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## Legacy sediments in a European context: the example of infrastructure-induced sediments on the Rhône River

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### Abstract:

The concept of legacy sediments (LS) as sediments periodically produced by anthropogenic disturbances has been introduced in the early 2010s and has been increasingly used since then, primarily in the USA. It is a key concept to characterize river corridors health and design relevant restoration schemes. Surprisingly, examples of legacy sediments in European rivers remain scarce in the literature, despite the long history of human influences in this part of the world. In this viewpoint paper, we argue that while land-use changes within upstream basins seem to be mostly responsible for legacy sedimentation along downstream river sections in New World countries like the USA or Australia, reach-scale engineering is the main driver of legacy sedimentation along large Alpine European rivers during the Anthropocene era. We give an example of LS induced by navigation infrastructures (groynes and lateral training walls) present along the Rhône River downstream of Lyon (France), and assume that analogous LS might exist in most engineered rivers. Those infrastructure-induced sediments differ from the classic examples of American LS in terms of formation mechanisms and characteristics, which leads us to suggest a broadened definition of legacy sediments in order to make the concept more applicable to the European context.

### Introduction:

The consequences of anthropogenic landscape modifications in river catchments have been of increasing concern in the last few decades (Magiligan, 1992; Brooks and Brierley, 1997; Lang et al.,

2003, Surian et Rinaldi, 2003; Dotterweich, 2008; Macklin et Lewin, 2008; Williams et al., 2014; Poepl et al., 2017). In the process, the idea of anthropogenic sediments emerged and has been progressively conceptualized under the term of “legacy sediment” (LS). The expression was introduced by Novotny (2004) to describe copper contaminated sediments and was then applied to a variety of context without a clear definition. James (2013) first suggested a precise characterization of LS, mainly based on studies about historical floodplain sediments in the eastern USA (Magiligan, 1992; Brooks and Brierley, 1997; Peck et al., 2007; Walter et Merritts, 2008; Merritts et al., 2011). He defines legacy sediments as deposits generated episodically by human disturbances in a watershed. Said disturbances, however, only comprise of land-use changes such as deforestation, agriculture development or mining upstream from the observed river corridor. This definition is particularly suited to the context of the New World territories (The USA, Australia, New-Zealand, etc.) that underwent drastic land-use changes following the colonization by European settlers. James (2013) acknowledges that his definition can also apply to European geomorphology, but mostly related to older land-use changes such as pre-historic gullying (Dotterweich, 2005; Vanwalleghen et al., 2006; Dotterweich, 2008). The term “legacy sediment” is actually rarely used in this context, being often restricted to Anthropocene era although this can be fully discussed and questioned.

Wohl (2015) suggested another definition of legacy sediments as “those for which the location, volume and/or presence of contaminants result from past [i.e. not only the Anthropocene] and contemporary human activities”. They can derive from three processes: reduced sedimentation, enhanced sedimentation and contaminated sedimentation. This characterization is broader than James's in the sense that such legacy effects can be caused by various disturbances besides upstream land-use changes e.g. dam building, flow regulation, channelization, removal of obstacles within a channel, etc. It is therefore more suited to the Anthropocene European context. Nevertheless, the concept of legacy sediment –with either definition- has hardly been applied to European rivers yet, even though most have a long history of human influences and have been especially impacted by anthropogenic activities from the 19<sup>th</sup> century onwards, following the industrial revolution. Nowadays, one of the major and persistent forcing on European rivers are infrastructures –including large upstream reservoirs, but also flood-protection walls, groynes and other devices meant to facilitate navigation, run-of-river dams, weirs, etc. According to Grill et al. (2019), only 33% of mid-sized rivers (500-1000 km) and 12% of long rivers (>1000km) are free flowing (i.e. connectivity status index  $\geq 95\%$ ) in Europe. While the consequences of

such river manipulations have often been studied in terms of main channel adjustment (e.g., incision, narrowing, armouring, stabilization: Surian and Rinaldi, 2003 ; Zawiejska and Wyżga, 2010 ; Arnaud et al., 2015 ; Habersack et al., 2016 ; Downs et Piégay, 2019; Vázquez-Tarrío et al., 2019), their potential role in creating new floodplain features due to legacy sedimentation has been less investigated, and the characteristics of these sediments have rarely been studied.

