- Case Studies -

demonstrating the improvement of ecological status/potential by restoration/mitigation measures

Annex of

Good practice in managing the ecological impacts of hydropower schemes; flood protection works; and works designed to facilitate navigation under the Water Framework Directive
Key for using the annex of case studies

Abbreviation for the driving force
Number of main pressure
Color for type of main pressure
Number of case studies

1. Abbreviations for the driving forces

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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
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<td>Flood protection</td>
</tr>
<tr>
<td>H</td>
<td>Hydropower</td>
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<tr>
<td>N</td>
<td>Navigation</td>
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2. Types of pressures

<table>
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<th>No</th>
<th>main pressure</th>
<th>subtype of pressure</th>
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<tr>
<td>1</td>
<td>Cross profile construction</td>
<td>groynes, weirs, dams,</td>
</tr>
<tr>
<td>2</td>
<td>Longitudinal profile construction</td>
<td>dikes</td>
</tr>
<tr>
<td>3</td>
<td>Channelisation, straightening</td>
<td></td>
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<td>4</td>
<td>Bank reinforcement</td>
<td>bank fixation, riprap</td>
</tr>
<tr>
<td>5</td>
<td>Deepening</td>
<td>Channel maintenance, dredging, removal of material</td>
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<td>6</td>
<td>Land drainage</td>
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<td>7</td>
<td>Land claim</td>
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<tr>
<td>Number</td>
<td>Title of Case study</td>
<td>Country</td>
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<td>F 1 01</td>
<td>Manshanden fishway for pumping stations</td>
<td>NL</td>
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<td>F 2 01</td>
<td>Construction of a bank protection to prevent erosion of salt marshes (Oosterschelde estuary, SW Netherlands)</td>
<td>NL</td>
</tr>
<tr>
<td>F 2 02</td>
<td>Restoration of a brackish water reduced tidal area with natural abiotic and biotic processes</td>
<td>NL</td>
</tr>
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<td>F 3 01</td>
<td>Restoration of the Jeseniscica River</td>
<td>SLO</td>
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<tr>
<td>H 1 01</td>
<td>Minimum flow requirements and new small weirs in a 5 km long river section in River Numedalslaagen</td>
<td>NO</td>
</tr>
<tr>
<td>H 1 02</td>
<td>Mitigation measures in and downstream of Halnejorden Reservoir in River Numedalslaagen</td>
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<tr>
<td>H 1 03</td>
<td>By-pass channels at the short-term regulated River Oulujoki</td>
<td>FI</td>
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<td>H 1 04</td>
<td>Fishway as a mitigation measure</td>
<td>FI</td>
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<td>H 1 05</td>
<td>Optimizing the minimum acceptable flow in the Bregenzerach river within the framework of the new power plant of Alberschwende</td>
<td>AU</td>
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<tr>
<td>Case Study</td>
<td>Description</td>
<td>Details</td>
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<tr>
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<tr>
<td><strong>H 1 06</strong></td>
<td>Sustainable solution of the hydromorphological pressures in the lower Bregenzerach by a projected power plant</td>
<td>AU surge and sunk waves reestablishment of the biological continuity - no digital exemplar available</td>
</tr>
<tr>
<td><strong>H 1 07</strong></td>
<td>Improvement of the discharge situation an enabling the fish migration in the river Ill by the new power plant</td>
<td>AU Seasonally dry river bed, no biological continuity, surge and sunk waves establishment of a fish ladder, installation of minimum flow - no digital exemplar available</td>
</tr>
<tr>
<td><strong>N 3 01</strong></td>
<td>Connection of a sandpit and creation of dynamic oxbow lake along the IJssel, a branch of the Rhine</td>
<td>NL Bank reinforcement, floodplain aggregation, winter and summer embankments Creation of a side channel with a permanent connection to the river, breach in summer dike, removal of riprap high</td>
</tr>
<tr>
<td><strong>N 3 02</strong></td>
<td>Creation of side channels along the Rhine</td>
<td>NL Bank reinforcement, winter and summer embankments Creation of three side channels, rehabilitation of riparian zone high</td>
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<tr>
<td><strong>N 3 03</strong></td>
<td>Establishment of a floodplain-typical island habitat dominated by the dynamics of varying river stages with an adjacent floodway</td>
<td>DE Loss of typical floodplain sites dominated by the dynamics of varying river stages Enlargement of the flood spillway and connecting it with the River Moselle for water exchange above mean-flow levels high</td>
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<tr>
<td><strong>N 3 04</strong></td>
<td>Controlling water levels in river-training projects to preserve floodplain habitats. The example of the Öberauer Schleife (oxbow lake)</td>
<td>DE Loss of typical floodplain sites with characteristic water-level variations Preserving essential elements of the hydrological dynamics in the floodplain by artificial floods and low-water stages high</td>
</tr>
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<td><strong>N 3 05</strong></td>
<td>Preserving the structural diversity of the bank of the bypass (floodway) Faulbach as compensation for river-training works</td>
<td>DE Loss of floodplain-typical landscape structures Establishment of an artificial water body (oxbow) in the floodplain with a connection to the River Main medium</td>
</tr>
<tr>
<td><strong>N 3 06</strong></td>
<td>Groundwater management</td>
<td>AU river regulation, river erosion due to channelization establishment of a groundwater management - no digital exemplar available</td>
</tr>
<tr>
<td></td>
<td>Case Study Description</td>
<td>Description 1</td>
</tr>
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<tr>
<td>N307</td>
<td>Irrigation System in the riparian woodland between Korneuburg and Altenwörth (Danube river)</td>
<td>river regulation</td>
</tr>
<tr>
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<td>Removal of a bank reinforcement on a slip-off slope of the Lower Rhine</td>
<td>Bank Reinforcement</td>
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<td>Bank Reinforcement</td>
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<td>Removal of a bank revetment in several sections of the limnetic tidal river Elbe</td>
<td>Bank Reinforcement</td>
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<td>N404</td>
<td>Establishment of a shallow water zone protected against the impact of ship-induced waves</td>
<td>Loss of characteristic bank zones</td>
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<td>N405</td>
<td>Establishment of a shallow water zone protected against the impact of ship-induced waves, vegetation-free gravel and pebble areas and succession zones. New harbour Würzburg, River Main</td>
<td>Loss of characteristic bank zones</td>
</tr>
</tbody>
</table>
Case study: F 1/01

**Manshanden fishway for pumping stations**

<table>
<thead>
<tr>
<th><strong>Driving force:</strong></th>
<th>Flood protection, water level management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pressure:</strong></td>
<td>Dykes, water level management</td>
</tr>
<tr>
<td><strong>Impact:</strong></td>
<td>Biological deficiency as a result of migration barriers</td>
</tr>
<tr>
<td><strong>Country</strong></td>
<td>Netherlands</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Outlet polder into River Oude Aa</td>
</tr>
<tr>
<td><strong>Water Body at risk</strong></td>
<td>Yes, provisionally identified as HMWB</td>
</tr>
</tbody>
</table>

**A  Status before reconstruction**

**Status of construction:**
- In the Netherlands more than 3000 pumping-stations contribute to the management of the water level.
- The noise of the pumps in the station makes fishes wary of passage, however when no alternative streams are present the fish will ultimately try to pass through the pumps. The passage through conventional pumping stations is dangerous for fish since the propeller- and centrifugal pumps that are often used for drainage rotate at high speed.

**Ecological Deficiency**
- For fishes, pumping stations represent migration barriers that disturb the natural connection between adjacent water bodies. Once fishes find themselves in a polder, they are unable to migrate downstream without the passage of at least one pumping station. The risk that fish passage through these pumps results in severe or lethal damage is high (Figure 1).

