would be the construction of a dry reservoir (ZDS), which would still be located in a protected area, but the channel of the Dragonja is a little less unspoiled in its area of influence than in the upper stream.

The Dragonja river and its tributaries are classified as the primary protected area (the strictest protection regime) and so is the meadow along Fermov mlin. Given the actual importance of the Dragonja valley and its tributaries as a natural asset and the restrictions arising from environmental regulations, the construction of reservoirs to improve flood safety of the broader area would be practically impossible.

An important goal which is the aim of the Landscape Park establishment is to promote environmentally friendly agriculture. Intensive agriculture in the Dragonja valley has a significant impact on the water quality – due to the excessive use of fertilizers and other chemical substances, the quality of water in the Dragonja channel is getting worse. The construction of reservoirs and the reduction of flood risk would only intensify agriculture in the Dragonja valley, which would bring more harmful substances. Improving the situation in one area can thus have negative effects on another area.

Within the FRISCO project, we obtained the opinion of IRSNC (Institute of the Republic of Slovenia for Nature Conservation) regarding the possible retention of high water of the Dragonja in the areas identified in this study. Their opinion is important both for the FRISCO project as well as for the protection of other areas (e.g. Portorož airport and the Sečovlje salt pans), which are not a part of the FRISCO project, but would nonetheless need to be placed under flood protection, which is something that will be planned in separate projects.

Other measures for significantly improving flood protection in the Dragonja valley (within the FRISCO project area) are either impossible to implement or unacceptable.

Position of IRSNC regarding the proposed reservoirs

The construction of reservoirs would significantly affect the above-mentioned qualities of the space and the torrential character of the watercourse, which has a great effect on the geomorphological, zoological and botanical characteristics of the river basin. Due to permanent changes to the hydrological characteristics of the watercourse and the conditions for the growth of vegetation and due to the destruction of habitats and similar issues, all retention basin options are completely unacceptable (if constructed, the ZD-1A and ZD-1B would completely destroy two natural assets). Such impact would probably be significantly smaller with the proposed dry reservoir (ZDS). However, its visual impact on the natural asset would be that much greater.

3.2.1.5 <u>Selection of possible reservoir construction options</u>

The reservoirs would not significantly affect the torrential character of the watercourse, since the passage of water through the outflow/barrier structure would remain unregulated up to a certain limit value, which is why the behaviour of the basin during precipitation events (short-period intense precipitation) would also remain practically unchanged. The reservoirs would only affect flows during which water would overflow from the channel onto the inundation surfaces/agricultural surfaces, where any influence of water on the morphology of the area is undesirable.

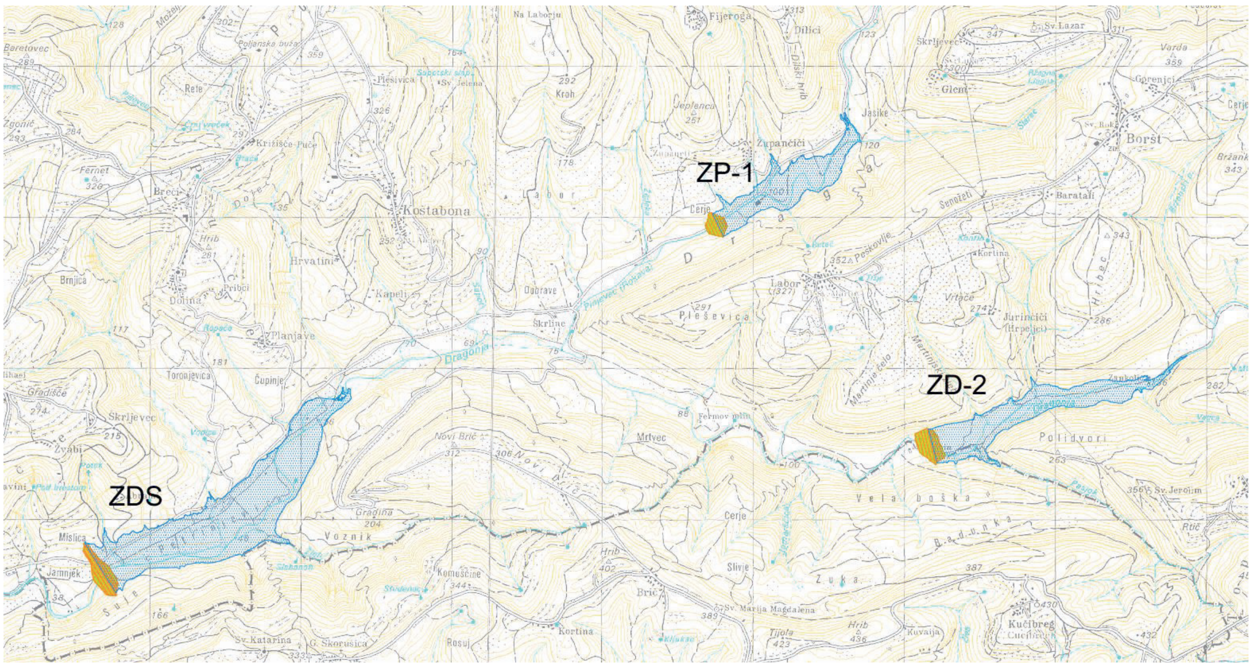
The inflow of all the Dragonja tributaries downstream of the reservoir would also remain unchanged, which would contribute to the preservation of the torrential character of the Dragonja.

