- Final -

TOOLBOX

ON IDENTIFICATION AND DESIGNATION OF ARTIFICIAL AND HEAVILY MODIFIED WATER BODIES

CIS Working Group 2.2 on Heavily Modified Water Bodies

15 January 2003

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1 INTRODUCTION

1.1 PURPOSE OF THE HMWB & AWB TOOLBOX

The HMWB & AWB toolbox supports the HMWB guidance document with practical examples illustrating the different steps of the HMWB and AWB designation process. Its purpose is to make the HMWB and AWB guidance document more practical and illustrated, which is vital to its future use. The toolbox examples are mainly derived from the HMWB case studies; the examples have either been directly contributed by the Members of the Working Group (based on a common template) or they have been extracted by Ecologic (Institute for International and European Environmental Policy) from the HMWB case studies, as well as the HMWB synthesis report.

The toolbox covers issues which need to be clarified through illustrations as pointed out at the HMWB workshop (30-31 May 2002, Berlin), as well as during the drafting of the guidance document. The identified issues (mentioned in brackets in several sections of the guidance document) have been covered to the extent possible, according to the examples contributed by the Working Group and knowledge gained from the evaluation of the HMWB case studies.

A preliminary 1st draft of the toolbox was produced for discussion at the 4th WG meeting on 18-19 June 2002 in Brussels. A 2nd draft was circulated to the Working Group for comments on 31 October 2002 including examples submitted by the Working Group and extracted from the case studies. This document is the final version of the toolbox. The toolbox does not constitute part of the guidance document itself and is hence not subject to the agreement of the HMWB Working Group.

1.2 INSTRUCTIONS TO THE USER

The toolbox is a complementary document to the HMWB & AWB guidance document and can, therefore, not be used without reference to the guidance document. In order to assist the user, the toolbox follows the same structure as the guidance document (chapters 4, 5 and 6 of the guidance document) with the different steps of the identification and designation process (see also Figure 1) placed as headings of the different sections.

The examples included in the HMWB & AWB toolbox, which range from general impact assessment methods to specific examples of restoration measures proposed for a specific hydropower scheme, are a first collection of suggestions and are not to be taken as prescriptive methods or approaches to be used in the identification and designation process. It should be noted that the latest guidance on particular issues such as water body definition and typology, which are not specific only to the AWB & HMWB identification and designation process, is not to be found in the toolbox examples; interested readers should look for such information in the relevant guidance documents issued by the EC on these particular issues. The applicability of the AWB & HMWB toolbox examples will differ between the Member

States. Before adopting any approach, it is important for the user to judge whether it fits his purpose and needs.

An attempt has been made to place the examples into a context and keep the illustrations short and focused. For each step of the identification and designation process, clear reference to the respective guidance chapter is made, followed by the examples. Each example is titled according to the issue illustrated, referring to the water body and country of origin. Each example is followed by a list of references providing the original source of information, as well as other references which the reader may find useful regarding the specific issue. For more details, the contact data of the author of the example or the author of the case study used as source is given. All case study reports are also available on the Scottish Environment Protection Agency webpage (http://www.sepa.org.uk/hmwbworkinggroup/). Each report includes a complete reference list for further information. It should be noted that in some cases the approaches followed in the case studies may not be strictly in line with the HMWB guidance document. This is due to the fact that most of them were completed before the issuing of the final agreed guidance; they were actually produced to inform the development of the guidance document.

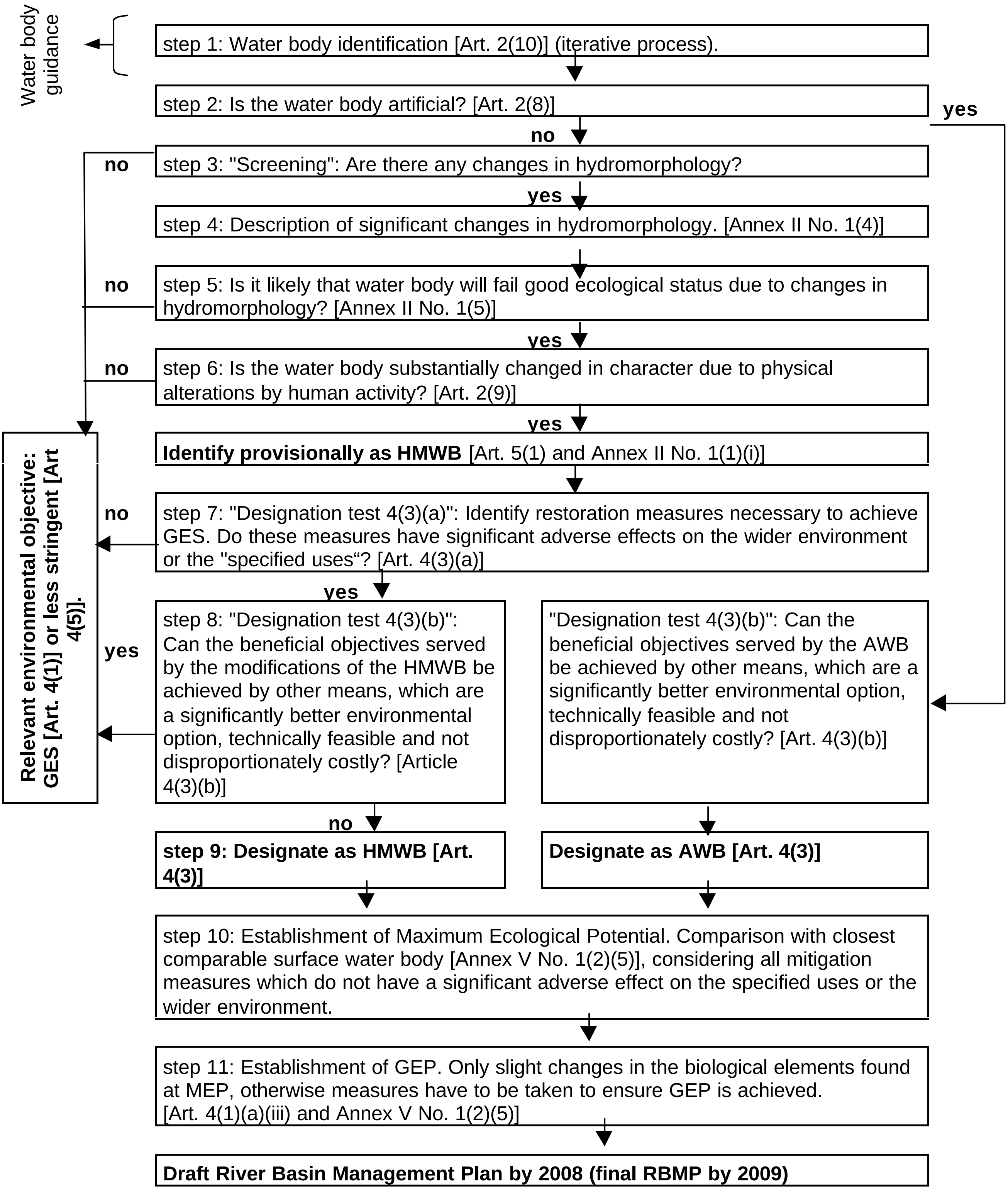

Figure 1: Steps of the HMWB & AWB identification and designation process (from the final AWB & HMWB guidance document)

2 STEPS LEADING TO THE PROVISIONAL IDENTIFICATION OF HMWB

2.1 WATER BODY IDENTIFICATION (STEP 1)

	Chapter	Step
HMWB-Guidance	2.1	1

This first step is of major importance for the implementation process, because water bodies represent the units that will be used for reporting and assessing compliance with the Directive's principal environmental objectives. Below you can find examples for the first step:

1. Identification of water bodies and subdivision on the basis of physical alteration and use on the River Lagan catchment (Northern Ireland, UK)
2. Identification of Water Bodies in the River Solgenan (Sweden)
3. Grouping water bodies for assessment and designation purposes in the River Dee (Scotland, UK)

Examples

1. Identification of water bodies and subdivision on the basis of physical alteration and use on the River Lagan catchment (Northern Ireland)

The method for typology and water body identification presented here has been used in the HMWB case study on the River Lagan, Northern Ireland. The method described here is also relevant to step 4.

The major typological influences of the River Lagan relate to the altitude range and more specifically the channel gradient along its travel to the sea, which ultimately defines parameters such as substrate typology, energy of flow, depth, valley shape, transport of solids, *etc*. This profile is illustrated graphically in Figure 1 and the predominant substrate types are indicated.

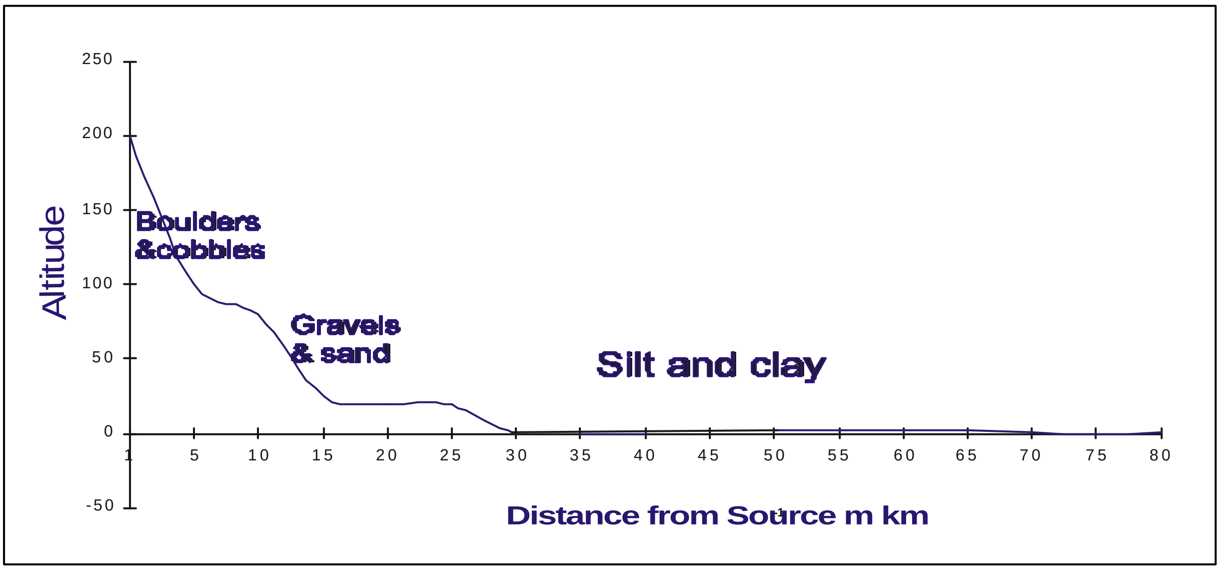

Figure 1: Gradient profile for River Lagan from source to sea

Based on this profile analysis the River Lagan can be split into a number of distinct water bodies.

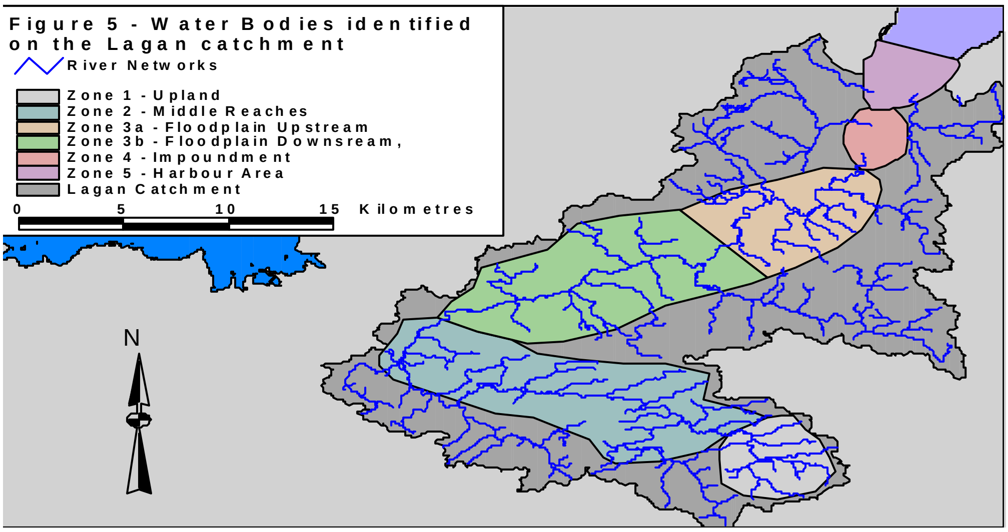

Figure 2: Water body identification on the Lagan catchement

Water body 1

The upper reaches above Dromara have an obviously sharp gradient as the river leaves its source on Slieve Croob. Substrates in this area are strongly dominated by boulder and cobble. The river flow regime is torrential during periods of high precipitation, but with only a low base flow during drier periods. The flora as would be expected is restricted to bryophytes and stonefly, mayfly and caddisfly larvae typically dominate the invertebrate biology. The riparian zones are relatively natural.

Water body 2

Between Dromara and Magheralin the gradient becomes progressively gentler and the substrates here are dominated by sands and gravels, interspersed with cobble and boulder. In this zone higher plants begin to colonise marking not only changes in flow but evidencing a degree of enrichment due to the agricultural use of the surrounding lands. The invertebrate biology of this zone is distinct in that organisms such as snails and leeches coexist alongside more pollution sensitive organisms, which is the result of the mixed influences of flow regime and a degree of enrichment. The riparian strip is again relatively natural and continuous.

Water body 3

Between Magheralin and the outskirts of Belfast at Stranmillis Weir the river is deeper and slower being heavily impacted by historic drainage. This zone has a very low gradient. Finer particulate matter, deposited from erosion upstream dominates the substrate. The physical typology in this area is expressed in the macrophyte and macroinvertebrate assemblages recorded, as they are distinct from any other zone of the river. The former form extensive stands whereas the fauna is dominated by oligochaetes, leeches, snails, *etc*. The riparian area in this section is virtually absent.

Water body 4

This water body is defined by physical modifications (Stranmillis and Lagan Weir) and represents the transitional zone of the Lagan. The position of Stranmillis Weir marks the freshwater limits of the River and the Lagan Weir marks the boundary between estuarine and coastal waters under the Urban Waste Water Treatment Directive. Downstream of the Lagan Weir, salinities of >30 are the norm. This area is impounded in order to cover the unsightly, anoxic muds. The salinity regime is managed and hence variable. There is no riparian strip and the channel boundaries are completely artificial. This water body has been declared as a sensitive area under the Urban Waste Water Treatment Directive (2001). The main nutrient inputs to the area are from 2 major waste water treatment works and an industrial fertiliser plant in water body 5.

Water body 5

Water body 5 extends from the Lagan Weir to the end of the dredged channel in the approaches to Belfast Harbour. This water body is defined again by its physical alterations. The Port and Harbour area extend from the Lagan Weir to the end of the dredged shipping channel in the approaches to the Port of Belfast. The area is characterised by engineered walls, docks, wharfs and reclaimed land. There are 3 major dredged channels; Victoria, Herdman and Musgrave Channels. The reclaimed land is the home for most of the heavy industry in Northern Ireland; a ship building and repair yard, aircraft manufacturer and major fertilizer plant. As the major Port in Northern Ireland, the reclaimed land also houses many storage and distribution centres including oil, coal, timber, grain, and animal feed. In addition to freight traffic, the port of Belfast also has many passenger ferries including new generation high speed ships.

Subdivision of water bodies for management purposes

Water body 3 has been further subdivided on the basis of type and extent of physical alteration and therefore on potential management and designation options.

In the middle reaches between Moira and Lisburn the immediate catchment is intensively farmed. The channel in this section of river has a classical U-shaped profile and due to the low gradient of the river, flows are particularly slow through this flood plain. This is an area of periodic flooding which has little physical alteration for flood defence purposes. Sediment deposition is hence enhanced with the dominant substrate being sand and silt encouraging excessive growths of rooted macrophytes each summer. This high level of biological activity is also expressed in sediment anaerobiosis. While sections of this part of the river have undoubtedly been straightened, there is still evidence of the relic natural meanders, although some were removed by private land owners approximately 10 years ago (water body 3a).

Significant sections of the lower river between Lisburn and Belfast have been straightened and canalised as a relic of navigation and in order to prevent flooding in this predominantly urban area (water body 3b). The situation is also reflected in the heavy management of many of the feeder streams in order to enhance the flow characteristics as a means of flood prevention, rather than showing any concern for the natural status of these watercourses. There are still channel cuts throughout the lower river, which are relics of the navigation canal. While these have the potential for use as flood relief and may be the subject of restoration, during the summer periods they represent areas of stagnant water with the associated biological problems of infestation by duckweeds, sediment anaerobiosis, oxygen level fluctuation, pH swings *etc*.

References	Contact
Hale, Peter, David Corbelli, Claire Vincent, Meg Postle, Teresa Venn and John Ash (2002), Heavily Modified Waters in Europe - Case Study on the River Lagan, the Tidal Lagan Transitional Water & the Port of Belfast Coastal Water, Northern Ireland, Environment and Heritage Service and Risk & Policy Analysts, Lisburn and London.	**Peter Hale, Environment and Heritage Service, 17 Antrim Road, LISBURN, BT28 3AL** **peter.hale@doemi.gov.uk**

2. Identification of Water Bodies in the River Solgenan (Sweden)

The definition of a water body is found in the WFD article 2(10). In the HMWB case study on the River Emån, the water bodies are defined as areas where physical conditions are believed to be homogenous, i.e. one kind of disturbance/lack of disturbance is dominating. The sub-catchment of River Solgenån (lower), which is part of the River Emån in the southern Sweden, has been divided into four water bodies by means of the results of a habitat survey (Fig. 10):

WB 1. The area from Lake Solgen down to the regulation of Lake Solgen near Värne. This is a separate area because it lacks any major morphological disturbances.

WB 2. The area from the regulation near Värne down to the dam of the Klinte hydropower plant. This is a separate area because of straightening and clearing of the river channel.

WB 3. The area from the dam of the Klinte hydropower plant down to the area where the influence from the Brunnshult hydropower plant ends. This is a separate area because of the influence from hydropower generation.

WB 4. This water body starts at the area where the influence from the Brunnshult hydropower plant ends and finishes where River Solgenån (lower) meets River Emån. This area is only influenced by minor clearing of the river channel and one smaller hydropower plant, Axelfors.

In this case the division into water bodies was made by means of a habitat survey. Where enough fauna samples are present, the division according to a consistent ecological type should also be taken into consideration. The study area has been divided into water bodies by means of the dominating morphological disturbance/lack of morphological disturbance, which indirectly provides different ecological types. Each water body should be an area which if possible, is only influenced by one kind of morphological disturbance. Apart from the defining of the extent of the water bodies along the river channel, the extent of the water bodies landwards should also be defined. The area, which in the biotope survey (Halldén et al 1999)[1] is refered to as local environment (0-30 m from the river), has been included in the water body definition since this part of the catchment area is the most carefully described one.

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[1] Halldén, A., Bäckstrand, A., Lind, B. och Haag, T. 1999. Biotopkartering Emån 1998 – En kartering av biotoper i och i anslutning till vattendrag inom Emåns avrinningsområde. Länsstyrelsen i Jönköpings län. 209 sidor.

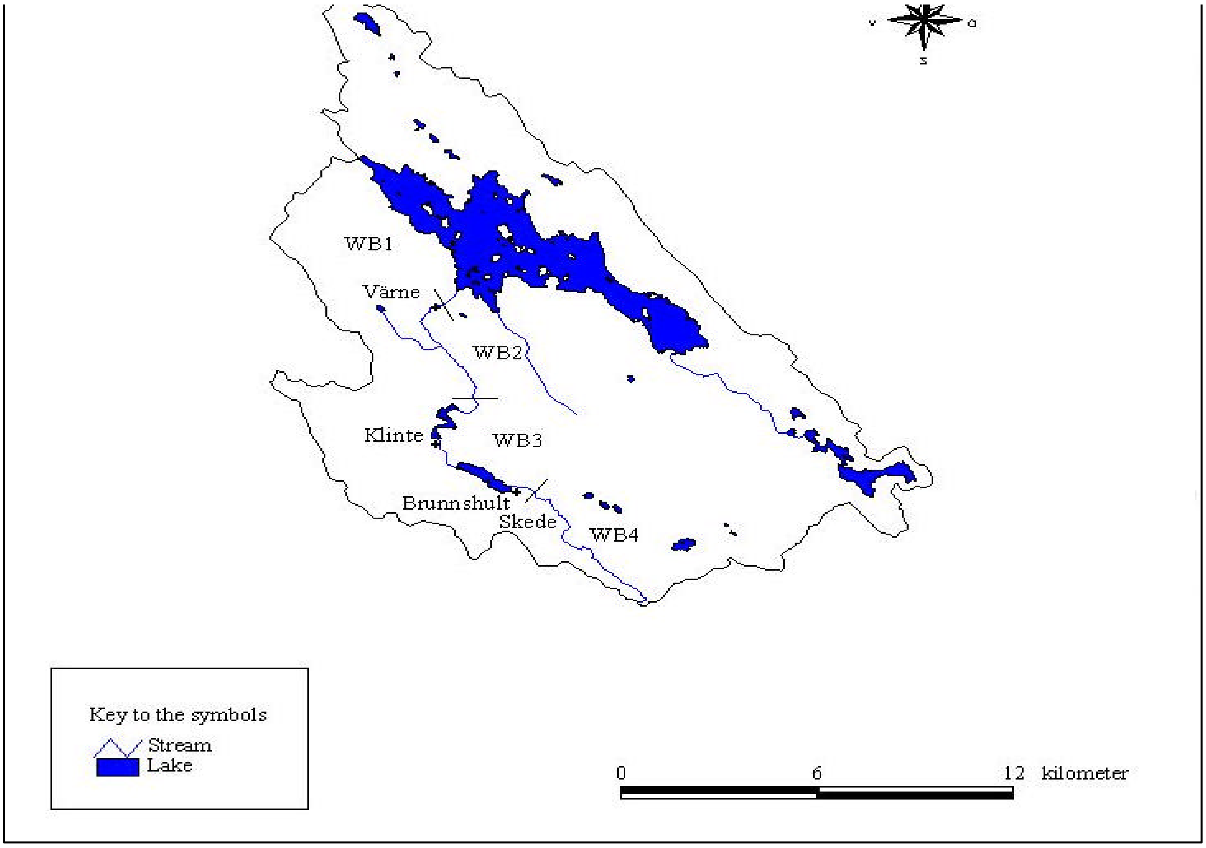


Figure 1: The division of the Solgenån (lower) sub-catchment into water bodies

References	Contact
Weichelt, Anna-Karin (2001), Heavily Modified Waters in Europe - Case Study on the Emån river, Sweden, County Administrative Board Jönköping, Jönköping.	**Weichelt, Anna-Karin, County Administrative Board Jönköping** **akwe@f.lst.se** **Lansstyrelsen@f.lst.se**

3. Grouping water bodies for assessment and designation purposes in the River Dee (Scotland, UK)

This example shows a case where a large number of identified water bodies have been grouped. In this particular case, the channel network is mainly affected by hydropower schemes and as a result, there is multitude of small component reaches and artificial segments such as tail races and aqueducts. Consequently, many of the water bodies identified were rather small (less than 1 km channel length). Grouping of water bodies was chosen as a pragmatic solution in undertaking the ecological assessment and the subsequent designation tests for HMWB.

The identification of water bodies in the Scottish case studies on the Rivers Dee and Tummel has been based principally on recognition of "hydromorphological" and "effective management" units. In the case of the Dee, the network of rivers and streams was first divided into primary hydromorphological units (segments), namely:

- Carsphairn Lane / Water of Ken main stem
- Black Water of Dee / River Dee main stem
- Tributaries to the main stems

In total, 42 individual water bodies were identified within the Galloway Dee system. Once defined, the water bodies were grouped according to the structure from which their modification arises, and finally according to the highest power station of the cascade at which the water collected by the structure(s) is used. A link between hydrological/ecological impact and generation of electricity (and therefore of revenue) is thus established. Figure 1 shows the extent of each group of water bodies. Several sets of unimpacted tributaries and segments of tributaries upstream of "farthest-upstream" structures were also grouped, on the basis of similar impacts, to form large composite water bodies.

The groups of water bodies formed the basis for the subsequent assessment of ecological status, provisional identification and designation of HMWBs. Assessments also took place on the level of the individual water bodies but results were always summarised at the water body group level.

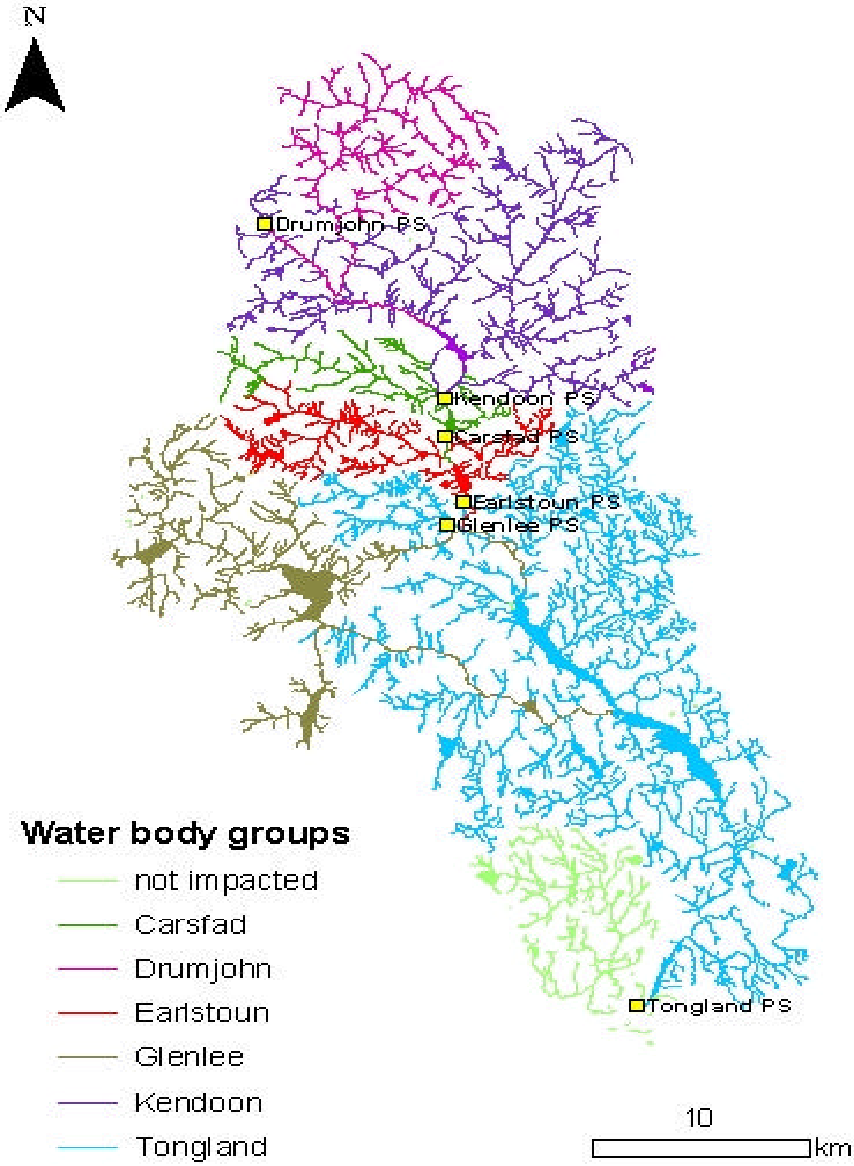


Figure 1: Water body groups defined within the Dee system.

References	Contact
Black, A. R., O.M. Bragg, R.W. Duck, A.M. Findlay, N.D. Hanley, S.M. Morrocco, A.D. Reeves and J.S. Rowan (2002b), Heavily Modified Waters in Europe - Case Study on the River Dee (Galloway, Scotland), Geography Department and Biological Sciences Institute, University of Dundee, and Department of Economics, University of Glasgow, Dundee and Glasgow.	**Andrew Black, Geography Department, University of Dundee** **a.z.black@dundee.ac.uk**

2.2 IS THE WATER BODY ARTIFICIAL (STEP 2)?

	Chapter	Step
HMWB-Guidance	4.3	2

The WFD gives distinct definitions for AWB and HMWB [Art. 2(8) and Art. 2(9) respectively]. In this second step, it should be determined whether the water body concerned is an AWB, i.e. has been "created by human activity". Below you can find following examples:

1. Differentiating between HMW or artificial for water bodies with a complex history and a natural reference condition. Example on the shallow Lake Loosdrecht (Netherlands).

2. Designation of a lake as HMW because of a change of category. Example on the Lake Veluwerandmeren (Netherlands).

Examples

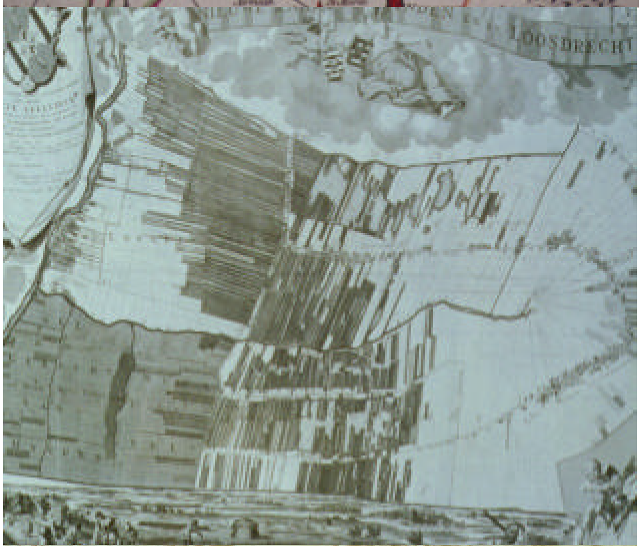
1. Differentiating between HMW or artificial for water bodies with a complex history and a natural reference condition. Example on the shallow Lake Loosdrecht (Netherlands)

The history of hydromorphological changes is complex for many Dutch shallow lakes. The creation of Lake Loosdrecht is a typical example: Human activity made the preconditions for its creation, but natural forces eventually created Lake Loosdrecht. Furthermore, Lake Loosdrecht resembles more a natural shallow lake than an artificial water body. The delineation between artificial or heavily modified water bodies is therefore not straightforward.

History of the creation of Lake Loosdrecht

Before its creation the Lake was Sphagnum peat marsh. In medieval times the peatland was drained for agricultural purposes. In 1633, industrial peat mining started and the peat was dredged from underneath the water surface and left to dry on adjacent banks. In this way an area with ditches and banks was formed. Continued peat mining led to smaller banks. Subsequent wind and wave action eroded the banks. A system of shallow, interconnected lakes originated; Lake Loosdrecht. Historical maps from the years 1585, 1734 and 1850 illustrate the changes from terrestrial peatland to ditches to a number of interconnected lakes.