**B  Reconstruction by restoration / mitigation measures**

**Execution of the measure:**
- The Manshanden fishway for pumping stations utilises the natural wariness of fishes to guide them. Fishes that approach the pumping station from the polder are discouraged from swimming into the inlet pipe of the station by strong stroboscopic lights from which fishes have an aversion.
- Dark and quiet inlet channels that are connected to a Venturi pump (Figure 2) are provided as alternative routes. The Venturi pump constitutes the core of the Manshanden fishway and is placed at a pumping station in addition to conventional pumps. It creates a water flow that is forced through a narrow
aperture into a discharge pipe where a vacuum develops as a result. The vacuum induces a water flow in the two side channels that are connected to the discharge pipe directly behind the narrow aperture. The water flow attracts fishes from the polder and moves them past the lethal pumps to the downstream waters. The presence of the bypasses thus provides an obstacle-free connection between upstream and downstream waters.

![Figure 1: Damaged eel that migrated through a conventional pumping station with a propeller pump.](image)

**Accompanying measures:**

Monitoring: The first Manshanden fishway was installed on the Meerweg pumping station in the River Oude Aa, part of the conservancy area of the Hunze and Aa’s Waterboard, in 2005 (figure 3). Total number of fish that passed through the pumping station in October 2005 and percentages mortality:

<table>
<thead>
<tr>
<th>Total number of fishes passed</th>
<th>8354</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of species</td>
<td>10 (eel, roach, bream, ruffe, pike, pikeperch, rudd, perch, river lamprey, gudgeon)</td>
</tr>
<tr>
<td>Length range</td>
<td>5-78 cm</td>
</tr>
<tr>
<td>Mortality with Venturi pump and stroboscopic lights turned on</td>
<td>0%</td>
</tr>
<tr>
<td>Mortality with Venturi pump turned on and stroboscopic lights turned off</td>
<td>18-23%</td>
</tr>
<tr>
<td>Mortality with Venturi pump and stroboscopic lights turned off</td>
<td>100% of the fish &gt; 10 cm</td>
</tr>
</tbody>
</table>

**Hydromorphological improvements**

**Ecological improvements**
- Restoration of fish connectivity.

**Assessment of the ecological efficiency:**

<table>
<thead>
<tr>
<th>High</th>
<th>Medium</th>
<th>Slight</th>
</tr>
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<tbody>
<tr>
<td>✗ (for fish only)</td>
<td></td>
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</tr>
</tbody>
</table>

**Effects on the uses:**
• There is only minor loss of pump efficiency.

**Costs of the measure (€)**

![Figure 2. The Venturi principle.](image)

![Figure 3. The Venturi at Waterboard Hunze & Aa's.](image)

Contact for further information:

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m.klinge@witteveenbos.nl
Case Study No.: F 2/01

Construction of a bank protection to prevent erosion of salt marshes (Oosterschelde estuary, SW Netherlands)

<table>
<thead>
<tr>
<th>Driving force:</th>
<th>Protection against flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure:</td>
<td>Changes in hydromorphological conditions (tidal range and silt supply) due to the construction of a storm-surge barrier and dams</td>
</tr>
<tr>
<td>Impact:</td>
<td>Erosion of salt marshes</td>
</tr>
<tr>
<td>Country</td>
<td>Netherlands</td>
</tr>
<tr>
<td>Location</td>
<td>Oosterschelde estuary</td>
</tr>
<tr>
<td>Water Body at risk</td>
<td>Yes, provisionally identified as HMWB</td>
</tr>
</tbody>
</table>

A Status before reconstruction

As a consequence of the construction of a storm surge barrier in the mouth of the Oosterschelde and the construction of dams in the eastern and northern landward branches of the estuary, the tidal range in the estuary diminished and silt concentrations have decreased. This resulted in a reduction of the accretion of the salt marshes, while erosion continued. The natural dynamical cycle of accretion and erosion changed into a continuous erosion process.

Due to the construction of the landward dams 1000 ha of salt marshes were lost (became part of freshwater systems with no connection to the estuary).

The average loss of salt marsh surface area caused by the net erosion is approximately 3 ha/year on a remaining total surface of 500 ha.
Figure 1. Picture of an eroding salt marsh

Ecological Deficiency
- Loss of salt marsh surface area

B Reconstruction by restoration / mitigation measures

Execution of the measure:
- Construction of a low dam of stones along the edge of salt marshes

Figure 2. Picture of a marsh protection

Hydromorphological improvements
- Reduction of the exposure of the marsh edge to wave attacks

Ecological improvements
- Preservation of the present area of salt marshes

Assessment of the ecological efficiency:
- The measure protects a valuable habitat from further losses

<table>
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<tr>
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<th>Medium</th>
<th>Slight</th>
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</table>

Effects on the uses:
- Positive effect on safety, as the marshes (when present) reduce the wave-attack on the dikes that protect the polders below sealevel bordering the Oosterschelde.

Costs of the measure (€)
Information follows

Contact for further information:
Case Study No.: F 2/02

Restoration of a brackish water reduced tidal area with natural abiotic and biotic processes

Driving force: Safety
Pressure: Dike between polder and sea
Impact: Biological deficiency as a result of loss of structural diversity
Country: Netherlands
Location: Near Ems-Dollart estuary
Water Body at risk: Yes, provisionally identified as (part of a) HMWB

The aim was:
- to develop and restore a brackish water area with natural abiotic and biotic processes;
- to create an opportunity for migratory fishes to migrate from the sea into freshwater and vice versa;
- to increase environmental awareness and public support for conservation.

A Status before reconstruction

Status of construction:
- in 1979 the polder was created for safety related to the construction of a canal for shipping and water transport;
- destination partially agricultural, partly natural habitat.

Ecological Deficiency
- Abrupt transition between salt and freshwater aquatic habitats

B Reconstruction by restoration / mitigation measures

Execution of the measure:
- Digging of the former watercourse (ca 2 km length) in the polder
- Building of a culvert in the dike between the polder and the Ems-Dollart

introduction (from 4 January 2001 onwards) of partial tidal processes (first with an amplitude of 0.6 m, later 0.3 m; in the estuary the tidal amplitude is 3 m)
Accompanying measures:

- (Monitoring)
  morphology (bottemprofiles),
  physical-chemistry (e.g. salinity, nutrients, suspended matter, several chemical substances)
  biologische (vegetation, fytobenthos, macro-invertebrates, fish and fish migration, breeding birds)

Hydromorphological improvements
- Partial restoration of the former tidal watercourse

Ecological improvements

Fish migration between salt and freshwater is made possible and occurs according to preliminary monitoring results

Assessment of the ecological efficiency:

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<tr>
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<tbody>
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<td>X</td>
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</table>

Effects on the uses:

- Effects on agriculture: poorly, effects on safety: none

Costs of the measure (€): 1.8 mil. euro's.

