Historical cartographic and topo-bathymetric database on the French Rhône River (17th–20th centuries)

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Abstract

Space and time analyses of channel changes, especially within large rivers subject to high levels of human impact, are critical to address multiple questions about rivers in the Anthropocene era. The reconstruction of long-term (>150 year) evolutionary trajectories permits an understanding of how natural and anthropogenic factors impact hydromorphological and ecological processes in rivers, helps with the design of sustainable management and restoration options, and may also help in the assessment of future changes. However, the reconstruction of channel changes can be challenging: historical data are often scattered across many archives, and the quantity and accuracy of information generally decreases as one goes back in time. This data article provides a historical database of 350 cartographic and topo-bathymetric resources on the French Rhône River (530 km in length) compiled from the 17th to mid-20th century, with a temporal focus prior to extensive river training (1860s). The data were collected in 14 national, regional, and departmental archive services. A table describes the properties of each archived data item and its associated iconographic files. Some of the historical maps are available in a georeferenced format. A GIS layer enables one-click identification of all archive data available for a given reach of the French Rhône River. This database provides substantial new material for deeper analyses of channel changes over a longer time period and at a finer time step compared with previously available data. The database has several potential applications in geomorphology, retrospective hydraulic modelling, historical ecology, and river restoration, as well as permitting comparisons with other large and multi-impacted rivers worldwide. The dataset is available at doi 10.1594/PANGAEA.922437 (Arnaud et al., 2020a). Iconographic extracts of the 350 archived items are available at http://photo.driihm.fr/index.php/category/52.

1 Introduction

30   Characterization of the evolutionary trajectories of the world's rivers and floodplains is crucial for assessment of space-time changes in biogeomorphic processes, the quantification of anthropogenic impacts, and the planning of sustainable management based on conservation and restoration options (Gabrowski et al., 2014; Mould and Fryirs, 2018). The analysis of long-term (>150 year) channel changes provides a holistic understanding of the trajectory of fluvial hydrosystems and their drivers, which helps in defining process-based restoration objectives, rather than determining static reference states (Dufour and Piégay, 2009;

35   Eschbach et al., 2018). It is necessary to extend the timescale of past trajectories to characterize possible shifts in baseline conditions related to climate variability and different degrees of human pressures to help in the assessment of future river changes in the Anthropocene (Pont et al., 2015; Slowik, 2015; Piégay et al., 2020).

The reconstruction of river trajectories requires substantial historical datasets. Series of maps, aerial images, topographic, and bathymetric surveys are generally selected at regular time steps, if available, or before and after major events (i.e. floods, river

40   engineering phases). These are used to extract channel features such as active channel width, bar-island areas (Hohensinner et al., 2004; Michalkova et al., 2011; Lestel et al., 2018; Scorpio et al., 2018), bed degradation/floodplain aggradation rates (Steiger et al., 2001; Downs et al., 2013; Arnaud et al., 2015), riparian vegetation patterns (Cadol et al., 2011; Belletti et al., 2013; Kui et al., 2017; Safran et al., 2017), and landscape unit characteristics (Dufour et al., 2015; Solins et al., 2018; Piégay et al., 2020). Following Roux et al. (1989) and Habersack and Piégay (2008), comparative analyses of large river changes,

45   notably in Europe, have become a critical issue for addressing a series of questions of interest to geographers, historians, engineers, ecologists, geologists, and geochemists. For example, historical maps can help to better contextualize sediment core samples and geophysical surveys when investigating floodplain evolution (Salvador and Berger, 2014) and delta evolution during the Holocene (Vella et al., 2005). Historical cartographic and topo-bathymetric datasets are also of interest to hydrologists analyzing flood frequency based on historical geometries (Billy et al., 2018). They are also key resources in

50   historical ecology, allowing the formulation of hypothesis on fish habitat-species relationships since the industrial revolution, especially given the lack of old quantitative data in terms of species number, abundance, and distributions (Carrel, 2002; Frimpong et al., 2016; Belliard et al., 2018).

A number of historical analyses have been conducted on the Rhône River in Western Europe. Whereas the Rhône was a braided and anabranching river along its 530 km-long French course during the 19th century, it has been deeply regulated for 150 years,

55   and is now targeted by large-scale restoration measures aimed at improving morpho-ecological processes (Riquier and Cottet, 2019). On the basis of a map series surveyed in the 1860s at the scale of 1:10 000 by the *Ponts et Chaussées* (Bridges and Roads) public administration, the mid-19th century period is usually considered the benchmark for fluvial patterns before extensive river training. Most studies have used this 1860 map series as a starting point for detecting geomorphic changes, by making comparisons with later maps surveyed at the end of the 19th century and mid-20th century, and aerial images taken

60   since the 1930s (Bravard, 2010; Provansal et al., 2014; Bravard and Gaydou, 2015; Parrot, 2015; Dépret et al., 2017; Räpple, 2018; Thorel et al., 2018; Tena et al., 2020). Therefore, the post-1860 planform adjustments are fairly well understood and are

combined with vertical adjustments measured on reaches where topo-bathymetric information has been available since the late 19th century. However, little is known about the morphodynamics of the Rhône in the early 19th century and times before this. This paper presents a historical database of 350 cartographic and topo-bathymetric resources covering the French Rhône River,

65   collected from 14 national, regional, and departmental archive services. The timescale extends from the 17th to the mid-20th centuries, with a pre-1860 focus for cartographic data and a pre-1900 focus for topo-bathymetric data. This database provides substantial new material to extend and detail historical trajectories of the Rhône River for the previously identified purposes, and enables further comparisons with other large braided/anabranching multi-impacted rivers worldwide.

2 Study area

70   The Rhône is an 812-km long river connecting the French-Swiss Alps with the Mediterranean Sea. Originating at the Furka Glacier, the alpine Rhône drains the Valais region up to Lake Geneva. The lower 534 km of the river course are in France. As a whole, the catchment size is 98 500 km², with 90 500 km² being in France (Olivier et al., in press) (Fig. 1). The river delimits or crosses 11 French administrative departments. The mean annual discharge is 1720 m^3 s^{-1} at its mouth, which makes the Rhône the most important freshwater input into the northwestern Mediterranean Sea (Van Den Broeck and Moutin, 2002). The

75   river drains areas with a wide range of geological, altitudinal, hydro-climatic and land-use conditions, which results in a heterogeneous channel reach characterized by alternating fixed and mobile channel beds, incised valleys, and wide floodplains, and distinct sediment and flow inputs from tributaries (Bravard, 2010; Riquier and Cottet, 2019). The mean bed slopes are 0.9 % on the Swiss river course, 0.1 % on the upper Rhône section (Lake Geneva to Lyon-Saône confluence), 0.05 % on the middle Rhône section (Lyon to Valence-Isère confluence), 0.06 % on the lower Rhône section (Valence to Arles-Gard

80   confluence), and 0.004 % at the delta (Parrot, 2015).

River training was conducted along both the Swiss and French parts of the Rhône. In France, human interventions were developed during three main periods (Thorel et al., 2018; Tena et al., 2020): (1) in the second half of the 19th century, with the construction of longitudinal unsubmersible dykes to locally protect the population from flooding; (2) from the late 19th to the early 20th century with the systematic construction of groyne fields connected to submersible dykes (infrastructures named

85   "Casiers Girardon" from the engineer who designed them), created almost continuously from Lyon to Arles, and aimed at concentrating flows into a narrow single-bed channel to improve navigation; and (3) from the 1920s to the 1980s, with the construction of 19 hydro-electric dams and by-passing schemes between Lake Geneva and the Mediterranean Sea by the National Company of the Rhône River (CNR).

Channel correction and flow regulation induced major hydromorphological modifications such as incision and armouring,

90   disconnection of secondary channels, floodplain terrestrialization, and subsequent loss of ecological functionalities (Roux et al., 1989; Amoros and Bornette, 2002; Parrot, 2015; Dépret et al., 2017; Tena et al., 2020). A large-scale restoration plan for the French Rhône has been conducted since 1998 to improve ecological conditions in the main channel and floodplain. This plan is based on the combination of two main measures: (i) increasing the minimum flow in by-passed reaches, and (ii)

reconnecting abandoned channels (Lamouroux et al., 2015). A second phase of restoration was launched in 2009, and currently

95 consists of enhancing sediment transport processes into by-passed and total channel sections. The measures include riprap removal to reinitiate bank erosion, and artificial reintroduction of gravels dredged from reservoirs and navigable channels or excavated from restored side channels. Monitoring programs are co-constructed between researchers and practitioners, to allow the latter to assess changing scenarios and incorporate them into policy strategies.

3 Material and methods

100 **3.1 Data collection**

This study started with an inventory of historical resources compiled in previous long-term research: the RhônEco program (2001–present), Rhône Sediment Observatory (2009–present), and Rhône Valley Human-Environment Observatory (2011–present). We found one long profile and 15 map series collected between 2009 and 2015 from the CNR, the Regional Directorate for Environment, Development and Housing (DREAL), the National Institute of Geographic and forest information

105 (IGN), and the Departmental Archives of Savoie (AD73), Drôme (AD26), Ardèche (AD07), Isère (AD38), Vaucluse (AD84), and the University of Grenoble (Univ. Grenoble). Most of the maps were scanned and integrated into a GIS interface. Their spatial coverage extends from about 10 km to the entire 530-km length of the French river course. The oldest map series is the Sardinian Maps, consisting of twenty communal maps of the left bank of the upper Rhône surveyed at the scale of 1:2372 (the original scale is in 'trabucs') by the Kingdom of Piedmont-Sardinia in 1728–1738. The most recent map series are the CNR

110 pre-work plans, consisting of 128 sheets surveyed between 1946 and 1983 at the scale of 1:10 000 to plan 19 damming and by-passing schemes on the Rhône River from Injoux-Génissiat to Arles.