Legacy sediments contribute to artificially modifying watercourses morphology and geochemistry and are thus a threat to the proper functioning and resilience of river systems. The potential remobilization of contaminated legacy sediments, for example, is a major ecological and health hazard in many rivers over the world (Dennis et al., 2009; Martin, 2015; Niemitz et al., 2013; Nováková et al., 2015; Pavlowsky et al., 2017; Clement et al., 2017; Rothenberger et al., 2017). Moreover, significant volumes of legacy sediments stored in the floodplains and river margins may cause unbalanced sediment budgets and flood management issues (Lecce et Pavlowsky, 2001; Knox, 2006; Richardson et al., 2014; Royall and Kennedy, 2016) as well as loss of connectivity between the river and the floodplain, which is a critical issue for river ecological and geomorphological health (Fryirs, 2013, Wohl, 2017; Fuller and Death, 2018). Finally, identifying the consequences of human activities on river corridor morphologies and functioning is essential to implement relevant restoration schemes (Wohl et al., 2005; Walter and Merritts, 2008; Eschbach et al., 2018).

Through the example of legacy sediments induced by navigation infrastructures on the Rhône River, we aim to determine how they compare to the widely described legacy sediments in the eastern USA, how well they conform to the existing concepts of legacy sediments and how these concepts can be adapted or broadened to include legacy sediments produced in a European Anthropocene context.

## 1. Main anthropogenic drivers of change in river systems in the New World and in Europe: a comparison in the Anthropocene period

The concept of legacy sediment originates from the USA, where the awareness around post-colonial sedimentation started in the 1940s, way before the term “legacy sediment” was formally introduced. Legacy sediments were then referred to as “modern sediment” or “post-settlement alluvium” (Happ et al., 1940, Knox, 1972; Dearman and James, 2019). Multiple examples of such deposits were described in the USA, mostly in the Mid-Atlantic region (Walter and Merritts, 2008; Merritts et al., 2011; Hupp et al., 2013; Donovan et al., 2015, Johnson et al., 2018). As a result, both their characteristics and their

formation mechanism are well-documented. Legacy sediments in the USA are typically recognizable as an important accumulation of fine sediments (up to 5 m high) on both sides of rivers, forming floodplain levels, even terraces that are mostly disconnected from the main channel (Walter et Merritts, 2008; Webb-Sullivan et Evans, 2014; Johnson et al., 2018). There is a consensus that such deposits were formed following European settlement in the 17<sup>th</sup> century: the subsequent development of intensive agricultural practices led to accelerated upland erosion, generating an unnaturally large amount of sediments that settled in valleys and caused the watercourses to aggrade. After the sediment loads returned to normal, channels incised back to their original level, creating the disconnection with the newly aggraded floodplains. This mechanism is often referred to as an aggradation-degradation episode (ADE) (James and Lecce, 2013; James, 2013). An additional driver according to some authors (Walter and Merritts, 2008; Merritts et al., 2011) are milldams: ubiquitous in the Eastern USA from the 17<sup>th</sup> century onward, they interrupt sediment transport and may therefore have further promoted sediment storage in valley-bottoms.

Land-use changes following colonization appears as the major anthropogenic disturbance in the USA: as pointed out in James (2013), pre-colonial land surfaces were relatively stable, making the superimposition of large volumes of post-settlement legacy sediments even more outstanding. Similar observations have been made in other settled countries such as Australia (Brooks and Brierley, 1997; Rustomji et Pietsch, 2007; Davies et al., 2018) or New-Zealand (Richardson et al., 2014; Fuller et al., 2015): in lands that were little impacted by their native population, massive and drastic land-use change in the catchment following the European settlement is indisputably the main driver of legacy sedimentation.

This cause-effect pattern is not so straightforward in lands that sustained continuous anthropogenic impacts over thousands of millennia such as Europe. Agricultural development in Europe, for example, happened gradually over the span of 7500 years with many periods of expansion and regression (Dotterweich, 2008; Houben, 2008; Dotterweich et al., 2012; Dotterweich, 2013), and so did agriculture-related modifications of rivers and floodplains (Hoffmann et al., 2007; Macklin et al., 2010; Brown et al., 2018). Multiple examples of sedimentation related to land-use changes (mainly agricultural development) dating back from the Iron Age, Gallo-Roman or Middle Age periods have been observed (Dotterweich, 2005; Lespez et al., 2008; Brown, 2009; Macklin et al., 2010; Lespez et al., 2015). This phenomenon might be the closest equivalent to the land-use induced legacy sediments in the New