The year 1585: Loosdrecht is the area under the two lakes Naardermeer and Horstermeer. The peatland was drained for agricultural purposes.



The year 1734: Long ditches have been dredged to mine the peat.

The year 1850: Storms and wave action eroded the small banks and a number of lakes were created.

Designation as HMW or artificial

Physically altered water bodies do not *have to* be designated as AWB or HMWB. The guidance document defines an artificial water body as "a surface water body which has been created in a location, where no significant surface water existed before and which has not been created by the direct physical alteration of an existing water body." According to that definition, there is the option for Lake Loosdrecht to be identified as artificial. However, Lake Loosdrecht resembles more a natural shallow lake than an artificial water. Therefore, the choice was made in this case study not to identify Lake Loosdrecht as an AWB.

References	Contact
Lorenz, C.M. in association with DWR and RIVM (2001), Heavily Modified Waters in Europe - Case Study on Lake Loosdrecht, Witteveen+Bos (W+B), DWR and RIVM, Deventer.	**Lorenz, C.M., Witteveen & Bos, Deventer** **c.lorenz@witbo.nl**

2. Designation of a lake as HMW because of a change of category. Example on the Lake Veluwerandmeren (Netherlands)

Many Dutch shallow lakes have been changed due to a complex history of human impact. A typical Dutch example is the creation of the Lake Veluwerandmeren as a product of the building of dikes and the reclamation of a polder (see Figure 1). The Veluwerandmeren illustrate the designation of a water body as a HMWB because of a change in category.

At present, the Veluwerandmeren are a system of shallow freshwater lakes. In earlier times, the Veluwerandmeren were the border of the Zuiderzee estuarium. In 1924, the Afsluitdike was built as a barrier between the coastal water and the Zuiderzee and the estuarium turned into the freshwater Lake IJsselmeer. The reclamation of the Flevopolder in the period 1955-1970 created the Veluwerandmeren, the borderlakes between new and old land.

According to the guidance document, a water body that has changed category as a result of physical modifications is not an AWB but a HMWB. The Veluwerandmeren have changed from an estuarium to a freshwater lake due to the building of dikes and the reclamation of land. So the Veluwerandmeren would be considered for designation as a HMWB.

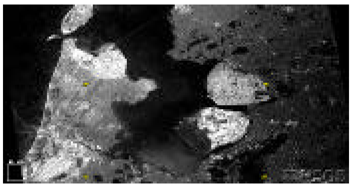
Period	Water body category and name	Physical alteration
before 1924	estuarium Zuiderzee  Old map of the Zuiderzee	
1924		Building of the Afsluitdike
1955-1970	freshwater lake IJsselmeer  Satelite photo of the Ijssellake in 1964: the northern part of the polder is ready, the southern part is dikes but undrained	Reclamation of the Flevopolder
after 1970	freshwater lakes Veluwerandmeren designated as Heavily modified Water 	• Unnatural water levels (summer high, winter low) • Sluices • Artificial banks • Sand and gravel extraction pits

Figure 1: Overview of history of Veluwerandmeren.

References	Contact
Lorenz, C.M. in association with DWR and RIVM (2001), Heavily Modified Waters in Europe - <u>Case Study on Lake Loosdrecht</u>, Witteveen+Bos (W+B), DWR and RIVM, Deventer. Source of satellite photo Ijsselmeer: US Geological survey	**Lorenz, C.M., Witteveen & Bos, Deventer** **c.lorenz@witbo.nl**

2.3 SCREENING (STEP 3)

	Chapter	Step
HMWB-Guidance	4.4	3 and 4

A screening process is likely to reduce effort and time in identifying water bodies which should not be considered for the HMWB designation tests. Those water bodies that will likely fail to achieve GES but show no hydromorphological changes should not be considered for HMWB designation, and hence be "screened out". Below you can find three “screening” examples from the following case studies:

1. Pre-screening method (case studies of England and Wales, UK)
2. Screening in a hydropower transfer scheme in the River Beiarelva (Norway)
3. Selection of pre-candidate sections in the River Sarre (France)

Examples

1. Pre-screening method (case studies of England and Wales, UK)

The designation process for HMWBs requires both the identification of modifications to the water body and economic tests which determine whether or not restoration measures could sensibly be undertaken. To avoid the need to apply the full designation process to all water bodies, it is highly desirable that many water bodies can be excluded from the process at an early stage.

The case studies of England & Wales (UK) used the so-called *'pre-screening methodology'* which involves the collation of data and the screening out of water bodies which are obviously not heavily modified (see Figure 1). The objective of the proposed procedure is, therefore, to enable water bodies to be pre-screened using a combination of available data and local knowledge. The purpose is to direct designation effort to borderline cases rather than those which may be clearly and obviously designated. A second objective is to present the physical context of a river in a standardised format for further consideration. The outcome of the pre-screening process is based on the presence of physical alterations and hydromorphological changes and is subsequently complemented by conclusions on the ecological status of the water body in order to proceed to provisional identification as HMWB or not.

Within the pre-screening process, a detailed description of physical alterations using data from the UK River Habitat Survey (RHS) and the Flood Defence Management System (FDMS) is performed. However, it was also suggested that at the early stages of an investigation, simple data sources can be used to assess physical alterations, such as Ordinance Survey maps. Several parameters measured in relation to both channel and bank modifications are used to derive habitat quality scores as well as Habitat Modification Scores (HMS)[2], by applying a simple set of rules to the RHS data (see Table 1).

Table 1: HMWB Pre-screening pro-forma P1

HMWB Pre-screening pro-forma P1 **River:** **Draft WB:**	**Completed by:** **Date:**			
Stretch:	**Stretch 1 <name>**	**Stretch 2 <name>**	**Stretch 3 <name>**	**Stretch 4 <name>**
Upstream NGR:				
Downstream NGR:				
Approx length (km):				
RHS sites				
Number of RHS sites				
Average spacing of RHS sites (km)				
Percentage of stretch defined by RHS data				
Number of non-candidate sites (HMS <8)				
Number of Borderline sites (HMS = 9-20)				
Number of potential HM sites (HMS >21)				
Percentage of defined stretch:				
Non-candidate				
Borderline				
Potential HMWB				
Channel modifications:				
Wholesale channel moved (% length)				
Additional artificial flood channels (% length)				
Culverts (number)				
Culverts (number per km)				
Weirs (number)				
Weirs (number per km)				
Water level influenced by d/s weir/dam (% length)				
Bed re-sectioned/dredged/deepened (% length)				
Bed reinforced (% length)				
Bank modifications (% length) (NB total length = stretch length*2)				
Bank re-aligned/straightened				
Bank re-sectioned (i.e. widened)				
Bank reinforced (whole)				
Bank toe reinforced				
Bank top embankments				

2 The HMS is currently being reviewed in the light of the wider requirements of the WFD. There are several areas which need fine-tuning for the purposes of HMWB definition, including how unnatural channel width can be scored, and scores for culverts and raised water levels (e.g. due to downstream weirs).

Bank top set-back embankments				
Maintenance (% length)				
Regular maintenance (at least every 2 years)				
Occasional maintenance				
No maintenance				
Data informed by FDMS (% length)				
Overall assessment (NC = Non-candidate, B = Borderline, P = Potential HMWB)				

If the rules are not satisfied, then the water body is a Potential HMWB and further analysis, including application of the designation tests, will be necessary to determine if the water body should proceed to designation as a HMWB.

The final pre-screening methodology proposed is not totally objective but requires local knowledge and data together with a degree of judgement. The given table for pre-screening should ideally be completed in a small workshop where staff from different disciplines can add a variety of experience and knowledge to the process.

When the proposed procedure is implemented, each water body will be divided into General Quality Assessment (GQA) stretches. Each stretch is assessed using the methodology summarised in Figure (see below). Experience and judgement together should be adequate for the assessment of the stretch. If there is any doubt, the stretch should be classified as borderline.

The following guidelines for classification may be useful:

- The presence of high percentages of stretch length with additional flood channels is likely to prevent the stretch from being classified as Non-candidate.
- The presence of weirs and sluices at a frequency of more than 0.3 per km is likely to prevent the stretch from being classified as Non-candidate, particularly where weirs or sluices have a major influence on water levels for a long distance upstream of the structure.
- The presence of re-aligned or straightened channel for more than 25% of the stretch length is likely to prevent the stretch from being classified as Non-candidate.
- If regular maintenance is carried out along most of the stretch, it is unlikely to be classified as Non-candidate.

The decision on progression to designation does not relate to each individual stretch, but to the whole water body. If only one stretch is a non-candidate, it is likely that the water body should proceed to the designation tests. If, however, there is a wide disparity in results across the stretches, consideration should be given to changing the boundary of the water body, or to sub-dividing the water body, as it is likely that it is non-homogeneous.

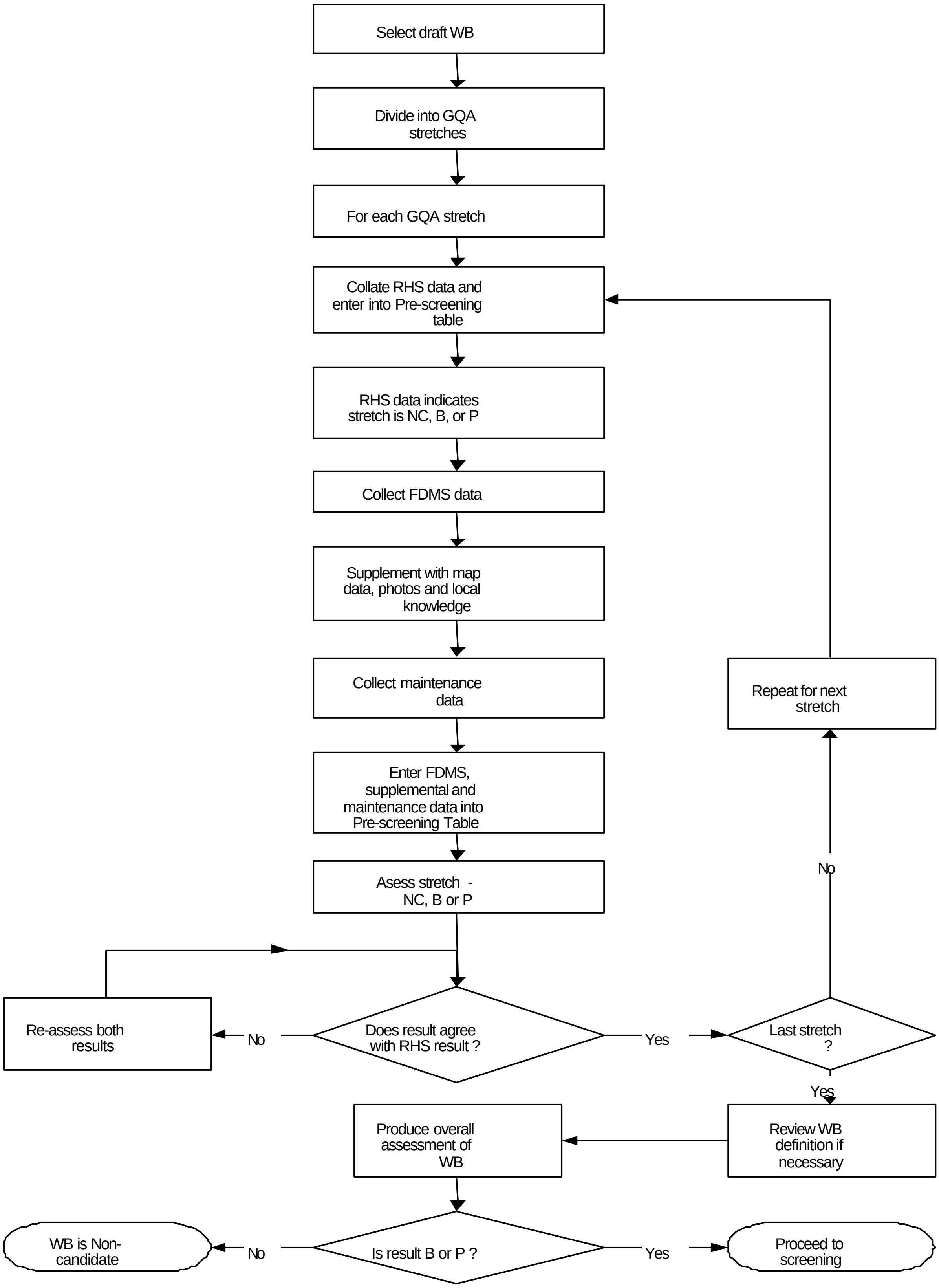


Figure 1: Outline of pre-screening process (NC-non candidate, B-Borderline, P-Potential)

References	Contact
Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002), Heavily Modified Waters in Europe – England and Wales Case Studies, Guidelines on identification, assessment and designation of rivers, Final Draft (Version 4), submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales.	**Michael Dunbar, Centre for Ecology and Hydrology** **Mdu@ceh.ac.uk**

2. Screening in a hydropower transfer scheme in the River Beiarelva (Norway)

The Beiarelva watercourse has been influenced by hydropower development since November 1993. Water is diverted from the river system through 11 intakes located in different tributaries at elevations between 600 and 700 m a.s.l. (Figure 1). One of the intakes is located in the main river itself. The water is permanently removed from River Beiarelva and transferred to the reservoir Storglomvatn, west of Beiarn.

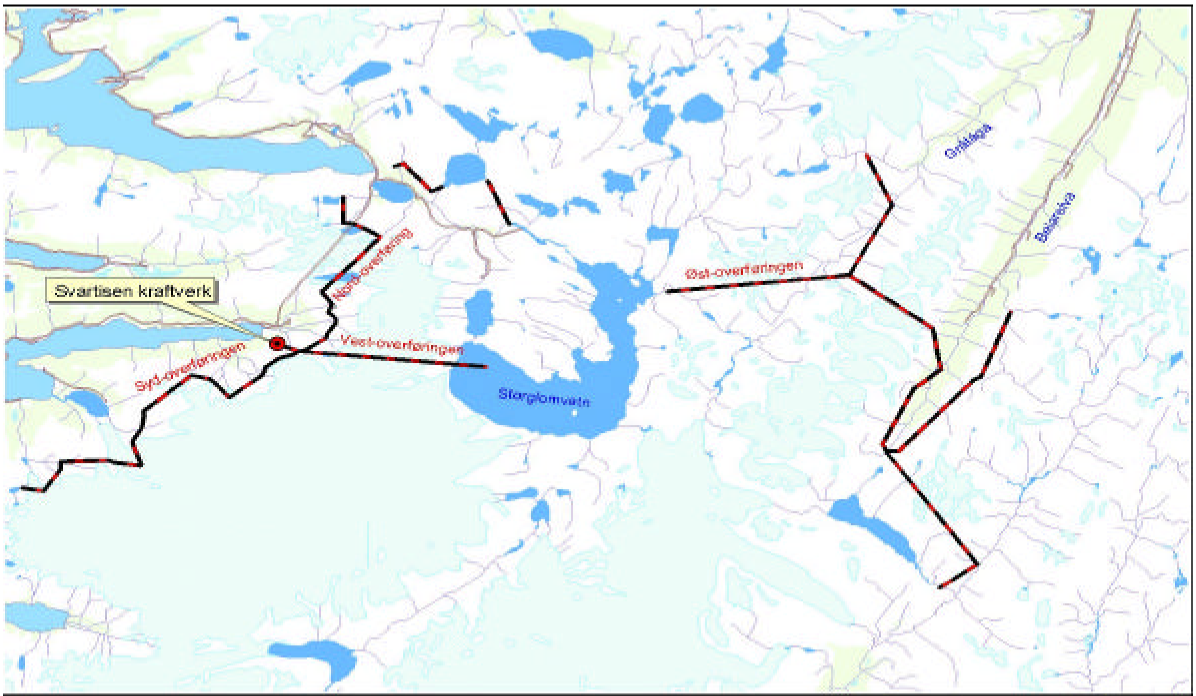


Figure 1: The upper parts of Beiarelva and Gråtåga are transferred into the Reservoir Storglomvatn from the eastern side.

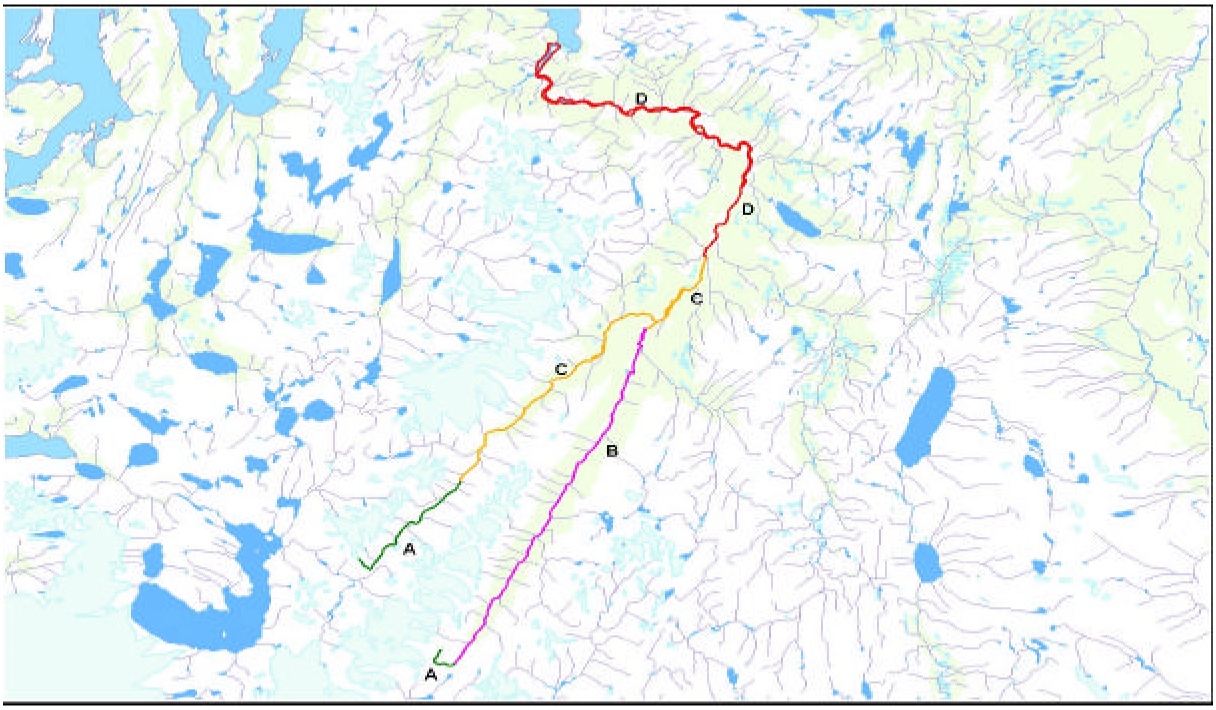


Figure 2: Divided water bodies from the River Beiarelva

The watercourse is divided into four water bodies, all in the river category (Figure 2). Water body A, consisting of the areas above the 11 intakes, is unaltered hydromorphologically, and is screened out of the HMWB identification and designation process, as fish migration upstream is not an issue.

- The specified use for the water bodies B, C and D is hydropower production (through diverted water), and recreation, in particular recreational fishery.
- The main anthropogenic pressure is the diversion of water.
- Water bodies B and C are downstream of the intakes (see Figure 1 and Figure 2). The hydromorphology of water bodies B and C is significantly changed, in a range from loosing all flow below the intakes to 36% reduction at the lower end of water body C. The glacier melt contribution is reduced; most of this water is transferred. As a result of this, sediment load is significantly reduced. In water body D, which is not directly downstream of the intakes, the flow is reduced by 36% at the upper end to 18% at the lower end.

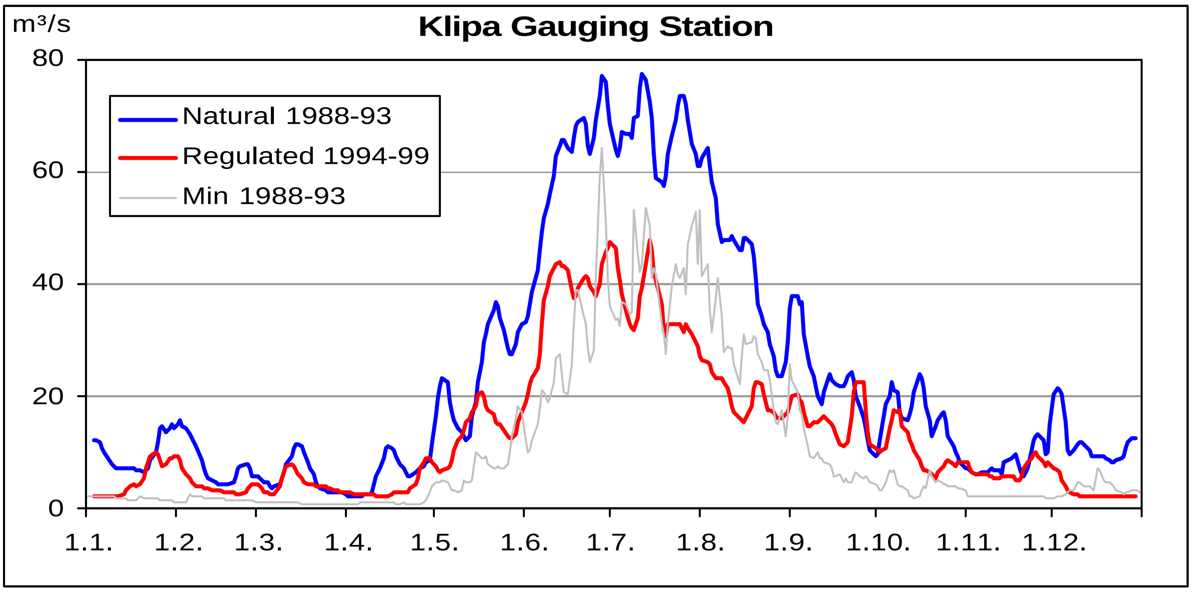


Figure 3: The hydrographs presented below are at the boundary between water body D and C.

As a conclusion, water bodies B and C show hydromorphological changes and significant reduction in sediment transport. Therefore, they are not screened out and should be considered for further detailed assessment. Water body A is screened out because it is unaltered hydromorphologically. Water body D is screened out because it is not directly downstream of the intakes and the only changes are hydrological.

References	Contact
Bjørtuft, Sigurd K., Jan-Petter Magnell and Jan Ivar Koksvik (2002), Heavily Modified Waters in Europe - Case Study on the Beiarelva watercourse, Statkraft Grøner and Norwegian University of Science and Technology (NTNU), Lysaker and Trondheim.	**Bjørtuft, Sigurd K., Statkraft Grøner as** **skb@statkraftgroner.no**

3. Selection of pre-candidate sections in the River Sarre (France)

In the French HMWB case study on the River Sarre, an initial sorting operation of the identified river sections was carried out using a qualitative description for situations which are clear-cut. This selection of pre-candidate HMWBs is also referred to as the 'physical filter' as opposed to the 'biological filter' which is used in the next stage of the ecological assessment. The purpose of HMWB pre-candidate selection is to investigate the physical characteristics of the river basin district and to make a first selection eliminating "obviously little modified and easily reversible" water bodies. It is, therefore, equivalent to a screening step.

In the following approach, the physical characterisation is carried out using transparent and replicable indicators for the description of the water bodies.

Description of water bodies:

The following indicators have been proposed: stream discharge, sediment discharge, riparian vegetation and valley gradient. These provide *a brief physical description* and a *characterisation of modification.* These control variables are subject to the disruptions below caused by the following environmental modifications as established by the HMWB working group:

Table 1: The modification inventory: methodical characterisation

Control variables (Inputs)	**Types of environmental modification**					
	1 Artificial modification of bed and banks	2 Diversion of all or part of the water course	3 Presence of continuous obstacles connecting the two banks of the water course	4 Release of retained volumes from locks	5 Surface runoff, surface sealing	6 Reduction in the surface area of the flood expansion field
Stream discharge	Reorganisation (increase in bankfull discharge) Transverse obstacles Disruption of the regime	Reduction of minimum flows and mean flows, flood control.	Disruption of natural flow rate diversity Disruption of the regime	Disruption of the regime (flood control, minimum flow compensation) Disruption of natural flow rate diversity	Radical reduction in roughness (stream channel and floodplain), increase of flood peaks (discharge from valley sides)	Transformation of hydraulic conditions (reduced flood coverage, concentration of flow)
Sediment discharge	Change in the nature of the river bed and banks	Reduction in the power of the water course (particularly for flows >BD)	Disruption of sedimentary transit	Removal of fine sediment, disruption of sediment discharge regime	Removal of bed load Additional delivery of eroded material	Concentration of erosion-**transport-deposition phenomena**
Riverain vegetation	Clear cutting Allochtonous species Monospecificity	-	Clear cutting around constructions Allochtonous plantations	Bank erosion	Transformation of roughness	Bed erosion and bank destabilisation
Valley gradient	Uplift of the alluvial plain, bed incision	-	-	-	-	Embankment, levelling

These modification types are assessed for each body of water and if present are recorded on the *diagnostic datasheet* (Table 2), which is used for the description and classification of each section.

Table 2: Diagnostic sheet

<table>
<tr><td colspan="3" rowspan="2">Section n°</td><td colspan="2" rowspan="2"></td><td colspan="2">Upstream limit</td><td></td><td colspan="2">Water course name</td></tr>
<tr><td colspan="2">Downstream limit</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="10">BRIEF PHYSICAL DESCRIPTION</td></tr>
<tr><td colspan="4">Type of water course</td><td colspan="6"></td></tr>
<tr><td colspan="6">Mean flow close to the section (m3/sec)</td><td colspan="2"></td><td>Valley length (m)</td><td></td></tr>
<tr><td colspan="6">Average width of the stream channel (m)</td><td colspan="2"></td><td>Sinuosity coefficient[3]</td><td></td></tr>
<tr><td colspan="5">Stream channel depth (description)</td><td colspan="3"></td><td>Channel gradient (‰)</td><td></td></tr>
<tr><td colspan="10">Q1 – MODIFICATIONS TO THE PHYSICAL ENVIRONMENT</td></tr>
<tr><td rowspan="2">Inputs[4]</td><td colspan="6">Modification to environments</td><td colspan="3">Description and Indicators</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>"has the section been significantly modified and in a neither obviously nor easily reversible way?" (Q1)</td><td>Yes</td><td>No</td></tr>
<tr><td>Ql</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Qs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>R</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>P</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7"></td><td>Is section a pre-candidate HMWB?</td><td></td><td></td></tr>
</table>

This description sheet is used as an intermediate decision-making step for the definition of pre-candidate sections. The assessment is based on expert opinion but framed by the following principles:

Choice of pre-candidate water bodies

A water body is designated heavily modified from a physical point of view if its physical characteristics, as a result of human activity, adversely affect the natural morpho-dynamic balance.

During this stage the expert must answer the question:

"1) has the section been significantly modified, and...

2) if yes, has it been done in a neither obviously nor easily reversible way?"

---

[3] Channel sinuosity coefficient = channel length / valley length

[4] Ql: stream discharge; Qs: sediment discharge; R: riverain vegetation ; P: valley gradient

This applies to each of the four variables broken down in the table above in relation to the six types of environmental modification recorded.

The questions above can be broken down into four intermediate questions:

Q1a – *Has the stream discharge been heavily modified **and** in a neither obviously nor easily reversible way?*

Q1b – *Has the sediment discharge been heavily modified **and** in a neither obviously nor easily reversible way?*

Q1c – *Has riverine vegetation been heavily modified **and** in a neither obviously nor easily reversible way?*

Q1d – *Has the valley gradient been heavily modified **and** in a neither obviously nor easily reversible way?*

An affirmative answer to just one of these four questions is enough to designate the section as a pre-candidate HMWB and an ecological analysis is then carried out. The decision criteria will be determined and justified by the expert responsible for selecting the pre-candidate water bodies. As the only purpose of this pre-selection phase is to lighten the workload in the subsequent stages of the process, any doubt should result in the water body being designated pre-candidate.

References	**Contact**
Agence de l'Eau Rhin-Meuse (2002), Heavily Modified Water Bodies – Case Study on the River Sarre, France	**Guillaume Demortier, Agence de l´Eau Rhin-Meuse** **DEMORTIER.G@Eau-Rhin-Meuse.fr**

2.4 SIGNIFICANT CHANGES IN HYDROMORPHOLOGY (STEP 4)

	Chapter	**Step**
HMWB-Guidance	4.5	4

For those water bodies which have not been "screened out" in step 3, significant anthropogenic pressures and the resulting impacts should be further investigated and described [WFD Annex II No. 1.4]. This step 4 is part of the characterisation of surface waters as required in Art. 5(1) by December 2004.

This characterisation involves the identification and description of:

- the main "specified uses" of the water body;
- significant anthropogenic pressures [WFD Annex II No. 1.4]; and
- significant impacts of these pressures on hydromorphology [WFD Annex II No. 1.5].

Below you can find eight examples relevant to step 4. Regarding this step, well-developed and tested methods for describing physical habitat may be useful such as the ones which exist in the UK (UK River Habitat Survey) and in Germany (German Stream Habitat Survey). Reference to the UK River Habitat Survey is made in the first of the following examples on the River Tame. The other examples provide information on other methods (developed or in development) which are used in different Member States for assessing the significance of anthropogenic physical pressures as well as the resulting hydromorphological impacts.

1. Significant changes in hydromorphology resulting from physical pressures in the River Tame (England & Wales, UK)
2. The 'Indicator method' to assess the significance of anthropogenic pressures in the Baltic coastal areas (Sweden)
3. Assessment of the intensity of the physical alteration in the case of River Dender (Belgium)
4. DHRAM application to the Galloway Dee catchment (Scotland, UK)
5. What is a physical alteration (Synthesis Report)
6. Identification and description of the significant pressures in the German case studies (Germany)
7. Identification and description of significant impacts on hydromorphology in the German case studies (Germany)
8. Risk assessment process for assessing the impact of modifications to the morphology of controlled waters (Scotland, UK)

Examples

1. Significant changes in hydromorphology resulting from physical pressures in the River Tame (England & Wales, UK)

The Tame river basin is an example of a catchment with widely varying land use, river use, river modification and ecology. It represents an example of a degraded urban river. The main River Tame runs through the heavily urbanised areas of Birmingham and has been subject to many pressures and modifications. The heavy urbanisation at the top of this catchment is unusual in the context of European rivers. Increased peak runoff due to urbanisation, combined with floodplain development has led to a channel that is heavily engineered for much of its length.