The operation of the reservoir in realistic conditions would primarily be based on a series of input data (the measurement sites of the water level at individual critical points above and below the reservoir, precipitation stations in the Dragonja basin and elsewhere, and forecasts of weather models). In addition to the hydraulic parameters, the operation of reservoirs could be (in agreement with the land owners and in the spirit of preserving hydrological/hydraulic characteristics of the Dragonja river basin) adjusted to the growing season and the use of inundated surfaces (the sensitivity of plants to floods). Under certain conditions, controlled flooding of selected surfaces next to the stream could also be carried out.

According to the IRSNC's opinion and other facts related to the characteristics of the proposed reservoirs and their location, two variants were selected as the most feasible:

a) the construction of **ZDS, a common reservoir**

b) the construction **of the ZD-2 reservoir** on the Dragonja and **the ZP-1 reservoir** on the Pinjevec brook



Locations of optimum viable variants of the reservoirs

3.2.2 ANALYSIS OF ALTERNATIVE SOLUTIONS

3.2.2.1 Comparison of solutions from a technical point of view

The advantages of the ZDS reservoir:

1) The common ZDS reservoir would be located farthest downstream in the Dragonja basin, which is why this would be the most efficient way to regulate the flood water flow to the lower parts of

the basin. From a hydraulic point of view (the size of the catchment area, the amount of inflowing water), the ZDS reservoir would be the most adequate of all possible reservoir construction option.

2) The ZDS reservoir would be located in the area of two general (wide-reaching) natural assets of Natura 2000 and the Dragonja, an ecologically important area, i.e. the Dragonja river basin, and, because of a part of the left reservoir embankment, within the Krkavška komunela forest reserve. The interventions within the forest reserve are planned on a smaller scale (~ 6,000 m^2 of the total ~ 500,000 m^2 area of the reserve). The lost forested surfaces could be replaced by implementing **green measures** – the free side of the embankment that does not face the water would be constructed with an additional (technically undemanding) layer of soil in adequate thickness (so that the root systems would not penetrate the actual base of the embankment) that would enable the planting and growth of tree species found in the forest reserve. In addition to replacing forests, it would be possible to at least partially replace the lost agricultural land by planting vineyards on the banks of the embankment and concurrently improve the look of the valley.

3) One reservoir downstream the confluence of two watercourses would be simpler to manage than one reservoir for each watercourse.

4) Quantitatively speaking, the construction of a single reservoir would represent a smaller intervention into the environment, since a single reservoir would only affect one location.

If the construction of a single reservoir proves infeasible, it makes sense to have a solution with two reservoirs in place – one for the Dragonja valley and one for the Pinjevec brook valley.

The decision for the combination **of the ZD-2** reservoir on the Dragonja and the **ZP-1** reservoir on the Pinjevec brook is based on the following:

1) The ZD-1 reservoir would be placed very close to the confluence with the Pinjevec brook, which would allow to regulate a larger part of the basin than the ZD-2 reservoir. Regardless of the fact that the position would be better from a hydraulic point of view, there are two natural assets (the Dragonja – dry meadow next to Fermov mlin, as well as Fermov mlin – flysch walls over the Dragonja) found in the area of influence of the reservoir (in addition to the Natura 2000 and Dragonja natural assets and the ecologically important area of the Dragonja river basin). The IRSNC's opinion is that the construction of a reservoir at this location would be unacceptable, which is why the only feasible option for the construction of a reservoir in the Dragonja river valley upstream of the Pinjevec brook would be the ZD-2 reservoir due to its adequate location.

2) In addition to the Natura 2000 and Dragonja natural assets and the ecologically important area of the Dragonja river basin, the area of ZD-2 influence also covers two other natural assets: the Buža pod

Hrpeljci cave and Pasjok brook – a stream with waterfalls and a left tributary of the Dragonja downstream from Topolovec. The surface of the ZD-2 reservoir also reaches the Pasjok brook valley, but not the waterfalls. Buža pod Hrpeljci, a cave with a vertical shaft and various levels, is located near the planned accumulation of the ZD-2 reservoir. The maximum projected surface level of the reservoir is 8 m lower than the mouth of the cave. The potential impact of the accumulation on the water regime in the cave is impossible to predict at this stage of the project.

3) The ZD-2 reservoir is technically less suitable than the ZD-1 variant due to the overhead power line that traverses the reservoir and due to the extent of the infrastructure needed to provide access to and the operation of the ZD-2 reservoir, but due to ZD-1 being environmentally unsuitable, ZD-2 remains the only option for a reservoir in the Dragonja valley upstream of the Pinjevec brook.

4) Given that the selected option for the Dragonja river includes a reservoir which is located quite high up in the basin and covers a smaller area than reasonably acceptable, it would be technically prudent to construct a reservoir on the lowest parts of the Pinjevec brook, since then the reservoir could retain water from as large of an area as possible. This reservoir is the ZP-1.

5) The construction of ZP-2 would have a greater impact on roads than ZP-1 and its area of influence would also be greater (25 hectares for ZP-2 and 20 hectares for ZP-1).

3.2.2.2 Comparing the solutions from a cost perspective

The basis for estimating the cost of the construction of the reservoir was the data from the construction of the barrier in Železniki (IDZ), which is comparable to the proposed reservoirs on the Dragonja, both height- and grade-wise. The Železniki barrier would be 20 m high, it would have a crown of 80 m in length and a capacity to retain 1 million m^3 of water. The cost of building such a reservoir would amount to EUR 3.9 million (excluding VAT), with the construction of the barrier (without HM equipment and electrical installations) representing 64% (EUR 2.5 million) of the total investment.