World countries. However, it is mainly apparent in lowland catchments where geomorphic modifications are slow and therefore allowed landforms inherited from the Neolithic to be preserved. It is rarely observed in mountainous river basins (except on main branches such as the Isère or the Rhône), presumably because the high-energy of those actively shifting rivers tends to reshape the floodplain landforms overtime, erasing anthropogenic legacies from the Neolithic. A possible example of legacy sedimentation in highland catchments is the increase in coarse sediment loads in Alpine Rivers during the Little Ice Age (LIA): this phenomenon supposedly derives from both climatic changes (e.g. increased runoffs) and high sensitivity of the basins to erosion due to intense clearing of hillslopes for grazing and exploitation of wood resources (Mather et al., 1999; Delile et al., 2016; Mensing et al., 2016; Bebi et al., 2017). Following this period of increased sediment supply, the upstream alpine basins underwent a rapid decline of agricultural practices associated with afforestation that coincided with the end of the LIA, which led to a strong decline in sediment inflow to the downstream floodplains (Mather et al., 1999; Liebault et Piégay 2002; Liébault et al., 2005; Bebi et al., 2017; Marchese et al., 2017). While these successive legacy effects must have impacted downstream catchments as well, studies generally focus on the local consequences in the small-scale upstream basins. A few instances of other contemporary legacy sedimentation related to land-use changes (agriculture, afforestation or deforestation, mining, etc.) have been documented, but still in small to medium-sized catchments (Piégay et al., 2004; Dalton et al., 2014; Buchty-Lemke et al., 2015).

At a larger scale, however, river manipulation arguably represents the most significant perturbation that recently impacted major European watercourses, along with contamination. Two types of river engineering associated with distinct time period can generally be distinguished: most infrastructures related to flood protection and facilitation of navigation (embankments, dikes, groynes, locks) were implemented in the 18<sup>th</sup> and 19<sup>th</sup> century, while infrastructures for hydroelectricity production (reservoirs, run-of-river dams and flow diversions) were mainly built during the 20<sup>th</sup> century (Habersack and Piegay, 2007). Construction periods may vary depending on regional or national development disparities: the first major engineering works in the Netherlands were carried out on the Rhine River in the early 1700s (Yossef, 2002); on the Oder River in Poland, weirs and groynes were built on a large scale from 1741 to 1896 (Buczyńska et al., 2018); in Hungary, flood-control dykes and groynes were built on the Middle Danube between 1871 and 1914 (Gupta, 2008) and groynes on the Loire River in France were built in the beginning of the 20<sup>th</sup> century (Barraud et al., 2013). Regarding hydropower, the first European plant

was built in 1893 in Serbia (Marković, 2012), and the number of facilities then grew exponentially over Western Europe during the next century. Even though their period of development is mostly over, engineering works remain ubiquitous on European rivers (figure 1 and table S1). It is thus surprising that the concept of legacy sedimentation related to river infrastructures is so underused, although a number of studies do address geomorphological and sedimentation issues related to engineering (Bravard et al., 1999; Surian et Rinaldi, 2003; Provansal et al., 2010; Provansal et al., 2014; Poepl et al., 2015; Habersack et al., 2016; Arnaud et al., 2019; Tena et al., 2020) –and especially large reservoirs (Kondolf, 1997; Grant, 2012; Kondolf et al., 2014; Heckmann et al., 2017; Piqué et al., 2017) without referring to the concept of legacy sedimentation. Throughout the rest of the paper, we will focus exclusively on river training infrastructures (e.g. dikes, groynes, weirs) and run-of-river dams as those engineering works may be present all along the river corridor and have been far less studied. Sedimentation processes related to large upstream reservoirs are also critical for river corridors morphology (Teal, 2011; Liro et al., 2019) and would certainly benefit from the legacy sedimentation perspective, but this topic would require a paper in its own right.