Hydrology

Hydrological regimes in the River Tame are modified by the large areas of impermeable surfaces, combined sewer overflows (CSOs), sewage treatment works (STW) and the addition of discharge from outside the catchment. All these factors combine to produce a flashy flow regime, with high magnitude flood flows that last for short periods of time, low flows are also augmented. This flow regime has led to a large amount of flood defence works and their subsequent effects on channel morphology. There is a lack of hydraulic diversity and disconnection between the river and the floodplain.

River Habitat Survey (RHS) data

The limited number of RHS surveys (five) on the main channel show that the bank material is probably earth with few 'bank features'. Water flows are predominantly smooth but also rippled and often flow over gravel-pebble substrates when visible. No channel features were recorded. Bank and channel vegetation is moderate but limited.

The degree of modification is reflected in low Habitat Quality Assessment (HQA) scores of 13-31 with a mean of only 22 and with upper and lower quartiles ranging from 18-27. Values of around 60 would be expected for benchmark sites of this type of low-energy upland river on soft geology. Management, particularly for access or originally for gravel extraction, probably restricts the development of channel and bank features. Bank vegetation structure (on average an HQA sub score of 5) could be improved to raise the general RHS quality of the river.

Table 1: River Tame Habitat Quality Asessment sub-scores

	RHS Site number	Distance to Source	HQA flow type 95-97	HQA channel substrate	HQA channel features	HQA bank features	HQA bank vegetation structure	HQA point bars	HQA channel vegetation	HQA land use	HQA trees	HQA special features 95-97	Habitat Quality Assesment score
Tame WB1	6693	25	6	3	0	6	5	0	4	3	8	0	35
Tame WB2	3694	40	5	4	0	3	2	0	3	0	3	0	20
Upper Tame[5]	692	13.5	0	4	0	2	11	0	3	0	8	0	28
	3692	16	6	5	0	0	11	0	2	1	2	0	27
	6691	7	5	5	0	4	0	0	10	1	0	0	25
	6692	13	6	3	0	4	2	0	2	1	2	0	20
	16846	14	7	3	0	0	7	0	3	1	3	0	24

[5] Not considered in this assessment

Hydromorphology

The stretch-specific hydromorphological changes, which result from the direct physical pressures, are as follows:

Stretch 1: Flood defence works and straightening of the channel to improve flood conveyance. This has resulted in less hydraulic diversity and lack to habitat refuges and a lack of connectivity with the floodplain.

Stretch 2: Flood banks are present resulting in a lack of connectivity with the floodplain.

Stretch 3: Some channel straightening is present, with flood defence works. This has resulted in less hydraulic diversity and lack of habitat refuges and a lack of connectivity with the floodplain.

Stretch 4: Weirs are present at Lea Marston Lakes in addition to the Lakes themselves. Weirs may be a barrier to fish migration.

Stretch 5: There is an entirely artificial channel in this stretch, as well as modification due to gravel extraction. This has resulted in less hydraulic diversity and lack of habitat refuges and a lack of connectivity with the floodplain.

Stretch 6: Straightening of the channel, road bridges, a canal aqueduct, flood defence works, dredging and re-shaped bank-profiles are all present in this stretch. This has resulted in less hydraulic diversity, lack of habitat refuges and a lack of connectivity with the floodplain.

Conclusions

The River Tame is an example of a highly urbanised catchment with several direct physical pressures. It can be difficult to attribute direct cause and effect relationships where several interacting factors are present. For example, the River Tame has poor hydraulic diversity and a lack of connectivity with the floodplain. This situation is directly attributable to a combination of flood defence works and management practices. However, the impermeable surfaces, combined sewer overflows (CSOs), sewage treatment works (STWs) and importation of discharge from outside of the catchment all contribute to the hydromorphological characteristics.

The Tame example has showed that at the early stages of an investigation, simple data sources can be used to assess physical pressures. Ordnance Survey maps show that the main Tame has an altered course as several reaches have been straightened (e.g. Sandwell Valley Country Park) and that large areas of the catchment have been urbanised and are therefore likely to be impermeable in nature. River Habitat Survey (RHS) data has clearly shown that a high level of channel modification was present and that there is poor hydraulic diversity in these urban rivers.

References	Contact
Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002), Heavily Modified Waters in Europe – Case Study on the Tame Catchment, submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales.	**Michael Dunbar, Centre for Ecology and Hydrology** **Mdu@ceh.ac.uk**

2. The 'Indicator method' to assess the significance of anthropogenic pressures in the Baltic coastal areas (Sweden)

Part of step 4 on the 'significant changes in hydromorphology' is the identification and description of significant anthropogenic pressures on the water body. This includes all physical alterations in morphology and hydrology of the water regime. This example describes the 'Indicator method' which was used in the Swedish case study on "Baltic coastal areas". The area investigated comprises, in the content of this case study, the southern part of Stockholm Archipelago and represents examples of more or less physically modified areas in coastal water environments. Main pressures are urbanisation, navigation and recreation, leading to physical modifications such as straightening of the shoreline, erosion protection, dredging and infrastructure along the shoreline.

The Swedish 'Indicator Method' is proposed as a method to describe the degree and extent of physical alterations (see Table 1 and 2 for a list of the physical alterations which are detected and not detected by the method). The use of the 'Indicator method' is recommended especially for recreational developments, harbours etc. and areas with a large number of geographically small disturbances. The method does not measure actual levels of disturbances but the amount or number of potentially disturbing factors. Indicators used are the number of jetties per km of shoreline, number of buildings per km of shoreline and road length per km of shoreline. The indicators also consider *population centres* with more than 200 inhabitants and surfaces larger than 1 hectare being *paved or heavily modified* for example: asphalt areas, gravel extraction sites and industrial land. Commonly available, official digital maps at a scale of 1:10 000 contain information of roads and buildings. The extension of population centres is obtained from official digital maps at a scale of 1: 250 000. Jetties, piers, quays, boathouses, marinas, and harbours are interpreted from aerial photographs. Either from analogue aerial photographs at a scale of 1:30 000 using a stereoscope or from digital ortho-photographs (aerial photographs at a scale of 1:30 000 or 1:60 000 transformed to orthogonal projection). The location of the constructions are transferred and digitised directly into a Geographical Information System (GIS) using the computer mouse, with an ortho-photograph and a digital map (at an original scale of 1:10 000) displayed on the computer screen. One "jetty" results in one dot "on the screen". The small marinas and big harbours are roughly marked by a polygon.

The shoreline is divided in 1 km long polygons or as long polygons as natural conditions allow when the shoreline is less than 1 km. For doing this, a special script has been developed for the GIS-programme *ArcView*. Each polygon is then classified into the 5 classes of disturbance level according to the number of buildings, jetties or metres of road it contains (see Table 3).

Results are presented as a map with different colours for the different classes. The results of the method can be used as an indirect assessment of hydromorphological impacts. For instance, the extent of related changes such as the number of jetties can be used for the assessment of the extent of shoreline alteration, the number of buildings for the assessment of shoreline alteration and dredging and the extent of erosion/road length for shoreline alteration and reclamation. Some important factors to remember are:

- The Indicator method does not consider natural conditions, for example water exchange exposure, vegetation, or substrate.
- The Indicator method does not consider all types of physical disturbances made by humans but indicates most of them.
- Aerial photographs are not suitable to map features beneath water surfaces.
- The Indicator method does not delimit areas as heavily modified or not; it only indicates that a certain part of the shoreline is more or less disturbed.

Table 1: Physical alterations that are mapped by the Indicator method

Indicator	May be used for	Sources
Numbers of jetties per 1 km of shoreline	Alterations of the shorelines Indirect: Disturbances of adjacent waterbodies	"Ekonomiska kartan" (Official map, scale 1:10 000)
Numbers of buildings per 1 km shoreline	Alterations of the shorelines Indirect: dredging, dumping, erosion	Aerial photographs or orthophotographs
Road length measured in metres per 1 km of shoreline	Alterations of the shorelines Indirect: Dumping/reclamation	"Ekonomiska kartan" (Official map, scale 1:10 000)
Harbours, marinas	Alterations of the shorelines Indirect: erosion, dredging, dumping/reclamation	Aerial photographs, councils, partly official map or charts.
Paved or heavily modified surfaces	Alterations of the shorelines	Aerial photographs, partly official map or charts.
Population centres	Alterations of the shorelines	Röda kartan or Ekonomiska kartan (Official map, scale 1: 250 000 or 1:10 000)

Table 2: Physical alterations NOT mapped by the Indicator method. Suggested other sources

The Indicator method does not map	Examples of how to get the information	Is it possible to use remote sensing?
Dredging	Diving, under water cameras, field controls, registers (if known)	Only for shallow areas (approx. 3m) and with good aerial photographs without shadowed areas.
Erosion from boat traffic	Field controls, diving, and underwater cameras, known ship channels. (Aerial photographs with high resolution).	Only very extensive erosion, not hidden by tree shadows.
Dumping/reclamation	Field controls, diving, and underwater cameras. (Aerial photographs with high resolution).	Dumping over approx. 90 m^2, above the water surface if not completely covered by vegetation.
Drainage from agricultural areas	Monitoring of nutrient levels, vegetation mapping and soil maps.	Seldom
Trawling	Diving, under water cameras, field controls, registers (if known)	No

Table 3: The classification of indication of disturbance

Classes	Levels of disturbance indication	Number of jetties per 1 km	Number of build-ings per 1 km	Road length measured in meters per 1 km
1	Nil	0	0	0
2	Slight	1-4	1-5	0-150
3	Significant	5-10	6-10	151-400
4	Extensive	11-20	11-25	401-750
5	Very extensive	> 20	> 25	> 751

References	Contact
Tullback, Klara and Cecilia Lindblad (2001), Heavily Modified Waters in Europe - A Case Study of the Stockholm Archipelago, Baltic Sea, County Administrative Board of Stockholm, Environment and Planning Department and Department of Botany Stockholm University, Stockholm.	**Klara Tullback, Administrative Board of Stockholm, Environment and Planning Department** **klara.tullback@ab.lst.se**

3. Assessment of the intensity of the physical alteration in the case of River Dender (Belgium)

In the Belgian case study (River Dender), a method of detailed assessment of river physical alterations was presented involving three groups of indicators:

- Indicators of hydrological quality
- stream continuity
- stream morphology

The method described here is also relevant and useful for step 6 of the HMWB identification and designation process, i.e. step on provisional identification of HMWB (see chapter 2.6).

To evaluate the intensity of the physical alteration, stress factors were determined in association with the different uses of the water body. For each of these stress factors, indicators were determined (relating to hydrological regime, river continuity, morphological elements of channel, erosion & sedimentation, navigation and riparian zone). These indicators were evaluated by classification according to the intensity of alterations. Based on the value of each indicator, an order of ranking was set, ranging from 'very heavily modified' (class 5) up to 'no modifications' (class 0) and the relationship between the degree of modification and the value of each indicator was given in a table (table 1). The method was then applied to each of the identified water bodies. The different indicator values were added up in order to be able to evaluate the degree of modification for each water body. The maximum value a section can obtain is the number of indicators multiplied by the maximum value of each indicator. The sum of the indicator values was re-scaled up to a maximum of 100 to compare with other studies or scripts. In this way, it is possible to express the degree of modification as a percentage (see results of the applications of the method on the 18 water bodies of the river Dender in table 2).

Table 1: Relationship between value of indicators and degree of physical alterations/modifications (source: case study on the River Dender, B)

Indicators	Intensity of modification					
	No modi-fication 0	Very limited 1	Limited modi-fication 2	Mediocre modi-fication 3	Heavy modi-fication 4	Very heavy modi-fication 5
Annual sediment trans-port to river (for each VHA-zone)	No sediment delivery	< 1.000 ton/ha	– 2.000 ton/ha	2.000 – 3.000 ton/ha	3.000 – 4.000 ton/ha	4.000 ton/ha
Annual cumulative sedi-ment transport to river	No sediment delivery	< 5.000 ton/ha	5.000 – 10.000 ton/ha	10.000-15.000 ton/ha	15.000 – 20.000 ton/ha	20.000 ton/ha

Indicators	Intensity of modification					
	No modi-fication 0	Very limited 1	Limited modi-fication 2	Mediocre modi-fication 3	Heavy modi-fication 4	Very heavy modi-fication 5
% hardened surface along the banks	0%	0 – 20%	20 – 40%	40 – 60%	60 – 80%	80 – 100%
% agricultural area along the banks	0%	0 – 20%	20 – 40%	40 – 60%	60 – 80%	80 – 100%
Canalisation	None	Gabarit to 300 ton	Gabarit to 600 ton	Gabarit to 1200 ton	Gabarit >1200 ton	
Artificial discharge	Percentage of waste water of the discharge Q_{90} is 0%	Percentage of waste water of the discharge Q_{90} is <20%	Percentage of waste water of the discharge Q_{90} is 20 - 40%	Percentage of waste water of the discharge Q_{90} is 40 - 60%	Percentage of waste water of the discharge Q_{90} is 60 - 80%	Percentage of waste water of the discharge Q_{90} is 80 – 100%
Artificial discharge	Percentage of withdrawals of the discharge Q_{90} is 0%	Percentage of withdrawals of the discharge Q_{90} is <20%	Percentage of withdrawals of the discharge Q_{90} is 20 - 40%	Percentage of withdrawals of the discharge Q_{90} is 40 - 60%	Percentage of withdrawals of the discharge Q_{90} is 60 - 80%	Percentage of withdrawals of the discharge Q_{90} is 80 - 100%
Locks	None	One lock over the entire length of the river	One lock for four river sections	One lock for three river sections	One lock for two river sections	One lock for each river section
Dams/ Water mills	None	One dam over the entire length of the river	One dam for four river sections	One dam for three river sections	One dam for two river sections	One dam for each river section
Intensity navigation (commercial)	None	< 10 boats/year	< 100 boats/year	< 1.000 boats/year	< 10.000 boats/year	>10.000 boats/year
Intensity navigation (recreational)	None	< 10 boats/year	< 100 boats/year	< 1.000 boats/year	< 10.000 boats/year	>10.000 boats/year
Change in sinuosity (winding factor of theriver) between 1850 and 1990)	0	-0.2 – 0	-0.4 - -0.6	-0.6 - -0.8	-0.8 - -1.0	> -1.0
Dredging operations	None	On 0 – 20% of the total length of the river section	On 20 – 40% of the total length of the river section	On 40 – 60% of the total length of the river section	On 60 – 80% of the total length of the river section	On 80 – 100% of the total length of the river section

Table 2: Indicator values for each river section

	Erosion (average of VHA-zone and cumulative erosion)	Degree of canalisation	Locks	Navigation (commercial)	Navigation (recreational)	Sinuosity (straightening)	Dams	Dredging operations	% hardened surface along the banks	Dikes	Impact of the waste water on the discharge	Impact of abstractions on the discharge	% agricultural area along the banks	SUM	Re-scaling to 100%
Mark1	2.5	0	0	0	0	0	5	0	1	0	4	0	0	12.5	19
Mark2	3	0	0	0	0	0	5	0	1	0	4	0	1	14	22
Mark3	3	0	0	0	0	0	5	0	1	0	4	0	1	14	22
Mark4	3	0	0	0	0	0	5	0	1	0	4	0	0	13	20
Mark5	3	0	0	0	0	2.5	5	0	1	0	4	0	1	16.5	25
Dender1	2.5	2	5	2	3	0	0	2	3	2	1	1	1	24.5	38
Dender2	2.5	2	5	2	3	0	0	2	1	2	1	1	0	21.5	33
Dender3	2.5	3	5	3	3	1	0	0	2	3	1	1	0	24.5	38
Dender4	3	3	5	3	3	0	0	3	2	3	2	1	1	29	45
Dender5	3	3	5	3	3	0	0	2.5	1	3	2	1	1	27.5	42
Dender6	3	3	5	3	3	1	0	2	4	3	2	1	0	30	46
Dender7	3	4	5	3	3	2.5	0	4	3	4	3	1.5	3	39	60
Dender8	3	4	5	3	3	1	0	3	2	4	3	1.5	2	34.5	53
Bellebeek1	2.5	0	0	0	0	0	0	0	1	0	2	0	1	6.5	10
Bellebeek2	2.5	0	0	0	0	0	2	0	2	0	2	0	1	9.5	15
Bellebeek3	2.5	0	0	0	0	0	1	0	2	0	2	0	1	8.5	13
Bellebeek4	2.5	0	0	0	0	0	1	0	2	0	2	0	1	8.5	13
Bellebeek5	2.5	0	0	0	0	0	1	0	1	0	2	0	1	7.5	12

The following (objective) classification has been used to determine the degree of physical modification:

- Sum of the different indicator values > 80 = very heavy modification
- Sum of the different indicator values between 60 and 80 = heavy modification
- Sum of the different indicator values between 40 and 60 = mediocre modification
- Sum of the different indicator values is between 20 and 40 = limited modification
- Sum of the different indicator values > 20 = very limited modification.

In the case of the river Dender, the results on the degree of modification are shown in Table 3.

Table 3: Evaluation results of each river section

	Degree of modification
Mark1	Limited modifications
Mark2	Limited modifications
Mark3	Limited modifications
Mark4	Limited modifications
Mark5	Limited modifications
Dender1	Limited modifications
Dender2	Limited modifications
Dender3	Limited modifications
Dender4	Mediocre modifications
Dender5	Mediocre modifications
Dender6	Mediocre modifications
Dender7	Mediocre up to heavy modifications
Dender8	Mediocre modifications
Bellebeek5	Very limited modifications
Bellebeek4	Very limited modifications
Bellebeek3	Very limited modifications
Bellebeek2	Very limited modifications
Bellebeek1	Very limited modifications

The above evaluation method can be used for other streams and catchment areas (if necessary adjustments of the class limits can be made and other stress factors like abstraction of drinking water can be included). It may be necessary to perform a field survey before using this method in other catchment areas.

The results on the degree of modification for each water body are combined with the results of a rating system on the ecological status (5-classes system based on the sum of the different values of indicators, maximum = 100). The provisional identification as HMWB is based on both physical and ecological evaluation. When the degree of modification is > 40 and the ecological status is < 60, then this section is a provisional HMWB.

References	Contact
Vandaele, Karel, Ingrid De Bruyne, Gert Pauwels, Isabelle Willems and Thierry Warmoes (2002), Heavily Modified Waters in Europe - Case Study on the Dender river, the Mark river and Bellebeek river in Flanders, Soresma, environmental consultants and Flemish Environmental Agency, Leuven and Antwerp.	**Karel Vandaele, SORESMA** **karel.vandaele@soresma.be**

4. DHRAM application to the Galloway Dee catchment (Scotland, UK)

DHRAM (Dundee Hydrologic Regime Alteration Method) has been developed as a tool for assessing the severity of hydrologic regime alteration on a 5-class scale, using the concept of risk to indicate the likely severity of regime alteration. The extent of alteration can be ascertained by repeated DHRAM applications at successive points on the river network.

The method is based on the comparison of a two time series of daily mean flows for the same point on the river network. Time series should be long – preferably 20 years or more – and should ideally relate to the same period of time, i.e. one series represents the natural flow behaviour of the river, while the other shows the effects of human alterations to the natural flow pattern. In practice, river flow records from nearby points upstream and downstream of an impact (such as a dam) may be used, or modelled river flows may be used to represent either the natural situation, the impacted one, or both.

The method is intended to give a guide to the severity of hydrological change, and it is assumed that increasing severity will cause an increase in ecological impact. The method uses threshold values which have been obtained from trial applications in Scotland. Values for other Member States or regions may be produced by empirical means with as much reference to known impacts on ecology as possible.

DHRAM is ideal as a screening tool which will identify the sites or reaches in which the greatest hydrological changes have occurred. Such screening may be used to target more focused studies of the aquatic ecology. A distinct variant of the DHRAM methodology has also been developed for lakes, again requiring un-impacted and impacted data. Details are available in the reference below.

DHRAM can also be used to assess likelihood of failing GES in the absence of appropriate biological data. Therefore, the physical estimate of hydrological alteration has been taken as a surrogate of biological status.

The map below shows an application of the DHRAM methodology to the Dee catchment in SW Scotland (~1000 km^2), in which DHRAM classes are shown via the legend provided. DHRAM Class 1 represents essentially un-impacted conditions; Class 5 is the most severely impacted class.

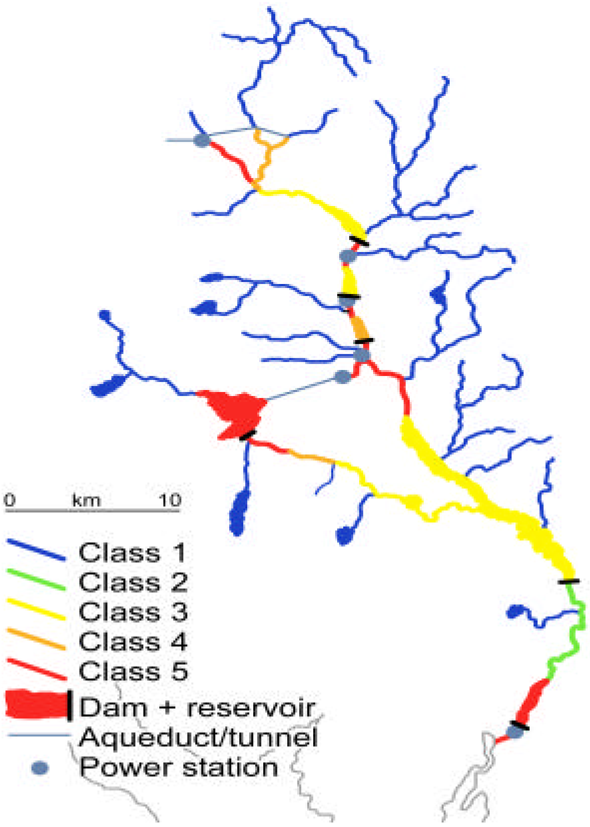


Figure 1: Application of the DHRAM methodology to the Dee catchment

References	Contact
Black, A R, Bragg, O M, Duck, R W, Jones, A M, Rowan, J S and Werritty, A (2000) Methods of assessing anthropogenic impacts on the hydrology of rivers and lochs: A user manual introducing the Dundee Hydrological Regime Assessment Method. Report to SNIFFER, No SR(00)01/2F, Stirling.	**Andrew Black, Geography Department, University of Dundee** **a.z.black@dundee.ac.uk**

5. What is a physical alteration? (Synthesis Report)

Specified uses of water bodies generally result in pressures that might impact the status of the water body. In the context of HMWB and AWB identification and designation process, changes to hydromorphology resulting from "*physical alterations*" are relevant.

Physical alterations include alterations in the morphology and hydrology of the water regime. For example, the most common physical alterations include dams and weirs, which disrupt the river continuum and cause alterations of the hydrologic and hydraulic regime impacts on hydromorphology. In the following tables, lists of the physical alterations and impacts on hydromorphology relevant to the different specified uses are provided.

These were extracted from the HMWB case studies for the purposes of the HMWB synthesis report.

Table 1: Specified use 'Navigation' plus related physical alterations and impacts on hydromorphology

Specified use	Physical alteration	Impacts on hydromorphology
NAVIGATION	RIVERS: CHANNEL/ BED	RIVERS: HYDROLOGICAL IMPACTS
	Locks, mills	Disruption of river continuum
	Dams and weirs	Change of hydrologic regime
	Sluices	Change from running river towards slowly flowing river
	Dredging operations/ channel maintenance	Change of hydraulically characteristics
	Straightening	Reduced velocity,/low flow above weirs
	Canalisation	Water level increase behind weir
	River widening/ deepening	Low water level downstream from weir
	Reservoirs/ impoundment	Change of groundwater level in the area of weirs (dropping below and rising above weirs)
	Cutting of meanders and wetlands	Reduced flow in river bed
	Change in channel course	Elevated flow velocity due to channel regulation
	Removal of islands and river divisions	Decrease of discharge fluctuations (min. and max.)
	Fixation of river bed	Change of storage capacity
	RIVERS: BANKS/ RIPARIAN ZONES	Disconnection from former catchment and discharge into a canal
	Bank reinforcement/ fixation	RIVERS: MORPHOLOGICAL IMPACTS
	Dikes	Loss of morphological variety in cross- and longitudinal profile
	Culverts	Change of linear profile
	floating quays	Loss of original length of river
	Moorings/ marinas	Decreased sinuosity
		Change of river depth/width
		Disruption of sediment transport
		Disturbance of bed load
		Reduced river bed diversity
		Change of particle size of the riverbed (from gravel to silt)
		Increased sedimentation behind weir
		Change of structural characteristics

Specified use	Physical alteration	Impacts on hydromorphology
		Uniform bank structure Detachment /restriction of natural floodplains Reduced exchange between river and riparian zone Loss of riparian zone Silting up of riparian zone Detached/ lost oxbow lakes/ wetlands
	LAKES: BASIN/BED Creation of islands (use of sand from shipping channel) Shipping channels Deepening of shallow areas	LAKES: HYDROLOGICAL IMPACTS Fixed water level/ water level management (high level in summer, low level in winter) LAKES: MORPHOLOGICAL IMPACTS Unnatural lake morphology
	COASTAL WATERS: SUBSTRATUM Shipping channels Deepening of shallow areas Channels/ waterways COASTAL WATERS: SHORELINE Landing stages/jetties/ quays Harbours	COASTAL: HYDROLOGICAL IMPACTS Change in flow direction Interference with water replacement due to quays COASTAL: MORPHOLOGICAL IMPACTS Bottom erosion Resuspension of silt from boats Shore erosion
	TRANSITIONAL WATERS: SHORELINE Shoreline reinforcement/ sea walls Harbours/ ports TRANSITIONAL WATERS: CHANNEL/BED Shipping channels	TRANSITIONAL WATERS: HYDROLOGICAL IMPACTS No changes explicitly noted in the case studies TRANSITIONAL WATERS: MORPHOLOGICAL IMPACTS Interruption of sediment exchange with intertidal areas Altered dynamics of sediment transport throughout the estuary

Table 2: Specified use 'Flood Protection' plus related physical alterations and changes of hydromorphology

Specified use	Physical alteration	Impacts on hydromorphology
FLOOD PROTECTION	RIVERS: CHANNEL/ BED Flood protection dams straightening Cutting of meanders and wetlands dredging/ channel maintenance Storage reservoirs/ impoundment Complete re-location of river channel Channelisation	RIVERS: HYDROLOGICAL IMPACTS Reduced fluvial dynamics Disruption of river continuum Decrease of discharge fluctuations (min. and max.) Accelerated flood waves Loss of vital periodic flooding Elevated flow velocity (channel regulation) Change from running river towards slowly flowing river

Specified use	Physical alteration	Impacts on hydromorphology
	Weirs	Reduced flooding volume
	Change of river depth	Anthropogenic peak flows
	<u>RIVERS: BANKS/ RIPARIAN ZONES</u>	Change of groundwater level in the area of weirs (dropping below and rising above weirs)
	Bank reinforcement/ fixation	Reduced velocity (above weirs)
	Artificial channels (parallel subsidiary)	Water level increase behind weir
	Embankment	Low water level downstream from weir
	Dikes	Reduced flow in river bed
	Culverts	Creation of impounded lakes
		Disconnection from former catchment and discharge into a canal
		<u>RIVERS: MORPHOLOGICAL IMPACTS</u>
		Loss of morphological variety in cross- and longitudinal profile
		Change of river depth/width
		Uniform bank structure
		Steep bank profile
		Disturbance of bed load
		Loss of original length of river
		Decreased sinuosity
		Increased sedimentation behind weir
		Disruption of sediment transport
		Lowered river bottom downstream of weir
		Reduced river bed diversity
		Change of particle size of the riverbed (fro
		m gravel to silt)
		Reduced diversity of bank structure
		Detachment /restriction of natural floodplains
		Reduced longitudinal and lateral connectivity
		Loss of riparian zone
		Silting up of riparian zone
		Detached/ lost oxbow lakes/ wetlands
	<u>LAKES: SHORELINE</u>	<u>LAKES: HYDROLOGICAL IMPACTS</u>
	Bank reinforcement/ fixation	Fixed water level/ water level management (high level in summer, low level in winter)
		<u>LAKES: MORPHOLOGICAL IMPACTS</u>
		Unnatural lake morphology
	<u>COASTAL WATERS: SHORELINE</u>	<u>COASTAL: HYDROLOGICAL IMPACTS</u>
	Straightening of shoreline	Change in flow direction
	Sea walls	Interference with water replacement due to quays
		<u>COASTAL: MORPHOLOGICAL IMPACTS</u>

Specified use	Physical alteration	Impacts on hydromorphology
		Bottom and shore erosion
	TRANSITIONAL WATERS: SHORELINE	TRANSITIONAL WATERS: HYDROLOGICAL IMPACTS
	Shoreline reinforcement/ sea walls	Altered tidal prism due to land claim
		Reduced tidal volume
		Reduced tidal amplitude
		TRANSITIONAL WATERS: MORPHOLOGICAL IMPACTS
		Interruption of sediment exchange with intertidal areas
		Altered dynamics of sediment transport throughout the estuary
		Reduced intertidal area

Table 3: Specified use 'Hydropower/Water supply' plus related physical alterations and impacts on hydromorphology

Specified use	Physical alteration	Impacts on hydromorphology
HYDROPOWER/ WATER SUPPLY	RIVERS: CHANNELS/BED	RIVERS: HYDROLOGICAL IMPACTS
	Hydropower stations /Dams	Disruption of river continuum
	Storage reservoirs/ impoundment	Artificial flow regime / discharge (upstream and downstream)
	Run-of-river structures	Change from river or estuary to freshwater lake
	Catchwater intakes	Reduced discharge/ flow and drying out (downstream of dams and catchwaters)
	Water diverting structures	Reduced water velocity
	Pipelines & aqueducts	Reduced flow in river bed
	Weirs	Violation of natural seasonally in flow regime
	Straightening	Extreme peaking amplitudes
	Channelisation	Reduced flood peaks
	Clearings (removal of boulders and stones, deepening)	Reduced occurrence of large floods
	RIVERS: BANKS/RIPARIAN ZONE	Loss of bed scouring floods
	Bank reinforcement/ fixation	Seasonal changes in flow regime
	Removal of riparian forest	Cross-catchment transfer
		Change in total water supply to segments of the river
		Permanent diversion /zero discharge downstream
		Reduction of glacier coverage/ change in annual flow distribution (lower in summer)
		Increased ice cover upstream of dams
		Disappearance of ice jam events