The calculation of the Dragonja reservoirs construction costs was made by using two methods. The first took a simplified approach that takes into account only the retention volume of the reservoir in determining the price. In this case, the estimation for m^3 of retained water was based on the data for the reservoir in Železniki. The price was calculated at 3.86 EUR/m^3.

In addition to the cost of the basic elements of the reservoirs, the construction cost included the relevant costs of the relocation/construction of roads and the cost of buying off two residential buildings. The construction of the ZDS reservoir entails the relocation of a 400-metre stretch of a local gravel road (the estimated price is 600 EUR/m'), while the ZP-1 entails the relocation of a 550-metre stretch of a local road (the estimated price is 600 EUR/m') and ZD-2 entails the construction of a 2.5 km long access road leading to the reservoir. Since the road uses some of the existing (narrow) cart tracks, the road construction costs were estimated at 400 EUR/m'. The prices are exclusive of VAT.

The second approach deals also with the geometric characteristics of the barrier – the most important feature is the length of the barrier. The cost of the barrier in Železniki is broken down into hydromechanical and electrical equipment and the construction of the barrier embankment. The cost of the Železniki barrier embankment was linearly increased in accordance with the length of the barrier of the Dragonja reservoirs. The cost of hydromechanical equipment was assumed to be somewhat higher than in Železniki, i.e. EUR 1.5 million for the ZDS reservoir (larger catchment area and higher flows than in Železniki), the ZD-2 reservoir was assumed to have the same cost (comparable flows of the Sora river and the Dragonja), while the cost for ZP-1 was assumed to be somewhat lower (EUR 1.1 million), because the flow of the Pinjevec brook is not as high as the flow of the Sora river in Železniki.

In addition to the cost of the basic elements in reservoirs, the cost of the construction included the relevant costs of relocation/construction of roads and the cost of buying two residential buildings. The construction of the ZDS reservoir entails the relocation of a 400-metre stretch of a local gravel road (the estimated price is 600 EUR/m'), while the ZP-1 entails the relocation of a 550-metre stretch of a local road (the estimated price is 600 EUR/m') and ZD-2 entails the construction of a 2.5 km long access road leading to the reservoir. Since the road uses some of the existing (narrow) cart tracks, the road construction costs were estimated at 400 EUR/m'. The prices are exclusive of VAT.

barrier	H [m]	V [in mil. m^3]	L of the crown [m]	cost of the barrier – breakdown: embankment	cost of the barrier – breakdown: HM and electrical equipment	cost of the barrier – breakdown: other – description	cost of the barrier – breakdown: other – cost [in million EUR]	cost of the barrier – breakdown: total [in million EUR]	cost of the barrier – by volume: EUR/m^3	cost of the barrier – by volume: in million EUR	**selected value [in million EUR]**
Železniki	20	1	80	2.54	1.32	/	/	3.86	3.86	3.9	
ZDS	21	4.7	400	12.70	1.5	relocation of a 400-m road stretch	0.24	14.94	3.86	18.1	**15**
						relocation of two residential buildings	0.5				
ZP-i	21	1.4	180	5.72	1.1	relocation of a 550-m road stretch	0.33	7.15	3.86	5.4	**7**
ZD-2	24	2.6	250	7.94	1.3	Construction of a 2.5-km access road	1	10.24	3.86	10.0	**10**

The annual cost of regular maintenance is estimated at 0.6% of the project investment, and the cost of maintenance with more significant investments would amount to 3% of the project investment costs every five years.

Nevertheless, at this stage of the analysis, the construction of reservoirs remains a justified investment, since this aspect (in accordance with the project assignment) does not include extensive agricultural land of the Ribila flats, Portorož airport, Sečovlje and the Sečovlje salt pans, which are areas that get flooded by the Dragonja and would contribute significantly to the joint damage potential and viability of the investment in an economical sense.

Based on a comparison of the hydraulic, environmental and technical characteristics of the proposed reservoir options, the common reservoir (ZDS)/a combination of two reservoirs (ZD-2 for the Dragonja, and ZP-1 for the Pinjevec brook) were chosen as the optimal solutions.

Since the construction of a reservoir is an extensive and expensive project, it would be unprofessional to design it for short return periods (Q10, Q25) and still retain the threat of flood events with longer return periods (Q50, Q100 etc.), which are usually the most problematic (the most intense flow, more depth, more damage). On the other hand, there are no elements or sets of elements with a significantly greater damage potential or other type of significance that would require flood risk protection during exceptional hydrological events. For this reason, the hydraulic calculations for the planned reservoirs will be made for Q50, Q100 and Q500 events.

The construction of larger reservoirs depends on their planned location. This is especially true of the variant with the two reservoirs, which are located quite high up the valley. The ZP-1 reservoir could retain inflowing water from a surface of 17 km^2, while the ZD-2 reservoir could retain water from a surface of 27 km^2, which adds up to 44 km^2 or 45% of the entire Dragonja basin (97 km^2). The ZDS reservoir would be able to retain 65 km^2 or 2/3 of the entire basin. The location of the reservoir high up in the valley can mean that in some cases (e.g. during an intense precipitation event in the middle parts of the basin), only the part of the river that is not within the reservoir influence area (e.g. the middle part) would get stronger flows. In order to reduce the impact of inflows on the water regime in sensitive areas, the inflow to the downstream section (i.e. outflow from the reservoir) would need to be reduced to a minimum, which would require additional reserves when designing the reservoir volume.