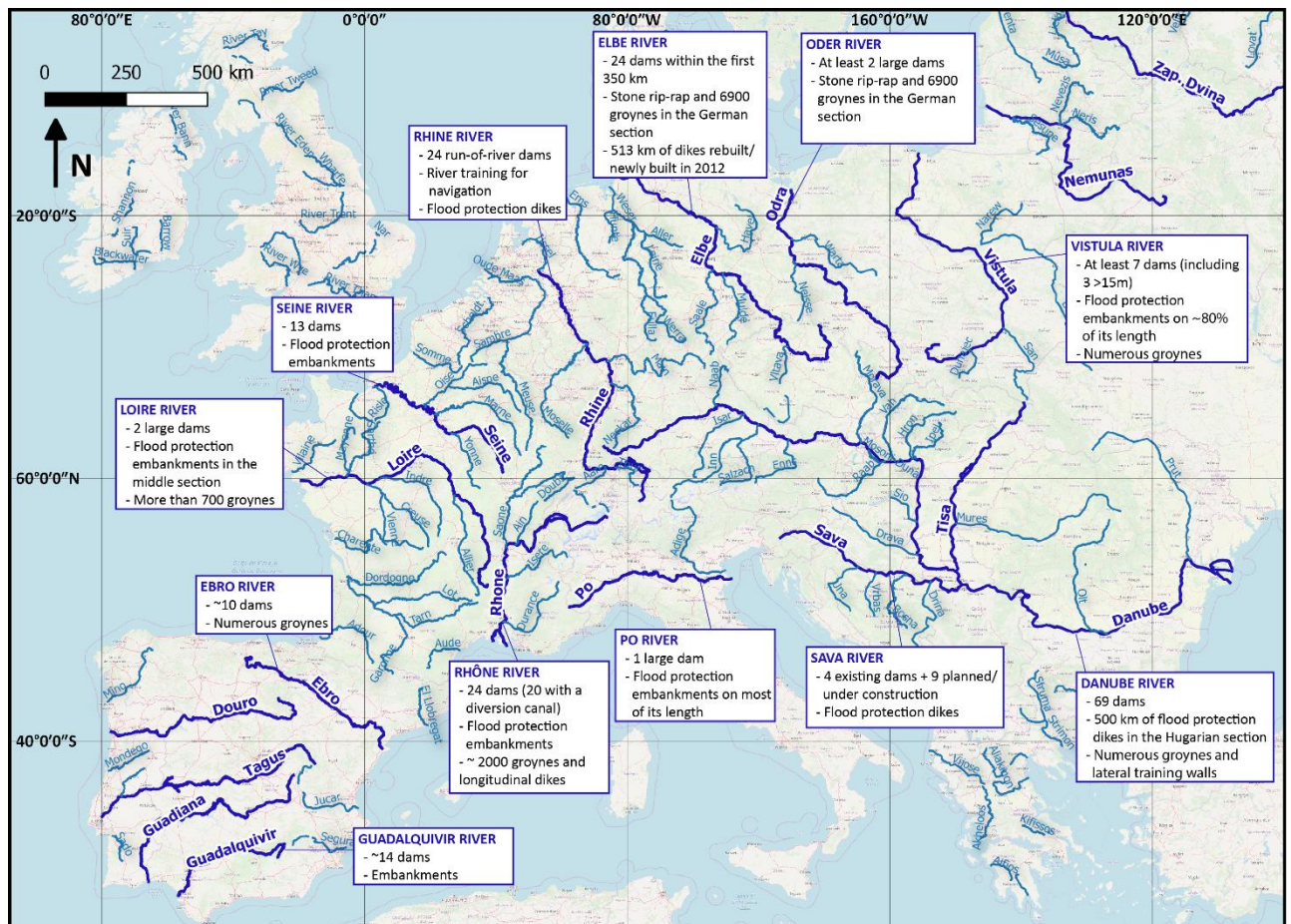


Figure 1: A non-exhaustive overview of the engineering works on the largest European rivers. Source: OpenStreetMap, see table S1 in supplementary material

## 2. Infrastructure-induced legacy sedimentation: an example from the Rhône River (France)

In order to illustrate the relevance of applying the concept of legacy sediment in European rivers, an example from the Rhône River in France is briefly presented.

The Rhône is an 8<sup>th</sup> order 812 km long river that runs from the Furka Glacier in Switzerland to the Mediterranean Sea; it is the 2<sup>nd</sup> longest river in France and the first in terms of mean annual discharge (Olivier et al., 2009). It is a highly engineered watercourse, with numerous dikes and groynes installed to channelize the river in the second half of the 19<sup>th</sup> century, and 19 dams along its French course built between 1948 and 1984 (figure 1 and table S1). Those infrastructures have impacted the river in many ways: increased slope and transport capacity, reduced sediment load, channel armoring, narrowing and incision, increased trapping efficiency, etc. (Petit et al., 1996; Bravard et al., 1999; Arnaud-Fassetta, 2003; Parrot, 2015). The study area in this example is located 50 km downstream from the urban area of Lyon (figure 2.a). It has undergone two periods of engineering and is therefore particularly relevant to potentially identify infrastructure-induced legacy sediments. Between 1840 and 1880, infrastructures



to channelize the river and facilitate navigation were implemented (mainly lateral training walls and groynes). In 1977, the reach was restructured for hydropower production: a canal equipped with a lock and a power plant was dug out and a run-of-river dam was added on the old channel to bypass most of the discharge of the Rhône in the newly built canal (figure 2.a).

