Lower Danube River Corridor -

FLOODPLAIN RESTORATION OPPORTUNITY ANALYSIS

2017

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1. Introduction

1.1. Background

Floodplain restoration has emerged as an important tool for counteracting flood risk and restoring lost ecological services resulting from urban and agricultural development mainly through embankment and land reclamation. Despite the serious impacts of human interventions, especially regulations of the river ecosystem, the lower part of the Danube River has high restoration and conservation potential with large free-flowing sections, floodplains, islands, side-arms, oxbows and the inner delta. These natural conditions not only ensure higher ecological results, but the planned restorations and conservation works are more beneficial for local communities as well.

Ten years has passed since the last devastating flood events along the Danube River and major tributaries but the political debate in Romania made little progress towards a more sustainable flood risk management and no floodplain restoration projects are identified, proposed or started to be implemented along the Danube by the water management national authorities, beside those succeeded in the Danube Delta. Although several significant studies were made to identify the restoration potential and storage capacity for flood mitigation and potential sustainable use of lower Danube floodplains, e.g. REELD by MoE, WWF's study on Danube restoration potential, little efforts was invested to assess and prioritize wetlands that can meet multiple restoration objectives to contribute to the thematic policies having an impact or being impacted by the flood risk management.

Sustainable floodplain management cannot be based on Floods and Water Framework Directives only, but more important are the content links with wider water legislation and nature legislation. The Floods Directive is related to nature legislation (Birds and Habitat Directives) only by the requirement to include protected areas in the flood risk maps and by a specific mention of the need to take into account nature conservation in the FRMPs. However, the specific needs for the nature conservation, being species or habitat ecological needs, natural processes and/or dynamics of the floodplains are far from being reflected by the current approaches to flood risk management. The Floods Directive also recognizes the opportunities created by giving rivers more space through the maintenance or restoration of floodplains in flood risk management plans. However, to come to a mutual understanding and synergies between water and nature policies, the objectives and working methods of the Floods Directive should be taken into account when developing actions under the WFD or the Birds and Habitats Directives (EEA Report, 2016).

While these policies have been developed to direct the implementation of floodplain and wetland restoration, recent evidence suggests that restored wetlands often fail to meet expressed performance goals or to function effectively as healthy environmental systems due to poor site selection, among other factors (Widis et al, 2015). Failure to recognize wetlands as part of larger natural landscapes also contributes to unsuccessful flood mitigation. Therefore, from an integrated landscape approach on floodplain management, floodplain restoration and prioritization of sites have to answer a critical question: **what attributes define a wetland and its ability to be restored to produce ecosystem functions** (e.g. flood reduction, habitat provision, water quality, etc.)?

There is no easy answer to this question since synergies between managing floods risk, reaching or maintaining a good ecological status, and safeguarding the nature or ecosystem services in floodplains can be very complex. As it is suggested by the EEA on their last report on the synergies between floodplain restoration, water policies and thematic policies (EEA Report, 2016), some form of prioritization needs to take place at least on the level of river basin management planning. This study can provide with an alternative approach to prioritization of potential restoration sites along the lower Danube River that can fill some of the gaps from previous studies.

1.2. Scope and objectives of the report

WWF and The Coca-Cola Foundation have signed a partnership to restore vital wetlands and floodplain areas along the Danube River. In Romania, the floodplain areas having great potential to replenish 5 million m^3 of water by 2020 are considered for restoration purposes. To further support the development of restoration actions along the Lower Danube Green Corridor in Romania, WWF Romania commissioned this study to identify potential sites for further implementation of wetland restoration and to provide with an assessment and prioritization approach of the potential areas.

The overall scope of this report is **to provide a simplified analysis for a planning-level study to quickly assess and prioritize areas that are suitable for floodplain restoration**. Over the past 20 years Geographic Information Systems (GIS) modeling has also become a powerful mechanism for prioritizing potential wetland restoration sites across a variety of geographic scales (Widis et al 2015). To support the identification, development and implementation of future restoration actions, a Floodplain Restoration Opportunity Analysis (FROA) was conducted in a GIS planning-level study for the lower Danube corridor in Romania, which is summarized in this report. For this scope of planning-level study we look for the already available data required by GIS-based approaches, or data that can be obtained without an extensive desktop analysis and/or work on data field collection. Due to the limitation of data **a simplified tool capable of rapidly identifying, quantifying and prioritize restoration opportunities** was desired for FROA.

Therefore, the GIS-based desktop analysis serves as a simplified and quick planning-level study aiming to understand the spatial extent of different floodplain land areas that can be connected and disconnected from the Danube River channel at certain flow conditions. The primary objective of the present study is to identify and prioritize areas with greater and/or more extensive potential opportunities for ecological restoration of the Lower Danube floodplain in Romania.

The proposed approach of FROA for the Lower Danube in Romania adapted existing GIS models and used variables from the available data in order to characterize 12 river reaches. Through multi-criteria decision analysis (MCDA), variable were quantified and then mathematically arranged to identify suitable areas for restoration and provide a suitability score allowing for comparative ranking between locations and selecting areas having greater and/or more potential opportunities for restoration.

The results of FROA are intended to support the subsequent planning and further development of a candidate restoration site having greater restoration potential on the basis of their ecological, replenish targets and flood attenuation benefits as well as costs, regulatory, technological and operational feasibility. The results of the desktop GIS analysis are not entirely tailored to specific areas due to data limitation and, will not be used to replace detailed hydraulic models and specific restoration actions of potential sites identified with FROA approach. The result of the FROA serves also for a specific objective of WWF's work along the Danube River, which is to find a new potential restoration site where key stakeholders agree to implement a restoration project by 2020 on an area that can contribute to the replenishment of approximately 5 million m^3 of water and, can be considered as best practice project on floodplain restoration by Romanian authorities.

The present study continues WWF's previous efforts to contribute to the importance of floodplain protection, conservation and restoration to mitigate the adverse effects of climate changes in the lower Danube region. In support of this long-term goal, the report provides with an assessment of stakeholder's interests from the candidate site and vulnerability of the potential wetland sites to be impacted by future developments and other plans. In the end restoration objectives were also defined for the candidate wetland restoration site is support for the preparation of a wetland restoration project taking also into accounts stakeholders' opinions.

Finally, taking into account the structural measures still being implemented in the FRMPs and RBMPs, this report allows us to make suggestions for an improved implementation of the Flood and Water Directives. The authors of the report believe that the FROA approach and MCDA tool can introduce a competitive alternative to floodplain restoration which otherwise could not have been considered by the existing flood risk mitigation alternatives that consider only flood peaks important for flood storage or RBD. Such approach can be further used to develop spatial decision support system (SDSS) as key tools in creating river restoration programs for RBM in Romania. Moreover, we think such tools will make the debate over the proper choice of floodplain restoration alternatives more informed and have a beneficial impact in the planning and transparency of the decision-making process for the implementation of EU Directives related to water and nature.

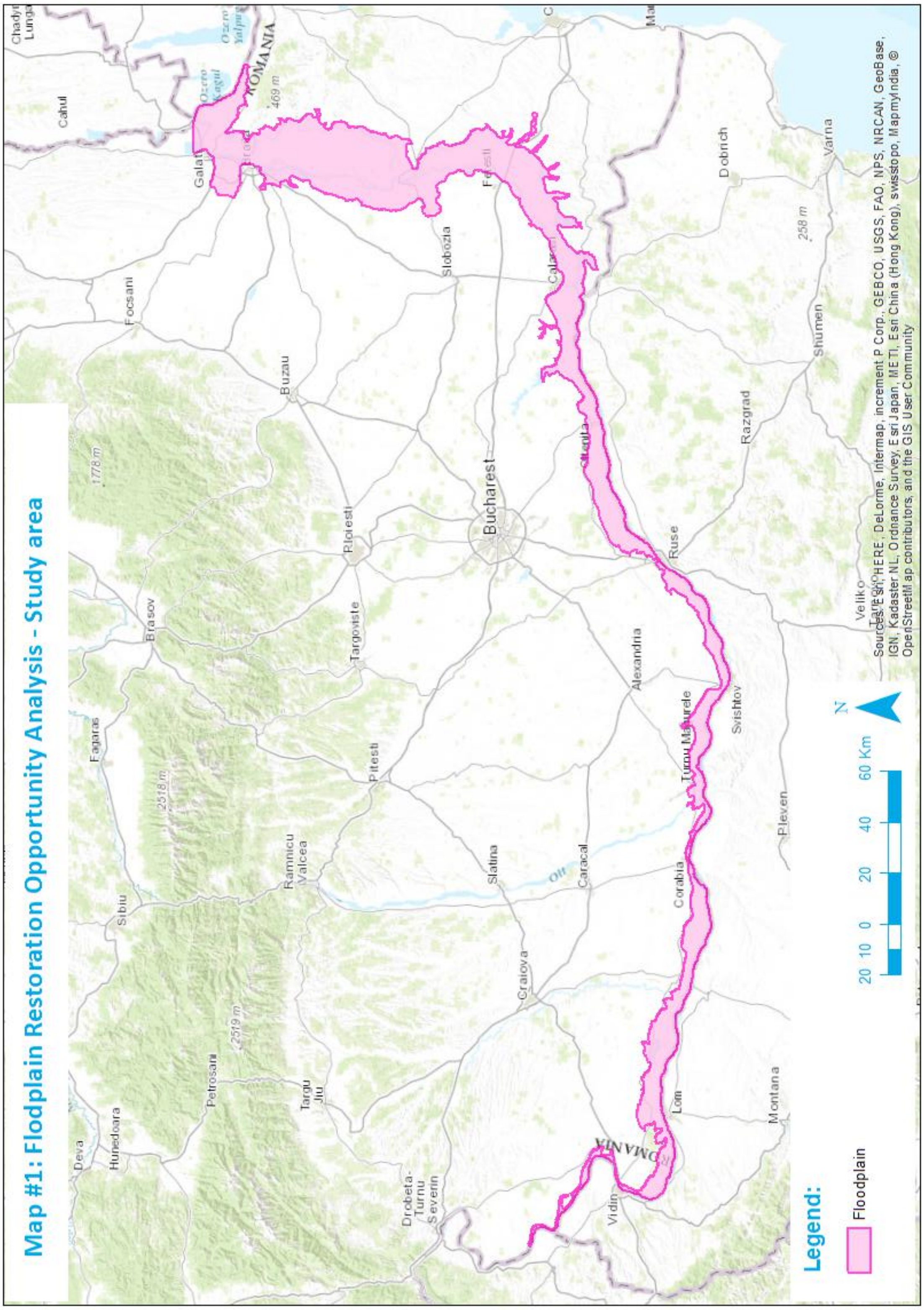
1.3. The study area

The study area consisted of the floodplain of the lower Danube River in Romania, bounded upstream (west) by the Iron Gates II dam, and downstream (east) by the Danube Delta Biosphere Reserve limits. The floodplain was defined to include all bottomland areas within the morphological floodplain (post glacial terraces) therefore including lands structurally protected by dykes and having potential to be inundated at different water levels. The entire study area covers 760 km of the Danube River, from km 863 where the Iron Gates II is situated to Isaccea at km 103. First a 20 km buffer along this sector of Danube River was delineated in order to include all potentially inundated floodplains then the final study area of the floodplain was delineated using HAR method.

Land cover in most of the floodplain is rural residential and agricultural, with extensive areas drained, cleared and irrigated since 1960's. Urban land cover is limited in the floodplain and mostly confined to the cities of Calafat, Corabia, Bechet, Turnu Magurele, Zimnicea, Giurgiu, Oltenita, Calarasi, Braila, Galati. Much of the lower Danube floodplain area is designated as Natura 200 sites for their importance to assure a favourable conservation status of species and habitats of community importance.

For the purpose of this study the detailed results of FROA are presented for 12 reaches that were chose considering the ease for further hydrological modelling of potential restoration areas, the need to be between two gauging station and other hydro-morphological aspects of the Danube River.

Figure 1: The study area



1.4. Report organization

The report is organized into the following sections:

- Section 2, Methods describes the steps conducted for FROA approach and details the tools and specific methods used to determine the areas with physical suitability for restoration and to identify potential candidate sites for restoration. The section also provides an overview on approaches to identify potential wetland restoration sites emphasizing the existing GIS-based models used for landscape approaches to the prioritization of restoration sites, hydrological modelling and floodplain delineation.
- Section 3, present the overall results of the FROA approach for the Lower Danube River in Romania and describe in more detail areas with greater potential for restoration identified for 12 reaches along the river. This section also includes maps and output table for each of the river reaches and reasons on selecting the candidate site for restoration.
- Section 4, goes deeper into to the description of the candidate restoration site and, provide a stakeholder mapping and vulnerability assessment to propose potential restoration objectives and alternative plan for the restoration area.
- Section 5, present conclusion and recommendations for further development of FROA and multiple criteria decision analysis tools for potential restoration sites selection and non-structural measures implementation along the Danube River.
- Section 6, References

1.5. Limitation of the study

The result of the GIS-based analysis based on limited data for this study is a simplified and quick approach proposed to understand the spatial extent of floodplain land areas that can be connected and disconnected from the river channel for certain flow conditions. Such results are not tailored to specific areas and will not be used to replace detailed site studies necessary for specific restoration actions of potential sites identified with this approach.

The resolution of the 30m DEM has some limitation given the cell size, which cannot be appropriate to determine minor landforms (e.g. dykes, depressions) smaller than 10m wide. The stream raster values, e.g. water level, are determined by the date at which the image data was obtained, e.g. low water table or springtime.

The GIS model used in the study is not intended to replace hydraulic models and is probably inferior to such models in terms of accuracy and realism. Floodplain inundation potential delineation does not consider the duration and frequency of floods that is only possible through hydraulic modelling and river gauge data. However for this planning-level study this is deemed to be sufficient in choosing the further potential site for restoration purposes by the desired objectives. Even with the existing hydrological data and/or flood extend layers of the existing probabilities of flood risk maps (e.g.1%, 3,3%, 10%, 0,1%) the study will not be able to identify areas that are connected, or could be readily reconnected to the river during specific flow events. This can results in a lack of opportunities for specific locations. The use of only the data for flood risk flows will lack the opportunities to identify acreage of floodplains potentially inundated during more frequent flows (occurring in 2 out of 3 years), which can be ecologically valuable for riparian habitats and a way to activate parts of the disconnected floodplain.

Due to the use of free open data, some layers could miss important information or have inaccuracies in spatial distribution of the data. Because of these potential actions on specific location cannot be considered.

The MCDA is subjective to a certain extent given the rationale for defining the variables and comparative values of each specific indicator. A ranking of potential restoration sites based only on the available data could limit the number of final available potential restoration sites and the added value of the study for key stakeholders.

The weights used in the model and the range over which they are varied are grounded in scientific expertise rather than functional relationships of sites attributes, which can only be performed with field data.

1.6. Acknowledgement

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1.7. Abbreviations and acronyms

APIA – Agency for Payments and Interventions in Agriculture

ANAR – Romanian National Water Administration

ADS – State Domain Agency

CLC – Corine Land Cover Data

DEM – Digital elevation model

EEA – European Environment Agency

FD – Floods Directive

FIP - Floodplain inundation potential

FRMP – Flood risk management plan

FROA – Floodplain Restoration Opportunity Analysis

IPPC – Integrated pollution prevention and control

MCDA – Multi-criteria or multiple attribute Decision Analysis

MoE – Ministry of Environment, Romania

MRDAP – Ministry of Regional Development and Public Administration

NAFA – National Agency for Fishing and Aquaculture

RAR – Romanian Archaeology Repertoire

RBD – River basin administration districts

RBMP – River Basin Management Plan

REELD – Ecological and Economic Resizing of the Lower Danube Floodplains in Romania

SDSS – Spatial decision support system

TCCC – The Coca Cola Company

WFD – Water Framework Directive

WWF – World Wide Fund for Nature

2. Methods

2.1. Overview

Today's complexity of floodplain management, with socio-economic and climate pressures, requires holistic approaches in which political decisions are sustained by recent scientific evidence, a multidisciplinary expertise and stakeholder involvement. Because floodplain areas are reduced in size or no longer function as **active floodplains**, thereby impacting on the delivery of environmental services to local and regional communities and economies. These services include regulating services such as protection against floods or water purification; provisioning services, such as nutrient collection and fertile soil formation; and cultural services, such as recreational, tourism and educational services; transport routes; and finally a secure water supply (EEA Report, 2016).

The floodplain area loss along the Danube River varies between 75% on the upper part to 79% on the middle part, whereas the Danube delta lost only about 35% of its wetlands. The floodplain along the lower Danube were disconnected from the main channel leading to losses of approximately 73% of its former floodplain, which was originally 5-10 km wide along the Romanian – Bulgarian stretch and reduced to only a few hundred meters (WWF, 2010). The main reasons for the loss of Danube's former floodplain areas are a result of land reclamation driven by the agriculture and development policies and of flood-protection measures to prevent new land uses from being flooded. Lower Danube hydraulics has also been altered by the dam construction, vegetation removal and change, dredging, and upstream reservoirs sediment capture.

Although not precisely documented, it is considered that these interventions cause bed lowering which leads to lower stages for a given river flow so that small floods can no longer inundate most of floodplain. As an effect these isolated floodplain surfaces may still support for example aging riparian forest for many decades but they not experience a dynamic connectivity with high flows required for regeneration of riparian tree species.

The main difficulty in developing a simple definition of an "**active**" or **ecologically valuable floodplain** - suitable for use in practical integrated water management decisions where e-flow and restoration actions are required by different policies, is that the large array of various ecological processes relies on inundation of a continuum of various-sized floods of different stages, duration, seasonality and variability. In addition, the same flood pulse might influence different geomorphic processes in different river reaches of the same river.

This complexity and the scientific uncertainty of linkages between hydrologic (and especially flood peaks) and geomorphic processes, and ecological functions, are leading to paralysis in restoration decision-making. In such cases, management decisions implicitly favour the *status quo*, where ecologic needs in floodplain restoration are not systematically addressed in the same way, for example, as flood management and water management (Williams et. all 2009).

The Floods Directive (EU, 2007, Art. 2) defines a 'flood' as the temporary covering by water of land not normally covered by water but 'floodplain' is not defined in this directive (EEA report, 2016). The main area of interest of flood risk management is the floodplain in which these peak floods happen, which is “the temporary covering of land not normally covered by water”. According to Flood Directive floodplains correspond roughly to flood hazard and risk areas with a yearly probability of flooding of 1% or less. Although intended for flood hazard delineation this widespread use of hydraulically – defined 100-year floodplain has provided a default definition of the extent of a floodplain. Thus, the genetic floodplain differs from the hydraulic floodplain and active floodplain, which is considered the areas within the flood protection dykes in regulated river.

Synergies between managing floods risk, reaching or maintaining a good ecological status, and safeguarding the nature or ecosystem services in floodplains can be very complex. To recognize these synergies between water and nature policies, the aims and working methods of the Floods Directive should also be taken into account when developing actions for the Water Framework Directive (WFD) and the Birds and Habitats directives. Although the WFD does contribute to mitigating the effects of floods; managing and reducing flood risk is not one of its principal objectives. Some form of prioritization needs to take place at least on the level of river basin management planning.

However, for ecologic functions floodplain extent is defined by more complex river stage characteristics such as inundation frequency, period, seasonality, and connectivity with the river channel. While infrequent floods such as the 100-year instantaneous peak flood are important for some ecological processes—for example, those that benefit from large scale geomorphic disturbance—the 100-year flood stage will generally be much higher than the smaller more frequent flood pulses that provide a wide array of ecologic benefits. This means that within a given mapped 100-year floodplain, large areas may be dry and floodplain processes inactive for long periods of time. The areal extent of the 100-year floodplain is therefore not a good metric for defining the extent of an ecologically functional floodplain.

Floodplain restoration intended to support a continuum of ecologic processes that rely on different types of flooding has to be designed first to inundate significant areas by this minimum flood pulse.

While various policies have been developed to direct the location and form of wetland restoration efforts, recent evidence has begun to call into question the effectiveness and success rate of these projects (Widis 2015). Research suggests that restored wetlands often fail to meet expressed performance goals or function effectively as healthy environmental systems (Russell et al. 1997, Brown and Veneman 2001, Williams 2002). Reasons for these failures are varied, but many times can be largely attributed to technical error (construction or mechanical), problematic hydrology, lack of financial resources, and/or poor site selection (Williams 2002). Failure to recognize wetlands as part of larger natural landscapes also contributes to unsuccessful mitigation (NRC 2001).

Previous studies for the restoration of Danube floodplain in Romania identified and proposed restoration areas based on their potential to store waters during high flood peaks, one in 100 years. They also consider some of the ecological functions of the protected areas along the Danube floodplain in establishing large areas for restoration. However the main selection of the areas is based only of their potential to store water during the peak floods. The choice of restoration sites does not take into consideration the floodplain processes that are inactive for long periods of time and smaller more frequent flood pulses that generate a wide array of ecologic benefits. Moreover, a prioritization approach based on the stakeholder preferences and an understanding of the spatial extent of different floodplain land areas that can be connected or disconnected from the Danube River at certain flow conditions can be helpful in creating a coherent decision system to support concrete restoration projects.

Therefore, **a GIS-based approach for this planning-level study is preferred** to understand the spatial extend of floodplain land areas that are connected and disconnected from the river at certain water levels. The analysis can include available spatial information data as well as stakeholders preferred restoration outcomes and help define multiple restoration objectives and prioritize potential restoration sites.

2.2. Floodplain Restoration Opportunity Analysis approach

The proposed approach of FROA for the Lower Danube in Romania adapted existing GIS models and variables of the available data in order to characterize the river reaches and identify reaches having greater and/or more potential opportunities for restoration.

Traditional approaches for identifying and analysing the inundation characteristics of river channel – floodplain land areas typically involve hydraulic models to define the hydraulic floodplain, which describe land surfaces based on one-dimensional cross-sections. Beside the fact that these models rely on 100-year flood pulses, one-dimensional cross-section approaches are limited in describing the land-surface and they involve a significant amount of time to develop and use. However, because of the large geographic area covered by the study on the Lower Danube River and also due to the number of potential restoration activities within the floodplain, **a simple computational tool capable of rapidly identifying, quantifying and prioritize restoration opportunities** was desired for FROA.

Any GIS-based approach and tools we might chose to use to determine the suitable floodplain restoration sites, require topographic and hydrologic data to identify the spatial extent of floodplain land areas under certain flow conditions.

To evaluate the suitability for restoration actions, the concept of floodplain inundation potential (FIP) was applied in GIS analysis of the lower Danube corridor in Romania. This approach is important for FROA because of the significance of floodplain inundation for ecosystem functions and is consistent with the available data necessary to define the extent of an “active” or ecologically functional floodplain, (e.g. the concept of frequently activated floodplain of Williams et all 2009), and comparable to the environmental flows concepts from EU environment-related legislation). For the scope of this work, the FIP is the term used to describe areas of floodplain, both directly connected to the river and disconnected from the river (e.g. behind natural or built levees or other flow obstructions) that could be inundated by particular floodplain flows.

The challenge of this approach for this particular study is that in order to evaluate the hydrological connectivity of floodplains with the river channel we had to adapt the existing methods to GIS-based tools that required basic hydrological data. Three GIS tools where evaluated for their capability to delineate the floodplain inundation potential and suitability of use in FROA: ArcHydro floodplain delineation tools; Height above a river (HAR); Thiessen polygon method to delineate flood-prone areas (Chendes, 2013).

All these GIS tools are computational simple and efficient to define flood-prone areas and river-floodplain hydrologic connectivity and require only basic hydrologic data (e.g. water level at flood peak from 2006 and a digital elevation model DEM).

Height above a river (HAR) method (Dilts et al. 2010) was preferred for FROA since it uses a 2D approach, is conceptually simple and is fairly computationally efficient. It also requires a DEM and a DEM derived stream raster. The advantage we've seen in using HAR method is that it can be used to calculate other important variables for discrete vertical intervals (every centimetre in our FROA) such as "inundation area" and "flood height"; both variables are important in establishing hydrological connectivity and identification of relative depth of depressions or other morphological features of floodplain that are visible on the elevation data and have potential to be restored.

Geographic Information Systems (GIS) modelling is also a powerful mechanism for **prioritizing potential wetland restoration sites** across a variety of geographic scales. There are numerous studies and GIS-based models for a variety of uses (Widis et al. 2015). Most of the GIS-based wetland prioritization models identify and select specific variables considered essential to achieve the goals and objectives of each study. In general the GIS-models use a multi-criteria or a multi attribute decision analysis (MCDA) to quantify variables and then mathematically arrange these variables to either identify suitable restoration sites and/or provide suitability scores allowing for comparative ranking between locations.

In a comparative study of 27 GIS-based models for wetland prioritization for restoration (Widis et al. 2015), the presence of hydric soils is the most used variable by such models (17 out of 27 studies, 62,9%) and the second most popular variable (44,4%) is termed "hydrologic connectivity". Following hydrologic connectivity were land use (37%), land cover (33.3%), wetland connectivity (29.6%), and "classified as wetlands" (29.6%).

MCDA facilitates collaborative decision-making and allows integration of preferences of attributes with objective measures of a variety of variables.

The results of FROA are intended to support the subsequent planning and further development of selected restoration sites on the basis of their ecological, replenish targets and flood attenuation benefits as well as costs, regulatory, technological and operational feasibility. The FROA approach can be useful in establishing a simple but fairly SDSS for river basin management with the possibility to include other variables of interest for water quality management and stakeholder preferences for restoration outcomes.

It is important to note that the FIP and FROA exercise will not make the decision, but rather provided support for the final decisions of selecting a candidate restoration site along the Danube River. Models and data available play an important role in the further alternative development dialogue under the proposed FROA approach.

The general FROA approach (Figure 2) consists of three main steps, which are detailed in the following sections:

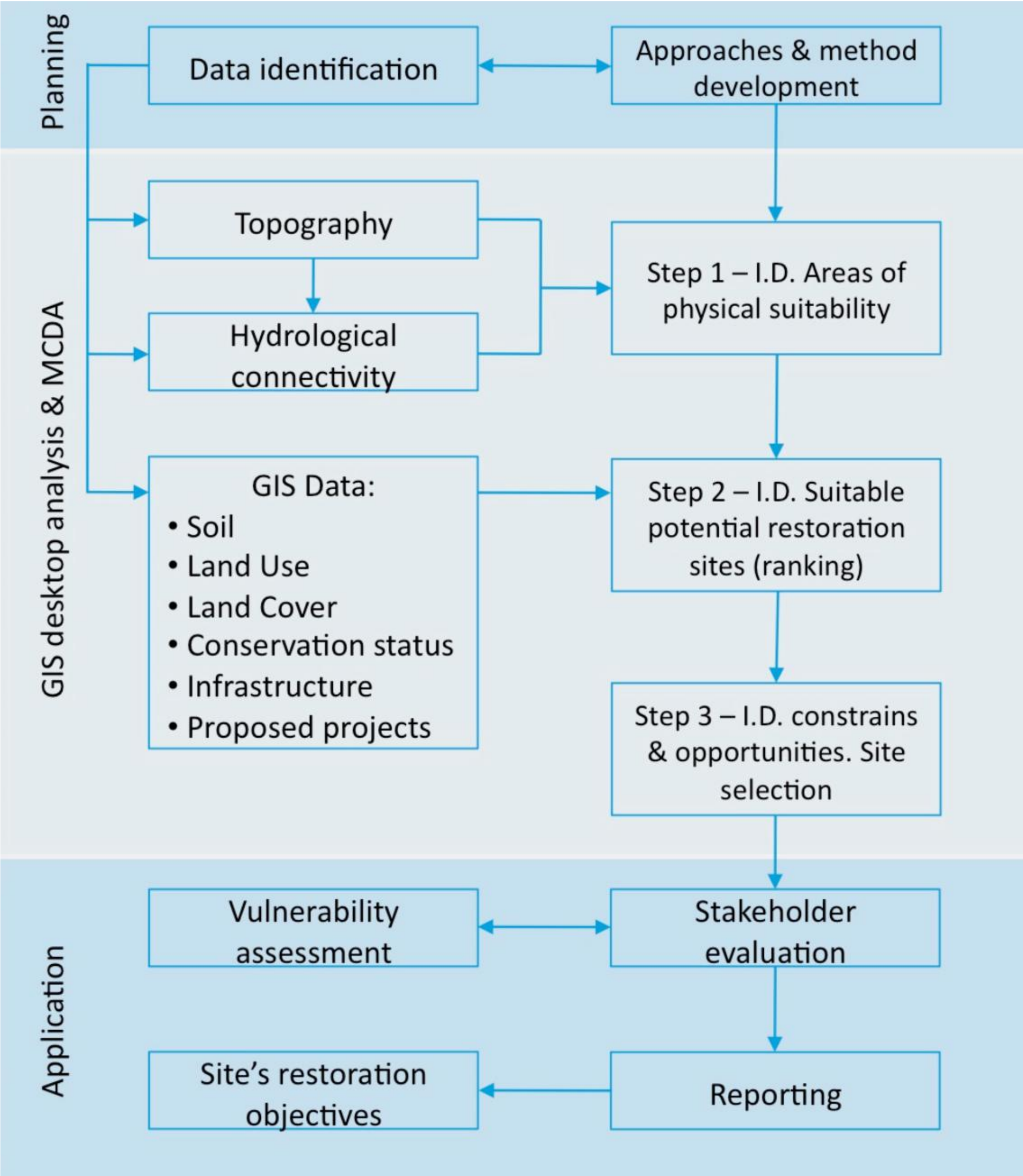
- **Identify areas of physical suitability**, in which we find an answer to the question where is actually ecologically effective to do restoration considering areas that can be connected with the Danube River at certain flood pulses;
- **Identify and prioritize suitable potential restoration sites**, where we take even further the analysis of ecologically effective areas by including various variables to list areas with greater or more extensive restoration potential thus to improve selection criteria for candidate restoration sites.
- **Select the candidate site for restoration** based on the identification of constrain and opportunities of potential candidate site/s.

Other steps are also presented in figure 2 as part of the FROA, e.g. vulnerability assessment and stakeholder evaluation, but their useful for taking a final decision on selecting the most suitable restoration site that have the greatest contribution to the study objectives (e.g. to find a new potential restoration site where key stakeholders agree to implement a restoration project by 2020 on an area that can contribute to the replenishment of approximately 5 million m^3 of water).

The data identified for this GIS planning-level study should offer input on one of the following characteristics:

- Have the potential to identify areas of physical suitability through intersection of flow with the topography in order to be able to extract information for areas inundated under different flow conditions.

Figure 2: FROA steps, adapted from California State Central Valley Flood Protection Plan



- Can be considered either an opportunity (e.g. protected areas, natural lands, arable land, natural channel, etc.) or constrain (e.g. arable land, urban areas, dykes, etc.) for floodplain restoration. Choosing which is which will be discussed under the MCDA methods in step 2 of FROA.

- Have sufficient spatial information to cover the entire study area and have importance in ranking the potential restoration areas.
- Data should be free for use, have reliable source or be official data from authorities.

2.2.1. Step 1 – Identify areas of physical suitability

The primary objective of FROA for the lower Danube in Romania is to identify potential restoration areas based on inundated or potentially inundated land surface that are below or above a specified water-surface level. For this planning-level study this simple approach for FIP is preferred to understand the hydrological connectivity of floodplains areas and identify the spatial extent of both areas directly connected to the river and disconnected from the river which can be inundated by particular water level (e.g. **behind natural or built levees or other flow obstructions**). Therefore, we are looking here to designate first those water levels that have the potential to inundate significant areas to activate the floodplain and provide ecological functions. The FIP method is not intended to be a replacement for detailed hydraulic modelling, but is considered a viable tool for this planning level for assessing areas that are physically suitable for restoration.

The assessment of FIP is performed with the application of the GIS tools provided within the ArcGIS Riparian Topography Toolbox as described by Dilts et al. in 2010. The ArcGIS Riparian Topography Toolbox is distributed by Environmental System Research Institute (ESRI) and offers a number of user-friendly tools that can be run with ArcGIS geoprocessing framework. The software uses digital elevation models and water surface elevation to calculate the relative height of terrain above a water surface and the depth of terrain below a water surface elevation, which is actually FIP. Therefore the “FIP method” used throughout this report, which serve the purpose of FROA, is the term used to describe the application of the GIS tools within the Riparian Topography Toolbox.

This analysis was selected because of the importance of floodplain inundation for ecosystem functions, and because, at this planning level of investigation of FROA the FIP method provide a relatively rapid assessment of floodplain inundation potential compared to detailed hydraulic modelling.

The analysis of FIP along the lower Danube River in Romania required topographic and hydrologic data. The data used and their specific analysis in the FIP method is the following:

- Topographic data:

Accurate topographic data are required to evaluate the inundation potential areas within floodplains and are important to obtain flood extent along a river with high precision. The DEM used for this study was obtained from http://earthexplorer.usgs.gov/ is available in raster format as ArcGIS GRID with the resolution of 1-arc second (30 m resolution).

The raster data was reduced to the study area using a buffer of 20 km from the Danube River. Digital Elevation Models (DEM) quality is important in areas with dykes (having small width of 5 – 10 meters) and other morphological features that can be helpful to identify the areas of potential suitability for restoration. Such data resolution of 0,5 – 2 m can be obtained only from LiDAR (Light Detection and Ranging) type of DTM existing at the MoE but not available for this study. However, for this planning-level study the 1-arc second DEM used is satisfactory to categorize low-lying areas that have the potential to be inundated at certain water levels.

- Hydrologic data:

The only available hydrological data for this study where the 2006 maximum discharge and maximum level along the Danube River (REELD, 2008). Although these data of 100-year floodplain does not capture the ecologically significant variables of inundation period and seasonality, we used to define metrics that captures the potential of the smaller floods (thus water levels) to inundate lowland areas. Therefore, the maximum water level was used to calculate the maximum inundation areas and then to calculate flood height for all elevation up to the maximum water level threshold. The result generated reasonable maps of flood height that are comparable with the distribution of 2006 floods along the Danube River (see map #2, 3). For the scope of the study is important to be able to define specific classes of flood height to evaluate the inundation potential, which then are utilized as variables for prioritization of potential restoration sites (step 2 of FROA). This approach is easy to use considering the deficiency of detailed hydrological data to evaluate specific ecological flows (in terms of magnitude and frequency), which can better define the concept of ecologically floodplain.

- FIP analysis:

To determine the FIP for the lower Danube River we followed the iterative model described by Dilts et al (2010) and used available tools in ArcGIS Model Builder for calculating height above river (HAR), inundation area for a given HAR, and flood height for the inundation area up to a user-specified elevation. Finally, inundation areas can be calculated for discrete vertical intervals (every centimetre) using the Calculate Flood Height tool. The calculate inundation area model floods all cells that are below a user-specified HAR and are physically connected to the river channel or another flooded cell.

The HAR tool requires a DEM and the Danube River in raster format. To produce the raster for the Danube River we generated a flow accumulation grid from the DEM (which was pre-processed initially), edited the flow accumulation grid (in order to remove areas that may actually have no water present at the surface), and then convert the output back to as raster.

Initial tests indicate that HAR performs best in relatively low-gradient river systems with high-resolution data (Dilts et al, 2010), which is satisfactory for the lower Danube River. However the DEM resolution available for the study can limit the accuracy of inundation area connectivity due to vertical accuracy of resolution.

Height above river is always less than flood height; therefore it is possible for some areas to be low-lying yet disconnected from the Danube River; however this variable is useful for mapping floodplain morphological features (visible on the elevation model) and can be used to predict potential restoration sites (e.g. areas that can be inundated with at least 50 cm).

The FIP method presented here should serve as a **planning reference only** and is intended to roughly illustrate the potential hydrologic connections between surface water features. The method was selected as a mean for selecting future restoration potential sites along the Danube River that can contribute to the study objectives. **It is not intended to replace hydraulic models and is probably inferior to such models in terms of accuracy and realism; however for this planning-level study is deemed acceptable.**

2.2.2. Step 2 – Identify and prioritize suitable potential restoration sites

In the context of restoration, prioritization is the process of ranking potential restoration sites to determine their sequencing for funding and implementation. The need for prioritization largely stems from the need to make the best of limited resources and the need to protect or secure lands for restoration purposes before further degradation and/or land use change occurs (Roni and Beechie, 2013). Suitability analysis is often used to support decision making in planning processes, such as environmental planning. Frequently, the goal is to identify the most suitable spot for a certain object (e.g. a power plant, a cable car, a nature reserve, a potential restoration site). The concept of suitability analysis describes the search for locations or areas that are characterized by a combination of certain properties or variables. Often, the result of a suitability analysis is a suitability map that shows which locations or areas are suitable for a specific use in form of a thematic map (e.g. potential restoration sites suitability map). The negative variation of the suitability map is the hazard or risk map, which segregates areas that are exposed to a specific hazard based on the criteria given (Roni and Beechie, 2003) (e.g. flood hazard maps of 1% probability of flooding).

