Fact sheet: Small, single-thread, lowland rivers

General description

Valley- and planform	The valley form varies from a no distinctive valley to a U-shaped valley and the channel planform from a straight/sinuous to a more meandering planform.
Hydrology	In the natural situation entrenchment is minimal and the floodplain is completely inundated during minor floods. Most rivers are permanent, although some may dry up periodically in summer (especially organic type rivers). The hydrograph is low-moderately dynamic.
Morphology	The erosion-sedimentation processes are only local. There is only passive meandering shaping a single-thread channel. The banks are irregular, mainly shaped by tree roots. The river bottom consists of a combination of mineral and biotic microhabitats ranging from silt, sand and gravel, to fine and coarse particulate organic matter (e.g. fallen leaves), mosses, local stands of vascular hydrophytes and course woody debris (logs, debris dams).
Chemistry	Depending on the geology pH can vary from 4.5 to 8. The water quality is meso-eutrophic, except for peat area fed rivers that are slightly acid. A distinction can be made between siliceous and calcareous rivers.
Riparian zone	The wide floodplain is dominated by deciduous swamp forest. The river channel is accompanied by mainly *Alnus* trees that more or less fully shade the river bed.

Photo: Small, single-thread, lowland river in the Netherlands.

Pressures

Major pressures

The prevailing hydromorphological pressure in small, single-thread, lowland rivers is channelization, in combination with flow alteration (resulting from impoundment and drainage of agricultural and urban land), and alteration of the riparian vegetation.

Score of pressure level imposed on small, single-thread, lowland 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**
Point sources	Point sources	H
Diffuse sources	Diffuse sources	H
Water abstraction	Surface water abstraction	L
	Groundwater abstraction	M
Flow alteration	Discharge diversions and returns	L
	Interbasin flow transfer	No
	Hydrological regime modification including erosion due to increase in peak discharges	H
	Hydropeaking	No
	Flush flow	H
	Impoundment	H
Barriers/Connectivity	Artificial barriers upriver from the site	L
	Artificial barriers downriver from the site	M
Channelization	Channelization / cross section alteration (e.g. deepening) including erosion due to this	H
	Sedimentation	M
Bank degradation	Bank degradation	H
Habitat degradation	Alteration of riparian vegetation	H
	Alteration of in-channels habitat	M
Others	e.g. Maintenance	H
	e.g. Exotic species	L

Problems and constraints for river restoration

Impoundment results in a reduction of natural flow velocity, causing the deposition of transported sediments. Overall channelization and impoundment strongly lowers microhabitat and flow velocity variety. Clearing of riparian forests reduces the amount of course woody debris in the channel and lowers the amount of shade which results in higher temperatures and temperature dynamics. Incision of the river bed due to channelization and flow alteration reduced the hydrological connectivity between river and floodplain.

Depending on the catchment groundwater abstractions can also play an important role in river degradation. Groundwater abstractions may indirectly lower the discharge of rivers, thereby decreasing the flow velocity and water depth. Reductions in base flow can lead to a drop in water level resulting in rivers to become intermittent.

A decrease in flow velocity combined with a lack of shading from riparian zone often results in strong macrophyte growth In many cases maintenance consisting of removing of aquatic vegetation and/or dredging is performed to counteract these effects.

Apart from hydromorphological pressures lowland rivers often suffer from eutrophication/ organic pollution resulting from a high proportion of agricultural land use in the catchment. Although this strongly the depends on the region, e.g. in Sweden acidification is the most important pressure.

Measures

Common restoration practice

Most of the measures taken in small, single-thread, lowland rivers aim to restore the channel planform (56%), mostly remeandering, or some intermediate solution, like a two stage profile. More often these measures are combined with in-channel measures, like removal of bank fixation and/or adding local structures such as groynes. Probably this is because of the low cost of in-channel measures compared to changes in channel planform that needs adjacent land. Measures that deal with the whole floodplain are rare, but when taken always in combination combined with in river or channel planform measures. Restoration of the riparian zone is always combined with channel planform and in-channel measures. The width is often limited.

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).