After analysis of the study area evolution since the 1800s, Ground Penetrating Radar (GPR) surveys and six sediment cores were recovered from the floodplain. The sediment cores were strategically positioned on the GPR profile so that they would cross interesting sediment structures identified on the surveys. Multiple analyses were performed on the cores: grain-size, Total Organic Carbon, metallic elements and PCBs quantification, and  $^{137}\text{Cs}$  dating. The comprehensive results are available in Vauclin et al. (2019), and a few key results are also presented in figure 2.b. This multi-criteria investigation allowed to identify a distinctive top layer in five out of the six cores, composed of fine ( $D_{50} < 100 \mu\text{m}$ ), homogeneous sediments that cover an unusually wide range of grain-sizes (figure 2.b). This layer is also contaminated by anthropogenic substances and can be dated by  $^{137}\text{Cs}$  trends. Based on the cores dating, we concluded that these singular floodplain deposits result from the implementation of the navigation infrastructures built on the Rhône River at the end of the 19th century: they can be described as infrastructure-induced legacy sediments. We also found out that the hydroelectric development implemented in the area in 1977 caused sedimentation on the river floodplain to stop altogether, meaning that the LS deposited in a restricted time-period -comprised between the 1850s and the 1970s in this site (Vauclin et al., 2019). Finally, by positioning the sediment cores on the Ground Penetrating Radar surveys (figure 2.c), we established that there is a consistent layer of infrastructure-induced LS deposited along the study area.

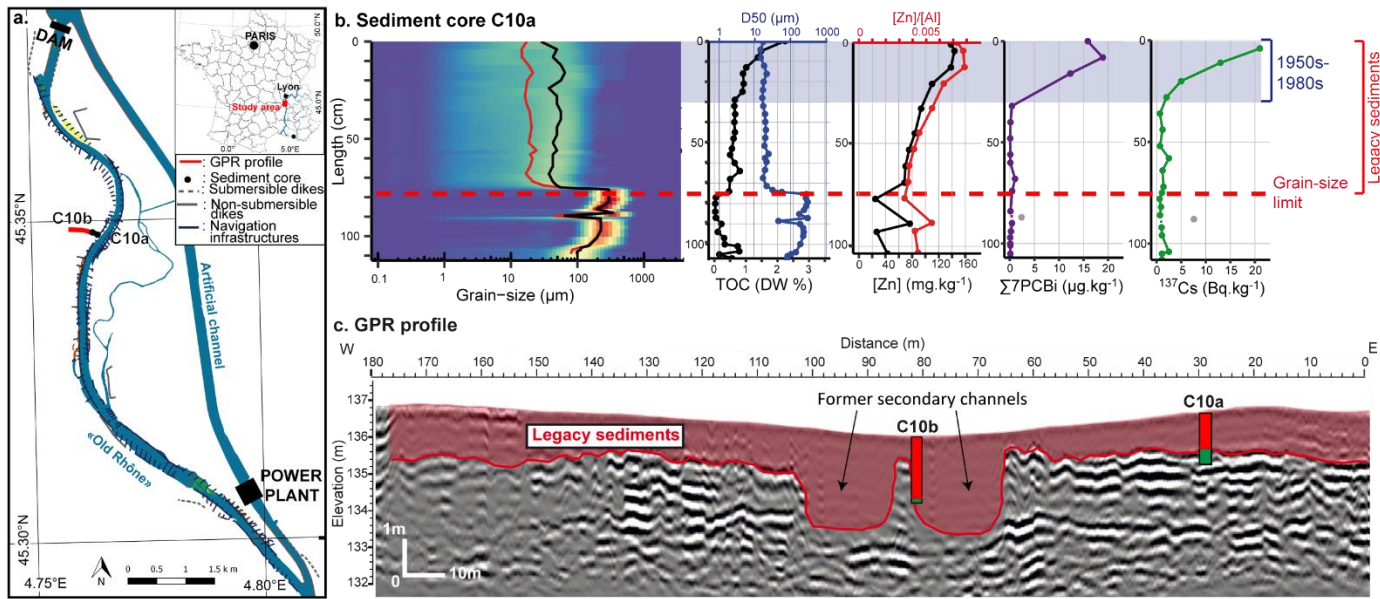


Figure 2: a. Study area of Péage-de-Roussillon on the Rhône River (France) with engineering works highlighted; b. An example of multi-criteria characterization of a sediment core allowing the identification of a layer of legacy sediments: (from left to right) grain-size, PCBs concentration and <sup>137</sup>Cs activity; c. Ground Penetrating Radar (GPR) survey of a transect of the study area, with corresponding sediment cores positioned.