Most of the GIS-based wetland prioritization models identified and selected specific variables considered essential to achieving the goals and objectives of each study. In general the GIS-models use a multi-criteria or a multi attribute decision analysis (MCDA) to quantify variables and then mathematically arrange these variables to either identify suitable restoration sites and/or provide suitability scores allowing for comparative ranking between locations. A series of mathematical calculations makes it possible to weigh various alternatives of a decision based on certain criteria and valuations.

MCDA facilitates collaborative decision-making and allows integration of preferences of attributes with objective measures of a variety of variables. This approach is preferred for prioritization of potential restoration areas along the lower Danube and is consistent with the available data for the study.

The proposed MCDA was created to rapidly identify and prioritize potential restoration areas across an extensive geographic area along the lower Danube River impacted by embankments, drainage and landscape modifications.

The MCDA proposed in this step of FROA operates in a tow-tier framework, first identifying potential restoration areas thorough binary weighting of two variables that narrow down and define the areas only to floodplain while excluding critical areas. Next, these potential areas are analyzed based on three performance metrics, the results of which rank potential sites based on wetland performance or functions: wetland restorability, provision of habitat and land favourability. This two-tier system was previously used in MCDA restoration prioritization projects first to define physical suitability and then to determine potential performance opportunities. Such MCDA used variable focusing on physical parameters that were seen as particularly important to define wetland properties and features.

The MCDA model we propose to identify and prioritize suitable restoration site as an important step in FROA for the Danube River in Romania was chosen primarily for several reasons. First, if extensive funding will be allocated for the restoration of Danube’s floodplain such MCDA is very important in decision-making and in assuring stakeholders’ understanding of how prioritization decisions will be taken. Second, such programmes will identify, prioritize and different types of ecological restoration based on much more socio-economic and ecological variables, which have to be weighted depending on costs-benefits and interests. If similar MCDA is used in a similar manner in the future any improvements to accuracy could have an influential impact on wetland restoration efforts elsewhere, and in future uses of SDSS on other rivers basins.

Based on findings on literature review and other similar approaches, the proposed MCDA system comprised in two major steps that are detailed further down in this section.

(A) **Create the *potential restoration area* layer considering two binary variables to define areas that can be potentially restored as wetlands.**

This is a continuation of the first step of FROA where the floodplain inundation areas (FIP layer) are better refined to focus our search for restoration sites only on those areas predisposed to flooding and thus can be potential buyout areas that can be restored to wetland as part of non-structural solution plans (e.g. potential green infrastructure). This refinement is also advancing a more realistic approach to the proposed objectives of the study to implementing a future site on ready available lands without excluding lands traditionally flooded with future potential for restoration. Potential restoration areas were selected by combining two different spatial layers: 1) floodplain layer and 2) non-natural & non-urban land cover.

1) **Floodplain**:

Description: derived with FIP method based on the 100-year flood data.

Purpose: areas that can be inundated beyond the protection dykes may be suitable for floodplain restoration as part of non-structural solutions or to contribute to the project objectives.

Processing: the FIP raster was converted to shapefile in order to delineate a single continuous area of floodplain, thus avoiding of HAR method limitation; the shapefile was converted to raster and reclassified. An overview of this layer is presented in map 1 while the full extent of the map is available online as *Danube_floodplain* layer.

Limitation: the floodplain areas represented in the raster may be incomplete due to the limitation of FIP method.

2) **Non-natural & non-urban land cover**:

Source: two land cover /land use layers were merged to create a continuous layer: a layer from MRDAP having up-dated information of land parcels distribution and 2011 land use-land cover from APIA (includes Mehedinti, Dolj, Olt, Teleorman, Slobozia, Constanta counties); a second CLC to cover Ialomita, Galati, Tulcea and Braila counties was obtained from Copernicus Programme and is dated 2012 (http://land.copernicus.eu/pan-european/corine-land-cover) .

Description: this layer consists of lands that can be restored to contribute to non-structural solutions or have potential to contribute to the project's restoration objectives.

Purpose: to identify restricted areas for restoration purposes and exclude them from investigations. We assumed that areas already in a "natural" state do not need to be restored (e.g. lakes, rivers, forests); all urban and industrial areas cannot be inundated due to safety reasons therefore are not appropriate for wetland restoration either. As a result, all the remaining areas can potentially be included as non-structural measures for floodplain restoration and/or to contribute to the project objective.

Processing: using "Union" function of ArcGIS the two land cover shapefiles were combined into one layer. The following land cover categories were classified as 'non-natural and non-urban' land and rated as 1: 'associations of crops and natural trees', 'herbaceous and woody crops', 'beaches, dunes, sands', 'channels', arable land', 'complex cultivation patterns', 'contiguous/discontinuous/fragmentary urban areas/fabric', 'industrial areas', 'orchards', 'vineyards', 'lakes and impoundments', 'grasslands' 'pastures', 'rice fields', 'scrublands', 'scrub crop', 'transitional woodland-shrub', 'waterlogged forest/vegetation', 'woodland'. All other areas are excluded/restricted from the final layer of potential restoration areas and were rated 0. An overview of this layer is presented in figure 5 and the result of land reclassify is online as the *Nonnatl_nonurban* shapefile.

Limitation: land cover may have changed since 2011 and the layer does not capture changes in land use that are les than 30 m by 30 m or the designation of new urban limits (which we assumed that should be protected against floods thus limited to creation of new wetland areas).

Any cell that fell within the areas covered by the two layers was considered to be part of potential area that can be restored. Map 6 is an overview of the maximum extent of potential areas along the lower Danube River in Romania. Full layer can be accessed on WWFROFW ArcGIS Online account, shapefile *Potential_areas*.

(B) **Prioritize *potential restoration areas* using different variables to measure the suitability of an area to be a functioning and sustainable wetland.**

With the potential restoration areas determined, the MCDA uses three performance metrics to determine suitability of potential restoration areas and prioritization of wetlands in the study area: wetland restorability, land cover favourability, provision of habitat and replenish/storage capacity. The description and reasoning of variable included in each category is presented below.

Wetland restorability metric included variables aimed at measuring the suitability of an area to be a functioning and suitable wetland. We included in our model the presence of *hydric soils* because it is a variable that defines wetlands functioning, chemistry and vegetation. Since the hydric soils can take several years to develop naturally the presence of hydric soils is a good indicator that an area was formerly a wetland. Moreover, the presence of such soils has a tremendous benefit in helping restored areas to function as wetland habitats since they have capacity to keep water longer than other soils (e.g. sandy soils). Another variable of wetland restorability metric is the *hydrological connectivity,* which is the attempt to quantify sites' location in relation to water height of flood inundation potential (HAR).

The study objectives and available data helped to shape and direct variable selection of the MCDA model, nevertheless the analysis is consistent with most of the similar models for wetland prioritization for restoration purposes. In a comparative study of 27 GIS-based models for wetland prioritization for restoration (Widis et. all 2015), the presence of hydric soils is the most used variable by such models (17 out of 27 studies, 62,9%) and the second most popular variable (44,4%) is termed "hydrologic connectivity". Indeed many authors and also the community of restoration practitioners have recognized the *presence of hydric soils* as a key indicator of either historic wetlands and/or the necessary hydrology essential for successful wetland function and vitality (Williams 2002, Mitsch and Gosselink 2000, Richardson and Gatti 1999, cited by Widis et. all 2015). Following hydrologic connectivity was land use (37%), land cover (33.3%) and wetland connectivity (29.6%) indicators, which we considered also as key variables in our model for prioritization of a suitable restoration sites.

We included land use in the prioritization variables in order to emphasize the important role of land availability for restoration purposes, and especially the need for landowners support.

1) **Hydric soil**:

Source: Romanian Soil Taxonomy System (SRTS), ICPA 2005.

Description: hydric soils have a folic soil horizon (0 < 50 cm) with >35% organic soil and/or A horizon followed by either intermediary layers with gleic properties in the first 50 cm or soil materials with stagnic properties (can retain water) in the first 50 cm and below; hydric soils are frequently saturated with water less than a months in most of the years. According to SRTS hydric soils are groups of gleysols, stagnic soils and limnosols as well as stagnic units of different groups of soils with gleic and/or stagnic properties.

Purpose: areas that can be inundated and have soil textures able to retain water provide a higher favourability to sustain functions necessary to natural development of wetlands than areas with sandy soil texture, which drain water more rapidly. Therefore, soil texture was used as variable of a site's hydrologic suitability to sustain a wetland.

Processing: polygons that contained hydric soils and/or with gleic and stagnic properties were ranked according to the soil texture from 1 to 5, where 5 is the highest favourability for restoration and 1 not favourable (from clay, loamy and silt textures of hydric soils to sandy soils without gleic or stagnic properties). Polygons with less favourable soil textures (sandy or varied textures non-hydric soils) were given lower scores but not excluded as indicator for prioritization only to be able to seize restoration opportunities with increased areas that can form a mosaic of floodplain habitats. The shapefile was converted to a 10-m to 10-m raster based on the soil texture favourability ranked and then reclassified (see table 1). This layer is show in map 7 and accessible online as *Hydric_soil* layer.

Limitation: the SRTS layer may not reflect the situation of the field due to the coarse resolution of the map scale, 1:200,000.

2) Hydrological connectivity:

Source: derived from FIP method based on the Height Above River data.

Description/Purpose: this layer depicts the predicted inundation extent of the floodplain on different categories of water heights, highlighting the most suitable category for wetland functioning and restorability from the defined water above river height range (0 to 450 cm). In order to select a more wide floods with potential for wetland functioning and restoration we selected as key range the height above water from 50 cm to 25cm. We found this to be more consistent with the inundation potential for a wide area along the Danube floodplain so that we do not exclude potential areas to be restored from the analysis.

Processing: the raster was reclassified to a 10-m to 10-m cell size raster with three categories of water heights segregated considering wetland functioning and restorability purposes. Map number 8 presents the layer which is also accessible online s *Hydro_connectivity* layer.

Limitation: same limitation as for HAR method due to DEM resolution.

To reach a final suitability for 'wetland restorability' metrics the scores for each raster cell form hydric soil and hydrological connectivity were summed with equal weighting. To determine the final wetland restorability score suitable for MCDA, the raster was reclassified and the data were broken down on a scale of one to five, with five being the most suitable and one being the least, using quintile classification. (table 1). Map 9 shows the 'wetland restorability' metrics used for MCDA and the full layer can be accessed online as *Wetland_restorability*.

3) Land cover favourability:

Source: two land cover /land use layers were used to cerate land cover favourability. First land cover/land use layer covers the floodplain area along the Danube between Romania-Bulgaria border, was obtained from the MRDAP and includes the initial information of LULC 2006 data updated in 2011 with the land parcels distribution and land cover/land use from APIA. The second layer is a CLC 2012 from the Copernicus programme.

Description/Purpose: the layer consists of different land categories that have potential to be restored considering their use, status and ownership.

Processing: the two separate land cover/land use layers where merged to a single continuous land cover layer for the study area then ranked as follow:

1: beaches, dunes and sands; artificial non-build up surfaces;
2: shrub crops; vineyards; fruit trees and berry plantations; waterlogged forest; association of herbaceous and woody crops;
3: transitional woodland-shrub; woodland; channels; arable lands; complex cultivation patterns; association of crops and natural trees;
4: association of crops and natural trees; scrublands; grasslands; pastures; lands principally occupied by agriculture with significant areas of natural vegetation;
5: lakes and impoundments; waterlogged vegetation; paddy rice fields.

The shapefile was then converted in a 10-m to 10-m cell size raster and overlaid with wetland restorability and provision of habitat raster to prioritize the suitable restoration areas. Map 10 shows classes of land favourability for restoration and the full layer can be accessed online as *Land favourability*.

Limitation: land cover may have changed since 2006/2011 and the layer does not capture changes in land use that are les than 30 m by 30 m.

4) Distance to open waters:

Source: derived from land cover layer by selecting lakes, river and the main channel network.

Description: this layer shows the closest distance, in meters, of every cell to the nearest cell delineated as open waters (rivers, channels, and lakes) in the study area (e.g. floodplain).

Purpose: Proximity of potential restoration sites to open waters is a variable indicating the potential to improve the hydrological regime of a restoration site if connected to a sustainable water source. Moreover, permanent open water that is proximate to the potential restoration areas can serve as additional habitat or foraging resource for resident and transient wildlife. This is a measure that is strongly advocated throughout many previous studies due to the presence of wetland hydrologic regimes and improved habitat connectivity (Widis et. all 2015).

Processing: the "Euclidean Distance" tool was applied to create a 10-m to 10-m cell size raster depicting closest distance (in meters) of each area in the floodplain to open waters. Three classes were defined based on a "Quintile" classification, which were then reclassified according to the MCDA scoring system. Map 11 shows the distance to open waters and the full layer can be accessed online as *Proximity_openwaters.*

Limitation: the selection of the main channels connected to the river that is used to pump water through the irrigation system. The other network channels were not included due to high density and their scope (drainage vs. water supply) and their complicated ownership.

5) Distance to protected areas:

Source: official layers of Natura 2000 sited distribution were downloaded from the Ministry of Environment, Water and Forest website (www.mmediu.ro).

Description: this layer shows the closest distance, in meters, of every cell from the floodplain to the nearest cell delineated as Natura 2000 site.

Purpose: restoring wetlands close to these protected areas to create corridors or new habitats that are beneficial for wildlife.

Processing: merging two existing separate layers (Natura 2000 sites SCI, Natura 2000 SPA) created a single protected areas shapefile. The "Euclidean Distance" tool was applied to create a 10-m to 10-m cell size raster depicting closest distance (in meters) of each area in the floodplain to protected areas. Three distance classes were defined based on a "Quintile" classification, which were then reclassified according to the MCDA scoring system. A preview of this layer is resented in map 12 and the full layer can be seen online named as *Distance_protect_areas.*

Limitation: the protected areas layer does not include any other type of land protection status e.g. archaeological sites, natural monuments. The limitation will be taken into account in the 'constrain and opportunities' evaluation step of the FROA by checking other available source data.

6) Distance to roads:

Source: national road network, open source data available on www.geo-spatial.org

Table 1: Functions metrics, variable and scores used in the MCDA model

Function	Variable	Raw value	Score
Wetland restorability	Hydric soils	clay	5
		clay loam, loam, silty clay loam, peat, hydric with varied texture	4
		loamy sand, sandy clay loam, varied texture (open water and wetland included)	3
		sandy loam, varied texture (non-hydric)	2
		sandy	1
	Hydrological connectivity (m)	0 – 50	5
		50 – 250	15
		250 - 450	10
Land cover	Land cover favourability	beaches, dunes and sands; artificial non-build up surfaces	1
		shrub crops; vineyards; fruit trees and berry plantations; waterlogged forest; association of herbaceous and woody crops	2
		transitional woodland-shrub; woodland; channels; arable lands; complex cultivation patterns; association of crops and natural trees	3
		association of crops and natural trees; scrublands; grasslands; pastures; lands principally occupied by agriculture with significant areas of natural vegetation	5
		lakes and impoundments; waterlogged vegetation; paddy rice fields;	5
Provision of wildlife habitat	Distance to open water (m)	0 – 548	15
		548 – 2,193	10
		2,193 – 8,738	5
	Distance to protected areas (m)	0 (inside protected areas)	15
		0 – 1,865	10
		1,865 – 19,025	5
	Distance to roads (m)	0 – 1,490	5
		1,490 – 3,756	10
		3,756 – 15,203	15

Description: the layer show the closest distance, in meters, of every cell from the floodplain to the nearest cell delineated as road.

Purpose: roads can limit the selection of a continuous block of potentially restored wetland and the restoration of such wetlands nearby to roads can be a source of disputes, regulation or hazard to restoration implementation. Nevertheless, roads are a potential source of disturbance to certain protected animals, which cold make the restored wetland les optimal as wildlife habitat.

Processing: The "Euclidean Distance" tool was applied to create a 10-m to 10-m cell size raster depicting closest distance to roads (in meters) of each cell in the floodplain. Three distance classes were defined based on a "Quintile" classification, which were then reclassified according to the MCDA scoring system. A preview of this layer is resented in map 13 and the full layer can be seen online and named as *Distance_roads.*

Limitation: the layer does not show local roads used to access arable lands/parcels or other areas used by locals; the variable doss not distinguish between different types of roads, some which are located on the river terrace and/or have less impact/importance on selection of restoration sites.

To reach a final suitability of 'provision of habitat' metrics the scores for each raster cell (form distance to open water, distance to roads and distance to protected areas) were summed with equal weighting. To determine the final suitability score, the data were broken down on a scale of one to five, with five being the most suitable and one being the least, using quintile classification (table 2). A preview of this layer is presented in map 14 and the full extent of this layer can be seen online and is named as *Provision_of_habitat.*

Table 2: The scores used to reclassify wetland function metrics

Function	Raw value	Score
Wetland restorability	6 – 13,00	1
	13,00 – 15,01	2
	15,01 – 17,99	3
	17,99 – 20,00	4
	20,00 – 25,00	5
Provision of habitat	15 – 19,94	1
	19,94 – 25,00	2
	25,00 – 30,05	3
	30,05 – 40,05	4
	40,05 – 45,00	5

Finally, to determine the final suitability score for the potential restoration sites the wetland functions were weighted together, by allocating a 40% weight to provision of habitat metric while each of wetland restorability and land favourability was given 30%, recognizing the limitations in these metrics estimates. Given that the MCDA should not make clear indication to favouring wetland restorability over the land uses, it only seems appropriate the weight those two metrics evenly.

Based on their score, each potential restoration site was assigned a value of 1- Low, 2- Medium-Low, 3- Medium, 4- Medium High, or 5- High, for each function. Classification into these values was based on dividing the actual range of scores for each function into five equal-range groups. A preview of this layer is presented in map 15 and the full extent can be seen online either as *High potential candidate sites* (showing only those site having the highest score of 5) or *All potential candidate sites* (sites with scores from 1 to 5).

2.2.3. Step 3 – Evaluate potential for restoration. Identify constrains on opportunities.

Constrains include a variety of physical and socio-economic factors that may limit restoration options. In most cases, **constrains are structures or land uses that have economic or social benefits that outweigh ecological values**. That is, where local or regional communities and authorities place greater value on gods and services provided by human infrastructure than on goods and services provided by a healthy river and its biota, the human infrastructure becomes a constrain on restoration (Roni and Beechie, 2013). For example levees that protect high-value arable lands are often more valued than restoration of floodplain habitats and river processes. Those levees are therefore not considered for removal or setback in a restoration plan and their continued existence becomes a constraint on the kinds of restoration actions that are possible.

Understanding these limits is crucial for setting realistic expectations for the outcomes of restoration efforts, as constrains may in some cases preclude achievement of restoration objectives. Constrains identified through this step of FROA are important since they can influence the selection of final candidate site and the prospective design of restoration actions that match the local restoration potential an proposed objectives.

Finally, socio-economic constrains often limit the time and extent of restoration and such limits were previously and partially assessed through several studies to which we will refer in the description of river reaches (Chapter 3.2). These socio-economic constrains do not limit potential biological and/or replenish outcomes in the same way that infrastructure constrains do, but they do limit the rate at which restoration can occur and ultimately how many restoration actions will be implemented. Capacity allocated for this study didn't made possible a throughout evaluation of socio-economic constrains, however where such constrain exist they limit the peace and magnitude of restoration and a transparent process for prioritizing restoration becomes more important, where sufficient time and stakeholders engagement strategies are a must.

Because the FROA is based on limited budget and a model that does not account for the assessment of all site-scale conditions or restoration needs, additional inventories are needed to identify specific opportunities and restoration actions.

The following information was considered for this step to identify as much as possible known existing constrains and opportunities for wetland restoration and based on the availability of the following data:

Inundation potential – areas of the floodplain lands inundated at a specific height above the river (HAR) that generate an inundation with at least 50 cm of water above the surface.

Block size - area of sites with high or medium-high potential for restoration was calculated for each river reach. An evaluation of alternatives to expand the block size of different categories of potential restoration sites so that larger non-structural solutions can be created (e.g. appropriateness of adjacent land use) was also hypothesized.

Land parcel and ownership - private or state owned lands (where information is available and including existing concessions) and appreciation of land fragmentation was compiled for each potential restoration site by consulting the information available on the website of the National Agency for Payment in Agriculture. We use parcel fragmentation as a rough guess of the potential number of owners that could be affected by the proposed restoration and, consider it as a potential constrain to hinder wetland restoration.

Archaeological sites - the existence of sites of cultural interest can block and/or delay the implementation of wetland restoration. Consulting the Romanian Archaeological Repertoire (RAR) database of cultural artefacts (http://map.cimec.ro) can give a glimpse of the presence of archaeological sites for every reach, which can delay or hinder restoration objectives.

Local infrastructure - e.g. dirt/unpaved road to access to lands, bridges, buildings, channels, dykes (other than protection dykes along the Danube), electric lines, etc. that are not already included in the potential restrictions where assessed as an indication of difficulties to wetland restoration implementation. Although some channels used for drainage or irrigation can favour restoration opportunities through reconnection at different flood stages or water sources (e.g. reservoirs). The presence of dykes raise concerns due to their scope and ownership and can favour or constrain restoration. Therefore, through this desktop assessment of local infrastructure we only aim at pointing out of their presence and where evidence exists to suggest potential constrains and opportunities of the most relevant ones.

Flood Hazard Maps – the data can be consulted to depict the flood extent for three scenarios of flooding risks and hazards for 10%, 1% and 0,1% of probability of occurrence (web: http://gis2.rowater.ro:8989/flood/). This information can be used to evaluate presence of high-risk industrial establishments in the floodplain that can block wetland restoration.

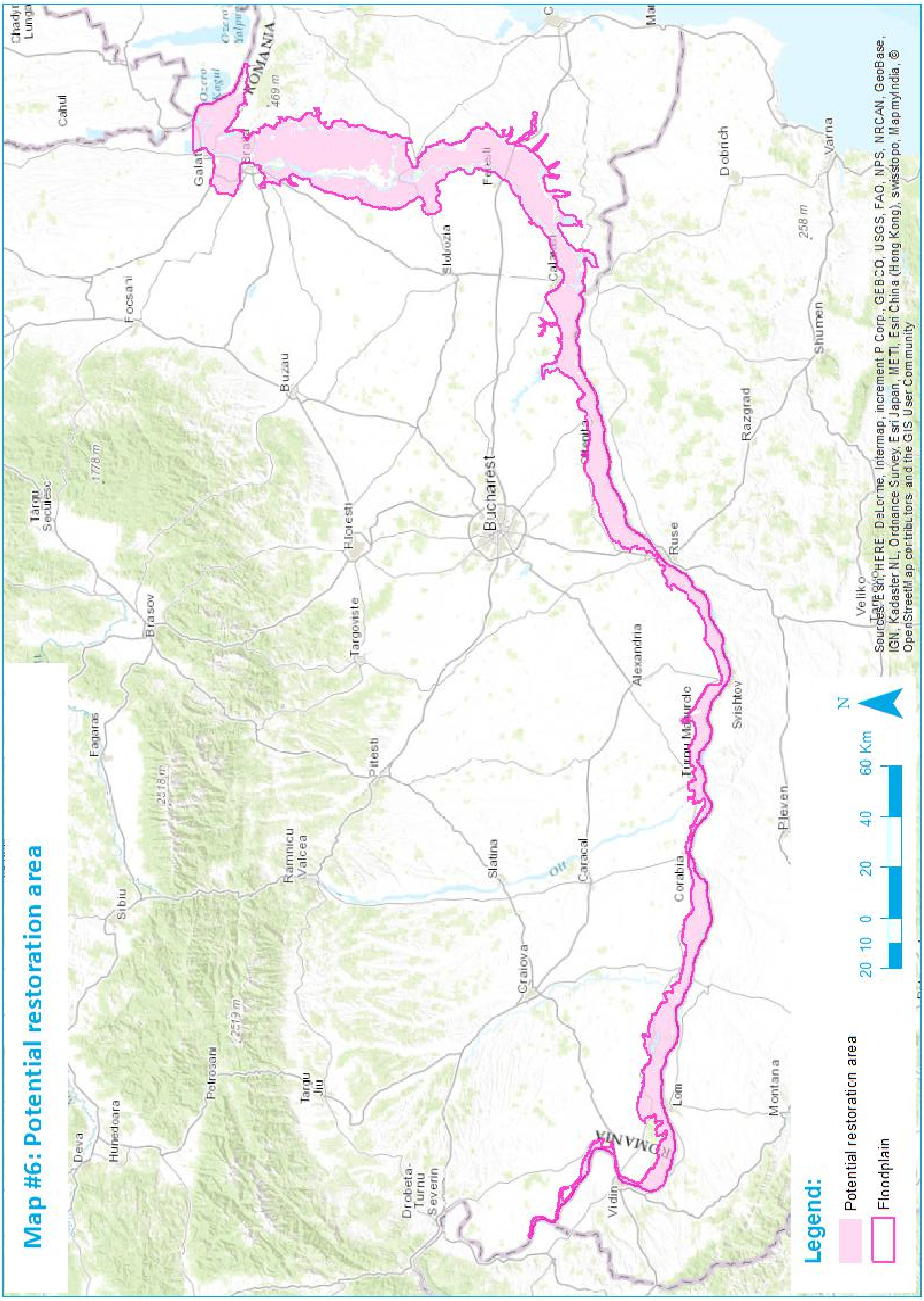
Conservation status – the presence of protected areas in each river reach is presented as an opportunity to wetland restoration.

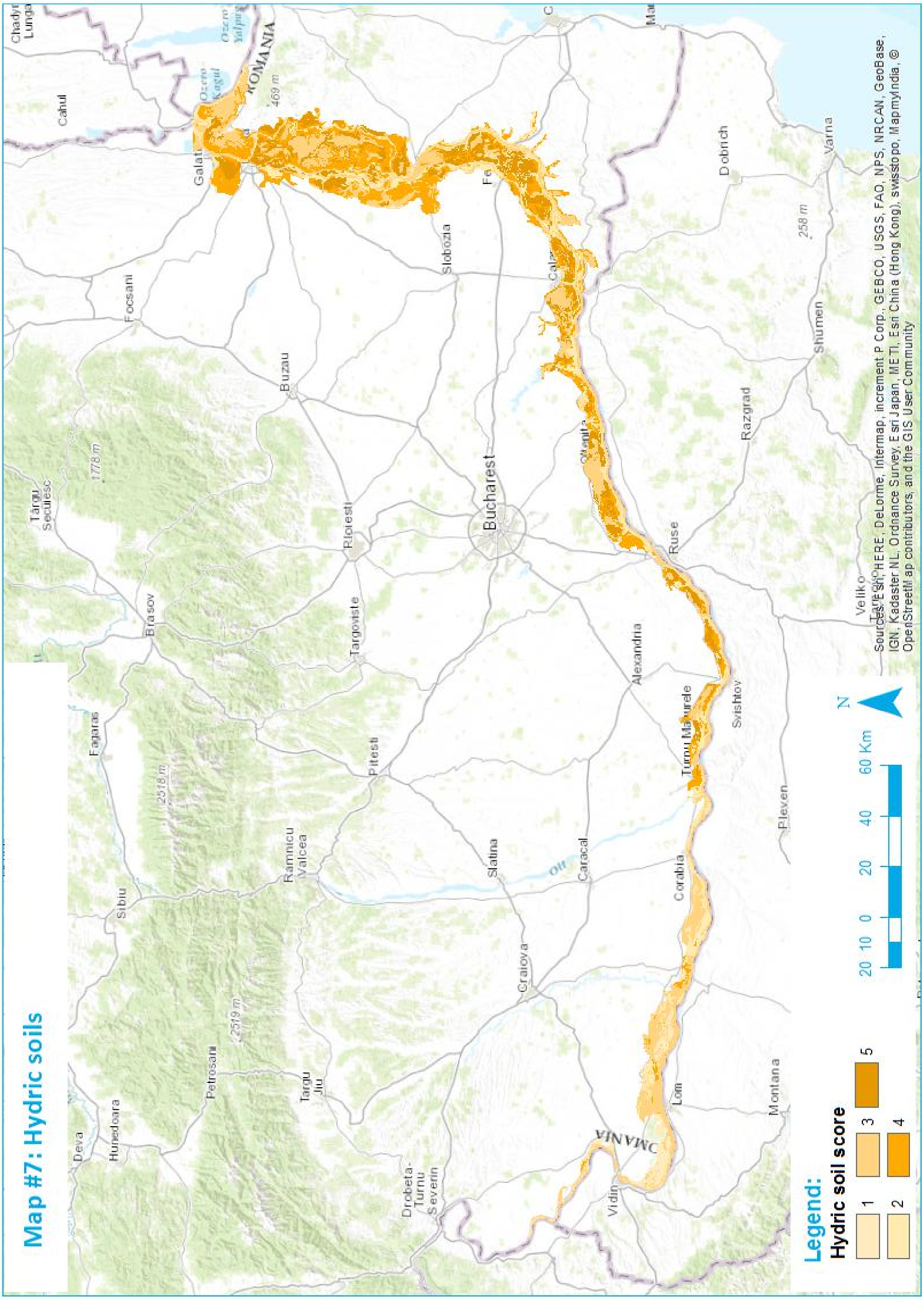
Stakeholder input – areas where stakeholders are supporting/opposing wetland restoration are evaluated based on previous studies/reports and considered as either opportunities or constrains to restoration initiatives.

Restoration opportunities – potential restoration areas identified in existing studies/reports (e.g. REELD) could support further wetland project implementation. Potential restoration approaches are also put forward considering the available information and site visit where possible.

In the section 3.2 we briefly describe this information and assess constrain on opportunities for 12 Danube River reach based on professional judgement, site visits and/or on-the-ground knowledge. Constrains on opportunities identified by this FROA step are then summarized in a matrix using an arbitrary scale presented in chapter 4.1, which will help the WWF team select the final candidate site for further stakeholder assessment of the final candidate wetland restoration site.


Map #5: Non-natural - non-urban land cover
Legend:
0 Restricted areas
1 Potential restoration area
20 10 0 20 40 60 Km
N
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Deva
Hunedoara
Sibiu
Fagaras
Targu Secuiesc
Brasov
Focsani
Cahul
Galati
Braila
ROMANIA
Petrosani
Ramnicu Valcea
Targu Jiu
Buzau
Targoviste
Ploiesti
Pitesti
Drobeta-Turnu Severin
Slobozia
Bucharest
Fetesti
Slatina
Craiova
Olt
Caracal
Calarasi
Oltenita
Vidin
Alexandria
Lom
Corabia
Turnu Magurele
Ruse
Svishtov
Razgrad
Dobrich
Montana
Pleven
Shumen
Varna
Veliko Tarnovo
2518 m
2519 m
1778 m
469 m
258 m


Map #6: Potential restoration area
Legend:
Potential restoration area
Floodplain
20 10 0 20 40 60 Km
N
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
ROMANIA
Bucharest
Galati
Braila
Fetesti
Calarasi
Slobozia
Focsani
Buzau
Ploiesti
Targoviste
Pitesti
Brasov
Fagaras
Sibiu
Ramnicu Valcea
Slatina
Caracal
Craiova
Targu Jiu
Petrosani
Hunedoara
Deva
Drobeta-Turnu Severin
Vidin
Lom
Montana
Corabia
Turnu Magurele
Alexandria
Svishtov
Pleven
Ruse
Veliko Tarnovo
Razgrad
Shumen
Dobrich
Varna
Cahul
Targu Secuiesc
Olt
1778 m
2518 m
2519 m
469 m
258 m


Map #7: Hydric soils
Legend:
Hydric soil score
1
2
3
4
5
20 10 0 20 40 60 Km
N
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Bucharest
Ruse
Svishtov
Turnu Magurele
Alexandria
Corabia
Craiova
Slatina
Caracal
Pitesti
Ploiesti
Targoviste
Brasov
Buzau
Focsani
Slobozia
Galati
Cahul
Sibiu
Fagaras
Ramnicu Valcea
Targu Jiu
Petrosani
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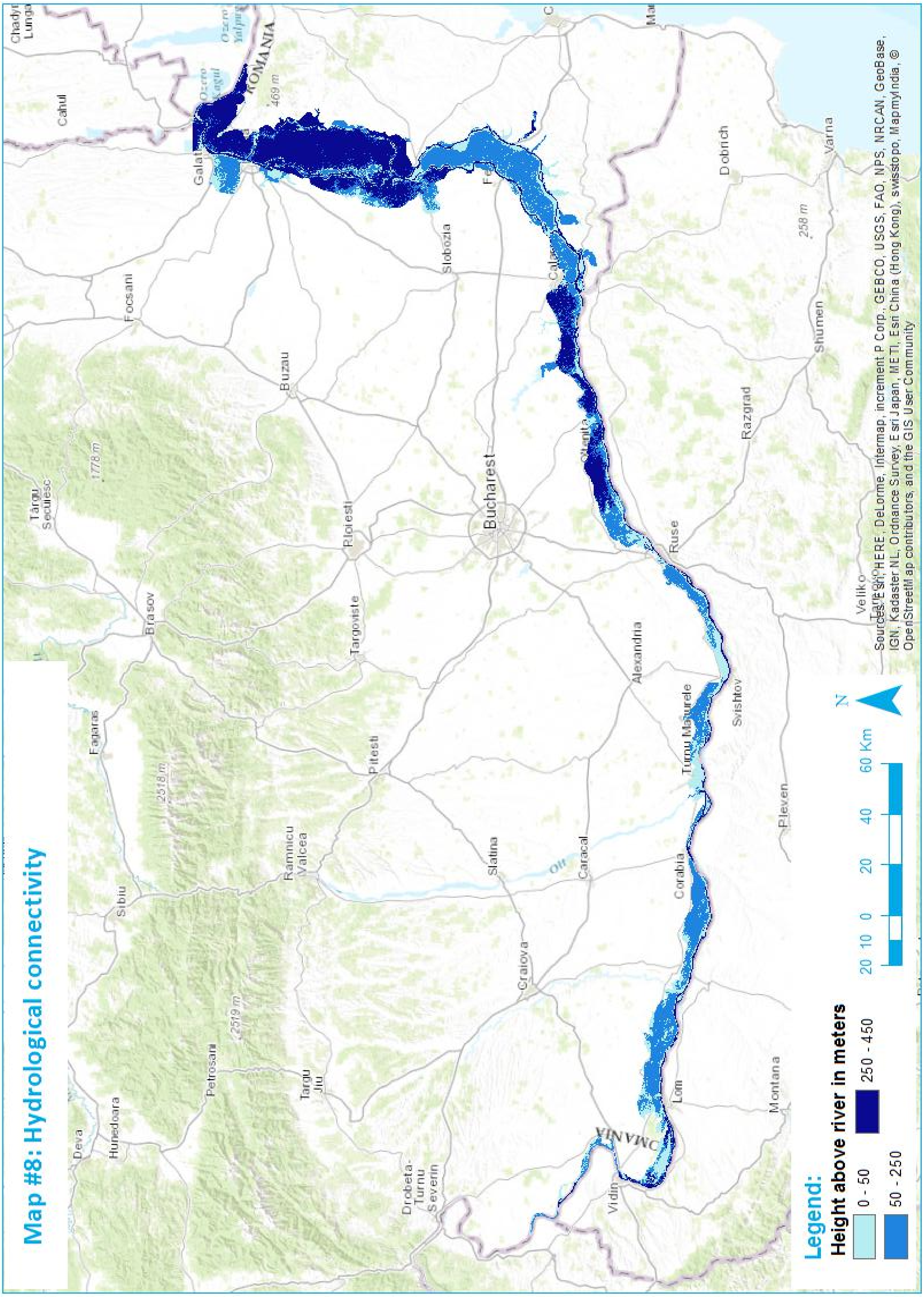
Varna
Veliko Tarnovo
Targu Secuiesc