Measure category	**Measure**	**Relevance**	**Effect in-channel**	**Effect floodplain**	**Costs**	**Prioritisation**
Decrease pollution	Decrease point source pollution	M	M	M	H	M
	Decrease diffuse pollution input	H	H	H	H	H
Water flow quantity	Reduce surface water abstraction	L	L	L	L	L
	Improve water retention	H	M	H	H	H
	Reduce groundwater abstraction	L	L	M	M	L
	Improve water storage	H	M	H	H	H
	Increase minimum flow	H	H	M	H	H
	Water diversion and transfer	L	L	No	L	L
	Recycle used water	L	L	No	L	L
	Reduce water consumption	L	L	No	L	L
Sediment quantity	Add/feed sediment	M	M	L	M	M
	Reduce undesired sediment input	M	M	L	H	M
	Prevent sediment accumulation	No	No	No	No	No
	Improve continuity of sediment transport	No	No	No	No	No
	Trap sediments	No	No	No	No	No

	Reduce impact of dredging	L	L	No	L	L
Flow dynamics	Establish natural environmental flows	H	M	H	H	H
	Modify hydropeaking	No	No	No	No	No
	Increase flood frequency and duration	M	M	H	H	H
	Reduce anthropogenic flow peaks	H	M	L	H	H
	Shorten the length of impounded reaches	L	L	No	L	L
	Favour morphogenic flows	M	M	L	M	M
Longitudinal connectivity	Install fish pass, bypass, side channels	L	L	No	M	L
	Install facilities for downriver migration	L	L	No	M	L
	Manage sluice, weir, and turbine operation	L	L	No	M	L
	Remove barrier	M	M	L	L	M
	Modify or remove culverts, syphons, piped rivers	L	L	No	M	L
In-channel habitat conditions	Remove bed fixation	M	M	L	L	L
	Remove bank fixation	M	M	L	L	L
	Remove sediment	L	L	No	M	L
	Add sediment (e.g. gravel)	L	L	No	M	L
	Manage aquatic vegetation	M	M	L	H	M
	Remove in-channel hydraulic structures	L	L	No	M	L
	Creating shallows near the bank	L	L	No	M	L
	Recruitment or placement of large wood	M	M	L	H	H
	Boulder placement	No	No	No	No	No
	Initiate natural channel dynamics	H	H	M	L	H
	Create artificial gravel bar or riffle	L	L	No	M	L
Riparian zone	Develop buffer strips to reduce nutrients	H	H	H	M	H
	Develop buffer strips to reduce fine sediments	M	M	M	M	M
	Develop natural vegetation on buffer strips	H	H	H	M	H
River planform	Re-meander water course	M	M	M	H	M
	Widening or re-braiding of water course	L	L	L	H	L
	Create a shallow water course	H	H	H	M	H
	Narrow over-widened water course	H	H	H	M	H
	Create low-flow channels	M	M	L	H	M
	Allow/initiate lateral channel migration	M	M	L	L	M
	Create secondary floodplain	M	M	M	H	M
Floodplain	Reconnect backwaters, oxbow-lakes, wetlands	M	L	M	L	M
	Create backwaters, oxbow-lakes, wetlands	M	L	M	M	M
	Lower embankments, levees or dikes	M	L	M	L	M
	Replace embankments, levees or dikes	M	L	M	H	M
	Remove embankments, levees or dikes	M	L	M	L	M

	Remove vegetation	M	L	H	L	L

Problems and constraints with common restoration practice

The most often applied measure in lowland rivers is remeandering. In theory, remeandering will affect in-channel habitat conditions. However, in small, single-thread, sand-bed, lowland rivers there is limited potential for substrate sorting. Research showed that active remeandering of lowland rives can also decrease microhabitat diversity, i.e, there were cases where remeandering led to a decrease in river velocity resulting in particulate organic material as the main microhabitat, while in the unrestored section more habitats were present.

Hydrological measures are more often only locally applied in river stretches without solving the hydrological dynamics that results from catchment wide activities, like drainage, water abstraction and paved surfaces.

Promising and new measures

Restoring natural processes in long reaches, such as removal of bed and bank fixation, re-profiling and free flow, has a higher effect on recovery compared to local scale interventions, such as wood or gravel addition. Especially, in small, single-thread, lowland rivers catchment wide measures and measures restoring the natural system conditions (processes that fit to the current climatological and geo-morphological conditions) are most effective (see table below).

Hydrology must be considered as the most important process of which effects reach over the whole floodplain. Hydrological measures should therefore focus on groundwater balances and flows at catchment level. Upscaling of many current hydrological measures to reduce discharge dynamics and increase water- and groundwater levels is a promising trend (see figure below).