Regarding the mechanism responsible for the deposition of these legacy sediments, our assumption is that the implementation of the navigation infrastructures (i) fixed the river morphology, allowing overbank sedimentation to take place continuously while floodplain sediments used to be reworked regularly under the previous braided configuration, and (ii) induced a partial loss of connectivity between the floodplain and the main channel so that fine sediments kept settling but medium/coarse sediments could not be transported overbank anymore. The decrease in floodplain/channel connectivity can also be linked to river narrowing (40% loss of the active channel surface) and incision (up to 2.5 m) following the implementation of the engineering works (Parrot, 2015; Tena et al., 2020), which might have lessened overbank flows frequency and magnitude. Additionally, engineering works might have acted as a buffer, trapping the coarse sediments before they reach the banks and slowing down the overbank flows, which allowed fine sediment deposition by decantation and/or uniform suspension (Dépret et al., 2017).

Additional findings from two other study areas on the Rhône River (Vauclin et al., 2019) show that legacy sediments related to the implementation of navigation infrastructures in the 19<sup>th</sup> century can be identified along the entire river corridor. We believe that infrastructure-induced legacy sediments might also be present along most engineered rivers in Europe, although further studies would be needed to ascertain it.

### 3. A conceptual comparison between synchronous legacy sedimentation events: land-use related sedimentation in the USA and infrastructure-induced sedimentation in the Rhône River.

The infrastructure-induced sediments characterized on the Rhône River have been described as legacy sediments on the sole basis that their deposition was influenced by anthropogenic modification of the river. It appears now interesting to assess how this type of deposit fits in the pre-existing definitions of legacy sediments and how they compare to the widely described legacy sediments in the eastern USA.

Legacy sediments production as defined by James (2013) is induced by catchment management: it is primarily driven by human activities that took place at a large scale in the upstream river catchment—essentially land-use changes (figure 3). The main cause for legacy sedimentation being human-induced erosion, a key notion to the concept is that there are sources (hillslopes) that produce LS and sinks or storage zones (mainly valley bottoms) where they deposit temporarily or more permanently. As a result, LS in the USA are systematically characterized by substantially accelerated rates of sedimentation due to intensification of uphill erosion (Knox, 2006; Walter et Merritts, 2008; James, 2013;). Wohl (2015) also highlighted sedimentation rates —either enhanced or reduced- as a key criterion to identify LS.

Meanwhile, infrastructure-induced legacy sediments in the Rhône River are a consequence of river management rather than catchment alterations (figure 3). The beginning of the legacy sedimentation episode coincides with the end of the Little Ice Age (around 1850) during which coarse sediment deposition induced by climate and upstream land-use decline was observed in the Rhône River catchment: it takes place in a context of overall decreasing sedimentation rates (Liébault and Piégay, 2002; Piégay et al., 2004; Citterio and Piégay, 2009, García-Ruiz and Lana-Renault, 2011). Values of sediment accumulation rates in the studied LS are average for a European watercourse or slightly reduced (Vauclin et al., 2019, Tena et al., 2020), but given the overall decrease in sediment load that characterizes the time period, this finding actually shows that infrastructure-induced LS were produced by trapping of fine sediments, resulting in sedimentation rates that are standard but still higher than if there were no river training structures. The key difference with the LS defined by James (2013) is that infrastructure-induced LS were not “generated” from upstream increased erosion but merely trapped in river margins following the implementation of navigation infrastructures that fixed the river morphology and allowed continuous deposition without remobilization of the sediments. Continuing with the “source and sink” analogy, there is no specific source of sediment for infrastructure-induced LS (the decrease

in upstream sediment inflow mentioned earlier can be considered as a source effect but it does not generate sediments, on the contrary) but the engineering works did transform the floodplain in a sink for fine sediments. However, sedimentation rates are not as elevated as for American LS and therefore cannot be used as a defining characteristic for infrastructure-induced LS.

According to James (2013), periodicity -i.e. the fact that anthropogenic sediments should be considered as LS only if they settle during a restricted time-period and in correlation with a clearly identified human disturbance- is also a requirement for legacy sediments. In the case of the USA legacy sediments, it is especially relevant as the disturbance from which LS derive (upstream land-use changes) is episodic ("pulse" disturbance as defined in Brunsden and Thornes, 1979; Rykiel, 1985; Lake, 2003; Piégay et al., 2018), and therefore so is the settlement of LS (figure 3). In the case of the Rhône River LS, the anthropogenic disturbance is sustained in time ("press" disturbance as defined in Brunsden and Thornes, 1979; Rykiel, 1985; Lake, 2003; Piégay et al., 2018) as most infrastructures will not likely be removed in the near future (figure 3). However, the LS still deposited in a restricted time period -between the 1850s and the implementation of the hydroelectric bypass (1977 in the example presented in section 2)- as a second engineering phase caused a near-total loss of lateral connectivity and the interruption of floodplain sedimentation. Even without this secondary disturbance, legacy sedimentation would have likely decreased overtime as the floodplain aggraded, and then stopped once the floodplain could not be overflowed anymore. Infrastructure-induced LS in the Rhône River therefore do qualify as episodic, although for slightly different reasons than the American legacy sediments.

