

Pilot 3 – Drava catchment

SERVICE PROVIDER

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TABLE OF ACRONYMS

AOI	Area Of Interest	LC/LU	Land Cover / Land Use
MMU	Minimum Mapping Unit	WMTS	Web Map Tile Service
MMW	Minimum Mapping Width	RMS	Root Mean Square
EU	European Union	RZ	Riparian Zone
ETC	European Topic Centres	OP	Original Path
EEA	European Environment Agency	CP	Current Path
GReD	Global Reservoir and Dam Dataset	MGI	Austrian Institute of Military Geography

1. INTRODUCTION

The overall objective with the digitisation of the historical hydrographic features is to support the Biodiversity Strategy 2030. The EU's biodiversity strategy for 2030 is a comprehensive, ambitious, and long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030 and contains specific actions and commitments [1]. Among them, the restoration of 25,000km of rivers through barrier removals is highlighted. So, point features such as dams, channels, barriers, etc. would become an important feature.

Besides, straightened rivers are ecologically less valuable, and it is also important to be able to measure how many rivers have been straightened.

This pilot may help to better understand the possibilities of developing quantitative measurements that allow for better "identification" of areas suitable for restoration. The document could be disseminated to different European Topic Centres (ETCs) and thematic experts to gather feedback and ideas on its potential for implementation.

The results of the pilot will be published in an online viewer and all the work that has been done is documented in this report.

2. STUDY AREA - PILOT 3

As suggested by the Water Assessment Experts team of the EEA, the Drava catchment was used as Pilot 3. This area, as the previous two ones, is located in the Danube basin, specifically in the southern area of Austria, see Figure 1. The main river of the Drava catchment is the Drava River.



Figure 1. Location of the digitised areas, Pilots 1, 2 and 3.

As first steps, (1) the [historical maps](#) covering the study area, (2) the availability of the [legend](#) used, and (3) the [accuracy](#) of these historical maps were checked.

Historical maps

Pilot 3 is covered by different historical maps that were surveyed between 1816 and 1836, [Tyrol \(1816-1821\)](#), [Illyria \(1829-1835\)](#), and [Styria \(1821-1836\)](#). All of them correspond to [Second military survey of the Habsburg Empire](#), see Figure 2.



Figure 2. Historical maps covering Pilot 3.

Besides, each map is composed by different map sheets, see Figure 3.

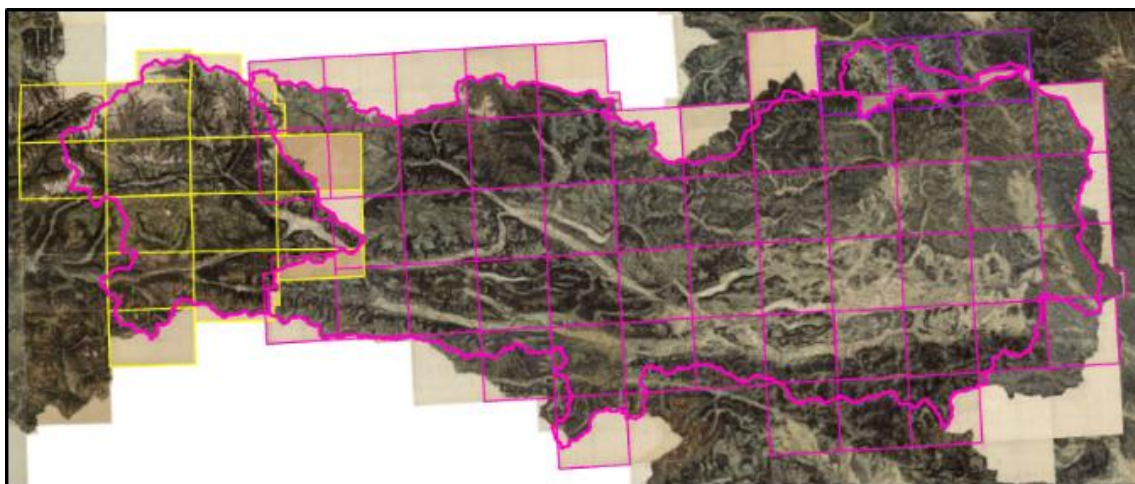


Figure 3. Different map sheets for Tyrol (yellow), Illyria (pink), and Styria (purple).

These maps or map sheets were not purchased, and the WMTS of the product distributor, Arcanum company [2], was used for digitisation purposes. The total number of map sheets needed are summarized in the following table:

Table 1. Maps and map sheets needed to cover Pilot 3.

Map	Scale	Number of map sheets
Tyrol, 1816-1821 (Second Survey)	1:28,800	15
Illyria, 1829-1835 (Second Survey)		54
Styria, 1821-1836 (Second Survey)		3
TOTAL		72

Legend

The surveying organization of these map sheets was the Austrian Institute of Military Geography (MGI) [3], and as stated in [4], from 1827 the MGI used consistent symbols, totally of 245 classes. This [legend](#) was available on the map website [5] [6], and moreover, it corresponded to the same legend as the one used in Pilots 1 and 2.

Positional accuracy

Regarding the [positional accuracy](#) of the maps, as stated in [4] and [7], in general, the accuracy observed was good in most parts of the catchment. However, a lack of precision was observed in some points of Alpine areas, see Figure 4.

These high positional errors could be due to the abrupt orography and the difficulty of on field data survey. Another source of error that could affect the entire area regardless of the orography could be, as stated in [4], *“most of the overall errors are due to the effect of the copy of the original sheets and the age, folding and drying of the paper sheets”*.

Although errors up to 400-500m were observed over some points of Alpine areas, the accuracy observed in the valley bottom ones was considered adequate, <50m, see Figure 4B and C.

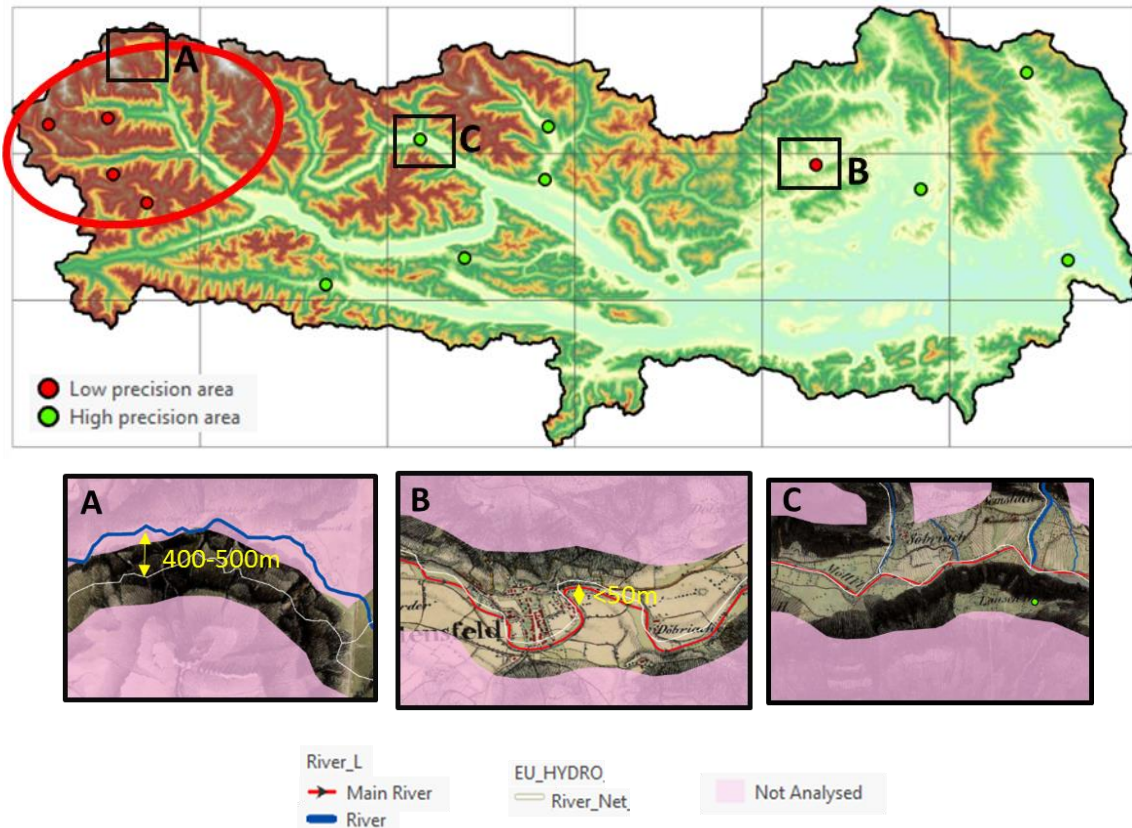


Figure 4. Analysis of the positional accuracy of the maps.

3. HISTORY OF DRAVA CATCHMENT

The history of this catchment is quite interesting, and its knowledge will allow to better understand the final results. As stated in [8], 140 years ago, *“The Upper Drava was a free flowing, meandering mountain river with numerous braiding stretches due to alluvial cones of the tributaries. In this dynamic river system with its annual floods and high bedload transport, the river course frequently changed. A braiding river - floodplain system with large gravel banks, grey alder, willow wetlands, and wetland meadows characterized the valley bottom”* [9].

In 1868 the first human impacts began, *“The first substantial human changes began with the building of the railroad line through the Upper Drava valley in 1868. In the following years, river-engineering channelized the river to reduce flood risk, as well as to allow intensive agricultural land use and the expansion of settlements. When the river was forced into a single main channel, the river dynamics were restricted and the number of side arms, gravel banks, wetland water bodies, and other natural habitats decreased. Due to the regulation processes and reduced sediment supply by the tributaries caused by torrent control structures, river bed incision occurred. This incision resulted in a decreased ground water level, causing desiccation of the remaining wetlands”* [9].

“In 1998, the river and its riparian zones became protected by designation as a Natura 2000 area. From 1999 to 2003 two EU LIFE projects were initiated under the title “Restoration of the wetland and riparian area on the Upper Drau River” and 2006 to 2011 (“Life vein – Upper Drau river”). These projects defined goals such as species and habitat protection and water management interests. Approximately 15 km of bank protection structures were removed, and several large scale river bed widening measures including new arms were realised.”

The following figure summarizes this history,



Figure 5. History of Drava catchment.

4. HYDROGRAPHIC FEATURE CLASSES

As a starting point, the same hydrographic feature classes and attributes defined for Pilots 1 and 2 were considered. Twelve feature classes were defined: six polygon feature classes, three line feature classes and three point feature classes, see Figure 6. Note that the “_A”, “_L”, and “_p” endings were added to polygon, line and point feature classes respectively. Note that there are two features to represent the rivers, lines and polygons. All rivers wider than 20m, were represented as a polygon and also as line feature class (this line represents the center of the river). Besides, in the case of Pilot 3, some rivers between 10 and 20m wide were also represented as both, polygon and line, see Section 5.2 Table 9.

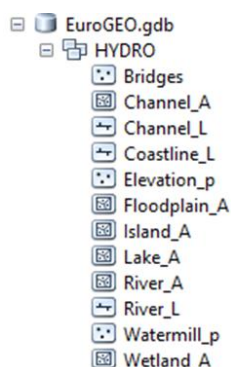


Figure 6. Structure of the ESRI File Geodatabase defined for Pilot 1.

In the case of Pilot 3, two new feature classes were added, “[River_Bank_A](#)” and “[River_Source_p](#)”. The river banks correspond to areas of sand or gravel located alongside the bed of a river or stream. They are of particular interest in fluvial geography, which studies the processes associated with rivers and streams and the deposits and landforms created by them. These areas were clearly identified over the historical maps, see Figure 7.

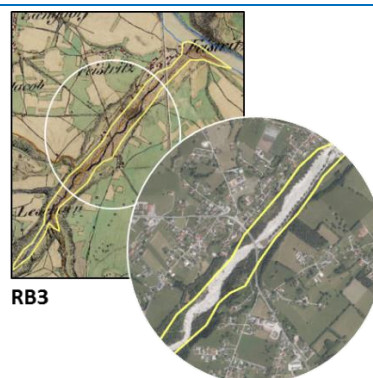


Figure 7. Examples of different riverbanks observed along the catchment studied.

Note that in the examples shown in Figure 7, the riverbanks are currently present. Regarding the river source, the point where the river starts, it was observed that the legend gathered a specific symbol to represent it.

This point, and thanks to the different information reviewed about the Drava River, was clearly identified over the historical map, see Figure 8.