Map #8: Hydrological connectivity
Legend:
Height above river in meters
0 - 50
50 - 250
250 - 450
20 10 0 20 40 60 Km
N
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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Caracal
Craiova
Targu Jiu
Petrosani
Hunedoara
Deva
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Corabia
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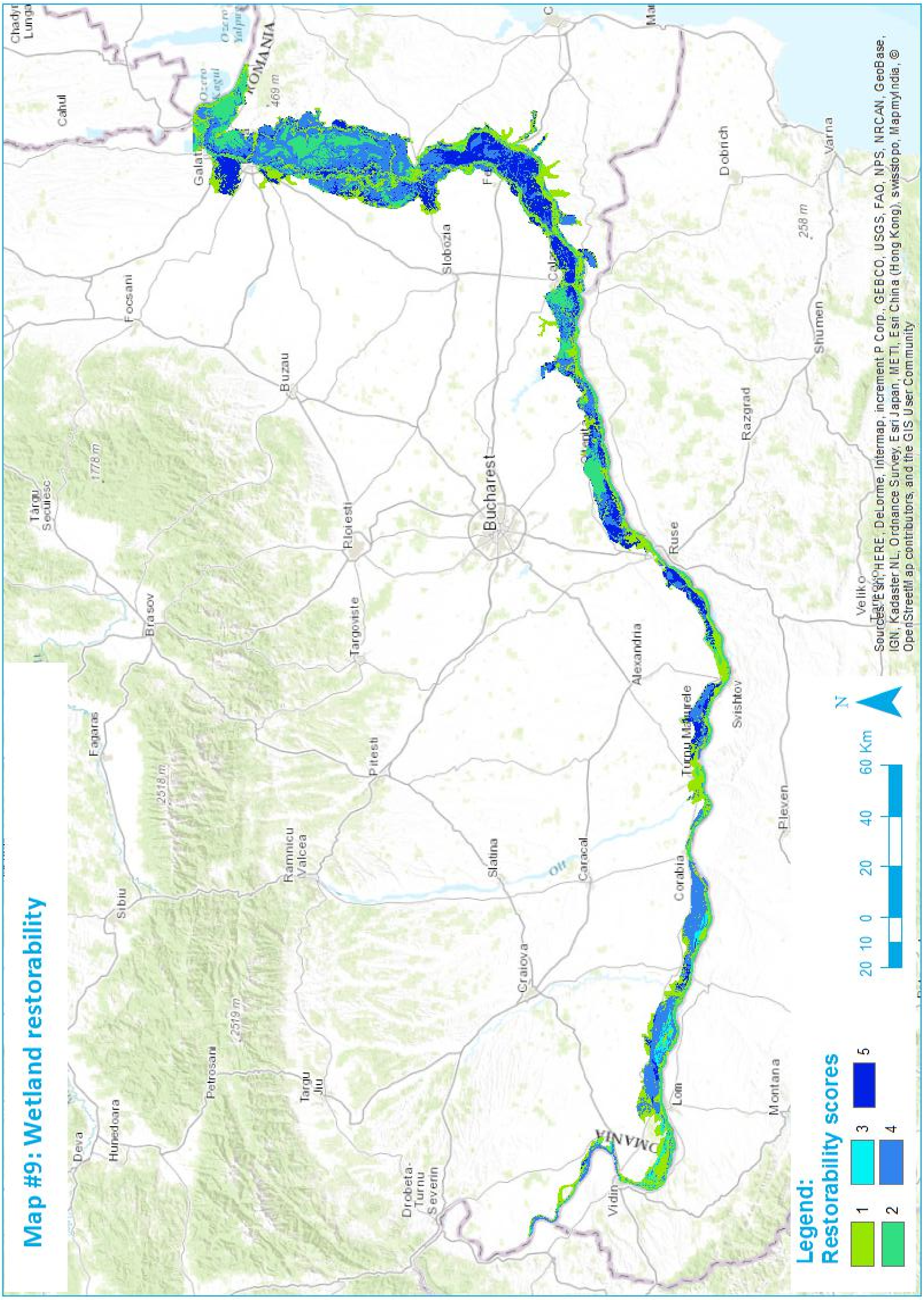
Olt



Map #9: Wetland restorability
Legend:
Restorability scores
1
2
3
4
5
20 10 0 20 40 60 Km
N
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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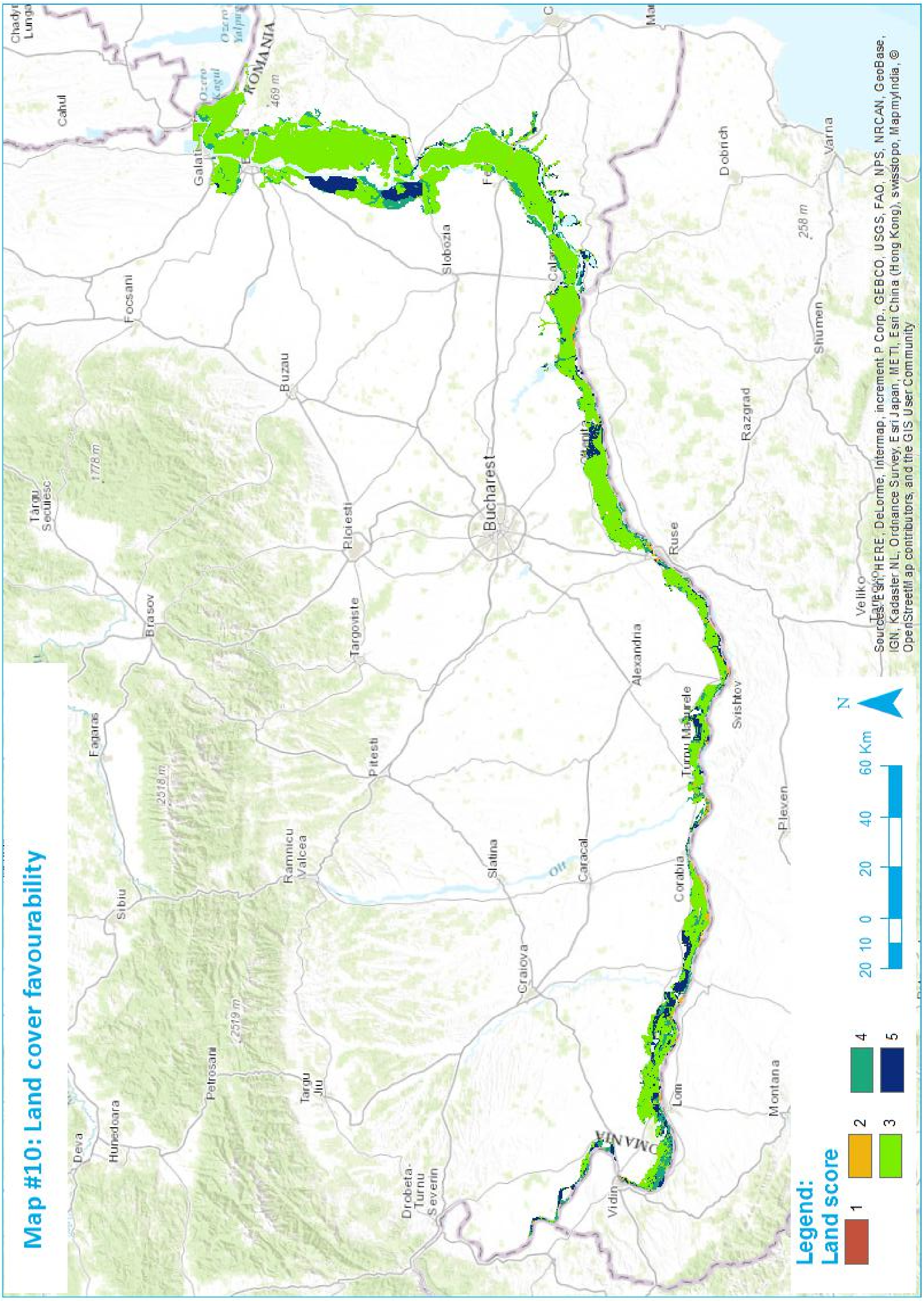
Map #10: Land cover favourability
Legend:
Land score
1
2
3
4
5
20 10 0 20 40 60 Km
N
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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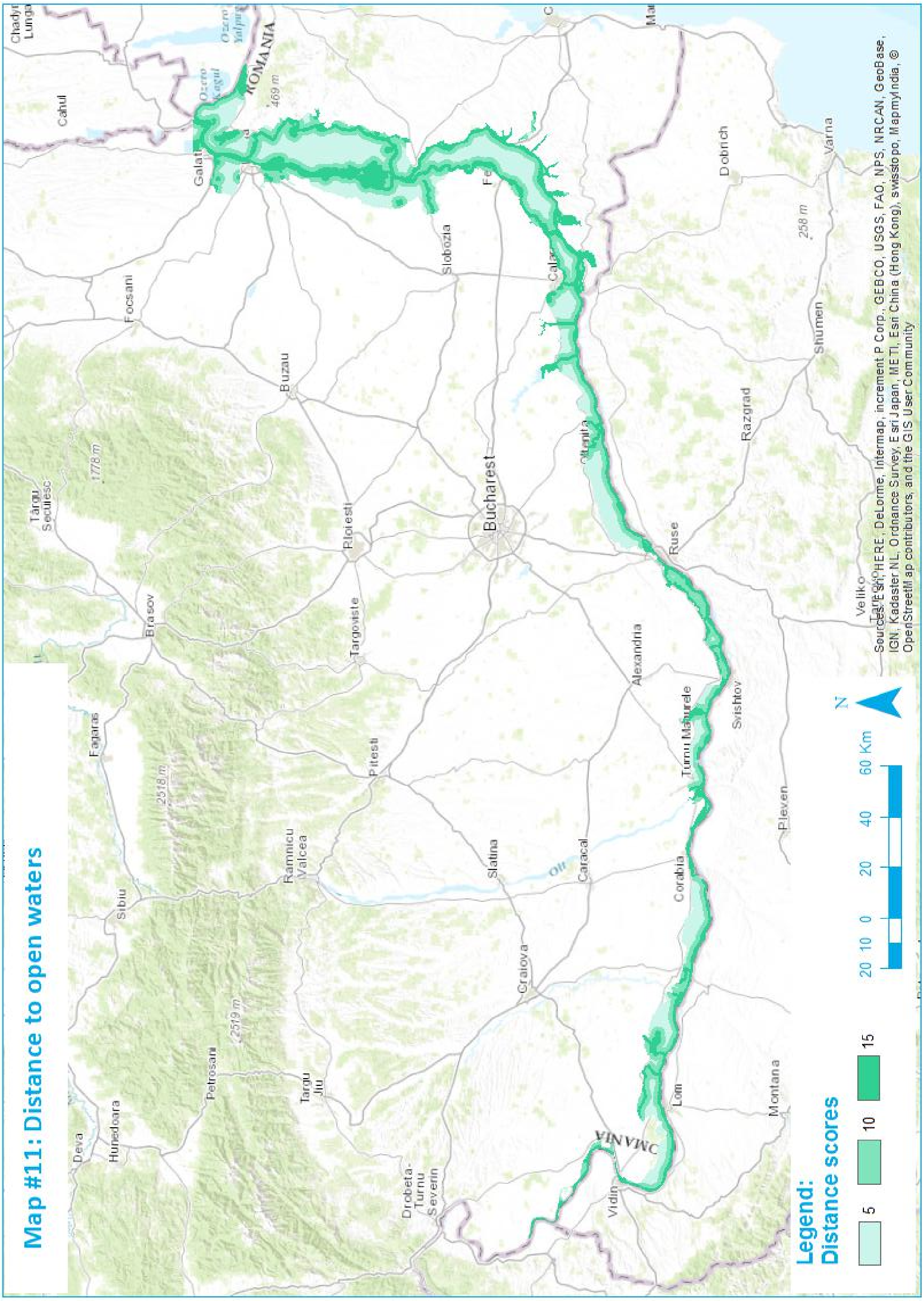
Map #11: Distance to open waters
Legend:
Distance scores
5
10
15
20 10 0 20 40 60 Km
N
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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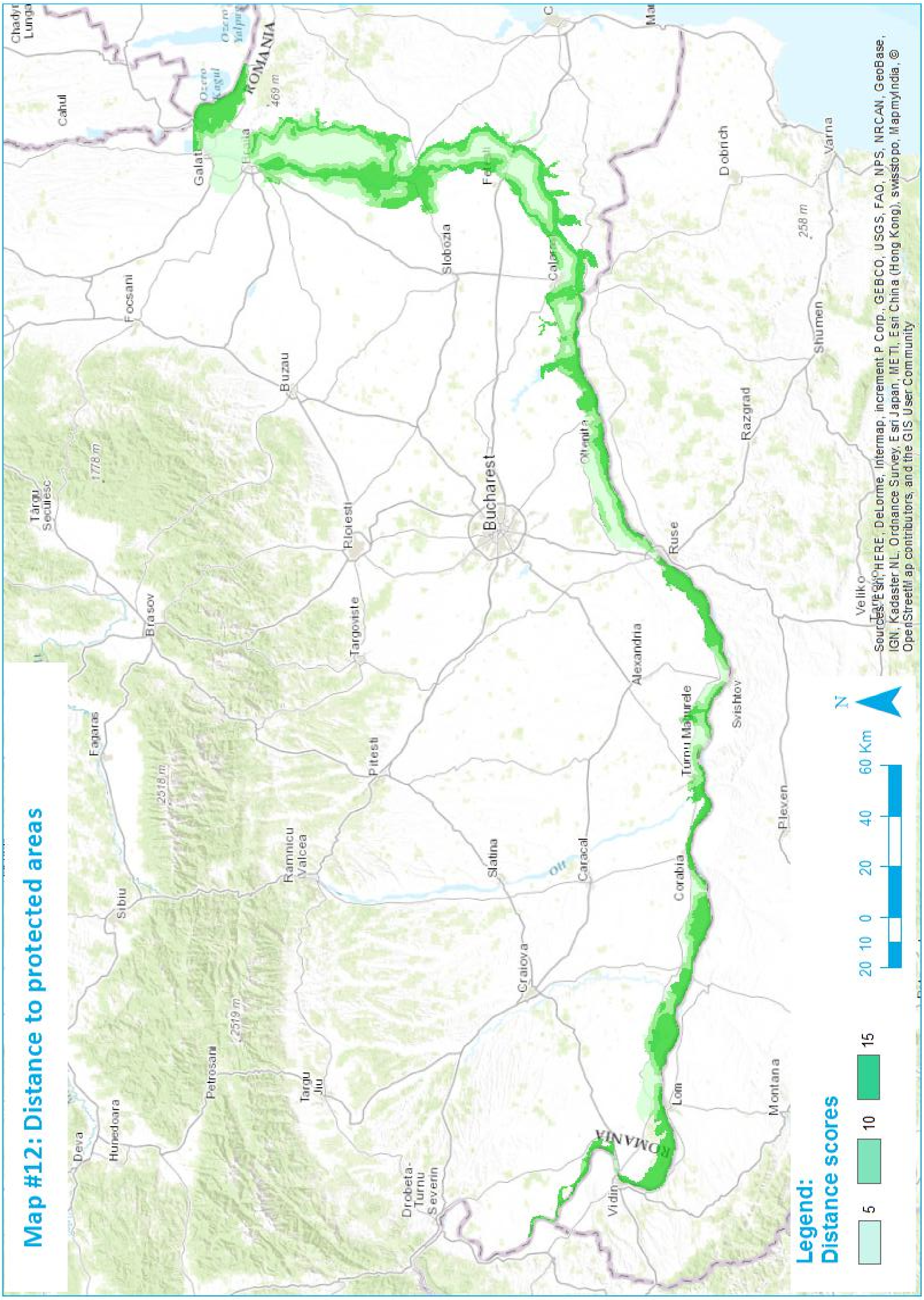
2518 m
2519 m
469 m
258 m



Map #12: Distance to protected areas
Legend:
Distance scores
5
10
15
20 10 0 20 40 60 Km
N
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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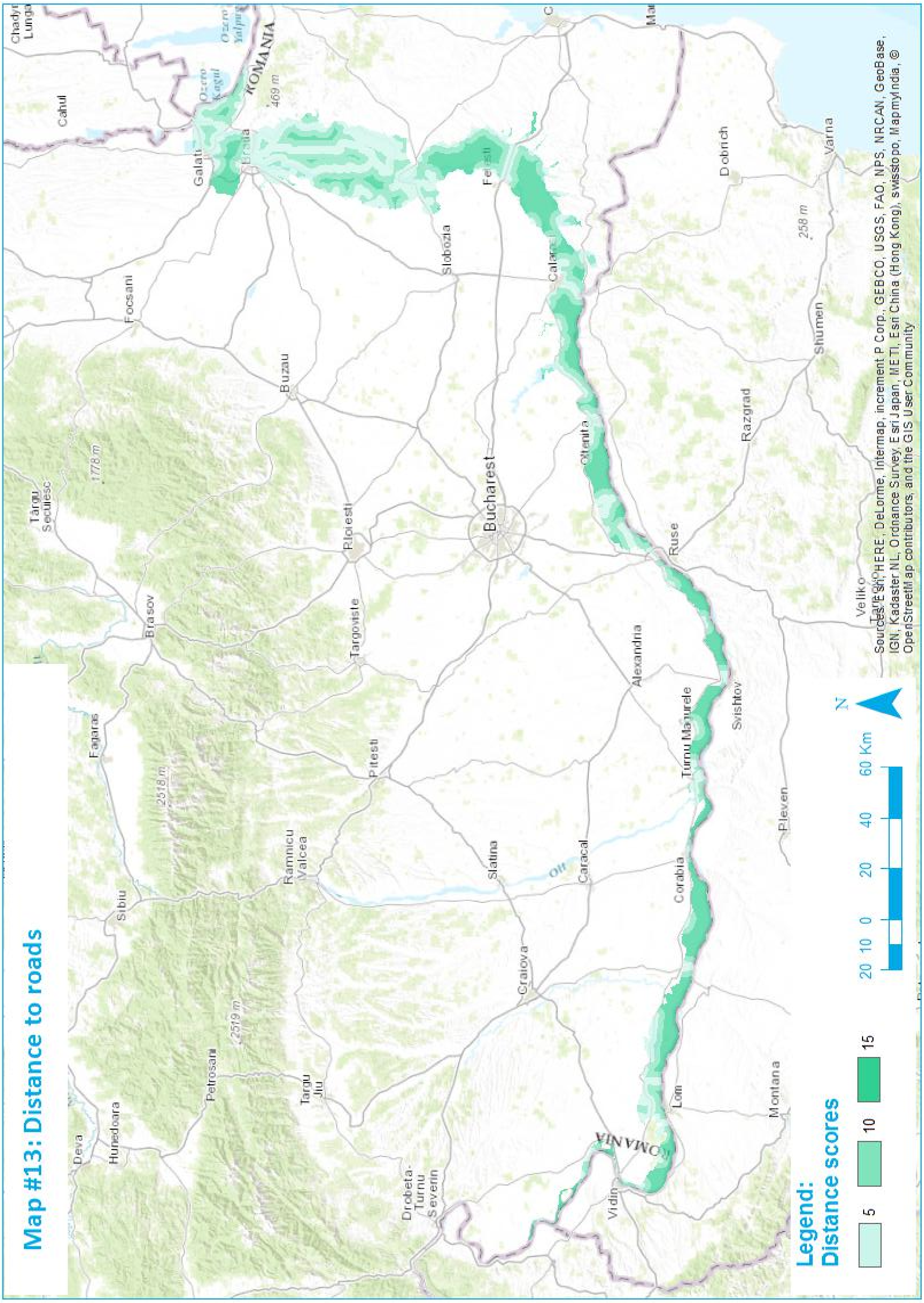
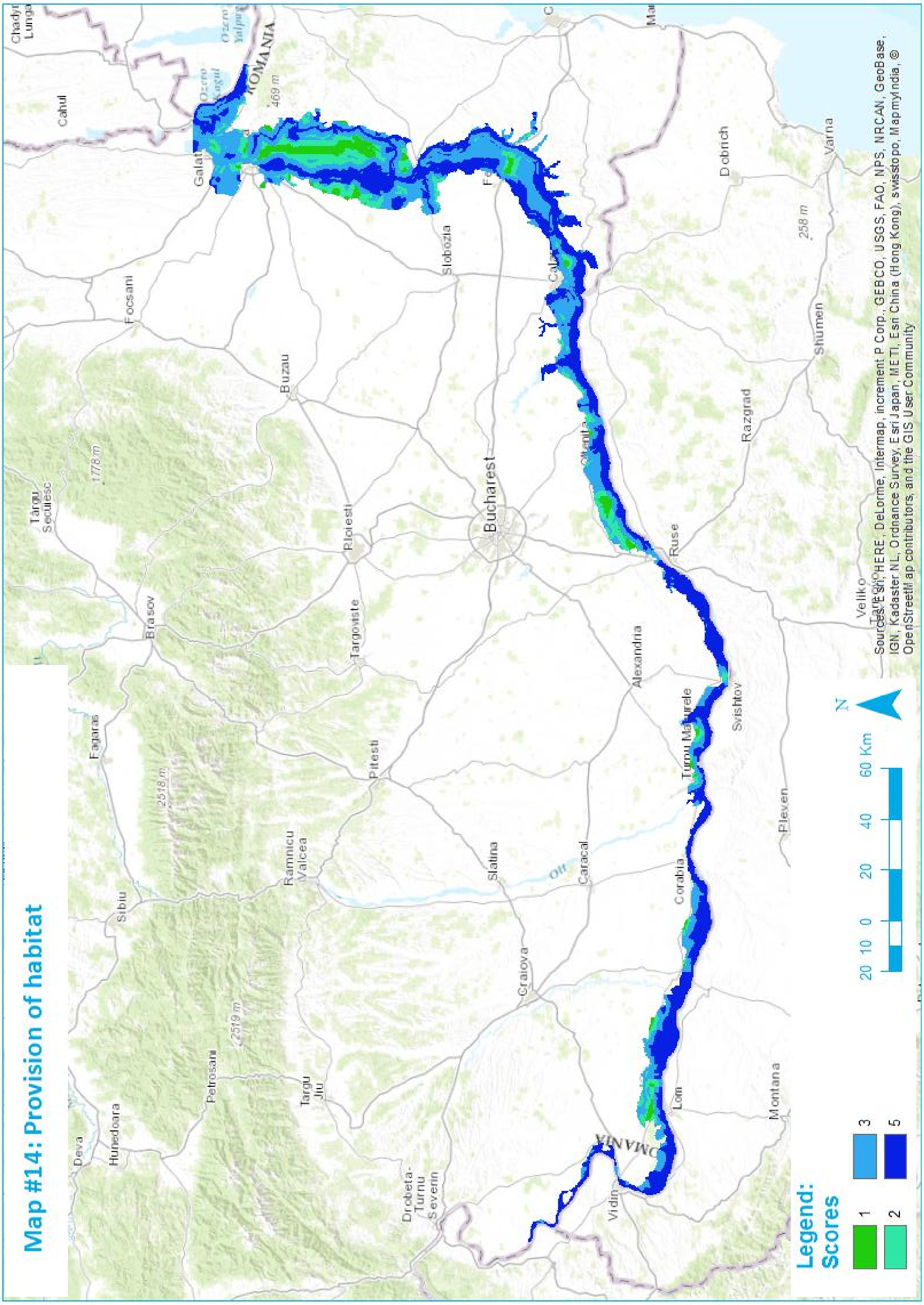
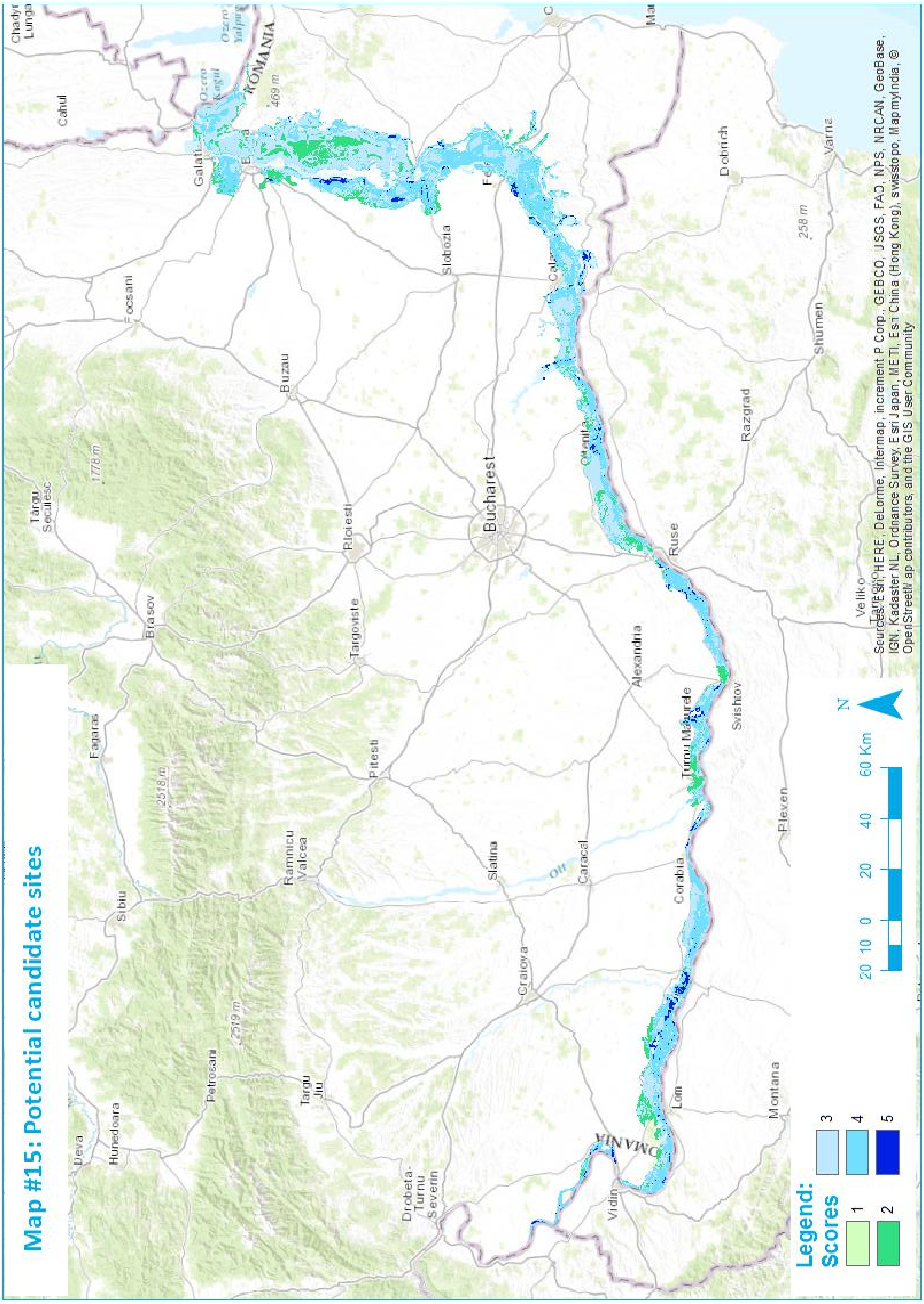


Map #13: Distance to roads
Legend:
Distance scores
5
10
15
20 10 0 20 40 60 Km
N



Map #14: Provision of habitat



Map #15: Potential candidate sites

3. Results of the Floodplain Restoration Opportunity Analysis

3.1. MCDA results and sensitivity modelling

Overall, the MCDA appears to be working as expected in identifying priority wetland restoration sites, especially in term of habitat provision for wildlife and restorability. The most apparent disadvantage in the MCDA is metrics consideration and scores for hydrological connectivity, since the variables used in this function does not adequately cover the true extent of flooding in certain areas at certain water heights (e.g. river confluences). This is not considered a major negative aspect in the selection of the future candidate site since these areas are already in the active floodplain, therefore not suitable for achieving the study objective of replenish targets. The quality of FROA would be improved if flood frequency maps of "active" or ecologically functional floodplain was available as GIS layer (as described in section 2.2). Another layer that would benefit the MCDA is one showing privately owned lands, state concessions and local public lands, which would be then used to expand the land cover favourability.

If additional useable GIS layers are made available in the future (e.g. land price, sensitive industrial sites, restoration costs, etc) or it is decided that certain variables should be weighted or scaled differently, or if different restoration blocks need to be evaluated, the nature of the MDCA is such that these changes can be made fairly easily and new maps can be generated quickly.

The MCDA produced quite a large number of sites (table 3), which is a result of the conversion of the input data to a 10m to 10m-cell size raster and also due to the high fragmentation imposed mainly by the channel network in the land cover favorability metrics. This translate into identification of the minimum potential restoration areas of only 0,05 ha which is the surface of a raster pixel.

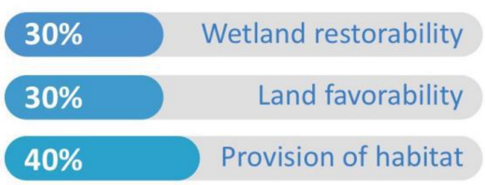


Figure 3: Baseline MCDA weighting

The baseline MCDA model weights wetland restorability and land favorability each at 30% and the provision of wildlife habitat at 40% (figure 3). The baseline analysis produced 58,116 sites with different block sizes covering a total surface of 458,708 ha (Table 3). Sites receiving suitability score of three or above – site with classified value of 3- medium, 4-medium high and 5- high, count for 86% (395,798 ha) of the overall potential restoration areas, with large proportion distributed to medium (43,76%) and medium high potential sites (39,9%).

The maximum area of contiguous block site is 45,311 ha classified as medium value potential restoration site followed by a medium high potential restoration site with a contiguous block size of 19,778 ha. High potential restoration sites account only for 2,6% of the total restoration potential areas with a maximum contiguous block size of only 1,293 ha.

Table 3: Final restoration prioritization scoring distribution for the baseline MCDA for the Danube River (total sites and hectares).

Classified value	Wetland 'restorability'		Provision of habitat		Land cover favorability		All functions	
	# of sites	Total ha	# of sites	Total ha	# of sites	Total ha	# of sites	Total ha
1	26,807	147,620	49	33,094	3	24,81	31	41,84
2	7,996	119,615	878	72,370	1,484	6,436	14,230	32,868
3	847	9,881	2,515	242,570	12,403	365,400	22,093	200,727
4	21,424	220,495	-	-	2,927	39,972	18,584	183,046
5	17,248	112180	96	261,942	4,003	42,431	3,878	12,026

As mentioned previously, variable weighting was inconsistent throughout the 27 studies consulted in a literature review of GIS-based wetland prioritization models performed by Widis et al (2015). In order to assess the sensitivity of our MCDA results to various weighting equations, we explored four alternative scenarios, each of which significantly altered the specific weights attached to the three performance functions (figure 4).

For the first alternative scenario in the sensitivity analysis, we assume equal weighting between wetland "restorability" and provision of habitat functions, each receiving 40% weight and assigning 20% weight to land cover favorability (figure 4). The results produced 65,804 sites covering a total area of 458,711 ha. Compared to the baseline MCDA there was an increase to 7,78% of sites receiving 5-high suitability scores, which includes higher values of maximum block size. The only decrease in suitability scoring was in sites receiving four, which dropped 11% compared to the baseline alternative.

Next, we reversed weighting between the functions metric, first putting emphasis on the importance of provision of habitat and land favorability in the analysis, each receiving a 40% weight (wetland restorability received 20%) and then assigning a 40% weight to wetland restorability and land favorability functions, while provision of habitats received 20% weight (figure 4b and 4c). Compared to baseline MCDA both weighting iteration produced small changes in results, with some percent increases in suitability score for values of five and three (table 4) and slight decline in number of suitability scores for vale four, especially when restorability is less considered in the analysis (scenario b).

Figure 4: Sensitivity analysis based on four alternative scenarios: a) focus on provision of habitat and wetland "restorability"; b) high importance of land favorability and provision of habitat functions; c) focus on wetland restorability and land favorability and d) equal weighting of all functions.

The final alternative scenario uses equal weighting of all functions, each receiving 33% weights. The results produced similar distribution of scoring as the baseline MCDA with minor reallocation of numbers between suitability score of values three and four.

The results of our sensitivity analysis underscore the importance of functions weighting in multi-criteria analysis. Modification in variable weighting result in minor changes of the final results in general when alternatives are compared. However, the importance of each function weighting in sensitivity analyses results in moderate changes (less than 15%) of suitability classes with values of three and four and minor changes (5%) of high suitability values.

Table 4: Distribution of suitability scores among sensitivity analyses (hectares and percentages)

Classs. value	Baseline		Less land		Less restorability		Less habitat		Equal influence	
	Total ha	%	Total ha	%	Total ha	%	Total ha	%	Total ha	%
1	42	0.01	3,969	0.87	42	0.01	42	0.01	42	0.01
2	62,868	13.71	64,169	13.99	51,756	11.28	64,513	14.06	62,932	13.71
3	200,726	43.76	223,560	48.74	261,196	56.94	218,621	47.64	220,233	47.99
4	183,046	39.90	131,343	28.63	133,076	29.01	160,898	35.06	163,601	35.65
5	12,026	2.62	35,670	7.78	12,677	2.76	14,816	3.23	12,075	2.63

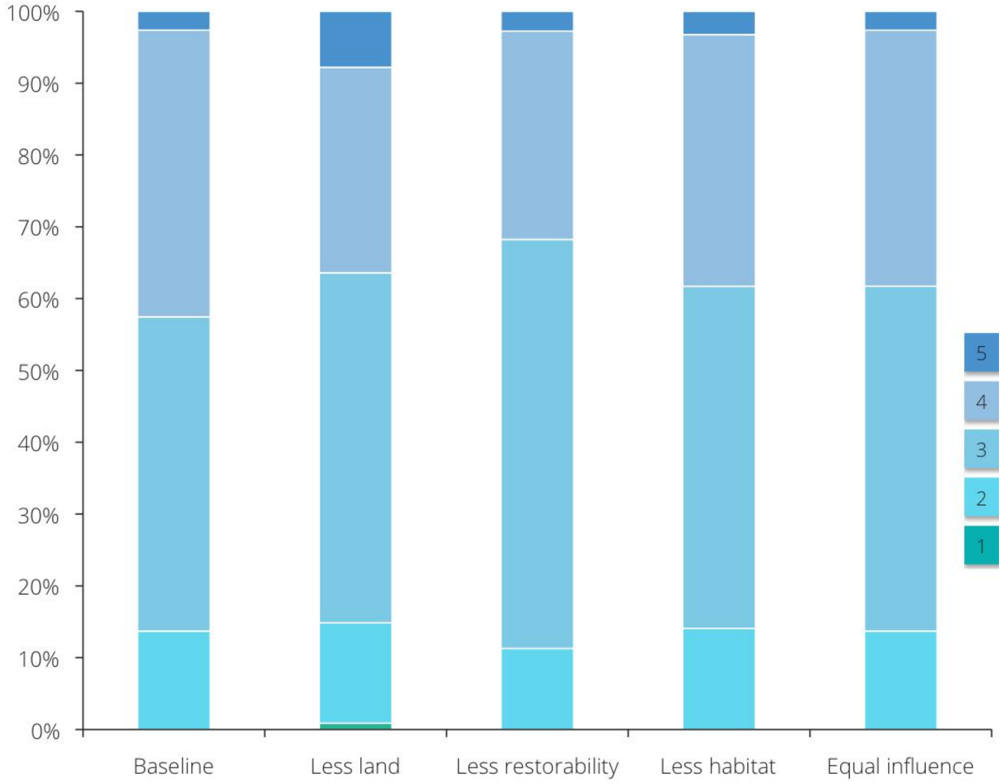


Figure 5: Final suitability scores distribution among sensitivity analyses

Guided by similar approaches and given the data constrains, the results of our MCDA proves the reliability of such tools to identify potential wetland restoration sites and prioritize them for desktop planning purposes and guide further investments on the field. While the model is still un-informed by hydrological model and calibration of recent land uses and ownership, a major advantage of the MCDA is the ranking capabilities depending of proposed objectives and the capacity of the beneficiaries. Validation of the most suitable sites including local knowledge, site visits and the quality of the potential for restoration is the next step helping to determine the potential candidate sites and finally to decide on the further investments on the restoration site.

While we consider that the MCDA achieves the proposed objectives of identifying and ranking potential restoration sites along the Danube River in Romania, the wetland restorability metric should be substantially improved with the FIP based on hydrological gauges data and the identification of "active floodplain" for each river reach. Such improvement to the MCDA with recent data on hydrology and land use will first make a clearer understanding of where wetland restoration will be more effective and where it will likely be accepted by those who influence the decision about the restoration investments (as well by the locals). Integration of other ecosystem services models and/or cost-benefits analyses will also strengthen the MCDA and the planning of the restoration actions along the Danube River.

3.2. Summary of constrains on opportunities for restoration on Danube River reaches

3.2.1. Iron Gates II to Calafat

The uppermost reach of the study area, between Iron Gates dam II and Calafat, has relatively large morphological floodplain constrained by uplands (terrace) of higher elevation. This river reach has higher floodplain altitudes, frequently over 33m and even 40m. Almost all villages along this reach are situated on the river terrace, therefore the flooding risk of the villages is insignificant for all the major flooding events. However, there is a probability of flood risk for Pristol and Cozia villages during the 1,000-year flood events that can outrun the actual protection dykes. For this area there are proposals to consolidate the existing dyke of 6 km in order to assure a better protection of Pristol - Cozia villages (REELD, 2010).