American LS can often be identified visually as they tend to form high terraces disconnected from the channel. That is not the case of the infrastructure-induced LS on the Rhône River that form a relatively thin layer (up to 1 m observed in Vauclin et al., 2019 and up to 2.5 m according to Tena et al., 2020) that does not always stand out in comparison to the channel level. Regarding sedimentological characteristics, besides important sedimentation rates, American LS can sometimes also be distinguished from earlier alluvium by lower organic carbon contents (Weitzman et al., 2014; Johnson et al., 2018; Dearman and James, 2019), lower bulk density and lower stratification (Dearman and James, 2019). The grain-size, however, can be similar in both sediment units (Dearman and James, 2019) and therefore cannot be used as a discerning criterion. Meanwhile, LS on the Rhône River were formed by preferential deposition of the fine fraction: smaller and homogeneous grain-size constitutes the main criterion to differentiate LS from the underlying sediments. Contrary to the American LS, the

organic carbon content was found to be slightly higher in the infrastructure-induced LS than in the underlying sediments (Vauclin et al., 2019), although this is likely due to terrestrialization and vegetation development on the LS. An additional criterion to characterize LS might be the contaminants repartition. Metallic elements tend to be more retained in infrastructure-induced LS (due to a matrix effect) compared to earlier alluvium, and the early trend of PCBs contamination is recorded in the top part of the LS exclusively. Besides, American LS are often characterized by important levels of metallic contaminants or excess nutrients (Niemitz et al., 2013, Pavlowsky et al., 2017).