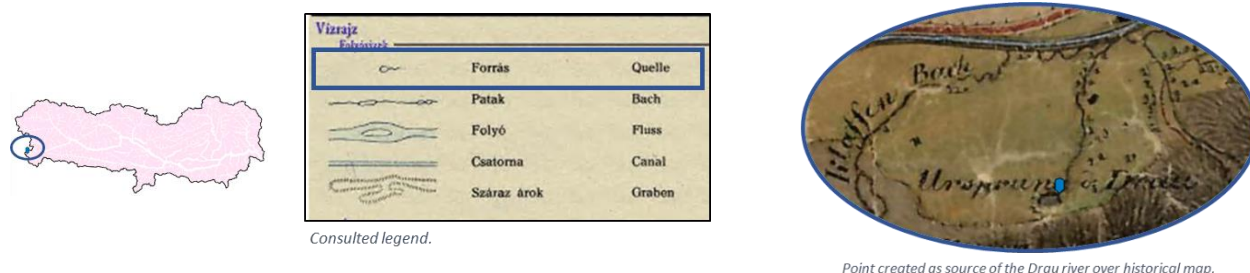


Figure 8. Identification of the river source.

The following tables summarize the hydrographic feature classes and attributes used for Pilot 3.

Polygon feature classes

Table 2. Polygon feature classes.

Polygon feature	Description	MMU
River_A	Streams and riverbanks or water edges.	10-20m width / 400m ²
Island_A	Land area surrounded by water. It can be a lake or river island.	
Lake_A	Gathers different inland water bodies: - Natural lake: lakes, ponds, swamps, lagoons. - Artificial: reservoir (dam). - Oxbow lake: lake – former part of river course – created by erosion. - Watermill pond: water body used as a reservoir for a water-powered mill.	
Wetland_A	Peatbogs, cane growing areas, soft lands, marsh lands...	
River_Bank_A	The terrain alongside the bed of a river or stream. They are of particular interest in fluvial geography, which studies the processes associated with rivers and streams and the deposits and landforms created by them.	

The following table shows the attributes defined for the polygon feature classes. Note that there are some common fields and other specific ones, *i.e.*, for islands and lakes.

Table 3. Attribute table of the polygon feature classes.

Polygon feature	Attribute table fields	
For all of them	Map name (Source info)	To choose among: "Illyria – Second military survey of the Habsburg Empire" "Styria – Second military survey of the Habsburg Empire" "Tyrol – Second military survey of the Habsburg Empire"
	Year	To choose among: "1829-1835" "1821-1836" "1816-1821"
	Digi_Author	"Tracasa Global"*
	Digi_Year	"2022"*
	Feature_name	If any, the name of the river, stream, lake,... is provided.
	Shape_Length	Automatically calculated
	Shape_Area	Automatically calculated
Island_A	Location	The location of the island. To choose among: Lake / River
	Lake_River_name	If known, the name of the river or lake on which the island is located is provided.
Lake_A	Type	To choose among: Natural lake / Artificial / Oxbow lake / Watermill pond
Wetland_A	Type	To choose among: Peatbog / Schilf growing areas / Soft land / Marsh land

* Text defined by default for this specific Pilot 3.

Line feature classes

Table 4. Line feature classes.

Line feature	Description	MMU
River_L	A naturally flowing watercourse. Represented by centre line of all streams and rivers.	50m length
DryDitch_L	Ditches where water can flow but are usually dry.	

Table 5. Attribute table of the line feature classes.

Line feature	Attribute table fields	
For all of them	Map name (Source info)	To choose among: "Illyria – Second military survey of the Habsburg Empire" "Styria – Second military survey of the Habsburg Empire" "Tyrol – Second military survey of the Habsburg Empire"
	Year	To choose among: "1829-1835" "1821-1836" "1816-1821"
	Digi_Author	"Tracasa Global"*
	Digi_Year	"2022"*
	Feature_name	If any, the name of the river, stream, channel, coastline,... is provided.
	Shape_Length	Automatically calculated
River_L	Accuracy	To choose among: Clear / Diffuse

* Text defined by default for this specific Pilot 3.

Point feature classes.

Table 6. Point feature classes.

Point feature	Description
Bridges_p	Different type of bridges that can be observed over the maps.
Watermill_p	Watermill points, associated with watermill ponds.
River_source_p	Point where the river starts.

Table 7. Attribute table of the point feature classes.

Point feature	Attribute table fields	
For all of them	Map name (Source info)	To choose among: "Illyria – Second military survey of the Habsburg Empire" "Styria – Second military survey of the Habsburg Empire" "Tyrol – Second military survey of the Habsburg Empire"
	Year	To choose among: "1829-1835" "1821-1836" "1816-1821"
	Digi_Author	"Tracasa Global"*
	Digi_Year	"2022"*

* Text defined by default for this specific Pilot 3.

5. DIGITISATION RULES ESTABLISHED

5.1. Basic specification

EuroGEO_Pilot3_DrauRiver.gdb was created containing all the hydrographic features defined in the previous section. Domains were created when needed, in order to facilitate the digitisation process and avoid typo errors, *e.g.*, different lake types (natural lake, artificial, oxbow lake and watermill pond).

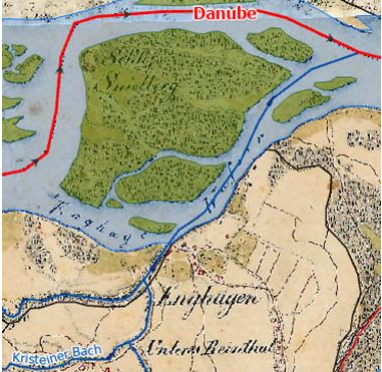
The digitisation scale was set on 1:5,000 – 1:20,000 in order to reach the MMU established.

In this case, the projected ETRS 1989 LAEA coordinate system was established.

5.2. Specific rules

All the specific rules defined for Pilots 1 and 2 were considered, and the following table summarizes all of them. Besides, a new one was added when working on Pilot 3, see Table 9.

Table 8. Specific rules used when digitalising Pilots 1, 2 and 3.

Rule	Description	Example
River polygons can contain gaps	River polygons could contain gaps, and these gaps corresponded to islands. In the case of branched rivers, all the connected branched rivers wider than 20m (established as a MMU) were considered.	
River unique centre lines	Each single river wider than 20m, was represented as polygon and also as line feature class. This line feature class represented the river centre line and was symbolized with a line with an arrow indicating the direction of the flow. In the case of branched rivers, it was also defined a unique centre line, and this line could not overlap with the islands.	
Stream lines connected with the main river line	The streamline was connected to the centre line of the main stream following the shortest way, the flow direction, and without overlapping the islands.	

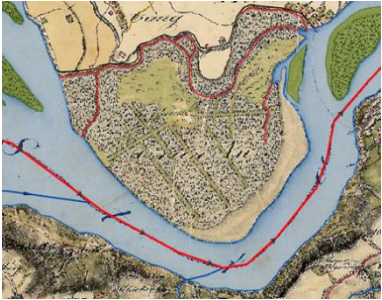
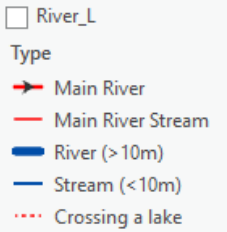
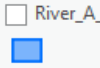
Branched rivers representation	All the connected branched streams or rivers wider than 20m were considered and drawn as polygons. Those narrower than 20m, were also considered, and were drawn as lines. These lines were not connected with the centre line of the mainstream since they correspond to the same river and did not contribute with an external water flow.	
Lakes centre lines	In cases where a stream flows to a lake, a centre line was also drawn in order to maintain a continuity.	
Dry ditches representation	Dry ditches were only represented as line feature class. Ditches of different sizes (width) were observed, but they were only represented as lines because they did not contain water.	

Table 9. Specific rule added for Pilot 3.

Rule	Description	Example
River lines and polygons for rivers <20m wide	Rivers represented as polygons whose wide was smaller than 20m.	
	(1) A new category was added to the river line feature named as "River (>10m)" 	
	(2) Based on the "River (>10m)" layer, the polygons of those rivers <20m wide that were represented as polygons in the historical maps were automatically extracted. 	

In the case of Pilot 3, it was realised that there were a lot of rivers represented as polygons whose width was smaller than 20m (the one established as MMU). The average width of these rivers was 10m and it was very difficult to draw them manually.

In order to represent them as polygons, like in the historical maps, it was decided to (1) add a new category to the river lines feature named "River (>10m)" in order to represent those rivers wider than 10m, and (2) automatically extract the polygons of those rivers' smaller than 20m wide that were drawn as polygons in the historical maps. For this aim, the "River (>10m)" lines that fell over those river polygons smaller than 20m wide were converted to polygons using "Feature to Polygon" tool and applying a buffer of 5m, see Table 9.

6. FINDINGS DURING THE DIGITISATION PROCESS

In this section, all the findings found during the digitisation process of Pilot 3 are described.

6.1. Complexity of maps

The complexity of different map sheets covering Pilot 3 was very variable because (1) the complexity of the river itself varied a lot, *e.g.*, single *versus* branched river, and (2) was not the same to digitalise over mountainous areas or over valley bottom areas.

6.2. Quality of maps

It was observed that the quality of the different map sheets was in general good. Slight differences were observed between consecutive map sheets regarding the color or symbology, but no differences were observed inside a single map sheet.

6.3. Accuracy of the maps

The accuracy observed was good in most parts of the catchment, that fits with as stated in [7], *i.e.*, "Accuracy of the Second Survey is surprisingly good in most parts of the Empire, the maximum error is cca. 200 meters". However, a lack of precision was observed in some points of Alpine areas, see Section 2.

6.4. Lack of continuity between consecutive maps

In some areas, a lack of continuity between consecutive map sheets was also observed. This may be due to the rectification errors, and also due to the effect of the copy of the original sheets and the age, folding and drying of the paper sheets previously mentioned, see Figure 9.



Figure 9. Lack of continuity observed over consecutive maps.

6.5. High level of detail of the historical maps

Due to the high level of detail that the maps show, it has been possible to identify the name of many features (*e.g.*, rivers, lakes, streams) and include them in the geodatabase. Besides, in cases where the name was not clear enough, available base maps have also been searched in order to get or verify the name.

7. ANALYSIS OF THE RESULTS AND FINAL CONCLUSIONS

7.1. Analysis of the results

Pilot 3 presents quite abrupt orography in some areas, see Figure 10. The differences observed from West to East are highlighted and note that in the grids shaded in orange, mountains up to 3000m in height are included. The standard deviation of the height in these grids is also high.

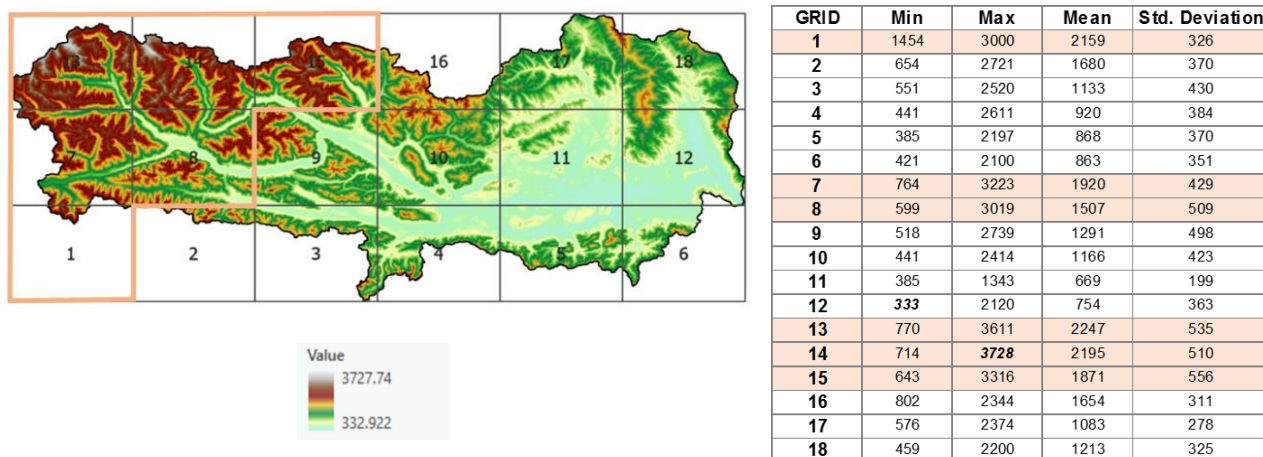


Figure 10. Differences observed regarding the orography in Pilot 3.