Contact for further information

Stichting Het Groninger Landschap te Haren (B. Speelman, tel: 050-313 59 01).
Peter Tydeman, RIKZ Haren. Tel. 050-5331378
Case Study No.: F 3/01

Restoration of the Jeseniscica River

<table>
<thead>
<tr>
<th>Driving force:</th>
<th>land reclamation – drainage works</th>
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</thead>
<tbody>
<tr>
<td>Pressure:</td>
<td>river straightening, bank reinforcement, cross sectional and longitudinal profile alteration</td>
</tr>
<tr>
<td>Impact:</td>
<td>ecological deficiency and habitat destruction as a result of decreased hydromorphological structural diversity</td>
</tr>
<tr>
<td>Country:</td>
<td>Slovenia</td>
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<tr>
<td>Location:</td>
<td>Jeseniscica River</td>
</tr>
<tr>
<td>Water Body at risk:</td>
<td>no</td>
</tr>
</tbody>
</table>

A Status before reconstruction

Status of construction:
- straightened river course in length of 1,5 km
- reinforced banks
- alterations of cross section and longitudinal profile
- lowered river bottom level
- partially reinforced river bottom
- unified current, width, depth and B / H ratio
- removed aquatic and riparian vegetation, fallen trees and debris from the river
Figure 1: Jeseniscica River at Novo mesto, river course straightening in late 80’, situation in 1990

Figure 2: Jeseniscica River at Novo mesto, river course straightening in late 80’, situation in 1990
Ecological Deficiency:

- loss of river sinuosity
- loss of current, river width and river depth variability
- loss of micro and mezzo hydromorphological structures (pools, rapids, riffles, sand bars, dunes etc.)
- loss of river corridor internal ecological structure (patches, corridors, mosaics, matrix)
- loss of canopy
- loss of habitat

B Reconstruction by restoration / mitigation measures

Execution of the measure:

- instalment of deflectors to initiate the process of bank erosion and consequently creation of river bends in the length of 1,5 km
- alteration of the cross sectional steps from concrete to wooden structures, designed to initiate downstream pools
- creation of temporary fish hideouts in river banks
- planting of riparian vegetation
Figure 3: Jeseniscica River at Novo mesto, situation in 2006

Figure 4: Jeseniscica River at Novo mesto, situation in 2006
Accompanying measures:
- intensive monitoring and maintenance of the restored river reach for the period of 5 years after restoration works were completed
- seasonal periodical monitoring and maintenance afterwards

Hydromorphological improvements:
- Initiation of river bank erosion, followed with the increase of sinuosity ratio, increased current, river width and river depth variability. Re-creation of micro and mezzo hydromorphological structures (pools, rapids, riffles, sand bars, dunes etc.)

Ecological improvements:
- Development of internal river corridor ecological structure (patches, corridors, mosaics, matrix), determined with the hydromorphological process, as well as ecological functioning, especially in terms of restored fish habitat structures.

Assessment of the ecological efficiency:
- Measures taken initiated semi-natural hydromorphological process in the river corridor, development of riparian vegetation canopy, fallen trees and debris appearance and consequently re-creation of stabile aquatic habitat.

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</table>

Effects on the uses:
- Restoration works were designed in manner not to have any impacts on the existing drainage works. Consequently, no impacts on use were recorded after restoration of the river.

Costs of the measure (€)
Costs of restoration works are estimated on today’s prices of labour and material on 20,000 €. Costs of monitoring and maintenance are not included.

Literature or/and contact:

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Slovenia
ales.bizjak@izvrs.si
Case Study No.: H 1/01

Minimum flow requirements and new small weirs in a 5 km long river section in River Numedalslaagen

<table>
<thead>
<tr>
<th>Driving force:</th>
<th>Hydropower production from existing project bypassing the river</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure:</td>
<td>No environmental flow requirements, hence none or low water discharge downstream of the intake</td>
</tr>
<tr>
<td>Impact:</td>
<td>Heavy impact on biology at site (only stagnant water behind weirs during low flow periods), loss of river continuum, reduced floods</td>
</tr>
<tr>
<td>Country</td>
<td>Norway</td>
</tr>
<tr>
<td>Location</td>
<td>River Numedalslaagen, southern Norway; river section between Rødberg dam and the Norefjord lake.</td>
</tr>
</tbody>
</table>

Water Body at risk  Yes, provisionally identified as HMWB

A Status before mitigation measures (before 2001)

Status of river section:
The river section is approximately 4 km long, has been provisionally identified as HMWB, and its typology parameters show low alkalinity and low colour, of medium altitude (i.e. below the tree limit).

- The hydropower production upstream Lake Norefjorden was licensed in 1914, without any requirements for release of minimum flow. This section of the river had therefore only water discharge during floods.

- Some small weirs constructed across the river stretch maintained still pools of water for esthetical purposes during low flow periods. The weirs were of an old type, made of concrete and not well adapted to maintaining good habitats for fish and other aquatic species.

A natural water fall is acting as a barrier far downstream of the selected river section, and this part of the river has therefore never been accessible for anadrome fish. Another natural water fall is found at the upper parts of the selected river section, and is acting as a barrier for local trout and other species. An ecological continuum can therefore not be maintained all the way up to the Rødberg dam.

Ecological Deficiency

- Almost no flowing water during long periods.
- Disrupted hydrological and ecological continuum and no migration of fish.
B  Reconstruction by restoration / mitigation measures

Execution of the measure:
In the new concession of 2001, the following requirements were given for this river section:

- Minimum continuous flow requirement of 3 m³/s during winter and 5 m³/s during summer.
- Reconstruction of the existing concrete small weirs across the river stretch; new weirs are so-called cell type weirs.

Cell type weirs (cf. Figure 1) are – as the name implies – constructed as smaller cells, thus providing a series of pools across the river. The water flow direction is changed and energy is dissipated in steps, resulting in decreased erosion of the river banks, and easier passage for migrating fish. The construction of cell type weirs had the following objectives:

- More natural looking weirs
- Conditions for resident species of fish and benthos are improved, including greater ease of upstream migration and greater diversity of in-situ micro-habitat
- Mitigating effects during flood situations; less bank erosion

The hydropower company is responsible for the construction and maintenance of the weirs, as well as the release of minimum flow.

Figure 1 shows the river section at 3.5 and 5.5 m³/s (slightly more than the minimum required flows of 3 and 5 m³/s).

Figure 1: Section of river stretch at 3,5 m³/s (left) and 5,5 m³/s (right).

(Photo: NLB)
Figures 2 and 3 show situations at two sites before and after the construction of new weirs.

Figure 2: Section of part of the river before (left) and after new weir constructions (right - water flow from right to left) (Photo: NLB)

Figure 3: Man-made weir in part of the river before (left) and after weir reconstruction (right). Water flow from right to left. (Photo: NLB)

Assessment of the ecological efficiency:
No systematic monitoring of the site has been done after the new mitigation measures, but electro-fishing has revealed that trout (Salmo trutta) and minnow (Phoxinus phoxinus) are living in the river section. By ensuring a river habitat of chutes and pools, the conditions for invertebrates should have improved significantly.

It should be noted that minnow is a fish species that is exotic and largely unwanted in Norwegian rivers, and it has been speculated if such weirs create habitat which
favours this species. However, minnow has been present in the river a long time before the new measures were implemented.

<table>
<thead>
<tr>
<th>High</th>
<th>Medium</th>
<th>Slight</th>
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</table>

**Effects on the uses:**
Loss of production amounts to 28 Gwh annually. However, the hydropower company is planning a new mini-hydro plant which will utilise the environmental flow. This will be positioned close to the natural water fall (and barrier), and should therefore not affect the ecological continuum of this water body significantly.

In terms of effects on other types of uses, the river is now more suitable for angling, and the new cell type weirs is contributing to a more natural-looking river, which should be beneficial for tourism.

**Costs of the measure (€):**
Approximately € 20 000 per weir for reconstruction works, thus a total of € 100.000. O&M costs are not yet available, since the measure is relatively recently finalised.

Upgrading the dam for release of minimum flow had a cost of € 250.000 (most Norwegian old dams do not have facilities for releasing minimum flows and reconstruction therefore has to be carried out).

Contact for further information:
Case Study No.: H 1/02

Mitigating measures in and downstream of Halnefjorden Reservoir in River Numedalslaagen

Driving force: Hydropower
Pressure: Reservoir with 4 meter regulation level; no minimum flow requirements downstream of dam, no hydrological continuum downstream of dam.
Impact: Erosion in littoral zone and exposure of lake bed to sub-zero climate due to winter drawdown of the reservoir. No migration of fish possible between reservoir and downstream river.
Country Location: Norway
          River Numedalslaagen, Norway, on the Hardanger mountain plateau; Halnefjorden Reservoir (previously a natural lake)
Water Body at risk: Yes, provisionally candidate for HMWB, but needs confirmation

A Status before mitigation measures (before 2001)

Status of Halnefjorden reservoir:
The Halnefjorden dam was finalised in 1953, and the reservoir has a total regulation level of 4 meters. The lake is located at high altitude (about 1100 masl), and the water typology parameters show low alkalinity and low colour.