Between 2017 and 2020, we searched archive services that had been only poorly explored previously: the National Archives of Pierrefitte-sur-Seine (AN; 10 days), Bibliothèque nationale de France (BnF; 2 days), and the Departmental Archives of Rhône (AD69; 6 days), Ain (AD01; 2 days), and Gard (AD30; 2 days). The AD Rhône holds the main collection of the *Ponts*

115 *et Chaussées* administration/Rhône Navigation Service. This consists of numerous maps, plans, and profiles regarding public works and authorizations in the public fluvial domain over the entire river course. We consulted the entire sub-series *S/Public Works (1784-1988)* and *3959 W 1-2030/Rhône-Saône Navigation Service (1807-1994)*. Other relevant references were identified in the AD Rhône numeric catalogue by entering the keywords 'Rhône River' and 'map', notably throughout the *Ancien Régime* (16th–late 18th century). In total, 113 archive boxes were consulted. This research was completed at the National

120 Archives, which also hold the *Ponts et Chaussées* collection. In terms of spatial extent and survey period, the online catalogue contained less information than the AD Rhône one. However, it was possible to identify adequate references with the keyword 'Rhône River' in the sub-series *F/14/Public Works*. Not all resources were described online; thus, the paper registers of the sub-series *F/14/Public Works* and *F/10/Agriculture* were also consulted. The other archive services were similarly searched by keywords, in both numeric catalogues and paper registers. A total of 211 archive boxes were consulted, with each box

125   containing a bundle of documents for either a specific sector at different periods, or a set of surrounding sectors at a given period (Fig. 2). The documents included letters, newspaper extracts, engineer reports, survey tables, cost estimates for further river management, and iconographic resources generally produced to survey flood damage or to plan new infrastructure. We systematically took pictures of iconographic resources, which included maps (Fig. 3.a, b), cross-sections, long profile series (Fig. 3.b), and topo-bathymetric information drawn on maps (Fig. 3.c).

130   The series *CP* (Maps and Plans Service) of the National Archives was given special attention. This series contains older, larger and/or fragile maps, field surveys, and engineering structure iconographies, and requires specific authorization for consultation (Fig. 3.b), with the resources having to be consulted one by one. Because of time constraints, we focused on maps covering long river reaches rather than detailed maps of ports and cities, and focused on reaches involved in present river restoration projects, notably those of Péage-de-Roussillon and Donzère-Mondragon. We selected 33 resources amongst the 53 available

135   for consultation in the sub-series *CP/F/14/Streams and Rivers* (6.5 p.). The sub-series *CP/F/14/Canals* had 12 pages dealing with a project for a continuous lateral canal from Lyon to the Mediterranean Sea, which was finally dropped, and 3 pages dealing with the canal from Arles to Port-de-Bouc at the Rhône delta. We selected 39 resources amongst the 113 available for consultation. The box references consulted in all the archive services are listed in the dataset at doi:10.1594/PANGAEA.922437 (Arnaud et al., 2020a).

140   All collected data were photographed on a table or on a magnetic board in the case of multiple-sheet and large documents, and were saved in .jpg format. The most interesting data were scanned at high resolution (.JPEG and .TIFF format, up to 3 GB each).

3.2 Database structure

        Table 1 describes the properties of the 350 archived data items available in the dataset of Arnaud et al. (2020a). This table has

145   18 columns that include the following: (1) the type of data: i.e. map, cross-section, long profile, table, topo-bathymetry drawn on the map, (2) the source (archive service) and reference (box number), (3) the original title (in French) and a translated English title, (4) the scale, author, and survey period, (5) the communes covered by the upstream-downstream Kilometric Points (KPs; km 0 is in Lyon, distances upstream from this reference point are negative and distances downstream are positive; the KPs were identified in ArcMap 10.5 using the GIS layer of riverine communes and active channels in 1860, to help in

150   locating the maps with secondary channels). (6) comments on the quality and content of the data, (7) the number of images and their type (on a table or a magnetic board, HD scan, scanned and georeferenced), and (8) the storage file and sub-file.

        The iconographic database available in Arnaud et al. (2020a) is 12.7 GB. It contains 3437 images stored in 32 files and 342 sub-files. Thirteen files are named after the engineer who did the surveys. For example, the 'Kleitz (1853-1864)' and 'Bouvier (1785-1848)' files contain 63 and 24 sub-files, respectively. These files describe maps of different reaches, sometimes

155   associated with topo-bathymetry data. The '*Ponts et Chaussées* (1807-1858)' file contains 37 maps surveyed by authors who are unknown or whose names are unreadable. The database also contains 14 files corresponding to a single engineer survey,

generally at scales of 1:10 000 or 1:20 000 along a long river course (from 60 to 530 km), e.g. the map by Josserand surveyed in 1845 between Lyon and Donzère (170 km long), or the long profile by the *Ponts et Chaussées* administration surveyed in 1869 from Seyssel to Lyon (151 km long; Fig. 3.c). Three files consist of maps of the three main reaches of the Rhône: the

160   French upper Rhône (16 maps from 1730–1875), the middle-lower Rhône (13 maps from 1642–1857), and the delta (16 maps from the 18th–19th century). Finally, the file 'Topo-Bathy (1799-1882)' contains 19 cross-section and long profile series surveyed by different authors.

The 350 archive resources include 330 maps and 93 topo-bathymetric data items (Fig. 4.a). About forty other documents were also collected, corresponding to plans (<1:1000), information on the Swiss Rhône, and books from the late 19th and early 20th

165   centuries on fish populations (Vingtrinier, 1882; Locard, 1901; Marchis, 1929). Maps and topo-bathymetric data mainly cover the period 1840–1855 (Fig. 4.b), which corresponds to the beginning of river training after the 100-year flood in October 1840 at Beaucaire (13 000 m^3 s^{-1}). This flood was responsible for significant damage, and led to the establishment of the Rhône Special Service within the *Ponts et Chaussées* administration in 1840 (Bravard, 2010). The 1856–1870 period was also well surveyed, after another 100-year flood in May 1856 at Beaucaire (12 500 m^3 s^{-1}). Nineteen percent of the database covers the

170   period 1640–1839. The oldest resource is a series of 6 maps found in the Chaponnay private archive of AD Rhône, surveyed in 1642–1660, and depicting the 'brotteaux' (grazing areas on recent alluvial deposits) between Pierre-Bénite and Irigny fluvial ports to the south of Lyon (Fig. 5). This map series represents the Rhône River in an artistic manner; however, the distances between villages were checked and were found to be realistic.

Fig. 6 provides a synoptic view of all cartographic data with corresponding spatial scales along the Rhône River. Most items

175   were surveyed between the scales of 1:1000 and 1:20 000, with 1:10 000 being mainly used. This latter scale is suitable for quantitative analysis of morpho-ecological units. Similarly, Fig. 7 depicts the longitudinal coverage of topo-bathymetric data.

3.1 GIS integration

The longitudinal coverage of each of the 350 data items was positioned along the Rhône River centreline in ArcMap 10.5, according to the upstream and downstream KPs. The individual coverages were then merged into one polyline layer available

180   in the dataset Arnaud et al. (2020a). This layer provides efficient identification, at a single click, of archive resources available for a given reach. For example, dragging a selection box over the Chautagne by-passed reach (KP −146 to −137) displays 24 data items on this reach (Fig. 8).

The dataset Arnaud et al. (2020a) provides 14 scanned map series, in both raw (.JPEG or .TIFF) and georeferenced (.GeoTIFF) formats (Table 2). They are among the most spatially extensive and accurate maps in terms of the features represented. Half

185   of these maps have been georeferenced in previous works of the Rhône observatories, using a first order polynomial transformation (between 3 and 15 Ground Control Points [GCPs] per image, RMS error up to 50 m). In this study, we tested spline transformations (named *Thin Plate Spline transformation* in QGIS) based on recommendations of Lestel et al. (2018) for old maps. The spline transformation is a true rubber-sheeting method optimized for local but not global accuracy. It

transforms the source GCPs exactly to the target GCPs, with minimal error around the points. The spline transformation is
190   therefore useful when the number of GCPs is important (www.esri.com). The spline transformation was tested on map series
of 1760 and 1831 by adding GCPs, and was compared with the first order polynomial transformation (Table 2). The positioning
on the present orthophotograph was significantly improved, and the spline transformation was therefore applied to the newly
collected maps. Raw and georeferenced images are usable in both ArcGIS and QGIS softwares.

4 Data use and application

195   The type of archive data, either manually photographed or scanned, and in some cases georeferenced, allows the user a
qualitative or quantitative analysis, including illustration of the fluvial landscape of a large river at the beginning of the 19th
century, evaluation of the main transformations following river regulation, and diachronic GIS extraction of metrics such as
channel widths, secondary channel numbers, and gravel bar areas. The scanning and georeferencing of the sources are not
exhaustive. The archive references are accurately described in the table of data properties to facilitate easy consultation and
200   scanning of data of interest.

The dataset depicts heterogeneous information, which depends on the survey date and map objectives. A critical analysis
should therefore be carried out before any use of the dataset on a given river reach. As an example, Fig. 9 compiles maps
surveyed in the upstream section of the Donzère-Mondragon (DZM) reach, which was involved in side channel reconnections,
riprap removal, and gravel augmentation. The 5-km-long section (KP 171 to 176) embraces the eastern Bayard secondary
205   channel, which was the main course of the river in the late 18th century. Among the 26 maps available prior to 1860, nine have
been selected at scales of 1:5000–1:10 000. Maps from 1810 to 1842 do not specify the nature of islands. Partial information
is given on the 1843 map, with gravel bars drawn in light orange. Symbols are then used on the 1846 map to differentiate
gravel bars and vegetated areas. These symbols are also used on the 1852 and 1856 maps: their base map is the 1846 edition
superimposed with the new channel pattern and engineering infrastructure, which is a common practice in engineering
210   cartography (Lestel et al., 2018). New islands and gravel bar areas formed after the May 1856 flood are drawn in light orange
on the 1856 map. The challenge of map-based historical studies is to use individual sources over time, with little information
on the context in which the map was created, and therefore on its certainty level. The comparison of multiple maps available
at close dates (some of them surveyed in the same year by different engineers) allows inconsistencies between individual
sources to be resolved while revealing persistent landscape features and patterns (Safran et al., 2017). For example, the
215   coloured map of 1842 from Switzerland to the Mediterranean Sea surveyed by the engineer Arnaud is fairly aesthetic; however,
a comparison with other maps highlights the lack of accuracy in the depiction of geomorphic features, notably on the
downstream part of the Bayard channel, as well as the non-exhaustive mapping of roads and villages, which limits the number
of ground control points available for georeferencing.