Specified use	Physical alteration	Impacts on hydromorphology
		RIVERS: MORPHOLOGICAL IMPACTS Linear profile modified / change in river profile Change in area and perimeter of reservoir Disruption / reduction of sediment transport Change in streambed morphology Reduced river bed diversity
		Accumulation of sediment in reservoir bottom / before dam
		Altered channel morphology downstream of dam Accumulation of sediments in upper river parts / reduced river transport capacity Reduction of total load of suspended material Interruption of litter transport Change from diverse substrate to fine particle sediment (siltation) Inadequate supply of sediment to delta Erosion downstream of dam Increased riverbed level Reduced exchange between river and riparian zone Reduced diversity of bank structure Detachment /restriction of natural floodplains Restriction of riparian zone Detached oxbow lakes/ wetlands
	LAKES: BASIN/ BED Hydropower stations /Dams Storage reservoirs/ impoundment LAKES: SHORELINE Bank reinforcement/ fixation Removal of riparian forest	LAKES: HYDROLOGICAL IMPACTS Lake/ reservoir level regulation Increase of lake/ reservoir level fluctuation Low flow/turn over of water (in detached lakes) Raise of natural lake level (especially in summer) Decrease of water level during ice-covered period-large areas under ice exposure LAKES: MORPHOLOGICAL IMPACTS Erosion of lake margins/ geomorphologic change of littoral zone Change in riparian vegetation/ bank morphology

Table 4: Specified use 'Agriculture/Forestry' plus related physical alterations and impacts on hydromorphology

Specifies use	Physical alteration	Impacts on hydromorphology
AGRICULTURE/ FORESTRY	RIVERS: CHANNEL/ BED Timber floating structures Diversion dams/ weirs Straightening (Water abstraction/ intakes) RIVERS: BANKS/ RIPARIAN ZONES Land drainage/ ditches Artificial channels (parallel subsidiary) Land reclamation Land use change Soil and bank erosion Plantation of water-demanding trees (poplar) Cattle fences Removal of riparian forest Dikes	RIVERS: HYDROLOGICAL IMPACTS Change of hydrological regime Change of hydraulically characteristics Artificial flow Affected connection with ground WB Lower groundwater buffer capacity (due to drainage) Large seasonal variations in flow quantity RIVERS: MORPHOLOGICAL IMPACTS Sediment transport into stream from field erosion Change of erosion/ sediment pattern (sediment supply) Change of structural characteristics Restriction of natural floodplains Change in river profile Detachment of wetland
	LAKES: BANKS Land reclamation	LAKES: HYDROLOGICAL IMPACTS Reduction of seepage water into lake LAKES: MORPHOLOGICAL IMPACTS No changes explicitly noted in the case studies
		OTHER IMPACTS Change of water quality (input of run-off)

Table 5: Specified use 'Urbanisation/industry' plus related physical alterations and impacts on hydromorphology

Specified use	Physical alteration	Impacts on hydromorphology
URBANISATION INDUSTRY	RIVERS: CHANNEL/ BED Dams and weirs straightening Gravel extraction/ spoil grounds Fixation of river bed	RIVERS: HYDROLOGICAL IMPACTS Change of hydrological regime Change of hydraulically characteristics Altered frequency of flooding Flashier flow due to reduced infiltration

Specified use	Physical alteration	Impacts on hydromorphology
	Pits/mines/ slagheaps	RIVERS: MORPHOLOGICAL IMPACTS
	(Water abstraction/ intakes)	Change of erosion/ sediment pattern (sediment supply)
	RIVERS: BANKS/ RIPARIAN ZONES	Change of structural characteristics (river depth, width)
	drainage/ ditches	Uniform bank structure
	Channels/ waterways	Reduced exchange between river and riparian zone
	Bank reinforcement	Restriction of natural floodplains
	Land reclamation	Loss of riparian zone
	Infrastructure (buildings, roads, bridges)	Reduced river bed diversity
		Decreased sinuosity
	LAKES: BASIN/BED	LAKES: HYDROLOGICAL IMPACTS
	Sand extraction	No changes explicitly noted in the case studies
		LAKES: MORPHOLOGICAL IMPACTS
		Creation of holes in lake bottom (sand extraction)
	TRANSITIONAL WATERS: SHORELINE	TRANSITIONAL WATERS: HYDROLOGICAL CHANGES
	Land reclamation	Altered tidal prism due to land claim
		TRANSITIONAL WATERS: MORPHOLOGICAL CHANGES
		No changes explicitly noted in the case studies
		OTHER IMPACTS
		Change of water quality (input of wastewater)

Table 6: Specified use 'Recreation' plus related physical alterations and changes of hydromorphology

Specified use	Physical alteration	Impacts on hydromorphology
Recreation	Rivers: channel/ bed	Rivers: HYDROLOGICAL impacts
(including angling, boat traffic)	Shipping channels	No changes explicitly noted in the case studies
	Creation of impounded lakes	Rivers: Morphological changes/impacts
	Rivers: banks/ riparian zones	Change of bank structure
	Marinas	Caving in of banks
	Tow path	
	Land reclamation	
	Buildings	
	Landing stages/ marinas	
	Roads	
	Picnic/ recreation areas	
		Other impacts
		Change of water quality

References	Contact
Hansen, Wenke, Eleftheria Kampa, Christine Laskov and R. Andreas Kraemer (2002), Synthesis Report on the Identification and Designation of Heavily Modified Water Bodies (draft), Ecologic (Institute for International and European Environmental Policy), Berlin, 29th April 2002.	**Ecologic Institute for International and European Environmental Policy,** **kampa@ecologic.de**

6. Identification and description of significant anthropogenic pressures in the German case studies (Germany)

Step 4 of the provisional identification of HMWB (identification and description of significant changes in hydromorphology) requires among other topics the identification and description of significant anthropogenic pressures [Annex II No. 1.4]. For that purpose, it is important to identify which pressures are "significant" because only this category of anthropogenic pressures (or physical alterations) has to be considered. A clear definition of what significant anthropogenic pressures are is necessary in order to achieve a consistent procedure and comparable statements by all Member States. Examples for significant anthropogenic pressures (or physical alterations) caused by the uses "navigation" and "hydropower generation" are given in the table below (see Table 1). A modified list of the LAWA (Länderarbeitsgemeinschaft) criteria for the identification of significant pressures on surface-waters also includes criteria for the uses of flood protection, agriculture, water supply and urbanisation (see Table 2). In order to make the criteria for "being a significant pressure" more distinct and to simplify the assessment/decision whether a pressure is significant or not, the 2nd column contains pressures which are not significant. These are criteria/arguments for the designation as natural WB.

The assessment of the significance of anthropogenic pressures is the first step of a 3-step process leading to the provisional identification of HMWB. The following steps include:

- Step 2: evaluation of ecological status (failure to achieve good status or not); and
- Step 3: separation of the impacts of a significant pressure upon hydromorphology and biology into negative and positive lists according to the findings of steps 1 and 2.

The aim of this approach is to simplify the HMWB provisional identification (and later designation) process by defining "non-significant" physical alterations (positive list) and "significant" physical alterations (negative list). A positive list means that for these physical alterations, measures can be identified to achieve good ecological status. A negative list includes physical alterations which influence the biology so strongly that the water body must be identified (and later designated) as heavily modified. Therefore, the development of a negative list leads to the provisional identification of the water body as heavily modified.

Table 1: Significant and not significant anthropogenic pressures at the Lahn river caused by navigation and hydropower generation – examples

Significant anthropogenic pressures	Not significant anthropogenic pressures
➢ Artificial alteration of river hydromorphology - Ratio of profile depth to profile width 1:4 and/or - Bank fixation (single or both sides) 10 % of total length of the WB and/or - Longitudinal profile 70 % stretched or straightened[6]	➢ Alteration of river hydromorphology not extensive - Ratio profile depth to profile width < 1:4 and/or - Bank fixation (single or both sides)< 10 % of total length of the WB and/or - Longitudinal profile < 70 % stretched or straightened
➢ Canalisation and maintenance as national water way	➢ WB is not a national water way
➢ Artificial barriers/ transversal buildings (such as weirs, sluices, river bottom sleepers etc.) not passable for fish fauna (and macroinvertebrate fauna)[7]	➢ Passable artificial barriers
➢ Impounded river sections at mean low water flow > 10 % of total length of the WB or single impoundments > 1.5 km	➢ Impounded river sections at mean low water flow 10 % and single impoundments < 1.5 km
➢ Compensation flow below hydropower plants < 1/3 of the mean low water flow above[8]	➢ Compensation flow below hydropower plants 1/3 of the mean low water flow above
➢ Missing cross-linking of the WB with ox-bow-lakes, spawning- and breeding habitats at river banks and in the flood plain	➢ Cross-linking with ox-bow-lakes and spawning- and breeding habitats existent

6 Equivalent to the LAWA (Länderarbeitsgemeinschaft) criteria “hydromorphological parameters profile depth, bank fixation and longitudinal profile 5”(5=distinctly affected) (LAWA 1998).

7 If no information about passability is available the criteria “height > 30 cm” for impassability (“height 30 cm” for passability) can be used (LAWA 2001).

8 As a first clue according to LAWA (1988). The exact value depends on hydromorphological quality and other individual properties of the WB (Jorde and Schneider 1998, Jorde 1999).

Table 2: LAWA criteria for the identification of significant pressures on surface-waters for the uses: flood protection, water supply, urbanisation

Specified uses	Significant pressures	Not significant pressures
Agriculture/ Forestry	tillage and grassland >50% of the catchment area	tillage and grassland 50% of the catchment area
	special crops >3-5% of the catchment area	special crops < 3-5% of the catchment area
	not passable artificial barriers with a height > 30 cm	artificial barriers with height 30 cm, passable artificial barriers with height > 30 cm
	> 50% of the entire river length in the rural landscape is impaired in the adjacent land zone	50% of the entire river length in the rural landscape is agriculture-like impaired in the adjacent land zone
Water supply	drafts > 10% of mean low water flow	drafts 10% of mean low water flow
	Fluctuated discharge ≥ 10% of mean water flow	Fluctuation of the discharge < 10% of mean water flow
	No minimum discharge (according to respective land regulations) in rivers	minimum discharge (according to respective land regulations) in rivers
	without recharge > 0,1 mean low water flow per single installation and > 0,5 mean low water flow total	without recharge 0,1 mean low water flow per single installation and 0,5 mean water flow total
	with recharge > 0,3 mean low water flow per single installation	with recharge 0,3 mean low water flow
Urbanisation	urban areas > 10-15% of the river length	urban areas < 10-15% of the river length
	> 50% of the entire river length are urban with bank fixation	50% of the entire river length are urbane with bank fixation

References	Contact
Borchardt, Dietrich and Petra Podraza (2002), Heavily Modified Waters in Europe – Case Study on the river Dhünn, Institute for Water Resources Research and Management, University Kassel, Kassel **Frey, Michaela, Dietrich Borchardt, Markus Funke and Ingrid Schleiter (2002a),** Heavily Modified Waters in Europe - Case Study on the Elbe River, Institute for Water Resources Research and Management University Kassel, Kassel. **Funke, Markus, Dietrich Borchardt, Michaela Frey and Ingrid Schleiter (2002),** Heavily Modified Waters in Europe - Case Study on the Seefelder Aach River - , Institute for Water Resources Research and Management, University of Kassel, Kassel.	**Dr. I. Küllmar, University of Kassel** **ingrid.kuellmar@uni-kassel.de** **PD Dr. D. Borchardt, University of Kassel** **Dietrich.Borchardt@uni-kassel.de**

Jorde, K. and Schneider, M. (1998). Einsatz des Simulationsmodells PHABSIM zur Festlegung von Mindestwasserregelungen. Wasser + Boden 50, Heft 4, S. 45-49.	
Jorde, K. (1999). Die Problematik des Restwassers. In: Lebensraum Fließgewässer – Charakterisierung, Bewertung und Nutzung. Laufener Seminarbeiträge 4/99. Bayerische Akademie für Naturschutz und Landschaftspflege, Laufen.	
LAWA (2001). Ermittlungen signifikanter Belastungen und Beurteilung der Auswirkungen auf Oberflächengewässer gemäß Anhang II der Wasserrahmenrichtlinie (WRRL). LAWA-Ausschuss "Oberirdische Gewässer und Küstengewässer". Entwurf, unveröffentlicht.	
LAWA (1998). Gewässerstrukturgütekartierung in der Bundesrepublik Deutschland – Verfahren für kleine und mittelgroße Fließgewässer.	
LAWA (1988). Grundsatzfragen zu Schwellenwerten im Niedrigwasserbereich.	
Schleiter, I., Borchardt, D., Frey, M., Funke, M. and Geffers, K. (2002). Identification and Designation of Heavily modified water bodies under the Water Framework Directive. Case study on the river Lahn. By order of the German Federal Environmental Agency (UBA).	

7. Identification and description of significant impacts on hydromorphology in the German case studies (Germany)

Examples of significant impacts on hydromorphology resulting from the pressures are (thresholds concerning small, middle and large running water bodies):

- Extensive discharge acceleration and river bed erosion due to

  - Ratio of profile depth to profile width 1:4 and/or

  - Bank fixation (single or both sides) 10 % of total length of the WB and/or

- Longitudinal profile 70 % stretched or straightened[9]

- Interruption of river continuity and sediment transport, prevention of fish migration[10]
- Artificial flow regime: low flow velocities, absence of natural flow variability
- Eutrophication manifested at lower threshold levels for nutrients; as a result increased temperature and elevated pH- and oxygen fluctuations
- Lack of spawning- and breeding habitats, i.e. natural reproduction and conservation of the stock is not possible[11]
- Missing cross-linking of the WB with ox-bow-lakes, spawning and breeding habitats at river banks and in the flood plain

Pressures and impacts can often be difficult to separate because of chain reactions. An impact resulting from one pressure may cause another impact, i.e. becomes a pressure itself. Furthermore, cause-effect-relations are not linear but multidimensional. Some pressures cause several different impacts (e.g. weirs and river straightening) while, on the other hand, one impact is caused by several pressures (e.g. artificial flow regime).

References	Contact
LAWA (1998). Gewässerstrukturgütekartierung in der Bundesrepublick Deutschland – Verfahren für kleine und mittelgroße Fließgewässer. **Schleiter, Ingrid, Dietrich Borchardt, Markus Funke and Michaela Frey (2002),** Heavily Modified Waters in Europe - Case Study on the River Lahn , Institute for Water Resources Research and Management, University Kassel, Kassel.	**Dr. I. Küllmar, University of Kassel** **ingrid.kuellmar@uni-kassel.de** **PD Dr. D. Borchardt, University of Kassel** **Dietrich.Borchardt@uni-kassel.de**

8. Risk assessment process for assessing the impact of modifications to the morphology of controlled waters (Scotland, UK)

A Series of risk assessment tables have been developed by the Scottish Environment Protection Agency (SEPA) to assist identification of pressures and assessment of impacts

9 Equivalent to the LAWA criteria "hydromorphological parameters profile depth, bank fixation and longitudinal profile ≤ 5" (5=distinctly affected) (LAWA 1998).

10 Impassability for fish (and benthic invertebrate) fauna is no impact on hydromorphology in the strict sense.

11 Not an impact on hydromorphology

on the morphology of freshwaters. The same process is also relevant for assessing the likely impact of future engineering activities that are likely to cause a deterioration in the status of /or compromise the restoration objectives for relevant waterbodies. The information provided in the risk assessment tables can assist steps 3, 4 and 5 of the designation process by helping to screen those water bodies with significant pressure on hydromorphology and by estimating likely impact of identified activities and modifications.

The process involves:

1. Identification of channel type

Different types of channel are differentially vulnerable to change. Classifying river channel types is notoriously difficult; as with any classification system, it involves identifying recognisable “types “ within a continuum.

Table 1 shows a broad, tentative, generic classification scheme for Scottish rivers. This has been developed from a classification that McEwan (1998) produced for Scotland and a scheme that Montgomery and Buffington (1998) produced for classifying rivers in north-west America. The classification starts with channel types that are more characteristic of upland areas where the main constraint on channel changes are limitations in sediment supply (e.g. bedrock lined channels – step pool systems). Moving downstream in catchments, channels sequentially become more characterised by levels of sediment transport (plane bed – pool/riffle – regime channels capacity) and, with the exception of braided channels (which can occur in a variety of situations tend to become more common in piedmont and lowland environments. A great many rivers, particularly in lowland Scotland have been heavily impacted by river engineering in the past, and their characteristics reflect their modified nature rather than the influence of natural channel controls.

2. Assessment of channel sensitivity

It is clear that some channels (such as cascade and step-pool reaches) are robust and relatively insensitive to flood events, whilst others (such as regime or braided reaches), are more dynamic and more sensitive to change.

The sensitivity of a channel reflects the interaction of sediment load, transport capacity and bank strength. Sensitivity will have a key influence on how particular channels will respond to different types of management. Robust channel types will be relatively insensitive to even quite large management intervention, whilst more sensitive channels may respond to small changes in any of the controlling variables shown in Figure 2. For example, removal of bankside vegetation may significantly accelerate erosion on a pool-riffle or regime type channel.

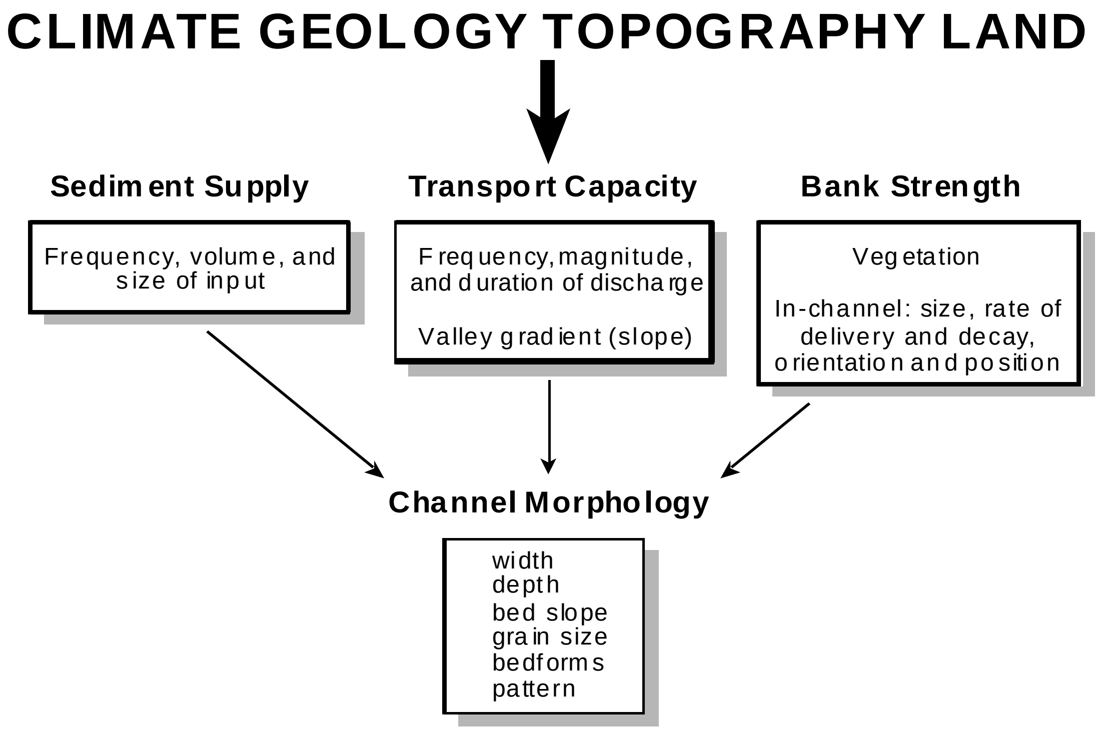


Figure 1: Conceptual model of controlling influences on channel morphology

3. Identification of key habitat features

Key habitat features for each channel type are then taken from the UK River Habitat Survey (RHS), see section 2.3 of the HMWB toolbox for an example of how this methodology is used in the pre-screening process.

4. Assessment of likely biological impact

Examples of habitat usage by associated species are then provided to aid estimation of the biological impact of past/future river engineering activities.

The full process involves reference to meta tables of management objectives and engineering activities associated with different river types and a pressure – state – response matrix for river management activities for particular channel types.

Table 1: Generic classification of Scottish river channel types

Channel Type	Predominant bed material	Channel pattern	Typical slope (%)	Dominant sediment sources	Typical pool spacing (channel widths)	Channel sensitivity	Key habitats (referable to RHS features)[12]	Examples of habitat usage by associated species
Bedrock	Bedrock	Generally straight	Variable	Fluvial erosion and hillslopes	Variable	Very robust	Bedrock shelves Exposed boulders Deep pools	Lichens including river jelly lichen Bryophytes Salmon, sea trout
Cascade	Boulder	Generally straight	8-30	Fluvial erosion and hillslopes	Variable	Robust – change limited to extreme events	Exposed boulders Marginal deadwater	Lichens Bryophytes
Step Pool	Cobble/boulder	Generally straight/sinuous	4-8	Fluvial erosion and hillslopes	<1	Robust – change limited to extreme events	Exposed boulders Marginal deadwater	Lichens Bryophytes
Plane bed	Gravel/cobble	Generally sinuous/meandering	1-4	Fluvial erosion	None	Robust but sensitive to large events	Stable sand patches Gravel beds Eroding cliffs	Fresh water pearl mussel Terrestrial invertebrates Salmonid spawning
Pool/riffle	Gravel	Sinuous/meandering	0.1-2	Fluvial erosion (especially bank erosion)	5-7	Dynamic and sensitive to change	Stable sand patches Gravel beds Eroding cliffs Exposed gravel bars	Fresh water pearl mussel Salmonid spawning Terrestrial invertebrates Aquatic macrophytes
Regime	Fine gravel/sand	Meandering	<0.1	Fluvial erosion (especially	5-7	Relatively stable	Eroding cliffs Stable cliffs	Terrestrial invertebrates Juvenile lampreys (silt

[12] NOTE: important habitats additional to those listed below may occur at any site

				bank erosion)			Discrete sand and silt deposits Exposed gravel bars	deposits) Aquatic macrophytes Marginal macrophytes Cliff nesting birds
Braided	Variable	Multi-thread channels	<3	Fluvial erosion (especially bank erosion)	Variable	Highly dynamic and sensitive to change	Exposed gravel bars Side channels and floodplain wetlands Eroding cliffs	Terrestrial invertebrates Aquatic macrophytes Cliff nesting birds Pool/wetland species
Modified channels	Variable	Often straightened	<3	Fluvial erosion and hillslopes	Variable	Variable; some may be very stable, other may be sensitive	Stable banks	Water vole Marginal vegetation

References	Contact
SEPA Technical guidance note on assessing the impact of modifications to the morphology of controlled waters.	**David Corbelli, SEPA** **David.corbelli@sepa.org.uk**

2.5 LIKELIHOOD OF FAILING GOOD ECOLOGICAL STATUS (STEP 5)

	Chapter	Step
HMWB-Guidance	4.6	5

Based on the information gathered in step 4 and an assessment of the ecological status, the likelihood of failing to achieve good ecological status (or an estimate of what GES may be, based on current knowledge) should be assessed [Annex II No. 1.5]. This should consider whether the risk of failing GES is due to hydromorphological changes and not other pressures such as toxic substances or other quality problems. Step 5 is part of the "risk assessment"[13] process to be completed by 22 December 2004. In order to assess the likelihood of failing to achieve GES, the ecological impacts of physical alterations on the water bodies in question should be estimated. For this step, Norway has contributed an example from the River Beiarelva.

1. Likelihood of failing Good Ecological Status in a hydropower transfer scheme on the River Beiarelva (Norway)

Example

1. Likelihood of failing Good Ecological Status in a hydropower transfer scheme in the River Beiarelva (Norway)

The Beiarelva watercourse is divided into four water bodies, all in the river category. According to step 3 (screening), water bodies B and C show hydrological changes and significant reduction in sediment transport. Therefore, they have not been screened out and proceed to further assessment.

The ecological status is judged to be high to good for all biological and physiochemical elements in all water bodies, except from for macroinvertebrates in B and C, where the status is considered to be moderate.

River continuum is permanently broken at the intakes. This is, however, of minor importance in an ecological context.

In order to increase the invertebrate abundance in the water bodies B and C to a level as before 1993, it is necessary to increase the water surface to the pre-regulation conditions.

[13] The "risk assessment" is undertaken as part of the Article 5 characterisation process and identifies the likelihood of water bodies to fail the environmental quality objectives set under Article 4.

That means, in this context, to discontinue the transfers and reduce the hydropower production in Svartisen hydropower plant accordingly.

A minimum flow might have improved the situation. In order to really amplify the water cover, such a flow must be of a considerable size, and the hydropower reduction will be significant, particularly due to the high pressure head in the plant. The likelihood of failing GES is high for water bodies B and C.

References	Contact
Bjørtuft, Sigurd K., Jan-Petter Magnell and Jan Ivar Koksvik (2002), Heavily Modified Waters in Europe - Case Study on the Beiarelva watercourse, Statkraft Grøner and Norwegian University of Science and Technology (NTNU), Lysaker and Trondheim.	**Bjørtuft, Sigurd K., Statkraft Grøner as** **skb@statkraftgroner.no**

2.6 IS THE WATER BODY SUBSTANTIALLY CHANGED IN CHARACTER DUE TO PHYSICAL ALTERATIONS BY HUMAN ACTIVITY (step 6)? PROVISIONAL IDENTIFICATION OF HMWB

	Chapter	Step
HMWB-Guidance	4.7	6

If it is likely that the water body will fail to achieve good ecological status due to hydromorphological changes, then the water body may be provisionally identified as heavily modified according to the criteria set out in section 4.7 of the HMWB guidance document. For this step, Norway and Finland have contributed examples. A useful method for the provisional identification of HMWB is also described in chapter 2.4 on step 4 [see example 3: “Assessment of the intensity of the physical alteration in the case of River Dender (Belgium)“].

1. Provisional identification of HMWB in the River Beiarelva (Norway)
2. Method for provisional identification of regulated lakes (Finland)

Example

1. Provisional identification of HMWB in the River Beiarelva (Norway)

The Beiarelva watercourse is divided into four water bodies, all in the river category. Water bodies B, C and D are all affected by the water diversion (see Figure 1 at step 3, example 2). The sediment load in water bodies B and C is significantly reduced.

The likelihood of failing GES is high for water bodies B and C. This failure is due to the reduced flow and reduced sediment load, and is thus caused by physical alteration.

There is a substantial and permanent alteration in the physical character of water bodies B and C, especially during summer. This is most pronounced in the upper part of the river, close to the intakes, but the water covered area is strongly reduced all through these two bodies.

This substantial change is a result of the specified use hydropower production. Water bodies B and C are provisionally identified as HMWB.

References	Contact
Bjørtuft, Sigurd K., Jan-Petter Magnell and Jan Ivar Koksvik (2002), Heavily Modified Waters in Europe - Case Study on the Beiarelva watercourse, Statkraft Grøner and Norwegian University of Science and Technology (NTNU), Lysaker and Trondheim.	**Bjørtuft, Sigurd K., Statkraft Grøner as** **skb@statkraftgroner.no**

2. Method for provisional identification of regulated lakes (Finland)

The provisional identification of HMWB has to be undertaken by 2004 and the designation by 2009. In the provisional identification phase, the aim is to identify those water bodies where physical pressures have caused substantial changes in the characteristics, as well as in the ecological status of the water body. In the final designation phase, the definition of ecological status and the possibilities to achieve it are the main subjects of interest. In many water bodies, there is lack of systematically gathered biological data. Besides, there are many open questions related to the classification of water bodies. Therefore, a method that is based on the use of indirect criteria would support the identification of heavily modified regulated lakes.

In most of the Finnish regulated lakes, the alteration of water level fluctuation is the most important physical pressure. The morphological changes are of minor importance or they are primarily due to hydrological changes. The ecological impacts of water level fluctuation have been the target of intensive research since the 1980's, and various methods have been developed to estimate the ecological impacts of lake regulation. A water level analysis tool has been developed to calculate the values for 50 different water level based indicators, characterising the impacts on e.g. aquatic macrophytes, littoral zoobenthos and fish reproduction (Hellsten *et al*. 2002). However, expert judgement is needed to interpret the results and to assess e.g. the ecological significance of water level fluctuation.

Description of the method

The method is comprised of three main phases (Figure 1).

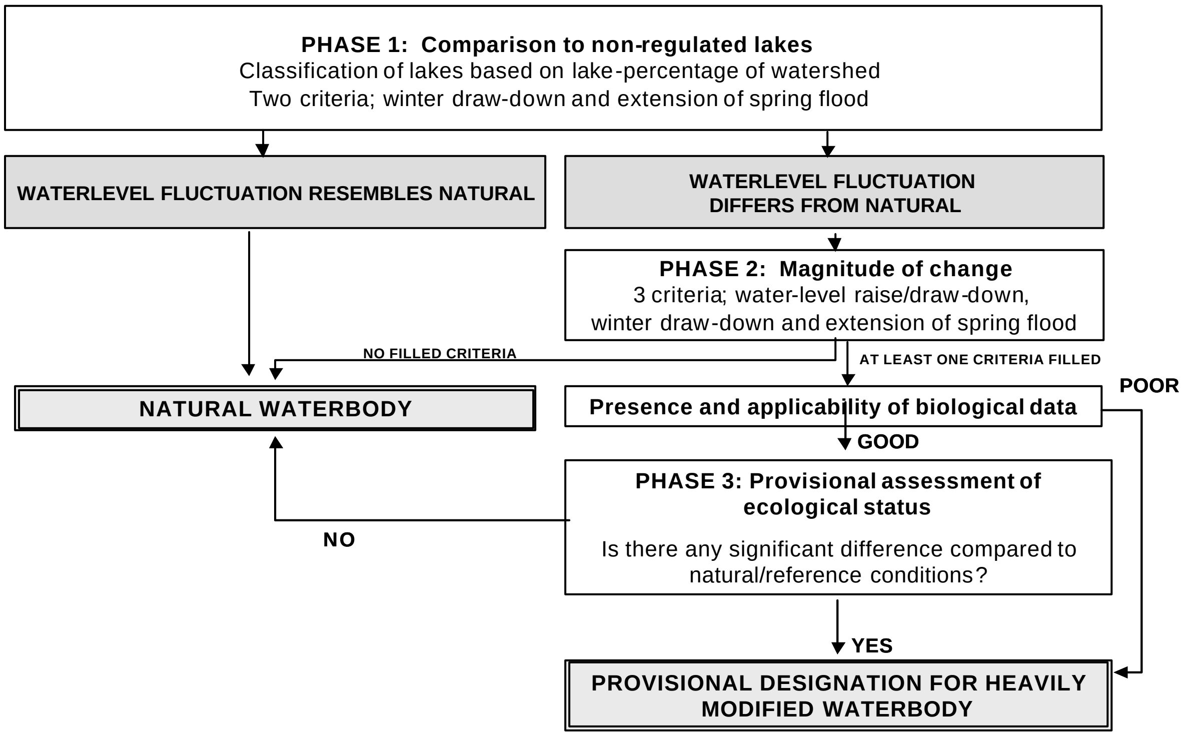


Figure 1. Phases of the provisional designation of regulated lakes

PHASE 1: The first phase was to identify those lakes that belong to the same lake type and which deviate from lakes with natural water level fluctuation. Both in the first and second phase the same two criteria have been applied, the magnitude of winter draw-down and extension of spring flood. The choice of the criteria was based on biological data from more than 20 regulated lakes and statistical analysis. Aquatic macrophyte and littoral zoobenthos data analyses suggest that in Finland where the ice cover period normally lasts from December to May the winter draw-down has significant adverse impacts by freezing sensitive species. The magnitude of the spring flood affects vegetation zonation, e.g. in lakes with a small spring flood the sedge (*Carex*) zone has been observed to be very narrow.