Furthermore, as previously mentioned, a lack of precision was observed in some points of this Alpine area, see also Figure 4. So, in order to avoid bias, it was decided to carry out the analysis of the results by grid.

Besides, when analysing the results, the polygonal and lineal features were separately analysed. The **polygon features** were compared with the ones gathered in the **Riparian Zone (RZ) layer** [10]. On the other side, the **lineal features** were compared with **EU Hydro layer** [11].

7.1.1. Polygonal features

The main digitised polygonal hydrographic features corresponded to: river, lakes, wetlands and river banks, see Figure 11.

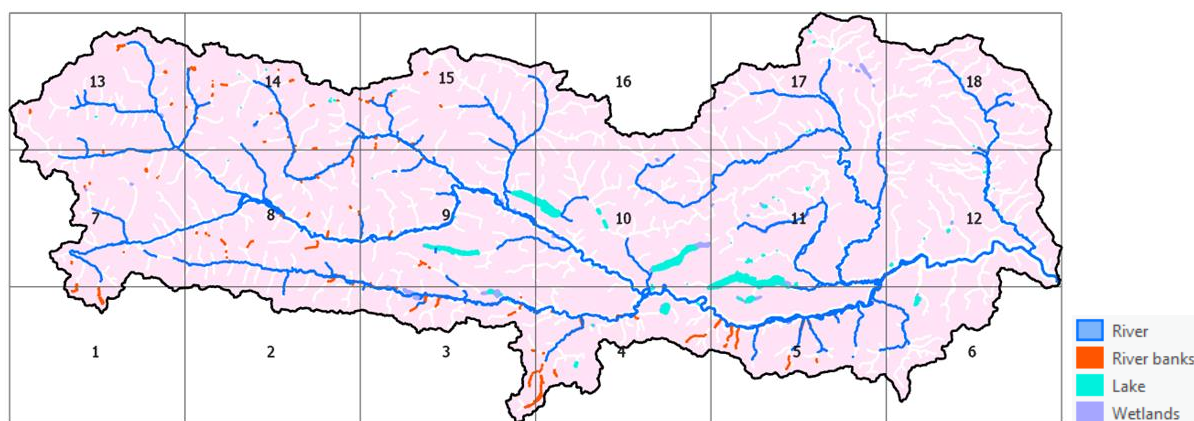


Figure 11. Main polygonal features digitised.

They were compared with the same categories contained in the RZ layer, see Figure 12.

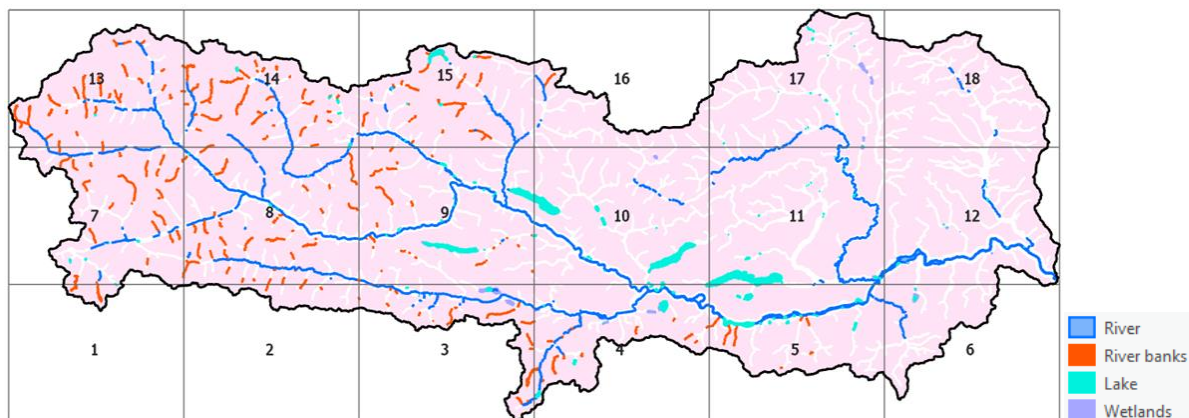


Figure 12. Main hydrographic features contained in the RZ layer.

Taking into account the entire study area, it is highlighted that the surface of rivers, wetlands and riverbanks have decreased while the surface of lakes has increased, see Table 10.

Table 10. Total digitised hydrographic surfaces, gathered in the RZ layer and its tendency along time.

Hydrographic feature	Digitised (km ²)*	Riparian Zone (km ²)*	Percentage of increase/decrease in terms of surface
River	56.84	47.26	16.85
River banks	22.76	17.14	24.69
Lake	60.20	67.40	11.96
Wetland	15.89	6.80	57.21
Islands	11.42	-	-

*Digitised reference years: 1816-1836 / RZ reference year: 2018

Next, each of the hydrographic features is analysed by grid.

7.1.1.1 River polygons

The table in Figure 13 shows the distribution of the river polygons over different grids in terms of square kilometers (km²). The numbers in blue refer to the digitised polygons while the grey ones to the RZ layer. Besides, the cells shaded in blue are the ones where an important increase has been observed, *i.e.*, the surface of rivers in the RZ map has risen with respect to what was extracted from the 19th century map. On the other hand, the ones shaded in light brown correspond to those where an important decrease has been observed over time. When analysing the other hydrographic features, the same template will be used.

Digitalised



Riparian Zone



Digi (km ²) (%)	Decreases (Digi>RZ)
RZ (km ²) (%)	Increases (Digi<RZ)

(%) Regarding the total Digi/RZ surface

0.74 (1%) 1.29 (3%)	1.05 (2%) 0.83 (2%)	2.00 (4%) 0.88 (2%)	0.26 (0%) 0.09 (0%)	1.17 (2%) 0.37 (1%)	0.89 (2%) 0.11 (0%)
0.93 (2%) 0.94 (2%)	6.96 (12%) 4.35 (9%)	7.91 (14%) 4.06 (9%)	3.54 (6%) 2.64 (6%)	5.55 (10%) 3.20 (7%)	7.81 (14%) 12.95 (27%)
- -	0.02 (0%) -	3.05 (5%) 1.86 (4%)	5.86 (10%) 5.25 (11%)	8.59 (15%) 8.13 (17%)	0.47 (1%) 0.26 (1%)
TOTAL Digitalised		56.84 km ²			
TOTAL Riparian Zone		47.26 km ²			

Figure 13. Results for river polygons when comparing with the RZ layer.

In this case, the main changes in the river surface were located over the grids from 8 to 12, that correspond to the areas where the Drava River flows. It was realised that the main decreases were located in areas where a significant decrease in river branches had been observed while digitalising, see Figure 14. The black spots show some locations where the river was observed to narrow.

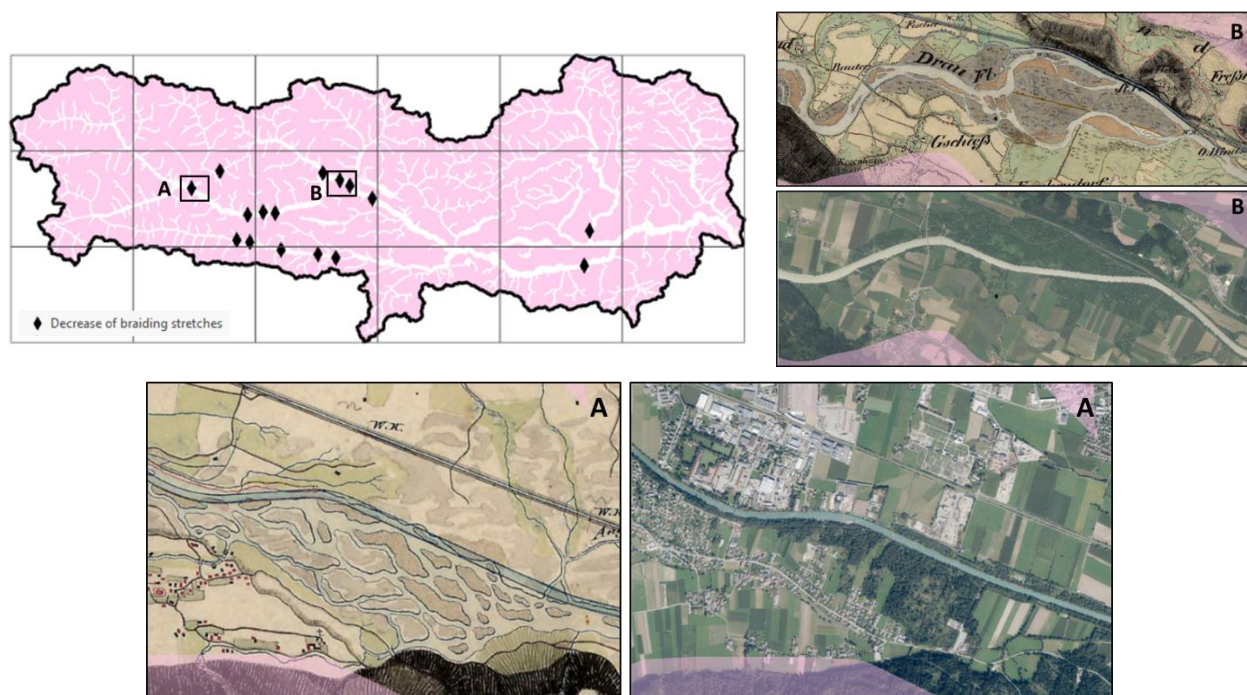


Figure 14. Locations where the river narrows.

On the other hand, the increase observed over grid number 12 could be related to the effect of building a dam, see Figure 15. It seems that currently, the volume of water that accumulates in this area is much greater than in the past because of the dam.

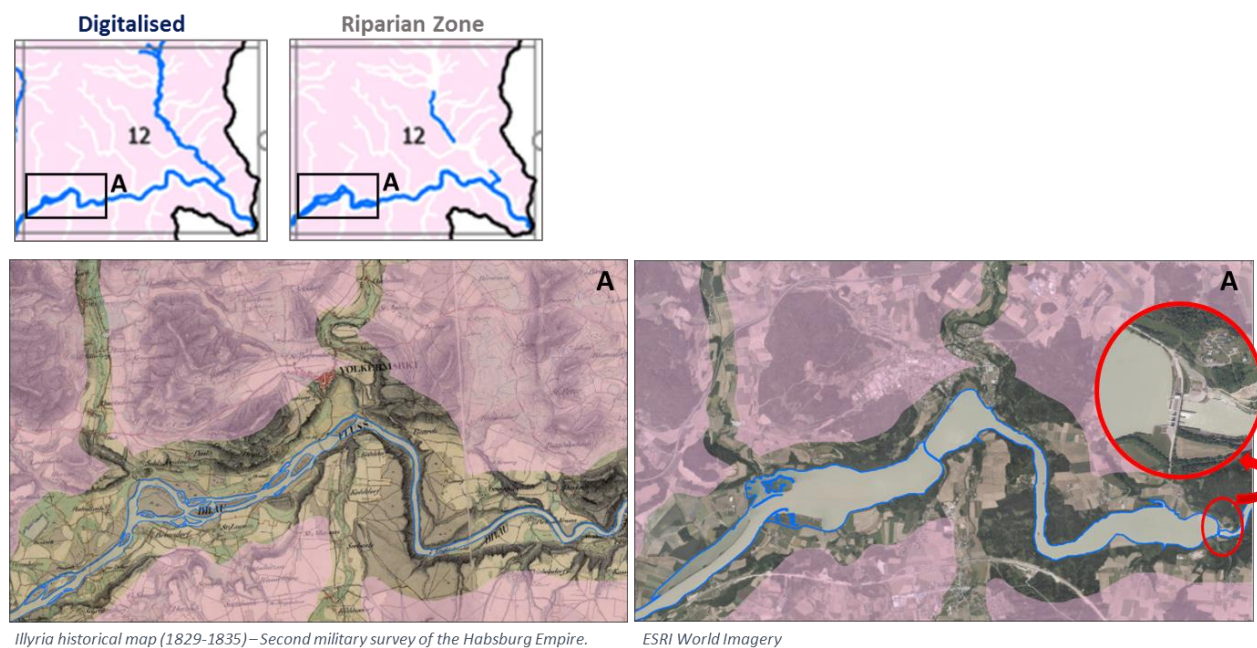


Figure 15. Effect observed due to building a dam.