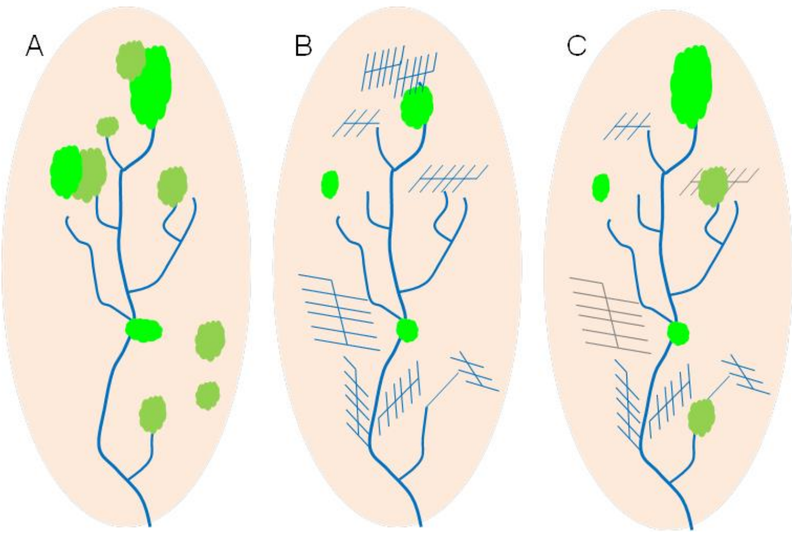

Figure: Hydrological restoration of combined ground water and surface water flows by restoring infiltration capacity and recreating water storage areas. (A: Natural catchment, B: Present situation with a high drainage intensity, C: Restored catchment with water infiltration, reduced drianage intensity, water storage areas (green) and water flow retarding by remeandering).

Especially, at the scale of the catchment and floodplain such measures will sort strong effects. The river is not considered in solitude but is seen and dealt with as part of its catchment and floodplain.

Furthermore, free flow and thus connectivity provides continuous potential of exchange of water, substances and propagules. Also tackling nutrient, organic and toxic load will sort most effect when tackled at catchment level. Here obligatory guidelines are needed.

But nutrients, organic and toxic substances and sediments can also be reduced at river stretch level by introducing wider or smaller riparian buffers (see figure below). There is clear and, in many cases, strong evidence for the role of wooded riparian buffers in controlling nutrient and sediment retention, water temperature and improving in-channel habitat structure.

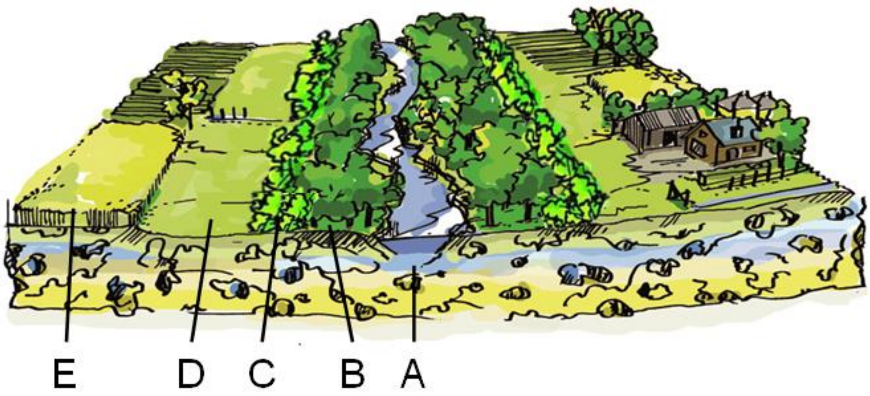

Figure: Installing extended buffer zones will control nutrient and sediment run off, cool water temperature and improve in-channel habitat structure. (A: river, B: Tree-zone, C: Bush-zone, D: grass-zone, E: adjacent land).

At river stretch scale also profile adaptations are in benefit. As the stream power of this river type is low active measures for re-profiling are considered beneficial. Also changing maintenance from a negative to a positive measure by lowering the maintenance frequency and diversifying the frequency and intensity depending on local plant growth and flow conditions, improves the river stretch.