PHASE 2: In the second phase, the changes in mean water level are considered, as well as the criteria of phase 1. The uplift or lowering of the mean water level might have dramatic impacts on the water ecosystem. Impacts depend on many lake specific factors (e.g. mean depth, area, time after action), and no clear threshold values can be presented; therefore, the degree of modification is concluded by expert judgement. Those lakes that fulfil one or more of the designation criteria will probably be designated as heavily modified.

PHASE 3: The third phase is optional. In this phase, a trend-setting assessment of biological status will be carried out only in those lakes where good biological data is available. The results of the biological analysis can confirm or reject the result of the second phase.

One of the basic ideas of the WFD classification system is to define reference conditions for each lake type and to assess the ecological status by comparing the current status to the reference status. The provisional typology of Finnish lakes suggests that the water level fluctuation can be taken into account if necessary. As a result we have divided lakes into three groups: lakes with watershed lake-percentage less than 7 %, 7-15 %, or more than 15 %. For each group, various threshold values for criteria were applied (Table 1). The division is based on the statistical analysis of the water level fluctuation and characteristics of the drainage basin of 105 non-regulated lakes. The results showed that the most important factor affecting water level fluctuation was the lake percentage of the watershed. It explained nearly 70 % of the variation.

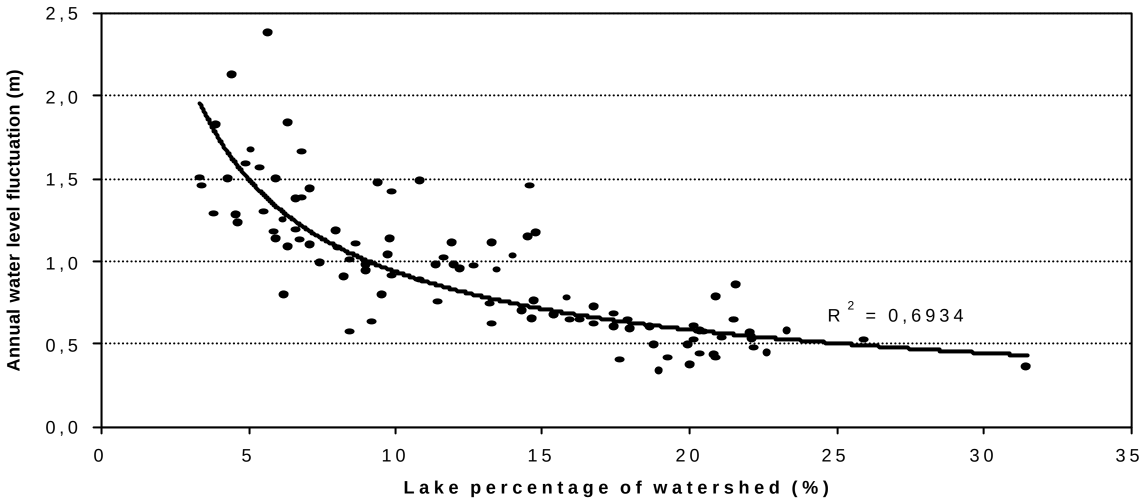


Figure 2: The relationship between lake percentage of watershed and annual water level fluctuation

The results of the provisional designation method:

PHASE 1: IDENTIFICATION OF THOSE REGULATED LAKES WHOSE WATER LEVEL FLUCTUATION DIFFERS FROM A NON-REGULATED LAKE OF THE SAME TYPE

There are about 330 regulated lakes in Finland. This method has been applied to 52 of them. Fortytwo of these differ from non-regulated lakes and are thus considered as possibly heavily modified lakes in phase 2 (Figure 3). The threshold values of the criteria in phase 1 are described in Table 1.

Table 1: The values of criteria to identify those regulated lakes where water level fluctuation differs from natural.

	Lake percentage of watershed		
	<7%	7-15 %	>15 %
Winter draw-down	> 0.6 m	> 0.6 m	> 0.3 m
Magnitude of spring flood	< 0.6 m	< 0.25 m	< 0.15 m

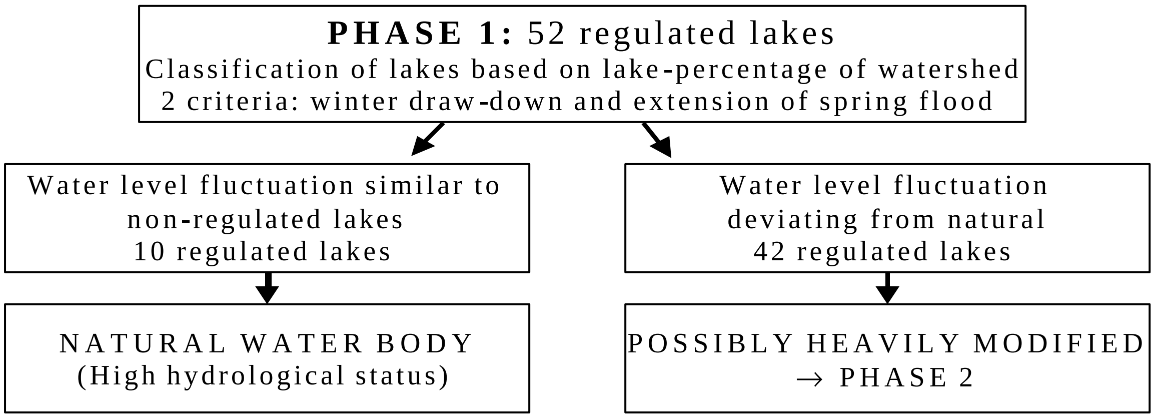


Figure 3: The results of phase 1

PHASE 2: IDENTIFICATION OF LAKES WHERE SUBSTANTIAL CHANGES IN WATER LEVEL FLUCTUATION HAVE OCCURRED

In the second phase, the changes in water level fluctuation caused by regulation are analysed. Though the general impacts of lake regulation are quite well known, there are, however, many lake specific factors which can alleviate or strengthen the impacts of regulation. Additionally, there are many open questions related to implementation of the WFD. These factors cause uncertainty, which hampers the identification of heavily modified water bodies. Therefore, two different sets of threshold values have been applied for designation criteria (see Table 2). In order to be designated as heavily modified, at least one criterion has to be fulfilled. The raising or lowering of the average water level in the beginning of regulation have not yet been included in the analyses. The investigated lakes have been relatively large varying from 2 km^2 to 1 100 km^2 with the mean size of 300 km^2. In large lakes the changes caused by the lowering of the mean water level are not as significant as in small lakes where it can lead e.g. to a substantial increase of aquatic macrophytes. Whereas, a rise of the mean water level can increase erosion and cause landslides.

Table 2: Threshold values for the criteria applied in phase 2

	"Broad criteria"	"Strict criteria"
Increase in the winter draw-down	1.5 m	3 m
Decrease in the spring flood	0.7 m	1.2 m
Change in mean water level	Expert judgement	

A total of 41 lakes passed phase 1 to phase 2. Of those, 4 - 11 lakes were entered to the group of possibly heavily modified depending on whether the broad or strict criteria were applied (Figure 4).

PHASE 2: 41 regulated
3 criteria:
Change in mean water level, winter draw-down, magnitude of spring flood

Broad criteria
Heavily modified: 11
Borderline cases: 7
Natural: 24

Strict criteria:
Heavily modified: 4
Borderline cases: 3
Natural: 35

Possibly heavily modified water bodies/borderline cases
& biological data available
→ **PHASE 3**
Possibly heavily modified water bodies
& NOT enough biological data
→ **PROVISIONALLY HEAVILY MODIFIED LAKE**

Figure 4: The results of phase 2

PHASE 3: TREND-SETTING ASSESSMENT OF ECOLOGICAL STATUS

In the third phase, a trend-setting assessment of ecological status is carried out. Biological elements such as macrophytes, zoobenthos and fish are analysed with various methods describing taxonomic composition and abundance.

References	Contact
Hellsten, S., Marttunen, M., Visuri, M., Keto, A., Partanen, S. and Järvinen, E.A. 2002. Indicators of sustainable water level regulation in northern river basins: a case study from the River Paatsjoki water system in northern Lapland. Large Rivers Vol. 13, No. 3-4. Arch. Hydrobiol. Suppl. 141/3-4, p. 353-370. **Hämäläinen H., Koskenniemi, E., Kotanen, J., Heino, J., Paavola, R. & Muotka, T. 2002.** Benthic invertebrates and the implementation of WFD: sketches from Finnish rivers. Typology and ecological classification of lakes and rivers. TemaNord 2002:566. **Ilmavirta, V. & Toivonen, H. 1986.** Comparative studies on macrophytes and phytoplankton in ten small, brownwater lakes of different trophic status. Aqua Fennica 16: 125-142.	**Mika Marttunen, Finnsh Environment Institute** **Mika.marttunen@ymparisto.fi**

3 TESTS LEADING TO THE DESIGNATION OF HMWB (STEPS 7 -9)

3.1 DESIGNATION TEST 4(3)(a) (step 7)

Designation test 4(3)(a)

Regarding this step please refer to the respective section of the HMWB guidance document:

	Chapter	Step/Sub-steps
HMWB-Guidance	5.4	7/ 7.1-7.3

3.1.1 IDENTIFICATION OF "RESTORATION MEASURES" TO ACHIEVE GES (STEP 7.1)

The first sub-step of the designation test 4(3)(a) is to identify the hydromorphological changes (restoration measures) which could lead to the achievement of GES. Below you will find extracts from the case studies on the Lake *Kemijärvi, River Hagmolen-Hegebeek and River Great Ouse* illustrating the identification of restoration measures and their effectiveness in achieving GES. There is also a list of some possible measures for hydropower and navigation.

1. List of possible restoration measures to achieve GES (synthesis report)
2. The assessment of effectiveness of restoration measures in the Stream Hagmolen-Hegebeeck (Netherlands)
3. The assessment of effectiveness of restoration measures in the River Great Ouse (England & Wales, UK)
4. Hydromorphological changes to achieve GES in regulated river stretches downstream of dams (River Lozoya, Spain)

Examples

1. List of possible restoration measures to achieve GES (synthesis report)

The hydromorphological changes for achieving GES (restoration measures) may range from measures aimed at reducing the environmental impact of the physical alteration to measures resulting in the complete removal of the physical alteration.

Initial check lists of restoration measures to improve hydromorphology are helpful for different specified uses.

For the uses hydropower and navigation, the following lists were worked out by the subgroups "Hydropower" and "Navigation".

Table : 1 List of Restoration Measures for Hydropower

Water flow and water-level fluctuations	reintroduce a spring flood
	decrease flow during summer to winter
	avoid flash floods downstream dams
	introduce minimum flows
Habitat improvements	terrace tributary outlets (reservoirs)
	reduce erosion in riparian zone
	return boulders to channel (former rapids)
	seed and plant species
Disruption in river continuum	remove dam
	build in fish passages, improve existing fish passages
	co-ordinated spillway releases (multiple dams)

Table 2: List of Restoration Measures for Navigation

Dams and Weirs	build in fish passages, improve existing fish passages
Channel maintenance / Dredging	reduce intensity of dredging
Channelisation / Straightening	connecting existing meanders to the main channel
	initiating meanders
Bank reinforcement	more natural embankments
Detachment of ox-bow lakes and wetlands	cross-linking of the river by deepening the ox-bow-lakes
	establishment of natural floodplains

References	**Contact**
-	**Contact leaders of the sub-groups:** **Bettina Rechenberg for navigation and Robert Konecny for hydropower**

2. The assessment of effectiveness of restoration measures in the Stream Hagmolen-Hegebeeck (Netherlands)

Hagmolen-Hegebeek is a small transboundary stream (length 27 km), located in the eastern part of the Netherlands at the border to Germany. This case study was chosen because it represents a typical lowland stream of the Netherlands significantly impacted by agriculture. The stream has been changed by channelization, the building of weirs and drainage in the catchment to optimise the hydrological conditions for agricultural use. Since the building of the Twente Canal (1936) for navigation, the Hagmolen-Hegebeek has been cut off the catchment of the stream Regge and flows directly into the Canal.

Choosing the necessary “restoration measures” to achieve GES

The required hydromorphological changes relate to the restoration of the three types of physical alterations to achieve GES in the Hagmolen-Hegebeek, namely:

- change in morphology;
- change in catchment areas and
- change in hydrology of the catchment.

The question is which hydromorphological change will lead to the good ecological status. To answer this question the ecological effect of the different changes has to be predicted: what is the effect of restoring only the morphology of the stream? What is the ecological improvement in case the hydrology is restored as well? To what extent has the hydrology to be restored? What is the natural, undisturbed discharge pattern of the stream? These are difficult questions and only a calibrated ecological model could predict quantitatively the effect of measures taken in the stream or catchment on the ecological condition over the whole length of the stream. Such a model is not available (yet). Therefore, a combination of expert judgement, data analysis and literature has been used to determine the hydro-morphological measures needed to achieve a good ecological status. We chose the approach of comparing the Hagmolen and Hegebeek with comparable reference streams (respectively the Ruenbergerbeek and the Hagmolenbeek) in order to detect the major factors for a certain ecological condition in a stream. The conclusions of the comparison are the following:

1. *Upstream part of the Hegebeek*

The Hegebeek has a moderate to good ecological quality. The Hegebeek has a natural morphology and no weirs. The hydrology of the Hegebeek has been changed by human impact; the German catchment has been enlarged and the hydrology of the German catchment has been adapted to agricultural needs (e.g. drainage). Due to the periodic high discharges from the German part of the catchment, the stream has become situated very low in the stream valley due to erosion. Although the Dutch part of the Hegebeek itself has no weirs, the parts upstream and downstream of the Hegebeek have numerous barriers limiting the migration of fish into the Hegebeek. Furthermore, the water quality is not suitable for sensible rheophilic species due to low oxygen values. Hydromorphological changes needed to achieve the good ecological status are:

- Restoration of the hydrology in the upstream German catchment of the Hegebeek leading to a more natural quantity and dynamics of flow. This should lead to higher stream velocities and quantities of flow in summer.

- Improvement of the possibilities for migration for fish and macro-invertebrates.

2. Downstream part of the Hegebeek and Hagmolenbeek

This part of the stream has a low ecological quality. Comparison with the reference stream showed that restoration of the natural morphology and improvement of the water quality will probably lead to an ecological status between good and moderate, depending on the amount of precipitation in a year (ecological status is higher in wet years). To achieve a stable good ecological status, the quantity and variation of flow probably has to be restored as well.

The validity of comparing the Hagmolen and Hegebeek with comparable reference streams in order to detect the major factors for a certain ecological condition in a stream is debatable. Two streams can be comparable to a certain extent, but they are never completely the same with regard to hydrology, morphology and ecology. This means that the derivation of the required hydromorphological changes to achieve Good Ecological Status on the basis of a comparison with a reference stream remains uncertain. It would be preferable to use a well-calibrated ecological model. This model should be based on a large number of data of different streams for the prediction of the required hydromorphological changes. As this model is not available (yet), we use the method of comparison with a reference stream.

Effectiveness of the necessary “restoration measures”

Therefore, three types of measures can be distinguished to improve the hydrology and morphology in the Hagmolenbeek. The three types of measures are:

1. Restoration of the morphology of the stream

2. Restoration of the former catchment area by removal of dividing works and reconnection and disconnection of catchments

3. Restoration of the hydrology in the catchment by decreasing the level of drainage in the catchment and increasing the groundwater level

A summary of the effect of the measures on the hydrology and morphology is described in table 1. A modelling exercise has been carried out to determine the effect of the first two measures on the hydrology and morphology of the Hagmolenbeek. The modelling results predict the relative effect of the restoration of the natural morphology and restoration of former catchments compared with the present situation. This means that only relative conclusions can be made on the basis of the modelling. The effect of the third measure (restoration of the hydrology in the catchment) has been determined by the use of literature and expert-judgement. A more detailed description of the modelling and expert judgement is presented in appendix B of the HMWB case study on the river Hegebeek-Hagmolenbeek (in Dutch).

Table 1: A summary of the effect of the restoration measures on the hydrological, morphological and ecological characteristics of the Hagmolenbeek

Measure	Description of measure	Effect on morphology	Effect on hydrology	Effect on ecology
Morphology restoration	the restoration of the former meandering pattern of the stream. changing the profile of the stream from the present broad profile with steep banks to a profile, in which the basic discharge is transported through the main channel (zomerbed). At high discharges, the additional water is transported through the riparian zone and floodplains (winterbed). allowing natural stream vegetation to grow on the banks. the restoration of side-channels and marsh areas in the stream valley. removal of weirs	Natural morphology is restored: the stream meanders and side channels occur natural vegetation grows on the banks and marshes occur in the stream valley the habitat diversity increases	The stream velocity increases strongly The diversity of stream velocity increases due to the higher morphological diversity The period of a stream velocity > 5 cm/s increases Due to the removal of weirs the stream will stand clear of water during dry periods instead of stagnant water in the present situation. Probably some pools will still be filled with water. The maximum water depth decreases The minimum water depth becomes zero (stream stands clear of water) instead of a certain minimum water depth as in the present situation (being determined by the height of the weirs)	Positive effect: The increased diversity of morphology and stream velocities has a positive effect on the species diversity The increase in stream velocity and the increase in the period of flowing water will stimulate rheophilic species Negative effect: The risk of a stream standing clear of water during dry periods increases The resulting vegetation may reflect higher trophic levels than desired (as a result of higher nutrient concentrations in the surface water)
Reconnection Buurserbeek	It is still uncertain if the Buurserbeek had been connected to the Hagmolenbeek in former times. The reconnection has been modelled by increasing the quantity of flow with 10% at the connection of the Rutbeek with the Hagmolenbeek	Morphological processes, such as erosion and sedimentation, will intensify at higher quantities of flow leading to a higher habitat diversity and a lower level of the stream bottom. This holds only in case the stream morphology has been restored.	The stream velocity increases to a limited extent The period of a stream velocity > 5 cm/s does not differ from the present situation Due to the presence of weirs the stream will have stagnant water during dry periods The maximum water depth increases due to a higher quantity of flow The minimum water depth is	Positive effect: It is expected that the limited increase in stream velocity will stimulate rheophilic species The risk of a stream standing clear of water during dry periods will probably decrease Negative effect: The risk of extreme high quantities of flow increases. These high quantities of flow can lead to the flushing out of species

			determined by the height of the weirs The risk of a dry stream will probably decrease. This will depend on the quantity of flow of the reconnected stream during dry periods.	
Restoration of morphology and reconnection of the Buurserbeek	Combination of the two measures described above	Restoration of the natural morphology as described above and increase of morphological processes due to higher quantities of flow	The stream velocity increases the most strongly compared to the other measures and the present situation The diversity of stream velocity increases due to the higher morphological diversity The period of a stream velocity > 5 cm/s increases to the largest extent compared to the other measures and the present situation Due to the removal of weirs the stream will stand clear of water during dry periods instead of stagnant water in the present situation The maximum water depth decreases compared to the present situation and the measure reconnection of the Buurserbeek, but increases compared to the measure restoration of morphology The minimum water depth becomes zero (stream stands clear of water)	Positive effect: The increased diversity of morphology and stream velocities has a positive effect on the species diversity The increase in stream velocity and the increase of the period of flowing water will stimulate rheophilic species The risk of a stream standing clear of water during dry periods will probably decrease Negative effect: The resulting vegetation may reflect higher trophic levels than desired (as a result of higher nutrient concentrations in the surface water)
Reconnection to Regge	Reconnection of the downstream part of the Hagmolenbeek to the Regge stream via connection under the Twente canal. The measure restores the original catchment. The catchment approach is important in the Water Framework Directive.	-	This measure will hardly affect the hydrological characteristics of the Hagmolenbeek, because the reconnection takes place in the downstream part of the Hagmolenbeek	The possibilities for fauna to migrate from the Hagmolenbeek to the Regge will probably increase, as fish migrates through these connections. The possibilities for migration increase with lower stream velocities and enough light in the connection. The improvement of the ecological situation after reconnection of former subcatchments depends also on the hydrological characteristics after reconnection and on

				the morphology of the stream and the naturalness of the banks. The downstream catchment of the Hagmolenbeek (northern of the Twente canal) has the same characteristics as the upstream catchment; its hydrology is adapted to the agricultural requirements (weirs, steep profile, drainage).
Restoration of hydrology in the catchment	Restoration of the hydrology of the catchment and stream. The objective is a more natural discharge pattern, which means a reduction of high discharges, a higher basic discharge and a longer period of basic discharge. This discharge pattern can be realised by a rise of the groundwater level in the catchment and a decrease of the drainage capacity in order to retain the water in the catchment for a longer time.	-	On the basis of expert-judgement and literature it is determined that for a restoration of the original quantity and pattern of flow a decrease of the drainage capacity of 70-80% and a rise of the groundwater level in the catchment with 20-50 cm is needed. The groundwater levels III, VI and VII will change to the levels I, II and III respectively. Decrease of extreme ranges of quantities of flow in the stream: during dry periods the quantity of flow will increase and during wet periods the quantity of flow will increase due to the larger retention of precipitation in the catchment	Restoration of the original quantity and pattern of flow in the stream The risk of a stream standing clear of water will decrease The risk of flushing out of organisms due to high quantities of flow in the stream will decrease Water quality will improve as the rainfall-runoff process proceeds more through the soil resulting in retention of pollutants

References	Contact
Lorenz, C.M. (2001b), Heavily Modified Waters in Europe - Case Study on the Hagmolen-Hegebeek, Witteveen+Bos (W+B), Deventer.	**Lorenz, C.M.,Witteveen & Bos, Deventer** **c.lorenz@witbo.nl**

3. The assessment of effectiveness of restoration measures in the River Great Ouse (England and Wales, UK)

The Great Ouse catchment covers much of East Anglia and represents a heavily regulated lowland river. Much of it has been heavily engineered for flood defence and land drainage purposes as well as for navigation purposes. Modifications include completely artificial cut-off channels, channel re-alignment and re-sectioning, bank reinforcement, weirs/locks and loss of floodplain channel diversity. As a result of drainage, fens were transformed from wetland with raised islands of clay into some of the most productive arable land in the UK.

The river is also used for water supply and the surrounding land is heavily used for agriculture. Overall population density is low, but the catchment receives relatively low rainfall and in some areas, population pressures are increasing. This has created increased demands on water resources.

Five technically feasible restoration measures to achieve GES are proposed:

- build a canal;
- load boats onto low-loaders and transport them by road to the nearest navigable point;
- reduce the width of the channel in certain sections to increase flow velocity;
- re-profile the banks to increase the potential for marginal vegetation; and
- add in non-navigable channels around the locks to act as 'natural' habitats (4 of the 6 locks within this reach already have these channels).

The following section lists the benefits of the proposed restoration measures, while their effectiveness in achieving GES is summarised in Table 1.

Build a canal

The return to a more natural river channel, as well as the intrusion of salt water will result in the return of anadromous species, some of which are considered endangered or vulnerable (shad, smelt, etc.). There is also the possibility of an increase of Atlantic flounder and mullet in the lower part.

Reduce width of channel (in certain sections)

The increase of flow velocity in certain sections as a consequence of the reduction in width of the channel will be beneficial for rheophilic species like dace and chub which, in this part of the Great Ouse, represent only 1% of the total fish density. This will result in an overall increase of habitat diversity, favourable to an increase of total fish biomass.

Elevated water velocities either by reduction in channel depth or possibly narrowing seem likely to promote macrophyte community changes which move towards a reference condition.

Some evidence for this can be obtained from the existing parallel bypass channels. In these channels, seasonally higher water velocities occur in summer, providing habitat variety for plant species that require maintained elevated flows and may moderate the effects of intermittent flow in the main river but such data are currently unavailable.

Thus, the removal of weirs and locks may not result in increased mean water velocities without associated channel narrowing and additional general changes in the river system.

Re-profile banks to increase marginal vegetation and add in non-navigable channels around locks to act as 'natural' habitats

As it has been discussed above, the return to a more natural river channel with an increase in marginal vegetation will be highly beneficial for coarse fish recruitment. This should also result in a short-term increase of the overall fish biomass.

Table 1: Measures for more detailed assessment of GES (Proforma 4)

River Ouse – Brownshill Staunch to confluence with River Ivel		
Modification	Restoration Measure	Effect on Ecological Status? (Achieve Full or Partial GES)
Navigation	Add in non-navigable channels around locks to act as 'natural' habitats (6 locks in stretch, 4 already have channel around locks)	Partial (small stretches of river affected - but could have positive knock-on effects that may increase the chance of achieving GES across the whole reach)
	Remove all locks, weirs, reduce width of channel	Full
	Build canal	Full
	Transport boats by road	Full
	Reduce width of channel (in certain sections)	Partial (improves variability of flow regime only and not bank or channel bed habitats)
	Re-profile banks to increase marginal vegetation	Partial (improves bank habitats only and not flow velocity or channel habitats)

In the England & Wales guidelines, proforma 4 provides space to record the effect measures will have on ecological status (see Table 1). Full GES is where it is expected (with a good degree of certainty) that good ecological status will be met for all of the affected reach of the waterbody. There may also be measures that could achieve some improvement in ecological status but may not improve it all the way to good. Such measures may warrant consideration if they are likely to cost considerably less than the 'full' measures, or if they could be packaged with other 'partial' measures to achieve full GES. In many cases, it will be preferable to consider the 'partial' measures individually at first, with the potential for combining them if the assessment shows them to be less costly than the 'full' measures.

In the column entitled 'achieve full or partial good ecological status?', it would be useful for those measures achieving partial GES to note whether this is partial within the whole reach, or full over only part of the reach. This is important when partial options are to be assessed in terms of their relative cost-effectiveness, and when trying to combine partial options so that there is a better chance of meeting full GES across the whole reach.

References	Contact
Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002), Heavily Modified Waters in Europe – Case Study on the Great Ouse Catchment, submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales.	**Michael Dunbar, Centre for Ecology and Hydrology** **Mdu@ceh.ac.uk**

4. Hydromorphological changes to achieve GES in regulated river stretches downstream of dams (River Lozoya, Spain)

The River Lozoya is an example of a Spanish river that has been significantly altered by the construction of a series of reservoirs, serving for nearly 50% of the total water supply for the metropolitan area of Madrid and to a lesser extent for hydropower generation (five hydropower plants). Nowadays, roughly fifty percent of the river's length is taken up by reservoirs. According to uses and physical alterations, the River Lozoya can be divided in three groups of water bodies:

Table 1: Groups of water bodies

Name of the group	Main pressures of the group	Main physical alterations of the group
Natural stream	None	None
	Minor physical alterations (tourist resort)	Channelisation, weirs, protected margins
Reservoir	Water supply and Hydropower (dams)	Change in river profile Disruption in river continuum and sediment transport (dams) Artificial discharge regime Direct damage to fauna/flora
Regulated river	Regulated river downstream of each dam	Disruption in river continuum and sediment transport Artificial discharge regime and reduced flow in the river bed Direct damage to fauna/flora

Current ecological status in the regulated stretches

Downstream of each dam, values for the biological quality elements generally range from bad to moderate (see Table 2).

Macrophytes. The strong, sudden fluctuations in flow have resulted in the reduction or elimination of the natural vegetation below each dam.

Macroinvertebrates. The number of taxa is low and the biotic indices indicate that the community reflects a modified or heavily modified water body.

Fish fauna. The fish fauna below the reservoirs is poor due to a scarce minimum flow and the strong oscillations in water level.

Table 2: Values of physico-chemical and biological quality elements in the regulated stretches of the River Lozoya

	Physico-chemical elements		**Biological elements**		
Water bodies	General conditions	Specific pollutants	Macrophytes and phytobenthos	Benthic invertebrate fauna	Fish fauna
Regulated stretches (from Pinilla dam to El Atazar dam)	Good	High	Poor	Moderate / Bad	Poor
Final regulated stretch (downstream of El Atazar dam)	Good	High	Moderate	Good	Poor

Table 3: Current ecological status in the regulated stretches of the River Lozoya

Water bodies	**Physico-chemical quality indicators**	**Biological quality indicators**	**Ecological status**
Regulated stretches (from Pinilla dam to El Atazar dam)	Good	Poor	Poor
Final regulated stretch **(downstream of El Atazar dam)**	Good	Moderate	Moderate

Restoration measures

In the regulated river stretches downstream of dams, the efforts for achieving GES should focus on restoration measures that would improve the quality of the biological quality elements, which currently have a rating of poor to moderate (Table 3), in contrast to the good conditions indicated by the chemical quality elements. Downstream of the dams, the communities are characteristic of heavily modified running waters.

In order to achieve GES, it would be necessary for all these stretches to have a hydrological regime, which would allow macrophytes, invertebrates and fish to thrive (Table 4). These measures have been defined according to the ecologic flow requirements for maintaining an optimal fish fauna biomass (applying Bovee's method –PHABSIM, Physical Habitat Simulation-) of native species (trout).

In addition, because of disruption in river continuum and sediment loading, some restoration of the river bed structure, as well of the riparian zone would also be necessary.

Table 4: Ecological water regime proposed in the Forestry Plan of the Autonomous Community of Madrid[14]

Water body	Ecological water regime	Percentage of the actual water flow	Water flow distribution along the year	Remarks
Regulated stretches (between Pinilla dam and Riosequillo dam)	Trout stretch that requires 59 Hm^3/year	34 %	2.3 m^3/s from mid-July to mid September, and from November to mid February 1.5 m^3/s the rest of the year	With a further increase in water flow (>2.3 m^3/s) there is no significant increase in fish biomass
Final regulated stretch (downstream of El Atazar dam)	Trout stretch that requires 29 Hm^3/year	12 %	1.5 m^3/s from mid-July to mid September, and from November to mid February 0.3 m^3/s the rest of the year	With a further increase in water flow (> 1.5 m^3/s) there is a slight increase in fish biomass

A further step would be to analyse whether these necessary measures to achieve GES have significant adverse effects on the specified uses, especially on water supply in the Metropolitan area of Madrid (step 7.2).