When analysing the river polygons, it was also observed that in some areas the rivers had no continuity. It was realised that this could be due to the limitations of the RZ layer itself since its MMU is 0.5ha and its

Minimum Mapping Width (MMW) is 10m. In the example shown in Figure 16, the river is clearly observed over the historical map and also in the optical imagery. However, because the river is not too wide or is covered with trees, it is classified as “*Natural and semi-natural broadleaved forest*” in the RZ layer.

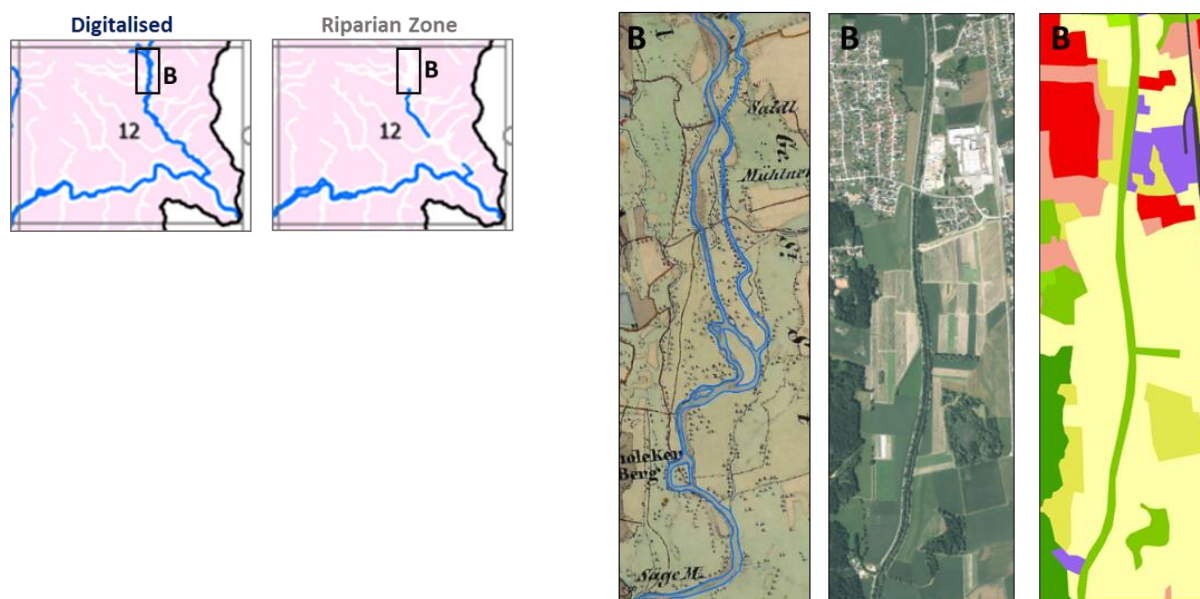


Figure 16. Section of the river that is not represented in the RZ layer.

7.1.1.2 Riverbank polygons

Focusing on riverbank polygons, it seems that in the past they were mainly located in valley bottom areas while currently they are mainly located over Alpine ones. Its total surface has gone down from almost 23km² in the past to the current 17km².

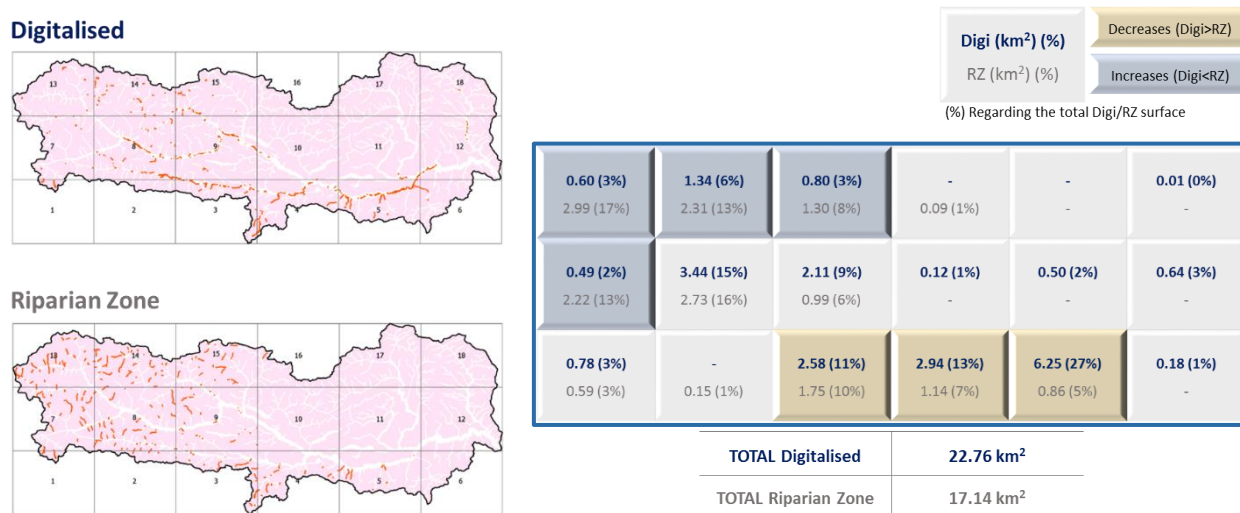


Figure 17. Results for riverbank polygons when comparing with the RZ layer.

Figure 18 shows two examples of riverbanks, the first one located in a valley bottom area and the second one in an Alpine one. In the first example, A, the riverbank is clearly observed in both the historical map and the current optical imagery. On the other side, in the second example, B, the riverbank is only observed over the current imagery.

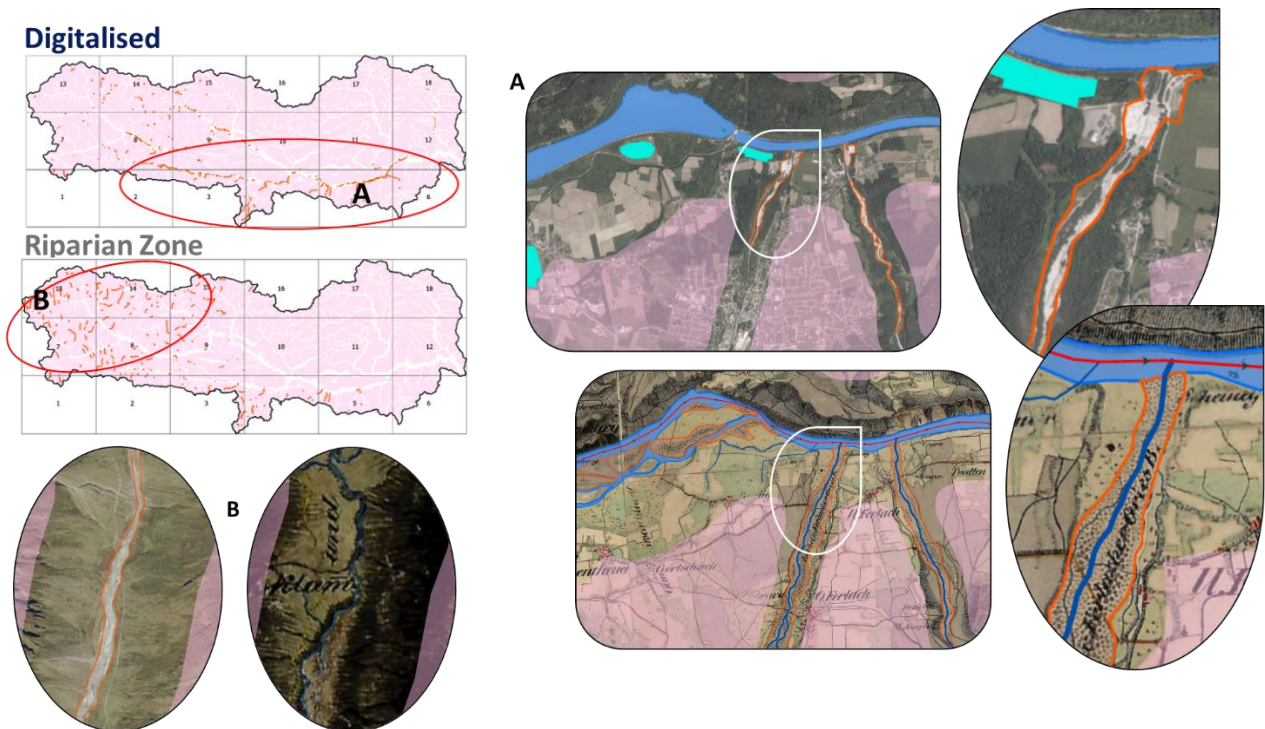


Figure 18. Riverbanks examples.

Although it is not clear enough, it seems that these changes could be related to (1) the construction of dams, (2) glacier retreatment, and/or (3) human impacts such as the building of the railroad line and agricultural development.

Regarding **dams**, a dams layer was created using different data sources, (1) Global Reservoir and Dam Database (GRanD) [12], (2) AMBER Barrier Atlas [13], and (3) the ones defined by Tracasa by means of photointerpretation of the current optical imagery, see Figure 19.

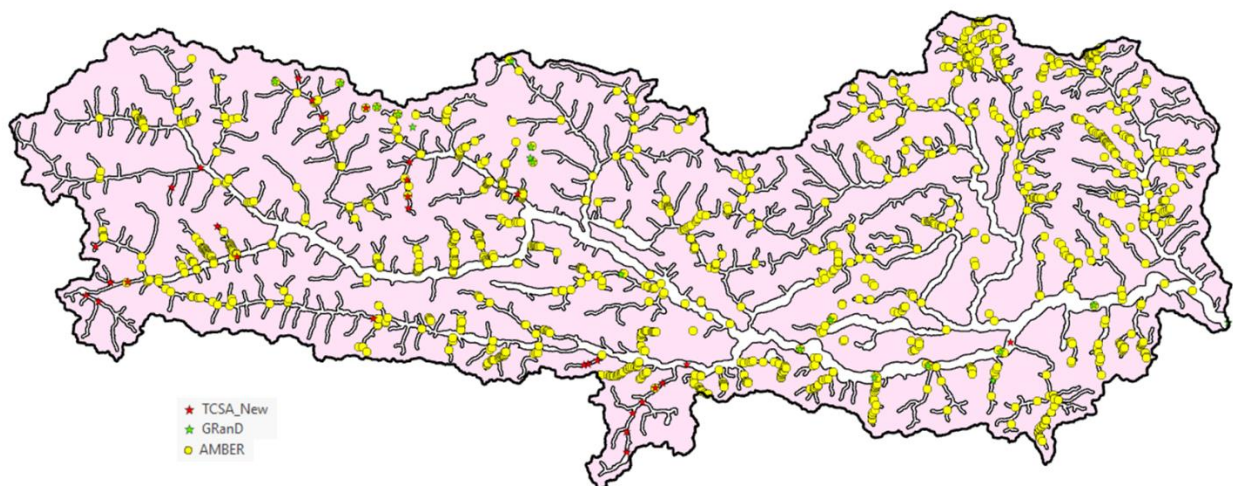


Figure 19. Dam points gathered from different data sources.

This study was carried out only for Pilot 3, and it was realised that of the two external data sources used, AMBER was the most complete one. It gathers 2,149 points for Drava catchment, classifying as dam, weir or other. From the 59 points gathered in the GRanD layer, only 3 did not fit with the ones contained in AMBER layer. Two of them were located outside the RZ layer while the other one was within the RZ area, specifically over the Drava River, see Figure 20.