Nearly the entire corridor along this Danube river reach is designated as Natura 2000 site, with two pSCI (Danube at Garla Mare – Maglavit ROSCI0299, Jiana ROSCI0306) partially overlapping three SPA (Blahnita ROSPA0011, Gruia – Garla Mare ROSPA0046, Maglavit ROSPA0074).

Areas with high and medium-high potential for restoration along this reach are at Salcia and Maglavit. There are approximately 200 ha of abandoned fish farm with high potential for restoration along the corridor at Salcia and other arable lands with mix uses as well as planted forest with medium-high potential for restoration complete the floodplain landscape. More than half of the river corridor at Salcia area has a chance to achieve 50 cm FIP at heights above the water (HAR) of 200 cm (the eastern part near the confluence) and the other half at 250 cm HAR. The parcel of arable land looks less fragmented suggesting few owners and the fish farm is state owned under the management of NAFA but is free for concession.

At Salcia potential restoration site there is no archaeological site registered in RAR. Infrastructure is insignificant and consist only from the fish farm contour and separation dykes and a transversal road facilitating the access from Salcia to Danube River, which is ending to fish farm. Many dirt roads necessary to access surrounding land parcels, forest and pasture are nearby the abandoned fish farm. There are no developed lands except a small farm with its buildings that is situated in the north proximity of the abandoned fish farm along the access road. However these buildings are on higher grounds and protected by the actual fish farm contour dyke from floods.

The area was considered having high potential for restoration in a previous study done by WWF (Schwartz 2010). Other stakeholders like ANAR, identified potential restoration opportunities along this reach at Salcia as mentioned by flood risk department staff during some informal meetings.

The area at Salcia has potential to be re-connected with the Danube flood pulse through out either the existing drainage channel from the western part or through the main inlet f the fish farm.

The other high and medium-high potential restoration areas along this reach are at the old Danube channel (a former meander actually) at Maglavit village (see map 19). The entire area consists of a series of fish farm ponds, lakes, marshy areas and arable lands along the Danube River protection dyke and the former meander (old channel/side arm). The north part of the area consisting of the fish farm and Hunia Lake has a chance to achieve 50 FIP at 300 m HAR while the southern area where Golenti Lake is situated can reach a 50 cm FIP during 200 cm HAR.

Between the Danube River and the former meander there is a large area/parcel with forest, pastures waterlogged vegetation crossed by dirt roads to access the area, somehow suggesting an intensive use with many forest owners and farmers/shepherds. Right in the middle of this forested area there is a monastery listed on the RAR that is accessed by a consolidated and raised road probably having also a role for flood protection. In the northeast part of the area there is an animal-breeding farm that could be listed as IPPC unit, which can restrict together with the road and protection dyke the opportunities for restoration/re-connection of the former meander. The entire area has low-insignificant risk of flooding during 100-years floods.

The area was not mentioned as potential restoration site in previous studies and stakeholders did not identify restoration opportunities along the old meander at Maglavit. However, further investigations of potential restoration opportunities could focus on the improvement of local hydrology and/or water storage in the fish farm (using abandoned fish ponds) and marsh areas to benefit protected species and general management of the areas and associated economic benefits.

3.2.2. Calafat to Ghidici

From Calafat to Rast the Danube River makes a big turn from the north-south flowing direction to west-east flowing, with a change in flow energy and the appearance of several islands. There is an extensive floodplain of approximately 5 km in width for an approximately 50 km length of the river (see map 20). The floodplain landscape is predominantly formed by sand dunes and micro-depressions with stagnant water mostly feed from underground and rainwater. There is a mix of land uses in this corridor with natural forest and grasslands, scrubland, waterlogged vegetation and forest, tree plantation, lakes and ponds pastures and arable lands and moderately fragmented parcels.

The corridor at this reach is included in the Natura 2000 sites Ciuperceni Desa ROSCI0039 and Calafat – Ciuperceni – Desa ROSPA0013, which can offer more great opportunity for some habitat management measures and wetland restoration. The corridor is scattered by many dirt roads to access arable land, pastures and plantation trees and there is a network of drainage/irrigation channels south to Ciuperceni – Desa – Pisculet villages.

The entire floodplain between Ciupeceni and Ghidici is flooded during 100-year events, however the lower parts of intra-dune areas increase the chances of 50 cm FIP during 150 cm HAR in the southwest and southeast part of this reach where some natural/former lakes/ponds exist/existed, e.g. Goniceanului, Arcerului, Catoaica, Casapu and Tarova lakes/ponds. At 300 cm HAR the 50 cm FIP area extend south Desa and Ciuperceni villages thus increasing the restoration opportunities to the entire floodplain with a mix of habitats of sand dunes, forest and wetlands. However, due to sandy substrate, plenty of natural vegetation and land fragmentation the area from Ciuperceni to Ghidici has medium-high restoration potential. Some constrains to restoration could be given by the complicated ownership and also by the existence of Desa-Castravita archaeological site situated near Desa village. There is also a roman settlement that is included in RAR at Ghidici – Tarova pond.

It is not known if local stakeholders have identified any specific restoration opportunities here but the area is mentioned as potential restoration site in previous WWF studies. REELD study does not include this area as potential restoration site probably because villages in this reach are not at risk to be flooded during 100-year floods. Further investigation could help the decision for any further investments into this area that is not protected by dykes along the Danube River and is potentially flooded during some minor recurrent floods.

3.2.3. Ghidici to Bechet

This reach has the most extended floodplain of the Danube before to split into branches and turn its course to north, especially the sector between Bistret and Jiu River where the floodplain width is approximately 11 km, between Bistret and Macesu de Jos (see map 21).

The western part of this Danube reach from Ghidici to Bistret villages is more artificial with heavily fragmented small arable parcels (many of 2-5 ha) with mix use, rice fields, some small areas of waterlogged vegetation, pastures and forest. The floodplain corridor at this reach is part of a large polder Ghidici – Rast – Bistret (9,085 ha) that is considered vulnerable to flooding and proposed for restoration according to REELD and previous WWF studies. Due to land uses, the area has medium and medium-high restoration potential and only few parcels have high potential for restoration that can be constrained by the increased land fragmentation, ownership and existing irrigation infrastructure. Dyke relocation can be considered as an alternative to make room for green infrastructure for flood measures build on pastures situated in the eastern part of this area. The Natura 2000 sites Calafat – Ciuperceni – Dunare (ROSPA0013) and Ciperceeni – Desa (ROSCI0039) cover only limited areas of this Danube reach mostly the area between dyke protection and the river.

The local infrastructure consists of a protection dyke along the Danube with an extension towards northwest at Ghidici that close the large polder of Ghidici – Rast – Bistret. An extensive irrigation and drainage network together with a pumping station at Danube complete the infrastructure of this polder. Many dirt roads are used to access the arable/pasture land parcels and tree plantation are along the Danube in the dyke-river zone.

The central part of this Danube reach, the floodplain between Bistret and Jiu River is almost entirely designated as Natura 2000 sites with the exception of lands south Gighera village and Bistretu Nou that are not included in Jiu Corridor (ROSCI0045), Jiu – Danube Confluence (ROSPA0023) or Bistret (ROSPA0010). The land use is diverse with a mix of arable lands, e.g fish-farms, rice fields, pasture and forest patches, waterlogged vegetation which are quite fragmented in large parcels between 20 to 50 ha in average. The local infrastructure is also diverse serving the land use and include protection dyke along the Danube and for Lake bistret and Nasta, fish farm and rice fields compartment dykes, pumping station and weir at the Danube, small buildings, dirt roads, drainage and irrigation channels. Most of the area has medium-high restoration potential and high potential areas with important compact surfaces are present in the south-eastern part of the polder, where rice fields are extended. The entire Bistret polder is proposed for ecological restoration by REELD study and other studies e.g. Redevelopment of the Danube floodplains in Romania: Scenarios for the development of the floodplains between Ghidici and Zaval (EURODITE, 2011) provide with detailed information on alternatives for restoration and stakeholder preferences. One archaeological site is mentioned in RAR as metal lodge from Dragobalta pond near Plosca village.

The floodplain corridor between Ghidici and Jiu River has a chance to achieve 50 cm FIP at 200 cm HAR over almost the entire area according to our analyses. Other studies (Chendes, 2013) show the area can be flooded entirely at medium frequency floods of approximately 32 m absolute altitude. The author of this study points out that there is a small difference between maximum and average flooding scenarios on this corridor due to the low altitudes in the floodplain "with negative values in the central areas bound northwards by the strongly dipping slopes of the terrace scarp".

The eastern part of this Danube reach, from Jiu River to Bechet is part of the Jiu Corrdior (ROSCI0045) and Jiu- Danube Confluence (ROSPA0023) Natura 200 sites. This floodplain here has high and medium-high restoration potential with chances to achieve 50 cm FIP at HAR of 200 cm on most of the floodplain area and 300 between Jiu River and Bechet. However, the land is fragmented with block size of 5 – 10 ha (in western part) and 30 – 50 ha (eastern part) due to land use (mostly mix arable uses) and drainage/irrigation network connected to the Danube River by a pumping station/sluice. Some pastures along the Jiet River contribute to general restoration potential that can be constrained by presence of the dyke protection along the Danube and small farm buildings, indicating a preference of the local stakeholders for status quo land use.

3.2.4. Bechet to Turnu Magurele

From Bechet to Turnu Magurele there is an extensive floodplain of approximately 8 km wide between Sarata and Potelu and, approximately 5 km wide further downstream near to Orlea village, which combined are the most important areas for restoration along this Danube reach (from Bechet to Corabia). This sector between Gracov and Olt confluence has unconstrained floodplain areas without protection dykes that were subject to hydrological improvements for some bird species.

The entire Danube floodplain between Bechet and Olt River has a chance to achieve 50 cm FIP at 200 cm HAR (see map 22). The restoration potential is medium-high for the floodplain from Bechet to Orlea with large block size that can be available for restoration, e.g. large surface pastures (≈100 ha), arable lands of 100 to 300 ha block size that are subject to concession from ADS and/or from local councils. However, there are also highly fragmented arable lands (10-50 ha) and drainage/irrigation infrastructure with weir and big pumping station that serve both lands within the floodplain and those from the terrace. One archaeological site is mentioned in RAR at Valea Caselor as Vinca de la Sura settlement.

The western part of this floodplain from Bechet to Dabuleni is included in Dabuleni Sands Natura 2000 site (ROSPA0135) and Jiu Corridor (ROSCI0045), while the eastern part is included in Corabia – Turnu Magurele (ROSCI0044) and Olt – Danube Confluence (ROSPA0024) Natura 200 sites. A large area between Grojdiboru and Orlea remain unprotected which ca constrain restoration opportunities here together with existing infrastructure. However, there is a strong support from local communities to open the weir at the Danube and flood important areas as a mean to wetland restoration and recreation of former Potelu Lake. Bechet – Dabuleni and Dabuleni – Poteu – Corabia polders are also proposed for restoration in the REELD study.

The floodplain area between Olt River and Turnu Magurele offers limited restoration opportunities with some small areas between Old – Danube confluence (actual oxbow Zatuan) and Saiu River that needs further investigation (due to HAR limitations at river confluences).

It is not known if local stakeholders have identified any specific restoration opportunities here Further investigation could help the decision for any further investments into this area that is not protected by dykes along the Danube River and is potentially flooded during some minor recurrent floods.

3.2.5. Turnu Magurele to Zimnicea

This floodplain reach offers medium-high and high restoration potential mostly in two large arable polders Seaca – Vanatori and Suhaia – Zimnicea (wit a total area of 14161 ha) that are separated by the Suhaia Lake (see map 23). These polders have a chance to achieve 50 cm FIP at 300 cm HAR, but the restoration potential is also given by the close vicinity to the main inlet channel of Suhaia Lake, where all the high restoration potential areas are distributed. This inlet channel is serving to store water in the Suhaia Lake through a pumping station/weir at the Danube and to feed irrigation network that scatters the arable polders. The land use is mix including pastures of large parcels (≈100 ha), fish farm, rice fields and arable land of ≈10 ha in average size fragmented by irrigation/drainage channels and dirt roads. The area is part of Suhaia (ROSPA0102) and Corabia – Turnu Magurele (ROSCI0044) Natura 200 sites. Several medieval discoveries are found at Suhaia according to RAR.

There is high potential for the restoration of the abandoned fish farm ponds and rice field, either to improve the existing management or to reconnect them through Suhaia inlet channel to Danube flood pulse or Calmatui River. The existing land use and ownership as well as infrastructure can be a major constrain to restoration opportunities, however the two existing polders along the Danube reach are proposed as water storage polders during high floods on the Danube River.

It is not known if stakeholders have identified any specific restoration opportunities here but the area is mentioned as potential restoration site in previous WWF studies. REELD study does consider Seaca- - Vanatori and Suhaia – Zimnicea as retention polders and in 2016 a large area on east side of Suhaia Lake was flooded unintentionally (Doronde, et. all, 2016, personal communication). Further investigation could help the decision for any further investments into this area that can be potentially flooded during some recurrent floods using the Suhaia Lake and channel network to divert water on large pasture areas.

3.2.6. Zimnicea to Giurgiu

At Zimnicea the Danube River makes a slight turn to northeast and until Giurgiu the floodplain width is around 4 km in with the largest extension of 6 km at Vedea River (see map 24). The floodplain along this reach is characterized by the existence of well-defined terraces and by small rivers and/or natural channels flowing at the base of the Danube's terrace e.g. Pasarea, Vedea, Pasarea channel, Cama. These river network drain most of the irrigation systems that was build here in two main arable polders, Nasturel - Bujoru – Pietrosani and Vedea – Slobozia with an approximate area of 23,000 ha. The floodplain between Bujoru and Slobozia villages is also part of two Natura 2000 sites, Vedea – Dunare (ROSPA0108) and Gura Vedei – Saica – Slobozia (ROSCI0088).

The restoration potential is high and medium-high along the floodplain between Nasturelu and Bujoru with chances to achieve first 50 cm of FIP at 300 cm height above river. The arable land is highly fragmented across this reach with land block units ranging from 20 ha to 150 ha, separated by natural or man-made channels for irrigation and drainage. Near Pietrosani village there is an archaeological site indexed in RAR named Poplar Lake.

The floodplain between Gaujani and Slobozia has medium-high restoration potential according to our study, with 50 cm FIP chance at 300 cm HAR but with some large pastures of approximately 100 ha present that can be connected to Pasarea or Cama rivers. However, land is fragmented with varying block size of 50 to 150 ha separated by irrigation/drainage network. A pumping station/weir at the Danube and many dirt roads complete the local infrastructure hat can constrain restoration investments in this arable polder, which is considered as a retention area during floods by the national authorities (REELD).

According to previous WWF studies the area between Vedea and Slobozia has very high priority for restoration but so far it is not known if any stakeholders have identified any specific restoration opportunities here Further investigation could help the decision for any further investments into this area that could offer a potential for local restoration approaches in relation with existing rivers by flooding some pastures.

3.2.7. Giurgiu to Oltenita

With an average width of 9 km the floodplain between Giurgiu and Oltenita (Arges River) (see map 25) is today one big arable polder of approximately 42,000 ha Gostinu – Greaca – Arges and a smaller polder between Giurgiu - Gostinu – Baneasa. The restoration potential here is medium to medium-high on most of the floodplain area mostly because the intensive agriculture practices between the dykes, the dense irrigation/drainage network and the extension of the Natura 2000 site (related to provision of habitat criteria only three site are found here Dunare – Oltenita ROSPA0038 and Gura Vedei – Saica – Slobozia ROSCI0088, Ostrovu Lung – Gostinu ROSPA0090) is between the Danube River and the protection dyke. Although the chances to achieve a 50 cm FIS are at 150 - 200 HAR in the eastern part of this Danube reach, the only high potential according to our study is restricted on small surfaces in the proximity of Arges River and Diaconu channel. Previous pre-feasibility studies requested by WWF and conducted by DDNI indicate the opportunities for the restoration of former Greaca Lake, which is also covered by FIP of 50 cm. The existing archaeological site from Baneasa Coada – Gostinu hill and from Cascioarele – Coinea 2 does not seem to be limiting the potential investments for restoration opportunities in this reach.

A very large arable landscape with channels and local roads scattering the floodplain, together with pumping station/weir at the Danube can restrict the restoration opportunities along this reach. However, local stakeholders are open for the restoration of Greaca Lake and other floodplain restoration activities as long as the economic incentives from agriculture are not considerably affected. The entire arable polder of Gostinu – Greaca – Arges is to be designated as retention areas during extreme floods according to national authorities (REELD study).

3.2.8. Oltenita to Calarasi

The Danube floodplain between Oltenita and Calarasi is separated in two large arable polders: Oltenita – Manastirea and Dorobantu – Calarasi by a large irrigation channel connecting Danube with Motistea Lake. Therefore, all this reach is disconnected from the river. Along this reach we found two main areas with high restoration potential: at Dorobantu and Iezerul Calarasi both areas situated along irrigation channels (see map 26). Other high potential restoration areas are situated along the Danube river and all are influenced by the presence of Natura 200 sites Oltentia - Ulmeni (ROSPA0136), Oltenita - Mostistea - Chiciu (ROSCI0131), Ciocanesti – Dunare (ROSPA0021), Iezerul Calarasi (ROSPA0051).

Various arable land uses with block sizes between 30 -100 ha and even more, pumping stations, irrigation/drainage network, protection dyke along the Danube River and polder separation dykes complete the floodplain landscape and can limit the restoration opportunities in this Danube reach. Although, the chances to achieve a 50 cm FIS are at 150 cm HAR on the floodplain here, the intensive agriculture practices determined the national authorities to consider this polders only as retention areas during extreme floods on the Danube.

Several archaeological sites are mentioned in RAR as lateen settlement “La Caramidarie”, Scoiceni monastery site, bronze settlement from Gradistea and Cosnogeni – Varasti settlement.

it is not known if any stakeholders have identified any specific restoration opportunities here but further investigation could help the decision for any further investments into this areas that could offer opportunities in relation with existing rivers/channels by flooding some pastures.

3.2.9. Calarasi to Harsova

From Călarași, the Danube River starts flowing towards north and splits into two main branches (Borcea and Danube) with two big islands, which are disconnected from the river through embankment. Altogether, the river branches, islands and morphological floodplain form an extensive floodplain of about 10-12 km, with maximum extension between Cegani and Dunarea (see map 27). The area is what used to be known as the inner delta due to its complex dynamic and varied habitat like ponds, lakes, swamps, floodplain forests, sand dunes, river canals and other typical wetlands. The floodplain on the left side of the river is more extended than the floodplain on the right side, which is confined by the Dobrogea plateau. However, due to its interest for agriculture most of the floodplain areas on the left side were disconnected from the river while on the right side there are still small portion of naturally flooded floodplain. Both sides have very well defined terrace (with just few exceptions along the sector Calarasi – Fetesti) where most of the settlements are located and well protected from floods.

Along this reach there we found more potential restoration areas along the right side of the floodplain then on the more extended floodplains on the left side, mostly due to sandy soils and agriculture.

Between Borcea and Fetesti there is a large area of arable lands with block size between 100 and 350 ha with mix uses where pastures have the largest distribution (arox. 600 ha). The extension of drainage network is limited to few transversal canals draining water to former side arm. The local infrastructure is scarce and, beside many dirt roads includes a road to the ferry pontoon at Borcea and farm establishment at Fetesti, which are protected by dykes. The restoration potential is high and medium-high in this area with chance to achieve a 50 cm FIP at 300 cm HAR. The floodplain here is included in the following natura 2000 sites: Bratul Borcea (ROSPA0012) and Fetesti swamp (ROSCI0319). Stakeholder preferences for floodplain restoration is not known but there are some opportunities for side arm reconnection and habitat improvement that need more investigation. According to REELD study this area is considered for restoration.

On the other side of the Danube River, the most promising restoration area is at Topalu where an area of aprox. 300 ha of pasture can be reconnected to the flood pulse by opening an abandoned sluice and reconnect a former side arm further north. The area has a chance to achieve first 50 cm of FIP at 200 cm HAR and improve the conservation status of habitats and species of Canarallele Dunarii Natura 2000 site (ROSCI0022). Some constrain to restoration opportunities could be the local people using the pasture for their livestock (mostly sheep) along these disconnected floodplain lands and the forestry district who has extensive poplar plantation north to this area identified in our study with medium-high restoration potential. A Roman fortress at Cichirigeaua hill is mentioned in RAR.

Other restoration opportunities could be the lands near Bugeac and Oltina lakes, identified with high restoration potential and chances to achieve 50 cm FIP at 200 cm HAR. This is due to their vicinity to both the river and the lake, however the areas are part of the lake complexes and some management of the water could e already in place. Nevertheless these areas worth a closer look to determine potential opportunities for restoration and fish farm management.

3.2.10. Harsova to Braila

This Danube reach between Harsova and Braila is used to be the largest, most productive and complex part of the former inner delta with very large floodplains and river branches (see map 28). Unfortunately, today here is the most productive arable polder along the lower Danube (officially recognized) and almost the entire floodplain is disconnected from the river. The only natural floodplain/wetland area along this Danube reach is the Small Marsh of Braila declared Natural Park and Natura 2000 site (ROSPA0005, ROSCI006). Due to extensive agriculture use of the lands along this reach we found only three large areas with high and medium-high restoration potential: Facaeni – Vladeni, Gura Calmatui – Stancuta – Tufesti and Ialomita River – Giurgeni, all on the left banks of the Borcea branch and, Garliciu on the right banks of the Danube River.

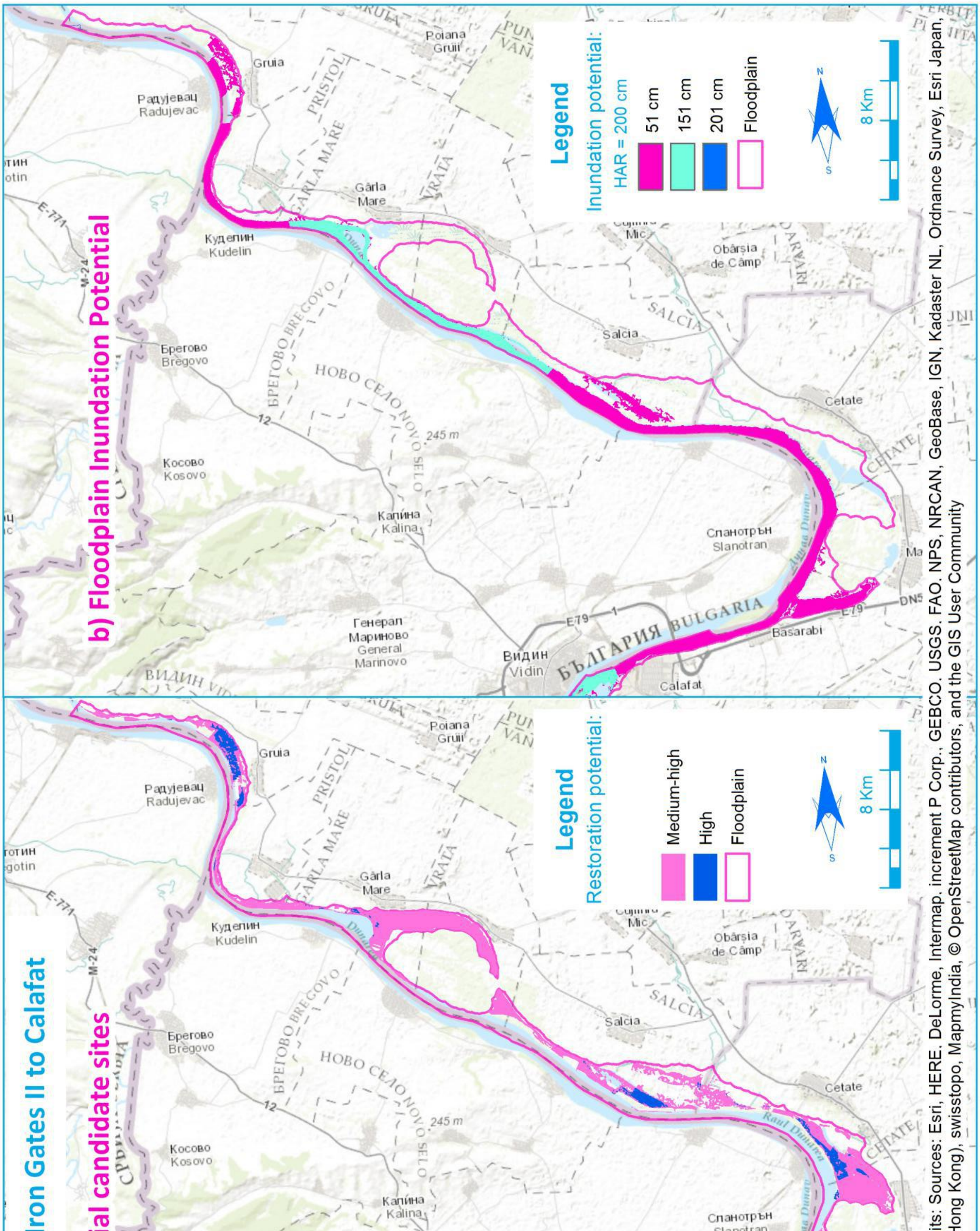
All these areas have chances to achieve first 50 cm FIP at 100 – 150 cm of HAR, however the land use and ownership is complicated with large rice fields near the Danube followed by large pastures parcels towards the terrace. This distribution of lands, together with local irrigation/drainage network and protection dykes along the river raise serious constrains to achieve the restoration potential in these areas. Stakeholder preference is not know but the area from Facaeni – Vladeni is proposed for ecological restoration by the national authorities (REELD study). Moreover, ANAR investigated the alternatives for restoration of the area of the confluence of Calmatui River with the Danube River, as part of project aiming at integrated planning (INTEREG Report, 2011). During personal debates with ANAR staff the area from Garliciu is also viewed with interest by the authorities as a demonstration site for floodplain restoration.

The large extent of Natura 200 sites along the Danube's flodplain is favouring the restoration approaches for habitat and species conservation in many of these potential candidate areas: Bratul Borcea (ROSPA0012), Bordusani – Borcea (ROSCI0278), Saraturile de la Gura Ialomitei – Mihai Bravu (ROSCI0389), Bertestii de Sus – Gura Ialomitei (ROSPA0111), Dunarea Veche – macin branch (ROSPA0040), Macin Branch (ROSCI0012).

Along this Danube reach there are numerous archaeological sites (tumuli and settlements) mentioned in RAR.

3.2.11. Braila to Isaccea

This reach is where the Danube River turns again to its general flowing direction from wets to east (see map 29) and the floodplain are disconnected from the river. Due to land uses, mostly industrial - urban and agriculture, our analysis have found any restoration potential, however the Cats bend is one restoration area that was investigated before by WWF, INCDD and local partners. Here together with local communities alternatives to reconnect a former side arms and restore some areas have agreed but due to land ownership the restoration action are stopped.