3.2.2.3 Comparison of solutions in terms of hydraulics

The planned state, meaning the state after the construction of the reservoirs, was evaluated in stages. The planned state analysis is made using the hydraulic model developed under the FRISCO 1 project (carried out by the Institute for Hydraulic Research).

The first phase entailed the analysis of the common ZSD reservoir. The first steps of the analysis were focused on determining the permitted outflow from the reservoir, where (with simultaneous inflow from the tributaries in accordance with the hydrological data) no critical flooding occurs and there is no significant damage or life-threatening situations.

The acceptable outflow from the reservoir was estimated at 50 m^3/s. At this outflow value, the Dragonja would flood minor parts of the grassland and agricultural surfaces near Mlake (south-east from the Dragonja border crossing), with a shallow depth and low speed of the stream (5–40 cm on average).

Minor overflowing on the immediate surface next to the Dragonja channel also occurs on the stretch from the planned barrier to the Pinjevec brook confluence, where bushes and trees are flooded. Because the outflow from the reservoir is planned at 50 m^3/s, no significant damage is to be expected on the flooded surfaces.

For 10-, 25-, 50- and 100-year return periods, a calculation was made with a constant outflow of 50 m^3/s. Depending on the volume of the flood wave detained in the reservoir when taking into account the outflow, we determined the basic characteristics of the reservoir (VQ100, H of the barrier, V of the barrier). Our target was a satisfactory performance during a 100-year event (ZSD-100).

The retention volume of ZSD-100 is 2.3 million m^3. Taking into account the 2 metres of safety height, the elevation of the barrier (embankment) is 56 metres above sea level, with the volume of the barrier embankment being 140,000 m^3.

For the Q500 flow, we took into account one additional possibility besides the basic modelling of the flood wave transition, i.e. the one including a reservoir with dimensions for a 100-year event: the option of retaining 500-year high water in the reservoir (ZSD-500). Taking into account these parameters, the characteristics of the reservoir are as follows: the volume of retention with a 50m^3/s outflow from the reservoir is 4.0 million m^3, the elevation of the barrier (taking into account the 2-metre safety height) is 59 m a.s.l., the volume of the embankment of the barrier is 220,000 m^3, which is 50% of the volume of the ZSD-100 barrier.

With the **ZSD-100** variant, the Q500 and Q1000 events would fill the reservoir before the entire flood wave gets there, which is why excess water would spill over the safety weir and onto lower (currently) inundation surfaces.

During a 500-year event, the waters overflow the grasslands, areas with bushes and trees and agricultural land (fields, vineyards) The water also floods a few buildings. Some flooded buildings are located near the Dragonja channel and some are next to the Valeta–Sečovlje road (north of the Sečovlje border crossing), which is also flooded. Overflowing also occurs on the Sečovlje–Dragonja road, from where the flood spreads to the north. The plateaus of the Dragonja and Sečovlje border crossings remain unflooded. To the south of the Dragonja border crossing, some overflowing occurs on a short section of the Koper–Dragonja road. (The Portorož airport area is partially flooded – the runway and part of the platform are flooded, while buildings remain unflooded.)

During a 1000-year event, the extent of flooding on the section between the reservoir embankment and the Dragonja border crossing does not increase significantly in comparison with 500-year events, but the depth of the water on the flooded surfaces does (approximately 0.4 metres). The extent of the flooding increases on the section between the Dragonja border crossing and Portorož airport. The Dragonja border crossing plateau is partially flooded. The Koper–Dragonja road is flooded south of the plateau, while the crossroads of the Sečovlje–Dragonja and Koper–Dragonja roads is also flooded, albeit on a smaller scale. There is also a large scale flooding on the Valeta–Sečovlje road (the same as in the case of Q500). Several other buildings in the villages of Sečovlje and Dragonja are also flooded. (The Portorož airport is not fully flooded – the runway and the tarmac are flooded, but the buildings remain unaffected, with the water only getting near them. The water does not flood the Sečovlje border crossing plateau.)

With the **ZSD-500** reservoir, **spilling over** the safety weir starts at Q1000 flows. In this case, the extent of the flood and the depth of the water can be compared to the 500-year event flood with the ZSD-100 reservoir.

The second phase consisted of an analysis of the construction of two reservoirs, one on the Dragonja (ZD-2) and one on the Pinjevec brook (ZP-1). In accordance with the location being high up in the basin, our starting point was a mode of operation in which reservoirs completely close down their outflow.

The possibilities of dimensioning reservoirs in accordance with the 100- (ZP-1-100, ZD-2-100) and 500-year (ZP-1-500, ZD-2-500) events were analysed. Short-period waves (up to 6 hours) and a long-period wave (24 hours) of a 100-year high water of the Dragonja were analysed. It was established that the volume of the long-period 100-year wave is larger than the volume of short-period waves, but that retaining just the short-period waves would cause water to spill over the barrier because of the long-period wave, and some small flooding would occur (the extent of the flooding downstream of the location of the ZSD reservoir is similar to the one in the ZSD-100). This is why the design of the reservoir is based on short-term waves. The characteristics of the ZD-2-100 reservoir are as follows: the retention volume is 1.5 million m^3, the altitude of the barrier (taking into account the 2 metres of safety height) is 134 m above sea level, and the volume of the barrier embankment is 203,000 m^3. The characteristics of the ZD-1-100 reservoir are as follows: the retention volume is 1.0 million m^3, the altitude of the barrier (taking into account the two metres of safety height) is 114 m above sea level, and the volume of the embankment of the barrier is 108,000 m^3. The characteristics of the ZD-2-500 reservoir are as follows: the retention volume is 2.1 million m^3, the altitude of the barrier (taking into account the 2 metres of safety height) is 137 m above sea level, and the volume of the barrier embankment is 208,000 m^3. The characteristics of the ZP-1-500 reservoir are as follows: the retention volume is 1.3 million m^3, the altitude of the barrier (taking into account the 2 metres of safety height) is 116 m above sea level, and the volume of the barrier embankment is 138,000 m^3.