Keeping in mind the preliminary examination of the data accuracy, the large number of historical data items collected in this
220   study should enable deeper analyses of channel shifting, island dynamics, and landscape changes over a longer time period

and at a finer time step than those performed in previous studies, and also on many reaches of the Rhône River for which no historical maps had been collected until now. The archives prior to 1860 provide us with historical benchmarks for process-based river restoration, and permit comparisons with other large rivers with available archives. A potential application could be the detailing of past trajectories of floodplain units, such as that performed by Tena et al. (2020) on three by-passed reaches

225 of the middle and lower Rhône (Fig. 10). Similarly, Dépret et al. (2017) combined historical maps and aerial images (1860-2009) to date a series of channel disconnections and study terrestrialization processes. They showed that terrestrialization of naturally cut-off channels was much quicker than that observed on artificially cut-off channels, probably because of much higher bedload transport, which promoted active sediment infilling. The historical dataset is also valuable to explore longer-term ecological succession, such as the work of Janssen et al. (2020), who showed that the critical changes undergone by the

230 riparian forests of the Rhône River strongly diverged from natural systems under persistent multiple stressors during the past century (1938–2002).

Historical data on fish communities along the Rhône River are available in documents of various types (e.g. Gobin, 1868, the numerous papers and maps from L. Léger and his collaborators, anonymous reports), and comparisons with present datasets allow assessments of changes in fish community assemblages to be made. Combining physical data describing habitat

235 heterogeneity (e.g. channel width, river bank length, diversity and accessibility of different types of floodplain channels; see Hohensinner et al. 2004; 2011 for examples on the Danube River) at different periods with data on fish habitat preferences (Lamouroux et al., 1999; Rifflart et al., 2009; Sukhodolov et al., 2009) may be useful to achieve a better understanding of the influence of fluvial landscape transformation over the last few centuries on fish abundance and spatial patterns. Historical maps and associated physical data can thus be used to assess abiotic conditions over time in the framework of biomonitoring

240 methods. For example, historical analysis (from the end of the 19th century) of fish community structure in the Seine River catchment highlighted the major role of river continuity alteration in the decline of migratory species, the importance of introductions of non-native species, and changes in the proportion of rheophilic/eurytopic species in relation to the increase of human population densities and water pollution (Belliard et al., 2018).

Finally, another potential use of the dataset is the reconstruction of extreme flood events based on historical channel

245 geometries. The Beaucaire-Tarascon station (KP 269.5) records flows of the whole basin, and is the oldest hydrometric station on the Rhône. Daily water level measurements started in 1816, and daily estimates of discharge started in 1920 (Billy et al., 2018). These chronicles are part of the HISTRHONE database, which contains a large volume of archives related to hydro-climatic events in the lower Rhône over a period between the 14th and 20th centuries (Pichard and Roucaute, 2014). Further work by hydrologists will involve exploiting historical topographic data prior to river training to reduce uncertainties in the

250 extrapolation of rating curves of hydraulic modelling based on original channel geometries. The topo-bathymetric data highlighted in this study will be of particular interest (Fig. 7 and 11).

5 Data availability

The dataset is freely available in Pangaea at doi 10.1594/PANGAEA.922437 (Arnaud et al., 2020a). It contains the iconographic database (12.7 GB), the .csv table describing the properties of the 350 data items (109 KB), the .csv table listing the 281 archive box references (13 KB), and the GIS layer of the longitudinal coverage of the 350 data items (10.8 MB). The dataset is available under the terms of the Creative Commons Attribution-NonCommercial (CC BY-NC) license, which permits use, distribution and reproduction in any medium, provided that the use is not for commercial purposes and that the original work is properly cited. This license was chosen to meet the data reuse policies of the 14 French archive services investigated in this study, 4 of which have a reuse policy equivalent to the CC BY license (National Archives, AD Ain, AD Vaucluse, DREAL, Univ. Grenoble), and 5 have a reuse policy equivalent to the CC BY-NC license (BnF, AD Rhône, AD Drôme, AD Ardèche, AD Gard). Data from AD Isère, AD Savoie, CNR, and IGN, i.e. 10 items among the 350 items in the dataset, are not furnished in the iconographic database. They are indicated as "available on request", because of specific reuse policies of these institutions. The URLs of each institution's reuse policy are given in Pangaea metadata.

Extracts of the 350 data items are available in the public photo gallery of the Rhône Valley Human-Environment Observatory, to enhance data visibility. This photo gallery uses the open source Piwigo software, with images being geolocated on an interactive map. Map extracts have been oriented according to the flow direction of the Rhône, as long as this did not disturb the toponym reading.

In addition to Pangaea, technical information on the dataset is available in the public metadata catalogue of the Rhône Valley Human-Environment Observatory. Based on the open source GeoNetwork software, this metadata catalogue is harvested by the LabEx DRIIHM (international consortium of Human-Environment Observatories) geocatalogue, which is then harvested by the French geocatalogue and the European INSPIRE Geoportal, so that data discovery is possible at several hierarchical levels (Arnaud et al., 2020b).

6 Conclusions

This study presents a historical database of 350 maps, topo-bathymetric cross-sections, and long profiles compiled on the French Rhône River over the period 1640–1950. Such an inventory of historical data over such a long time period and long river course (530 km) has never been created before for the Rhône, and has rarely been created for other large rivers. This database will enable further comparisons with other multi-impacted large rivers in Europe, such as the Danube, the Rhine, the Ebro, and the Po, or even from one continent to another when data are available. The densification of archived time series is useful to detail and extend past trajectories of geomorphic, hydraulic, and ecological river features, and for conducting comparative analyses to detect differences and similarities between reaches and between rivers located in different geographical settings. Recently, restoration measures have been extended to other by-passed reaches of the Rhône River (Baix-le-Logis-Neuf, Saint-Vallier, Montélimar), and these will also require analyses of channel changes over the last two centuries to improve restoration strategies. Some archive services were consulted in entirety for the time period and theme of this data

article, notably the National Archives and AD Rhône, whereas additional investigations could be conducted in CNR or other departmental archives in coming years. Possible updates or extensions to the dataset might therefore happen in the future.

Author contributions

All co-authors actively participated in the project "Collection and visualization of historical biophysical resources on the Rhône River" (OHM Vallée du Rhône, 2017-2019). Fanny Arnaud and Lalandy Sehen Chanu searched archive services, photographed historical resources, and prepared the database. Jules Grillot performed GIS treatment of scanned data. Jérémie Riquier brought his expertise on historical data compiled in previous long-term research on the Rhône River. Fanny Arnaud supervised the project and wrote the paper. Hervé Piégay, Dad Roux-Michollet, Jérémie Riquier, Georges Carrel, and Jean-Michel Olivier revised the manuscript and provided important contributions in the section "Data use and application".

Competing interests

The authors declare that they have no conflicts of interest in respect to this study.

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References

Amoros, C. and Bornette, G.: Connectivity and biocomplexity in waterbodies of riverine floodplains, Freshwater Biology, 47, 761–776, 2002.

Arnaud, F., Sehen Chanu, L., Grillot, J., Riquier, J., Piégay, H., Roux-Michollet, D., Carrel, G., and Olivier, J. M.: Cartographic
310   and topo-bathymetric archive dataset on the French Rhône River (17th-20th centuries).
       PANGAEA, doi:10.1594/PANGAEA.922437, 2020a.

Arnaud, F., Lerigoleur, E., Jean-Charles, A., Le Berre, I., Pardo, C., Raynal, J. C., Fozzani, J., Michel, K., Trémélo, M. L., and
       Roux-Michollet, D.: Managing and sharing multidisciplinary information in human-environment observatories: feedbacks
       and recommendations from the French DRIIHM network. Journal of Interdisciplinary Methodologies and Issues in Science,
315   doi:10.18713/JIMIS-120620-6-3, 2020b.

Arnaud, F., Piégay, H., Schmitt, L., Rollet, A. J., Ferrier, V., and Béal, D.: Historical geomorphic analysis (1932–2011) of a
       by-passed river reach in process-based restoration perspectives: The Old Rhine downstream of the Kembs diversion dam
       (France, Germany), Geomorphology, 236, 163–177, doi:10.1016/j.geomorph.2015.02.009, 2015.

Belletti, B., Dufour, S., and Piégay, H.: What is the relative effect of space and time to explain the braided river width and
320   island patterns at a regional scale? River Res. Appl., 31(1), 1–15, doi:10.1002/rra.2714, 2013.

Belliard, J., Beslagic, S., Delaigue, O., and Tales, E.: Reconstructing long-term trajectories of fish assemblages using historical
       data: the Seine River basin (France) during the last two centuries, Environ. Sci. Pollut. Res., 25, 23430–23450,
       doi:10.1007/s11356-016-7095-1, 2018.

Billy, P., Bard, A., Lang, M., Naulet, R., and Mallet, T.: Updating flood assessment of the Rhône river, a new methodology,
325   in: Proceedings, 3rd International Conference, Integrative Sciences and Sustainable Development of Rivers, Lyon, France,
       June 2018, 4–8, available at: https://www.graie.org/ISRivers/docs/ISRIVERS2018_%20Actes_web.pdf (last access: 19
       May 2020), 2018.

Bravard, J. P.: Discontinuities in braided patterns: The River Rhône from Geneva to the Camargue delta before river training,
       Geomorphology, 117 (3-4), 219–233, doi:10.1016/j.geomorph.2009.01.020, 2010.