Map #19: Iron Gates II to Calafat
a) Potential candidate sites
b) Floodplain Inundation Potential
Legend
Restoration potential:
Medium-high
High
Floodplain
Legend
Inundation potential:
HAR = 200 cm
51 cm
151 cm
201 cm
Floodplain
8 Km
Gruia
Radujevac
Gârla Mare
Kudelin
Bregovo
Kosovo
Kalina
General Marinovo
Vidin
Calafat
Basarabi
Slanotran
Salcia
Cetate
Obârsia de Câmp
Poiana Gruii
BULGARIA
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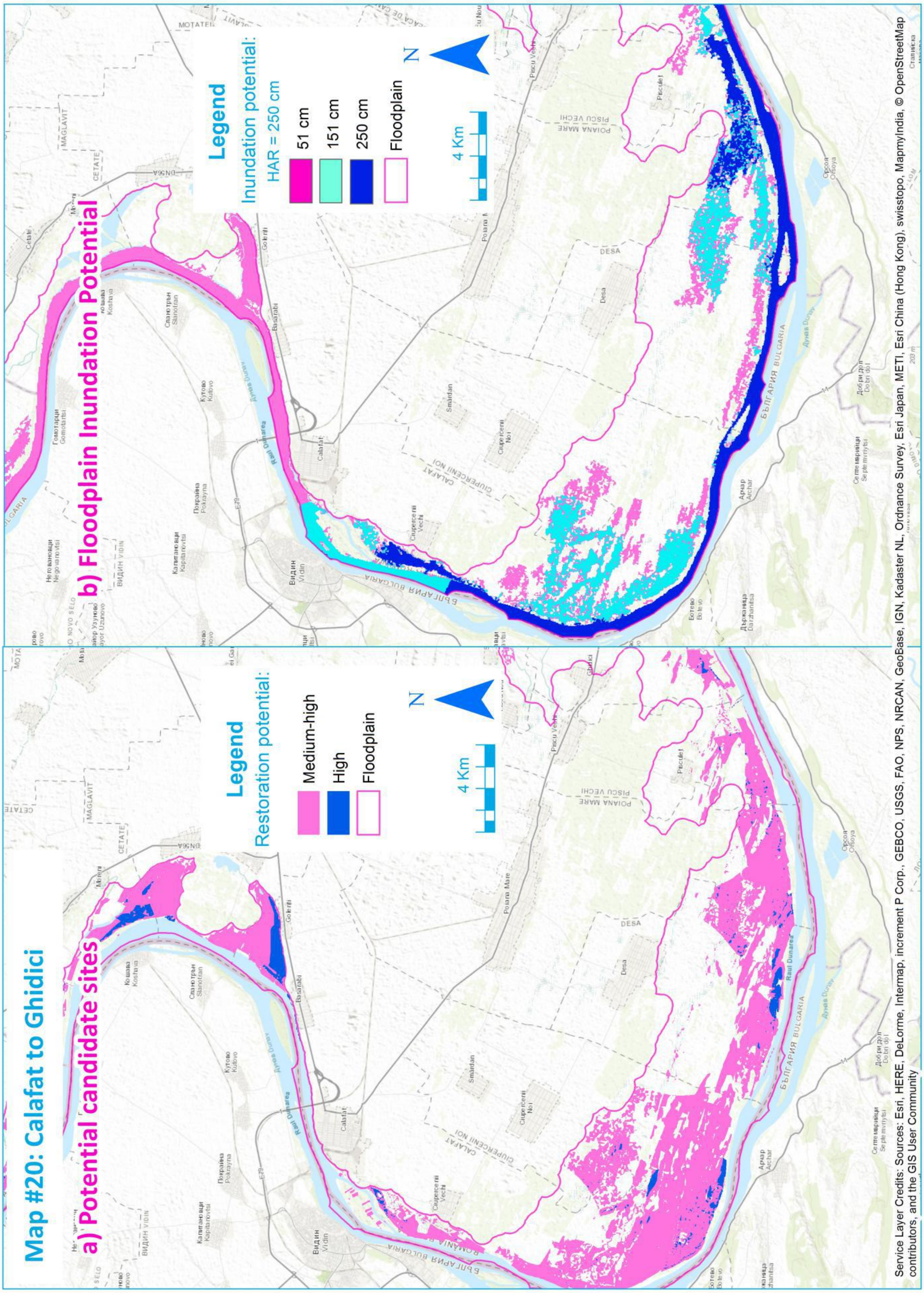
Map #20: Calafat to Ghidici
a) Potential candidate sites
Legend
Restoration potential:
Medium-high
High
Floodplain
4 Km
N
b) Floodplain Inundation Potential
Legend
Inundation potential:
HAR = 250 cm
51 cm
151 cm
250 cm
Floodplain
4 Km
N
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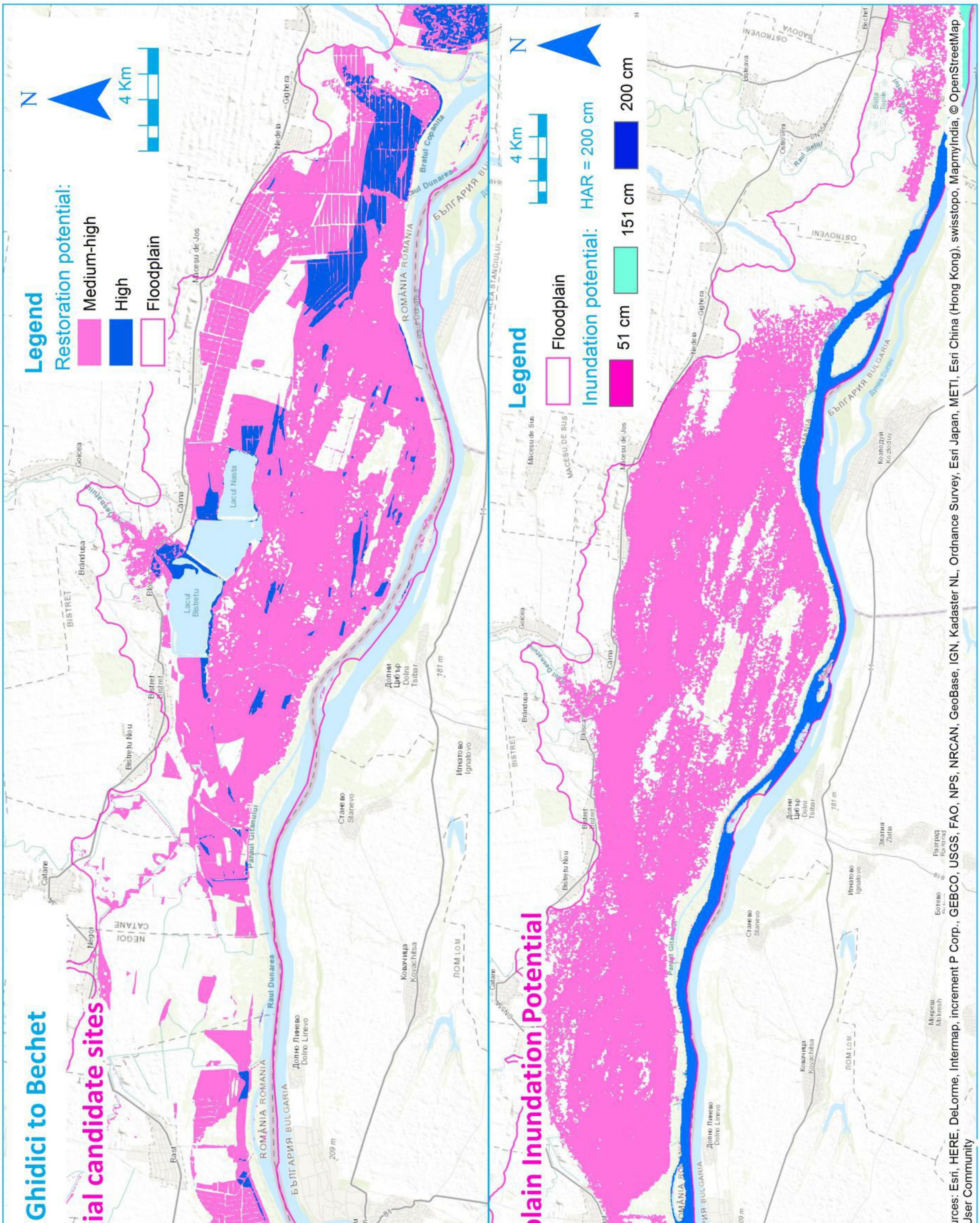
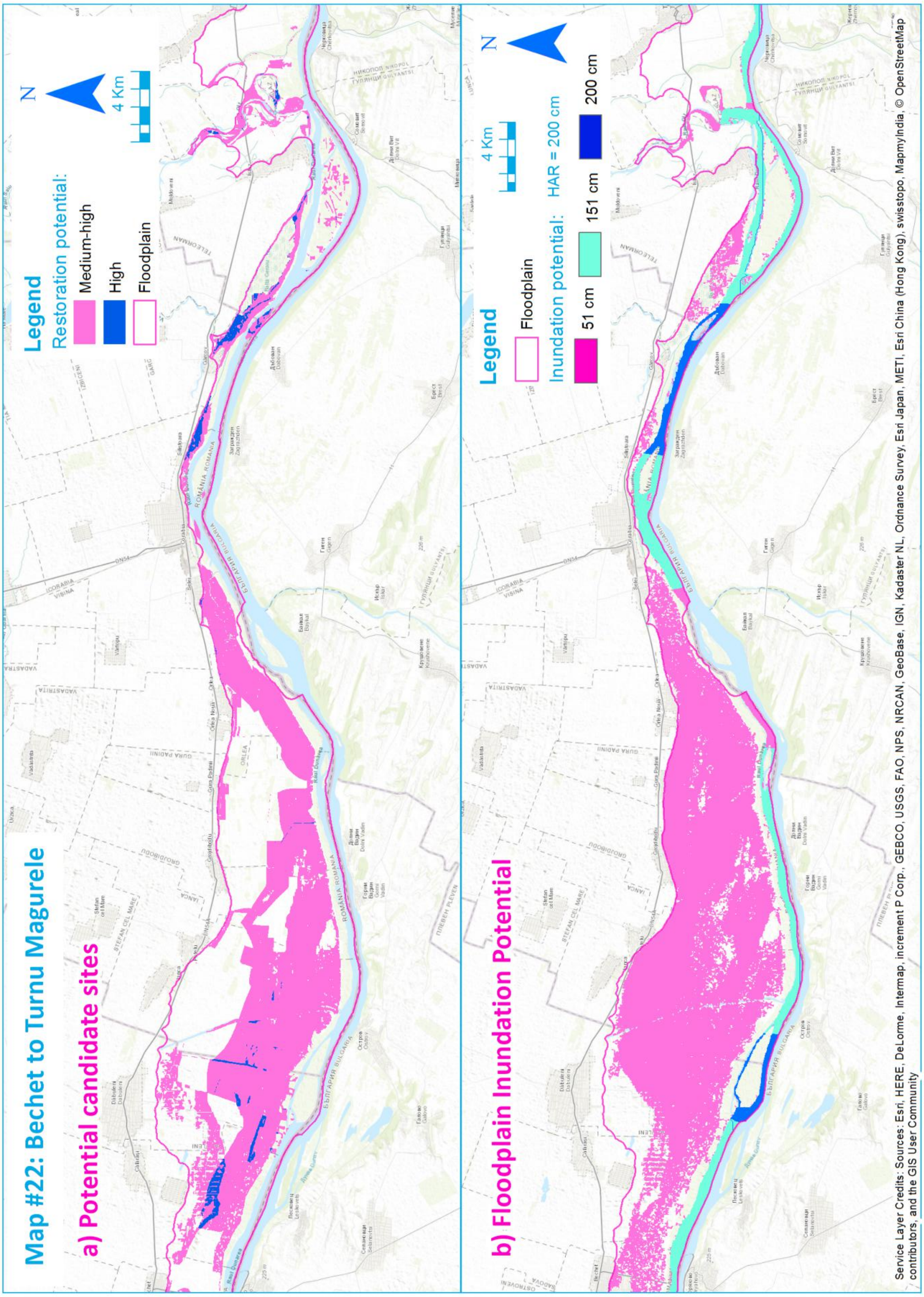
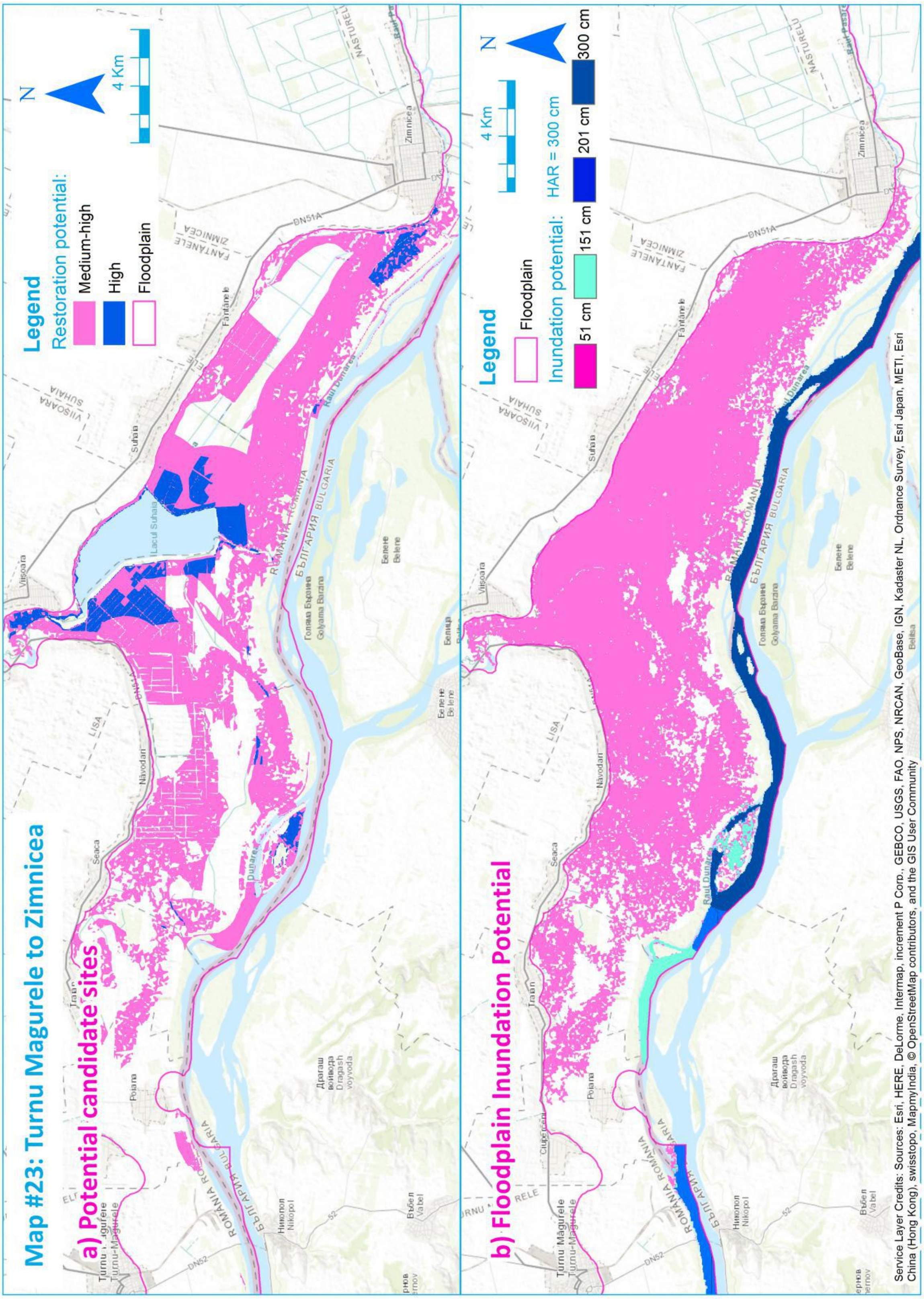
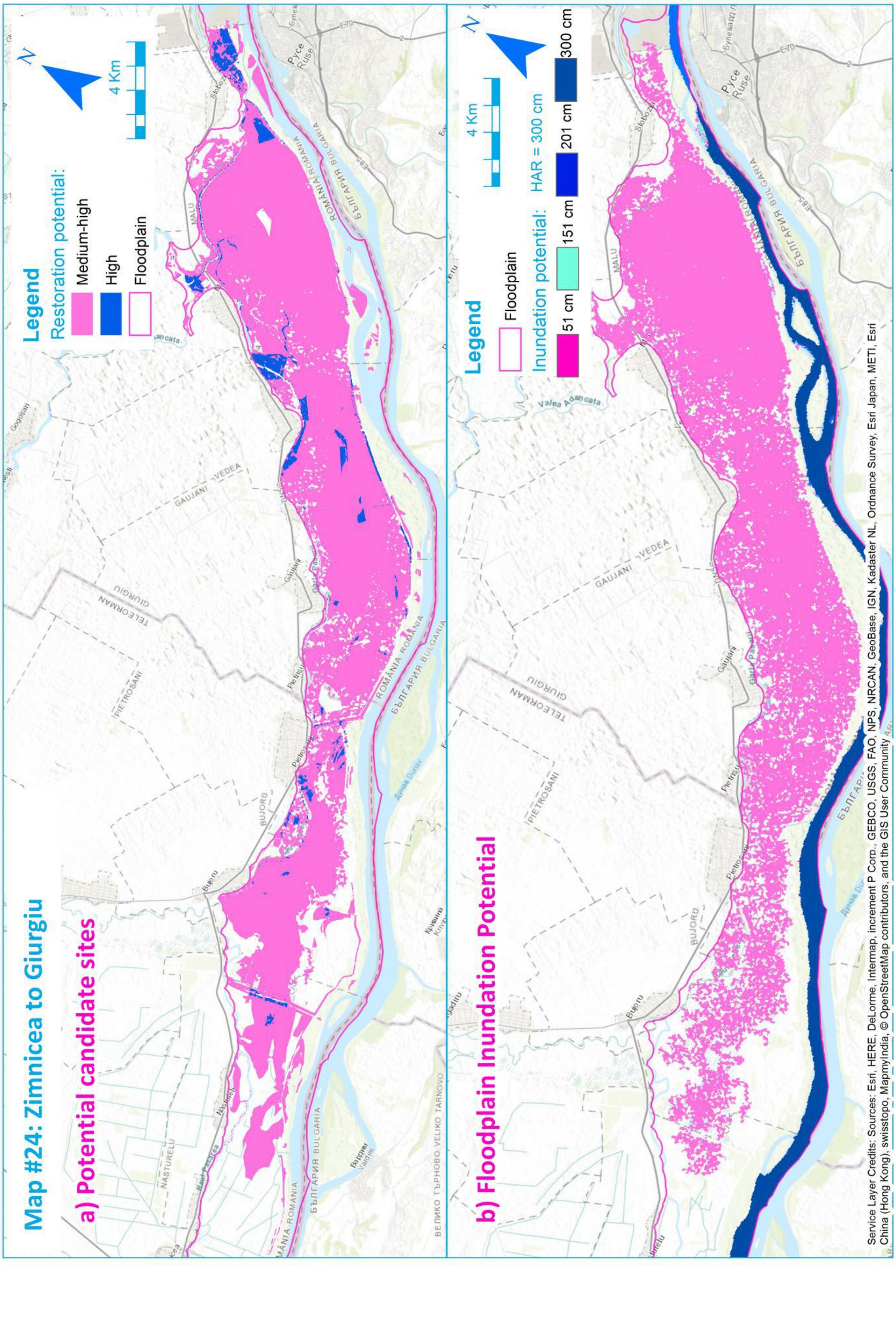
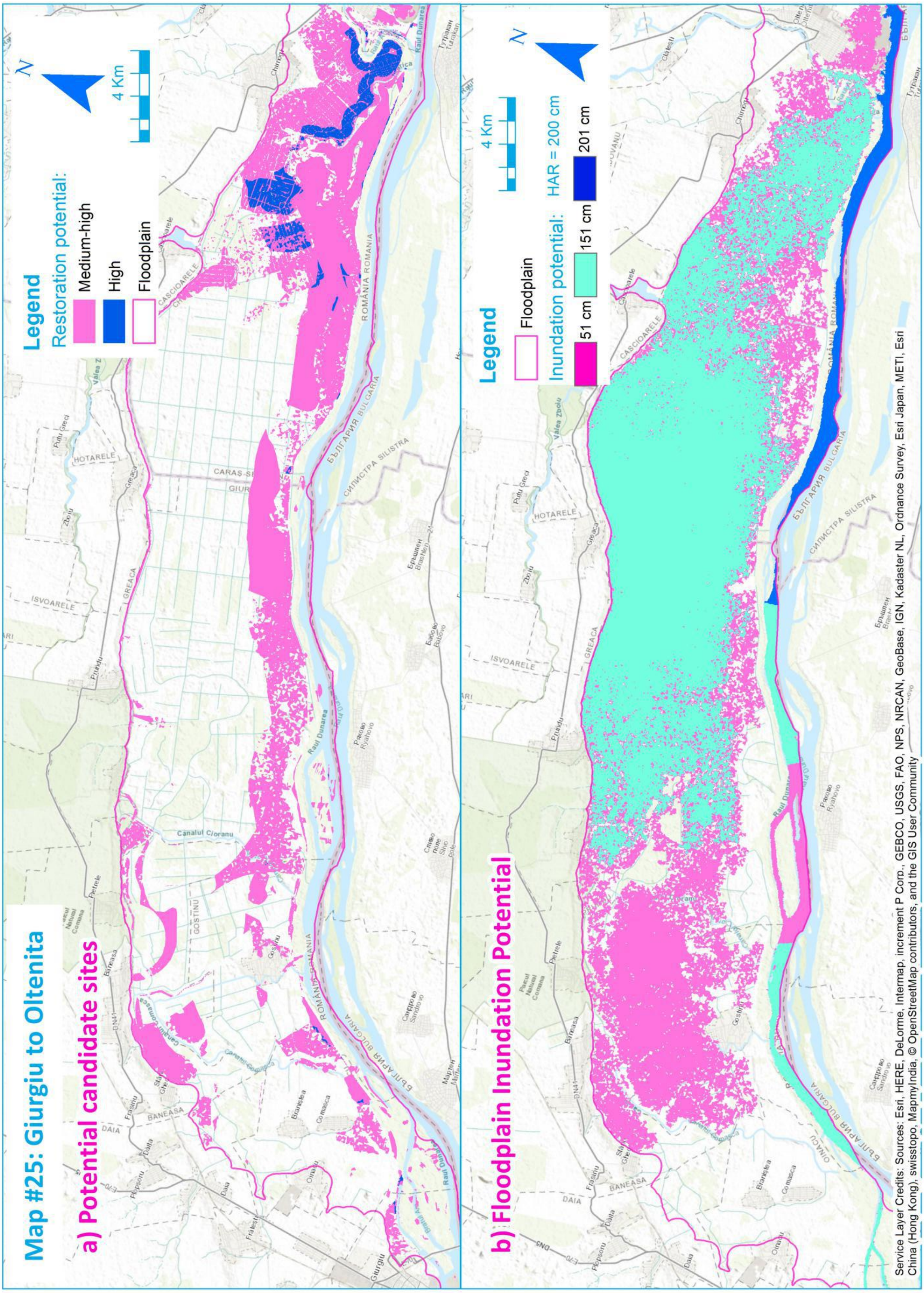

Map #21: Ghidici to Bechet
a) Potential candidate sites
Legend
Restoration potential:
Medium-high
High
Floodplain
N
4 Km
b) Floodplain Inundation Potential
Legend
Floodplain
Inundation potential: HAR = 200 cm
51 cm
151 cm
200 cm
N
4 Km
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

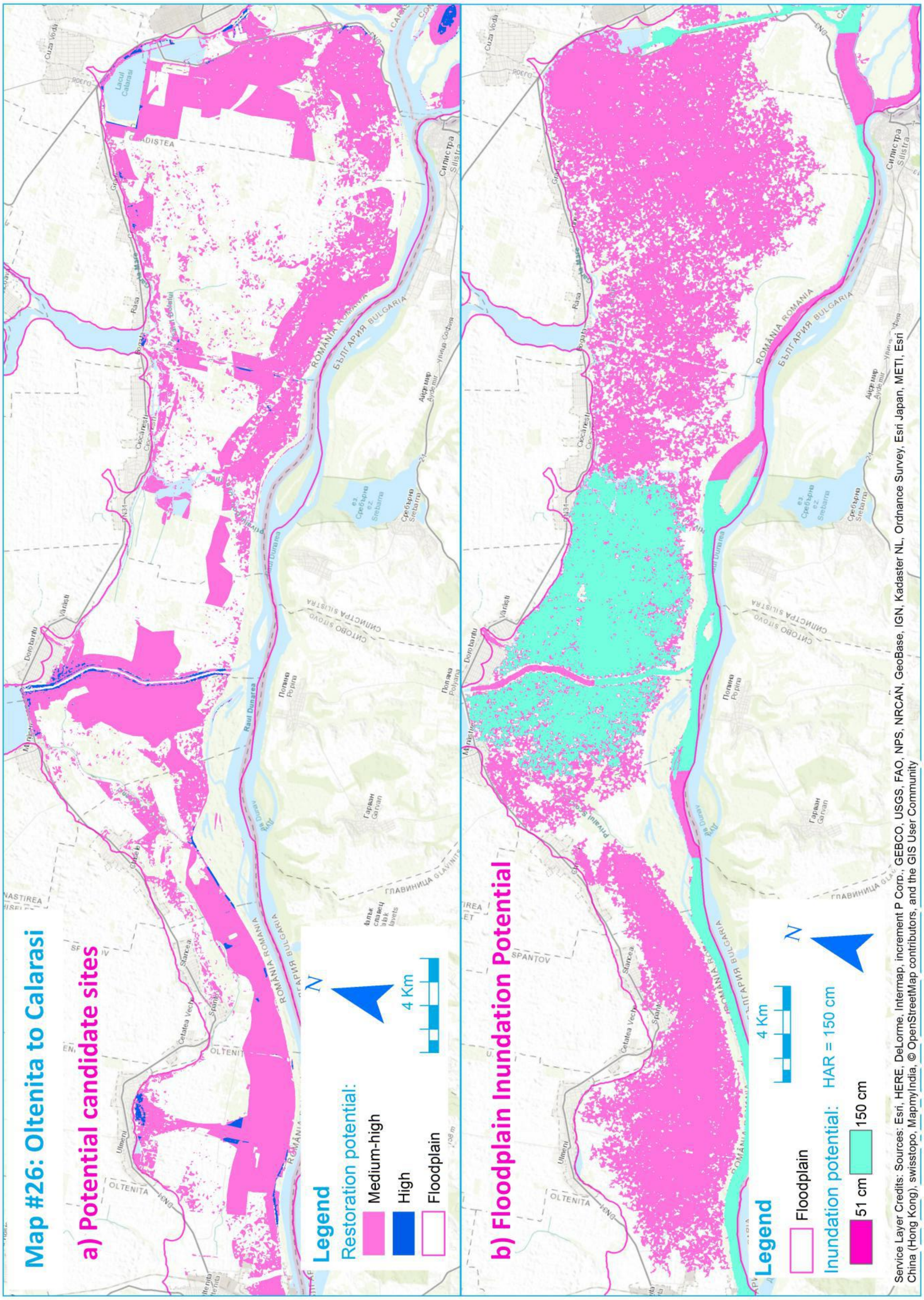


Map #22: Bechet to Turnu Magurele
a) Potential candidate sites
Legend
Restoration potential:
Medium-high
High
Floodplain
N
4 Km
b) Floodplain Inundation Potential
Legend
Floodplain
Inundation potential: HAR = 200 cm
51 cm
151 cm
200 cm
N
4 Km
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community


Map #23: Turnu Magurele to Zimnicea
a) Potential candidate sites
Legend
Restoration potential:
Medium-high
High
Floodplain
N
4 Km
b) Floodplain Inundation Potential
Legend
Floodplain
Inundation potential: HAR = 300 cm
51 cm
151 cm
201 cm
300 cm
N
4 Km
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community


Map #24: Zimnicea to Giurgiu
a) Potential candidate sites
Legend
Restoration potential:
Medium-high
High
Floodplain
4 Km
b) Floodplain Inundation Potential
Legend
Floodplain
Inundation potential: HAR = 300 cm
51 cm
151 cm
201 cm
300 cm
4 Km
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
GAUJANI
VEDEA
TELEORMAN
GIURGIU
PIETROSANI
BUJORU
NASTURELU
MALU
ROMANIA
BULGARIA
БЪЛГАРИЯ
Русе
Ruse
ВЕЛИКО ТЪРНОВО VELIKO TARNOVO


Map #25: Giurgiu to Oltenita
a) Potential candidate sites
Legend
Restoration potential:
Medium-high
High
Floodplain
4 Km
N
b) Floodplain Inundation Potential
Legend
Floodplain
Inundation potential:
HAR = 200 cm
51 cm
151 cm
201 cm
4 Km
N
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community


Map #26: Oltenita to Calarasi
a) Potential candidate sites
Legend
Restoration potential:
Medium-high
High
Floodplain
4 Km
b) Floodplain Inundation Potential
Legend
Floodplain
Inundation potential: HAR = 150 cm
51 cm
150 cm
4 Km
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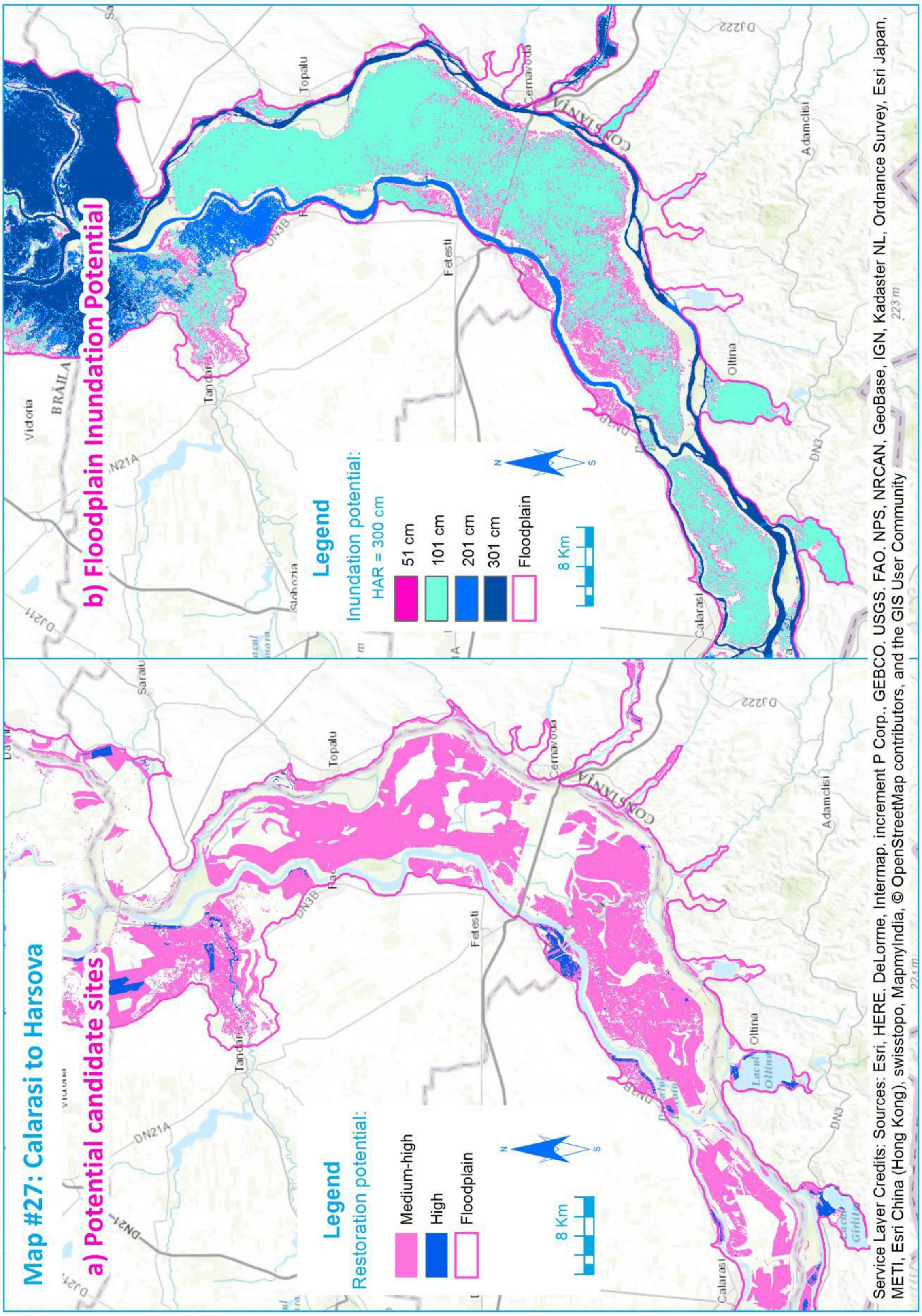
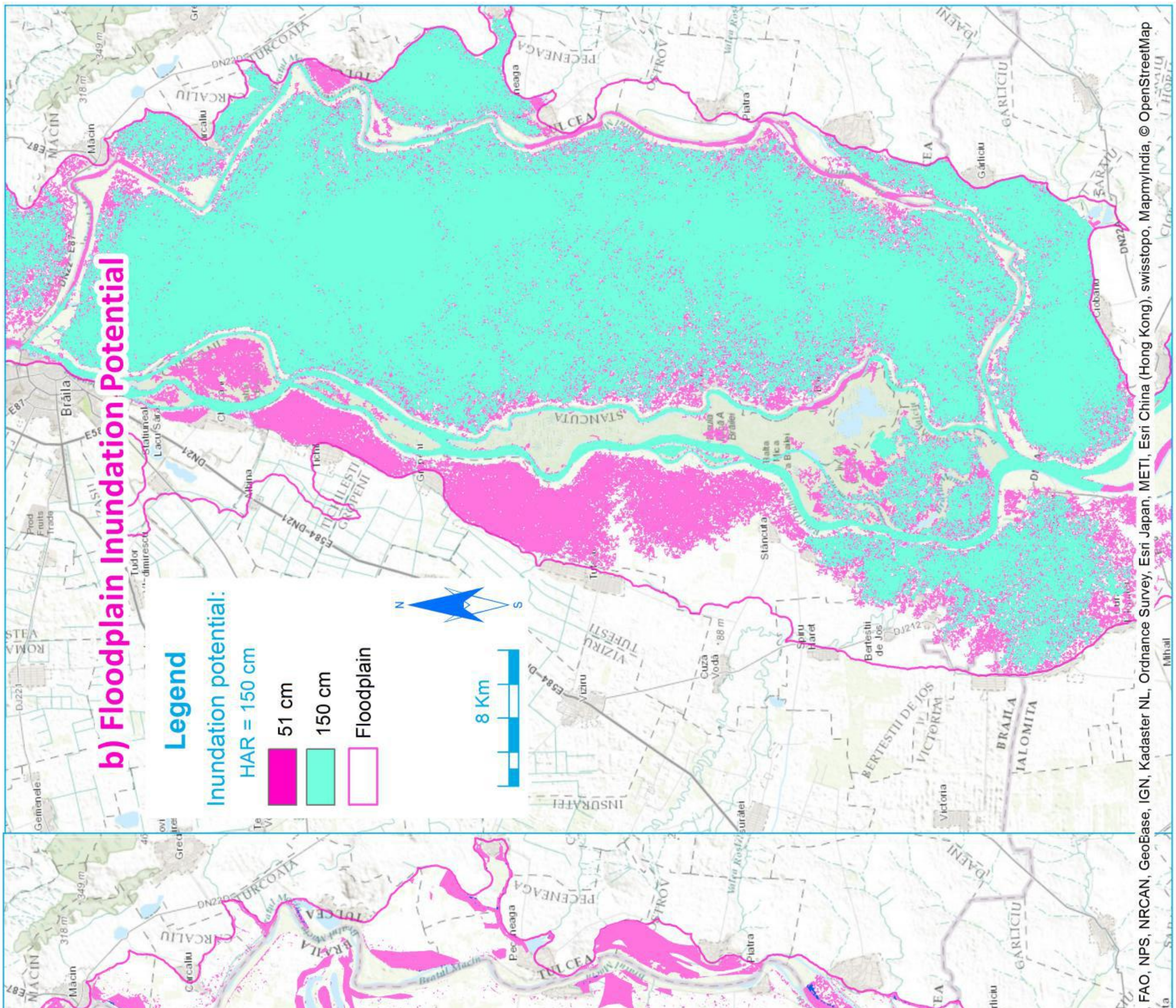
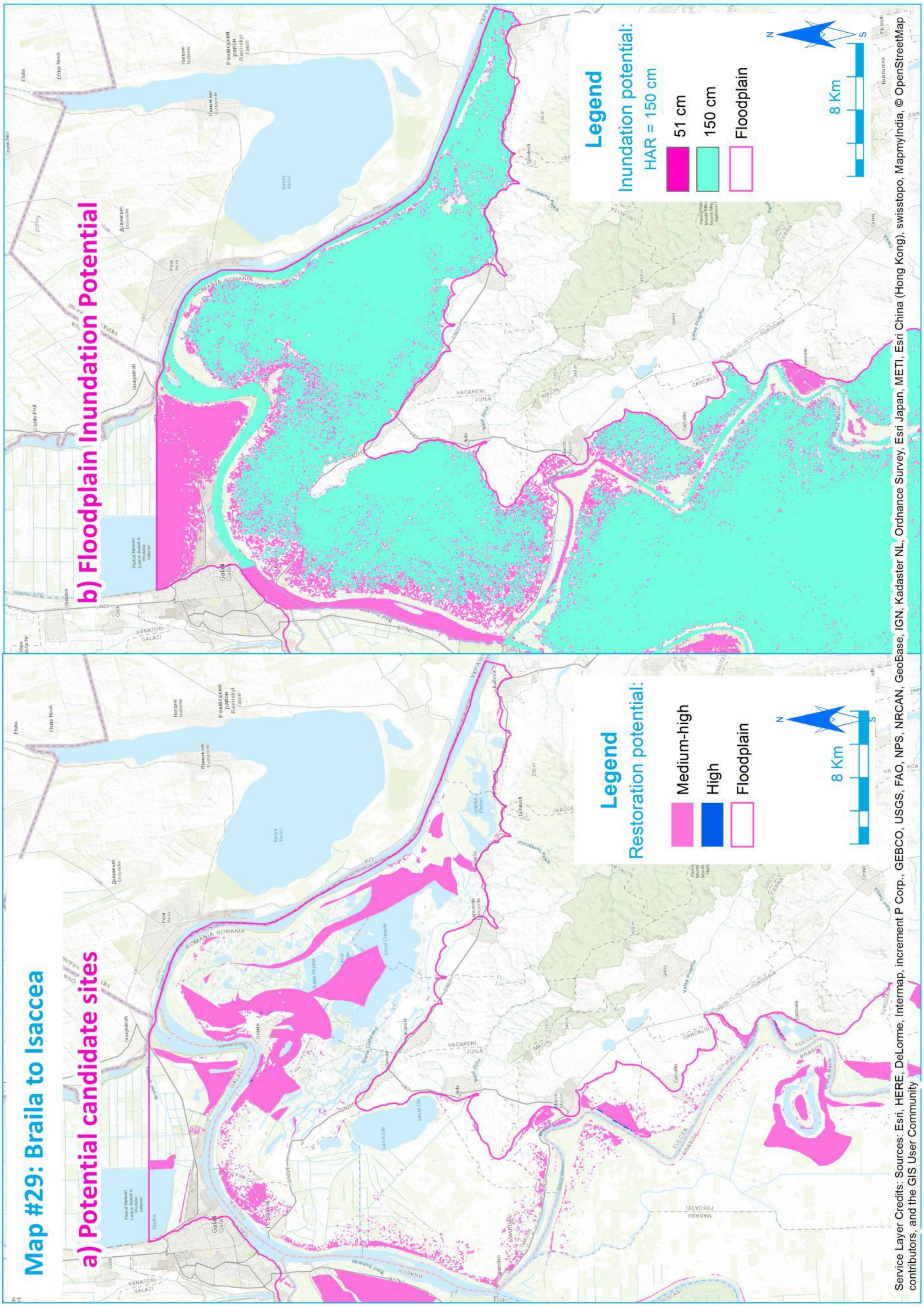


Map #27: Calarasi to Harsova
a) Potential candidate sites
Legend
Restoration potential:
Medium-high
High
Floodplain
8 Km
b) Floodplain Inundation Potential
Legend
Inundation potential:
HAR = 300 cm
51 cm
101 cm
201 cm
301 cm
Floodplain
8 Km
Calarasi
Slobozia
Tandarei
Fetesti
Topalu
Cernavoda
Oltina
Adamclisi
Victoria
BRĂILA
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community


Map #28: Harsova to Braila
a) Potential candidate sites
Legend
Restoration potential:
Medium-high
High
Floodplain
8 Km
b) Floodplain Inundation Potential
Legend
Inundation potential:
HAR = 150 cm
51 cm
150 cm
Floodplain
8 Km
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Map #29: Braila to Isaccea
a) Potential candidate sites
Legend
Restoration potential:
Medium-high
High
Floodplain
8 Km
N
S
b) Floodplain Inundation Potential
Legend
Inundation potential:
HAR = 150 cm
51 cm
150 cm
Floodplain
8 Km
N
S
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

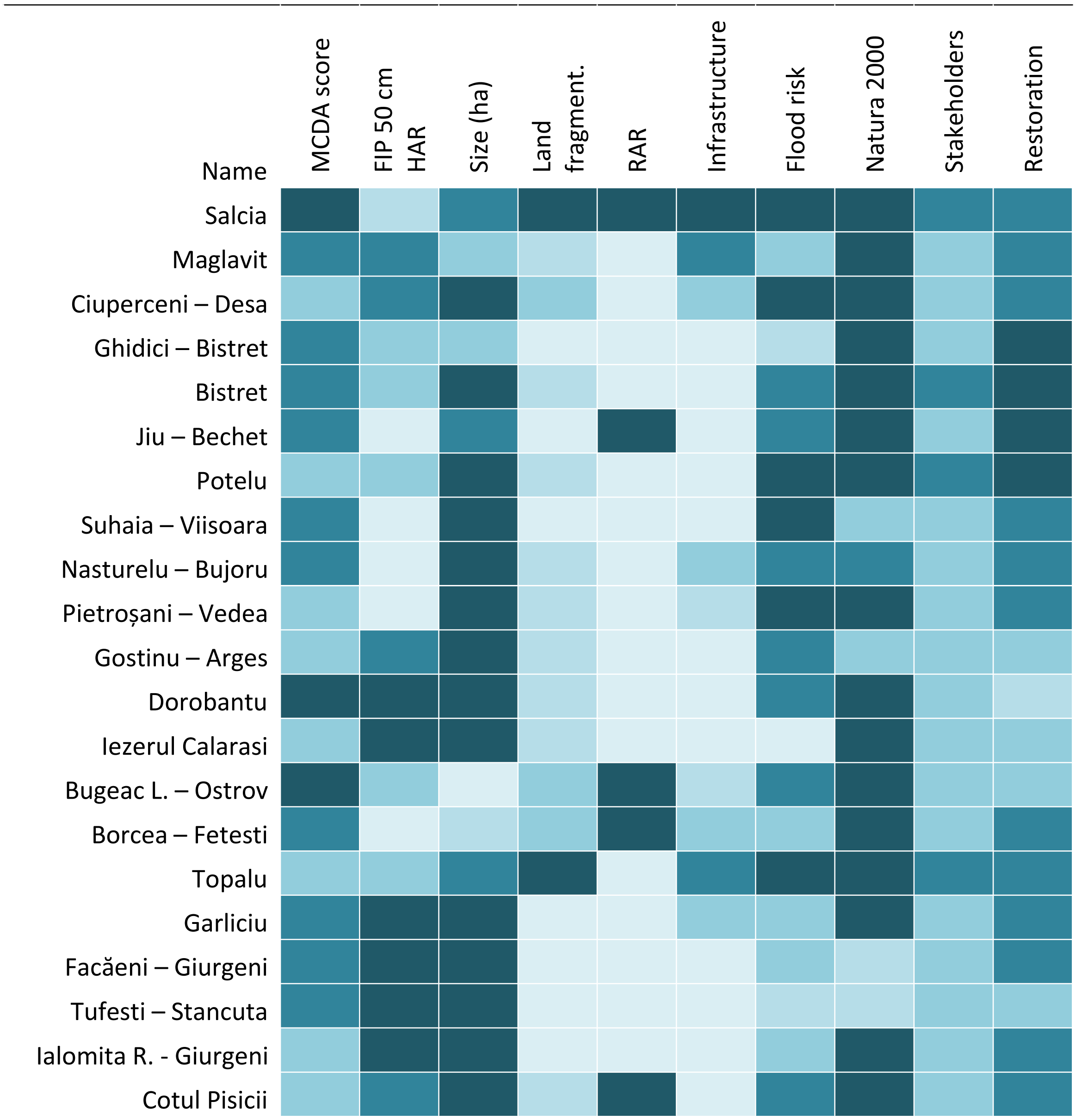
4. Candidate site selection

4.1. Site selection

Despite the ranking performed with MCDA, a variety of factors can influence the candidate site selection including potential costs, complexity of prospective works, permitting, a complicated labor of responsibilities and land ownership, willingness of landowners and the planning horizon needed to implement and complete the desired restoration project. Moreover, even the highest-ranking project or projects may not be feasible due to land-use constrains or if funds are not available. Nevertheless, these projects are necessary to achieve restoration goals, among which one important one is to replenish 5 million m^3 of water by 2020. For example, achieving replenish objectives could require large areas and relocation of protection dykes in some floodplain areas, but these dyke relocation can take many years to realize because of legal and socio-economic issue and the number of studies required to advance the project. In contrast, smaller ready available restoration sites does not necessary mean it should never be implemented because does not sustain the replenish targets. In practice, small lower-ranking projects (e.g. with 50 cm chances of FIP and higher HAR) are either easier to implement, have more technical challenges (with clear/simple problems and solutions) then adaptive challenges, where the focus of work is on stakeholders and the solutions require learning.

For these reason above, the decision team or the technical team who will take part in selection of the candidate sites for restoration is critical because can affect the acceptance of the further investments on the selected restoration site by internal/external managers, donor, stakeholders and the local community. Getting input from the stakeholders is also critical to gaining further support for the implementation of the proposed restoration works, and this is addressed for three selected candidate sites in the next chapter on stakeholder mapping. What is important here for the selection team is to consider the necessary capacity to be invested for the implementation of final candidate sites and the approach and efforts for the implementation of the selected sites. Key factors for the decision are data availability, resources and staff needed, cost of additional data collection, time needed to complete the project and a throughout understanding of uncertainties and stakeholders, to name a few.