Despite the complete closure of outlets, some overspilling occurs downstream due to the inflow of tributaries. In the event of the 25-year high water, the extent of the flooding downstream of the location of the ZSD reservoir embankment would be slightly larger than the flood of the Q100 event with the ZSD-100 reservoir. With the 100-year high water event, the extent of flooding would be even greater. Waters would overflow the grasslands, areas with bushes and trees, and agricultural land (fields, vineyards).

Some buildings would also be flooded. The Dragonja and Sečovlje border crossings are not at risk of flooding. The Valeta–Sečovlje and Koper–Dragonja roads are also not at risk of flooding, while the Sečovlje–Dragonja road (east of the Sečovlje border crossing) get partially flooded. (The Portorož airport is not at risk.)

The results of the hydraulic analysis showed that due to the location of the reservoirs high up the stream and consequential substantial inflows along the stream of the Dragonja under the reservoirs, significant flooding of agricultural land and, in some cases, inhabited areas still occurs despite the complete closing of the reservoirs, which is why other flood protection measures would need to be carried out along the Dragonja river. However, given the findings in the previous phases of the project and the environmental restrictions, they would be difficult (or practically impossible) to carry out.

3.2.3 SELECTION OF THE MOST SUITABLE SOLUTION

3.2.3.1 Choosing the appropriate measures

Based on the described results of hydraulic modelling and spatial constraints, we only analysed the ZSD-100 and ZSD-500 variants in the following chapters.

3.2.3.2 Investment costs of the arrangements & financial and economic viability

The investment is divided into the following groups: preparatory activities, land, construction works, equipment, project management, and unforeseen costs.

- **Preparatory activities** include the drafting of study, as well as the elaboration of the project and tender documentation. The cost of drafting the documentation for the study and the project documentation depends on the type (level of detail) of documentation (feasibility studies, design, project, obtaining a building permit) and can be evaluated based on prices from similar projects.
- **The land** includes the costs of resolving property relations and obtaining the necessary consents and building permits.
- **The construction costs** include the costs of construction and its supervision.
    - If there is no data about the cost of investment for the planned construction, the construction costs can be estimated according to the technical characteristics of the proposed investment and based on similar realised construction projects in the vicinity.
    - The costs of supervising the construction, which are tied directly to the estimated costs of construction in individual buildings/infrastructure, are estimated at 5% of the construction costs.
- **The equipment costs** include the supply, installation and commissioning of equipment.
- **The project management costs** are defined in accordance with the Law on Business and Activities for Spatial Planning and Construction (OG 78/2015). For all investment projects in the construction of infrastructure where the total investment value is more than HRK 10 million (approx. EUR 1.33 million), the investor is obliged to appoint a project manager or group. The

project management cost is estimated at 2.5% of the investment costs for the entire project (including costs of preparatory activities, land, construction and equipment).

- **Unforeseen costs** are often encountered during the construction phase and cannot be predicted at the planning stage. The costs are eligible, but are not included in the financial analysis in line with the recommendation of the European Commission. The unforeseen costs are estimated at up to 10% of the investment costs of the entire project (including costs of preparatory activities, land, construction, equipment and project management).

The total investment costs are estimated at EUR 27,415,465 with VAT included.

The benefits of reducing the flood risk are shown in the table below.

	Expected annual flood damage EUR/year		
Damage category	*Existing*	*ZDS-100 reservoir*	*ZDS-500 reservoir*
local roads	17,106.44	8,835.01	8,742.92
state roads	12,314.23	2,169.73	1,847.77
agriculture	4,706.17	929.49	770.99
buildings (buildings and fixtures) – residential	5,381.17	100.57	75.17
buildings (buildings and fixtures) – commercial	4,753.70	0.00	0.00
buildings (buildings and fixtures) – undefined	6,953.05	132.26	92.03
buildings (buildings and fixtures) – agricultural	7,815.07	38.46	18.27
Total of all damages defined by category:	**59,029.83**	**12,205.50**	**11,547.15**
Other damages – undefined damages (Huizinga – 20% of all damage)	14,757.46	3,051.38	2,886.79
All damages – the basis for a cost-benefit analysis:	73,787.29	15,256.88	14,433.94

Comparison of expected flood damages for the area included in the FRISCO Dragonja project – the existing situation and situation of expected flood damages after the implementation of the measures

For the sake of comparison, the table includes the value of the existing expected yearly flood damages in the amount of EUR 73,787.29, which is a result of a survey over the model database and confirms the suitability and directness of the modelling used.