330   Bravard, J. P. and Gaydou, P.: Historical development and integrated management of the Rhône River floodplain, from the
       Alps to the Camargue Delta, France, in: Geomorphic Approaches to Integrated Floodplain Management of Lowland Fluvial
       Systems in North America and Europe, edited by: Hudson, P. F. and Middelkoop, H., Springer, New York, 289–320,
       doi:10.1007/978-1-4939-2380-9, 2015.

Cadol, D., Rathburn, S. L., and Cooper, D. J.: Aerial photographic analysis of channel narrowing and vegetation expansion in
335   Canyon de Chelly National Monument, Arizona, USA, 1935–2004, River Res. Appl., 27(7), 841–856,
       doi:10.1002/rra.1399, 2011.

Carrel, G.: Prospecting for historical fish data from the Rhone River basin: a contribution to the assessment of reference
       condition, Arch. Hydrobiol., 155(2): 273–290, 2002.

Dépret, T., Riquier, J., and Piégay, H.: Evolution of abandoned channels: Insights on controlling factors in a multi-pressure
340   river system, Geomorphology, 294, 99–118, doi:10.1016/j.geomorph.2017.01.036, 2017.

Downs, P. W., Dusterhoff, S. R., and Sears, W. A.: Reach-scale channel sensitivity to multiple human activities and natural events: lower Santa Clara River, California, USA, Geomorphology 189, 121–134, doi:10.1016/j.geomorph.2013.01.023, 2013.

Dufour, S. and Piégay, H.: From the myth of a lost paradise to targeted river restoration: forget natural references and focus on human benefits, River Res. Appl. 25(5), 568–581, doi:10.1002/rra.1239, 2009.

Dufour, S., Rinaldi, M., Piégay, H., and Michalon, A.: How do river dynamics and human influences affect the landscape pattern of fluvial corridors? Lessons from the Magra River, Central–Northern Italy, Landscape and Urban Planning, 134, 107–118, doi:10.1016/j.landurbplan.2014.10.007, 2015.

Eschbach, D., Schmitt, L., Imfeld, G., May, J. H., Payraudeau, S., Preusser, F., Trauerstein, M., and Skupinski, G.: Long-term temporal trajectories to enhance restoration efficiency and sustainability on large rivers: an interdisciplinary study, Hydrol. Earth Syst. Sci., 22, 2717–2737, doi:10.5194/hess-22-2717-2018, 2018.

Frimpong, E. A., Huang, J., and Liang, Y.: IchthyMaps: A database of historical distributions of freshwater fishes of the United States, Fisheries, 41, 590–599, doi:10.1080/03632415.2016.1219948, 2016.

Gobin, M.: Note sur les ressources que présente actuellement le Haut-Rhône, Annales de la Société Impériale d'Agriculture. Histoire Naturelle et Arts Utiles de Lyon, 1, CI-CXX, 1868.

Grabowski, R. C., Surian, N. and Gurnell, A. M.: Characterizing geomorphological change to support sustainable river restoration and management, WIREs Water, 1, 483-512, doi:10.1002/wat2.1037, 2014.

Habersack, H. and Piégay, H.: River restoration in the Alps and their surroundings: past experience and future challenges, in: Gravel-bed Rivers 6: From Process Understanding to the Restoration of Mountain Rivers, edited by: Rinaldi, M., Habersack, H., and Piégay, H., Elsevier, Amsterdam, 703–737, ISBN 978-0-444-52861-2, 2008.

Hohensinner, S., Habersack, H., Jungwirth, M., and Zauner, G.: Reconstruction of the characteristics of a natural alluvial river-floodplain system and hydromorphological changes following human modifications: the Danube River (1812-1991), River Res. Appl., 20, 25–41, doi:10.1002/rra.719, 2004.

Hohensinner, S., Jungwirth, M., Muhar, S., and Schmutz, S.: Spatio-temporal habitat dynamics in a changing Danube River landscape 1812-2006, River Res. Appl., 27, 939–955, doi: 10.1002/rra.1407, 2011.

Janssen, P., Stella, J. C., Piégay, H., Räpple, B., Pont, B., Faton, J. M., Cornelissen, J. H. C., and Evette, A.: Divergence of riparian forest composition and functional traits from natural succession along a degraded river with multiple stressor legacies, Sci. Total Environ., 721, 137730, doi:10.1016/j.scitotenv.2020.137730, 2020.

Kui, L., Stella, J. C., Shafroth, P. B., House, P. K., and Wilcox, A. C.: The long-term legacy of geomorphic and riparian vegetation feedbacks on the dammed Bill Williams River, Arizona, USA, Ecohydrology, 10(4), doi:10.1002/eco.1839, 2017.

Lamouroux, N., Capra, H., Pouilly, M., and Souchon, Y.: Fish habitat preferences at the local scale in large streams of southern France, Freshwater Biology, 42, 673–687, 1999.

Lamouroux, N., Gore, J. A., Lepori, F., and Statzner, B.: The ecological restoration of large rivers needs science-based,
375   predictive tools meeting public expectations: an overview of the Rhône project, Freshwater Biology, 60(6), 1069–1084,
       doi:10.1111/fwb.12553, 2015.

Lestel, L., Eschbach, D., Steinmann, R., and Gastaldi, N.: ArchiSEINE: une approche géohistorique du bassin de la Seine,
       Fascicule No. 18 PIREN-Seine, ARCEAU-IdF, 64 pp., ISBN 978-2-490463-07-7, 2018.

Locard, A.: Sur quelques modifications récentes survenues dans la faune zoologique lyonnaise, hirondelles et moustiques,
380   soafe et hotu, mouettes, A. Rey, Lyon, collected in Bibliothèque nationale de France, MFICHE 4-S piece-1517, 1901.

Marchis, E.: Poissons d'eau douce et d'eau salée. Saumon, Alose, Esturgeon, Anguille, Muge, poissons d'estuaires, étangs et
       lacs salés, Société d'Éditions géographiques, maritimes et coloniales, Paris, collected in Bibliothèque nationale de France,
       MFICHE 8-S-18530, 1929.

Michalková, M., Piégay, H., Kondolf, G. M., and Greco, S. E.: Lateral erosion of the Sacramento River, California (1942–
385   1999), and responses of channel and floodplain lake to human influences, Earth Surf. Process. Landf., 36(2), 257–272,
       doi:10.1002/esp.2106, 2011.

Mould, S. and Fryirs, K.: Contextualising the trajectory of geomorphic river recovery with environmental history to support
       river management, Applied Geography, 94, 130–146, doi:10.1016/j.apgeog.2018.03.008, 2018.

Olivier J. M., Carrel, G., Lamouroux, N., Dole-Olivier, M. J., Malard, F., Bravard, J. P., Piégay, H., Castella, E., and
390   Barthélémy C.: The Rhône River Basin, in: Rivers of Europe, edited by: Tockner, K., Zarfl, C., and Robinson, C.T.,
       Academic Press, Elsevier, London, in press.

Parrot, E.: Analyse spatio-temporelle de la morphologie du chenal du Rhône du Léman à la Méditerranée, PhD thesis,
       Université Lyon 3, France, 2015.

Pichard, G. and Roucaute, E.: Sept siècles d'histoire hydroclimatique du Rhône d'Orange à la mer (1300-2000), climat, crues,
395   inondations, Méditerranée, 192 pp., ISBN 9782853999410, 2014.

Piégay, H., Arnaud, F., Belletti, B., Bertrand, M., Bizzi, S., Carbonneau, P., Dufour, S., Liébault, F., Ruiz-Villanueva, V.,
       and Slater, L.: Remotely sensed rivers in the Anthropocene: state of the art and prospects, Earth Surf. Process. Landf., 45,
       157–188, doi:10.1002/esp.4787, 2020.

Pont, D., Logez, M., Carrel, G., Rogers, C., and Haidvogl, G.: Historical change in fish species distribution: shifting reference
400   conditions and global warming effects, Aquatic Sciences, 77, 441–453, doi:10.1007/s00027-014-0386-z, 2015.

Provansal, M., Dufour, S., Sabatier, F., Anthony, E., Raccasi, G., and Robresco, S.: The geomorphic evolution and sediment
       balance of the lower Rhône River (southern France) over the last 130 years: hydropower dams versus other control factors,
       Geomorphology, 219, 27–41, doi:10.1016/j.geomorph.2014.04.033, 2014.

Räpple B.: Patrons de sédimentation et caractéristiques de la ripisylve dans les casiers Girardon du Rhône: approche
405   comparative pour une analyse des facteurs de contrôle et une évaluation des potentialités écologiques, PhD thesis,
       Université de Lyon, France, 2018.

Rifflart, R., Carrel, G., Le Coarer, Y., and Nguyen the Fontez, B.: Spatio-temporal patterns of fish assemblages in a large regulated alluvial river, Freshwater Biology, 54, 1544–1559, doi:10.1111/j.1365-2427.2009.02200.x, 2009.

Riquier, J. and Cottet, M.: The Rhône River, in: Rivers of the Alps, edited by: Muhar, S., Muhar, A., Siegrist, D., and Egger, G., Haupt Verlag AG, Bern, 456–459, ISBN 978-3-258-08117-5, 2019.

Roux, A. L., Bravard, J. P., Amoros, A., and Pautou, G.: Ecological changes of the French Upper Rhône River since 1750, in: Historical Change of Large Alluvial Rivers: Western Europe, edited by: Petts, G. E., Möller, H., and Roux A. L., John Wiley & Sons, Chichester, 323–350, ISBN 0-471-92163-7, 1989.

Safran, S. M., Baumgarten, S. A., Beller, E. E., Crook, J. A., Grossinger, R. M., Lorda, J., and Stein, E. D.: Tijuana River Valley Historical Ecology Investigation, prepared for the State Coastal Conservancy, SFEI-ASC's Resilient Landscapes Program, SFEI Contribution No. 760, Aquatic Science Center, San Francisco Estuary Institute, Richmond, CA, 2017.

Salvador, P. G. and Berger, J. F.: The evolution of the Rhône River in the Basses Terres basin during the Holocene (Alpine foothills, France), Geomorphology, 204, 71–85, doi:10.1016/j.geomorph.2013.07.030, 2014.