Table 5: Decision matrix used for candidate restoration sites selection. Darker the colour on a rows better suits as final candidate site for restoration (see scale used at the bottom of the table)



Scale used in the matrix										
	5	≤150	>350	Low	No	Low	Low	In	+	High
	4	200	250			Med		Near	N.A.	Med
	3	≥250	<250	High	Yes	High	High	Out	-	Low

What are the commitments and beliefs guiding the behaviors and decision-making processes of WWF? This is one key question to ask while selecting the candidate sites.

In this respect, the matrix proposed in table 5 in not intended to be a fix tool for selecting the candidate sites but a decision process that can be frequently used to re-prioritize the sites as new funding becomes available, new opportunities are identified and new stakeholders are learning the benefits of wetland restoration.

Based on the information provided in the decision matrix for selecting the best candidate sites for restoration the following sites are proposed for stakeholder evaluation and prospects to support the implementation of the restoration: Slacia, Potelu and Topalu. The stakeholder evaluation for these three sites was considered important by the WWF team for deciding on the final site where to continue with the future investments for the implementation of a new restoration project along the Danube River. Stakeholder evaluation for each of the three sites is presented in the next section based on the available information and understanding of stakeholders' interests.

Field validation for the three candidate sites selected as a result of decision matrix was performed in November 2016 to check validity and applicability of the results. At each site, photographs were taken, and general observation as to the restorability of the site, including any relevant information, not included in the MCDA, such as the economic use of the area, infrastructure use and status. The field observation are summarized below for each site so that it can be compared with the scores generated by the decision matrix and used to decide the final candidate site for restoration.

Al sites visited had a wetland restorability function rating of at least "medium-high" and most of them could potentially be restored into wetlands based on what was seen on the ground.

Topalu site is situated north to the village of Topalu along the Borcea branch of the Danube and along the former floodplain between the river and the Danube terrace for a length of 4 km. The entire area has a medium-high restoration potential based on having alluvial soils, close proximity to open waters, high and medium-high restorability index and good land-use favourability. The area was drained in 1959 with the construction of a polder having 260 ha and foreseen with a pumping station with a volume capacity of 0,20 m^3/ha and power of 17 kW (Visinescu, 2014). The longitudinal dyke at the Danube has 4 km and no other compartment dykes were initially constructed. No other irrigation systems (channels or pumping stations) or drainage channels were foreseen for the arable polder and no rice field were considered for further use of the polder.

The site includes today 3 agriculture polders from which two are used as grazing pastures and one as arable land. The biggest dyke enclosure from the northern part of the area has a surface of 245 ha and is connected with the Danube River through a former channel 10-15 m wide that also continue inside the polder along the foot of the terrace. This channel is interrupted by the dyke construction where the water use to be controlled by a sluice, which is now abandoned, broken and with missing parts. For this reason this part of the dyke where the sluice use to be is now consolidated with dirt, sack of sands and knitting filled with local materials to protect against water erosion that enters this channel at high Danube levels and affect the structure of the dyke and sluice (see picture below).

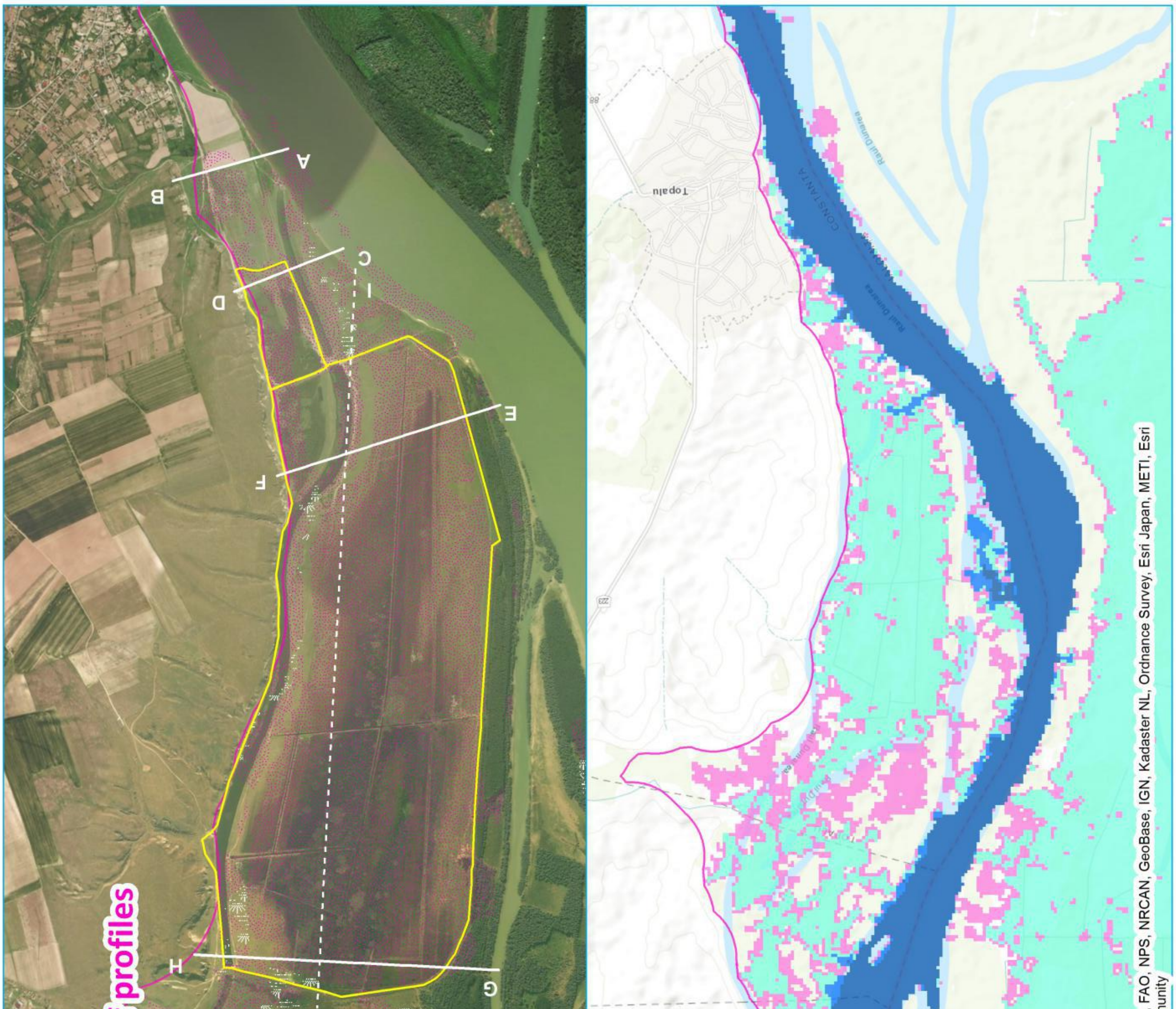
The south view of the dyke where the sluice was "buried" to prevent water entering the grazing area.

The entire polder is scattered by ditches that are connected with the channel along the terrace. This can be considered an advantage for diverting water inside the entire polder at low levels in case of a restoration approach. The most northern part of the polder is probably the lowest in altitude and the stagnant water stay longer during the year since there are visible signs of vegetation typically to wetlands. According to the information on land parcel this polder is flat now with a slope of only 1,59%, which makes perfect for water to stagnate and not drain naturally.

Topalu candidate site also includes on smaller polder along the east side of the inlet channel that is used for grazing. This polder has smaller dykes that enclose a surface of 10,79 ha and can be easily reconnected in several points to allow the water in in order to improve the pasture quality. Following south there is another small polder used for agriculture having 15,97 ha, which was not considered as potential for restoration due to proximity to the village where some houses are at lower part of the terrace.

All together these two polders from the north and central part of Topalu floodplain account for a total surface of 293 ha, which can store approximately 2,3 M m^3 for a water depth of 1m inside these polders. The attached profiles of the Topalu area are an indication of the potential for flooding during four discharges (1%, 2%, 5%, and 10%) considering the data from the closest gauge station upstream at Vadu Oii (with an altitude of the gauge at 2,630 m).

Picture illustrating the inlet channel; on the far right is the smaller polder suitable for flooding.


Map #30: Topalu candidate site
a) Potential restoration area & location of profiles
Legend
Restoration potential:
Medium-high
High
Floodplain
Potential restoration area
(293 ha = 2,293,000 m3 for a water depth of 1 m)
500 m
N
A
B
C
D
E
F
G
H
I
J
b) Floodplain Inundation Potential
Legend
Floodplain
Inundation potential: HAR = 300 cm
51 cm
101 cm
201 cm
500 m
N
Topalu
HARSOVA
GHINDARESTI
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

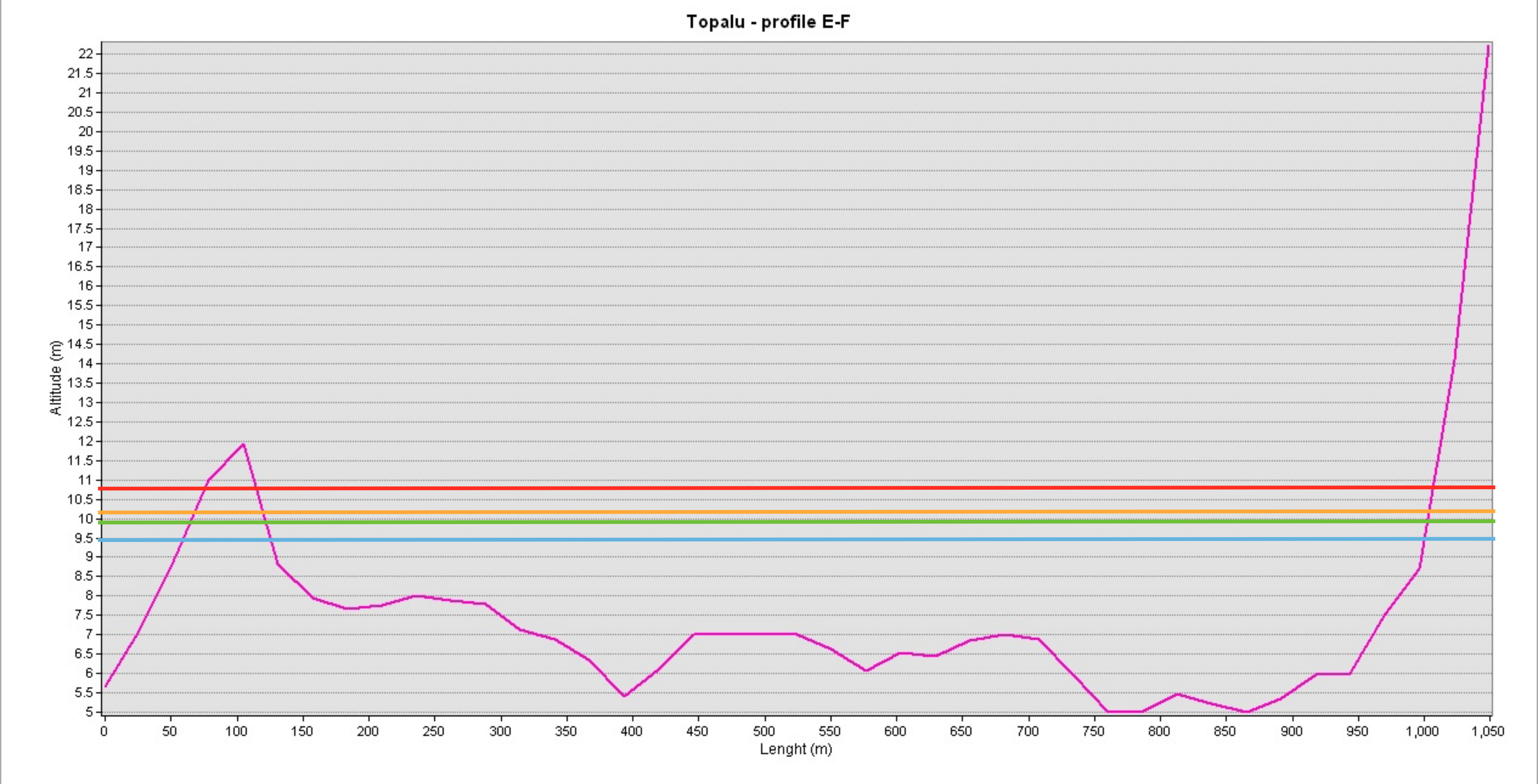
The minimum altitude in Topalu area is 3m and the maximum is 12m, while the medium altitude is 7,25 m, which makes the area suitable for flooding even during higher probabilities of flooding, considering the difference of more than 1 m in most of the profiles between the local altitudes and the altitude of the water levels at 10% probability of flooding. However, this is a theoretical approach to calculate the storage capacity of the polders in case of flooding and further detailed modeling is necessary to establish the horological conditions of flooding and storage capacity for different scenarios of Danube discharges and water levels.

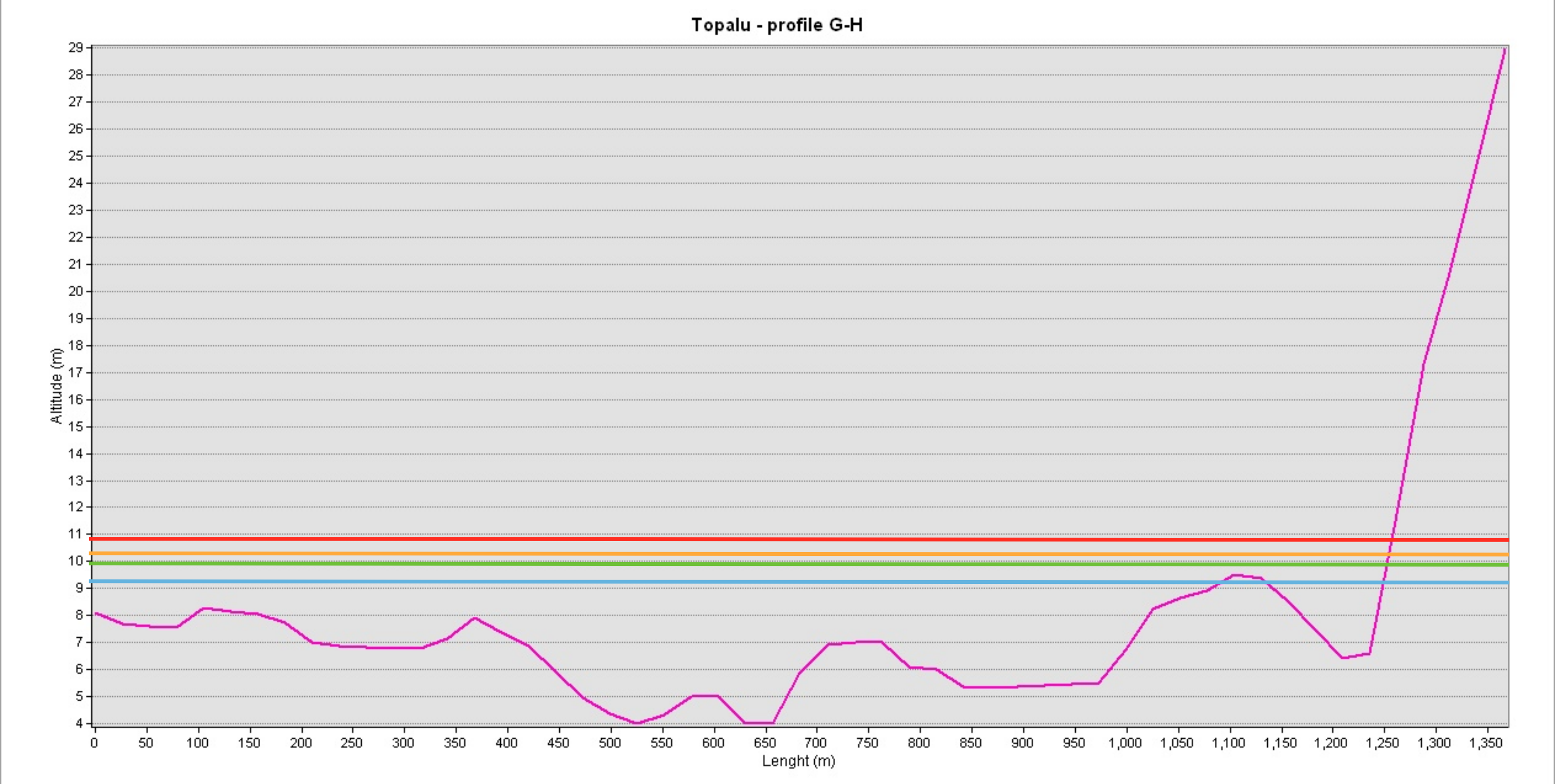
These two polders are grazed all year round by several sheepfolds located along the foot of the terrace (we counted only five along the smaller polder), which makes the interest for restoration potentially low.

Picture above: the channel inside the big polder. Picture below: the small polder east side of the channel; two sheepfolds can be seen at the foot of the terrace.

Picture above shows the dyke protecting the arable lands in the south polder not considered for restoration at Topalu site. Pictures below illustrate the flooding of the areas in 2005.

The potential for restoration is exemplified in the picture below for the floods from 2005 and at Danube discharge of 12,900 m^3, which is less than 10% probability of flooding as exemplified in the profiles.

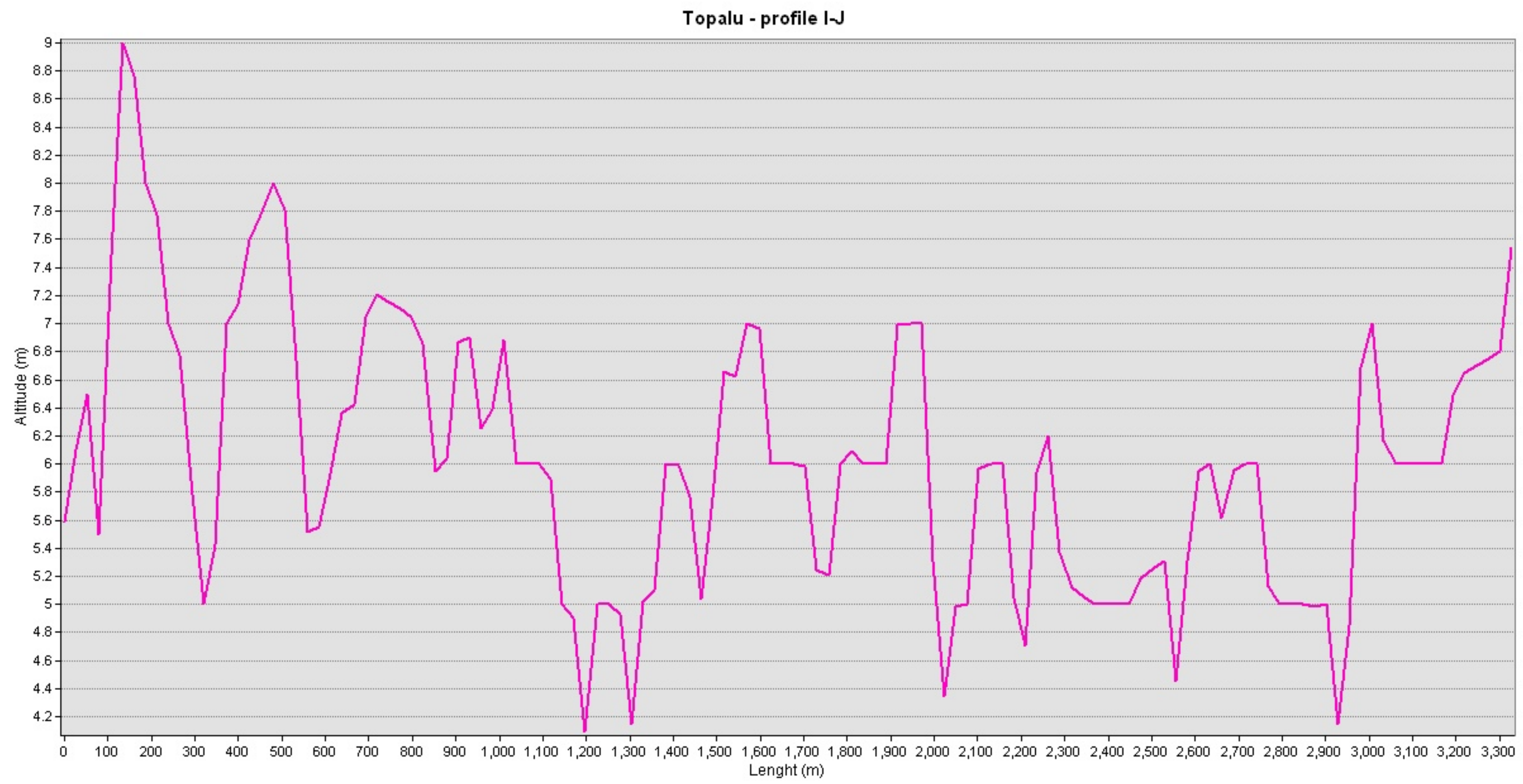




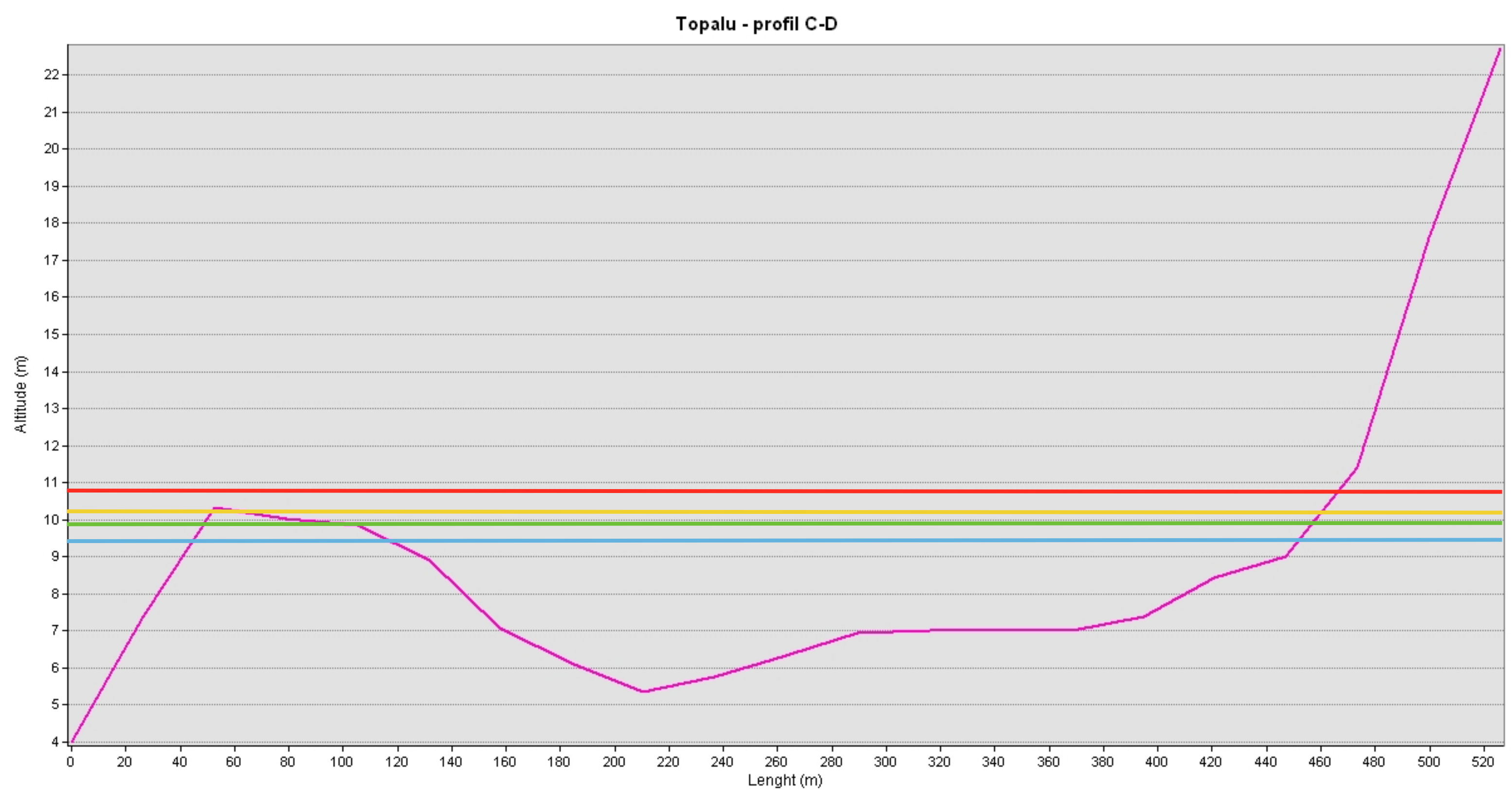
Maximum water levels (p%) indicated for terrain altitude for Vadu Oii gauge station (data after REELD, 2006):

1% = 10,82 m 2% = 10,23 m

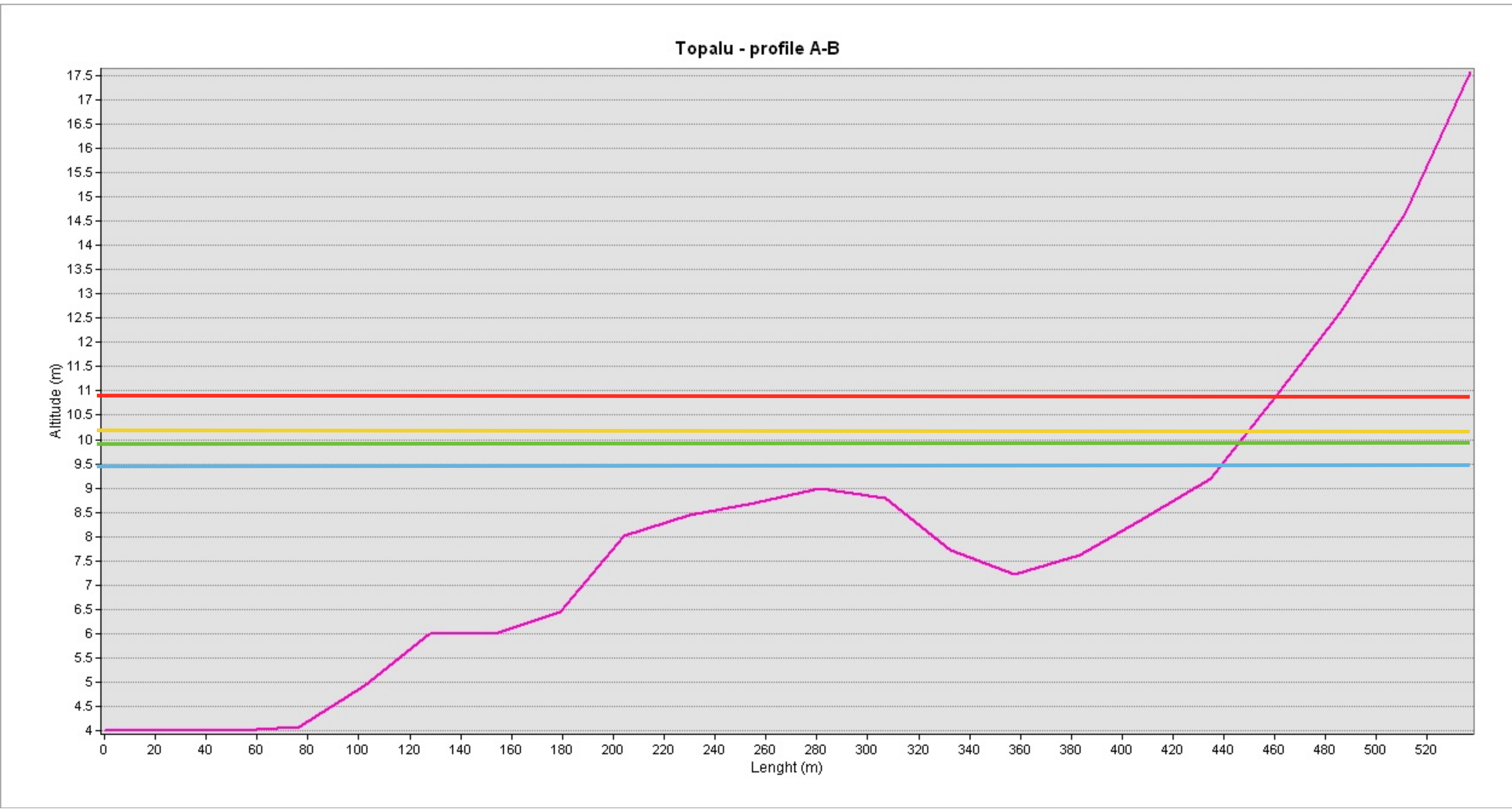
5% = 9,95 m 10% = 9,48 m



Topalu - profile I-J
Altitude (m)
Lenght (m)



Topalu - profil C-D
Altitude (m)
Lenght (m)

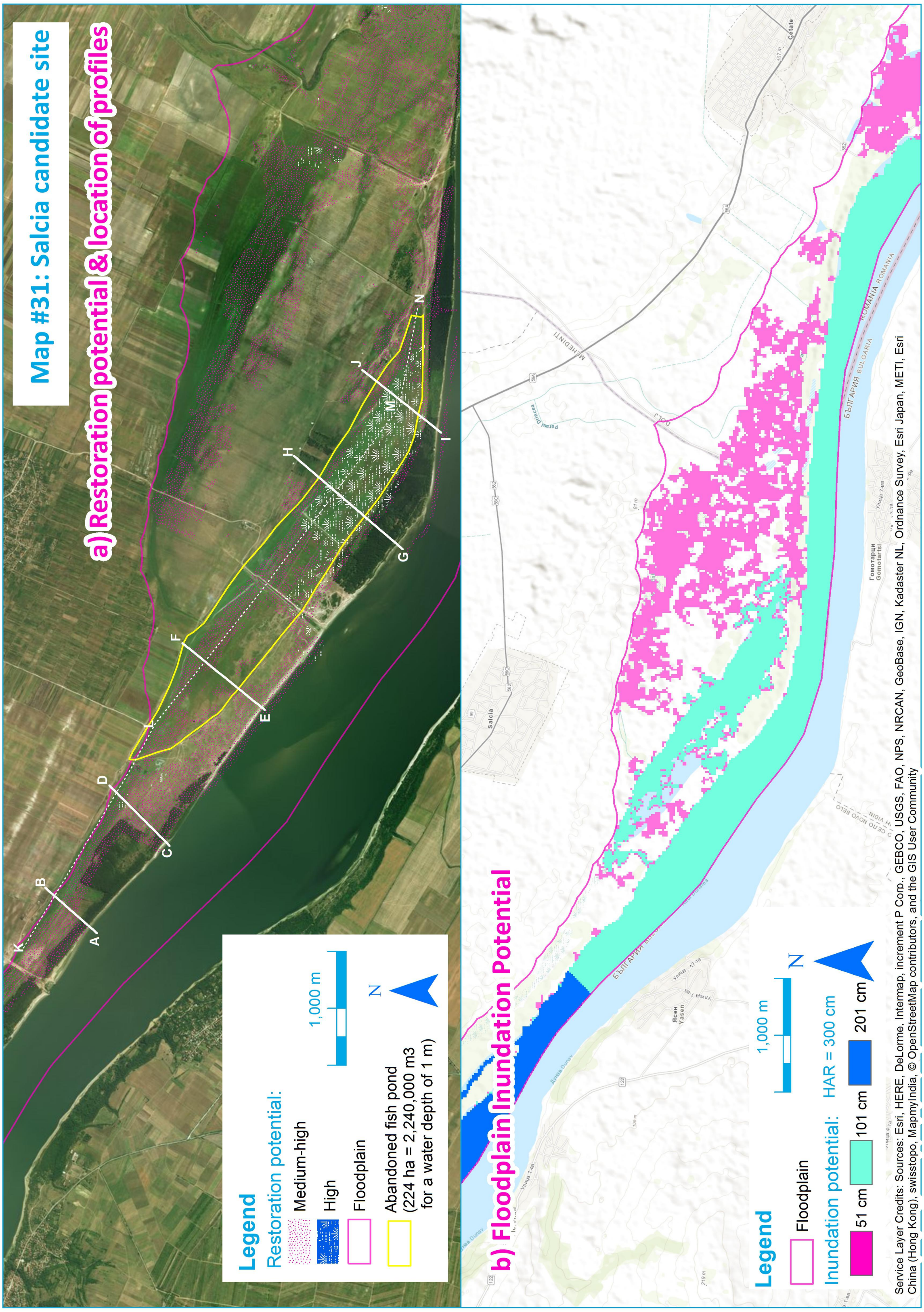


Topalu - profile A-B
Altitude (m)
17.5
17
16.5
16
15.5
15
14.5
14
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520
Lenght (m)

Salcia site comprise mostly an abandoned fish farm situated south to the village of Salcia between km 820 - 823 on the Danube river. The north-western half of the area has a medium-high restoration potential based mostly on having sandy soils, while the south-eastern part has high restoration potential mainly due to presence of lower altitudes. The fish farm was constructed by reshaping the former floodchannel (back channel indicated as former Salcia pond - observed at the valley margin), levee and backswamps (floodplain wetlands, ponds and lakes such Lunga pond, Crap Pond and Salcia pond). Remnants of the former Salcia pond that acted as floodchannel (back channel) for the flow alignment along the the floodplain during discharge events increasing the water storage, can be seen today west side of the fish farm along the terrace. This wide channel that initially communicated with Cioara lake, near Vrata village, was called Salcia pond still has an uniform shape along the floodplain margin and has potential to be activated if reconnected with the Danube and the fish farm. According to our observations and after discussing with local shepherds, this flodchannel is flooded during high water discharges, groundwater infiltration or via perpendicular channels cut through the levee near the western end of the fish farm.

Picture showing the floodchannel observed at the floodplain margin, initially called Salcia pond, has an uniform morphology and act as a straight depression to occasionally convey flood waters during discharge events.

Pictures showing the perpendicular channel most probably used for drainage the floodplain wetlands, that acts as an inlet to occasionally flood the lower depressional area during discharge events.


Map #31: Salcia candidate site
a) Restoration potential & location of profiles
Legend
Restoration potential:
Medium-high
High
Floodplain
Abandoned fish pond
(224 ha = 2,240,000 m3
for a water depth of 1 m)
1,000 m
N
b) Floodplain Inundation Potential
Legend
Floodplain
Inundation potential: HAR = 300 cm
51 cm
101 cm
201 cm
1,000 m
N
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Today, the site includes two big fish basins used for fish development, with a surface of 75 ha and 92 ha and, six smaller basins used for reproduction of fishes, with surfaces of 5 ha, 0,6 ha, 4,5 ha, 5,9 ha, 3,9 ha and 3,85 ha (data from APIA). The limit of the fish farm to the Danube River is delineated by an enclosure dyke while the limit towards the north-eastern side is delineated by a higher topographic ground most probably build during the excavation of the fish ponds. Smaller areas of pastures situated in the north vicinity of the abandoned fish farm complete this potential restoration site with a total estimated area of 224 ha (according to APIA). All together these fish farm basins can store 2,24 M m^3 of water at a depth of 1 m.

