Fact sheet: Very large rivers

General description

Valley- and planform	Various planforms possible depending on slope. In general due to gentle slopes sinuous or meandering, but often also island-braided or sometimes anastomosing. Valley form unconfined with wide floodplains
Hydrology	More or less predictable seasonal discharge patterns with a mixture of snow-, rain- or groundwater-fed.
Morphology	Wide channels with high width/depth ration, gentle inner bends and steeps outer bends, bare and vegetated islands. Besides the main channels there are side channels and downstream connected oxbows.
Chemistry	The water quality is mostly eutrophic, sometimes mesotrophic. Large rivers are calcareous/mixed or sometimes organic rivers.
Riparian zone	Generally vegetated with soft-wooded floodplain forest (Populus, Salix), herbaceous grasslands or bare (sand, gravel). Extensive floodplains (several hundred to kms wide) with disconnected water bodies (oxbows, scour holes) in various successional stages. These water bodies can remain for decades or centuries. Soil type, inundation frequency and duration direct the terrestrial and aquatic vegetation community.

Figure: The River Don (Russia) still has significant near-natural stretches along its course.

Large rivers have upstream catchments > 10,000 km^2 and the very large even > 100,000 km^2 (e.g. Danube, Rhine, Elbe, Vistula and several Russian rivers). Due to their size the flow regime is more stable and the role of vegetation is less than in small and medium-sized rivers. Most very large rivers are situated in the lowland i.e. below 200 m ASL though large rivers are also found in the midland regions (e.g. the confluence of the River Inn (25,700 km^2) with the Danube is at 291 m ASL).

Reaches of large rivers are diverse and could be of the following REFORM types (15 – 22) having gravel, sand, silt and clay as the dominant sediment and being braided, meandering, sinuous, straight or anabranching depending on slope and sediment supply. Depending on width and depth (vegetated) islands occur.

Most large rivers originally had and some still have wide floodplains covered with soft-wooded or hard-wooded forest or agricultural land use ranging from extensive grasslands mowed for hay or intensive crop production such as maize. In the floodplains there are water bodies either in permanent connection with the main channel or only connected during flood events. These predominantly stagnant water bodies are more comparable to lakes than to rivers.

The present key reference for large rivers in Europe is Tockner et al. (2008). We recommend to consult this standard book as a first gateway for further information on specific large rivers.

Pressures

Major pressures

Large rivers are generally impacted by multiple pressures due to pollution originating from point and diffuse sources, hydromorphological modifications to serve water supply for agricultural, industries and drinking water, navigation, energy production, flood protection and fragmented by dams. The most regulated are found in central and southern Europe and the less modified in Eastern and Northern Europe. More details on six large river case studies and the impacts of pressures are documented in a specific REFORM deliverables on large rivers (Van Geest et al. 2015)

Scores of pressure level imposed on very large rivers categorised according to pressure category and pressure, respectively (score in comparison to other pressures within this river type: No = no pressure/stress, L = low pressure/stress, M = moderate pressure/stress, H = high pressure/stress).

Pressure category	**Pressure**	**Score[1]**
Point sources	Point sources	M
Diffuse sources	Diffuse sources	H
Water abstraction	Surface water abstraction	L / M
	Groundwater abstraction	N / L
Flow alteration	Discharge diversions and returns	N / L
	Interbasin flow transfer	L
	Hydrological regime modification including erosion due to increase in peak discharges	L
	Hydropeaking	L
	Flush flow	N
	Impoundment	H
Barriers/Connectivity	Artificial barriers upriver from the site	M
	Artificial barriers downriver from the site	H
Channelization	Channelisation / cross section alteration (e.g. deepening) including erosion due to this	H
	Sedimentation	L
	Channel fixation preventing lateral migration	H
Bank degradation	Bank degradation	H
Habitat degradation	Alteration of riparian vegetation	H
	Alteration of in-channels habitat	H
Others	Floodplain embankment	M
	Invasive species	M

[1] Score differs substantially between individual large rivers e.g. abstraction and diversion occur in large Mediterranean rivers and less elsewhere. Point sources have been a significant problem in many large rivers, but are treated by WWTP. Impoundment in particular for water supply, energy production and navigation.