References	**Contact**
Díaz, José-Antonio & Montserrat Real (2001). Heavily Modified Waters in Europe – Case Study on the river Lozoya (Tajo, Spain), Confederación Hidrográfica del Tajo, Calidad de Aguas and Limnos, S.A., Madrid and Barcelona.	**Real Montserrat, Limnos, S.A.,** **Montserrat_Real@URSCorp.com**

3.1.2 SIGNIFICANT ADVERSE EFFECTS ON SPECIFIED USES (STEP 7.2)

The second sub-step 7.2 of the designation test 4(3)(a) requires an assessment of whether the necessary "restoration measures" to achieve GES will have significant adverse effects on the specified uses (e.g. on navigation, on hydropower, on recreation, or on other specified uses). In the guidance document, the need has been identified for toolbox examples regarding the issue of scale for the assessment of significant adverse effects. Below you may find relevant examples:

1. Assessment of significant adverse affects on a local scale in the Lake Kemijarvi (Finland)
2. Assessment of significant adverse effects on a local and regional scale in the River Ruhr (Germany)

[14] Comunidad Autónoma de Madrid (1998). Plan Forestal de la Comunidad Autónoma de Madrid.

3. Assessment of significant adverse effects on a local and national scale in the Lake Verluwerandmeren (Netherlands)

4. Adverse effects of low restoration on hydropower production and land use in the Suldalslågen River (Norway)

Examples

1. Assessment of significant adverse affects on a local scale in the Lake Kemijarvi (Finland)

This illustration deals with the issue of assessing the effects of 'restoration measures' to achieve GES as part of the designation test 4.3(a); it may serve as an example where an assessment at a local scale has been sufficient and appropriate. The study area encompasses the region of the Lake Kemijärvi which is the largest natural lake within the catchment of the River Kemijoki in Finland. Lake Kemijärvi is the most heavily regulated lake of Finland. Water level regulation which serves the purpose of hydropower production and flood protection has a maximum amplitude of 7 m, which is the largest regulation amplitude encountered in Finnish lakes. Regulation has had significant impacts on the littoral ecosystem, and fish stocks and substantial improvements are probably needed before a good ecological status can be achieved.

In 1999, a large lake regulation development project was started in Lake Kemijärvi. One of the main goals is to assess the needs and possibilities to alleviate the adverse impacts of current regulation. The project comprises several subprojects where the ecological, social and economic impacts of regulation are assessed and various regulation alternatives are compared. Good ecological status for Lake Kemijärvi has been defined as the situation where among others the erosion of shoreline, especially from sandy shores, would decrease and the zonation and width of littoral vegetation would become more natural (width of Carex zone would be more than 60 % of natural state (or reference conditions). More information on the characteristics of good ecological status for Lake Kemijärvi can be found in the case study report.

To achieve these goals, several crucial modifications to current regulation practice have to be carried out, including

- Minimum water level at the beginning of February (date which determines the depth of the frozen zone in Northern Finland) should be above N_{43}+147, 40 m (currently N_{43}+146, 90 m)
- Winter draw-down should be only 2-3 m at its maximum (currently 7 m)
- Water level during open water period should not exceed N_{43}+148,75 m (currently HW is N_{43}+ 149,00 m)
- Water level fluctuation during summer time should be increased by 0,7 m or current fluctuation is adequate depending on the reference
- Reproduction areas of brown trout and migratory whitefish should be restored in the tributaries of Lake Kemijärvi

The impacts of the good ecological status regulation (GES-regulation), i.e. necessary hydromorphological changes to achieve GES, on recreational use, flood protection and hydropower were roughly estimated by utilising the preliminary results of this regulation development project (Table 1). The impacts on recreational use are based on the results of field surveys, a mathematical model and the results of a questionnaire directed to the users of Lake Kemijärvi. The impacts on floods and energy production were assessed by applying heuristic estimations and simple calculations. The assessment of effects comprised both Lake Kemijärvi and River Kemijoki.

Table 1: The impacts of GES-regulation of Lake Kemijärvi

VARIABLE	IMPACT
Erosion of shorelines	Moderate decrease in erosion of sandy shorelines.
Littoral ecosystem	Frost sensitive species of aquatic macrophytes and zoobenthos will recover.
Fish stocks	Reproduction and food resources of whitefish will improve.
Recreational use and fishing	Benefits 0,1-0,5 million Euros/year. Positive impacts during winter and spring. Negative impacts especially in wet conditions due to too high water levels and flows. If water level fluctuation in summer is increased then negative impacts and contradictions with recreational users will occur.
Flood damages	Flood risk in Lake Kemijärvi and River Kemijoki will significantly increase. Damages for buildings and infrastructure.
Hydropower production	Losses 3 million Euros/year (30 % of the total benefits of Lake Kemijärvi regulation)

References	**Contact**
Marttunen, Mika and Seppo Hellsten (2002), Heavily Modified Waters in Europe - <u>Case Study on the Lake Kemijärvi, Finland</u>, Finnish Environment Institute, Helsinki.	**Mika Marttunen, Finnsh Environment Institute** **Mika.marttunen@ymparisto.fi**

2. Assessment of significant adverse effects on a local and regional scale in the River Ruhr (Germany)

The River Ruhr, a tributary of the River Rhine, is situated in the mid-western part of Germany with a length of 219 km. The “Ruhrgebiet” located in the western part of the catchment is one of the largest industrial areas in Europe, including the large inland harbour of Duisburg. The water of the Ruhr serves as drinking water resource for over 5 million people and as industrial water supply. To provide water supply, 14 reservoirs with dams have been built in the upper catchment also used for hydropower generation.

In the assessment of adverse effects of the necessary restoration measures of this example, different scales have been used: level of region of Northrine-Westphalia, level of catchment and level of core region of the case study.

Required measures to reach the good ecological status

To decide if GES can be reached, two scenarios have been constructed to test and assess different ways to achieve GES. These scenarios only consider realistic factors. They do not challenge the existing drinking water abstraction plants and settlement areas. Regarding the remaining potential areas in the flood plain, it can be expected that the GES is achievable while maintaining these uses. Scenario A is described here in detail:

The objective being closest to the natural status is a continuous stream without back-waters. This means that the impounded lakes have to be abandoned and the weirs have to be replaced by artificial riffle sections. Bank fixations can be removed locally. In the core region with drinking water abstraction plants and settlements continuously lined up on one side of the river, bank fixations can only be removed on the opposite side of the river. Thus, dynamic streambed migration can be achieved in some stream sections. The establishment of alluvial forests or groves is an accompanying measure. Further on, the input of organic material such as leave litter and wood debris, is an important factor for the development of the aquatic fauna. By reattaching oxbows, spawning grounds for cyprinid fish species and habitats for young fish can be developed. Because of heavy metal pollution, sludge removal from the bottom of the lakes is a likely measure to be taken before the dams can be removed.

Impact on water uses and significant adverse effects

The adverse effects on uses have to be considered in detail:

a) general definition of criteria and levels of significance
b) qualitative description of adverse effects on uses
c) identification of significantly affected uses based on the levels of significance

Criteria and levels of significance for adverse effects on uses

For the decision process, a socio-economic sectoral analysis, as well as an individual economic analysis is necessary. The analysis regarding the uses of hydropower generation and agriculture are here presented:

- Hydropower generation

The degree of hydro power production decreases due to the described measures is used as a level of significance. A loss of 2% of the energy produced per year is determined as an acceptable adverse effect for the economic sector and the single user (level of significance). For the sectoral analysis the values are related to the energy produced by hydro power in Northrhine-Westphalia (NRW) per year.

- Total of NRW: 516 GWh/a
- Total of River Ruhr: 235.38 GWh/a (=46 % of total NRW)
- core region of this case study: 72.48 GWh/a (= 31 % of the production at the River Ruhr, 14 % of the production in NRW)

Assuming that there are intentions to reduce energy production at other hydroelectric power plants as well, 2% of the hydro power energy produced in the core region of this case study (72.48 x 0.02 = 1.45 GWh/a) is considered as sectoral level of significance.

- Agriculture

The loss of area used for agriculture is used as criterion of significance. This criterion is especially important for the individual economic analysis. A sectorial economic analysis can be neglected because the need of producing food in the Ruhr area is of minor importance. Concerning the individual economic analysis, the level of significance is the loss of 2 % of area used for agriculture.

For a rough calculation, we assume the reduction of 2 % of agricultural area due to measures will be the same for every user (here: farmer), so this percentage is used as a level of significance in the individual economic analysis.

To estimate the percentage of reduction, the loss is related to the agricultural area of the whole catchment of the River Ruhr. As it has to be expected that there is also the need for space to develop the stream in other sections, the area reduced should be related proportionally to the agricultural area in the core region of this case study:

- Total length of streams in the catchment area: 4 573 km
- Total area used for agriculture (LN) in the catchment area: 1 400 km²
- Length of stream section in the core region: 42 km (about 1 % of total length)
- Area used for agriculture (LN) in the core region: 14 km² (=1 % of agricultural area in the whole catchment)

⇨ Level of significance for the core region: 2 % of 14 km² = **0.28 km**

Qualitative description of adverse effects and identification of significantly affected uses

Scenario A has adverse effects especially on hydropower generation. The discharge and difference in water level altitude defines the energy produced by hydropower generation. After destruction of the weirs, hydropower production is to be abandoned.

In Northrhine-Westfalia, 516 GWh/a are produced by hydropower. In the core region, there is a total energy production of 72.48 GWh/a = 14 % of the annual electricity produced by hydropower in Northrhine-Westfalia. The expected adverse effects are considered significant. The designation of HMW is justified by sectoral and individual economic analysis.

Measures to accelerate dynamic processes in streambed morphology (e.g. by destructing bank fixations) will cause increased erosion rates and streambed migration, reducing area used for agriculture. In the core region of the case study, about 13 km along the river are used for agriculture. Using a 50 m corridor in the valley of the River Ruhr as space for dynamic stream bed migration and as a buffer zone for the retention of nutrients, pesticides and eroded solids, there will be a reduction of 0.65 km² of agricultural area. As this is more than twice as much as 0.28 km² (level of significance), a significant adverse effect on farms can be expected.

In summary, realising this scenario will lead to total loss of hydropower production and a significant loss of agricultural area.

References	Contact
Podraza, Petra, Dirk Glacer, Martin Halle, Andreas Müller and Thomas Zumbroich (2002) Heavily Modified Waters in Europe - Case Study on the River Ruhr, University of Essen, Institute of Ecology, Department of Hydrobiology, Essen.	**Petra Podraza, University of Essen, Institute of Ecology, Department of Hydrobiology** **petra.podraza@uni-essen.de**

3. Assessment of significant adverse effects on a local and national scale in the Lake Verluwerandmeren (Netherlands)

The Veluwerandmeren is a Dutch shallow freshwater lake system influenced strongly by hydromorphological changes. It was created by the reclamation of a polder and the building of dikes at a former estuary. The main uses of the lake are fisheries and recreation, accompanied by heavy recreational shipping, as well as water supply (for irrigation and industrial processes). It has been designated as a protected area according to the Birds Directive.

To achieve good ecological status, the present lake has to be changed into a mesotrophic, clear lake with macrophytes, natural banks and marshes and natural water level management. The following hydromorphological measures have to be taken:

- Changing the unnatural water level management into a natural water level management.
- Removal of the fortified banks, dikes and recreation beaches and creation of natural banks and marshes
- Restoration of the bottom of the lake by filling of the holes of 5 and 8m deep and the channel of an average depth of 3,5-4,5 m and stopping further mineral extraction.
- Replacing the artificial restoration measure of flushing seepage water through the lakes by nutrient poor seepage water from the stream in the Veluwe. Therefore, the drainage and diffuse agricultural pollution in the stream catchments of the Veluwe has to be reduced. This process of restoration of former ground- and surface water flows and quality will probably take decades or longer.

Impact on water uses and significant adverse effects

The required measures will have the following effects on water uses:

- Natural water level dynamics increase the risk of floods in the Flevopolder and the border of the Veluwe. This impacts the towns and the recreational facilities located at the border of the lakes (local scale). Additionally, the water level management of the Lake Ijssel has to change to a natural water level management as well. This will lead to negative effects on related waterbodies, as the water quantity management of the whole of the northern part of the Netherlands depends on the water management of the Lake IJssel. Thus, 30% of the Netherlands will have to adapt their water management, as a consequence of restoration measures for the Veluwerandmeren and the Lake Ijssel (national scale).
- The change of the fixed banks into natural banks and marshes will negatively impact the recreation function of the Veluwerandmeren. Yachting basins, camping sites, landing stages and beaches will have to be removed to enable the creation of nature at the border of the lake (local scale).
- The filling of the shipping channel will negatively impact the transport function of the Veluwerandmeren. Shipping will be impossible in the shallow lake if the shipping channel is filled, which is a significant effect (local scale).
- The reduction of the drainage and diffuse agricultural pollution in the stream catchments will impact the agricultural yield in these catchments, as the hydrology is less optimal for the agricultural function and the application of manure and fertilisers has to be reduced (regional scale).

References	**Contact**
Lorenz, C.M. in association with RDIJ and RIZA (2001a), Heavily Modified Waters in Europe - Case Study on the Veluwerandmeren, Witteveen+Bos (W+B), RDIJ and RIZA, Deventer.	**Lorenz, C.M., Witteveen & Bos, Deventer** **c.lorenz@witbo.nl**

4. Adverse effects of low restoration on hydropower production and land use in the River Suldalslågen (Norway)

In the case of the River Suldalslågen, the strongly reduced frequency of large floods after regulation and disappearance of ice jam events have given increased moss cover. The reduced floods have also reduced the transportation capacity for sand and fine sediments, while the local sources are at least as active as before the regulation. This has led to increased siltation in the river bed.

The increased moss cover and the changed substrate have affected the ecological status for benthic algae, invertebrates and fish. Disregarding pressures in the ocean life cycle of the salmon and possible effects of acidification, the changed moss cover and substrate is considered the main cause for reduced abundance of Atlantic salmon.

Two restoration alternatives are considered:

1. Full restoration of natural flow regime.

2. Introduction of occasional large scouring floods, typically 500 m^3/s, with a frequency of approximately five years. The flood should last several (five) days to ensure that scoured material is washed out of the river. The capacity of the gate in the dam is approximately 200 m^3/s. A flood of 500 m^3/s can thus only be obtained by spilling 300 m^3/s over the dam and opening the gate. This is only viable during a heavy inflow event, especially if the flood is to last for a prolonged period.

Alternative 1, full restoration of the flow conditions in the river reach to pre-regulation conditions would require additional releases of approximately 1350 mill m^3 per year. These releases would bypass the Hylen HPP, with a head of 68 m, but also some redistribution of production in the high head hydropower plants in the system might be necessary. The lost energy production in Hylen would be approximately 220 GWh/yr (close to half the present production) with a first hand production value of approximately 4 mill EUR.

Alternative 2, release of scouring floods every five years or so would require extra releases of in the order of 25 mill m3/yr if it is combined with high runoff events. The energy production loss would be moderate, in the order of 4 GWh/yr - production worth 50 000 EUR.

The hydropower regulation also provides flood mitigation. Restoration of a flood regime that is closer to the natural regime will have negative effects on the established use of the former flood plains.

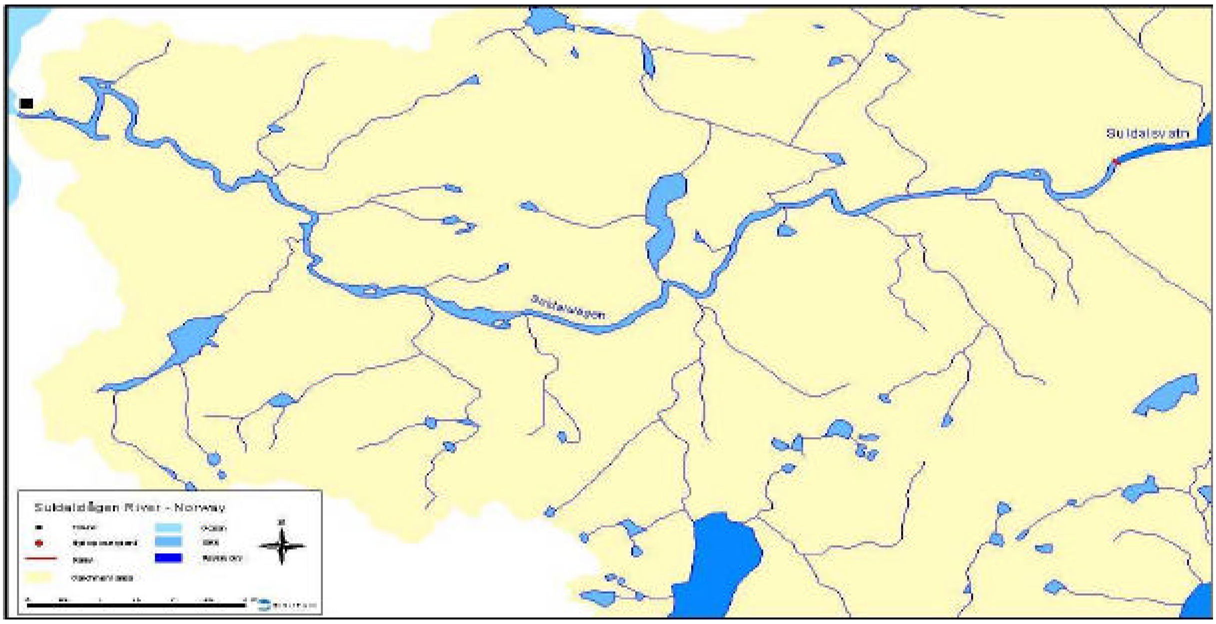


Figure 1: Suldalslågen River in Norway

References	Contact
Johansen, Stein W., Jan-Petter Magnell, Svein Jakob Saltveit and Nils Roar Saethun (2002), Heavily Modified Waters in Europe - Case Study on the Suldalslågen River, Statkraft-Grøner, NIVA and LFI, Lysaker.	**Nils Roar Saethun, NIVA** **Nils.saethun@niva.no**

3.1.3 SIGNIFICANT ADVERSE EFFECT ON THE WIDER ENVIRONMENT (STEP 7.3)

The intent of sub-step 7.3 of the designation test 4(3)(a) is to ensure that restoration measures required to achieve GES do not deliver environmental improvements for the water body whilst creating environmental problems elsewhere. Below you can find an example extracted from the case study on the River Tame.

1. Effect of measures to achieve GES on the wider environment in the River Tame (England & Wales, UK)

Example

1. Effect of measures to achieve GES on the wider environment in the River Tame (England & Wales, UK)

The Tame river basin is an example of a catchment with widely varying land use, river use, river modification and ecology. It represents an example of a degraded urban river. The main River Tame runs through heavily urbanised areas of Birmingham and has been subject to many pressures and modifications. The heavy urbanisation at the top of this catchment is unusual in the context of European rivers. Increased peak runoff due to urbanisation, combined with floodplain development has led to a channel that is heavily engineered for much of its length.

In the River Tame case study, effects of restoration on the wider environment included all of the positive impacts associated with a move to good ecological status, plus any other impacts (positive or negative) that may occur as a result of the restoration measures. These can be described in the column headed ‘impacts of rehabilitation on wider environment’ in proforma 1 of the Engand & Wales (UK) methodology. A decision then has to be made as to whether the overall impact is positive or negative, and if this is small, moderate or large.

A wide range of impacts should be considered when completing this section of the proforma. This should include the direct environmental benefits, such as achievement of good ecological status (fully or partially), creation, improvement or loss of habitat for plants, animals, invertebrates, etc., impacts on flooding, connection of river to floodplain, loss of agricultural land, impacts on traffic and the landscape. Apart from environmental benefits possible impacts on the economy, recreation and social aspects - all of which form part of the 'wider environment' - can be considered.

The decision as to whether effects either on the use or the wider environment are 'small', 'moderate' or 'large' is based on judgement and a consideration of the impacts of other restoration measures (where other restoration measures could be undertaken on the reach, or restoration measures for other reaches). In most cases, however, this will be quite straightforward. The example here is taken from the case study on the River Tame. A number of different stretches have been considered due to significant differences between the modifications along the river from the confluence of the River Rea (in Birmingham) to the confluence of the River Anker (just south of Tamworth). In this case it is actually concluded that the effects on the wider environment are slightly positive. There are no significant adverse effects on the wider environment but there are significant adverse effects on the uses.

Where it is concluded that there are no significant adverse effects from undertaking restoration, then recommendations on the appropriate restoration measures should be developed with these acting as the stopping point for the assessment. Under these circumstances, the water body is not designated as a HMWB for the purposes of the Water Framework Directive.

Where significant adverse effects would be likely to arise (or where you are unsure as to whether significant adverse effects may occur), then designation may be appropriate depending on the conclusions of the assessment with regard to the designation test 4.3(b).

Table 1: Proforma 1 - Reach 5: RIVER TAME Assessment for Test 4.3(a) – would rehabilitation have a significant adverse effect on uses?

River Tame – *Lea Marston (Coton bridge) to Kingsbury Brook*										
Modification and Intended Uses	**Potential Re-habilitation Measures**	**Impacts of Rehabilitation on Intended uses**	**Significance of Impacts and Direction**			**Impacts of Rehabilitation on Wider Environment**	**Significance of Wider Impacts**			**Significant Adverse Effect?**
			Small	**Mod**	**Large**		**Small**	**Mod**	**Large**	
River now flows through artificial channel; original route now partly used by Birmingham and Fazeley Canal; modification to allow gravel extraction	Restore river to more natural planform	Loss of farmland (no properties affected); loss of navigation on canal; bridges needed for roads (incl. M42, some re-routing of roads may also be required)			-ves	More natural channel with much wider floodplain than at present	+ves			Yes

References	Contact
Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002), Heavily Modified Waters in Europe – Case Study on the Tame Catchment, submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales. **Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002),** Heavily Modified Waters in Europe – England and Wales Case Studies, Guidelines on identification, assessment and designation of rivers, Final Draft (Version 4), submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales.	**Michael Dunbar, Centre for Ecology and Hydrology** **Mdu@ceh.ac.uk**

3.2 DESIGNATION TEST ACCORDING TO ARTICLE 4(3)(B) (STEP 8)

Regarding this step, please refer to the respective section of the HMWB guidance document:

	Chapter	Step/Sub-steps
HMWB-Guidance	5.5	8/8.1-8.5

3.2.1 IDENTIFICATION OF "OTHER MEANS" FOR ACHIEVING THE BENEFICIAL OBJECTIVES (STEP 8.1)

In this first sub-step of the designation test 4 (3)(b), "other means" should be identified which will deliver the beneficial objectives of the modified characteristics of the water body. "Other means" may involve the replacement or displacement of the existing specified use. Below you may find lists of other means for different specified uses.

1. Identification of "other means" for achieving the beneficial objectives (Synthesis Report)

Example

1. Identification of "other means" for achieving the beneficial objectives (Synthesis Report)

It has been attempted to produce lists of “other means” for the different specified uses using the HMWB synthesis report as a basis. To be in accordance with the HMWB guidance document only the following categories of other means could be used:

- Complete removal of the existing use (and performing it in an alternative way):

e.g. replacing hydropower with other energy sources (e.g. case study on Kemijärvi (SF), Danube (A), Beiarn (NO)), replacing navigation with rail or road transport (Great Ouse (UK), Veluwerandmeren (NL), Elbe (D)) or delivering water supply from groundwater instead of surface waters (Loosdrecht, NL).

- Displacement of the existing use to other water bodies/catchments:

e.g. displacement of recreational facilities (Veluwerandmeren (NL), Loosdrecht (NL) and agricultural production (Loosdrecht (NL), Forth Est. (NL)).

The “other means” mentioned in the following tables are initial check lists based on the information of some of the HMWB case studies.

Table 1: possible “other means” for different uses

Specified uses	Example for “other means”
Hydropower	power production by other means (nuclear, wind, gas) naturalised flow and energy production by other means (savings) removal of power station, import of electricity
Navigation	transport of good by other means/other routes build a canal partly transport by train/road removal of the harbour, transport by train removal of docks
Water supply	water supply from other catchments, destruction of the dams change drinking water supply from groundwater to surface waters
Land for habitation and agriculture	displacement of habitation and agriculture reversing agricultural reclamation
Flood protection	parallel drainage channel

References	Contact
Hansen, Wenke, Eleftheria Kampa, Christine Laskov and R. Andreas Kraemer (2002), Synthesis Report on the Identification and Designation of Heavily Modified Water Bodies (draft), Ecologic (Institute for International and European Environmental Policy), Berlin, 29th April 2002.	**Ecologic (Institute for International and European Environmental Policy) ,** **Kampa@ecologic.de**

3.2.2 ASSESSMENT OF "TECHNICAL FEASIBILITY" OF "OTHER MEANS" (STEP 8.2)

It has to be assessed whether "other means" are technically feasible. Technical feasibility is put as the first check as it represents a relatively simple test and there is clearly no value in assessing the environmental impact of options that are not technically feasible. Below you may find one relevant example from the HMWB case study on the Sankey Catchment.

1. Other means which are technically feasible in the Sankey Catchment (England & Wales, UK)

Example

1. Other means which are technically feasible in the Sankey Catchment (England & Wales, UK)

The Sankey catchment is subject to a mixture of pressures arising from urbanisation and agricultural development, including land drainage, flood defence, poor water quality and general degradation of instream and riparian habitats.

For each physical modification on the Sankey, there will be a range of potential other means that could be used to provide the same beneficial objectives. Here a selection of the modifications and other means are presented. Those other means that are not technically feasible can be screened out at this stage by ticking the '***no***' box under '***technically feasible?***' in Proforma 2 of the England & Wales (UK) methodology. These other means do not need to be considered further. The reasons why they are not considered technically feasible should be recorded. This information can then be used to explain to stakeholders why a particular other means has not been considered further.

Table 1: Proforma 2: Assessment for Test 4.3(b) - are there technically feasible alternatives?

Rainford Brook - from source upstream of Rainford to confluence with Sankey Brook				
Modification	**Possible other means for providing intended uses**	**Technically Feasible? (✓)**		**Factors Affecting Implementation**
		Yes	**No**	
Straightening and embanking for flood protection				
	Off-channel embankments	✓		Not always feasible because of proximity of housing to river
	Residential protection works (e.g. flood gates, barriers at doors)	✓		Relies on householders being home and responding to flood warnings; high risk of failure on demand
Culverting of river for access to agricultural land	Construction of new bridges over river	✓		Although technically feasible would lead to potentially significant losses of agricultural land; unlikely to be acceptable to land owners and some technical problems concerning alignment of bridges likely to arise
Road bridge	Construction of new road bridge that does not obstruct channel		✓	Not feasible within constraints of road system

As part of future investigations, one might want to revisit this table to provide the basis for drawing up a modified list of other means, particularly where technical advancements have been made or other factors/characteristics have been affected by changes in the catchment.

References	**Contact**
Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002), Heavily Modified Waters in Europe – <u>Case Study on the Sankey Catchment</u>, submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales.	**Michael Dunbar, Centre for Ecology and Hydrology** **Mdu@ceh.ac.uk**

3.2.3 ASSESSMENT OF WHETHER "OTHER MEANS" ARE BETTER ENVIRONMENTAL OPTIONS (STEP 8.3)

The purpose of this sub-step 8.3 of the Article 4(3)(b) test is to ensure that proposed "other means" do represent a better environmental option and that one environmental problem is not replaced with another. The examples from the River Elbe and River Umealven are presented as two cases where the proposed "other means" have been assessed as better environmental options. In total, three examples are given:

1. "Other means" as better environmental options to navigation in the River Elbe (Germany)
2. "Other means" as better environmental options to hydropower production in the River Umealven (Sweden)
3. Environmental profile of other means for local hydropower production in the River Suldalslågen (Norway)

Examples

1. "Other means" as better environmental options to navigation in the River Elbe (Germany)

The River Elbe is one of the biggest rivers in central Europe with its springs in the central highlands of the Czech Republic. Today, the entire German Elbe is a national waterway and Hamburg is the most important harbour in Germany. For this case study, two representative sections were selected, one in the upper and one in the middle Elbe. The upper Elbe stretch reflects typical impacts of navigation, while in the middle stretch flood protection prevails.

Identification and definition of the beneficial objectives served by the modified characteristics of the water body

The main beneficial objective served by the hydro-morphological changes of the investigated part of the River Elbe is transport. In addition to the transport function, navigation fulfils income and employment possibilities, but within the designation process, the focus is put on shipment.

Other means to the existing "water use"

Other means to achieve the same beneficial objective are the modification of navigation (local view) and, on a regional view, replacing this function with road or rail transport. An abandonment of navigation is not considered as necessary to achieve good status. Therefore, it is not discussed as an other means.

Only a replacement with existing transport is considered. Hence, the existing use is compared with the modification as the proposed alternative and discussed concerning the technical feasibility, the environmental effects and the costs. The technical feasibility of the restoration measures is given. On a regional level, the replacement of navigation with road or rail transport is taken into account. There is an existing railway network along the river Elbe.

Different types of costs can be differentiated. On the one hand, there are investment costs for river restoration measures (i.e. puncturing of harbour-basins, breakthrough of bank impairments). These types of restoration measures cause no costs for the use ‘navigation’ or the beneficial objective ‘transport’. On the other hand, there are costs relating to the existing use, i.e. costs for foregone economic benefits due to ecological requirements. In the case of the River Elbe, an assessment of the costs with regard to the foregone benefits cannot be done within this investigation. It would require a detailed analysis of the operation costs, the freight charges and types of cargo ships.

Environmental effects

The negative effects of changes in river profile and morphology to allow shipping with a sufficient water depth are well-known: Increase of the flow velocity, a degradation of the channel, modification of the hydraulic regime, losses of biodiversity and habitats (above all flood plains), etc. A restoration has accordingly positive environmental effects.

In the following table, the environmental effects (positive and negative) of different means of transport are compared. The ecological effects of the means of transport refer to the emission of pollutants, to noise pollution and to demand for surface area. In the comparison regarding emissions, railway transport has less environmental effects compared with inland navigation (related to energy consumption per transport unit). However, the quantity of transported goods have to be considered. The following table shows the amount of transported goods in the catchment area of the Elbe.

Table 1: Transport of goods along the Elbe River

in 1.000 t	Railway	share	navig.	share	road	share	total
Saxony	19.053	4,53%	386	0,09%	400.852	95,37%	420.291
Saxony-Anhalt	30.368	9,29%	7.239	2,21%	289.382	88,50%	326.989

According to these results, inland navigation is less environmentally harmful as measured by total emissions.

Inland navigation causes higher impacts of noise pollution compared to railway transport. The investigation which assessed the externalities of different means of transport was conducted in areas of higher population density. There are no specific results with regard to the catchment area of the Elbe. Therefore, the situation along the Elbe could not be evaluated exactly.