- Although the regulation level is only 4 meters, erosion problems in the littoral zone cause disruption of littoral water vegetation and increase the turbidity of lake waters. Erosion is also threatening cultural heritage sites near the banks.
- Before 2001, there was no hydrological continuum between the reservoir and the downstream river, no fish pass, and the downstream river was occasionally dry.

Ecological Deficiency

- Loss of vegetation in littoral zone, causing erosion and increased turbidity in waters, as well as decreased food production for fish (especially trout) in the littoral zone.
- No flowing water during low flow periods in downstream river caused severe stress on aquatic flora and fauna.
- Disrupted hydrological continuum and no migration of fish between reservoir and downstream river.
B Reconstruction by restoration / mitigation measures

Execution of the measure:

- Minimum continuous flow requirement of 0.5 m$^3$/s in the river downstream of the dam; and a requirement to keep the water level stable at the highest regulated level in the period between the spring flood and October 1st.
- New fish pass; to ensure that migratory fish can access spawning and breeding grounds. Also diversion barrier to prevent fish migrating up the wrong river channel (cf. Figure 4).
- Coconut matting erosion protection laid out in littoral zone to improve re-vegetation of barren zones and hinder erosion progressing towards cultural heritage sites

Figure 4: Downstream the dam of the Halnefjord reservoir. In the river channel to the left there is now a new requirement of 0.5 m$^3$/s of minimum flow (photo shows situation at significantly higher discharge). A barrier has been constructed to ensure that fish do not swim up the channel to the right. The new fish pass is constructed at the top of the left-hand channel, Cf. Figure 5.
Figure 5: New fish pass at the dam of the Halnefjorden reservoir.

Figure 6: Coconut matting in the littoral zone of the Halnefjorden reservoir.

Assessment of the ecological efficiency:

The mitigation measures are relatively recent, but experiences from similar measures at other sites have shown that

- The fish pass ensures that trout and other fish species may gain access to upstream spawning grounds
- Minimum flow in the downstream river ensures that fish may migrate all year, and that other aquatic species have a better chance of surviving during low flow periods.
- Coconut matting enhances re-vegetation and reduces erosion from lake littoral zones
Effects on the uses:
0.5 m³/s continuous environmental release is a small constraint to reservoir operations and subsequently reduces power income to a small extent.

Costs of the measure (€):
Total costs of fish pass and erosion abatement measures amount to € 550-600.000.

Contact for further information:
Case Study No.: H1/03

By-pass channels at the short-term regulated River Oulujoki

<table>
<thead>
<tr>
<th>Driving force:</th>
<th>Hydro power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure:</td>
<td>Damming, short-term regulation</td>
</tr>
<tr>
<td>Impact:</td>
<td>Hydro-morphological changes affecting habitat and species diversity</td>
</tr>
<tr>
<td>Country</td>
<td>Finland</td>
</tr>
<tr>
<td>Location</td>
<td>River Oulujoki, North Ostrobothnia</td>
</tr>
<tr>
<td>Water Body at risk</td>
<td>Yes, preliminary identified as heavily modified</td>
</tr>
</tbody>
</table>

A Status before reconstruction

Status of construction
- The River Oulujoki is efficiently built for hydro power production. The seven power plants are using almost all of the 122 m natural head loss at the distance of 110 km between Lake Oulujärvi and the sea. The plants have small water reservoirs. Due to the short-term regulation the discharge varies daily and weekly, typical summer time variation being between 50 and 250 m$^3$/s and specified flow rate being 450 m$^3$/s.

Figure 1. Schematic picture of the River Oulujoki and the power plants.

Ecological Deficiency
- Nature of the river has changed into a chain of small lakes with short retention times and river stretches with slow water flows due to hydromorphological changes. As a consequence, the original fish fauna of the river has changed.
Damming has interrupted the migration of fish such as salmon and trout. All the notable rapid sections (some 400 - 500 ha) have disappeared affecting the breeding and living areas of fish and bottom fauna species. In the tributaries there are altogether 40 hectares of rapid sections.

B  Reconstruction by restoration / mitigation measures

**Implemented measures:**
- The lowermost power plant Merikoski has a fishway which allows migration to the half of the river as well as to the two main tributaries.
- Currently, fish stockings are made systematically in the river area and sea in front of the river.
- Additional stream habitat restoration measures have been carried out in certain places of the river. These measures cover practically all suitable places. Altogether the extent of these measures is only few hectares.

**Further ecological improvements:**
- Building by-pass channels to the six power plants has been considered in a preliminary study. The aim would be to create rapid-like stream habitat in the river and allow access to the upper reaches and tributaries.

![Figure 2. Schematic picture of the by-pass channel in one power plant.](image)

**Further hydromorphological improvements:**
- The continuity of the river would be improved by the six by-pass channels. Also access to the tributaries would be allowed.
• A flow of 2 - 5 m³/s in a by-pass channel would produce in total 5 - 12 hectares of stream habitat. The rapid-like areas would increase diversity on water velocities and depths. Additionally, the bottom structure of the by-pass channels could be designed to have variation in coarseness.

Ecological improvements
• 5 - 12 hectares of stream habitat could produce 500 - 1200 smolts.
• The channels would create brook-like habitat for bottom fauna species.

Assessment of the ecological efficiency:
• The expansion of the smolt-producing area would be relatively small. It is unlikely that the habitats could maintain a self-sustaining population and life-cycle due to the mortality and uncertain migration to the furthest power plants.
• The brook-like habitat might be better for trout and grayling than salmon. Salmon normally requires bigger streams.
• The bottom fauna species maintained by the new habitats would not be typical for a larger river but for a smaller stream. A demand of type-specific communities in the Water Framework Directive would therefore not be fulfilled.
• To sum up: The ecological changes would not extend to the scale of whole water body but they would concentrate on narrow sections of the artificial channels. It is obvious that the changes do not affect the WFD status classification in the scale of the whole water body.

Effects on the uses:
• Effect on the use due to the loss of water. The six by-pass channels with 2 - 5 m³/s discharge would cause energy loss of 2 - 4,8 MW which equals 18 - 45 GWh.

Costs of the measure (€)
• Construction costs are not assessed. Cost assessment is inaccurate due to the small amount of cases implemented in large power plants in Finland. Based on the experience of earlier built natural by-pass channels the costs can roughly be assessed by
  • water intake constructions 100 000 €/plant x 6 plants 600 k€
  • channel construction 15 - 40 000 € / head meter x 112 m 1 700 - 4 500 k€
  • totally 2,3 - 5,1 million €.
• Annual cost due to the lost energy 500 000 - 1 250 000 € with 2 - 5 m³/s discharge
• For comparison: The annual costs of current fish stocking measures (250 000 smolts) are 20 000 € on the river area and almost 400 000 € on the sea area.
Contact for further information: Jukka Muotka, Fortum Hydropower Services, jukka.muotka@fortum.com

References:


Fishway as a mitigation measure

### Driving force:
Hydro power

### Pressure:
Damming

### Impact:
Interruption in the river continuum

### Country
Finland

### Location
River Kuusinkijoki, North-eastern Finland

### Water Body at risk
No

#### A Status before reconstruction

**Status of construction**
- Myllykoski power plant has a head of 11 m and specified flow rate of 16 m³/s. There is practically no regulation of the discharge. The power plant is located in the River Kuusinkijoki at the outlet of the Lake Ala-Voutunkijärvi where the catchment area is 784 km². The upper watercourse consists of several lakes and streams. The length of the river downstream is some 15 km ending to the Lake Paanajärvi in Russia. There are no other power plants on the area and no other hydromorphological changes.