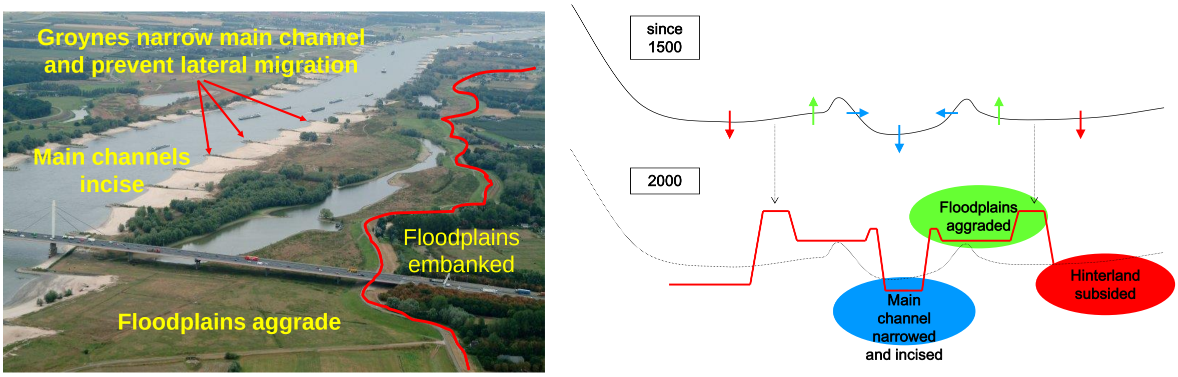

Figure: Aerial view of the Waal branch of the River Rhine (the Netherlands) showing several hydromorphological modifications and their impacts and a schematic presentation of the morphological changes.

Problems and constraints for river restoration

Large rivers cannot be restored to original state and thus can at best be partially rehabilitated. Furthermore the options for rehabilitation are directed by boundary conditions (altered discharge regimes of water and sediments) which causes may be distant or in other member status. Rehabilitation of the very large rivers requires international cooperation and negotiation. Because most large rivers serve multiple socio-economic functions the major challenge is the trade-off between rehabilitation and these functions and to identify synergies e.g. removing bank protection to create near-natural riparian zones may conflict with navigation due to enlarge sedimentation in the main channel thereby reducing navigational depth and uncontrolled growth of floodplain forest and herbaceous vegetation may enlarge flood risks. Large rivers in particular are colonised rapidly by invasive species, because many are interconnected through canals facilitating the distribution of benthic invertebrates and fish. Simply due to the size and scale restoration and mitigation measures for large rivers are expensive e.g. the estimated cost for a vertical slot fish passage in the Iron Gate dam to improve sturgeon migration in the Danube is 20 M€.

Measures

Common restoration practice

Restoration practice in large rivers started by improving the water quality in particular by treating industrial and municipal waste water (point sources) and more recently focusses on improving migration through fish passes at dam and weirs, environmental flow regimes for large hydropower schemes and improving the ecological quality of riparian zones and floodplains either by removing bank protection, re-connecting side channels and changing land use from agriculture and forestry to nature. More and more synergy is sought between flood protection and ecological improvement. In-channel measures, e.g. gravel supply downstream dams, are relatively rare in large rivers and reduction of pollution originating from diffuse sources almost fully depends on measures in the catchment of the tributaries.

Score per measure category/measure of relevance, effect in-channel, effect on the floodplain and costs the measure in comparison to other measures within this river type (No = no relevance or effect, L = low relevance or effect, M = moderate relevance or *effect, H = high relevance or effect of the measure) and indication a prioritisation of measures (L = low priority, M = moderate priority, H = high priority). Note: when relevance is no or low then not further specified. Information on costs is not specified, because they are too site specific or unknown.*

Measure category	Measure	Relevance	Effect in-channel	Effect floodplain	Prioritisation	Where or why?
Decrease pollution	Decrease point source pollution	H	H	M	H	
	Decrease diffuse pollution input	M	L	L	M	Tributary catchment
Water flow quantity	Reduce surface water abstraction	L				
	Improve water retention	M	L	H	M	Floodplain
	Reduce groundwater abstraction	L				
	Improve water storage	M	L	H	M	Floodplain
	Increase minimum flow	H	H	M	H	Hydropower
	Water diversion and transfer	M	M	M	M	Mediterranean
	Recycle used water	N				
	Reduce water consumption	L				
Sediment quantity	Add/feed sediment	M	H	L	M	Below dams
	Reduce undesired sediment input	L				
	Prevent sediment accumulation					
	Improve continuity of sediment transport	H	H	L	M	Impounded stretches
	Trap sediments	L				
	Reduce impact of dredging	M	H	L	?	Navigation
Flow dynamics	Establish natural environmental flows	M	M	M	M	Hydropower
	Modify hydropeaking	H	H	L	H	Hydropower
	Increase flood frequency and duration	H	L	H	H	Incised channels and aggradated floodplains; non-active floodplains (‘polders’)
	Reduce anthropogenic flow peaks					
	Shorten the length of impounded reaches	N				
	Favour morphogenic flows	L				
Longitudinal connectivity	Install fish pass, bypass, side channels	H	M	L	H	Dams and weirs
	Install facilities for downriver migration	M	L	L	M	Only where required e.g. eel
	Manage sluice, weir, and turbine operation	M	L	L	L	
	Remove barrier	L				
	Modify or remove culverts, syphons, piped rivers	N				