The results of the modelling of flood damage after the implementation of the measurements for reducing flood damage show that the damages decrease about EUR 60,000 per year (EUR 58,530.41 for the ZDS-100 reservoir and EUR 59,353.35 per year for ZDS-500). The constant prices method damages from December 2017 were taken into account, because the reference GDP value that we used for the calibration of the Huizinga method was also from 2017.

Among the various categories of flood damages we can recognise a marked reduction in flood damages to buildings of all categories and to agriculture. This is expected, since virtually all buildings are safe from flooding after the implemented measures. The category for which the minimum reduction in flood damage is observed are local roads.

The average annual benefit of flood damage reduction arising from the lower damage occurrence at flood events was calculated for the project. With a reservoir, average annual damage to roads, agriculture and buildings would decrease EUR 58,530.41.

The present economic net value of the investment is negative and amounts to EUR 23,042,032. The financial rate of return of the investment is also negative, amounting to 27.77%.

The present financial net value of the investment is negative and amounts to EUR 25,877,402. The financial rate of return of the investment is also negative, amounting to 24.36%.

3.2.3.3 Multicriterial analysis

The variant that both countries consider to be the most suitable in terms of consequences of a 100-year event will be selected as the best variant for implementation. If there are many suitable solutions, the one with the best B/C ratio in the country which covers more than 50% of the investment will be selected as the most suitable one.

Considering that both variants of the reservoir have the same impact on high water with a 100-year return period, they also both have the same evaluation and are both placed in Category 4 – Suitable.

3.2.3.4 Improving the water flow of the Dragonja channel

Since the flooding of the Dragonja often causes damage to agricultural land, it would still be possible to reduce the frequency and intensity of frequent (yearly and 1 to 10-year) floods with the regular maintenance of the river channel. Today, the Dragonja river channel is quite overgrown and uncultivated on the section downstream from the Pinjevec brook confluence (the Rokava brook, where agricultural land is present on the riparian plains). The riparian vegetation is a natural phenomenon and one of the key elements of the natural characteristics of a watercourse defined as a natural asset. Nevertheless, inspections of some parts of the river channel in the main riverbed uncovered multiple fallen trees that can negatively influence the flow capacity of the channel. Fallen trees are obviously a natural phenomenon which adds further authenticity to the natural environment in its role as a natural asset. Nonetheless, it would probably be sensible to carry out some selective maintenance work and optimise the flow of the river channel by removing fallen trees and by partially and locally removing some riparian vegetation on those sections of the river that are more prone to flooding and interfering with agricultural land. Due to the sensitivity of biotopes and due to environmental restrictions, the maintenance regime for individual parts of the river would need to be discussed and coordinated with IRSNC.

The results of hydraulic analysis and the related calculations in the channel flow in different parts would be the basis for identifying areas that are prone to flooding and serve as agricultural land. The FRISCO project involved measurements of the cross-sections of the Dragonja that were 300–500 (and more) metres apart, which are only suitable for very rough modelling and not for precise estimations of the water regime for individual (a few 100 metres long) sections.

Data for the most problematic areas could be obtained through a more precise hydraulic model (which was not produced within the scope of the project) and/or by regularly recording of the most frequent high-water events and identifying the most problematic areas (a long-term process). In the light of the above-mentioned facts, it is therefore not possible to define with greater precision those areas that would benefit from improvements to the flow of the river channel to at least partly reduce the flood risk for areas with intensive agricultural activity as part of the FRISCO project.

Possible arrangements for performing maintenance work are as follows:

- In areas where the cross-section is substantially larger than in the upstream or downstream sections, the river channel can be kept in its natural state, i.e. with fallen trees. Even if the flow of the riverbed was weaker due to vegetation, spillover would be expected on the upstream and/or downstream section of the river channel. The section featuring fallen trees is therefore not the most critical part, which is why no interventions are needed.
- In sections where the cross-section of the riverbed is more or less even, it would make sense to maintain an even flow by removing elements that can affect it significantly (fallen trees, accumulated debris).

- On those sections of the river where flooding poses significant problems during yearly floods, measures for improving the flow of the river channel would need to be considered. Some of the possible (cyclical) measures:

  a) Selective removal of vegetation – thinning of bushes and trees within the cross-section area. These activities can be carried out on one or both banks.

  b) Sectional removal of bushes and trees to allow grass growth only – implemented on one bank only.

  c) Sectional removal of bushes and trees with a partial re-landscaping of the banks. Suitable only for the most critical sections, banks will be re-landscaped in a sustainable way – with formations that are inherently present in the area (e.g. a steep indentation due to erosion).

Any interventions should be carried out with minimal physical interference in the natural environment and be evaluated in advance within the framework of a project and coordinated with IRSNC. When choosing suitable solutions for specific micro-locations, it would be necessary to take into account the requirement to restore bushes within 2 to 4 years and trees within 8 to 10 years (saplings). The stability of the banks (where necessary) is achieved by keeping trees and bushes in place – together with their root systems. If a section is hydraulically problematic from the point of flooding, only flexible bushes should be kept.

Special treatment can be applied for the regulated section of the Dragonja river channel extending downstream of the Dragonja border crossing. On this section, the Dragonja river channel has a relatively large water flow cross-section (between 50 and 60 m^2). High water of the Dragonja does not pose significant problems on this section, since the excess water spills over the banks upstream from the Dragonja border crossing and flows across the right-bank plain towards Drnica and the Sečovlje salt pans. Most of this water does not return to the Dragonja river channel.