**Ecological Deficiency**
- The watercourse has a lake trout population, some of which used to migrate to the upper reaches while most of the population left to the river area downstream of the power plant. Lake trout migration to the upper reaches was blocked by the power plant.

#### B Reconstruction by restoration / mitigation measures

**Execution of the measure**
- A fish ladder of combined denil and borland type was constructed in the beginning of 1990's at the power plant. It is in use three months a year during summer time.

**Accompanying measures:**
- Additional fish stockings are carried out to compensate efficient fishing and lost breeding habitats under the power plant.

**Hydromorphological improvements**
- Continuity of the river has been improved so that fish can nowadays migrate.
Ecological improvements

- Fish are allowed to migrate to their upstream breeding areas. Migration has an important role in maintaining the lake trout population in the upper reaches of the watercourse.

Assessment of the ecological efficiency:

- The fishway has worked as assumed. Number of migrant fish has been in proportion to the size of the upstream migrative population and breeding areas. Natural life cycle of the lake trout has been strengthened.

Effects on the uses:

- No significant effects on the use. Discharge through the fishway is about 0,2 m³/s three months a year. This equals to 40 MWh.

Costs of the measure (€)

- The cost of the fishway construction was approximately 150 000 €. Energy losses can be assessed to be 1200 €/year. Additional fish stockings cost 12 000 €/year.

Contact for further information: Jukka Muotka, Fortum Hydropower Services, jukka.muotka@fortum.com
**Case Study No. : N 3/01**

**Connection of a sandpit and creation of dynamic oxbow lake along the IJssel, a branch of the Rhine**

**Driving force:**
- Navigation, safety, sand extraction

**Pressure:**
- Bank reinforcement, floodplain aggregation, winter and summer embankments

**Impact:**
- Biological deficiency as a result of loss of shallow river bed and floodplain marshland

**Country**
- Netherlands

**Location**
- IJssel km 962-965 floodplain Duursche waarden

**Water Body at risk**
- Yes, provisionally identified as HMWB

**A Status before reconstruction**

**Status of construction:**
- A deep river channel fixed by groynes.

- The main channel was bordered by elevated floodplains. Winter- and summer embankments caused inundation with a low frequency. Oxbow lakes filled up with sediment and became isolated from the main river canal. Floodplains were used by agriculture and a source for mineral extraction such as sand and clay.

**Ecological Deficiency**
- Loss of the specific riverine habitats, especially marshland and dynamic waterbodies.

- Abrupt transition between aquatic and terrestrial habitats; loss of the hydromorphological continuity between main channel and side waters (floodplain channels).

**B Reconstruction by restoration / mitigation measures**

**Execution of the measure:**
- Connecting the existing waterbodies in the floodplain to a new long channel with a permanent connection to the river on the down stream part.

- Creation of an isolate waterbody

- A breach in the summer dike in order to obtain a variety of inundation frequencies.

- Removal of rip rap on the riverbank.
Accompanying measures:
• Deceasing grazing intensity.
• Monitoring
  ➢ Ecotope mapping of the current state of the floodplain
  ➢ Physical-chemical survey of water and sediments
  ➢ Biological survey
  ➢ Recreation aspects

Figure 1: The Duursche Waarden, a rehabilitated floodplain near the river IJssel, attracts more than 10,000 visitors a year.

Hydromorphological improvements
• The idea behind the nature development project Duursche waarden was the maintenance, rehabilitation and development of a natural floodplain. The inundation frequencies and, consequently, the diversity of riverine habitats increased. Reclamation of the old sandpit by natural sedimentation will take a long period. The connection of the small waterbodies to one channel resulted in habitat variation.

Ecological improvements
• After 10 years of development different ecological elements increased (+), while other decreased (-).

<table>
<thead>
<tr>
<th>Vegetation</th>
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</thead>
<tbody>
<tr>
<td>Riverbank plants</td>
<td>+</td>
</tr>
<tr>
<td>Red list species</td>
<td>+</td>
</tr>
<tr>
<td>Water plants</td>
<td>- -</td>
</tr>
</tbody>
</table>
Vegetation structure ++
Willow growth +

Summer birds
Number of species +
Number if territories ++
Rough herbages birds ++
Marsh birds +
Wood birds +
Meadow birds - -

Fish
Stagnant water species +
Rheophilic water +

Invertebrates
Branched channel +
Isolated channel - -
Butterflies +
Dragonflies + +

Assessment of the ecological efficiency:
• The measure created dynamical riverine habitats typical for the river Rhine and the species associated with those habitats. The wideness of the floodplain is only several hundreds of meters compared to several kilometres in a natural state.

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<th>Slight</th>
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<tbody>
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</tr>
</tbody>
</table>

Effects on the uses:
• Each year more than 10,000 visitors coming each year to the floodplain. Schools, nature groups and clubs regularly explore the footpaths with a ranger.
• There is no sedimentation in the main channel or destabilization of the riverbank.
• The loss of agricultural area is significant for the floodplain, but insignificant compared with the total catchment and national agricultural area.

Costs of the measure (€)

Contact for further information:
Frank Kok – RWS Directie Oost-Nederland, P.O. Box 9070, 6800 ED Arnhem, the Netherlands. f.r.kok@don.rws.minvenw.nl


Case Study No.: N3/02

Creation of side channels along the Rhine

<table>
<thead>
<tr>
<th>Driving force:</th>
<th>Navigation, safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure:</td>
<td>Bank reinforcement, winter and summer embankments</td>
</tr>
<tr>
<td>Impact:</td>
<td>Biological deficiency as a result of loss of shallow river bed</td>
</tr>
<tr>
<td>Country</td>
<td>Netherlands</td>
</tr>
<tr>
<td>Location</td>
<td>Rhine-km 936-939 floodplain Gamerensche waard</td>
</tr>
<tr>
<td>Water Body at risk</td>
<td>Yes, provisionally identified as HMWB</td>
</tr>
</tbody>
</table>

A Status before reconstruction

Status of construction:
- A deep river channel fixed by groynes.
- The main channel was bordered by elevated floodplains. Winter- and summer embankments caused inundation with a low frequency and high amplitude. Floodplains were used by agriculture.

Ecological Deficiency
- Loss of the specific riverine habitats, especially shallow riverbeds.
- Abrupt transition between aquatic and terrestrial habitats; loss of the hydromorphological continuity between main channel and side waters (floodplain channels).

B Reconstruction by restoration / mitigation measures

Execution of the measure:
- Creation of three side channels in 1996-1999. A permanent channel of 2 km, a 1 km channel flowing ca 265 d/y and a channel flowing ca 100 d/y (Figure 1).
- 200 m rehabilitation of riparian zones by planting willows, transforming sandy beaches to softwood forest.
Figure 1: River Rhine at Gameren after hydromorphological improvement. On the right the main channel with groynes and rehabilitated riparian zones. On the left winter embankments. In the middle the floodplain (128 ha) with three channels; on the left a permanent channel of 2 km, at the top a 1 km channel flowing ca 265 d/y and below a partly silted up channel flowing ca 100 d/y (photo Jaap de Vlas, July 2001).

Accompanying measures:
• Deceasing grazing intensity.

• Monitoring
  ➢ Ecotope mapping of the current state of the floodplain
  ➢ Morphological activity in the main channel (sedimentation), floodplain channels (especially erosion in the direction of winter embankments)
  ➢ Physical-chemical survey of water and sediments
  ➢ Biological survey

Hydromorphological improvements
• Room for riverine processes resulted in a diversity in flow conditions and inundations frequencies, erosion and sedimentation. This created specific habitats, such as dynamic shallow water, sandy banks and soft wood forest, and a more natural gradient between water and land.