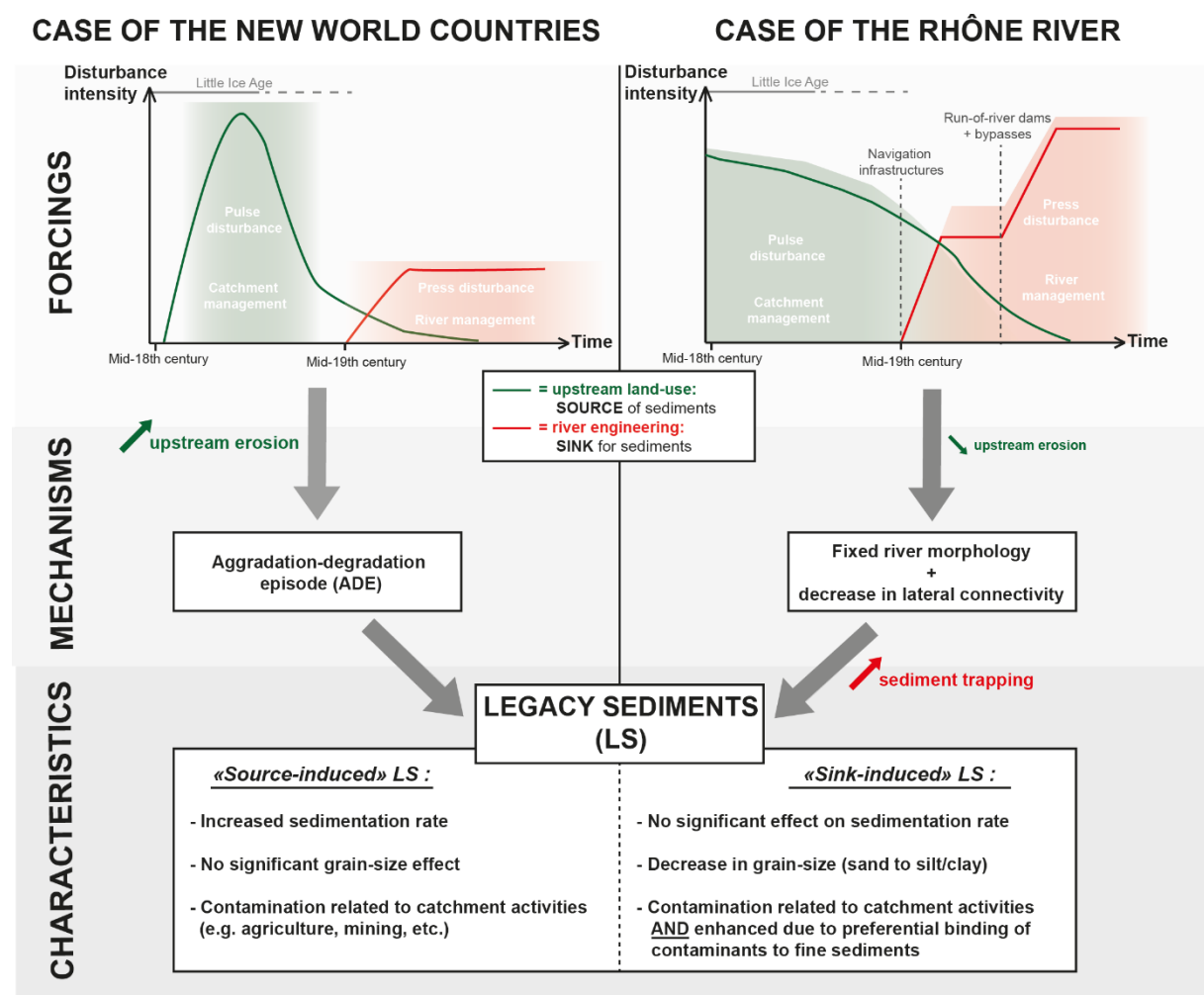


Figure 3: A comparison of the forcings, mechanisms and resulting characteristics of legacy sediments in the New World countries and on the Rhône River

These considerations lead us to suggest criteria -inspired from previous works (James, 2013; Wohl, 2015) and with additional findings from this study- to formally identify legacy sediments, whether in Europe or in the New World countries. Legacy sediments should:

- Result from human disturbance of the river corridor (e.g. pulse of sediment due to upland grazing and erosion, increased trapping efficiency from river training structures, etc.),
- Be associated with a restricted time-period related to the human disturbance,
- Display significant modifications of their characteristics due to the human-induced change in sedimentation processes; the affected characteristics may be of various types: accumulation rates, typology (grain-size, density, organic carbon content, magnetic susceptibility, macro-remains, etc.), contamination, etc.

## Conclusion:

In this viewpoint paper, we highlighted the concept of infrastructure-induced legacy sediments from an example on the Rhône River (France) and found out that they differ from the widely described post-settlement sediments from the New World countries in terms of causes, genesis and discriminating characteristics. Due to the ubiquity of engineering works along European large rivers, we believe that such deposits are widely spread in Europe and require further investigation on other major rivers. While this paper focused on the European context, the topic of infrastructure-induced LS is also relevant in most watercourses around the world, as few catchments remain pristine from anthropogenic manipulation (Grill et al., 2019). Even in the USA, Australia and New-Zealand, where the most obvious legacy is related to land-use changes, investigating potential legacy effects due to river training might prove useful for a comprehensive assessment of human impacts on river corridors (e.g. Smith and Winkley, 1996; Remo et al, 2009; Remo et al., 2018) and the definition of pertinent restoration guidelines. Additionally, legacy sedimentation related to large dams remains understudied all over the world. In particular, sedimentation processes upstream reservoirs that result in subaerial deltas(or artificial riparian zones) seems to qualify as legacy sedimentation and constitute an important sedimentological, geomorphological and ecological challenge (Teal, 2011; Tang et al., 2014; Volke et al., 2015; Tang et al., 2016; Liro, 2019).

A growing number of river restoration projects are being implemented –mainly in industrialized countries- in an attempt to mitigate the effects of human activities and river training on hydrosystems. In the USA, more than 37 000 restoration programs were identified between 1990 and 2003, with a total cost

exceeding \$17 billion (Bernhardt et al., 2005). In Europe, the Water Framework Directive (WFD, 2000) set the achievement of a good ecological status as a legal requirement, with hydromorphological characteristics recognized as key factors to reach this objective. Numerous restoration projects were instigated as a consequence: for example, more than 500 restoration schemes have already been implemented in France between 2013 and 2018, while over 2000 schemes have been carried out in Denmark (Brown et al., 2018). On the Rhône River, a major restoration program was launched in 1998 (Lamouroux et al., 2015) with variable results from bioassessments conducted on the rehabilitated reaches (Dolédéc et al., 2015). In that context, investigating infrastructure-induced legacy sediments is essential to define relevant reference conditions that can be used as a goal for an efficient restoration (Wohl, 2018).

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