Scorpio, V., Surian, N., Cucato, M., Dai Prá, E., Zolezzi, G., and Comiti, F.: Channel changes of the Adige River (Eastern Italian Alps) over the last 1000 years and identification of the historical fluvial corridor, Journal of Maps, 14(2), 680–691, doi:10.1080/17445647.2018.1531074, 2018.

Słowik, M.: Is history of rivers important in restoration projects? The example of human impact on a lowland river valley (the Obra River, Poland), Geomorphology, 251, 50–63, doi:10.1016/j.geomorph.2015.05.031, 2015.

Solins, J. P., Thorne, J. H., and Cadenasso, M. L.: Riparian canopy expansion in an urban landscape: Multiple drivers of vegetation change along headwater streams near Sacramento, California, Landscape and Urban Planning, 172, 37-46, doi:10.1016/j.landurbplan.2017.12.005, 2018.

Steiger, J., Gurnell, A. M., Ergenzinger, P., and Snelder, D.: Sedimentation in the riparian zone of an incising river, Earth Surf. Process. Landf., 26(1), 91–108, 2001.

Sukhodolov, A., Bertoldi, W., Wolter, C., Surian, N., and Tubino, M.: Implications of channel processes for juvenile fish habitats in Alpine rivers, Aquatic Sciences, 71, 338–349, doi:10.1007/s00027-009-9199-x, 2009.

Tena, A., Piégay, H., Seignemartin, G., Barra, A., Berger, J. F., Mourier, B., and Winiarski, T.: Cumulative effects of channel correction and regulation on floodplain terrestrialisation patterns and connectivity, Geomorphology, 354, 107034, doi:10.1016/j.geomorph.2020.107034, 2020.

Van Den Broeck, N. and Moutin, T.: Phosphate in the sediments of the Gulf of Lions (NW Mediterranean Sea), relationship with input by the river Rhone, Hydrobiologia, 472, 85–94, doi: 10.1023/A:1016308931115, 2002.

Vella, C., Fleury, J., Raccasi, G., Provansal, M., Sabatier, F., and Bourcier, M.: Evolution of the Rhône delta plain in the Holocene, Marine Geology, 222-223, 235–265, doi:10.1016/j.margeo.2005.06.028, 2005.

Vingtrinier, A.: La pêche à l'Alose dans la rivière d'Ain, in: Fantaisies lyonnaises, Lyon, 44–72, collected in Departmental Archives of Ain, BIB E 525, 1882.

List of Tables

Table 1: Extract of the .csv table describing the properties of the 350 archive resources collected in this study. The symbol ~ in the Scale column means that it was not provided in the document, and the scale was therefore estimated by direct measurement of the distance between two benchmarks or by comparison with similar maps.

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ID	Type	Source	Ref data	Original title (in French)	Translated title (in English)	Scale	Author(s)	Period
44	Map	AD01	100Fi 67	Plan du cours du Rhône depuis Seyssel jusqu'à Pierre-Châtel sur le territoire de Virignin, ainsi que les communes avoisinantes	Map of the Rhône river from Seyssel to Pierre-Châtel on the territory of Virignin and neighbouring towns	Toises	*NA*	~ 1750
264	Map/Cross section	AN	CP/F/14/10074/1/A/piece25	Projet de halage pour le passage du Pont-St-Esprit	Towing project for the Pont-St-Esprit passage	*~ 1:5000*	Grangent	1812
261	Map	AN	CP/F/14/10074/1/B/piece34	Plan de la partie du cours du Rhône et de la rive gauche de ce fleuve comprise dans le département de la Drôme, entre l'embouchure du ruisseau du Dolon (...) et celle du Lauzon	Plan of the part of the Rhône river and the left bank of this river included in the department of the Drôme, between the Dolon confluence (...) and that of the Lauzon	1:10 000	Grailly	1833
96	Cross section	AN	F/14/6501	Barrage du bras de Lavours	Dam of the Lavours channel	1:1000	O'Brien	1835
255	Map	AN	CP/F/14/10074/1/B/piece35	Plan général de la rive droite du cours du Rhône depuis Limony, jusqu'au pont de Saint-Just. Troisième feuille de Meisse à St-Just	General map of the right bank of the Rhône river from Limony to the St-Just bridge. Third sheet from Meisse to Saint-Just	1:10 000	Ponts & Chaussées	1835
304	Map/Bathy-metry	AD69	S 1434	Amélioration du Rhône devant Beaucaire	Improvement of the Rhône river at Beaucaire	1:10 000	Goux	1851
100	Long profile	AD69	S1356	Nivellement en long sur les deux rives du Rhône	Longitudinal levelling on both banks of the Rhône river	1:10 000	Ponts & Chaussées	1869
10	Map	CNR, AD01	*NA*, 100Fi 69 to 100Fi 114	Plans Branciard	Branciard maps	1:2000, 1:5000	Branciard	1910

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Sector	Upstr. KP	Downstr. KP	Length (km)	Comment	Nb of images	Image acquisition	Storage file	Sub-file
Seyssel to Virignin	-151	-117	34	This map may have been surveyed after the Sardinian Maps of 1738 and before 1760 because 'lateral lines' from 1760 are not visible everywhere	20	Table	1730-1875_Plans_UpperRhone	1750_NA_Seyssel-Virignin
Pont-St-Esprit	191	193	2	Names of the bridge piers. 3 cross sections	8	Table	1756-1822_Grangent_Plans	PontStEsprit_1812
St Rambert to Pont-St-Esprit	61.5	191.5	130	Map of 12 m long. Name of some islands but not their nature. Left bank only. The Drôme River is visible	25	Table	1833_Grailly_Plan_Dol-Lauz	
Lavours	-131.5		Ponctual data	1 cross section	8	Table	1799-1882_Topo-Bathy	1835_OBrien_Lavours_CS
Meysse to St Just	151	191	40	Not the nature of bars and banks. Right bank only	10	Table	1807-1858_PontsChaussees_Plans	Meysse-StJust_1835
Beaucaire	260	268.5	8.5	2 general maps, 3 detailed maps	3, 6, 3, 3, 4	Magnetic board	1839-1853_Goux_Plans	Beaucaire_1851
Seyssel to Lyon	-150	0	150	Long profile indicating water depth and thalweg elevation	14	Table	1869_PC_LP_Upper Rhone	
Virignin to Caderousse	-116.5	219	335.5	Upstream of Lyon: AD01. Downstream of Lyon: CNR (available on request)	47, 107	HD scan, Georef 1st	1910_Branciard_Plan_Viri-Cad	

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Table 2: Georeferencing information on 14 map series of the database. The BD ORTHO® and PARCELLAIRE® base maps are provided by the IGN.

Translated title (in English)	Scale	Author(s)	Period	Sector	Length (km)	Nb img	Georeferencing transformation	Nb GCPs / img	RMS error (m)	Base map
Map of part of the Rhône river from Cordon to Hyenne (…)	1:30 000	*NA*	18th c.	Yenne to Cordon	25	2	Spline	12-24	10^{-5}	BD ORTHO® & PARCELLAIRE®, OpenStreetMap©
Geometrical map of part of the Rhône river from Geneva to the Guyer confluence (…)	1:28 246	De Bourcet	1760	Genève to St-Genix	107	7	1st Order Polynomial & Spline	13-25 & 20-26	34-44 & 10^{-5}	BD ORTHO® & PARCELLAIRE®, OpenStreetMap©
Map of the marshes and the plain from Beaucaire to Aiguemortes (…)	~ *1:100 000*	Delisle	Late 18th c.	Beaucaire to the sea	57	1	Spline	31	10^{-5}	BD ORTHO® & PARCELLAIRE®, OpenStreetMap©
Napoleonic land register	1:10 000	Napoleon I	1810-1832	St-Maurice to Piolenc	63.5	16	1st Order Polynomial	*NA*	*NA*	BD ORTHO® & PARCELLAIRE®
The Rhône river : border between the Kingdom of France and the Duchy of Savoy	1:14 400	Corefa	1831	Cressin to St-Genix	30	1	1st Order Polynomial & Spline	23 & 38	59 & 10^{-5}	BD ORTHO® & PARCELLAIRE®, OpenStreetMap©
General plan and project for the dyke to be built against the highest floods of the Rhône (…)	1:10 000	Dignoscyo	1837	Jons to Pierre-Bénite	31	2	Spline	50-85	10^{-5}	BD ORTHO® & PARCELLAIRE®, OpenStreetMap©
Map of the Rhône river between Donzère and Arles	1:10 000	Ponts & Chaussées	1846	Donzère to Arles	116	12	Spline	19-52	10^{-5}	BD ORTHO® & PARCELLAIRE®, OpenStreetMap©
NA	1:10 000	*NA*	1854	Anglefort to Massignieux	23	5	Spline	10-14	10^{-5}	BD ORTHO® & PARCELLAIRE®, OpenStreetMap©
Topographical map of the Rhône river	1:10 000	Ponts & Chaussées	1857-1876	Surjoux to the sea	489	58	1st Order Polynomial	~ 15. Improvement of 9 images: 10-17	< 50. Improvement of 9 images: 4.6-12.8	BD ORTHO®
Completion and first maintenance works	1:10 000	Girardon	1891	Lyon to Donzère	169.5	55	1st Order Polynomial	6-15	3.0-9.5	BD ORTHO®
Bathymetric maps of the Rhône river	1:10 000	Ponts & Chaussées	1897-1908	Lyon to the sea	307	66	1st Order Polynomial	4-12	0.6-20.5	BD ORTHO®
Branciard maps	1:2000, 1:5000	Branciard	1910	Virignin to Caderousse	170	107	1st Order Polynomial	3-15	0.3-11.3	BD ORTHO® & PARCELLAIRE®
General staff maps	1:20 000-1:80 000	Etat-Major	1832-1941	Genève to the sea	535	162	1st Order Polynomial	4-6	0.8-26.3	BD ORTHO®
Pre-work plans	1:10 000	CNR	1946-1983	Anglefort to Caderousse	162	128	1st Order Polynomial	4	*NA*	BD ORTHO®