Ecological improvements
• Riverine habitats were recreated. Rheophile fish and macro-invertebrate species profit from the shallow water habitat. The macro-invertebrates are less affected by invading species compared to the main channel. The floristic value improved by the change in management of the floodplain. Wintering birds (ducks, goose) partly replaced by typical riverine species.
Assessment of the ecological efficiency:
- The measure created dynamical riverine habitats typical for the river Rhine and the species associated with those habitats. The wideness of the floodplain is only several hundreds of meters compared to several kilometres in a natural state.

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Effects on the uses:
- There is only minor sedimentation in the main channel at the entrance of the largest floodplain channel.
- Due to erosion towards the winter embankment, several reinforcements have been made in the floodplain channel.
- The loss of agricultural area is significant for the floodplain, but insignificant compared with the total catchment and national agricultural area.

Costs of the measure (€)

Contact for further information:

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fr.kok@don.rws.minvenw.nl


Establishment of a floodplain-typical island habitat dominated by the dynamics of varying river stages with an adjacent floodway

<table>
<thead>
<tr>
<th>Driving force:</th>
<th>Navigation</th>
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</thead>
<tbody>
<tr>
<td>Pressure:</td>
<td>Loss of typical floodplain sites dominated by the dynamics of varying river stages</td>
</tr>
<tr>
<td>Impact:</td>
<td>Loss of biological diversity through riverbed levelling for improved navigability</td>
</tr>
<tr>
<td>Country:</td>
<td>Germany</td>
</tr>
<tr>
<td>Location:</td>
<td>River Moselle, km 183.8 - 184.7, near the harbour of Trier, District Ehrang</td>
</tr>
<tr>
<td>Developer:</td>
<td>WSA Koblenz and WSA Trier</td>
</tr>
<tr>
<td>Project:</td>
<td>Deepening of the River Moselle, compensation pursuant to BNatSchG</td>
</tr>
<tr>
<td>Water Body at risk?:</td>
<td>Yes, preliminarily rated as &quot;significantly modified&quot;</td>
</tr>
</tbody>
</table>

Figure 1 Hahnenwehr floodway (Photo of 1999)
Figure 2  Hahnenwehr floodway (Photo of 2004)
A  Status before reconstruction

Status of construction:
- Island (5.2 ha) connected with the bank by a causeway with a flood spillway

Ecological Deficiency:
- Impairment of recreational uses
- Planting with allochthonous trees and shrubs

B  Reconstruction by restoration / mitigation measures
Execution of the measure:
- Interruption of the causeway
- Enlargement of the flood spillway and connecting it with the River Moselle for water exchange above mean-flow levels
- Planting of typical floodplain trees and shrubs

Accompanying measures:
- 10-year monitoring with morphological, faunistic and vegetation surveys (1994-2004)

Hydromorphological improvements:
- Improvement of water exchange between flood spillway and river
- Improved physical-structural diversity of floodplain habitats

Ecological improvements:
- Enlargement of the shallow water zones and improved flow condition
- Increased species diversity of the macrozoobenthos
- Improved habitat conditions for fish
- Unhindered vegetation growth

Assessment of the ecological efficiency:
- [...]  

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<th>High</th>
<th>Medium</th>
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<tbody>
<tr>
<td>Effects on the uses:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No significant negative consequences for navigation</td>
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</table>

Costs of the measure (€)
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Contact:
Case Study No.: N 3/04

Controlling water levels in river-training projects to preserve floodplain habitats. The example of the Öberauer Schleife (oxbow lake)

<table>
<thead>
<tr>
<th>Driving force:</th>
<th>Navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure:</td>
<td>Loss of typical floodplain sites with characteristic water-level variations</td>
</tr>
<tr>
<td>Impact:</td>
<td>Loss of biological diversity through riverbed levelling</td>
</tr>
<tr>
<td>Country:</td>
<td>Germany</td>
</tr>
<tr>
<td>Location:</td>
<td>River Danube, Öberauer Schleife (oxbow lake in former river bend) in the impoundment of Straubing</td>
</tr>
<tr>
<td>Developer:</td>
<td>Rhein-Main-Donau Wasserstrassen GmbH</td>
</tr>
<tr>
<td>Project:</td>
<td>River training by impoundments and flood protection</td>
</tr>
<tr>
<td>Water Body at risk?:</td>
<td>Yes, preliminarily rated as heavily modified water body</td>
</tr>
</tbody>
</table>

Figure 1 The Öberauer Schleife (aerial view; south direction)
A Status before reconstruction

Status of construction:
- Technically necessary cut-off of the river loop for river training of the Danube

Ecological Deficiency:
- Because of the cut-off and the total sealing of the flood-defence dykes during the Danube river training, the river loop lost any connection to the main river and became an oxbow lake
- No flow of river water through the oxbow lake
- No variations of groundwater levels as responses to floodflow, mean-flow, or low flow conditions
B  Reconstruction by restoration / mitigation measures

Execution of the measure:
• Measures taken to preserve the best possible water quality and to prevent eutrophication
• Preserving essential elements of the hydrological dynamics in the floodplain by artificial floods and low-water stages
• Maintaining a certain influence of seep water on the polder areas behind the dykes
• Preserving the floodplain meadows for breeding birds

Accompanying measures:
• Long-term monitoring over 10 years of the effectiveness of actions defined in the landscape plan

• Hydromorphological improvements:
  • Maintaining the groundwater dynamics in polder areas
  • Supporting the water level during most of the growth period (imitating the former mean groundwater levels): Generating a flood situation in the upper part of the oxbow from mid-February to the end of March

Ecological improvements:
• Oxygenation of the water in the oxbow (the upstream inflow was backfilled and shaped as a rapid, strongly meandering watercourse with gravel bed)
• Trenches parallel to the dyke prevent access to the foreland, on the one hand, and divert water for artificial flooding into the remote furrow drains, on the other hand
• The artificial flooding ensures the waterlogging of the meadows in spring and fills the furrow drains
• In areas lying below the lower mean-water level, extremely flat slopes of river banks enlarge the amphibious zones and establish a wider bank vegetation zone
• Establishment of a succession area south of the cut-off dam where nearly the whole species inventory of the amphibious zone is represented

Assessment of the ecological efficiency:
• Assessment is not yet possible (The report will be submitted at the end of the 10-year effectiveness-monitoring period at the end of the year 2006.)

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</table>

Effects on the uses:
• No significant negative consequences for navigation

Costs of the measure (€) ---

Contact:
Federal Institute for Hydrology
Dr. Schleuter
Am Mainzer Tor 1
56068 Koblenz
Telephone: 0261-1306-5469
E-mail: schleuter@bafg.de
Homepage: http://www.bafg.de
Preserving the structural diversity of the bank of the bypass (floodway) Faulbach as compensation for river-training works

Driving force: Navigation  
Pressure: Loss of floodplain-typical landscape structures  
Impact: Loss of biological diversity through mid-mole elongation  
Country: Germany  
Location: River Main, km 151.96-152.53, impoundment Freudenberg  
Developer: Waterway New-construction Office (WNA) Aschaffenburg  
Project: Development of the River Main/Compensation pursuant to BNatSchG  
Water Body at risk?: Yes, preliminarily rated as heavily modified water body

Figure 1: Faulbach, view of the well-structured bank before project implementation
A Status before reconstruction

Status of construction:
- The diversified shallow-water structures with boulders on the left-hand bank formed an area of intensive water currents and provided a habitat for a rich benthos community that should be preserved.