Measure category	Measure	Relevance	Effect in-channel	Effect floodplain	Prioritisation	Where or why?
In-channel habitat conditions	Remove bed fixation	L				
	Remove bank fixation	H	H	L	H	Natural banks allowing for sedimentation and erosion
	Remove sediment	L				
	Add sediment (e.g. gravel)	M	H	L	M	Below dams
	Manage aquatic vegetation	N				
	Remove in-channel hydraulic structures	L				
	Creating shallows near the bank	H	H	L	H	Plankton production; Spawning and nursery habitat for fish
	Recruitment or placement of large wood	H	H	L	H	Habitat diversity. Substrate for benthic invertebrates; Shelter for fish.
	Boulder placement	N				
	Initiate natural channel dynamics	M	H	L	M	Side channels
	Create artificial gravel bar or riffle	N				
Riparian zone	Develop buffer strips to reduce nutrients	L				
	Develop buffer strips to reduce fine sediments	N				
	Develop natural vegetation on buffer strips	H	L	H	H	
River planform	Re-meander water course	L				
	Widening or re-braiding of water course	H	H	M	M	In large rivers without navigation
	Create a shallow water course	H	H	L	H	Spawning and nursery habitat for fish
	Narrow over-widened water course	N				
	Create low-flow channels	H	H	L	H	Spawning and nursery habitat for fish
	Allow/initiate lateral channel migration	H	H	H	L	Conflict with other functions. Probably complex to achieve
	Create secondary floodplain	N				
Floodplain	Reconnect backwaters, oxbow-lakes, wetlands	H	H	H	H	Enlarge habitat diversity in particular for young fish
	Create backwaters, oxbow-lakes, wetlands	M	L	H	M	
	Lower embankments, levees or dikes	M	L	M	M	To increase inundation frequency and duration
	Replace embankments, levees or dikes	L				Flood protection measure to enlarge storage and discharge capacity
	Remove embankments, levees or dikes	M	L	M	M	To increase inundation frequency and duration
	Remove vegetation	L				Flood protection - terrestrial to enlarge discharge capacity

Figure: Restoration measures to improve longitudinal connectivity: the fish pass near Hagestein in the Neder-Rijn. Monitoring showed that among 38 fish species numerous diadromous lampreys migrated through this fish pass)

Figure: Restoration measure to improve floodplains: Floodplain lakes which inundate a limited number of days per year harbour limnophilic fish species such as tench

Development of isolated water bodies and marshes

During past decades, a number of lakes and ponds have been excavated in the floodplains along the Delta Rhine. Such created or rehabilitated lakes were readily colonized by various submerged macrophytes in the years after excavation. In the first four years, pioneer species such as Chara vulgaris, Potamogeton pusillus, and Elodea nuttallii dominated these lakes. Remarkably, after this first stage of macrophyte dominance, a large proportion of the excavated lakes lost their aquatic vegetation within a few years. Only lakes that were small (< 1-2 ha) and shallow (< 1.5-2 m) remained vegetated by submerged macrophytes (Van Geest, 2005).

Floodplain lake morphometry, as well as amplitude of water-level fluctuations during non-flooded conditions, strongly determined cover and composition of aquatic vegetation. During non-flooded conditions along the Rhine, lake water-level fluctuations are largely driven by groundwater connection to the river. Hence, water-level fluctuations are largest in lakes close to the main channel in strongly fluctuating sectors of the river and smallest in more remote lakes. Additionally, water-level fluctuations are usually small in old lakes, mainly due to reduced groundwater hydraulic conductivity resulting from accumulated cohesive clay and silt on the bottom. The reduced amplitude of water-level fluctuations with lake age has a strong impact on macrophyte succession in floodplain lakes from desiccation-tolerant species (e.g. Chara spp.) in young lakes to desiccation-sensitive species (e.g. Nuphar lutea, Figure 5.11) in old lakes (Van Geest, 2005).

Floodplain lakes with abundant vegetation, which inundate less than 20 days per year have low fish species richness, but provide suitable habitat for the reproduction of limnophilic species such as Tench (Tinca tinca), Rudd (Rutilus erythrophtalmus) and Crucian carp (Carassius carassius) (Grift et al. 2006; Figure 5.11). The proportion of limnophilic species in these lakes is, however, outnumbered by eurytopic species such as Bream (Abramis brama). Some limnophylic species such as weatherfish (Misgurnus fossilis) and Ten-spined stickleback (Pungitius pungitius) were extremely rare, suggesting that most remote and seldom flooded lakes have disappeared completely from the floodplains along the Delta Rhine.