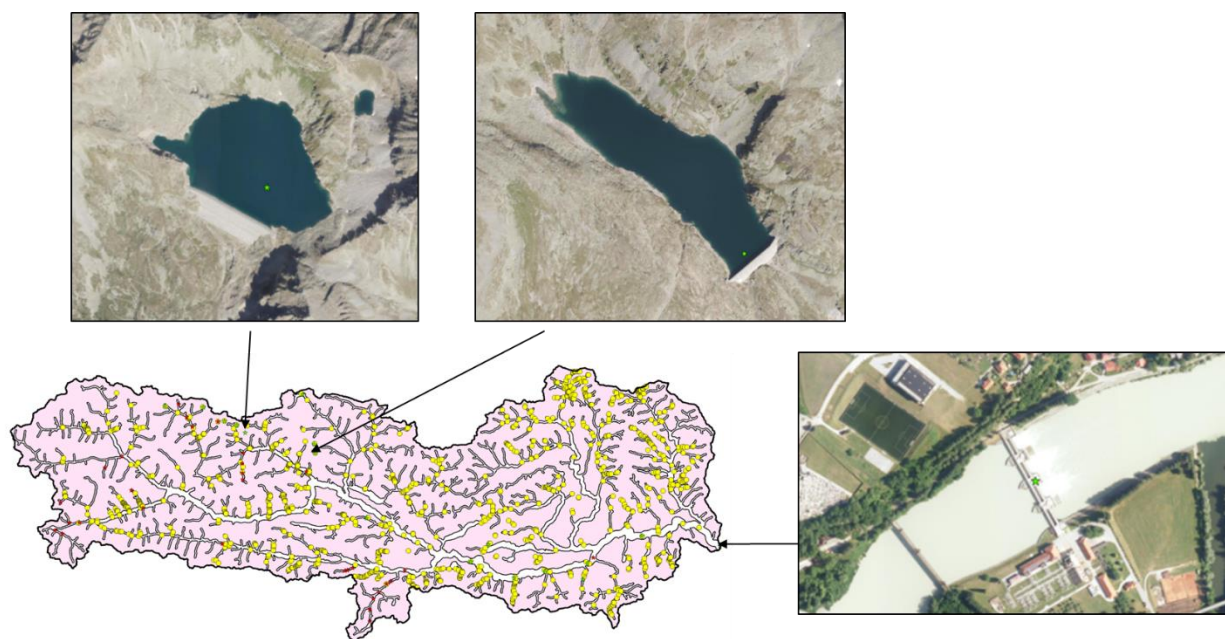


Figure 20. Dam points gathered in GRand layer that did not fit with the ones contained in AMBER layer.

Besides, other 29 dams not gathered in either of the previous datasets were identified by Tracasa, see Figure 21.

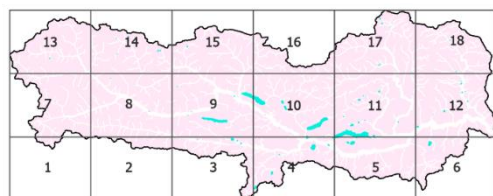


Figure 21. Dam layer created using different data sources, and examples of some of the ones defined by Tracasa.

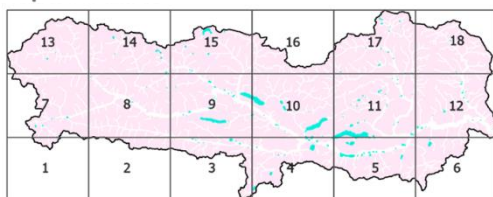
7.1.1.3 Lake polygons

The estimated surface covered by lakes is similar for both, digitised and Riparian Zone layers. The highest volume of water is focused on the central area of the basin, grids 9 to 11, see Figure 22.

Digitalised



Riparian Zone



Digi (km²) (%)
RZ (km²) (%)
(%) Regarding the total Digi/RZ surface

0.02 (0%) 0.04 (0%)	0.11 (0%) 0.52 (1%)	0.03 (0%) 2.87 (4%)	- -	0.12 (0%) 0.26 (0%)	0.01 (0%) -
- 0.18 (0%)	0.01 (0%) 0.10 (0%)	11.61 (19%) 12.06 (18%)	20.48 (34%) 20.48 (30%)	19.73 (33%) 19.22 (29%)	0.38 (1%) 0.16 (0%)
- 0.01 (0%)	- -	0.58 (1%) 0.56 (1%)	3.58 (6%) 3.86 (6%)	2.44 (4%) 6.71 (10%)	1.08 (2%) 0.34 (1%)

TOTAL Digitalised	60.20 km ²
TOTAL Riparian Zone	67.40 km ²

Figure 22. Results for lake polygons when comparing with the RZ layer.

The main changes are observed over grids 14, 15 and 5, and in all of them, the surface of lakes has increased. Analysing a possible reason for this increase, it was seen that the increase observed could be due to (1) the effect of building a dam, (2) the creation of new lakes due to glacier retreat, or (2) both effects together. Figure 23 and Figure 24 show different examples. In Figure 23 A and B, the creation of new lakes due to both the glacier retreat and the construction of a dam is highlighted (grids 14 and 15). The glacier is clearly identified over the historical map (indicated with a red rectangle) while the dam is observed only over the current optical imagery (green star). In Figure 23C, only the creation of a lake due to the construction of a dam is observed.

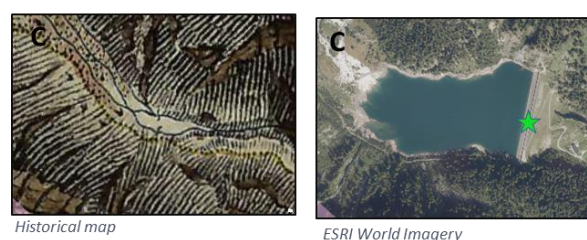
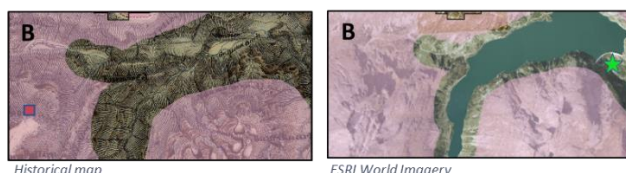
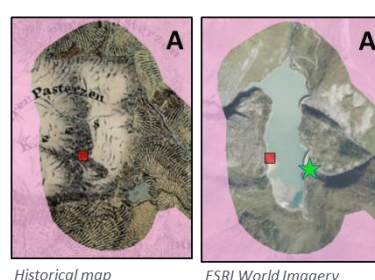
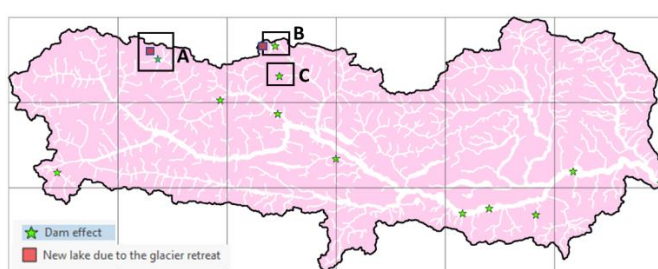


Figure 23. Possible reasons for the increase of lake surfaces.

On the other side, in Figure 24A, the increase of the water surface due to the construction of two dams is observed (grid 5). The upstream water surface of one of them, the one located more to the West, is considered a “Natural Lake” in the RZ layer, which makes the lake surface of this area increase. On the contrary, the upstream water surface of the other dam is classified as “Water course (river)”, so this is not contributing to the lakes category.

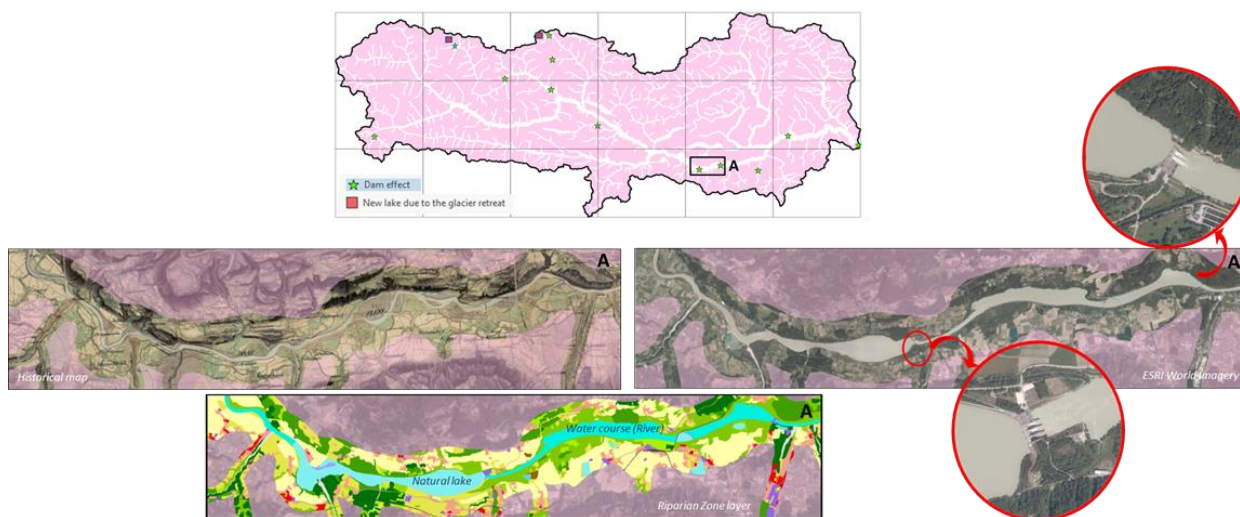


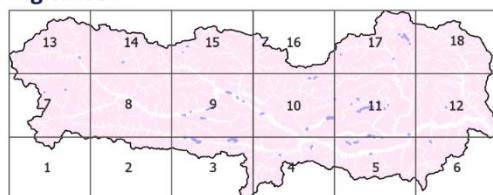
Figure 24. Possible reasons for the increase of lake surfaces.

Note that the example shown in Figure 24 explains a possible reason for the increase in the lake surfaces observed over this area. However, the inconsistency of the RZ layer is also highlighted, since the classification of these two big water surfaces located upstream of the dams should be the same.

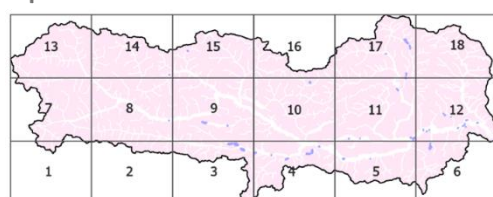
7.1.1.4 Wetland polygons

Most of the wetland polygons are located in the valley bottom or medium areas and considering the entire study area, a clear decrease has been observed, going from almost 16km² of wetland surface in the past to the current 7km², see Figure 25. It doesn't seem to be an area where the wetlands are highlighted like in Pilot 2. Their decrease in this area, as in Pilot 2, could be mainly related to agricultural development.

Digitalised



Riparian Zone



Digi (km ²) (%)	Decreases (Digi>RZ)
RZ (km ²) (%)	Increases (Digi<RZ)
(%) Regarding the total Digi/RZ surface	

0.14 (1%)	0.17 (1%)	0.11 (1%)	-	1.53 (10%)	-
-	0.02 (0%)	0.04 (1%)	-	1.12 (16%)	-
0.15 (1%)	-	1.94 (12%)	2.91 (19%)	2.75 (18%)	0.12 (1%)
-	0.02 (0%)	0.16 (2%)	0.20 (3%)	0.36 (5%)	0.32 (5%)
-	-	4.51 (29%)	0.26 (2%)	1.18 (7%)	0.12 (1%)
-	-	2.68 (39%)	1.13 (17%)	0.08 (1%)	0.67 (10%)
TOTAL Digitalised		15.89 km ²			
TOTAL Riparian Zone		6.80 km ²			

Figure 25. Results for wetland polygons when comparing with the RZ layer.

7.1.2. Lineal features

The main digitised lineal hydrographic features corresponded to rivers. The main river of the catchment, its tributaries and all the streams located inside the Riparian Zones areas were digitised, see Figure 26.