Ecological Deficiency:
- Potential loss of the rich benthos community during excavation of the bank
B Reconstruction by restoration / mitigation measures

Execution of the measure:
- Establishment of an artificial water body (oxbow) in the floodplain with a connection to the River Main
- Bank protection against wave impact
- Establishment of flat banks and shallow-water zones

Accompanying measures:
- Compilation of a catalogue of actions in the context of an expert report about the ecological improvement of compensation sites along the River Main from an ornithological perspective

Hydromorphological improvements:
- [...] 

Ecological improvements:
- Additional benefit: Establishment of an island that is not accessible for visitors (succession area) and has high ornithological benefit
- Establishment of bulrush and small reed stands
- No action to keep the water-surface open, because slowly advancing silting along with extension of the reed stands increases the ornithological benefit of the area
- Dense willow growth on the training walls supplements the bank vegetation of alder and poplar trees

Assessment of the ecological efficiency:
- Applies generally to benthos, aquatic invertebrates, fish, insects in the land-water transition zone, and birds: the ecological objectives and expectations were achieved)  

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<th>Medium</th>
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<td>X</td>
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</tbody>
</table>

Effects on the uses:
- No significant negative consequences for navigation
Costs of the measure (€)

Contact:

Federal Institute for Hydrology
Dr. Schleuter
Am Mainzer Tor 1
56068 Koblenz
Telephone: 0261-1306-5469
E-mail: schleuter@bafg.de
Homepage: http://www.bafg.de
Case Study No.: N 4/01

Removal of a bank reinforcement on a slip-off slope of the Lower Rhine

<table>
<thead>
<tr>
<th>Driving force:</th>
<th>Navigation</th>
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</thead>
<tbody>
<tr>
<td>Pressure:</td>
<td>Bank Reinforcement</td>
</tr>
<tr>
<td>Impact:</td>
<td>Biological deficiency as a result of loss of structural diversity</td>
</tr>
<tr>
<td>Country:</td>
<td>Germany</td>
</tr>
<tr>
<td>Location:</td>
<td>Rhine-km 774.3 – 775.7 Duisburg Rhine floodplain (urban industrial landscape)</td>
</tr>
<tr>
<td>Water Body at risk:</td>
<td>Yes, provisionally identified as HMWB</td>
</tr>
</tbody>
</table>

A  Status before reconstruction

Status of construction:
- continuous stone filling (LD-slag\(^1\)); used to stabilize the slip-off slope over a length of 1.4 km; partly with poured groyne
- A 400 metre wide strip of grassland adjoins the river bank.

---

\(^1\) LD-slag is an industrial by-product resulting from the transformation of hot metal into steel by oxygen refining. Selective process steps allow this slag to be transformed into building material, which is considered as one of the hardest "stone".
Figure 1: River Rhine at Duisburg, bank reinforcement (stone filling)

Ecological Deficiency:
- Loss of the morphological continuity of the slip-off slope with its extensive gravel bank; loss of the structural diversity and therefore of the natural habitat zoning according to the different water depths and water current conditions
- Abrupt transition between aquatic and terrestrial habitats

B Reconstruction by restoration / mitigation measures

Execution of the measure:
- Removal of the embankment material (building rubbish) at the toe of the groynes, which are located at the downstream river bank
- Covering of the LD-slag with a 0.5 m thick gravel layer over a distance of 1.4 km
- The removal was gradually carried out according to the demand for slag and basalt material, which is used elsewhere for maintenance measures.
Accompanying measures:
• Quantity survey of the current state of the structure
• (Monitoring) Inventory documentation in the year 2003 (situation before the measure)
  ➢ Habitat mapping, hydrographic structural mapping
  ➢ Detailed inventories and photographic documentation of the altitude profile and the vegetation along transects
  ➢ The inventory documentation will be repeated in 2006.

Hydromorphological improvements:
• Initiation of the development of a shallow gravel bank, determined by erosion and sedimentation, with different water depths and water current conditions depending on the water level

Ecological improvements:
• Development of a morphological and vegetational zoning of the river bank determined by the dynamic of the river; associated with the development of habitat structures particularly for rheophile fish species
Assessment of the ecological efficiency:
- The measure initiates the development of a natural river bank typical for the river Rhine.

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</table>

Effects on the uses:
- Effects on the waterway and its function are not known.

Costs of the measure (€)

Literature or/and contact:
Case Study No. N4/02:

Interruption of a bank reinforcement on the bank of the limnetic tidal river Elbe

<table>
<thead>
<tr>
<th>Driving force:</th>
<th>Navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure:</td>
<td>Bank Reinforcement</td>
</tr>
<tr>
<td>Impact:</td>
<td>Biological deficiency as a result of loss of structural diversity</td>
</tr>
<tr>
<td>Country:</td>
<td>Germany</td>
</tr>
<tr>
<td>Location:</td>
<td>nature conservation area “Heuckenlock” (tidal section of the river Elbe near Hamburg)B</td>
</tr>
<tr>
<td>Water Body at risk:</td>
<td>Yes, provisionally identified as HMW</td>
</tr>
</tbody>
</table>

A  Status before reconstruction

Status of construction:
- massive reinforcement of the bank of the limnetic tidal river Elbe through an extensive stone filling; prevention of bank erosion through currents

Ecological Deficiency:
- Loss of the formerly shallow bank profile with the typical zoning (at low tide) of shallow water zone, freshwater tidal flat and tidal reeds; thus loss of valuable fish spawning and breeding habitats in the sandy and muddy shallow water zones.

B  Reconstruction by restoration / mitigation measures

Execution of the measure:
- Stone fillings were removed at short bank sections. The construction works were carried out within few days.

Accompanying measures:
- (Monitoring) So far, no systematic investigations of the hydromorphological and biotic development have been carried out. But the area is regularly surveyed by a local nature conservation organisation (NGO).

Hydromorphological improvements:
- Restoration of the formerly continuous shallow bank profile in the short sections of the bank leads to activation of the typical hydromorphological processes through small-scale erosion and sedimentation.
Figure 1: Inlet in the stone filling at the shore of the limnetic tidal river Elbe (January 2006, at low tide).
- The iced area marks the small-scale mud and sand flat, which appears at low tide.
- The course of the interrupted stone filling is visible in the middle of the picture. Approaching from land, tidal reeds infiltrate the stone filling.
- The pictured situation can be found in several sections of the river bank in the natural conservation area “Heukenloch”.

Ecological improvements:
- During the last years, the small-scale shallow river profile and the dynamic of the river caused the development of the typical natural habitat zoning with direct connection to the alluvial forest (Weichholzaue?). Due to the opening of the bank, the alluvial forest is directly linked to the tide river.

- The fish fauna uses this small bank section, which is structured through different water depths, substrates and moderate current conditions, as feeding, spawning and breeding habitats and as resting place, which is even accessible at low tide.

Assessment of the ecological efficiency:
- The measure resulted in a development, which represents, on a small-scale, a significant improvement of the ecological status.

- It is an ecological effective initial measure that is suitable to examine small-scale hydromorphological and ecological development possibilities under the specific conditions of a navigated tidal river.
Effects on the uses:
- Effects on the waterway and its function are not known.

Costs of the measure (€)
- The measure involves comparatively low costs.