The regulated Dragonja river channel is mostly home to reeds, while trees and bushes grow locally, on the upper parts of embankments and banks of the river. Reeds are generally not a major obstacle for intense flood flow since they can bend and break easily, but they can significantly affect the water level during less intense events. Given the proximity of two hydrometric stations, it would make sense for the Dragonja river channel to be cleaned (removal of reeds, only grass allowed to grow) on the section from at least 20 m upstream from the hydrometric station to the first downstream drop in the amount of at least 2/3 of the water flow cross-section (from bottom to top). This would ensure the consistency of external conditions which influence the measurements of the Dragonja water level at the hydrometric station for the majority of high water events.

Although the removal of reeds on the other sections of the regulated river channel is not of key importance, it is still important for keeping embankments and banks accessible for inspections. Maintenance work can be carried out periodically in these areas, e.g. partial or complete removal of vegetation on the right bank within the first year and then the same procedure can be implemented on the other bank after a year or two.

3.3 CONCLUSION

The Dragonja valley is at risk of flooding. The floodplains are mostly cultivated for agriculture, while the settlements are located at the edge of the valley and are largely found outside the Dragonja flood zone. In order to examine this problem, the Dragonja river basin was analysed as part of a comprehensive study for the Dragonja river basin.

The study area comprises the Dragonja river between its source and the Sečovlje International border crossing. The study and hydraulic modelling area does not comprise the airport and the salt pans, which is why only solutions aimed at reducing the flooding of agricultural land and the possible implementation of local measures for the protection of individual facilities were considered.

Based on the collected data and documentation, as well as hydrological and hydraulic analyses, the study identified the present flooding of the area under consideration. The most extensive floods in the area were recorded in 2010. Regardless of the large volume of expected floods in the Dragonja valley, the possibility of damage is small, since the Dragonja valley is very sparsely populated.

The Dragonja valley represents an important natural asset, since practically the entire channel section above the Dragonja settlement represents wild nature and the surrounding plains are either used as agricultural land or are covered in forest and shrubs in the upper part. Any structural regulation of the river channel and the channelling of water into the primary riverbed would be unacceptable from an environmental point of view and inconsistent with water directives that attempt to conserve the natural overflow areas and keep as much water in the basin as possible.

Furthermore, a construction of embankments along the river channel would represent a huge intervention into the environment, as they would be positioned at a certain distance from the main riverbed, which means that the secondary riverbed between the embankments would need to be significantly larger and that would significantly reduce the proportion of the nearby agricultural land. The construction of the embankments would also degrade the natural environment between the Dragonja settlement and the Pinjevec brook confluence.

Throughout the study, it became apparent that the construction of reservoirs can be the only way to solve the problem. Several technical solutions and locations were analysed and examined from the point of environmental restrictions.

The search for possibilities of flood risk reduction in the Dragonja valley was carried out in phases. When we examined the possibilities for retention, the first phase was focused only on the technical aspects –

the available locations according to the current use and morphology of the area. The proximity of the areas protected by the measure is also important in determining the locations of reservoirs. In principle, the measures carried out at remote locations have less impact than those carried out closer to the threatened areas. Hydrologically speaking, the closer the location of the implemented measure, a larger portion of the drainage basin it covers, so it has greater influence on the water regime of the protected area.

There were several different proposals given for retaining the high waters of the Dragonja in the hinterland. Based on the hydrological, morphological and topographic characteristics, the areas where retention would be possible were defined in the first (technical) phase.

In the second phase, the individual areas were also evaluated with regard to restrictions of individual protected natural areas. We found that all proposed locations of the reservoirs are located in at least three protected areas (Natura 2000, the Dragonja natural asset, Ecologically important areas: the Dragonja river basin), which is why the possibilities for the construction of reservoirs in the Dragonja valley are quite limited or perhaps virtually non-existent.

From a technical point of view, the proposed options were quite similar to one another, but considering the environmental and technical constraints related to the construction as well as its expected costs and benefits, the options chosen for further analysis as the most suitable ones were a combination of reservoirs ZD-1A and ZP-1 and the construction of the ZDS reservoir.

The results of the hydraulic analysis of the optimally feasible proposed options showed that significant floods would still occur due to the location of the reservoirs high in the hinterland and considerable inflows into the Dragonja that would consequently be located downstream from the reservoirs, which would mean that some other flood protection measures along the Dragonja would need to be implemented. However, due to environmental restrictions, they would be difficult or impossible to carry out.

Based on the results of hydraulic modelling and spatial constraints, a cost-benefit analysis was carried out for a dry reservoir (code ZDS) in two variants, i.e. ZDS-100 and ZDS-500 (for the retention of a 100-year and a 500-year flood wave). The investment value of the measures and their effectiveness in flood protection (reduction of flood damage) were evaluated and economic, financial and multicriterial analyses were carried out.

Given the protection regimes, the relatively high investment value of the proposed solutions and low damage potential (the area in question is almost exclusively agricultural), a cost-benefit analysis showed that none of the proposed solutions would yield the desired benefits.