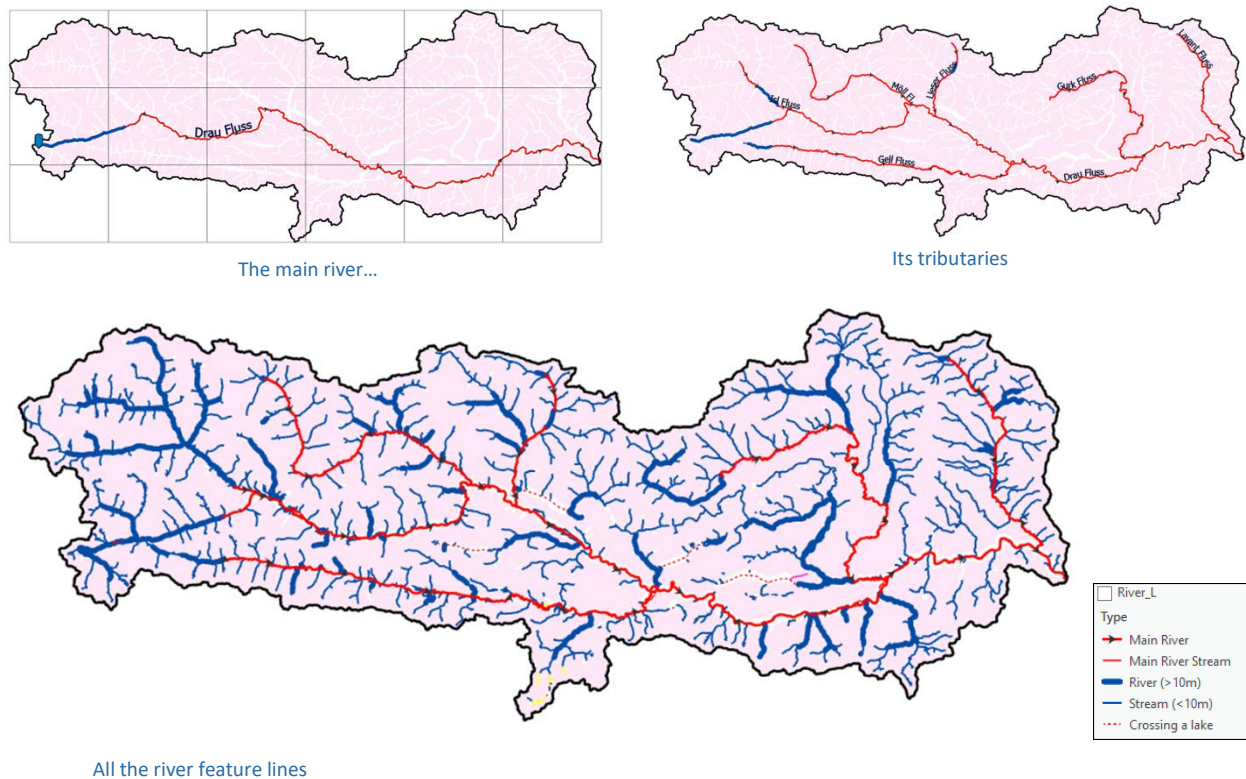


Figure 26. digitised river feature lines.

Using the EU Hydro layer [11] as a reference of the current situation, it was assessed the changes observed over some rivers, *i.e.*, it was analysed how much the rivers have been straightened.

In the following figures, some examples of the straightened river sections are shown. The one shown in Figure 27 refers to Drava river. A total of 292.84km were digitised and according to the EU Hydro layer, its length is 281.94km. So, a reduction of approximately 11km has occurred.

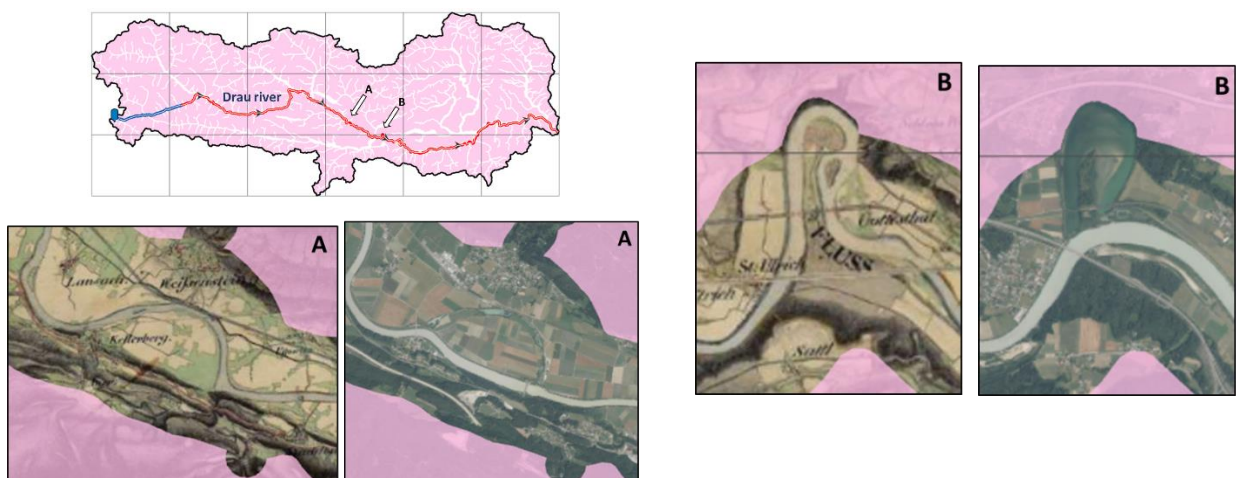


Figure 27. Straightened river, example 1 (Drava river).

Among the tributary rivers, it seems that the Lavant river is the one that most changes have suffered. A total of 72.98km were digitised and according to the EU Hydro layer, its length is 65.81km. So, a reduction of approximately 7km has occurred. In the following figure, different sections of the straightened river are shown.

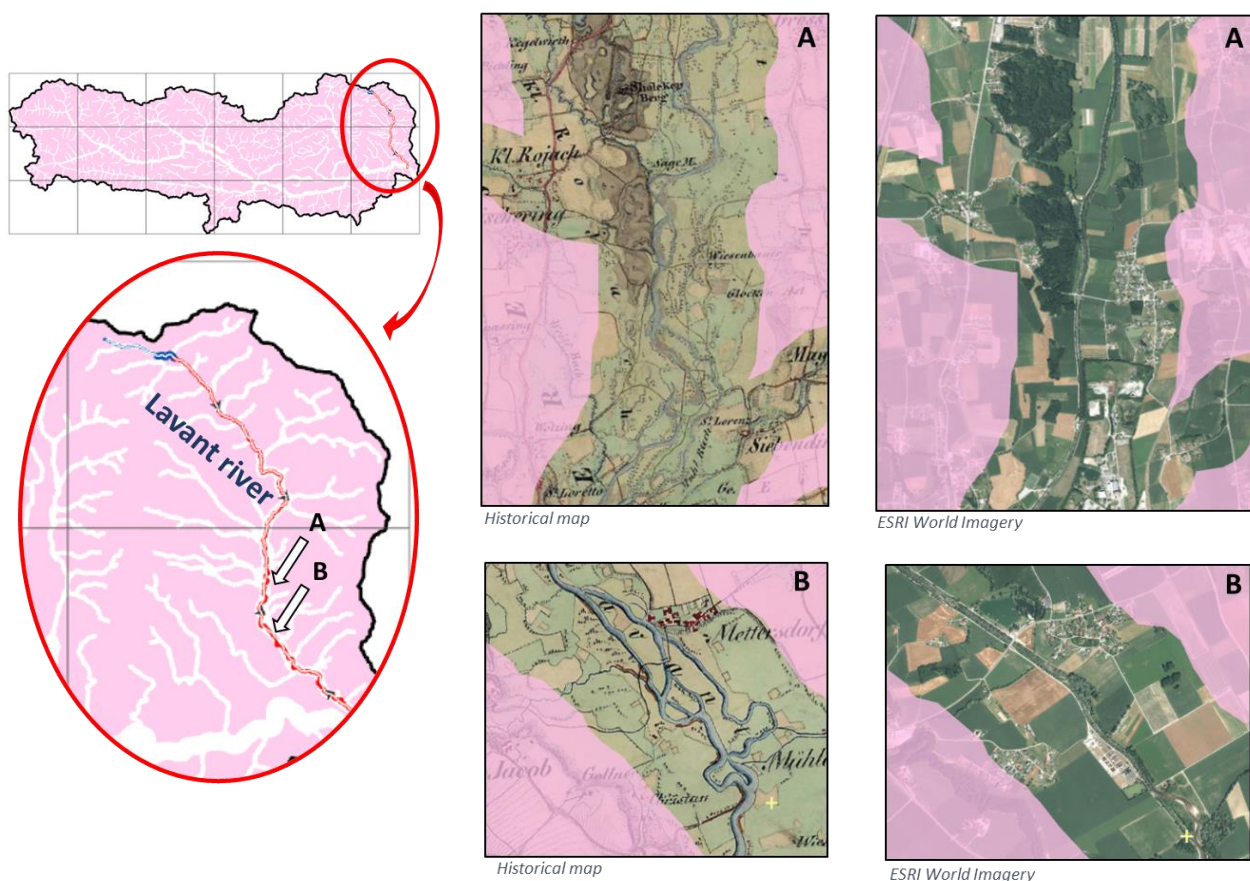


Figure 28. Straightened river, example 2 (Lavant river).

7.1.3. Cross comparison (Digitised features vs. Riparian zones)

In order to complete the analysis of the results obtained, a cross comparison was carried out. For this aim, the digitised hydrographic features (river, lake, wetland, riverbank and island polygons) were compared with the current categories of the RZ layer, see Figure 29. This analysis gives an idea of the changes of Land Cover / Land Use (LC/LU) that have occurred over the years.

The cross comparison was not carried out taking into account the grid used in the previous section. At first, the idea was to cross “everything against everything” as it was done with Pilot 2. However, due to the lack of precision observed in some Alpine areas, see Section 2, the cross comparison was carried out separately for (1) Alpine areas (considered as low confidence ones), and (2) Valley medium/bottom areas (considered as high confidence areas), see Figure 30.

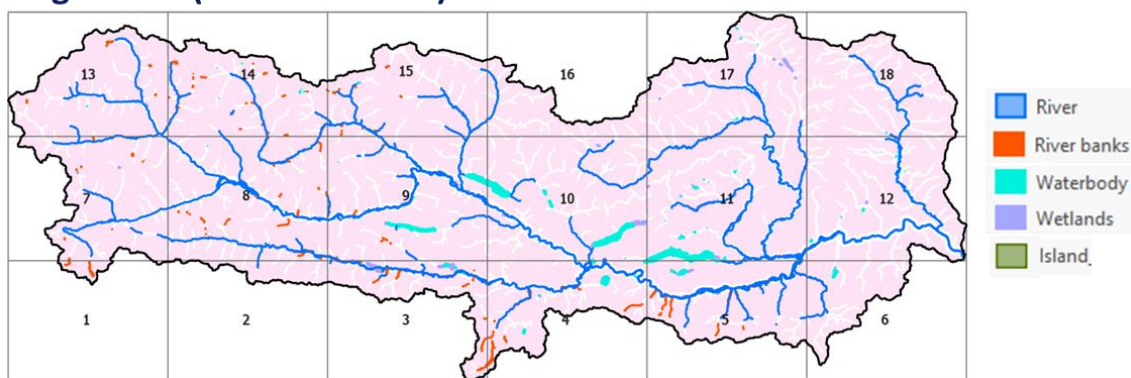
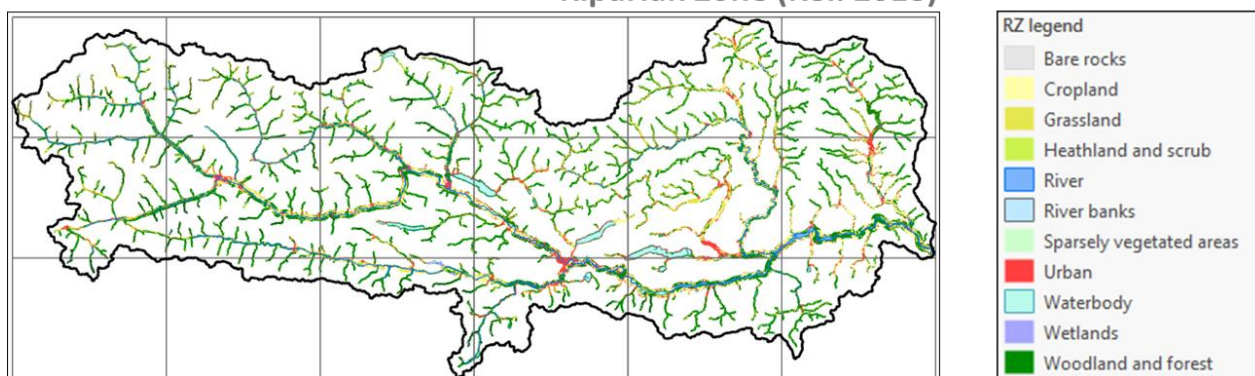
Digitalised (Ref. 1816-1836)**Riparian Zone (Ref. 2018)**

Figure 29. hydrographic features digitised and the Riparian zones categories with whom it crosses.