Literature or/and contact:
Case Study No.: N4/03

Removal of a bank revetment in several sections of the limnetic tidal river Elbe

<table>
<thead>
<tr>
<th>Driving force:</th>
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<tbody>
<tr>
<td>Pressure:</td>
<td>Bank Reinforcement</td>
</tr>
<tr>
<td>Impact:</td>
<td>Biological deficiency as a result of loss of structural diversity</td>
</tr>
<tr>
<td>Country:</td>
<td>Germany</td>
</tr>
<tr>
<td>Location:</td>
<td>nature conservation area “Borghorster Elblandschaften” near Altengamme (Hamburg) in the range of the limnetic tidal river Elbe; downriver of the impoundment Geesthacht</td>
</tr>
<tr>
<td>Water Body at risk:</td>
<td>Yes, provisionally identified as HMW</td>
</tr>
</tbody>
</table>

A  Status before reconstruction

Status of construction:
- Bank reinforcement of the limnetic tidal river Elbe through a massive revetment consisting of a rough stone filling; prevention of bank erosion through currents and wash of the waves

Ecological Deficiency:
- Loss of a bank section with gently sloping profile of sand and mud substrate and corresponding zones (at low tide) of shallow water and freshwater tidal flat; thus loss of valuable fish spawning and breeding habitats in the sandy and muddy shallow water zones. The tidal reeds are separated from the river and are no longer inundated at high tide.

B  Reconstruction by restoration / mitigation measures

Execution of the measure:
- Bank revetment was removed at several sections. The execution of the measure was carried out within few weeks.
Figure 1: View of a reconstructed section of the river bank (length of section: about 100 m), January 2006 at low tide. The iced marks the zone of the bank which is flooded at high tide.

Figure 2: Southern end of the reconstructed revetment. The difference in the design of the bank profile can be noticed clearly.
Accompanying measures:
• The German Federal Waterways and Shipping Administration carries out controls of the bank.

• (Monitoring) Significant erosion and sedimentation processes are noticed. Until now, systematic observations of the hydromorphology, habitat development as well as of the colonisation by plant and animal species are not available. Thus so far, a revision of the concept of the measure was not needed.

Hydromorphological improvements:
• Activation of the typical hydromorphological process through the extension of the flood plain and through small-scale erosion and sedimentation; objective is the development of a broad and gently sloping bank profile

Ecological improvements:
• Initiation of a typical bank zoning of the limnetic tidal river Elbe (at low tide) with shallow water zone, freshwater tidal flat on sand and mud substrate and tidal reeds; the resulting bank section is structured by the dynamic of the river and serves different fish species as spawning and breeding habitats due to its different water depths, current velocities and substrates; parts of bank section are even accessible at low tide.

Assessment of the ecological efficiency:
• Over a longer bank section, a habitat development is initiated which leads to small-scale differentiated morphological, aquatic and semiterrestrial structures typically for the bank of the river Elbe.

• It is a measure with high ecological efficiency that is suitable to examine hydromorphological and ecological development possibilities under the specific conditions of a navigated tidal river.

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Effects on the uses:
• Effects on the waterway and its function are not known.

Costs of the measure (€)
• The measure involves comparatively low costs.

Literature or/and contact:
## Case Study No.: N 4/ 04

### Establishment of a shallow water zone protected against the impact of ship-induced waves

<table>
<thead>
<tr>
<th><strong>Driving force:</strong></th>
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<tbody>
<tr>
<td><strong>Pressure:</strong></td>
<td>Loss of characteristic bank zones</td>
</tr>
<tr>
<td><strong>Impact:</strong></td>
<td>Loss of biological diversity through riverbed levelling for improved navigability</td>
</tr>
<tr>
<td><strong>Country:</strong></td>
<td>Germany</td>
</tr>
<tr>
<td><strong>Location:</strong></td>
<td>River Moselle, km 135.1 - 135.8, right-hand bank between Brauneberg and Mühlheim</td>
</tr>
<tr>
<td><strong>Developer:</strong></td>
<td>WSA Koblenz and WSA Trier</td>
</tr>
<tr>
<td><strong>Project:</strong></td>
<td>Deepening of the River Moselle, compensation pursuant to BNatSchG</td>
</tr>
<tr>
<td><strong>Water Body at risk?:</strong></td>
<td>Yes, preliminarily rated as heavily modified water body</td>
</tr>
</tbody>
</table>

Figure 1: Training wall (Photo of 1999)
A Status before reconstruction

Status of construction:
- Steep bank profiles, nearly continuously secured by natural rock rip-rap
- Riparian forest and extensively cultivated meadows
- Mouth of an inflowing rivulet in near-natural condition

Ecological Deficiency:
- Steep bank profiles: Bank protection against erosion by ship-wave impacts
- Bank reinforcement and steep banks restrict vegetation growth
- Steep banks impacted by ship-waves provide inadequate habitats for macrozoobenthic organisms and fish
B  Reconstruction by restoration / mitigation measures

Execution of the measure:

- Construction of a 700-m training wall parallel to the bank with connection to the river flow in 1993

Accompanying measures:

- 10-year monitoring programme with morphological, faunistic and vegetation surveys (1994-2004)

Hydromorphological improvements:

- Improved physical-structural diversity
- Reduced impact of ship waves on banks
- Wide and shallow water area behind the training wall

Ecological improvements:

- High fish-ecological significance as habitat for different age stages of limnophilic species spawning on macrophytes such as carp and tench
- The alluvial fan of the inflowing rivulet is a potential habitat for fry of rheophilic, species spawning on gravel that is better protected by the training wall against detrimental impacts of ship waves
- Favourable conditions for the establishment of aquatic vegetation
- Ecologically significantly improved habitat conditions regarding diversity and abundance against the steep, rip-rap banks of the Moselle in this impounded reach

Assessment of the ecological efficiency:

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Effects on the uses:

- No significant negative consequences for navigation
Costs of the measure (€)

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Contact:

Federal Institute for Hydrology
Ms. Sommer
Am Mainzer Tor 1
56068 Koblenz
Telephone: 0261-1306-5409
E-mail: sommer@bafg.de
Homepage: http://www.bafg.de
Establishment of a shallow water zone protected against the impact of ship-induced waves, vegetation-free gravel and pebble areas and succession zones. New harbour Würzburg, River Main

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<td>Country:</td>
<td>Germany</td>
</tr>
<tr>
<td>Location:</td>
<td>River Main, km 248.2 - 248.9, right-hand bank near Würzburg</td>
</tr>
<tr>
<td>Developer:</td>
<td>Waterway New-construction Office (WNA) Aschaffenburg</td>
</tr>
<tr>
<td>Project:</td>
<td>Development of the River Main/Compensation pursuant to BNatSchG</td>
</tr>
<tr>
<td>Water Body at risk:</td>
<td>Yes, preliminarily rated as &quot;significantly modified&quot;</td>
</tr>
</tbody>
</table>

Figure 1: Wetland habitat "Neuer Hafen", a short time after the compensation in 1990
A Status before reconstruction

Status of construction:
- Ploughland between the area of the harbour of Würzburg and the River Main

Ecological Deficiency:
- Depletion of the benthos community and of the bank vegetation through the construction works
B Reconstruction by restoration / mitigation measures

Execution of the measure:
- Establishment of shallow-water zones with connection to the River Main, succession zones, vegetation-free gravel and pebble areas as well as two bluffs on a former ploughland area of approximately 5 ha. Implementation 1989

Accompanying measures:

Hydromorphological improvements:
- Improved physical-structural diversity
- Reduced impact of ship waves on banks

Ecological improvements:
- Wide and shallow water areas offer favourable conditions for the establishment of aquatic vegetation
- Enlargement of the amphibious zone and thus promotion of amphibious plants and animals
- Diverse habitat structures (bluffs, vegetation-free areas, coppices, meadows, and tall forbs) offer favourable conditions for avifauna
- High fish-ecological significance as habitat for different age stages of limnophilous species spawning on hydrophytes
- Significantly higher ecological habitat value in terms of species diversity and abundance than rip-rap banks

Assessment of the ecological efficiency:
- The ecological objectives and expectations were fully achieved

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Effects on the uses:
• No significant negative consequences for navigation

Costs of the measure (€)
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Contact:
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