At local scale morphological processes (e.g. sorting of bed material, creation of pools, bars and cutbanks) are generally the result of high flows in rich structured beds. By addition of wood or gravel habitat morphology can be improved. Monitoring results indicated that channel incision could alternatively be decreased or even reversed by placing a large number of naturally shaped logs randomly in the river. Logs in combination with sand addition to the river will heighten the river bed, increase the flow and flow variability and improve habitat heterogeneity.

Table: Promising measures and respective scale. The higher the scale the more effective the measure.

	Ecological key factor				
Schaal	Temperature and light regime (System conditions)	Flow regime (Hydrology)	Profile variation, substrate heterogeneity and organic material (Morphology)	Oxygen regime, nutrient and toxic load (Chemistry)	Connectivity (Biology)
Catchment	Ground water				
		Surface water hydrology			
		Free flow	↔	Connectivity	
			Nutrients and organic load		
				Toxicants	
	Riparian zone				
River stretch		Profile			
		Maintenance			
Site		Habitat			

In conclusion, one can hierarchically order in nine steps the measures to restore small, single-thread, lowland rivers keeping both stress and key ecological processes into account:

Scale	Stressors	Order of restoration	**Temperature** regime	**Light** regime	**Flow** regime	**Substrate** variation	**Organic matter**	**Oxygen** regime	**Nutrients**	**Salinity**	**Toxicity**	**Connectivity**
		Ecological key factors/ processes										
Catchment	Changed hydrology	1	■		■	■						
	Diffuse sources	2		■	■	■	■	■	■	■	■	
	Point sources	3	■	■	■	■	■	■	■	■	■	
Stretch	Current alterations	4	■		■	■		■				
	Channelization	5	■	■	■	■	■	■				■
	Bank degradation	6	■	■	■	■	■	■	■			■
	Maintenance	7		■	■	■	■	■				
Site	Barriers	8	■		■	■		■				■
	Habitat degradation	9	■		■	■	■					

Monitoring scheme

Monitoring schemes should follow some basic principles that apply to all river types:

- Biotic as well as abiotic variables should be monitored. The restoration measures might have succeeded to create the desired habitats but the effect on biota might be limited due to other pressures at larger scales which have not been addressed in the restoration project.
- In-channel, riparian, as well as floodplain conditions should be monitored. Besides the biological quality elements relevant for the Water Framework Directive, restoration can also have positive effects on other semi-aquatic and terrestrial organism groups, like ground beetles and floodplain vegetation. Indeed, there is empirical evidence that effects on other organism groups can be larger.
- Monitoring has to be conducted at appropriate spatial and temporal scales that reflect (i) the habitat needs of the organisms (e.g. monitoring microhabitat substrate patches for macroinvertebrates, mesohabitat features for fish), (ii) all life stages (e.g. monitoring in-channel and riparian habitats for macroinvertebrates with terrestrial life-stages), (iii) and the reproductive cycle as well as dispersal abilities (long-term monitoring to also cover effects of restoration on long-lived species and weak dispersers).
- Looking at the spatial and time scale of many current restoration measures macro-invertebrates are most suited for river monitoring. Fish population are strongly managed and reflect larger scale conditions, macrophytes bear a long history as they disappear only slowly and algae reflect to short time scales and very, very local conditions. Floodplains are large scaled and best be monitored by vegetation. Riparian zone can be monitored by using vegetation or carabid beetles.
- A Before-After-Control-Impact design should be applied to allow disentangling the effect of restoration from general trends in the whole river or catchment.

- However, the final selection of the organism groups, and spatial / temporal scales monitored strongly depends on the objectives and applied measures. Of course, it is reasonable to focus on the abiotic and biotic variables and scales that potentially have been affected by the restoration measures (e.g. in-channel habitat conditions by in-channel measures).
- Monitoring results should be used for adaptive management, i.e. to react on unanticipated effects and trends, and this should be included in the planning from the beginning ("Plan-B").

For further reading and practical guidelines we refer to the handbook of the River Restoration Centre (River Restoration Centre 2011).

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		H	H	H
In-channel hydraulics		H	M	L
Floodplain morphology		L	L	M
In-channel morphology	Profile (longitudinal, transversal)	H	M	M
	Meso-/micro-structures	H	L	No
Chemistry	Nutrients	H	M	L
	Toxicants	H	M	L
	Others			
Biology	Algae	L	No	No
	Macrophytes	M	L	No
	Macroinvertebrates	H	L	No
	Fish	H	L	No
	Floodplain/riparian vegetation	L	H	H
	Terrestrial fauna	No	H	M