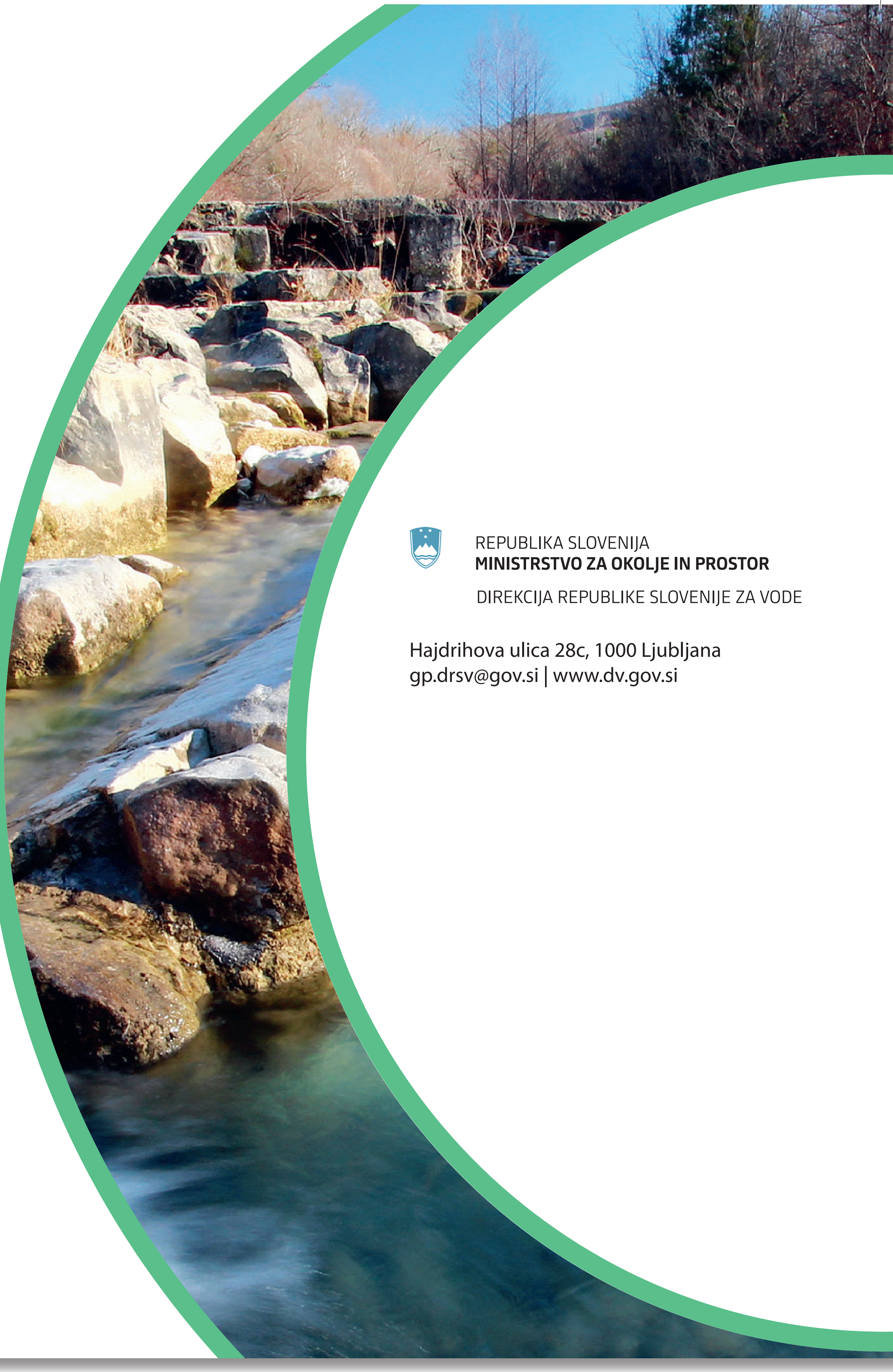
For this reason, the study paid special attention to the design and implementation of maintenance works, which can reduce the frequency and, to a lesser extent, the severity of floods in critical spots within the area in question.

Since the flooding of the Dragonja often causes damage to agricultural land, it would still be possible to reduce the frequency and intensity of frequent (yearly and 1 to 10-year) floods with the regular maintenance of the river channel. Today, the Dragonja river channel is quite overgrown and uncultivated on the section downstream from the Pinjevec brook confluence (the Rokava brook, where agricultural land is present on the riparian plains). The riparian vegetation is a natural phenomenon and one of the key elements of the natural characteristics of a watercourse defined as a natural asset. Nevertheless, inspections of some parts of the river channel in the main riverbed uncovered multiple fallen trees that can negatively influence the flow capacity of the channel.

Fallen trees are obviously a natural phenomenon which adds further authenticity to the natural environment in its role as a natural asset. Nonetheless, it would probably be sensible to carry out some selective maintenance work and optimise the flow of the river channel by removing fallen trees and by partially and locally removing some riparian vegetation on those sections of the river that are more prone to flooding and interfering with agricultural land.

The regulated Dragonja river channel is mostly home to reeds, while trees and bushes grow locally, on the upper parts of embankments and banks of the river. Reeds are generally not a major obstacle for intense flood flow since they can bend and break easily, but they can significantly affect the water level during less intense events. Although the removal of reeds on the other sections of the regulated river channel is not of key importance, it is still important for keeping embankments and banks accessible for inspections.

In accordance with the application form and the objectives of the FRISCO1 project, the implementation of construction measures on the Dragonja during the current implementation period of the European Directive (2016–2021) is not planned. Nevertheless, it is possible to mitigate flood risk in the area under consideration, primarily through a more intensive maintenance of the river channel. The frequency and, to a lesser extent, the intensity of flooding can be reduced in the critical areas by well designed and consistent maintenance. Any interventions should be carried out with minimal physical interference in the natural environment and be evaluated in advance within the framework of a project.



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