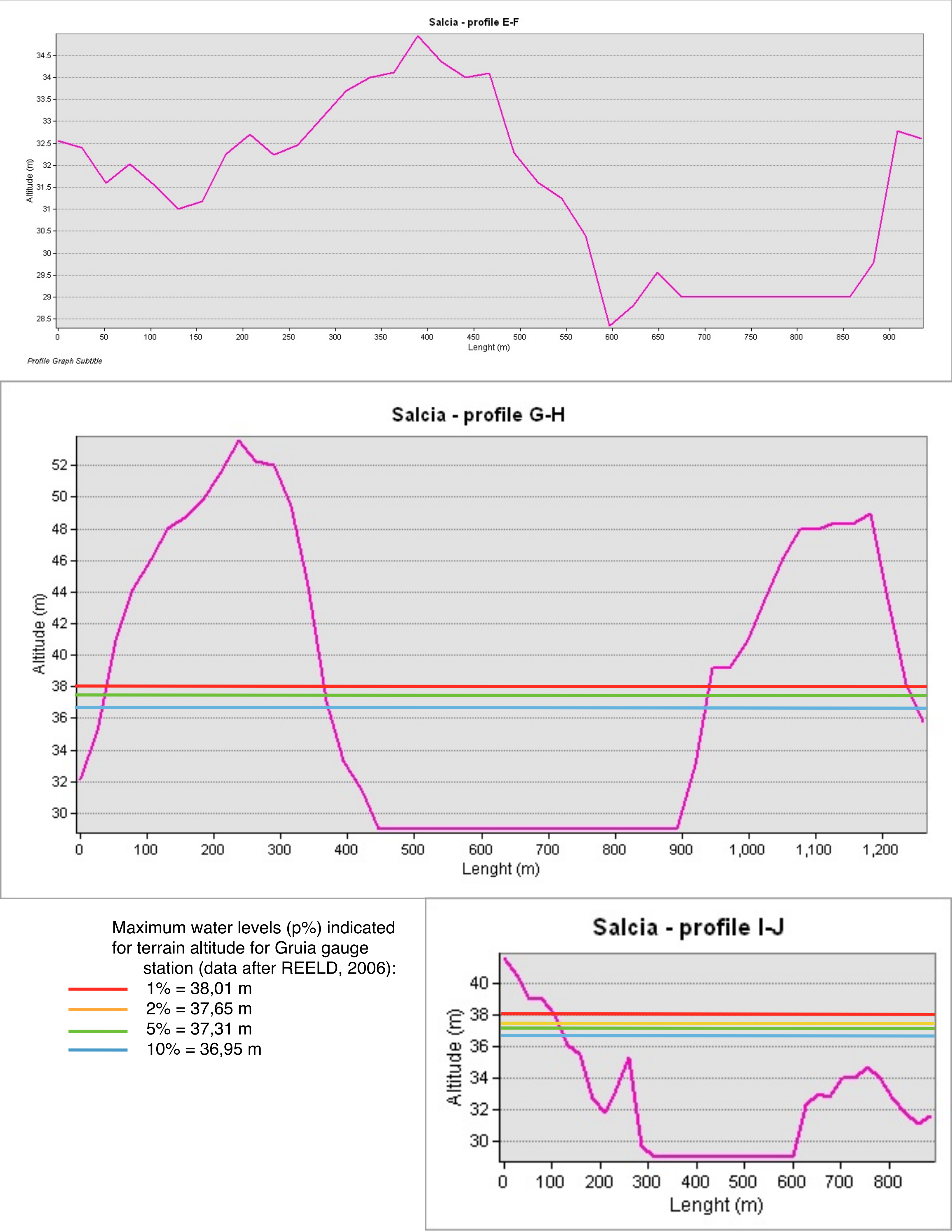
The fish farm was connected with the Danube River through an inlet channel of 240 m length and wide (approx. 50 m) and deep enough to store water necessary for a pump station to deliver the water into the fish basin. The water use to be diverted through a channel of 10-15 m wide and from here in the fish basins through sluices build in compartment dykes.

An outlet channel was foreseen for each of the two big basins having connection through submerged pipes beneath the dyke. The water flows and levels use to be regulated through sluices, which are now degraded. The channel connecting the Danube River and the north-western fish basin is filling with some water this basin during high waters on the Danube River. The size of the construction of the water pumping station, dykes and overall of the fish farm indicate that the fish farm activity was to run on high energy inputs during the time of subsidizing the aquaculture in Romania. Since this is not the case in the present times, the fish farm was abandoned by the last concessionaire and the fish farm is used as grazing ground by the locals. The owner of the fish farm, ANPA, indicated that the they still want to keep the main use of the area e.g. aquaculture and fish production and, any restoration proposal for the site can be agreed with the future concessionaire. However, when the site will be given for concession is unknown and the same is for the financial investments necessary for rebuilding the infrastructure to proper use the fish farm for aquaculture.

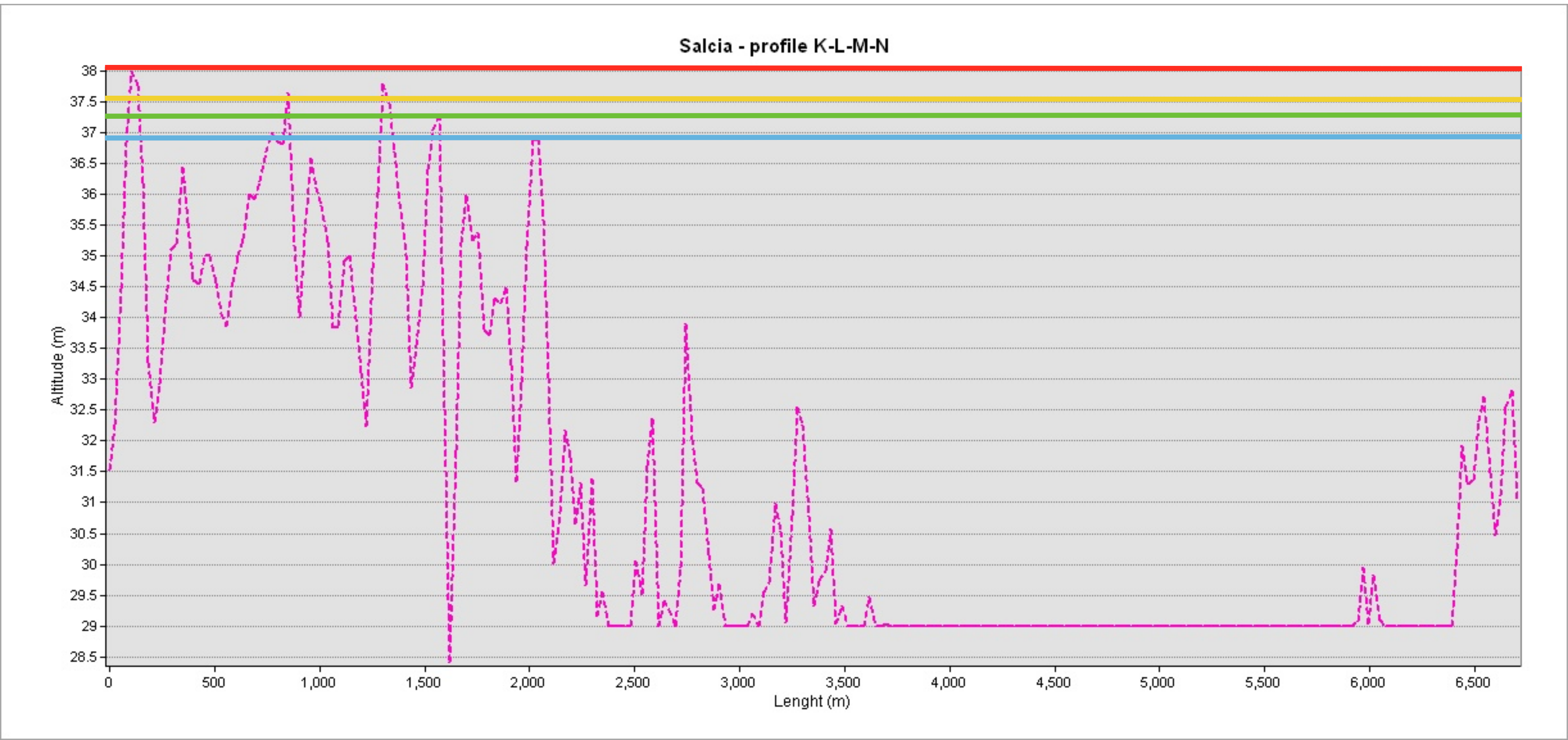
The Salcia candidate site area can be increased with the inclusion of the former backswamps in the restoration approach e.g. distal wetland area situated northeast to the actual fish farm. The area is connected through a channel with the fish farm on the west side and has an altitude between 31 -34 m and the connection point of the channel is at approx. 34 m. Considering the altitudes of 36,95 m for the probability of 10% discharges of the Danube River, the area can convey flood waters at relatively good frequency necessary to improve the wetland areas and act as a storage unit for water and sediments. In case of emergencies a potential outlet for this backswamp can be the existing perpendicular drainage/irrigation channel situated in the eastern part of the area. However, the local hydrology have to be investigated for further flooding scenarios and the impact to the arable lands surrounding the backswamp.

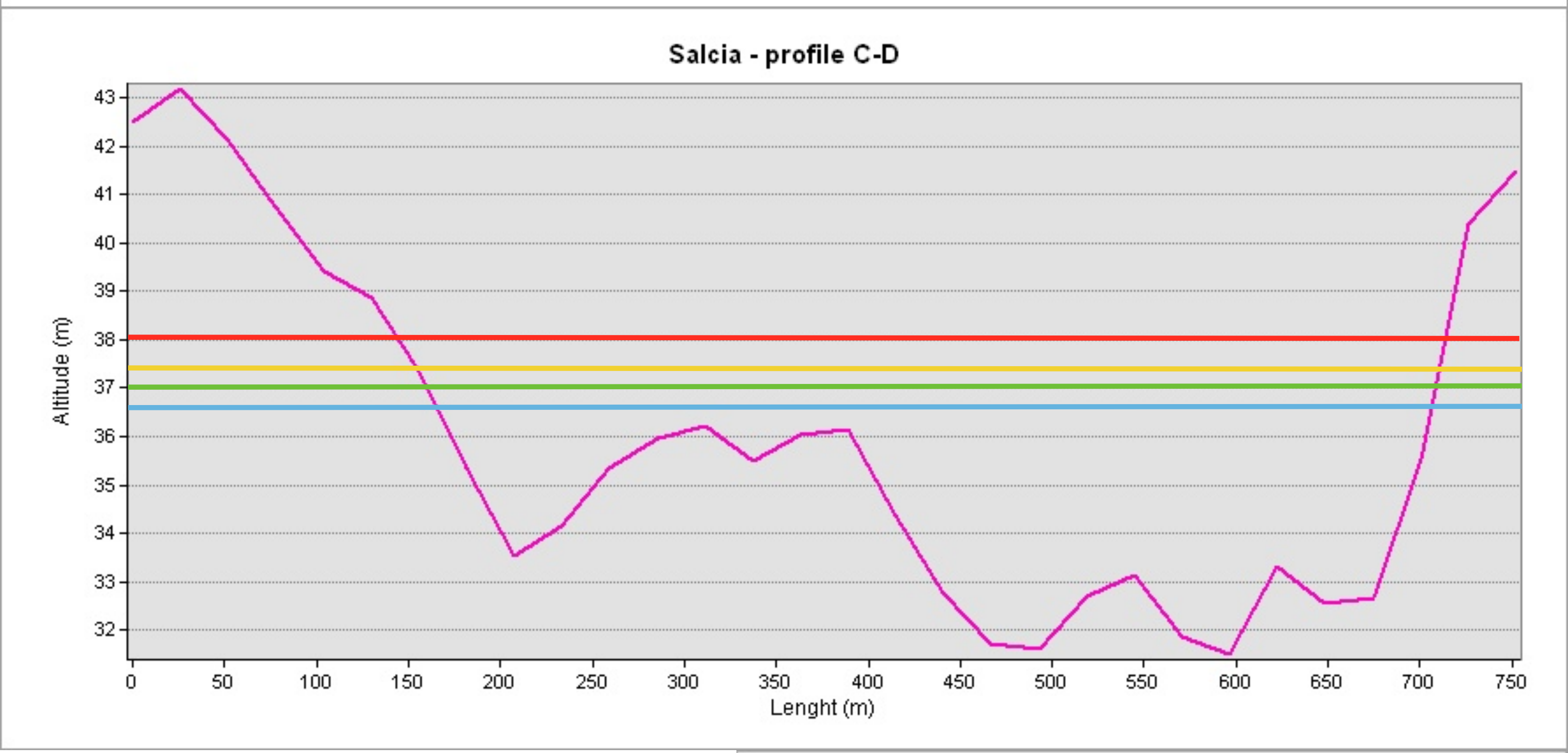
Views of the Salcia candidate site - above and below the western fish basin seen from the main compartment dyke.

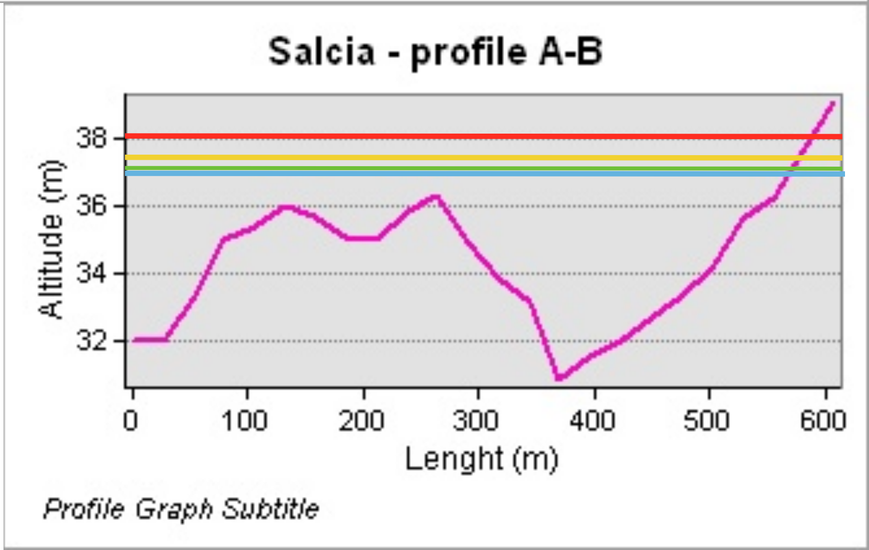
Views of the Salcia candidate site - above: the nursery basins seen from the main dyke; below: a sluice on the main compartment dyke diverting water in the fish basin.



Salcia - profile E-F
Altitude (m)
Lenght (m)
Profile Graph Subtitle
Salcia - profile G-H
Altitude (m)
Lenght (m)
Maximum water levels (p%) indicated for terrain altitude for Gruia gauge station (data after REELD, 2006):
1% = 38,01 m
2% = 37,65 m
5% = 37,31 m
10% = 36,95 m
Salcia - profile I-J
Altitude (m)
Lenght (m)


Salcia - profile K-L-M-N
Altitude (m)
Lenght (m)


Salcia - profile C-D
Altitude (m)
Lenght (m)


Salcia - profile A-B
Altitude (m)
Lenght (m)
Profile Graph Subtitle

Potelu site comprise on arable lands situated between Dabuleni village (aprox km 660) and Corabia (km 632) on the Danube river. This candidate site has a medium-high and medium restoration potential based mostly on having fragmented arable lands. However, the area was planed for restoration in previews studies (REELD) since can store large amounts of water during floods providing good inundation potential not only during high discharges but also medium water levels mostly because low altitudes.

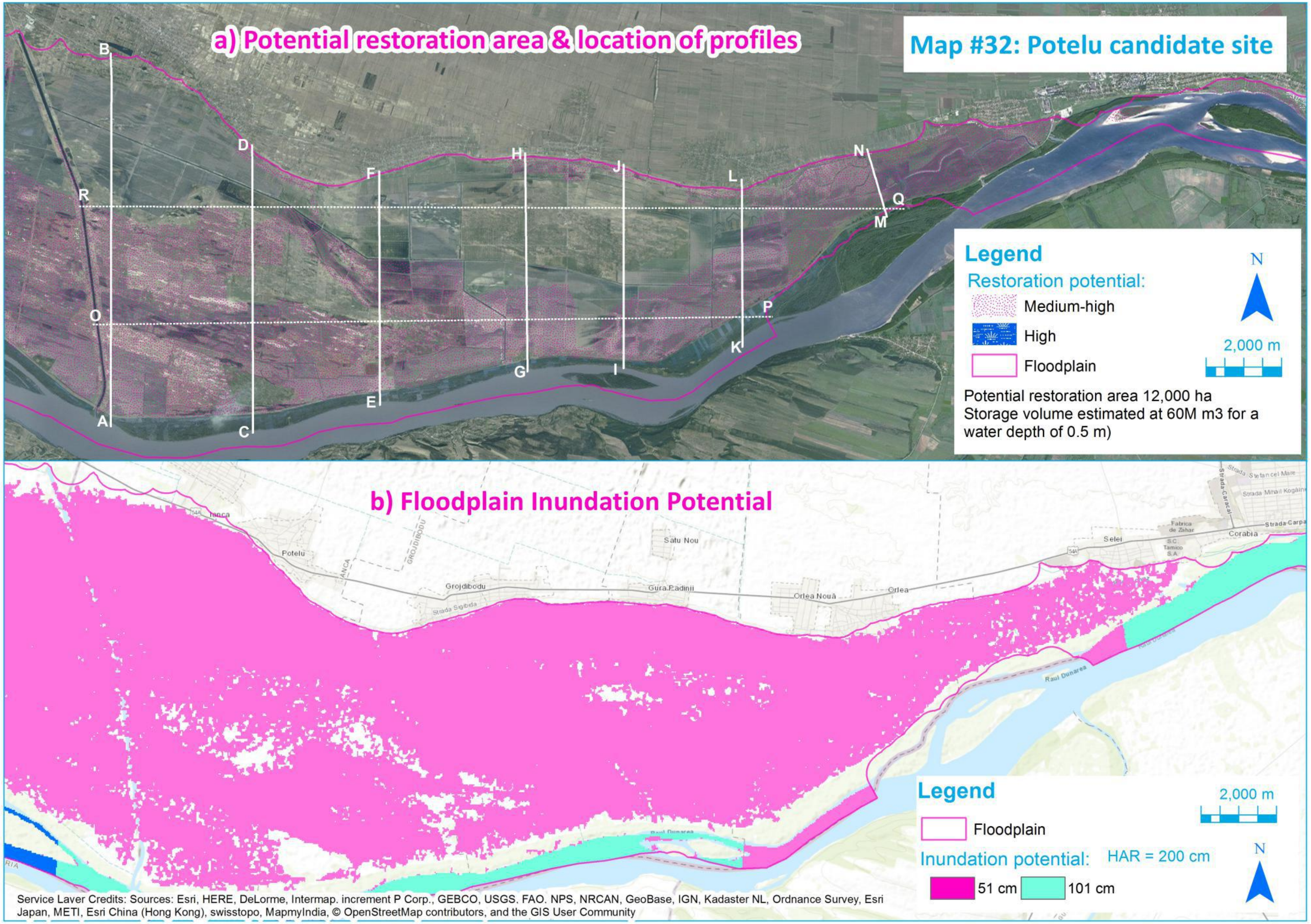
The area was one of the most productive floodplain areas along the lower Danube River, with one large lakes, e.g. Potelu Lake, and multiple floodplain wetlands, channels and other morphological features providing a variety of habitats and services for local population. The entire area was drained between 1965 and 1966 on a surface of 14,445 ha as a reclamation project in order to make room for agriculture. There were 32,4 km of dykes build along the Danube river to protect the arable lands from flooding. Luckily the big arable polder has no compartment dykes and there only irrigation and drainage systems accompanied by 5 pumping stations, sluices and big weirs at the Danube.

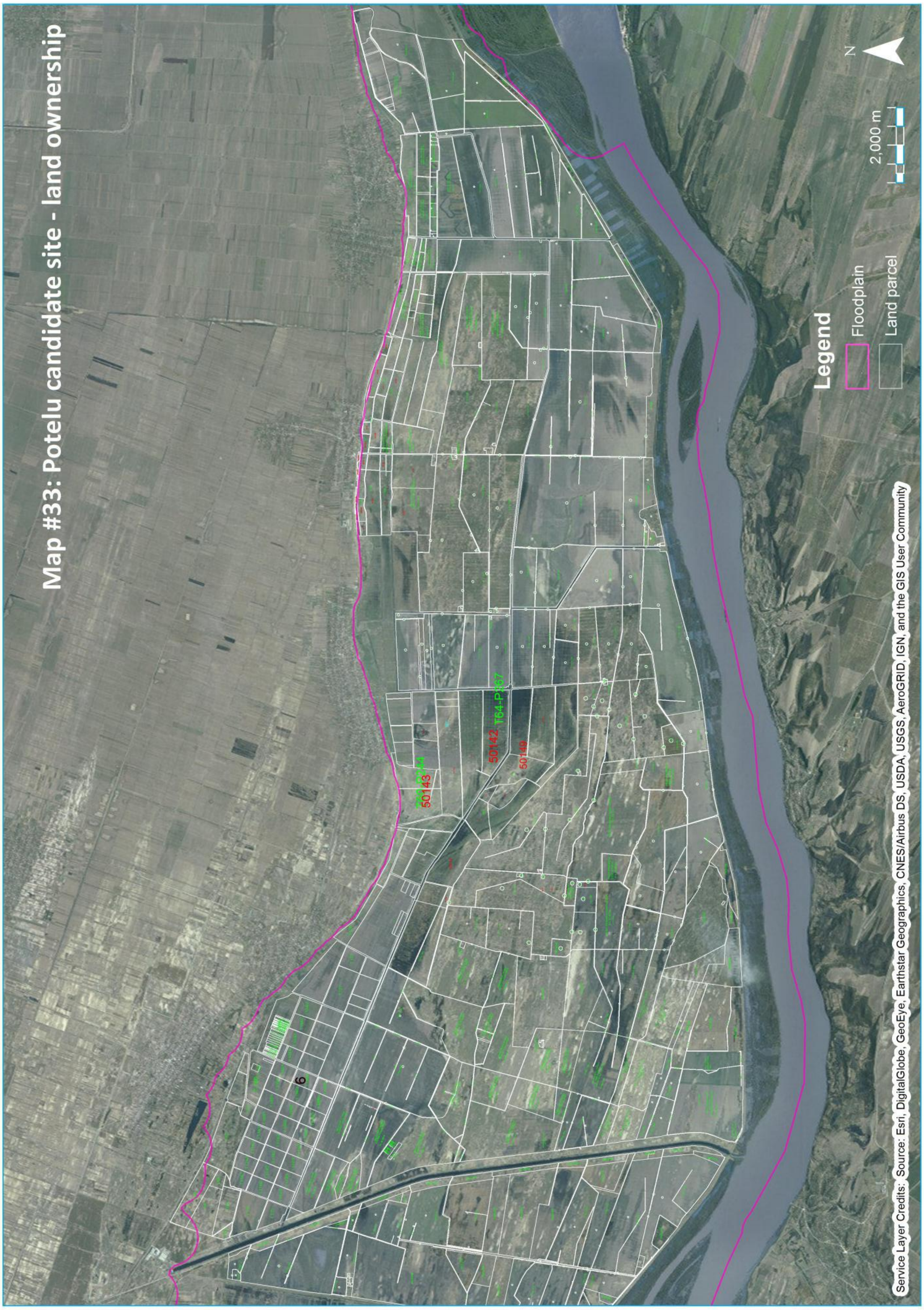
The entire area can store aprox. 60M m^3 at a water depth of just 0,5 m, which is by far the highest water storage capacity among the three candidate sites. However, the complicated land ownership, with many concessions and land uses and the existent irrigation associations with big infrastructure, prevent the restoration potential of this area to be accomplished. Although the local communities are willing to give their lands to restore the former Potelu lake and floodplain wetlands, a common understanding for the potential restoration area and measures with all key stakeholders is a challenging task that no organization is so far willing to undertake. WWF proposed this candidate site to be includes on the short list due to local support and relatively easy restoration solutions e.g. flooding the area using the existing channel and weir at the Danube River and diverting the water through irrigation/drainage channels. More insight of the potential areas to be flooded and at what discharges is necessary in order to proper delineate potential restored areas and affected lands.

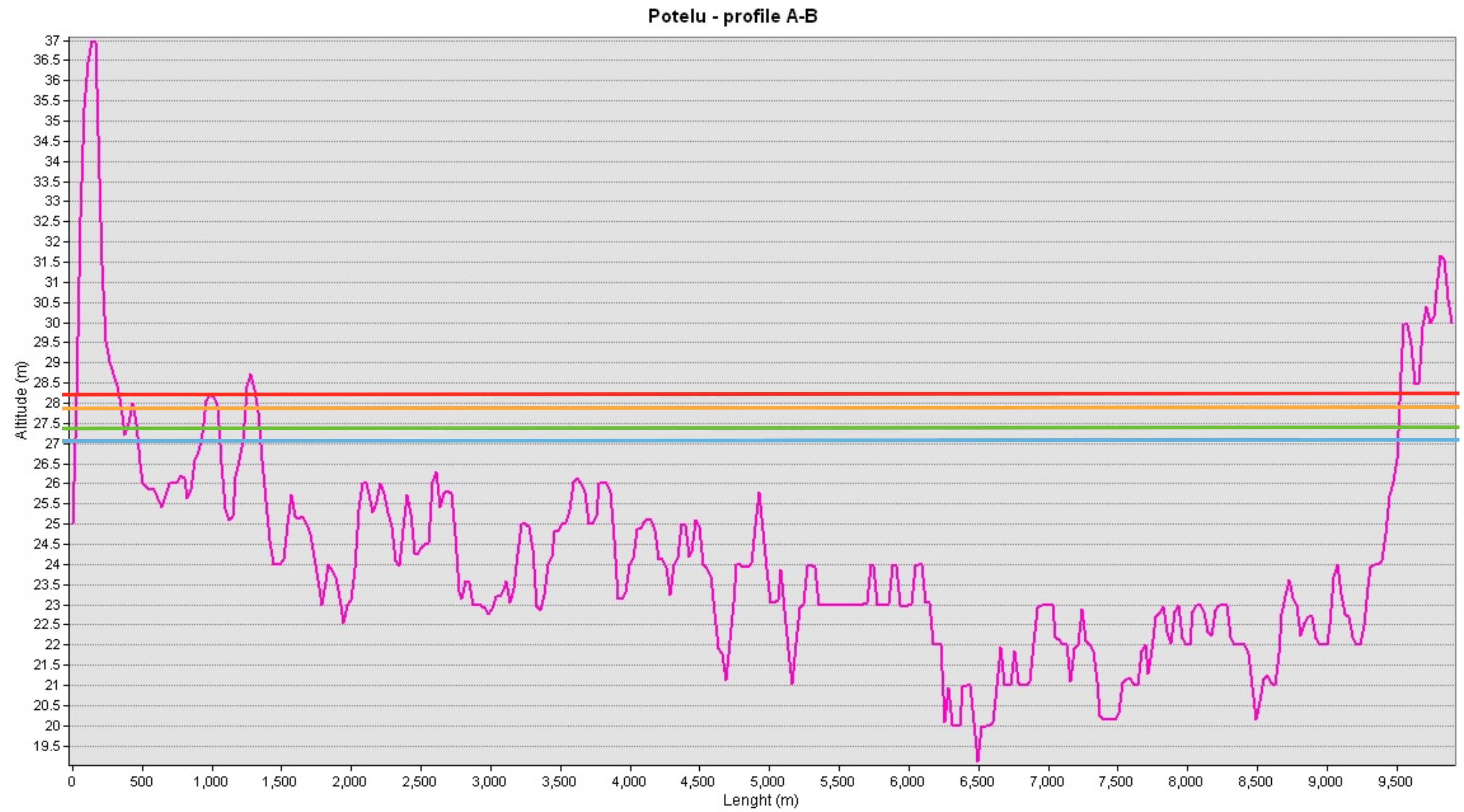
The area offers one of the best prospects for restoration but the complicated decision making process is not yet supported at the local and national level by political and administrative factors. Nevertheless, there are already investments made to improve the irrigation and drainage systems by local farmers most of them with EU funding, which is impeding even more the restoration efforts on short and medium terms in this area.

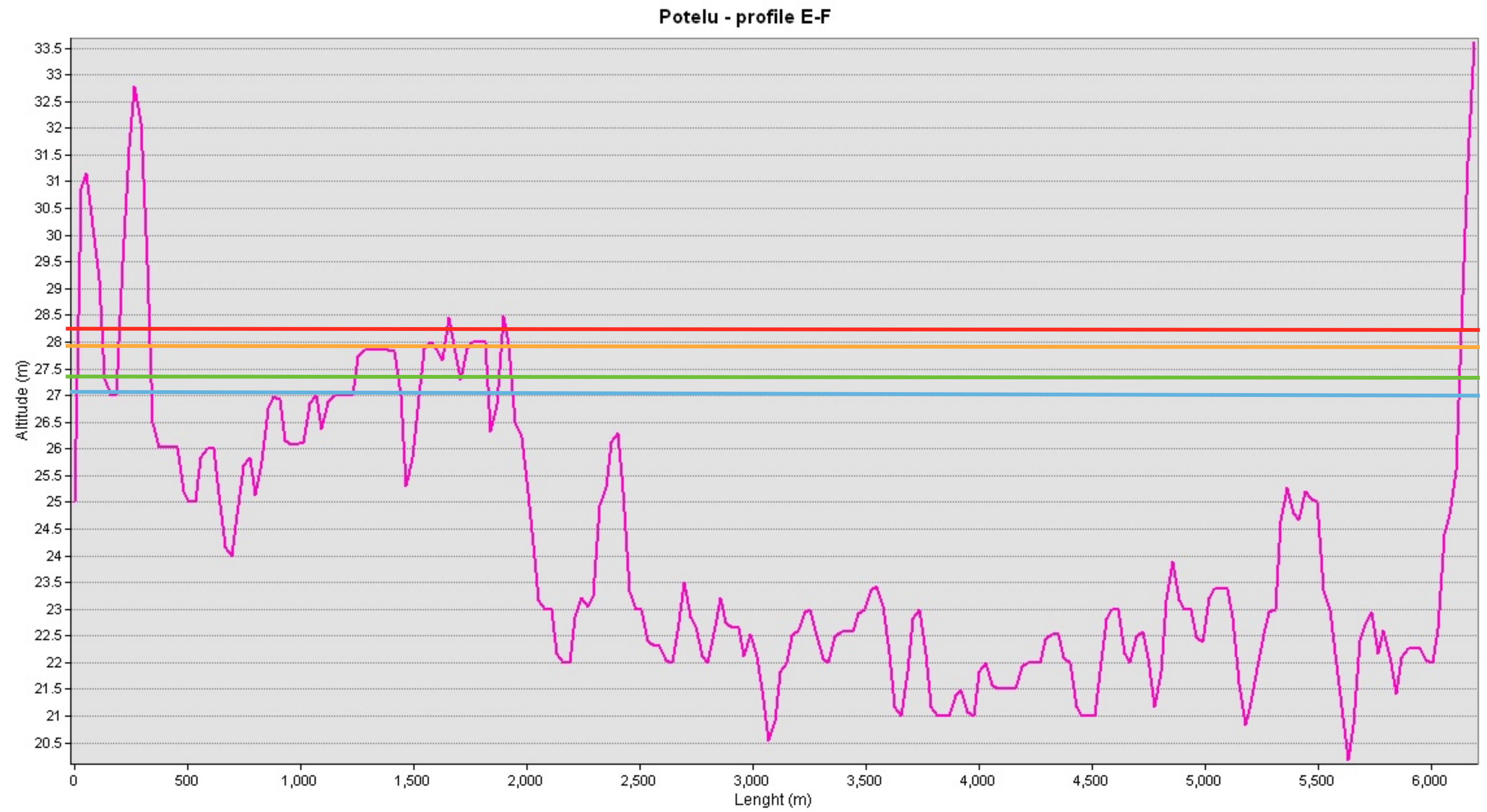
Views of the Potelu candidate site - above: the channel connection with the Danube River seen from the weir; - below: the main channel as seen from the weir to the arable polder.

Views of the Potelu candidate site - above: the arable lands seen from the protection dyke at the Danube River; - below: the area seen from the Danube terrace.


Map #32: Potelu candidate site
a) Potential restoration area & location of profiles
Legend
Restoration potential:
Medium-high
High
Floodplain
Potential restoration area 12,000 ha
Storage volume estimated at 60M m3 for a water depth of 0.5 m)
N
2,000 m
b) Floodplain Inundation Potential
Legend
Floodplain
Inundation potential:
HAR = 200 cm
51 cm
101 cm
N
2,000 m
Potelu
Grojdibodu
Gura Padinii
Satu Nou
Orlea Nouă
Orlea
Celei
Corabia
Raul Dunarea
Service Layer Credits: Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

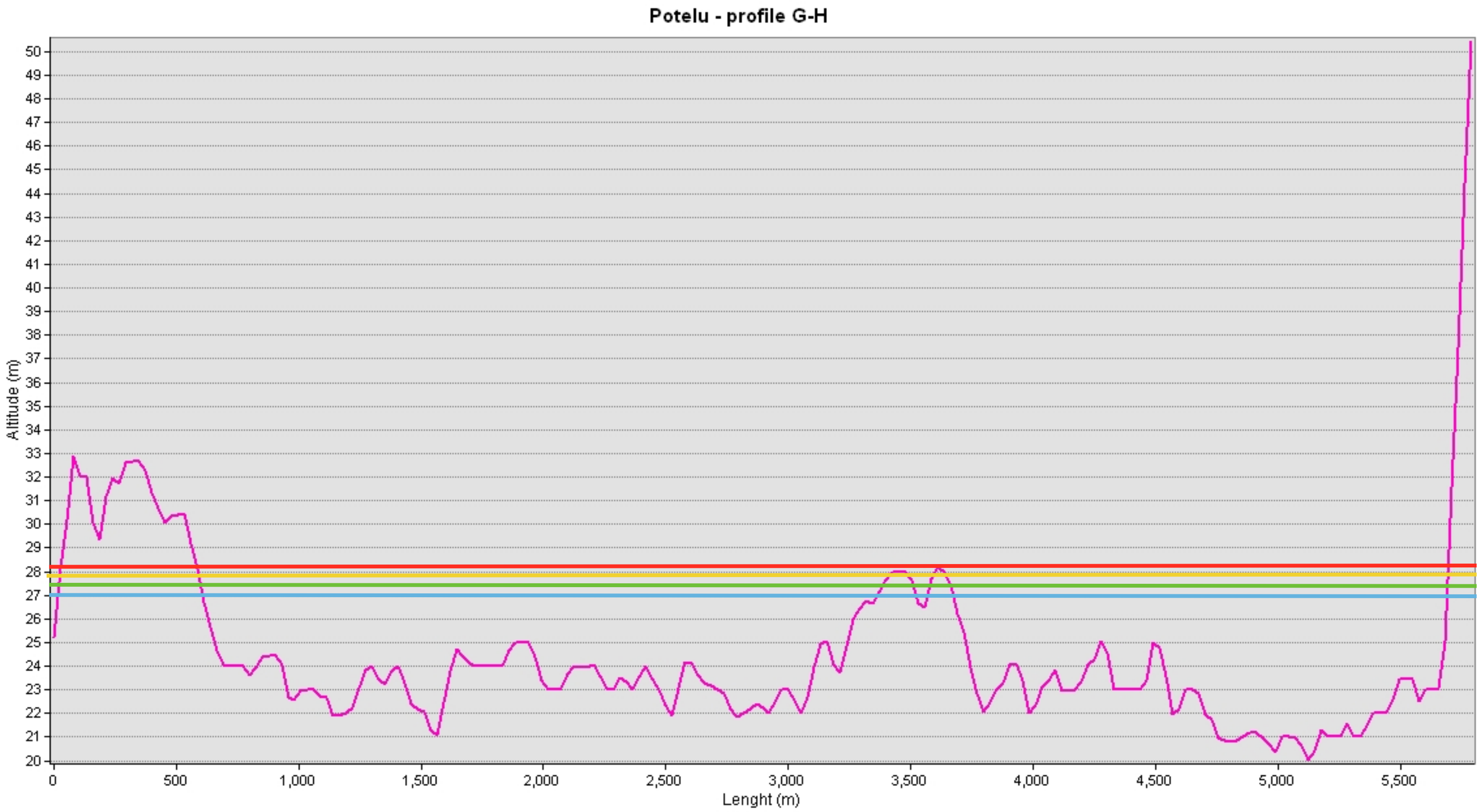

Map #33: Potelu candidate site - land ownership
Legend
Floodplain
Land parcel
2,000 m
N
T64-P167
50142
50143
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