List of Figures' captions

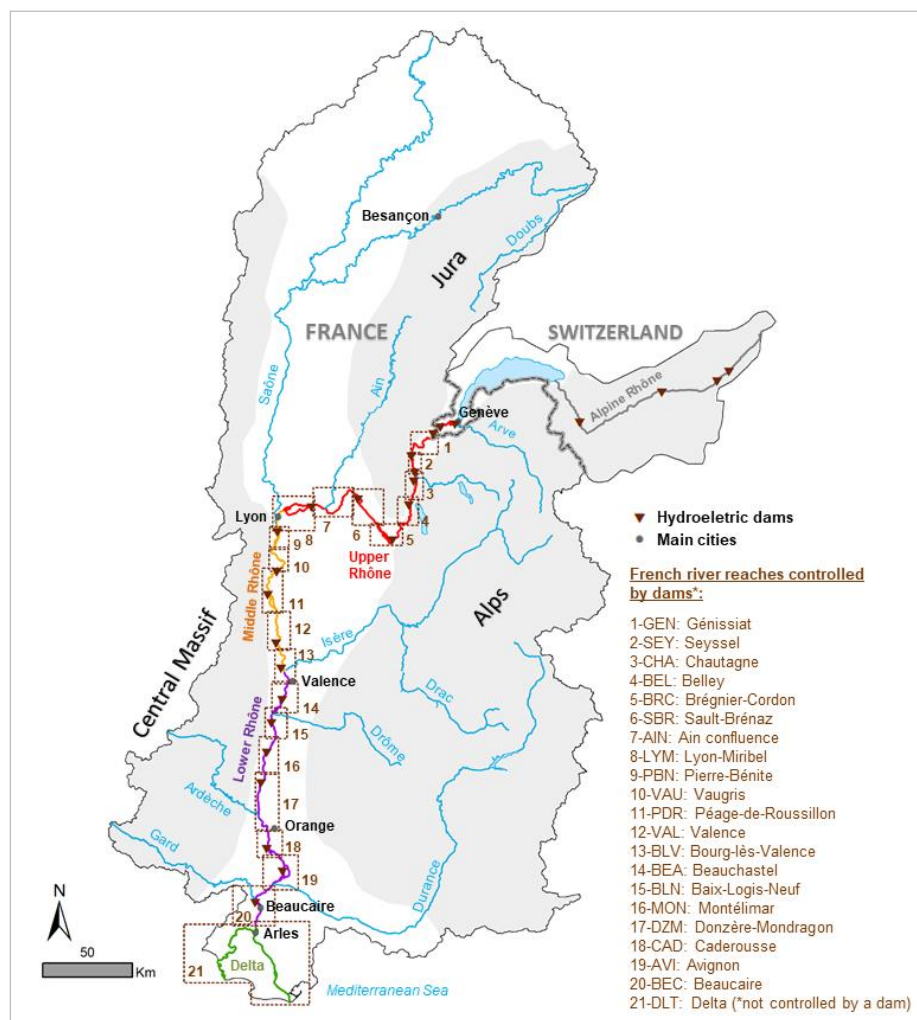



Figure 1: The Rhône River corridor in the French-Swiss basin.

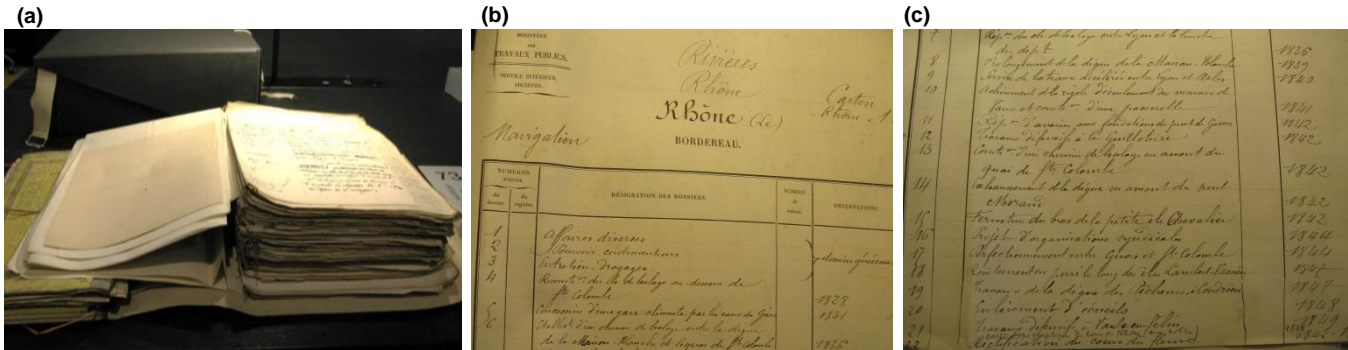



Figure 2: Example of the box F/14/6706 in the National Archives (online catalogue information: 'Rhône River, Files 1-22, 1828-1849'): (a) bundle of documents; (b) and (c) content description.

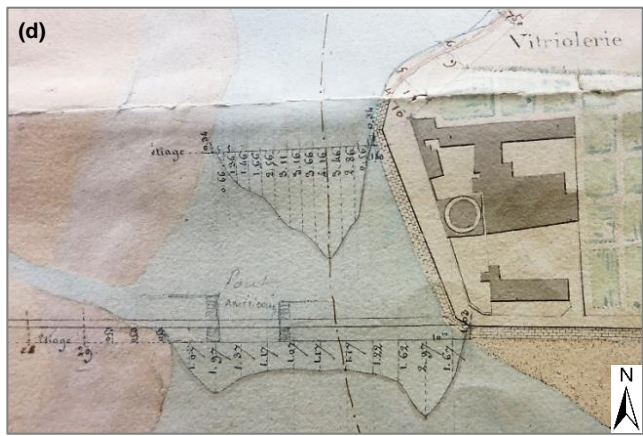
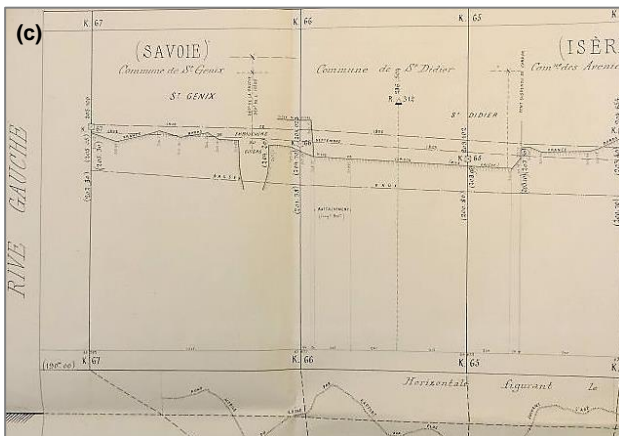
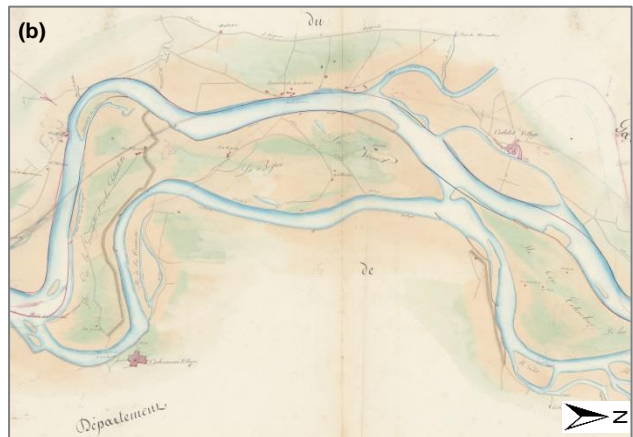
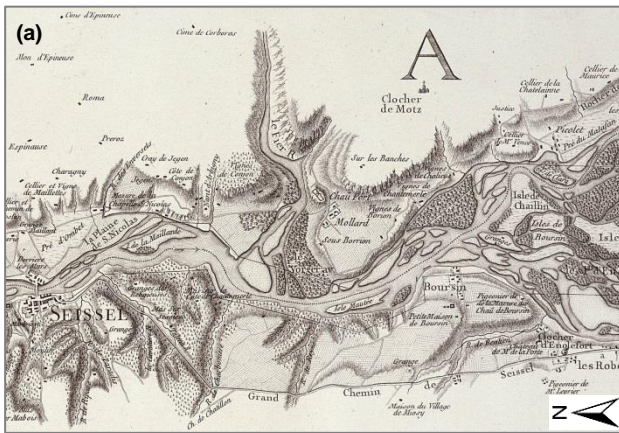



Figure 3: Examples of the archive resources collected in this study: (a) map series at 1:28 246 between Geneva and the Guiers confluence, 1760. Extract of sheet n°3/7 (source: De Bourcet, AD Savoie, 1Fi S52-53); (b) bathymetric information on a map at

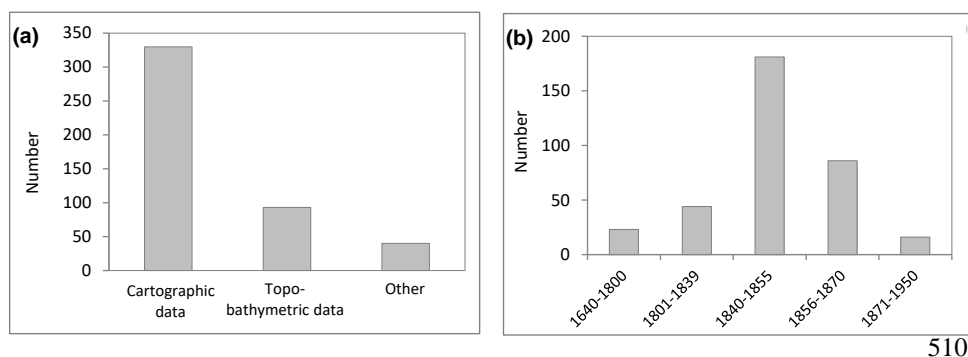
495 **1:2000 in Lyon, 1833 (source: Garella, AD Rhône, S 1361); (c) long profile of the left bank and the thalweg of the upper Rhône, 1869. Extract of the sheet n°6/6 (source: *Ponts et Chaussées*, AD Rhône, S 1356); (d) map series at 1:10 000 from Geneva to the Mediterranean Sea, 1842. Extract of the sheet n°20/25 (source: Arnaud, National Archives, CP/F/14/10074/2/Piece 8).**