Considering the environmental effects in the case of the Elbe River, a replacement of navigation with rail transport was considered as a better environmental option. When one considers the negative impacts of channelisation for navigation purposes for ecosystems and compares the low costs (income losses) and low profitability of inland navigation, the Elbe River should not be assessed as heavily modified.

References	Contact
Frey, Michaela, Dietrich Borchardt, Markus Funke and Ingrid Schleiter (2002a), Heavily Modified Waters in Europe - Case Study on the Elbe River, Institute for Water Resources Research and Management University Kassel, Kassel.	**Michaela Frey, University of Kassel** **m.frey@bauing.uni-kassel.de**

2. "Other means" as better environmental options to hydropower production in the River Umealven (Sweden)

Overall, the replacement of hydropower with energy production from nuclear or fossil fuels was not considered to be a better environmental option in the HMWB case studies (mainly due to increased air emission, CO2 production). The case study on the River Umealven (S) was one of the few which considered alternative energy forms such as wind power, solar energy, geothermal energy, as well as potential for energy savings.

The River Umealven is heavily affected by hydropower, but comparatively unaffected by other human activities, and therefore, a good example to study the effects of hydropower. The hydropower stations (run-off river impoundments) use almost the entire fall height of the river, from the storage reservoir at 520 m a.s.l. to the sea. The Ume River now contributes about 12% of the annual production of electricity from hydropower in Sweden. In a normal year, 64 TWh of electricity is produced by hydropower, which is almost half of the annual electricity production in Sweden (Fig. 1). The case study explored the possibilities of replacing this use with other power sources. The assessment is restricted to techniques that are presently available, and not disproportionately costly. The cost of electricity for domestic use in Sweden is among the lowest for any industrialised country, and options leading to price increases to approach those of other comparable countries were considered to be within the scope of the assessment.

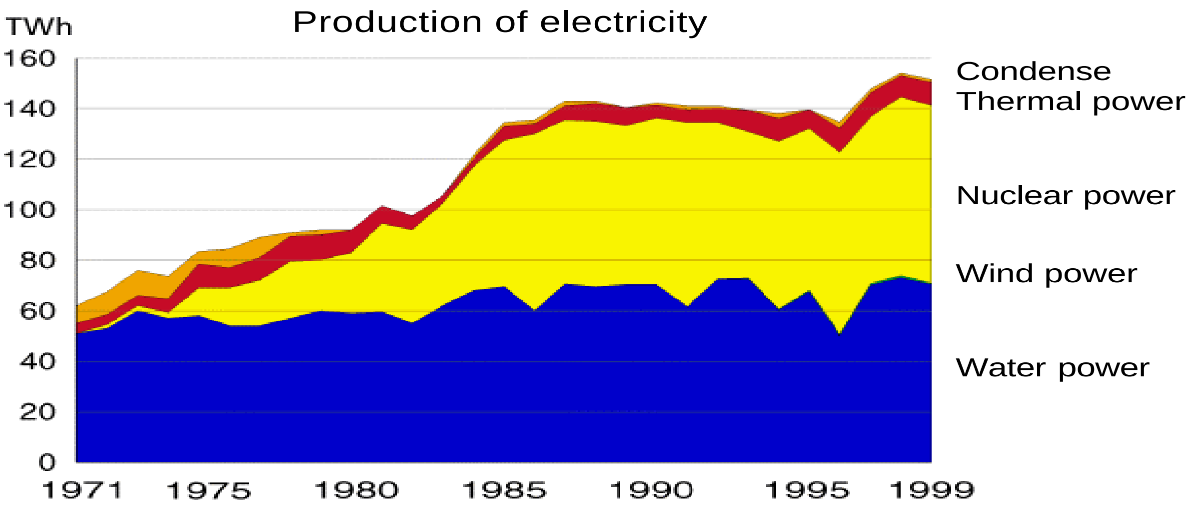


Figure 1: The annual production of electricity in Sweden from 1971 to 1999.

Today, there is no single source of electricity that could replace hydropower with an environmentally better option, without considerably increasing the cost of electricity. Fossil fuels and nuclear power are not environmentally better options: Fossils fuels lead to greenhouse-gas emissions, and nuclear power produces radioactive waste, which remains radioactive long into the future. Moreover, environmental problems surround the mining for nuclear fuel. According to decisions in the Swedish Parliament, nuclear power should be phased out, and emissions of greenhouse gases should be reduced.

Although hydropower could not be replaced, parts of the present use of electricity could be replaced by more environmental-friendly options, and by better housekeeping. First, Sweden uses about 32 TWh per year for heating. Two-thirds of this is for heating of houses; the remaining is used e.g. for hot tap water. Much of this electricity use could be replaced by energy from other sources. Heat is the lowest form of energy and is generated as a by-product in many industrial processes. Using such excess heat energy is technically feasible and would not be disproportionately costly. Wood or wood waste fuel, which do not contribute to greenhouse gas emissions, could also be used. However, it would require switching to district heating with accompanying investment costs. Another alternative is to install heat exchangers, which utilise heat from the ground and reduce electricity consumption considerably.

In 2000, wind power produced 0.45 TWh. The total potential for wind power production on land and at sea in Sweden is estimated to be about 25 TWh. The technique is environmental-friendly, but more research is needed to investigate possible effects on migrating birds.

To conclude, there is scope to replace some of the present use of hydropower and nuclear power with other, environmentally better options, but to entirely replace hydropower with alternatives is not a viable option in the foreseeable future if prices are not allowed to increase. The uncertainty surrounding the future of Sweden’s nuclear power makes it difficult to determine how much scope there is for reducing the use of hydropower. However, nuclear power production is due to end as the present nuclear power plants are taken out of operation. This would allow only for marginal decreases in hydropower production during the phase out period.

References	**Contact**
Jansson, Roland (2002), Heavily Modified Waters in Europe: Case Study on the Ume River in northern Sweden, Landscape Ecology Group, Department of Ecology and Environmental Science, Umeå University, Umeå.	**Roland Jansson, Swedish Environmental Protection Agency/Department of Environmental Assessment** **roland@eg.umu.se**

3. Environmental profile of other means for local hydropower production in the River Suldalslågen (Norway)

If the production in a Norwegian hydropower plant is reduced or discontinued, this could only in rare cases be substitued locally. Substitution would take place on the national and/or international (regional) level.

In the case of Suldalslågen replacement production (other means) could be:

1. Increasing production in other Norwegian or Scandinavian hydropower plants by reducing compensation flow;
2. Substituting with new hydro plants;
3. Substituting with new natural gas powered plants;
4. Substituting by new wind power plants;
5. Increasing production in existing European coal powered plants;
6. Increasing production in existing Scandinavian or European nuclear plants.
7. Shift from electricity to other energy carriers.

General comments on the environmental profile of these other means:

1. The policy for setting compensation flow in the Norwegian system has varied over the long history of Norwegian hydropower development, and there has been no systematic comparison of the potential environmental benefits/losses of changing compensation flow. Shifting compensation flow levels between plants could thus give environmental gains. It would be legally complicated, especially shifting between different companies. A recent regulation, like the one in Suldalslågen, generally has more “environment-friendly” compensation flow restrictions than older ones. It is, therefore, to be expected that compensation flow changes within the frame of maintaining the total hydropower production would generally lead to reduced compensation flow in recent regulations and increase it in old ones - contrary to the effect sought for this water body.
2. A national framework for hydropower development in Norway has been established, ranking the remaining potential hydropower schemes according to environmental impact. Generally, very few schemes with little or moderate environmental impacts are left. It is, therefore, not to be expected that new schemes would have less environmental consequences than existing ones. New schemes tend to be small schemes. The environmental merits of small schemes vs large schemes involves questions of scale that presently have not been fully resolved.
3. Natural gas powered electricity production plants emit CO_2 and other greenhouse gases, although less than coal based plants. The weighing of CO_2 emissions as an environmental pressure against local environmental impacts is extremely difficult.
4. Wind power is generally considered environmentally friendly renewable energy but not without environmental impacts. Generally, wind power is a poor substitute for hydropower

due to its variable effect output, which makes hydropower an ideal complementary electricity source.

5. Coal powered electricity production has high CO_2 emissions and other greenhouse gas and pollutant emissions. It is generally considered an environmentally more problematic energy source than hydropower.

6. The environmental profile of nuclear plants is generally unresolved - the comparison of low probability/high consequences adverse events of the nuclear plants with the environmental impacts of other energy sources probably defies objective approaches.

7. Generally, electricity is considered a high value energy carrier, also in environmental respects.

References	**Contact**
Johansen, Stein W., Jan-Petter Magnell, Svein Jakob Saltveit and Nils Roar Saelthun (2002), Heavily Modified Waters in Europe - Case Study on the Suldalslågen River, Statkraft-Grøner, NIVA and LFI, Lysaker.	**Nils Roar Saelthun, NIVA, Nils.saethun@niva.no**

3.2.4 ASSESSMENT OF DISPROPORTIONATE COSTS OF "OTHER MEANS" (STEP 8.4)

Those "other means" which are considered to be "technically feasible" and which represent a "significantly better environmental option" should be subject to an assessment of whether they are "disproportionately costly". The approach of England and Wales (UK) on the interpretation of disproportionality is presented here together with two examples on the assessment of disproportionate costs in the Haringvliet Estuary (Netherlands) and the Forth Estuary (Scotland, UK). An example on cost comparisons for hydropower in Norway is also presented.

1. Evaluation of disproportionate costs in England and Wales (England and Wales, UK)

2. Assessment of disproportionate costs in the Haringvliet Estuary (Netherlands)

3. Assessment of disproportionate costs in the Forth Estuary (Scotland, UK)

4. Cost comparisons for partial displacement/replacement of hydropower in the River Suldalslågen (Norway)

Examples

1. Evaluation of disproportionate costs in England and Wales (UK)

As mentioned in the HMWB guidance, disproportionality does not mean that costs simply exceed quantifiable benefits. The HMWB case studies used qualitative assessments quite often to come to a conclusion regarding disproportionate costs. In the few cases of quantitative assessments, the costs of the 'other means' were usually compared with benefits. If the resulting net-benefit is negative, it is usually regarded as disproportionately costly; if it is positive, it is not regarded as disproportionately costly. This approach, however, does not clearly demonstrate whether the costs are disproportionately greater than the benefits.

With regard to the meaning of disproportionality, E&W have provided an evaluation table accompanied by a sensitivity analysis, which takes also qualitative benefits into account to avoid a bias towards "quantifiable" benefits (Table 1). This table is part of the E&W guidelines on identification, assessment and designation of rivers produced to cover a scoping methodology for the identification and designation of HMWB under the WFD. In the document of the E&W guidelines, the reader can find a series of proformas to work through the proposed methodology for the HMWB designation tests. This includes detailed assessment of the costs and benefits of the existing use and the proposed 'other means'.

The final part of the detailed assessment is to summarise the findings and undertake a small sensitivity analysis to check the robustness of the assessment. The first step is to make sure that all costs and benefits are given in present value terms. This is done by discounting all of the costs and benefits associated with each of the sub-categories described in the same way that the capital and operating costs of the 'other means' were discounted. Once all of the costs and benefits have been converted to present value costs, they can be compared.

Most economic methodologies consider an option to be 'worthwhile' if the benefits outweigh the costs. Two different ways of presenting this comparison are usually used:

- net present value – this is simply the benefits minus the costs; and
- benefit-cost ratio – this is the benefits divided by the costs.

When the net present value (NPV) is greater than zero and the benefit-cost ratio (BCR) is greater than one, the option is considered economically 'worthwhile'. However, there will be some uncertainty within both the cost and benefit estimates.

This uncertainty should be tested through sensitivity analysis. This is used to examine the robustness of the overall conclusions of the appraisal. In sensitivity analysis, some of the assumptions (for example in values of underlying variables) are changed to allow for uncertainties[15]. The greater the uncertainty, the greater the importance of this analysis.

In the sensitivity analysis you can examine changes in any of the values used in order to assess the impact on the final benefit or cost estimates. However, it is most useful to

[15] HM Treasury (1997). Appraisal and Evaluation in Central Government (The Green Book).

consider where your estimates are most uncertain. For example, if you have assumed that the measure will result in an improvement from a poor quality coarse fishery to a high quality coarse fishery (an increase in value of £13,230/km/year), you may want to assess how the benefits would change if the fishery only improved to a 'good quality coarse fishery' (an increase in value of £4,230 from a poor quality coarse fishery).

It may be useful to consider what (and how many) changes you need to make to get the costs to be larger than the benefits (if benefits were originally greater than costs) or to get benefits larger than costs (if costs were originally larger than benefits). Decide whether the 'new' assessment looks reasonable or not. In other words, is it necessary to make unreasonable assumptions in order to make the measure 'worthwhile' or 'not worthwhile'. Details of the sensitivity analysis are recorded in the final proforma (proforma 11 as shown below from the HMWB case study on the River Tame). Details of the qualitative impacts should be recorded in the 'notes on benefit estimate and sensitivity analysis'. It is necessary to describe the scale, nature and significance of these impacts but the qualitative ratings should not be added. Instead, a note on the most significant benefits and the most significant costs should be included.

Once the sensitivity analysis is completed, one needs to decide whether the measure is considered 'disproportionately costly' or not. Guidance to help make this decision is given in Table 1.

Table 1: Evaluation table for disproportionate costs

Costs versus Benefits	Disproportionately Costly?
Costs outweigh benefits significantly (>2:1); no significant qualitative benefits	Yes
Costs outweigh benefits slightly (sensitivity analysis shows benefits could outweigh costs but only if unreasonable changes to assumptions are made); no significant qualitative benefits	Yes
Costs outweigh benefits slightly (sensitivity analysis shows benefits could outweigh costs); significant qualitative benefits (particularly environmental)	Unsure – qualitative benefits may mean measure is 'worthwhile'
Costs outweigh benefits slightly (sensitivity analysis shows benefits could outweigh costs if reasonable changes to assumptions are made); no significant qualitative benefits	Unsure – can the costs be reduced (or benefits increased) by combing the measure with other measures; or are there other measures with larger benefit-cost ratios?
Costs outweigh benefits slightly (sensitivity analysis shows benefits could outweigh costs if reasonable changes to assumptions are made); significant qualitative benefits (particularly environmental)	Unsure – can the costs be reduced (or benefits increased) by combing the measure with other measures; or are there other measures with larger benefit-cost ratios? Qualitative benefits may make the measure 'worthwhile'
Benefits and costs are very similar; no significant qualitative benefits	Unsure – can the costs be reduced (or benefits increased) by combing the measure with

Costs versus Benefits	Disproportionately Costly?
	other measures; or are there other measures with larger benefit-cost ratios?
Benefits and costs are very similar; significant qualitative benefits (particularly environmental)	Probably no
Benefits outweigh costs slightly; no significant qualitative benefits; (sensitivity analysis shows costs could outweigh benefits if reasonable changes to assumptions are made)	Unsure - can the costs be reduced (or benefits increased) by combing the measure with other measures; or are there other measures with larger benefit-cost ratios?
Benefits outweigh costs slightly; no significant qualitative benefits; (sensitivity analysis shows costs could outweigh benefits but only if unreasonable changes to assumptions are made)	Probably no
Benefits outweigh costs slightly; significant qualitative benefits (particularly environmental); (sensitivity analysis shows costs could outweigh benefits but only if unreasonable changes to assumptions are made)	No
Benefits outweigh costs significantly (>2:1)	No

Table 2: Assessment summary table for determining disproportionate costs

Proforma 11: Assessment Summary Table for Determining Disproportionate Costs *River Tame - Reach 6: Kingsbury Brook to Hopwas bridge* *Measure: Raise height of river bed, introduce riffles or shoals, remove unnatural bank profiles*				*Discount Rate : 6% Time Period: 30 years* *Length achieving good ecological status: 12 km* *Present Value Costs: £350,000*	
Impact Category	**Baseline (current situation)**	**Qualitative Description**	**Quantitative Data**	**Benefit/Cost Transfer Assessment**	
Summary of Results and sensitivity	Present Value Costs of Measure				£350,000
	Additional Present Value Costs				None quantified - but could be significant costs to farmers from flooding
	Total Quantified Present Value Costs				£350,000
	Total Annual Benefits			£13,000 to £22,000	
	Present Value Benefits (Benefit Transfer) - discounted at 6% over 30 years			£190,000 to £320,000	
	Notes on benefit estimate and sensitivity analysis Quantified benefits do not outweigh quantified costs suggesting that this measure should not be introduced. Furthermore, costs to farmers from flooding of grazing land are not included within the costs estimates (and may be significant). Conservation benefits are likely to be significant, however, and may provide benefits at least equal to those of recreation (however, an estimate of non-use benefits gives just £720 per year (using a per household value of £0.004/km/annum across households in wards alongside the river Tame), equivalent to present value costs of less than £11,000 The estimated costs (£350,000 present value costs, across 30 years) may also be a high estimate, hence, costs and benefits may be very similar				
	Designation Decision and reasons: Although this measure may be disproportionately costly, there are other measures (technically feasible alternatives) which are not but which provide only partial achievement of GES. It is recommended that these partial measures be undertaken with riffles/shoals introduced at selected locations along the reach. This may not realise all of the potential benefits, but should minimise impacts on farmers, and hence minimise the costs of the measure. It will be important to determine how many/size of riffles required to achieve GES			Not HMWB (providing it is possible to meet GES using a combination of measures)	

References	Contact
Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002), Heavily Modified Waters in Europe – Case Study on the Tame Catchment, submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales. **Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002),** Heavily Modified Waters in Europe – England and Wales Case Studies, Guidelines on identification, assessment and designation of rivers, Final Draft (Version 4), submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales.	**Michael Dunbar, Centre for Ecology and Hydrology** **Mdu@ceh.ac.uk**

2. Assessment of disproportionate costs in the Haringvliet Estuary (Netherlands)

The Haringvliet Estuary represents an example for transitional waters with a strong influence by human activities and substantially changed character. The rivers Rhine and Meuse form a combined estuary in the south-west of the Netherlands. The northern outlet of the Estuary is the Rotterdam Waterway. The southern outlet is the so-called Haringvliet Estuary, which is the focus of this case study. After completion of the Haringvliet Dam in 1970, this area changed from a dynamic brackish tidal inlet into a semi-stagnant freshwater area. The flow regime is regulated by sluices to ensure a minimum water flow in the Rotterdam Waterway.

Actually, there are plans to open/remove the Haringvliet Dam in the future in order to restore the estuary system.

The main beneficial objectives served by the modified characteristics of the estuary are safety against flooding and secondly the supply of fresh water. The HMWB case study on the Haringvliet Estuary identified the following as the most realistic and environmentally (other means) better alternative to the existing use:

Construction of a different dam supplemented with measures to mitigate the salinisation of the water. This alternative maintains the objectives of both safety and freshwater supply. Table 1 summarises the costs and benefits of the existing use and proposed alternative.

Table 1: Alternative option to safeguard safety and supply of fresh water

	Present situation: Haringvliet	**Alternative + supplementary measures**
Costs	Maintenance, operation and replacement value costs	Destruction of the Haringvlietdam, operation, maintenance and capital costs of new dam, mitigation measures for loss of fresh water supply, remediation sediments
Benefits		Ecological benefits of reaching GES

For the alternative option, a full comparison of costs and benefits will be most difficult, as ecological benefits will be difficult to quantify or monetise in order to make a comparison with all other costs. Table 2 presents the costs involved in the alternative (1387 Millions € in total).

Table 2: Estimated economic costs for alternative water use

Measures	**Estimated costs (in millions €)**	
Destruction present Dam	PM	
Adjustment of the design of the dam	450[16]	
Dredging and disposal of contaminated sediment Haringvliet	512[17]	
Total costs for mitigating measures	962	
	Future	Present
Agricultural water supply	410	0
Drinking-water supply	15	0
Total costs for alternative water uses	425[18]	0
Total estimated economic costs	1387	0

16 Based on the construction costs of the Maeslant Storm Surge Barrier in the New Waterway

17 Based on the total amount of contaminated sediments (HV 32 Mm3) and the costs for dredging, transportation and storage (approximately € 16/m ^{3})

18 Based on estimated costs for alternative water use due to implementation of the Storm Surge Barrier alternative, as presented in the EIA study on the management of the Haringvliet sluices

The remediation of the polluted sediments refers only to the Haringvliet. This step only requires a comparison of alternatives with the present way the beneficial objectives are served, thus not all measures to be undertaken to reach GES. Therefore, remediation of sediments in the Hollandsch Diep and Biesbosch is not presented here. Moreover, Dutch Policy foresees a partial remediation for the Haringvliet sediments already, which covers almost 1/3 of the presented costs. This implies that for the costs analyses under the designation test 4.3b the additional costs will be reduced by 1/3 *512=170 Milion €. From Table 2, it is concluded that the total economic costs for the alternative option are (in the order of) 1387 – 170 = 1217 Million €. Although it is difficult to compare the ecological benefits of GES with the costs, 1217 Million € are likely to be considered as disproportionately costly. Therefore, the water bodies in question are designated as HMWB also due to the questionable technical feasibility of the other means.

References	Contact
Backx, J.J.G.M., G. v.d. Berg, N. Geilen, A. de Hoog, EJ. Houwing, M. Ohm, M. van Oirschot and M. van Wijngaarden (2002), Heavily Modified Waters in Europe - Case Study on the Haringvliet Estuary, RIZA Dordrecht.	**J. Backx, RIZA** **J.Backx@riza.rws.minvenw.nl**

3. Assessment of disproportionate costs in the Forth Estuary (UK)

The Estuary and the River Firth of Forth together form a key segment of the east coast of Scotland, stretching from the centre of the country eastwards past Edinburgh to join the North Sea. Characteristic for this classic trumpet shaped estuary of about 45 km length are high tidal ranges (up to 5m) and large areas of intertidal mud. The margins of the Forth Estuary are densely settled with four major urban settlements. Main pressures on the Forth Estuary are agriculture land takes for harbour / industrial purposes and navigation. In the HMWB case study on the Forth Estuary, two water bodies (B and C) are considered candidates for designation as HMWB. In the following examples, disproportionality of costs of “other means” is described as one of the issues considered to reach a decision on HMWB designation of these 2 water bodies.

Water Body B

On the northern shore, the main objective served by the existing modification is the production of electricity at Longament power station. An option which seems disproportionately costly on common sense grounds is the decommissioning, and worse still removal, of Longannet power station. Not only would this forgo an annual value of output of over £30m for the remaining 19-24 years of operation of the plant, but it would also render un-economic the associated deep coal mine, which currently provides direct employment for 800 people. This action would also have profound knock-on economic impacts on the economy of Southern Fife. Closure of Longannet might also necessitate higher imports of electricity from England in the short run, which have higher SO_2 emissions than Longannet (a worse environmental option). In the long run, the emissions shortfall would be made up by a number of different sources, which would have uncertain net impacts on emissions.

On the southern shore, the main beneficial objectives are industrial activity at the Port of Grangemouth and agricultural production at skinflats. One of the main alternatives is to remove the Port of Grangemouth and restore the inter-tidal zone. This would also avoid the need for dredging, and so would reduce re-suspension of contaminants from bottom sediments. The Port of Grangemouth is integral to the operation of the associated industrial site. For example, British Petrol ships 6 million tonnes of product in and out of Grangemouth annually. Alternatives would include increased road haulage from and to distant ports, or use of Leith Docks with subsequent road/rail haulage to Grangemouth. This would impose additional costs on industry of around £30/tonne of product shipped, implying extra costs of nearly £200 million p.a., whilst additional road traffic would be undesirable on environmental grounds (note that even rail transport would require some new road use). New capital facilities would also have to be constructed. Finally, the technical feasibility of a plan to remove the Port of Grangemouth and restore the intertidal zone must be questioned. Reversing agricultural reclamation in the Skinflats area would not necessarily imply the need to increase agricultural output elsewhere. However, assuming that it would (since this seems the rationale behind the Directive), the cost of this lost production is relatively simple to quantify. The areas of cropping for each major crop/livestock activity in the relevant area can be identified from June census returns, and then valued using standard farm accounting data from the Scottish Agricultural College Farm Management Handbook (SAC, 2000). These figures represent private costs to farmers of lost output. However, the Directive implies that it is social costs which should be considered (i.e. costs viewed from the perspective of the nation as a whole). These will diverge from private costs due to the presence of support payments (subsidies) to farming. We make an approximate adjustment from private to social costs using the Producer Subsidy Equivalent calculated by the OECD for the EU, which is 40%.

Water Body C

Main beneficial objectives include protection of property against flooding in Alloa and agricultural activity on claimed land. Reversing agricultural land take in the relevant area would not necessarily imply the need to increase agricultural output elsewhere. However, assuming as above that it would, the cost of the alternative use may be estimated using the same procedure as for Water Body B.

Removing Alloa docks would require re-building of properties that might thus be liable to flooding: we have not been able to quantify these costs.

For both Water Bodies B and C, quantifying the monetary value of the benefits of ecological restoration is not possible due to an absence of any suitable studies in the literature from which values can be transferred. The only economic valuation studies of environmental benefits in Scottish estuaries have been concerned with reductions in sewage pollution, and so are clearly not relevant here.

Social costs of lost agricultural output were estimated for each of the relevant areas for Water Bodies B and C using the method outlined above. Results are given in Table 1.

Table 1: Agricultural costs

	Net Social Value of Lost Annual Farm Output
Water Body B	**£ 2,151**
Water Body C	**£ 76,447**

Overall conclusions regarding possible designation are set out in Table 2. For Water Body B, no better environmental option would appear to exist in terms of alternative transportation facilities. This conclusion is strengthened, however, by recognising (i) the technical difficulties of removing the Port of Grangemouth, and (ii) the very high costs of foregoing the current benefits of the port and of Longannet power station.

For Water Body C, it is uncertain whether a better environmental option is available for current agricultural production, as it depends where this was located. Restoration is probably technically feasible. However, costs of around £76,000 per year would be incurred from lost production. Whether this is disproportionate to expected benefits is hard to judge, since no estimates of the money value of these benefits exist. However, one could ask whether a population of, say, 30,000 households located in the immediate area of the Estuary at this point would be willing to pay at least £2.55 per year for the expected benefits, which seems plausible. We have thus decided that Water Body C should not be designated as “heavily modified“ on the grounds of disproportionate cost. However, no relevant empirical estimates exist of these benefits to prove the point.

Table 2: Overall conclusions on the designation test 4(3)(b)

	better environmental option available?	**technically feasible alternatives?**	**disproportionately costly alternatives?***	**designate as HMWB?**
Water Body B	no, in terms of alternative transportation arrangements for The Port of Grangemouth	doubtful	yes: costs of shutting down Longannet and moving The Port of Grangemouth	**YES**
Water Body C	uncertain, depends on location of alternative production	yes, probably	Agricultural costs of £76k/yr: not “too high”. Uncertain cost implications for Alloa.	**NO**

***: recall that monetary estimates of benefits not available.**

References	**Contact**
Black, A. R., O.M. Bragg, C.M. Caudwell, R.W. Duck, A.M. Findlay, N.D. Hanley, S.M. Morrocco, A.D. Reeves and J.S. Rowan (2002a), Heavily Modified Waters in Europe - Case Study on the Forth Estuary, Geography Department and Biological Sciences Institute, University of Dundee, and Department of Economics, University of Glasgow, Dundee and Glasgow.	**Black, A. R, Geography Department, University of Dundee,** **a.z.black@dundee.ac.uk**

4. Cost comparisons for partial displacement/replacement of hydropower in the River Suldalslågen (Norway)

The ‘other means’ considered in this case consists of a partial replacement of the energy production of the hydropower scheme in place (Hylen HPP) with energy production in other plants (mixture of hydropower, thermal and nuclear).

In specific, the proposed ‘other means’ would require a full restoration of the flow conditions in the river reach of Suldalslågen to pre-regulation conditions with additional releases of approximately 1350 mill m^3 per year. This would bypass the Hylen HPP, but some redistribution of production in the high head hydropower plants in the system might also be necessary. The lost energy production in Hylen would be approximately 220 GWh/yr (close to half the present production and, therefore, considered as disproportionate) with a first hand production value of approximately 4 mill EUR. Compared to the total hydropower production in the two main schemes in the river, Ulla- Førre and Røldal-Suldal, with a total production of 7180 GWh/yr, the production loss is around 3%, possibly within economical acceptable limits when considered as a single case. The owner of the plant, Statkraft, has an annual production of 40000 GWh/yr. The production loss would be approximately 0.5%. However, such an evaluation is not relevant, since it indirectly includes the user’s ability to pay.

The lost energy production could be replaced with energy production in other plants in the Scandinavian/North European Electricity production system, with its mixture of hydropower, thermal power and nuclear power plants, or by new production facilities in the Norwegian system - hydropower, natural gas power plants or wind power plants. Considering the present situation in the system, a large part of the substitution will be through thermal power systems, or hydropower plants with larger environmental impacts than the Hylen scheme.

References	**Contact**
Johansen, Stein W., Jan-Petter Magnell, Svein Jakob Saltveit and Nils Roar Saethun (2002), Heavily Modified Waters in Europe - Case Study on the Suldalslågen River, Statkraft-Grøner, NIVA and LFI, Lysaker	**Nils Roar Saethun, NIVA,** **Nils.saethun@niva.no**

3.2.5 WILL THE "OTHER MEANS" ALLOW THE ACHIEVEMENT OF GES? (STEP 8.5)

No example

3.3 DESIGNATION OF HMWB IN 2008 (STEP 9)

No example

3.4 GUIDANCE ON METHODS FOR APPLYING THE DESIGNATION TESTS 4(3)(A) & (B) (FOR STEPS 7 AND 8)

Regarding guidance methods for steps 7 and 8 please refer to the respective section of the HMWB guidance document:

	Chapter	Steps
HMWB-Guidance	5.7	For 7 and 8

3.4.1 METHODS FOR DETERMINING SIGNIFICANT ADVERSE EFFECTS (FOR STEP 7)

The following example is given in this section:

1. Assessment of the “significance” of adverse effects on uses (England and Wales, UK)

Example

1. Assessment of the “significance” of adverse effects on uses (England and Wales, UK)

The HMWB paper 8ver6[19] on possible appraisal techniques involved in the HMWB designation provides a table on the range of issues and information that may be considered when assessing the ‚significance‘ of adverse effects on the use (under test 4.3a) and when comparing the existing use with ‚other means‘ (under test 4.3b). This table has been proposed as a standard format that may be used for evaluation and reporting purposes (see Table 1).

The HMWB case studies (E&W) carried out detailed assessment of the proposed measures with a series of proformas. Regarding test 4.3(a), a proforma on the assessment of the significance of adverse effects on the use and the wider environment should be filled out (see Table 2). An assessment in qualitative terms is carried out but sufficient detail should be included to be able to reach a decision as to whether any of the negative impacts are significant enough to prevent restoration from being undertaken.

[19] Produced by the HMWB working group and members of the WATECO working group.