Problems and constraints with common restoration practice

Large rivers fulfil major and often vital socio-economics functions. Rehabilitation programmes needs to be balanced with flood protection, energy production, navigation and freshwater supply for agriculture and drinking water. This puts restrictions to the array of measures. Next, interventions to regulate rivers do have long-lasting impact (several decades or even over a century) on the hydromorphological processes and as such direct and restrict the range of possible measures. Furthermore measures are mostly morphological interventions in the riparian zone and floodplains i.e. at the reach scale. There are hardly to none (sub-)basin wide hydrological measures, because they require a trade-off with hydropower generation or freshwater supply for agriculture and win-win options are not so obvious as for flood protection. Lastly, simply due to the size and scale rehabilitating large rivers is expensive and time-consuming due to the wide range of stakeholders who need to understand and appreciate the benefits.

Promising and new measures

New possibilities arise in particular when programmes deliver multiple benefits. Room for the Rivers with the main aim to reduce flood risk gave unforeseen to reactivate embanked floodplains transforming agricultural land into a wetland (‘polder Noordwaard’, the Netherlands; several reopened polders previously used for agriculture or aquaculture e.g. Babina, Popina and Holbina polders, Danube delta, Romania). Training walls in the main channel replacing groynes or riprap can substantially naturalise riparian zones and creates shelter for benthic invertebrates and young fish against the impact of passing ships (River Rhine, the Netherlands, Figure:). The measure is meant to benefit flood protection, navigation during low discharges and improve the ecological quality of riparian habitats Adding sediments through gravel introduction below dams may rejuvenate instream habitats and banks and reduce channel incision and lowering of groundwater tables (Rhine downstream Kembs, border Germany and France). Enlarging flow discharges in impounded reaches where water is abstracted for hydropower rejuvenate habitats in the main channel and connected water bodies (River Rhône, France; Lamoroux et al. 2015).

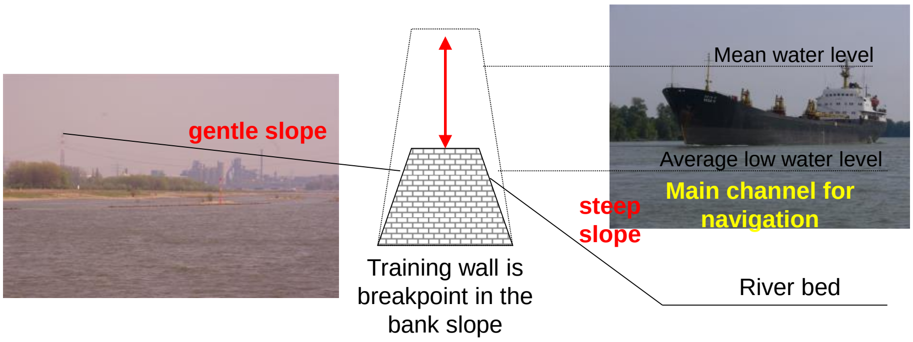

Figure: Training wall in the main channel creates a side channel with shelter.

Monitoring scheme

The present approach to monitor rehabilitation projects along large rivers too often suffers from a poor sampling design mostly caused by restricted financial budgets. Many evaluation programmes does follow a before-after or control-impact scheme. It regularly occurs the only the post-project situation is monitored without having documented the baseline. The consequence is that only conclusions can be drawn on what it now is, but not how it changed or improved. In addition, monitoring programme only last for a few years. Acknowledging the requirements of the WFD to demonstrate improvements and the large costs to realize large river rehabilitation programmes more emphasis should be given to proper monitoring schemes that allow drawing well-founded conclusions.

The relevance of a variable at the scale of the river, riparian zone and floodplain scored in comparison to other variables within this river type (No = no relevance, L = low relevance, M = moderate relevance, H = high relevance)

Variable group	**Variable**	**River**	**Riparian zone**	**Floodplain**
River hydrology		M	H	H
In-channel hydraulics		H	H	N
Floodplain morphology		N	L	H
In-channel morphology (including the shoreline)	Profile (longitudinal, transversal)	H	H	M (groundwater levels)
	Meso-/micro-structures	H	H	N
Chemistry	Nutrients	M	L	H
	Toxicants	H	M (heritage in sediments)	L (heritage in sediments)
Biology	Algae	L	L	M
	Macrophytes	M	M	H
	Macroinvertebrates	M	H	H
	Fish	H	H	M
	Floodplain/riparian vegetation	N	H	H
	Terrestrial fauna	N	H	M