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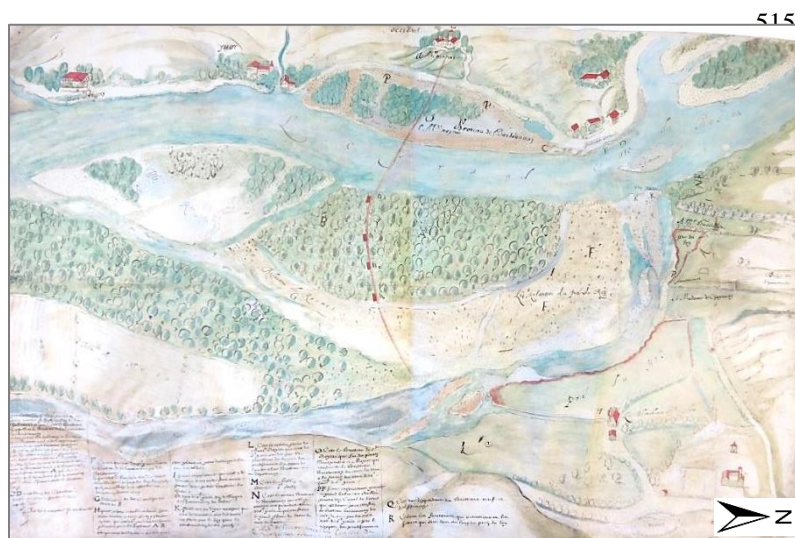
Figure 4: (a) Number of archive data items compiled in this study. "Other" corresponds to plans <1:1000, long profiles of the Swiss Rhône, and books. (b) Temporal extent of cartographic and topo-bathymetric data.

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Figure 5: Map at ~1:10 000 between Pierre-Bénite and Irigny, 1644 (source: Maupin, AD Rhône, 44 J 336).

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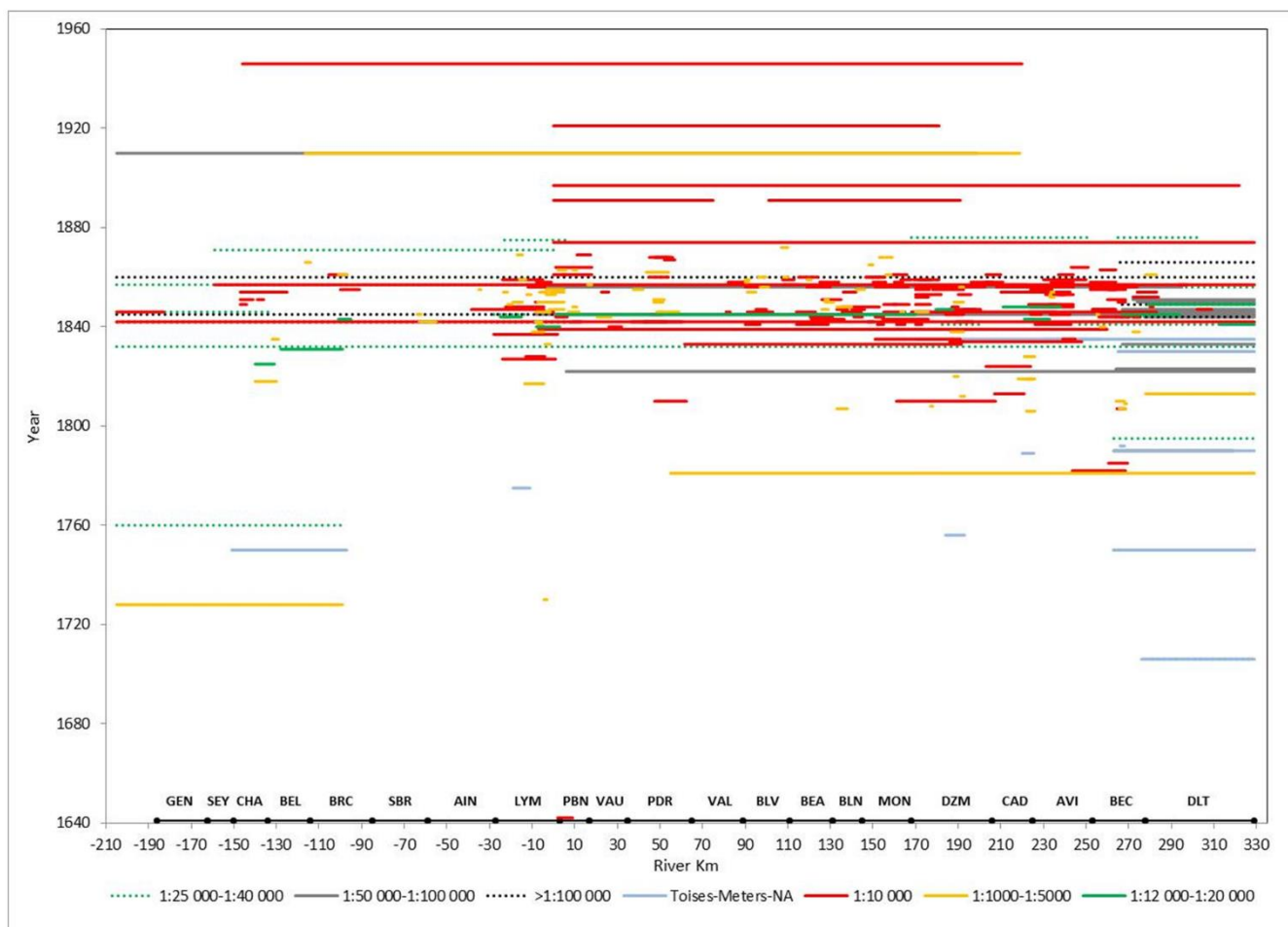
Figure 6: Longitudinal coverage and spatial scales of the cartographic dataset. The spatial extent of present river reaches is superimposed on the x-axis (see Fig. 1 for acronyms).

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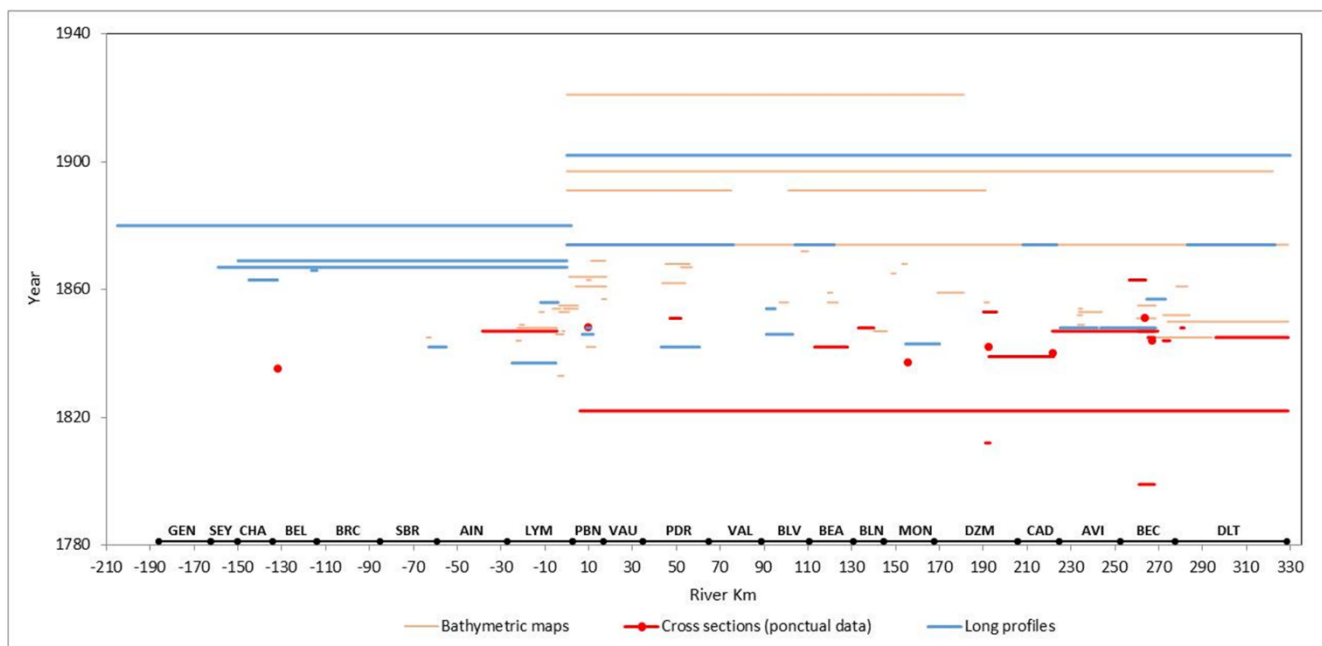


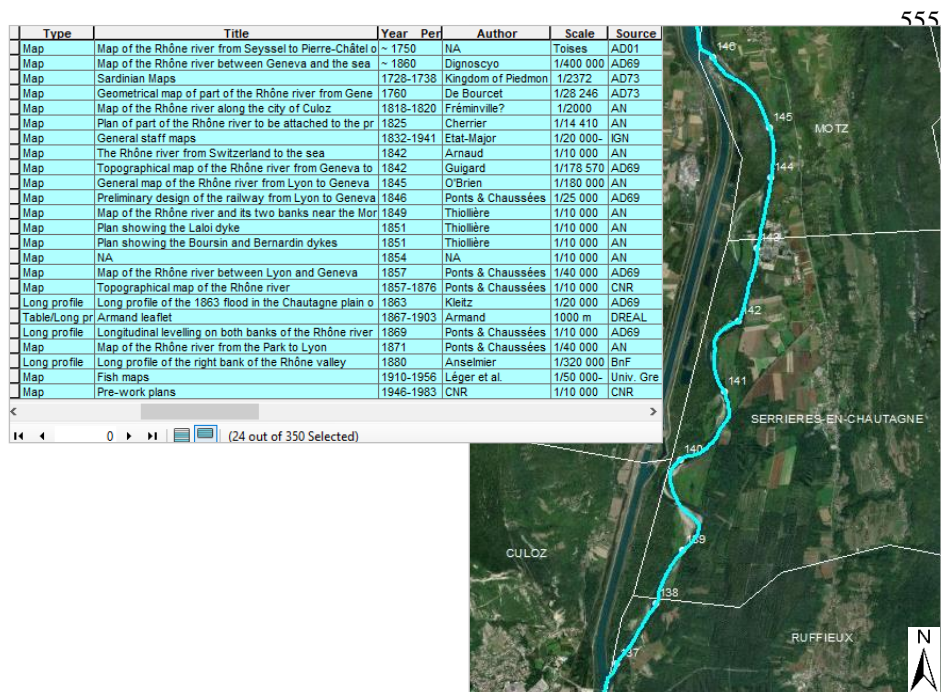
Figure 7: Longitudinal coverage of the topo-bathymetric dataset. The spatial extent of present river reaches is superimposed on the x-axis (see Fig. 1 for acronyms).