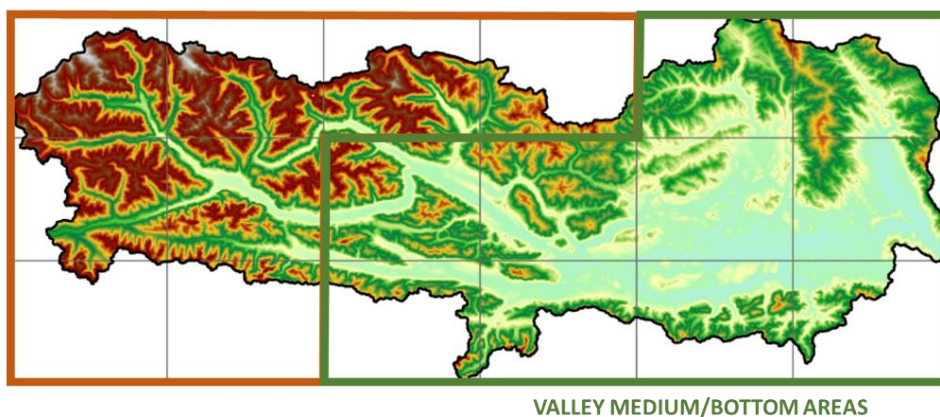
ALPINE AREAS**VALLEY MEDIUM/BOTTOM AREAS**

Figure 30. Different areas where the cross comparison was carried out.

Following, the results of the cross comparison are shown in a tabular format. The results for the Alpine areas are not analysed in depth because of their low confidence and only general comments of the tables are made at the end of this section.

7.1.3.1 Cross comparison results for Valley bottom areas

The first table, Table 11, shows the cross-comparison results as a confusion matrix, where the digitised classes are shown in columns and the categories gathered in the RZ layer are shown in rows. The numbers located in the diagonal position, the ones in bold and shaded or highlighted in blue, correspond to the square kilometres where both layers fit (e.g., River_{Digi} - River_{RZ layer}, etc.). Besides, this matrix also shows other interesting statistics that are presented in % values, and that have been named here as **Original path** and **Current path** percentages. They would be similar to the omission and commission errors, terms commonly used when analysing confusion matrices, but in this case, they have a somewhat different meaning and that is why they have been renamed. In the case of the River category for example, the **Original path (%)** corresponds to the % of the total digitised river areas that were covered with rivers **only in the past**, see Equation 1.

$$OP(\%)_{river} = \frac{0.13+1.80+0.19+4.10+5.64+0.03+3.15+12.86}{44.65} \times 100 = 62.49\% \quad \text{Eq. 1}$$

Following with the same example, the **Current path (%)** corresponds to the % of the total river areas contained in the RZ layer that are **currently covered** by rivers and **not in the past**, see Equation 2.

$$CP(\%)_{river} = \frac{2.84+0.01+0.18+2.25+16.93}{38.96} \times 100 = 57.02\% \quad \text{Eq. 2}$$

Table 11. Cross comparison results (digitised vs. RZ categories), in terms of area (km²).

		Digitised hydrographic features						TOTAL (km ²)	Current path (%)
		River	River bank	Lake	Wetland	Island	No data		
Riparian zone categories	River	16.75	2.84	0.01	0.18	2.25	16.93	38.96	57.02
	River bank	0.13	0.93	0.00	-	0.03	3.66	4.75	80.48
	Lake	1.80	0.57	54.98	0.52	0.15	5.66	63.68	13.66
	Wetland	0.19	0.06	0.72	2.72	0.12	2.90	6.72	59.47
	Bare rocks	-	0.03	0.00	-	-	0.98	1.01	
	Cropland	4.10	0.80	0.22	4.71	1.42	207.87	219.11	
	Grassland	5.64	1.32	0.73	3.62	1.32	307.90	320.54	
	Heathland and scrub	0.00	0.00	0.00	-	-	0.48	0.49	
	Sparsely vegetated areas	0.03	0.02	0.00	-	-	1.74	1.80	
	Urban	3.15	1.23	1.75	0.91	0.66	180.84	188.53	
	Woodland and forest	12.86	7.43	1.21	1.68	3.73	756.96	783.87	
	TOTAL (km²)	44.65	15.23	59.64	14.35	9.69	1485.90	1629.45	
Original path (%)		62.49	93.91	7.81	81.02				

In Table 12, the results are shown in percentage (%) values with respect to the total of each digitised hydrographic feature class. So, analysing each column separately, it can be easily interpreted to which RZ category the digitized class currently belongs, in terms of % value. Besides, the last column represents the percentage values of each category of the RZ layer that is observed over the studied area. The most relevant results are highlighted in blue.

Table 12. Cross comparison results in terms of % values with respect to the total of each digitised feature.

Digitised	River	River bank	Lake	Wetland	Island	No data	Total
Riparian							
<i>River</i>	37.51%	18.63%	0.02%	1.28%	23.19%	1.14%	2.39%
<i>River banks</i>	0.29%	6.09%	0.00%	-	0.36%	0.25%	0.29%
<i>Lake</i>	4.02%	3.76%	92.19%	3.61%	1.55%	0.38%	3.91%
<i>Wetlands</i>	0.43%	0.42%	1.20%	18.98%	1.28%	0.20%	0.41%
<i>Bare rocks</i>	-	0.19%	0.01%	-	-	0.07%	0.06%
<i>Cropland</i>	9.19%	5.22%	0.37%	32.83%	14.61%	13.99%	13.45%
<i>Grassland</i>	12.64%	8.69%	1.23%	25.23%	13.67%	20.72%	19.67%
<i>Heathland and scrub</i>	0.00%	0.03%	0.01%	-	-	0.03%	0.03%
<i>Sparsely vegetated areas</i>	0.07%	0.16%	0.00%	-	-	0.12%	0.11%
<i>Urban</i>	7.05%	8.05%	2.93%	6.37%	6.82%	12.17%	11.57%
<i>Woodland and forest</i>	28.80%	48.77%	2.03%	11.69%	38.53%	50.94%	48.11%
TOTAL	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

No data category derives from areas corresponding to one of the RZ categories and with no information in the digitised layers (because they do not correspond to any of the hydrographic features). For the total of 1629.45km² analysed, 1485.90km² corresponds to the **No data** category.

Regarding the other categories, for the total of 44.65km² digitised **River** polygons, 16.75km² (37.51%) fits with the *River* category of the RZ layer, and 12.86km² (28.80%) falls over *Woodland and forest* category.

In the case of **Lakes**, the agreement is very high, since 54.98km² of the total of 59.64km² (92.19%) digitised lake polygons overlap with the *Lakes* contained in the RZ layer.

Oppositely, the agreement observed for **River banks** and **Wetlands** is much lower, of 6.09% and 18.98% respectively. In the case of **River banks**, most of them fall over *Woodland and forest* (48.77%) and *River* (18.63%) categories. In the case of **Wetlands**, most of them fall over *Cropland* (32.83%) and *Grassland* (25.23%) categories. **Island** category is not gathered in the RZ layer.

According to the last column of Table 12 it is observed that currently this area is mostly covered by *Woodland and forest* (48.11%) followed by *Grassland* (19.67%), *Cropland* (13.45%) and *Urban* (11.57%) areas.

When representing the agreements (overlaps) and disagreements (Original and Current path) between digitised and RZ layer for each category as a figure, the changes that have occurred are clearly and easily detected. Following, the resulting figures for river, river banks and lake categories are shown.

River category

In the overview of the entire catchment, the overlaps (in blue), the original path (in green) and the current path (in purple) areas are shown. Besides, different interesting zooms are also presented, Figure 31A to D.

In Figure 31A to C, areas where the lateral connectivity or branched rivers have disappeared are shown. As well, in the Northern and Easter parts of Figure 31C, it seems that the river has not suffered lots of changes.

Figure 31D shows a river section that has been straightened.

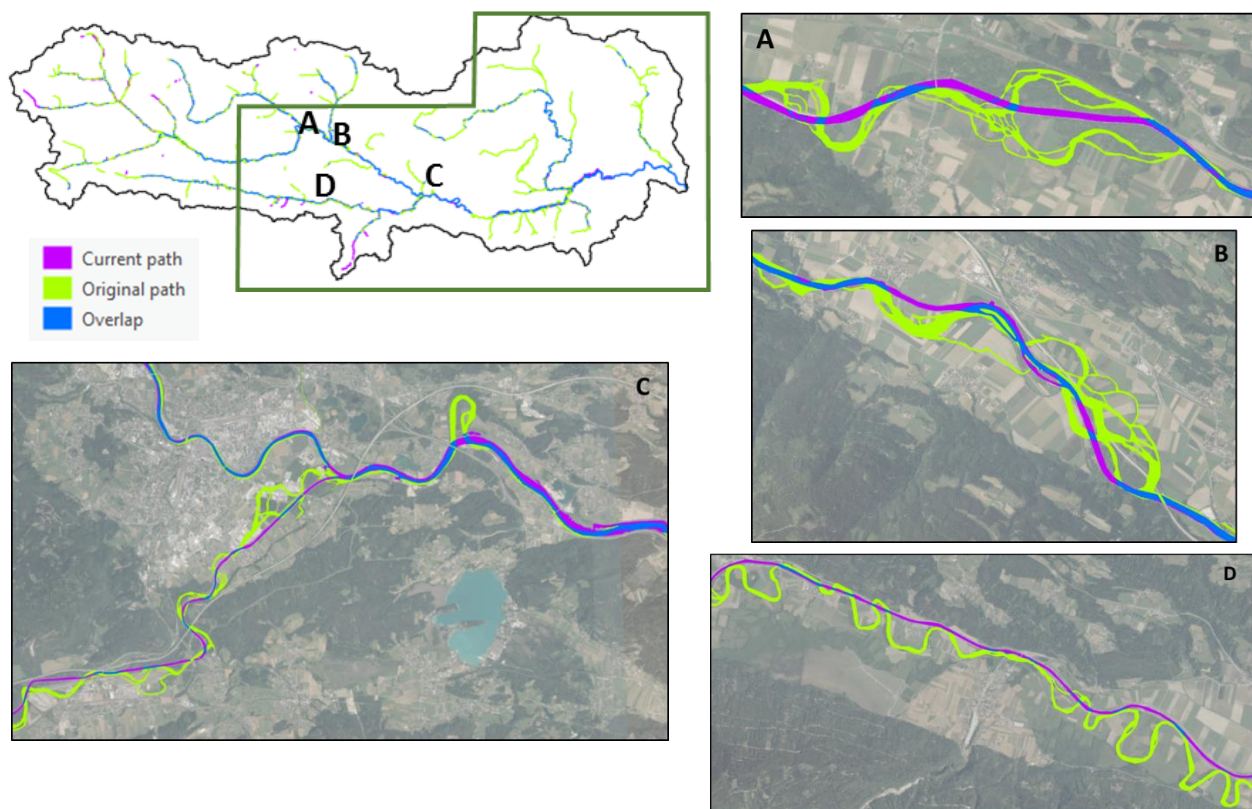


Figure 31. Agreements and disagreements for River category.

River bank category

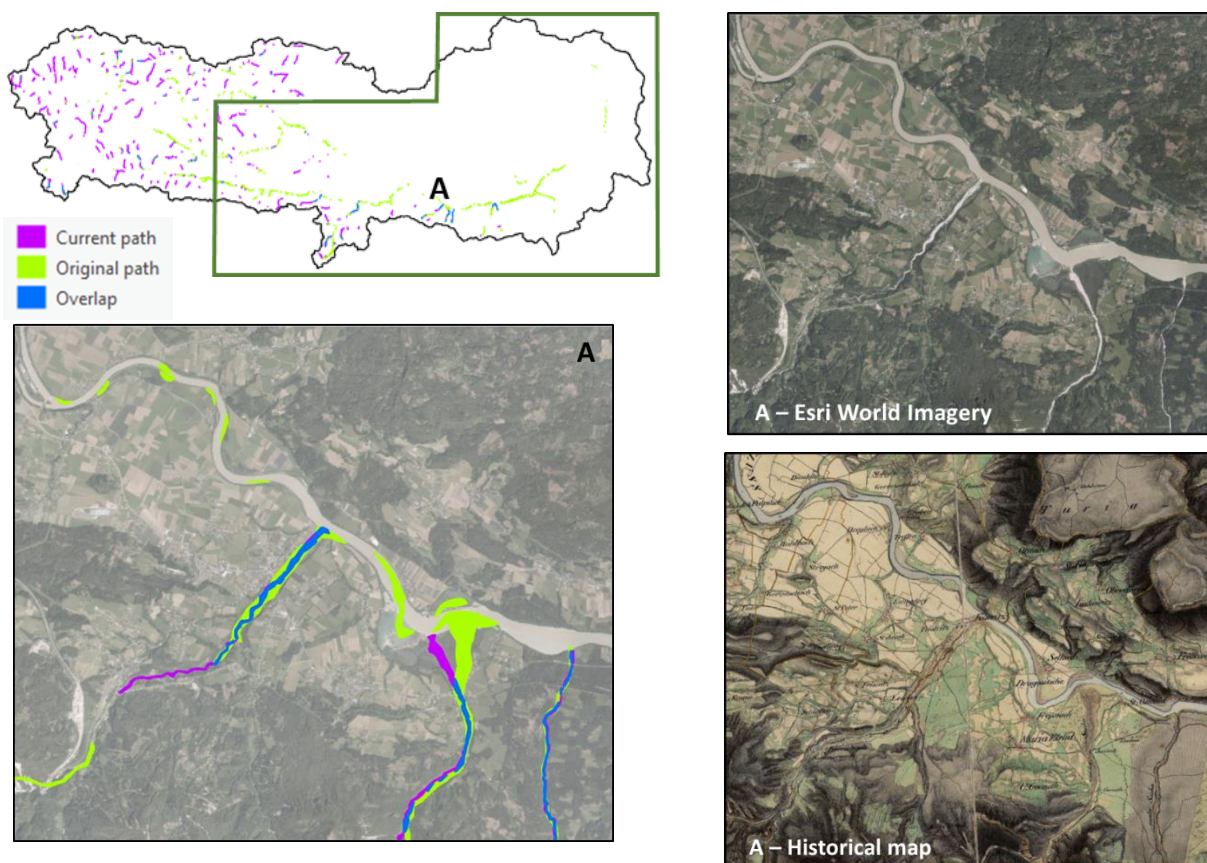


Figure 32. Agreements and disagreements for River bank category.