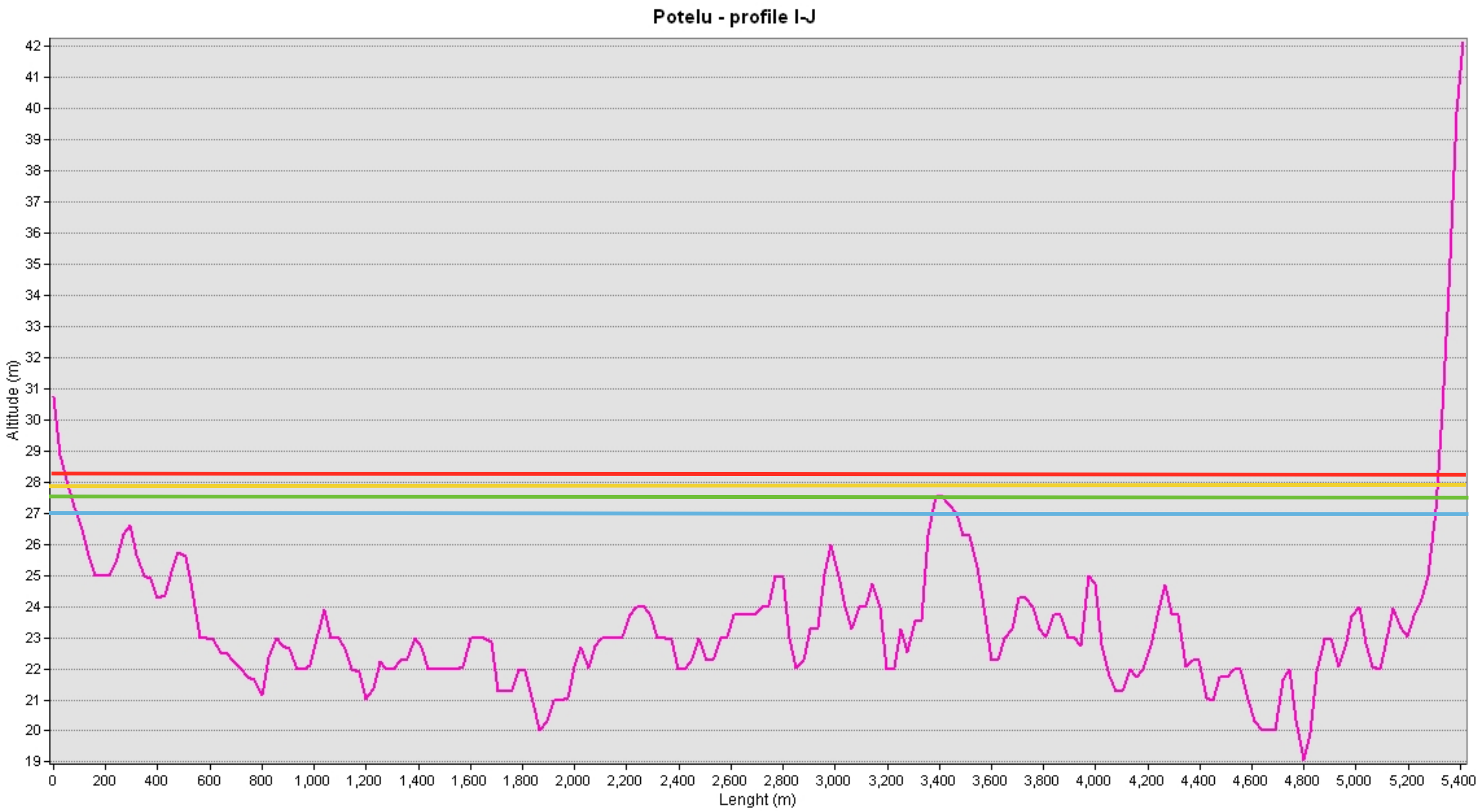


Maximum water levels at Corabia gauge station (p%) indicated as terrain altitude (data after REELD, 2006):

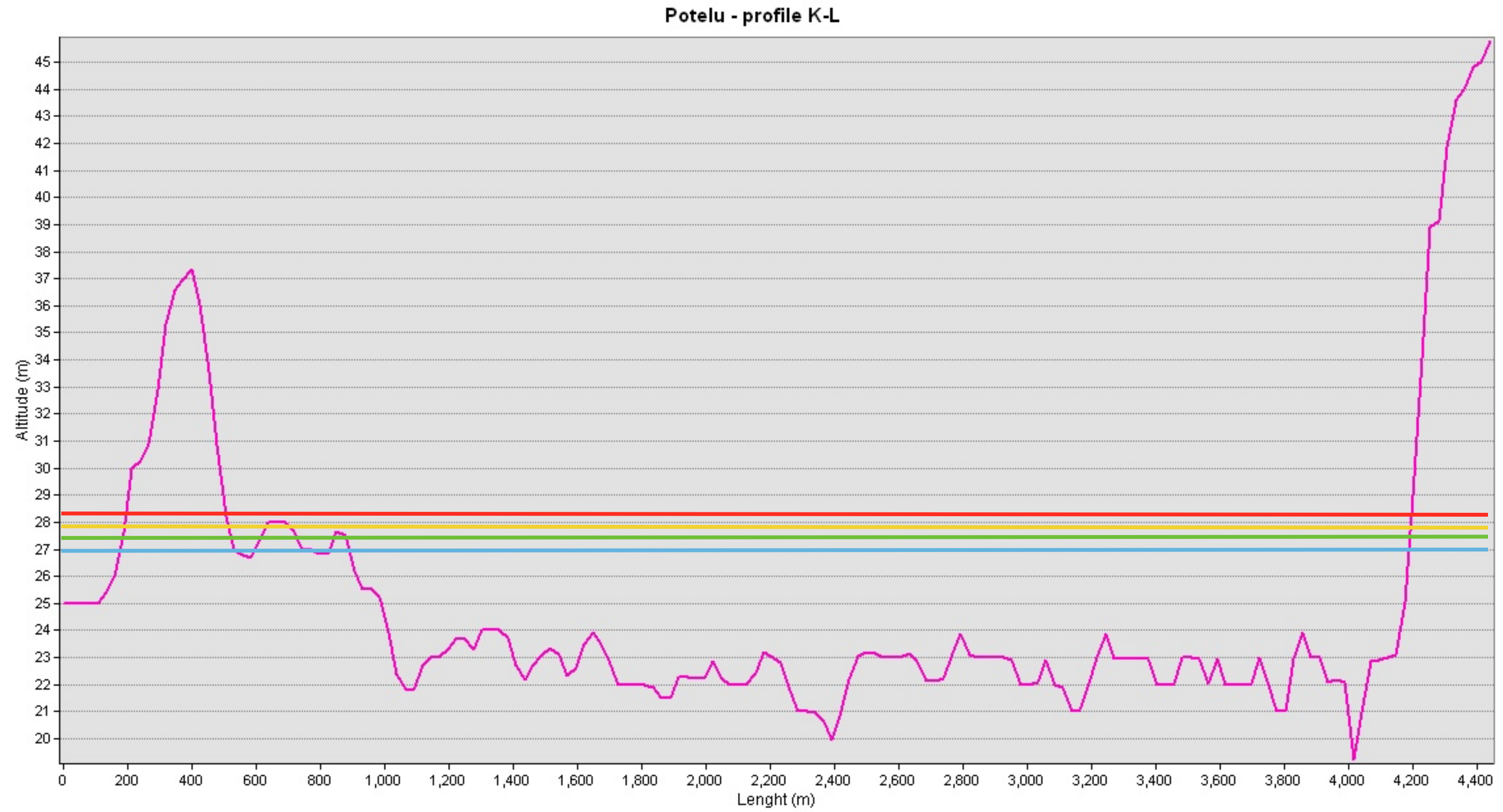
1% = 28,22 m   2% = 27,92 m   5% = 27,42 m   10% = 27,02 m



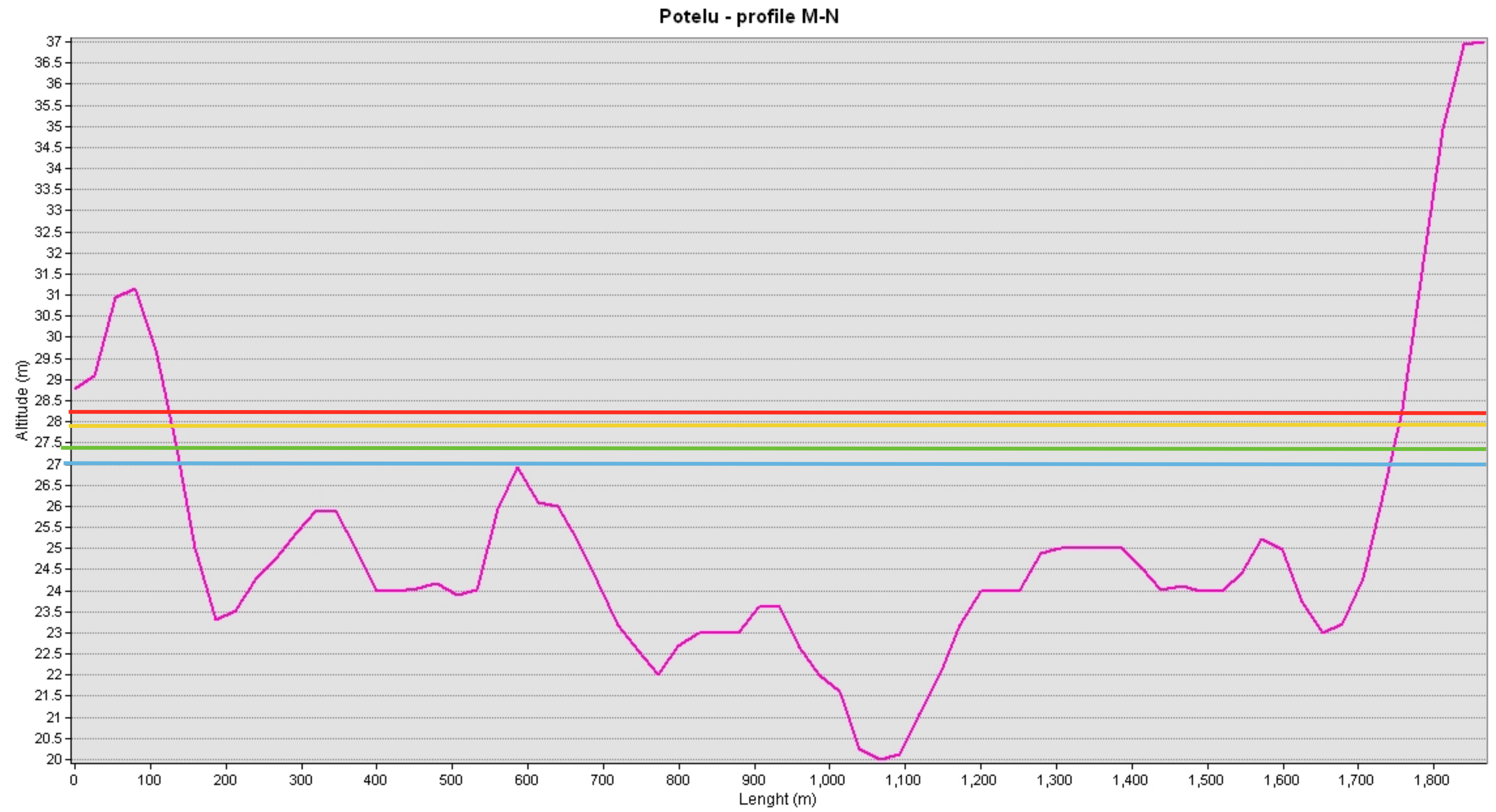
Potelu - profile G-H
Altitude (m)
Lenght (m)



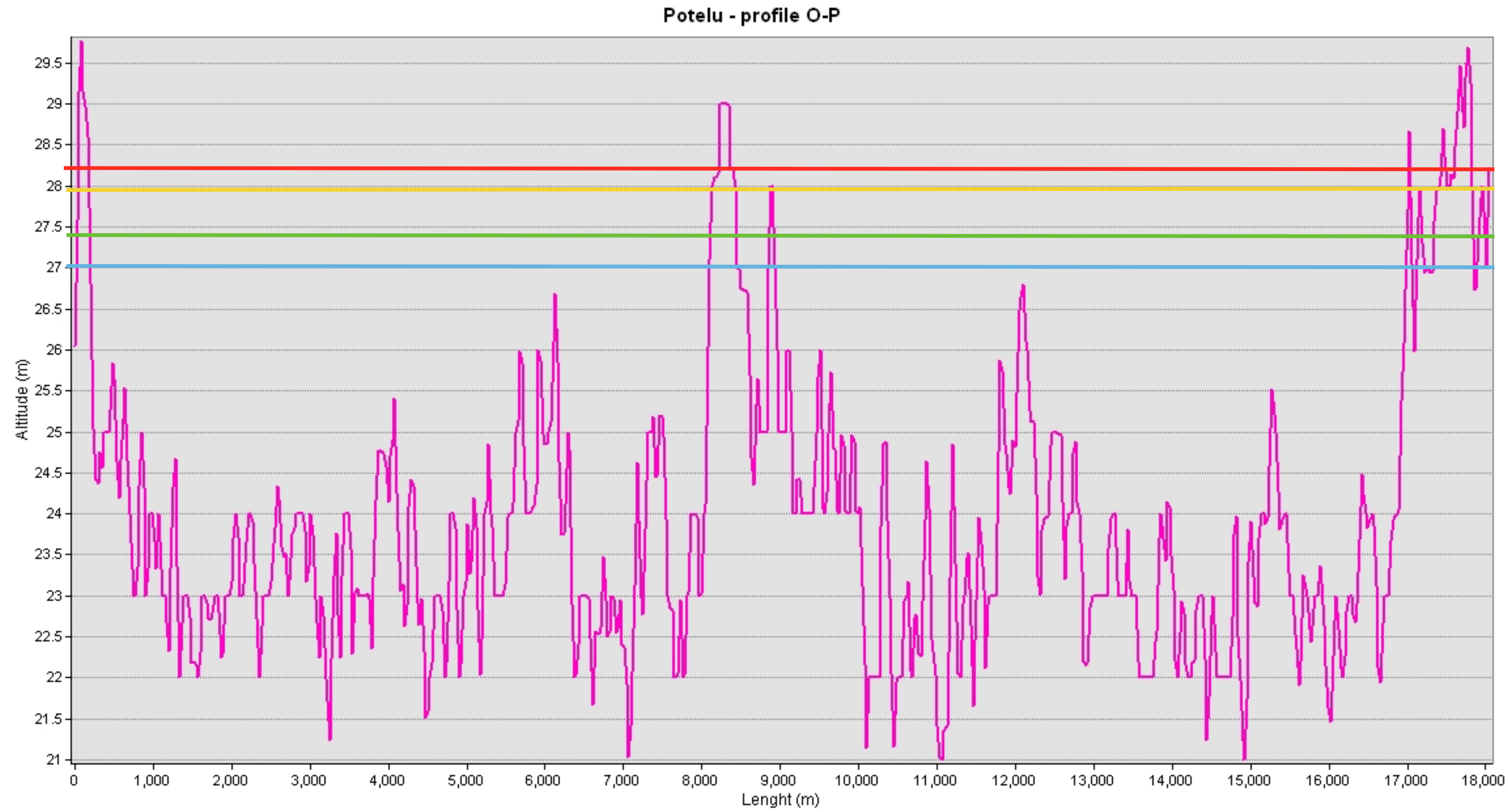
Potelu - profile I-J
Altitude (m)
Lenght (m)

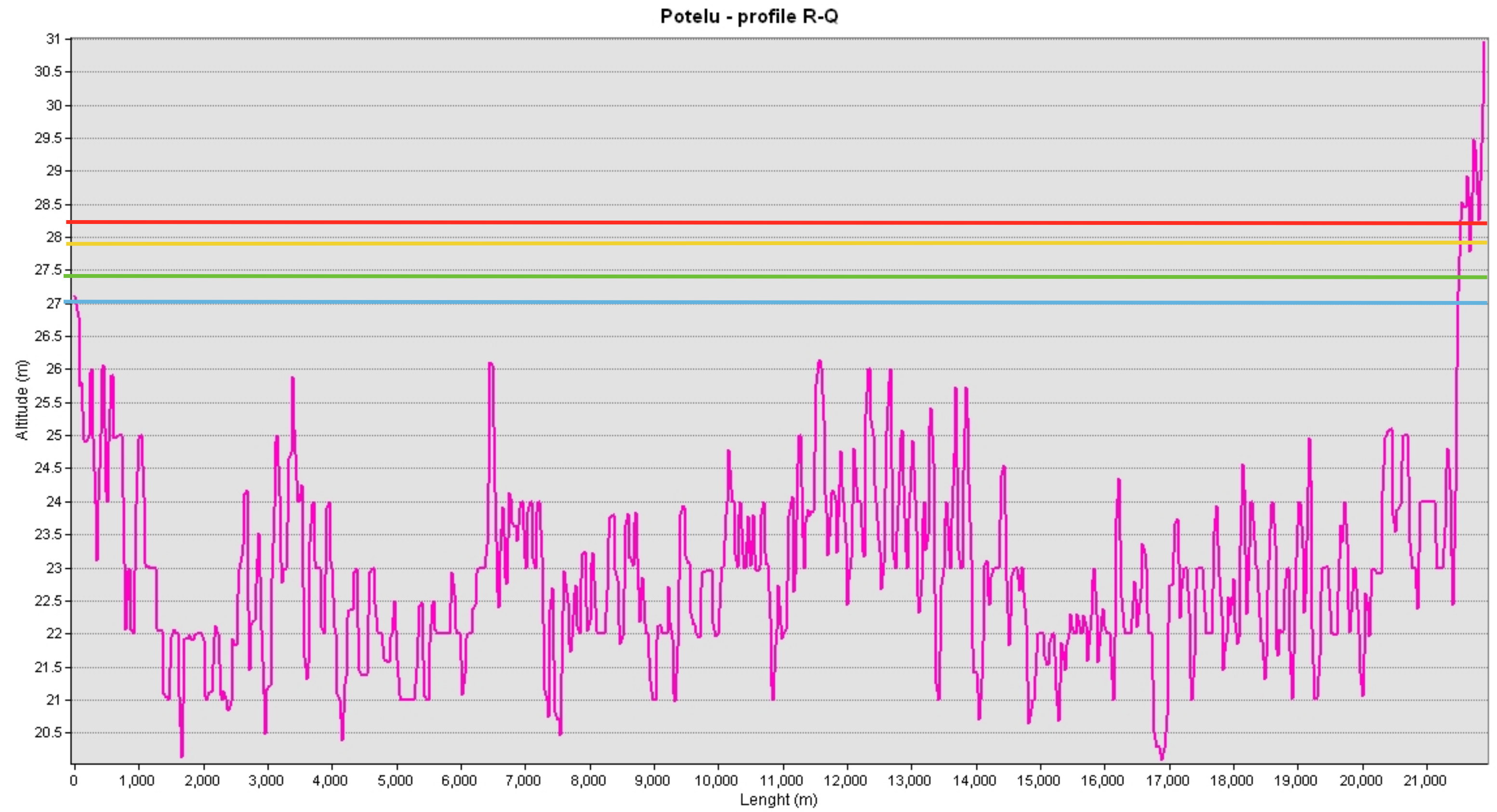


Potelu - profile K-L
Altitude (m)
Lenght (m)



Potelu - profile M-N
Altitude (m)
Lenght (m)


Potelu - profile O-P
Altitude (m)
Lenght (m)
29.5
29
28.5
28
27.5
27
26.5
26
25.5
25
24.5
24
23.5
23
22.5
22
21.5
21
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000


Potelu - profile R-Q
Altitude (m)
Lenght (m)
31
30.5
30
29.5
29
28.5
28
27.5
27
26.5
26
25.5
25
24.5
24
23.5
23
22.5
22
21.5
21
20.5
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
16,000
17,000
18,000
19,000
20,000
21,000

4.3. Stakeholder mapping

We believe floodplain restoration is not just a technical fix but also a *challenge* in a *system* where stakeholders coexist. This understanding requires identifying the *adaptive* elements of the challenges faced by each stakeholder. Making *contextualized interpretation*, rather than personal /organizational, can help stakeholders think politically and map the issue's, spot opportunities to build unusual alliances and solutions, and determine the outline interests or losses at risks for each stakeholder group.

Adaptive challenges, like those posed by floodplain restoration initiatives, are difficult because their solutions require people/organizations to change their usual ways of doing things. Change happens one step at the time. Working at the "table of interests" helps you acknowledge when you score some wins and to see if there is some avoidance from stakeholders on the issue e.g. define the problem just to fit their expertise, focus only on technical part of the challenge, etc.

Managing stakeholders. Remember that more complex your issue is, more attention you need to pay in managing stakeholders. You can do all the right things for a project, but mismanaging a stakeholder who has power, influence and interest can cause failure of the project.

Flexibility. Remember the context changes and evolves, and a successful floodplain restoration program needs to respond proactively to significant changes in the context/system of the issue at hand. Remain flexible and re-map the context allowing stakeholders to adapt and move forward.

Opportunities for collaboration. Knowing your opponents and allies will give you the opportunity to build unusual collaboration and reframe arguments. The process will give you access to involve technical expertise and best practices that are feasible for stakeholders to adopt.

Focus on the next steps. The process will give you chances to build effective interventions to when and where to focus your capacity in order to make progress e.g. on group of stakeholders, senior authorities, scientific / technical arguments, etc.

We see stakeholder mapping as a process of systematically gathering and analyzing qualitative information to determine whose interests should be taken into account when developing and/or implementing restoration project. The stakeholder engagement process is not an end where we have obtained something, e.g. concluded an agreement for the use of the area (although this is important step in the process) but a continuous collaboration for the proper management of the restored areas. The challenge for constructing a restoration project increases for every additional stakeholder whose permission is required. Objection from some stakeholders have stalled projects, reduced opportunities or obstructed restoration programs in many places in Europe as well as in Romania (see the REELD study).

Figure 6: Stakeholder evaluation for candidate sites Topalu, Potelu and Salcia. Dark blue circles represent circles with high degree of stakeholders being affected by the restoration (IA=indirectly affected, DA=directly affected). The other light blue circles represent circles with different degree of stakeholder influence (HI=high influence, SI=some influence, LI=low influence, NI=no influence/unknown). Stakeholders identified for candidate sites are: ADS - State Domain Agency; ANPM - National Agency for Environmental Protection; ANAR - National Water Administration; ANIF - National Agency for Land Improvements; ANPA - National Agency for Aquaculture; CJ - County Council; CL - Local Council; CON - concessionaires; DSCT - Constanta Forestry District; EPA - Local Environmental Protection Agency; FARM - local farmers; MoWF - Ministry of Water and Forests; MoE - Ministry of Environment; MoA - Ministry of Agriculture; ROMSILVA - National Forest Administration; OUAI - Organization of Farmer's Irrigation.

When it comes to stakeholder engagement in restoration projects along the Danube floodplain, voluntary access to needed property is difficult and time consuming, but not impossible (as experienced with Garla Mare fish farm restoration project implemented by WWF). Understanding each type of ownership will help in developing an effective strategy to build support for collaborative restoration of targeted sites. Each of the stakeholders presented in the table of interests and type of ownership present advantages and disadvantages when proposing a floodplain restoration project. As seen in the table of interests presented above, in most of the cases/sites the government administrations are the most affected by the restoration projects. This is because in all cases these administrations owns much of the infrastructure affected by the restoration projects and play a regulatory role on their lands and other ownership (e.g. concessions and irrigation both under the MoA although through different administrations). Similarly, there are multiple layers of government that have the potential to affect a restoration project and while they have the time, capacity, resources to implement restoration projects, they have difficulty building a consensus within their own organization on the most effective restoration approach on lands they own or control. On most of the candidate sites the access to land necessary for restoration require a more coercive measure such as expropriation or condemnation, which take more time and are politically more difficult. The restoration actions in the selected candidate sites are promising yet unproven and in this respect the restoration techniques are still considered experiments and have to be innovative.

Therefore, the challenge for proposing restoration projects along the Danube River is convincing stakeholders of both the need and for the action necessary for restoration and the efficacy of the proposed restoration actions. From this point of view, proposing a final candidate site where to target the further investment of time and resources is challenging and highly dependent on the continuous interaction with the key stakeholders and cooperation for the proposed restoration plans. In the context of prioritization of restoration actions, there is a need to persuade stakeholders for a new alternative, a new way of solving problems or simply a new idea. Most of the stakeholders identified for the candidate sites may or may not know about either the need for the restoration project or the benefits of the specific action proposed. Understanding of how people accept new ideas is key in stakeholder involvement and acceptance of restoration projects. To be accepted the restoration action must be innovative and perceived to provide a relative advantage to the stakeholder over existing techniques while be compatible with existing land use practices (in the case of abandoned fish farm from Salcia) and not too complex to understand or use. Most of the stakeholders look for a testable solution on an experimental or limited basis (ANAR, ANPA) and for solutions where the results are observable and clearly articulate in short time.

Proper meetings with key stakeholders from the proposed candidate sites were not possible during the time of the elaboration of this study. The only stakeholders approached by WWF for each of the candidate sites where ANPA for Salcia candidate site and the representatives of the local communities and land owners from Potelu candidate sites.

ANPA is the owner and legal administrator of the Salcia fish farm and they expressed their interest on continuing the aquaculture and fish production on all the fish farms along the Danube. Therefore, they cannot support directly the restoration efforts but only if the future concessionaire see advantages in doing such works on the fish farms. As mentioned before it is not sure from the interaction with ANPA if they see any potential to accomplish their interest, or part of it, through restoration efforts, e.g. to improve the fish farm status until a new concessionaire is interested in the area, to seek alternatives for reducing the costs with water pumping thorough restoration efforts etc. Moreover, we do not know if the decision not to support the restoration efforts of Salcia fish farm in entirely aligned with ANPA higher objectives of ensuring for example the natural spawning grounds for fishes. This leaves the negotiation process with ANPA open since just a short interaction with ANPA staff does not make possible to turn on the identified issues into opportunities to ensure that all the interests are satisfied. At this moment we can only take the feedback and continue proposing a prospective design for the restoration of the Salcia candidate site as agreed with the beneficiary, having the hope that a proper engagement process with NAPA can make the restoration efforts possible by satisfying all shared interest.

Similar, stakeholder involvement for Potelu candidate site has to continue in order to make it a priority for the national decision-makers and find the best solutions for the restoration of the area. Alternative for controlled flooding of some areas can make people see the benefits of the restoration and offer opportunities for those administration managing the infrastructure to test the technical solutions and adapt to the new requirements as well as be more confident in restoration solutions for their management objectives.

The approach used for stakeholder evaluation for the proposed candidate sites should focus on finding as much as possible key information during meetings and/or interviews with key stakeholders:

- How generalized in every participant/organization is the urgency to do anything about the restoration of the candidate site, or do you have to ripen the issue?
- What are the key elements that can influence stakeholders for starting a planning process for the restoration of candidate site?
- What are the *adaptive* challenges for the restoration of candidate site and what are the *technical* aspects?
- Who are the key planning actors? How can the key planning actors (the level where the planning is taking place) and stakeholders be influenced?
- How the decision favoring floodplain restoration will be made?
- What groups are going to lose something as a result of this decision, and what precisely are they going to lose?
- How will she be affected by the resolution of the challenge?
- How much does the stakeholder care about the issue and the context?
- What does the stakeholder know about the issue and how it is defining the problem? How does this differ from your and what are the common issues?
- What resources does the person/organization control, and who wants those resources?
- What would she like to see come out of the resolution of the issue?
- What are the commitments and beliefs guiding the behaviors and decision-making processes?
- What obligations do the stakeholder has to organizations/people outside her immediate group?
- What does the organization/people fear loosing if things should change?
- What shared interests does the people have with people from other major stakeholder groups that could lead the person to form an alliance that could build influence?

4.4. Vulnerability assessment, uncertainties and risks

Vulnerabilities refer to the potential for restored wetland to be impacted by future development or other land use activities.

The only vulnerabilities we are aware at this moment concerning the selected candidate site from Salcia is the further development of the aquaculture investments on the fish farm. However, if solutions are to be found with ANPA for the hydrological improvement on the fish farm, such vulnerabilities can be reduced through financial incentives or sustainability use for habitat management in Natura 2000 sites.

Considering the proposed restoration objective within the project, to replenish 2,2 M m^3 of water, which is counted only the first time when this target is accomplished, the vulnerabilities of further development of aquaculture at Salcia can be turned into new opportunities for habitat management of an already abandoned area within a Natura 2000 site.

Other vulnerabilities could be related to the road infrastructure development, especially the road from the village to the Danube river potentially affecting the alternative of reconnecting the backswamp with the abandoned fish farm and, in the case of feasibility of such alternative.

Potelu candidate site pose some vulnerabilities related to drainage and irrigation investments that are made already with structural funds or can be implemented in the future. This is valid especially for partial restoration of arable polder where the restoration target only some lands that are give voluntary for the restoration actions, like pastures, community lands, private lands, while excluding of big concessionaires lands from the restoration project.

One of the visible vulnerability at Topalu could be the implementation of bank stabilization measure or navigation improvement on this sector of the Danube River that could affect the local hydrology and/or hydraulics during low or medium discharges through the proposed inlet channel.

All the site have vulnerabilities related to the land use activities in the restored areas especially related to the management of the wetland areas, the use of the restored areas during the drought and Danube low discharges periods. Those activities that can potentially affect the restored areas have to be identified together with key stakeholders and managed according to wise use plans or other applicable plans (e.g. limit of use for natural resources, Natura 2000 site management plan, regulatory permits, local development plans).

Uncertainties refer to unknown that cannot be resolved in project design or by available research and generally it is related to natural variability, knowledge or preferences of stakeholders.

Such uncertainties have to be acknowledged in the project design phase and be managed properly during their time of occurrence. Some stakeholders preferences can shift during time of construction or after implementation due to social political or economic changes. It might be the case during long period of drought (natural variability) that local stakeholders do not see the value of the wetland areas anymore and might return to a more productive land use. All the candidate sites present such uncertainties especially those where traditional knowledge related to Danube floodplain was lost or where the capacity to manage the restored areas is difficult to be build due to social context.

Limitation of the analysis for a planning-level study to quickly assess and prioritize areas that are suitable for floodplain restoration along the Danube River are another example of research uncertainties related to knowledge and discussed in previous chapters. These uncertainties are related to source of input data and models used and can be reduced by improving the model with more accurate local data and hydrological modelling, which was to costly for this study. All these can be done in the technical design phase for each of the candidate site in order to provide more accurate restoration scenario for the stakeholder involvement.

Further uncertainties are related to the temporal and spatial scale of the recovery process of the restored areas, flooding conditions and other impacts that can be only uncovered with more accurate research at the scale of each site. As a rule of thumb, the uncertainties in restoration projects have to be accepted and use it as a feature of research to investigate it, quantify if possible and include it in reports and in the communication with stakeholders (Darby and Sear, 2008). Some researchers consider there are uncertainties in communicating to the public and policy makers the restoration expected results. The numbers used to quantify the restoration results are sometimes results of predict models and usually include some discussions and deviations from the expected value. Reporting all these errors and ranges of possible values rather than a single number protects the interests of many stakeholders and produce more reasonable expectation from them, potentially making them supporting the restoration actions.

Risks can be defined as the combination of the chance of a particular event (probability) and the impact that the event would cause if occurred (consequences), and it is related to potential project failures to meet its declared objectives. All sites can have risks related to costs or liability to the property or project beneficiaries and even potential displacement of biot, considering a drastic change in land use and habitat preference for some species. Reducing risks in project restoration comes with an increase of costs and can be done also by balancing the restoration objectives and the degree of uncertainties. Evaluating the range of potential outcome during the project design phase can help reduce the risks that a project will result in undesired outcomes (Roni and Beechie, 2013)

4.5. Restoration objective and prospective design of the Salcia candidate site

Restoration design for the candidate site have to illustrate what the final project will consist of and how the project will look when it is complete, but does not necessarily indicate how it will perform. However, the final design requires more detailed investigative analyses than the lower Danube river scale analyses performed in this study in order to assess and prioritize areas suitable for restoration. The most commonly investigative analysis performed for floodplain restoration projects includes at least a detailed survey and mapping, hydrologic investigations and hydraulic modeling, sediment transport analysis, geotechnical assessment and topographic survey and, biological survey. Depending of the project specificity and legal requirements a combination of these analyses is preferred depending on the project objective in order to define specific project parameters relevant for the project and to design feasible solutions. Here we just propose a prospective design based on the intended outcome, the available information which have to be reconsidered pending detailed investigative analyses and based on stakeholders preferred outcomes and existing project capacities.

The prospective design for Salcia site is defined as much as possible based on the owner outcome preferences including:

- goal and objective of the restoration: necessary to express an intended outcome that addresses the identified problems with consideration and accommodation of socioeconomic, ecological and, physical context.

- specific project elements necessary to meet objectives: these are features intended to remedy sources of problems and includes all distinct project components that can be designed independently, but together constitute a holistic restoration design;

- design criteria for elements that define expectation: these are specific and measurable attributes of project elements, such as how it will be

Table 6: Examples of potential prospective design and hypothetical project elements for the restoration of the Salcia candidate site, including specific parameters for restoration objectives and targets.
* target discharges are established through hydrological and hydraulic analyses according to the project objective and the most feasible alternatives (project boundary)

Goal	Objective	Parameter	Project element	Design criterion	Target
Restore degraded fish farm and floodplain wetlands to a healthy state	Restore access to historic extent of spawning habitat for fish species	Hectares of spawning habitats with connection to the Danube river. Length of channel meters with unrestricted flow	Modify channel dimensions by raising/lowering the bed for water flows at target discharges	Channel capacity will be equal to target discharge. Flood protection infrastructure will not increase.	75% of estimated historic extent of spawning habitat
	Improve natural processes (ability) to provide habitat for native fish	Population size of native fish species	Modify fish basin by excavating ponds, channels and depression	Morphological features will be improved to effective discharges	20% of fish basin with morphological features
	Increase abundance of native vegetation and fauna	Percent cover of wetland native species	Modify fish basin by lowering the topography. Plant native trees.	Location of native trees will improve habitat. Number of breeding pairs of tree bird species. Native vegetation succession and edge habitat.	> 35% cover of native plant species
	Increase inundated floodplain area and storage capacity	Hectares of inundated areas at targeted discharges* Water storage capacity at target discharge	Ensure proper connectivity between fish basin and the main channels at target discharges (e.g. sluices or other hydro technical infrastructures)	Hydro technical infrastructure will not increase. Water level duration and storage at target discharges will increase.	At least 50% of the restored area will be inundated at the 3-year discharge
	Reconnect the backswamp at target discharges	Hectares of wetlands inundated at target discharges Water level duration at discharges	Modify the connection channel between fish farm and backswamps. Build natural levees to secure high discharges flow to arable lands	Channel capacity will be equal to target discharge. Levees will contain the target discharge flow.	At least 30% of the backswamp will be inundated at the 3-year discharge
	Improve the floodchannel hydrology	Water level duration at discharges	Ensure the connectivity with the fish farm and/or floodplain at target discharges. Modify channel dimension through excavation.	Flow capacity improved. Water storage capacity improved.	At least 50% of the floodchannel will be inundated at the 3-year discharge

constructed or implemented (prescriptive criteria) and, what are the specific performance attributes of the design elements describing how they will perform(like the water depths and velocities in a channel). Design criteria are stated in the design documentation based on the preferred outcomes and as part of the design and investigative analyses process.

- assess/verify further information and research necessary for specific design that address restoration objectives: project design is a iterative process and changes of an element may necessitate changes to other project elements and in some cases new information or perspective on constrains to specific design elements require the revision of design criteria.

This is also the case of the prospective design drafted for Salcia candidate site and presented in the table 6. where the revision of the hypothetical project elements and the design criteria have to be adjusted and revised considering the investigative analyses necessary for a proper design phase.

5. Conclusions and recommendations

Despite negative impacts of human interventions, especially regulation of the river ecosystems through embankment and land reclamation for agriculture, forestry and aquaculture, the Danube floodplain in Romania still offers opportunities for restoration. The analysis and prioritization of such opportunities was performed using a multi-criteria decision tool using available data and variables to quantify and then mathematically arrange them and to identify suitable restoration sites along the floodplain.

MCDA facilitates collaborative decision-making and allows integration of preferences of attributes with objective measures of a variety of variables. The results of FROA are intended to support the subsequent planning and further development of selected restoration sites. Thus, FROA approach can be useful in establishing a simple but fairly SDSS for floodplain management with the possibility to include more accurate and updated data (e.g. hydrology, land use) and, other variables of interest for water quality management or stakeholder preferences for restoration outcomes.

The results of this desktop GIS analysis is not entirely tailored for specific areas identified as having high and medium-high restoration potential due to data limitation. Therefore, the floodplain restoration opportunity analysis is just a simple tool for a planning-level study supporting further investments for restoration and hopefully increasing the confidence of such efforts. We recommend that such efforts include detailed investigative analyses for each site and proper stakeholder involvement process.

Although our analysis demonstrate there are still many opportunities for restoration of small and medium size areas along the Danube River, ownership of the required lands is paramount for successful restoration projects. In order to be accepted we believe the further restoration solutions for the candidate sites or other suitable areas must be innovative and perceived as to provide a relative advantage to the stakeholders over the existing land use techniques. Most of the stakeholders look for a testable solution on an experimental/limited basis and for solutions compatible with the existing practices. They also look for results that are observable and clearly articulate in short time, which we believe can be accomplished through innovation and collaboration.

Multiple layers of government affect the decisions for restoration and, while they have the time and capacities to implement such projects, they have difficulty building a consensus within their own organization on the most effective restoration approach on land they usually control. This complexity and the scientific uncertainty of linkages between hydrologic (and especially flood peaks) and geomorphic and ecological functions, are leading to paralysis in restoration decision-making. In such cases, management decisions implicitly favor the *status quo.* Therefore the social-ecologic needs in floodplain restoration are not systematically addressed in the same way, for example, as flood management and water management.

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