555

Figure 8: GIS layer of the longitudinal coverage of data collected in this study. Example of the 24 available data items on the Chautagne river reach (KP −146 to −137). Basemap: Esri.

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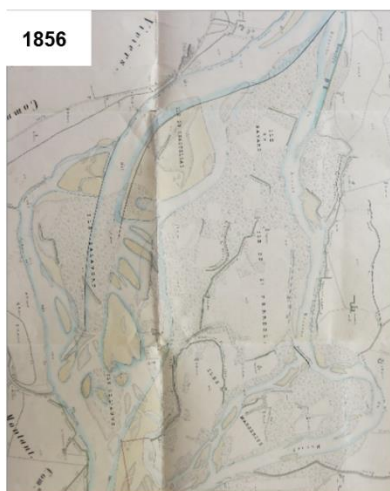
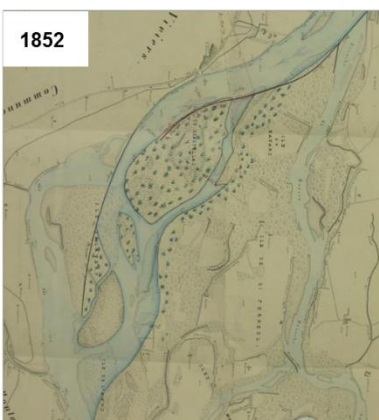
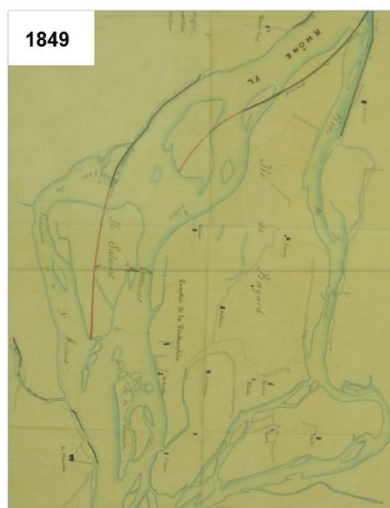
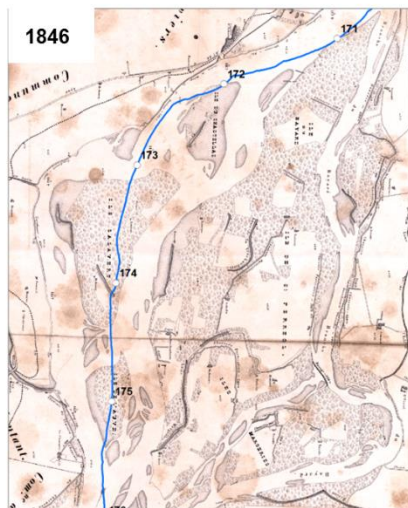
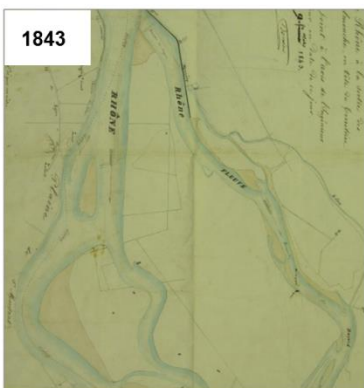
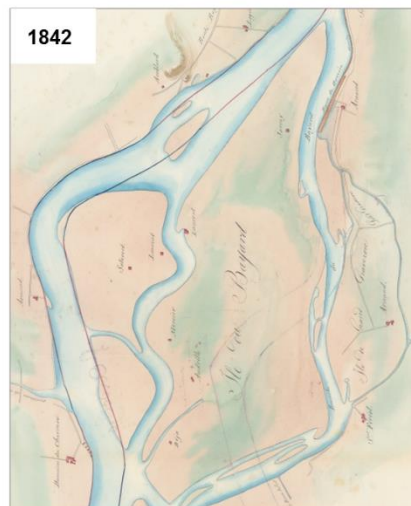
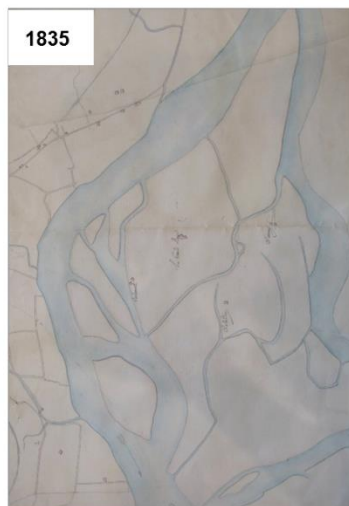
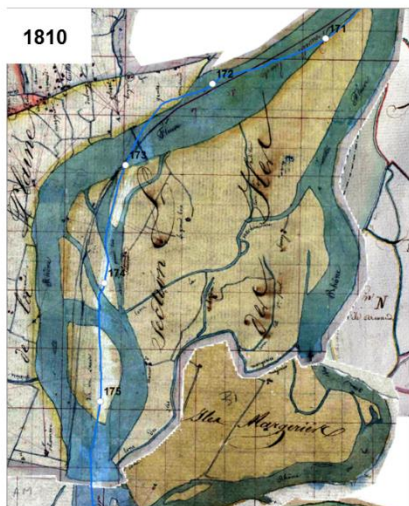
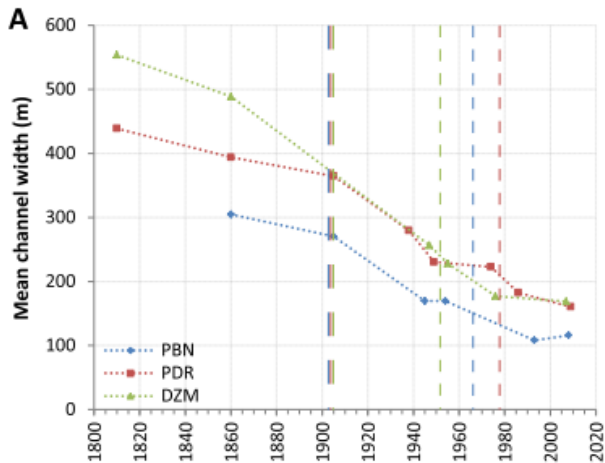


Figure 9: Examples of maps surveyed on the upstream section of the Donzère-Mondragon reach, 1810–1860. The present Rhône
580 **centreline and Kilometric Points (KPs) are superimposed on the 1810 and 1846 georeferenced maps. The "1860-2020" map shows the present orthophotograph, on which the delineations of aquatic channels in 1860 were superimposed (Source: 1810: Napoleonic Land Register; 1835, 1846, 1856 and 1860:** *Ponts et Chaussées***; 1842: Arnaud; 1843: Bouvier; 1849 and 1852: Goux; 2020: Esri).**

595 **Figure 10: Temporal variation in the mean active channel width of three reaches of the Rhône between 1810 and 2009. Long dashed lines correspond to the Girardon training phase and short dashed lines correspond to the channel by-passing for each reach (Tena et al., 2020).**

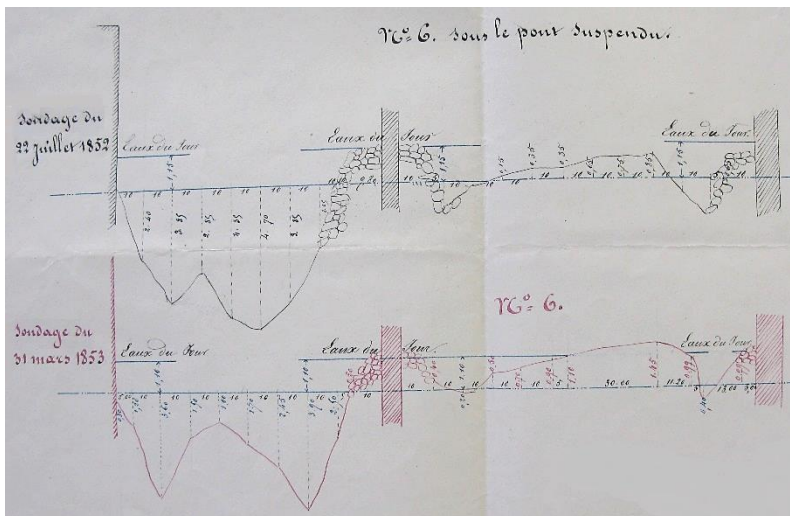



Figure 11: Cross-sections under the suspension bridge of Beaucaire-Tarascon with water level and channel bottom surveyed on July 22, 1852, and March 31, 1853 (source: Aymard, AD Rhône, S 1434).