As mentioned before, when analysing the confusion matrix, the overlap for the river bank category is low. Most of the river banks are currently located in the Alpine areas while in the past were mainly located in the valley bottom areas, see Figure 32.

In the example in Figure 32, areas where the river banks currently remain (in blue), have disappeared (in green) or new ones have been created (in purple) are shown. These areas where the river banks currently remain are clearly observed over both optical imagery and historical map. Note that most areas from where the river banks have disappeared are located along the main river or its tributaries.

Lake's category

The overlap for this category is very high, see the blue polygons in Figure 33. The purple areas correspond to areas that are currently covered by lakes.

In Figure 33C a new lake that has been formed because of the construction of a dam is shown.

The example shown in Figure 33B corresponds to the inconsistency observed over the RZ layer and that has been previously mentioned in Section 7.1.1.3 Figure 24. The big purple polygon corresponds to the Drava River, so it should appear as a “River course” instead of “Natural Lake” in the RZ layer.

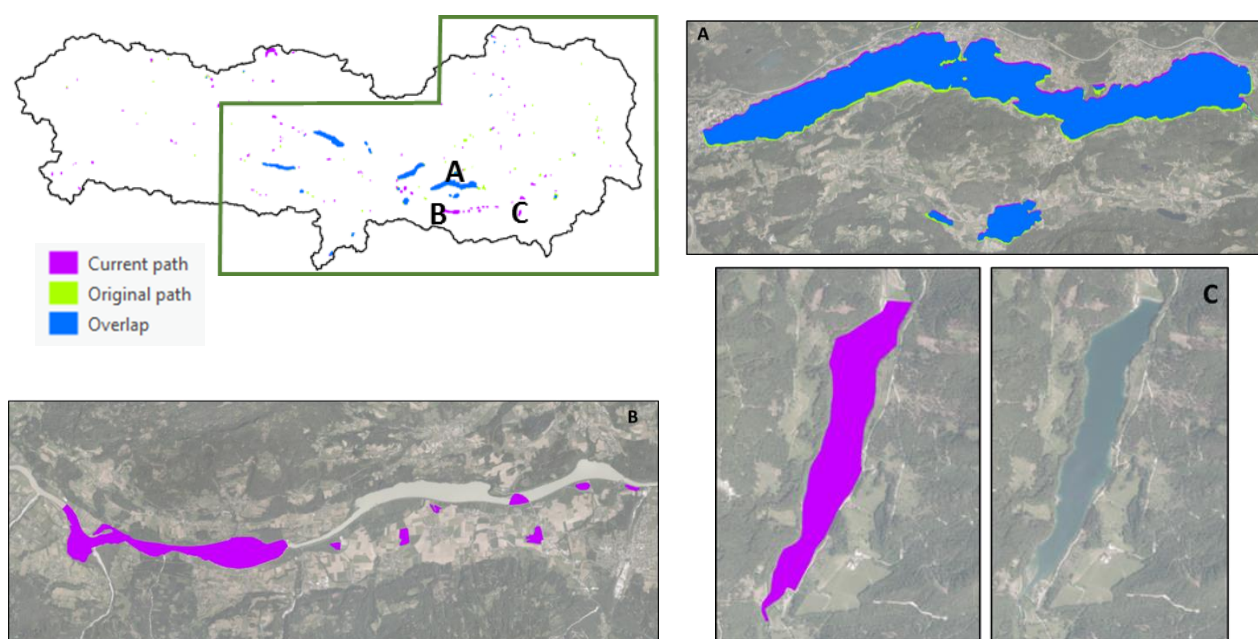


Figure 33. Agreements and disagreements for Lake category.

7.1.3.2 Alpine areas

The first table, Table 13, shows the cross-comparison results as a confusion matrix, and as in the previous case, the digitised classes are shown in columns and the categories gathered in the RZ layer are shown in rows.

In Table 14, the results are shown in percentage (%) values with respect to the total of each digitised hydrographic feature class.

The most relevant results are highlighted in blue.

Table 13. Cross comparison results (digitised vs. Riparian zones categories), in terms of area (km²).

		Digitised hydrographic features						TOTAL (km ²)	Current path (%)
		River	River bank	Lake	Wetland	Island	No data		
Riparian zone categories	<i>River</i>	1.95	0.37	-	0.00	0.19	5.88	8.39	76.76
	<i>River bank</i>	0.10	0.75	0.01	0.07	-	11.48	12.40	93.99
	<i>Lake</i>	0.02	0.03	0.03	0.01	0.01	3.63	3.73	99.10
	<i>Wetland</i>	0.01	-	0.00	0.01	0.00	0.05	0.08	83.54
	<i>Bare rocks</i>	0.00	0.07	0.00	0.00	-	3.27	3.35	
	<i>Cropland</i>	0.68	0.26	-	-	0.20	12.53	13.67	
	<i>Grassland</i>	3.19	1.38	0.05	0.24	0.50	190.68	196.04	
	<i>Heathland and scrub</i>	0.02	0.19	0.01	0.01	-	13.45	13.68	
	<i>Sparsely vegetated areas</i>	0.01	0.07	0.02	0.01	-	6.95	7.06	
	<i>Urban</i>	1.36	0.71	0.00	0.07	0.20	38.97	41.31	
	<i>Woodland and forest</i>	4.52	3.57	0.00	0.12	0.59	387.94	396.75	
	TOTAL (km²)	11.85	7.40	0.13	0.55	1.70	674.82	696.45	
	Original path (%)	83.55	89.93	73.67	97.64				

Table 14. Cross comparison results in terms of % values with respect to the total of each digitised feature.

Digitised		River	River bank	Lake	Wetland	Island	No data	Total
Riparian								
<i>River</i>		16.45%	4.95%	-	0.53%	11.32%	0.87%	1.20%
<i>River banks</i>		0.81%	10.07%	4.35%	13.17%	-	1.70%	1.78%
<i>Lake</i>		0.20%	0.43%	26.33%	1.22%	0.31%	0.54%	0.54%
<i>Wetlands</i>		0.06%	-	2.58%	2.36%	0.11%	0.01%	0.01%
<i>Bare rocks</i>		0.02%	0.96%	2.63%	0.84%	-	0.48%	0.48%
<i>Cropland</i>		5.76%	3.51%	-	-	11.60%	1.86%	1.96%
<i>Grassland</i>		26.88%	18.63%	38.23%	44.16%	29.60%	28.26%	28.15%
<i>Heathland and scrub</i>		0.20%	2.60%	5.42%	1.44%	-	1.99%	1.96%
<i>Sparsely vegetated areas</i>		0.09%	0.95%	14.98%	1.58%	-	1.03%	1.01%
<i>Urban</i>		11.44%	9.62%	2.17%	11.97%	12.01%	5.77%	5.93%
<i>Woodland and forest</i>		38.09%	48.28%	3.31%	22.74%	35.04%	57.49%	56.97%
TOTAL		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

No data categories derive from areas corresponding to one of the Riparian zone categories and with no information in the digitised layers (because they do not correspond to any of the hydrographic features).

Only 16.45% and 10.07% of the digitised **River** and **River bank** polygons respectively correspond to the same categories of the current RZ layer, *River* and *River banks*. Most of the digitised **River** and **River bank** polygons fall over *Woodland/forest* and *Grassland* categories.

The percentage value of the agreement for **Lake** polygons is a bit higher, 26.33%, and most of the digitised ones fall over *Grassland* categories (38.23%). Regarding the **Wetland** polygons, most of them fall also over *Grassland* (44.16%).

The last column of Table 14, "Total", represents the percentage values of each category of the Riparian Zone layer that is observed over the Alpine area. It is observed that currently this area is mostly covered by *Woodland and forest* (56.97%) followed by *Grassland* (28.15%).

7.2. Final conclusions

Although the positional errors of the historical maps themselves could be over- or under- estimating the results, this study reveals and allows us to identify the high changes that have occurred in hydrographic features over time.

Riparian Zones layer has demonstrated to be a good layer to use it as a mask when digitalising. On the other side, some incoherencies have been detected (*e.g.*, river surfaces considered as lakes, etc.), so, this fact could be introducing some errors when cross-comparing Digi *versus* RZ layer.

Doing a preliminary study of the area of study (AOI) to be digitised can be very interesting and useful. It can help to interpret the results obtained.

In the Valley medium/bottom areas of Pilot 3 the straightened rivers in combination with the disappearance of the branched river sections are highlighted.

The construction of dams affects the surrounding areas, so, it is interesting to take them into account when developing hydrographic studies. Two external data sources showing the dams geolocation were used, AMBER and GRanD. The first one turned out to be the most complete one. It gathers 2,149 points for Drava catchment, classifying as dam, weir or other. From the 59 points gathered in the GRanD layer, only 3 did not fit with the ones contained in AMBER layer.

The digitised riverbanks could be used to identify potential future risk for flooding areas.

Historical maps also contain information regarding glaciers, and this could be used to assess their retreatment. Its study was out of the scope of this project.

The digitisation rate was quite uniform because (1) the learning curve was done with the previous case studies (Pilots 1 and 2), and (2) the legend was known. However, it was more complex than Pilot 2 due to the characteristics of the digitised area (heterogeneous).

8. MAP VIEWER CREATION

In order to show all the hydrographic features that were digitised, a map viewer mock-up was developed.

Link to the map viewer:

<https://portal.discomap.eea.europa.eu/arcgis/apps/webappviewer/index.html?id=159f049883564aa2a583af2f6d4c61df>

9. DELIVERABLES

Together with this report, the .GDB is also provided. The link to the created map viewer is indicated in the previous section.

-
- [1] https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en
- [2] <https://www.arcanum.com/en/>
- [3] https://icaci.org/files/documents/ICC_proceedings/ICC2015/papers/18/fullpaper/T18-696_1428396969.pdf
- [4] <http://charta1864.gis-it.ro/essay.pdf>
- [5] <https://www.arcanum.com/media/uploads/mapire/legend/secondsurvey1.pdf>
- [6] <https://www.arcanum.com/media/uploads/mapire/legend/secondsurvey2.pdf>
- [7] Timár, Gábor & Biszak, Sándor & Székely, Balázs & Molnár, Gábor. (2011). Digitized Maps of the Habsburg Military Surveys – Overview of the Project of ARCANUM Ltd. (Hungary). DOI: 10.1007/978-3-642-12733-5_14.
- [8] <https://reformrivers.eu/news/168>
- [9] AMT DER KÄRNTNER LANDESREGIERUNG (2004): LIFE-Projekt Auenverbund Obere Drau, Endbericht; Klagenfurt; 2004
- [10] <https://land.copernicus.eu/local/riparian-zones>
- [11] <https://land.copernicus.eu/imagery-in-situ/eu-hydro>
- [12] <https://globaldamwatch.org/grand/>
- [13] <https://portal.amber.international/> or <https://www.eea.europa.eu/data-and-maps/data/external/the-amber-barrier-atlas>