Impacts of rehabilitation on the wider environment include all of the positive impacts associated with a move to good ecological status, plus any other impacts (positive or negative) that may occur as a result of the rehabilitation works. These can be described in the column headed 'impacts of rehabilitation on wider environment'. A decision then has to be made as to whether the overall impact is positive or negative, and if this is small, moderate or large.

A wide range of impacts should be considered when completing this section of the proforma. This should include the direct environmental benefits, such as achievement of good ecological status (fully or partially), improvement or loss of habitat for plants, animals, invertebrates, etc., impacts on flooding, connection of river to floodplain, loss of agricultural land, impacts on traffic and the landscape. You should not just consider environmental benefits but possible impacts on the economy, recreation and social aspects - all of which form part of the 'wider environment'.

Does Rehabilitation have a Significant Adverse Effect?

The decision as to whether impacts are 'small', 'moderate' or 'large' is based on judgement and a consideration of the impacts of other rehabilitation measures (where other rehabilitation measures could be undertaken on the reach, or rehabilitation measures for other reaches). In most cases, however, this will be quite straightforward. Table 3 provides an example taken from the case study on the River Tame. A number of different stretches have been considered due to significant differences between the modifications along the river from the confluence of the River Rea (in Birmingham) to the confluence of the River Anker (just south of Tamworth).

Where it is concluded that there are no significant adverse effects from undertaking rehabilitation, then recommendations on the appropriate rehabilitation works should be developed with these acting as the stopping point for the assessment. Under these circumstances, the water body is not designated as a HMWB for the purposes of the Water Framework Directive.

Where significant adverse effects would be likely to arise (or where you are unsure as to whether significant adverse effects may occur), then designation may be appropriate depending on the conclusions of the assessment with regard to Test 4.3(b).

Table 1: Assessing the “significance” of adverse effects on the use

Assessing the significance of the impact on use(s)													
Assessing the significance of the impact on use(s)	Actual use				Foreseen use with good ecological status				Comparison actual versus good ecological status				Asses-ment
	Use (quantity, quality)	Production	Turn over, income	Employ -ment	Use (quantity, quality)	Production	Turn over, income	Employ -ment	Use (quantity, quality)	Production	Turn over, income	Employ -ment	
Use 1													
Use 2													
Wider environment													
Significant impact on use(s) - Overall assessment													

Comparing existing modification with “other means” serving the same beneficial objectives													
Environ-mental impact	**Actual Use**			**Option 1**			**Option 2**			**Option 3**			
	Qualitative	Physical	Monetary	Qualitative	Physical	Monetary	Qualitative	Physical	Monetary	Qualitative	Physical	Monetary	
Air													
Water													
Soil													
Land-scape													
Environmental impact - Overall assessment													

Costs	Actual use	Option 1	Option 2	Option 3	
Investment / Capital costs					

Operation, Maintenance, and Replacement costs					
Possible foregone economic benefits for cost-benefit analysis					
Total annualised costs					

Table 2: Assessment for Test 4.3(a) - would rehabilitation have a significant adverse effect on uses?

Modification and Intended Uses	Potential Rehabilitation Measures	Impacts of Rehabilitation on Intended uses	Significance of Impacts and Direction			Impacts of Rehabilitation on Wider Environment	Significance of Wider Impacts			Significant Adverse Effect?
			Small	Mod	Large		Small	Mod	Large	

Table 3: Reach 5: RIVER TAME Assessment for Test 4.3(a) - would rehabilitation have a significant adverse effect on uses?

River Tame – Lea Marston (Coton bridge) to Kingsbury Brook										
Modification and Intended Uses	**Potential Rehabilitation Measures**	**Impacts of Rehabilitation on Intended uses**	**Significance of Impacts and Direction**			**Impacts of Rehabilitation on Wider Environment**	**Significance of Wider Impacts**			**Signi-ficant Adverse Effect?**
			Small	**Mod**	**Large**		**Small**	**Mod**	**Large**	
River now flows through artificial channel; original route now partly used by Birmingham and Fazeley Canal; modification to allow gravel extraction	Restore river to more natural planform	Loss of farmland (no properties affected); loss of navigation on canal; bridges needed for roads (incl. M42, some re-routing of roads may also be required)			-ves	More natural channel with much wider floodplain than at present	+ves			Yes

References	Contact
Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002), Heavily Modified Waters in Europe – Case Study on the Tame Catchment, submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales. **Joint Chair of the CIS Working Group 2.2 on HMWB (2001),** Working Paper 8ver6: Consideration of the possible appraisal techniques involved in the designation process for heavily modified waters, October 2001 **Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002),** Heavily Modified Waters in Europe – England and Wales Case Studies, Guidelines on identification, assessment and designation of rivers, Final Draft (Version 4), submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales.	**Michael Dunbar, Centre for Ecology and Hydrology** **Mdu@ceh.ac.uk**

3.4.2 METHODS FOR EVALUATING "OTHER MEANS" (FOR STEP 8)

The following example is given in this section:

1. Determination of disproportionate costs (England and Wales, UK)

Example

1. Determination of disproportionate costs (England and Wales, UK)

The HMWB case studies in the UK (E&W) carried out a detailed assessment of the proposed measures (other means) with a series of proformas, including quantitative examination of costs and benefits. In these case studies, costs were also annualised using appropriate discount rates to ensure that costs between existing modifications and, other means‘ can be compared. For instance, regarding the determination of disproportionality, a proforma was used (proforma 11 as seen in Table 1), according to which costs should be discounted at 6%

over 30 years (values used in the E&W case studies). In the individual E&W case studies, real examples of the completed proforma are provided which, however, cannot be presented here due to size restrictions.

Proforma 11 (see Table 1) is divided into seven categories:

- water-related environment;
- recreation and amenity;
- priced uses of waterbody;
- wider environment;
- wider economic impacts;
- social considerations; and
- policy integration.

For each of these categories, it is necessary to consider the potential costs and benefits that might be generated from alternative options. Changes are only considered from the current situation. This means that the current situation forms the baseline for the assessment. To ensure assessment of measures against a common baseline, a description of the current situation should be included in the proforma in the column headed 'current situation (baseline)'. The baseline is best selected as a snapshot at the time you begin the assessment.

The proforma should be used as a checklist, and it is necessary to consider whether there are likely to be any impacts (positive or negative) on each of the categories and sub-categories given in the proforma. Where an impact (positive or negative) is expected, it should be described in as much detail as possible, giving quantitative information where available. The scale, nature and significance of impacts should also be considered when completing the proforma. If impacts are expected to be negligible, this may be included in the proforma. If no impacts are expected to occur, 'no impacts expected' should be inserted with a reason. This is important as the proforma will then provide an audit trail showing that you have fully addressed a wide range of *potential* impacts.

Proforma 11 effectively forms a framework which can be used to record the results of the detailed assessment. There are five steps involved in this assessment:

- Step 1: describe the impacts of each alternative against the baseline (where the baseline is the current situation). Qualitative descriptions are added to the 'qualitative description' box with any quantitative information (such as numbers of species, houses, or lengths of river) recorded in the 'quantitative data' box;
- Step 2: determine the most appropriate valuation (if any) from the annexes attached to these guidelines (E&W guidelines; Dunbar et al., 2002). Not all of the impacts or sub-categories can be valued;
- Step 3: determine the appropriate population over which to aggregate the valuations;

- Step 4: record the estimated benefit or cost in the appropriate box under ‘benefit/cost transfer assessment’. You should also record the data upon which your benefit/cost estimate is based (including the valuation and population used) as well as any factors that might affect the estimate (such as presence of alternative sites of a higher/lower quality, level of access, etc.); and
- Step 5: total benefits and costs (in Present Value terms) should be summarised. There is space for a small sensitivity analysis where the impact of factors affecting the estimates (as recorded in Step 4) can be assessed. Step 5 also includes comparing the costs and benefits to determine if the measure is ‘worthwhile’ (i.e. if the benefits outweigh the costs).

Table 1: Assessment Summary Table for Determining Disproportionate Costs (Proforma 11)

Proforma 11: Assessment Summary Table for Determining Disproportionate Costs ***Option being assessed: X***				***Discount Rate : 6% Time Period: 30 years*** ***Length achieving good ecological status: x km*** ***Present Value Costs: £y***	
Impact Category	**Baseline (current situation)**	**Qualitative Description**	**Quantitative Data**	**Benefit/Cost Transfer Assessment**	
				Benefits	**Costs**
Water-Related Environment					
Water quality					
Physical habitat					
Conservation Importance:					
Designated sites					
Non-designated sites					
Plants					
Macro invertebrates					
Fisheries					
Recreation and Amenity					
Angling					
In-stream recreation					
Informal recreation					
Residential amenity					

Proforma 11: Assessment Summary Table for Determining Disproportionate Costs ***Option being assessed: X***				***Discount Rate : 6% Time Period: 30 years*** ***Length achieving good ecological status: x km*** ***Present Value Costs: £y***	
Impact Category	**Baseline (current situation)**	**Qualitative Description**	**Quantitative Data**	**Benefit/Cost Transfer Assessment**	
				Benefits	**Costs**
Commercial amenity					
Priced Uses of Waterbody					
Public water supply					
Industrial water use					
Agricultural water use and productivity					
Commercial fisheries/shellfisheries					
Wider Environment					
Archaeology					
Heritage					
Landscape and geomorphology					
Townscape					
Air quality:					

Proforma 11: Assessment Summary Table for Determining Disproportionate Costs ***Option being assessed: X***				***Discount Rate : 6% Time Period: 30 years*** ***Length achieving good ecological status: x km*** ***Present Value Costs: £y***	
Impact Category	**Baseline (current situation)**	**Qualitative Description**	**Quantitative Data**	**Benefit/Cost Transfer Assessment**	
				Benefits	**Costs**
Local					
Regional					
Global					
Waste					
Energy					
Wider Economic Impacts					
Employment					
Regeneration/development					
Tourism					
Competitiveness					
Property (i.e. flood damages)					
Infrastructure (transport)					
Social Considerations					
Social inclusion/cohesion					
Equity					

Proforma 11: Assessment Summary Table for Determining Disproportionate Costs ***Option being assessed: X***				***Discount Rate : 6% Time Period: 30 years*** ***Length achieving good ecological status: x km*** ***Present Value Costs: £y***	
Impact Category	**Baseline (current situation)**	**Qualitative Description**	**Quantitative Data**	**Benefit/Cost Transfer Assessment**	
				Benefits	**Costs**
Policy Integration					
Summary of Results and sensitivity	Present Value Costs of Measure				
	Additional Present Value Costs				
	Total Quantified Present Value Costs				
	Total Annual Benefits				
	Present Value Benefits (Benefit Transfer) - discounted at 6% over 30 years				
	Notes on benefit estimate and sensitivity analysis				
	Designation Decision and reasons:				

References	Contact
Dunbar, Michael, Douglas Booker, Charlie Stratford, Peter Latimer, Helen Rogerson, Jonathan Bass, Hugh Dawson, Rodolphe Gozlan, Stewart Welton, John Ash, Teresa Fenn and Meg Postle (2002), Heavily Modified Waters in Europe – England and Wales Case Studies, Guidelines on identification, assessment and designation of rivers, Final Draft (Version 4), submitted by the Environment Agency of England & Wales and the UK Government Department for Food, Environment and Rural Affairs, England and Wales.	**Michael Dunbar, Centre for Ecology and Hydrology** **Mdu@ceh.ac.uk**

3.5 DESIGNATION OF ARTIFICIAL WATER BODIES (STEP 9)

No example

4 REFERENCE CONDITIONS AND ENVIRONMENTAL OBJECTIVES FOR HMWB & AWB (steps 10 & 11)

4.1 ESTABLISHING THE MAXIMUM ECOLOGICAL POTENTIAL - MEP (step 10)

Regarding this step, please refer to the respective section of the HMWB guidance document:

	Chapter	Step/Sub-steps
HMWB-Guidance	6.2	10/10 -10.4

4.1.1 CHOOSING THE APPROPRIATE QUALITY ELEMENTS FOR MEP (STEP 10.1)

No example

4.1.2 ESTABLISHING MEP HYDROMORPHOLOGICAL CONDITIONS (STEP 10.2)

The hydromorphological conditions at MEP are the conditions that would exist if all mitigation measures were taken to ensure best approximation to the ecological continuum. In the sections below, lists of proposed mitigation measures for different water categories and for different specified uses are presented as extracted from the HMWB synthesis report. The following examples on mitigation measures have been extracted from case studies and the Synthesis Report:

1. Mitigation measures for different water categories (Synthesis Report)
2. Mitigation measures for different specified uses and physical alteration (Synthesis Report)
3. MEP hydromorphological conditions and effectiveness of mitigation measures in the Lake Kemijärvi (Finland)
4. MEP hydromorphological conditions and effectiveness of mitigation measures in the River Tummel (Scotland, UK)

Examples

1. Mitigation measures for different water categories (Synthesis report)

In the following Tables, check lists of "mitigation measures" were selected for the different water categories:

River

Lakes

Coastal waters

Transitional waters

Table 1: Mitigation measures for achieving MEP for rivers

River	Name of Case Study	Main physical alterations necessary for the specified uses	Measures for achieving MEP (Best Environmental Practice approaches)
	Lozoya R.	Dam (reservoirs)	<u>Measures to improve hydromorphological quality</u> 1.minimum water level fluctuations compatible with the current water supply 2.creation of wetlands in the riverine zone of reservoirs 3.regeneration of the littoral zone 4.fish passages <u>Measures to improve physico-chemical quality</u> 5.reduction of diffuse source and point discharges: creation of wetlands, waste water treatment facilities
	Hagmolenbeek-Hegebeek R.	River straightening channelisation	- stream restoration (re-meandering) - restoration of the catchment - all mitigation measures that have to be taken to ensure te best approximation to ecological continuum -measure to achieve the water qualtiy objectives (feasibility of measures evaluated in a table)
	Suldalslågen R.	Dams (hydropower)	Restored flood regime reducing erosion in tributaries instream habitat improvement build fish passages
	Beiarn R.	Water abstraction via tunnel intakes	Ensure stable river flow below the intakes, best operation practice
	Eman R.	Dams (hydropower)	-minimum release of 5% -gradually increase/decrease in tapping -restoration of cleared and straightened stretches -fish ladders -creation of peak flows
	Umealven R.	Dams (hydropower)	Ecological Water flow and water level fluctuations (interferes with power production, production losses up to 10% assumed as acceptable) fish passages Habitat improvements(boulders, erosion reduction..) coordinated spillway releases

River	Name of Case Study	Main physical alterations necessary for the specified uses	Measures for achieving MEP (Best Environmental Practice approaches)
			seed and plant species, removal of plant biomass
	Tummel R.	Dams and weirs	-fish passages -reverse acidification (liming) -import of appropriate sediment* -compensation water at ambient temperature* In some WBs compensation flows and modified operation schedule

Table 2: Mitigation measures for achieving MEP for lakes

Lakes	Name of Case Study	Main physical alterations necessary for the specified uses	Measures for achieving MEP (Best Environmental Practice approaches)
	Kemijärvi L.	Water level regulations sequence of hydropower stations downstream	-slight or moderate changes in current regulation practice -restoration of important bird areas -restoration of tributaries -bottom weirs in sheltered bays -fish ladders -fish stockings
	Loosdrecht L.	Controlled water level bank fixation	1. reduction of P load (dephosphorization of seepage; biomnanipulation,) 2. decreasing of turbidity (creation of silt catch) 3. removing of bank fixations, creating natural banks and marshes
	Veluwerandmeren L	Controlled water level bank fixation	1. creation of natural banks and marshes 2. reduction of nutrient load of incoming water (sewage works)

Table 3: Mitigation measures for achieving MEP for coastal waters

Coastal waters	Name of Case Study	Main physical alterations necessary for the specified uses	Measures for achieving MEP (Best Environmental Practice approaches)
	Baltic coastal	Navigation and recreation facilities	Nynäshamn: cease the discharge of petrochemical compounds restriction of harbour activities, stricter environmental standards for boats reduction of nitrogen and phosphorus discharges Landfjärden Regulations for recreational crafts (speed...) restrictions for the construction of new recreational cottages, control of private wastewater treatments regulation of sport fishing in spawning periods

Table 4: Mitigation measures for achieving MEP for transitional waters

Transitional	Name of Case Study	Main physical alterations necessary for the specified uses	Measures for achieving MEP (Best Environmental Practice approaches)
	Forth Est.	Land claim Dredging Power station	Minimise dispersion of dredged spoil outwith the designated channel (BEP) Reduce rate of water intake at Power Station to typical levels for "dry" technology (BEP) Reduce temperature of water discharged from station to ambient Re-establish estuarine habitats
	Haringvliet Est.	Dam	1) Management of Haringvliet sluices as storme surge barrier+relocation of drinking water inlet points 2) remediation of contaminated sediments 3) partial removal of shore protection works

References	Contact
Hansen, Wenke, Eleftheria Kampa, Christine Laskov and R. Andreas Kraemer (2002), Synthesis Report on the Identification and Designation of Heavily Modified Water Bodies (draft), 29th April 2002.	**Ecologic, Institut for International and European Environmental Policy,** **Kampa@ecologic.de**

2. Mitigation measures for different specified uses and physical alterations

Lists of possible mitigation measures for the specified uses of ‘hydropower’, ‘navigation’ and ‘flood protection’ could be produced and are presented here. These can serve as initial check lists which can be consulted also with regard to the specific physical alterations and hydromorphological changes in question.

Table 1: List of mitigation measures of the pressure subgroup on 'Hydropower'

Water flow and water-level fluctuations	- reintroduce a spring flood - decrease flow during summer to winter - avoid flash floods (downstream dams) - introduce minimum flows (downstream dams)
Habitat improvements	- terrace tributary outlets (reservoirs) - reduce erosion in riparian zone - return boulders to channel (former rapids)

	- seed and plant species
Organism and nutrient transport	- build in fish passages (dams) - co-ordinated spillway releases (multiple dams) - remove dam (dams) - reduce nutrient content in effluents

Table 2: List of mitigation measures of the pressure subgroup on 'Navigation'

Dams and Weirs	- build in fish passages, improve existing fish passages
Channel maintenance / Dredging	- reduce intensity of dredging
Channelisation / Straightening	connecting existing meanders to the mean channel initiating meanders
Bank reinforcement	more natural embankments
Detachment of ox-bow lakes and wetlands	cross linking of the river by deepening the ox-bow lake establishment of natural floodplains
Estuaries	restore estuarine conditions (salinity gradient, tidal fluctuation, estuarine morphological processes, migration of fauna,

Table 3: List of mitigation measures on 'flood protection'

River straightening, channelisation	- stream restoration (re-meandering) - restoration of the catchment
Controlled water level, bank fixation	- removing of bank fixations, creating natural banks and marshes - creation of natural banks and marshes

References	Contact
Hansen, Wenke, Eleftheria Kampa, Christine Laskov and R. Andreas Kraemer (2002), Synthesis Report on the Identification and Designation of Heavily Modified Water Bodies (draft), 29th April 2002.	**Ecologic, Institute for International and European Environmental Policy,** **Kampa@ecologic.de**

3. MEP hydromorphological conditions and effectiveness of mitigation measures in the Lake Kemijärvi (Finland)

Lake Kemijärvi is the most heavily regulated lake of Finland. The main objectives of regulation are hydropower production and flood protection. Water level regulation of Lake Kemijärvi has a maximum amplitude of 7 m, which is the largest regulation amplitude encountered in Finnish lakes, and has caused harmful impacts on the littoral vegetation, the benthic invertebrate fauna biomass and fish stocks.

In the HMWB case study on the Lake Kemijärvi, the lake was designated as HMWB.

Ecological regulation practice (ERP)

In order to achieve good ecological status, major modifications to current regulation practice are needed. Such changes would have significant adverse impacts on use and, therefore, they are not considered acceptable. However, this does not necessarily eliminate a need to revise the current regulation practice in MEP.

To get an overall picture of the impacts of hydrological changes on biology, the REGCEL water level analysis tool was applied. Regarding mitigation measures to define MEP, changes in regulation practice, which have greater benefits than losses and no significant adverse effects on the use, were mainly considered along with some additional measures. It was found that the impacts of regulation, both positive and negative, depend on the extent of change in regulation practice. Generally, minor changes in water level fluctuation result in minor impacts. However, certain changes in regulation practice can have significant negative impacts and only minor positive impacts on the ecological status of the lake. In order to find out the possibilities to improve the ecological status of the lake, they defined an ecological regulation alternative and assessed its impacts (hydrological changes and their impacts on biology and uses are summarised in Table 1). The procedure for determining ecological regulation practice (ERP) has been applied in several Finnish regulated lakes during regulation development projects (Hellsten et al. 1996, Marttunen et al. 2001)[20].

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[20] HELLSTEN, S., MARTTUNEN, M., PALOMÄKI, R., RIIHIMÄKI, J. & ALASAARELA, E.(1996): Towards an ecologically-based regulation practice in Finnish hydroelectric lakes.-Regulated Rivers: Research & Management 12:535-545.

MARTTUNEN, M., HELLSTEN, S. & A. KETO (2001): Sustainable development of lake regulation in Finnish lakes. VATTEN 57:29-37.

Table 1: Trend-setting assessment of the impacts of ecological regulation. Scale: 0 no impact, +/- slight impact, ++ / - - moderate impact +++ / - - - significant impact. [1)]in shallow and sheltered bays with long residence time the impact can be negative, [2)]if the water level fluctuation during summer time is decreased then also negative impacts can occur, [3)]depends on the water conditions, in wet conditions the impact is negative, [4)]1,2 mill. Euro/year.

$W_{FEBRUARY}$	**=**	**Water level in the beginning of the February (6.2.)**
W_{MIN}	**=**	**Minimum water level in spring**
$W_{DURING\ ICE\text{-}OFF}$	**=**	**Water level after the ice-break off**
$W_{MAX,SUMMER} - W_{MIN,\ SUMMER}$	**=**	**Summer water level fluctuation**
$W_{MAX,\ AUTUMN}$	**=**	**Highest water level in autumn**

	$W_{FEBRUARY}$ (+50 cm)	W_{MIN} (+200 cm)	$W_{DURING\ ICE\text{-}OFF}$ (+50 cm)	$W_{MAX,SUMMER}$ - $W_{MIN,SUMMER}$ (+30 cm)	$W_{MAX,\ AUTUMN}$ (-25 cm)
EROSION (DECREASE)	0	0	0	+	++
WATER QUALITY	0	+/- [1)]	0	0	0
MACROPHYTES	+	+	0	++	+/- [2)]
ZOOBENTHOS	+ +	+	+	+	+
FISH FAUNA	+	+	+	+	+
ECOLOGY	+4	+4 – +2	+2	+5	+5 – +3
RECREATIONAL USE	+	+	+	-	+
FISHING	+	+	+	0	0
FLOODS	0	0/- [3)]	0/- [3)]	+	+
HYDROPOWER	- -	- - - [4)]	-	-	- -
USE	0	0 – -1	+ 1 – 0	-1	0

All of these improvements in whole lake water level alterations are compared in the summary row of Table 1 as a simple summation of ecological and use parameters separately. However, it should be noted that the use of plus and minus signs gives only a slight indication of the effect and depends on the amount of available variables with in fact many of the impacts are incommensurable. Table 2 includes the summary of the effects of ecological regulation practice (ERP) on biological elements, use and costs. The results of the analysis propose that the lowering of the highest water levels in autumn, as well as the early winter fluctuation in water level would be the best options to change water level regulation.

On the one hand, the ERP would have some positive impacts on the littoral ecosystem and fish stocks, but on the other hand it has concrete negative impacts on flood protection and particularly on hydropower production. For instance, the losses for hydropower would be over 2 million Euro/year. The positive ecological impacts of ERP are partly uncertain and difficult to quantify. Therefore, it is evident that ERP could not be included in the MEP. However, it might be possible to include some elements of ERP in the MEP, for instance, the lowering of the highest water level.

Table 2: Comparison of some mitigation measures in terms of ecological impacts, impacts on use, ecological significance (O no impact, +/- slight impact, ++ / -- moderate impact, +++ / --- significant impact) and costs (- low costs, -- moderate costs, - -- high costs, (L) = only of local importance), [1)] = (impacts in L. Kemijärvi), [2)] = Only such changes which do not have significant adverse impacts on use. Refer to the text for details.

	Ecol. Regulation Practice (Table 15)	Restoration of important bird areas	Protection of erosion shores	Removal of tree stumps	Recovery of shore meadows	Restoration of tributaries[1)]	Bottom weirs in sheltered bays	Fish ladders
Macrophytes						0		0
Vegetation area	+	+ (L)	+ (L)	+ (L)	+ (L)		+ (L)	
Species composition	0/+	+ (L)	+/- (L)	- (L)	+ (L)		+ (L)	
Sensitive species	+	+ (L)	+ (L)	- (L)	+ (L)		++ (L)	
Macroinvertebrates				0	0	0		0
Species composition	0/+	+ (L)	+ (L)				+ (L)	
Sensitive species	+	+ (L)	+ (L)				++ (L)	
Fish fauna			0		0			
Species composition	0	+ (L)		0		0/+	0	0/+
Age structure/ reproduction	+	+ (L)		- ?		++	+	+

Use	--	-	0	0	0	0	-	-
Hydro power	-	0	0	0	0	0	0/-	0
Flood protection								
Recreational use and fishing	++	++	++	+++	+	+	+	+++
Erosion shores	+	0	+++	-	0	0	0	0
Costs								
Construction	0	--	--	--	--	-?	--	---
Use	0	0	0	0	0	0	0	-
Ecological continuity	+	+	0	0	+	++	-	+++
Best env. practice	yes	yes	no?	yes	yes	yes	yes	yes?
Ecological significance	*	*	0	0	0	**	*	*
Rating of measure	MEP[2)]	MEP	NR	NR	NR	MEP	GEP/ MEP	NA/ MEP

Other mitigation measures

In addition to alteration of the water level fluctuation regime, there are plenty of different methods representing “all mitigation measures” in Annex V for improving the ecological status of Lake Kemijärvi. Some of the most important and already applied measures are collected in Table 2 with the estimation of effects on use and costs. Determination of MEP in WFD emphasises ecological continuity and best environmental practice (BEP), which are also estimated separately in the context of different measures.

In Lake Kemijärvi, the possible mitigation measures include the restoration of important bird habitats, protection of eroded shores, removal of tree stumps, recovery of shore meadows and restoration of tributaries. All of these methods except the mechanical recovery of shore meadows have already been applied in Lake Kemijärvi. All other measures except the restoration of bird areas with bottom weirs do not have any effect on the use. The large scale protection of eroded shores provides a suitable method, but its ecological significance is very low and large scale use is also unacceptable because some plant species benefit highly from eroded shores, which are grounds free of competition.

The most efficient mitigation measure for improving the ecological continuity in the Lake Kemijärvi area is the *restoration of tributaries*. Most of the tributaries are dredged for timber floating and also siltation has changed the spawning grounds of salmonids. The restoration may have significant positive impacts locally on fish stocks; however, more information of the current status of tributaries and migrations of fish is needed in order to assess the impacts of restoration on, e.g., whitefish or brown trout stocks in Lake Kemijärvi.

The water level fluctuation can be decreased in some sheltered bay areas by constructing *bottom weirs* (Table 2). The effect on ecological status, as well as use depends largely on the upper level of the weir. The ecological effects are local and partly unclear, but positive impacts have been observed in zoobenthos. Large ice-sensitive species can survive when the decrease in water level is diminished. However, occasionally it has some negative effects on water quality and during the low water level, ecological continuity is not fulfilled if bottom weirs do not include fish ladders.

Other measures to increase ecological potential include the installation of *fish ladders*. Fish ladders improve ecological continuity but have a clear negative effect on hydropower production. The ecological efficiency of fish ladders is debatable in the River Kemijoki because there are many sequential power plants. It might be questionable to equip all seven power plants with fish ladders. The benefits of fish ladders depend on the available spawning areas for migrating fish. At least in the lower part of the River Kemijoki spawning areas are deteriorated and impossible to restore, but one of the main tributaries, the River Ounasjoki, is in quite pristine status. Although the River Kitinen is fully developed and the River Luiro is affected by reduced flow due to the diversion of Reservoir Lokka, there is a relatively large natural tributary River Ylä-Kemijoki upstream to Lake Kemijärvi. It is in pristine condition and offers a relatively good spawning area for migratory fish.

As a conclusion, measures that are required in the MEP and establish the MEP hydromorphological conditions are:

- Slight or moderate changes in current regulation practice (e.g. lowering the highest water levels) in order to stabilize conditions in the littoral zone.
- Restoration of important bird areas. In spite of the fact that birds do not belong to the biological quality elements of the WFD, the restoration will have positive impacts on the littoral flora and fauna.
- Restoration of tributaries, which might have positive impacts on the natural reproduction of whitefish and brown trout.
- Bottom weirs in some bays to improve conditions in the littoral zone, particularly for ice sensitive zoobenthos and macrophyte species. Bottom weirs can also provide an area for autumn spawning fish eggs and sensitive species of benthic fauna to survive.
- More information on the ecological, economical and social impacts of fish ladders are needed before it is possible to decide whether they are required in the MEP or are not acceptable (NA) measures.

The removal of tree stumps and recovery of shore meadows are considered to be not required measures (NR) in the WFD context. However, the tree stumps significantly harm the recreational use of lake and, therefore, it would be important to continue shore restoration on a voluntarily basis.

The ecological impacts of the measures included in the MEP are difficult to quantify. It is quite evident that the measures would not have dramatic effects on the scale of the whole lake, because the current regulation practise with 7 metres of regulation amplitude and a raised summertime water level still has a major impact on the ecological status of the littoral. However, the changes in the littoral zoobenthos and aquatic macrophytes can be locally significant.

References	Contact
Marttunen, Mika and Seppo Hellsten (2002), Heavily Modified Waters in Europe - Case Study on the Lake Kemijärvi, Finland, Finnish Environment Institute, Helsinki.	**Mika Marttunen, Finnish Environment Institute** **Mika.Marttunen@ymparisto.fi**

4. MEP hydromorphological conditions and effectiveness of mitigation measures in the River Tummel (Scotland, UK)

The catchment of the River Tummel is located in the northern highlands of Scotland. The Tummel study area has a very low population density (less than 0.10 persons per hectare). The single pressure in the River Tummel Basin is a large-scale hydropower generation by a scheme of five hydropower stations and an extensive channel system to direct water from other catchments towards the stations.

In hydropower terms, quantities of water at specific locations relative to power stations (in terms of altitude/hydraulic potential) are directly equivalent to quantities of generated electricity and are generally expressed by practitioners in MWh. According to the HMWB guidance document, the mitigation measures for setting MEP should not have a significant adverse effect on the specified use. Thus, no water can be directed away from reservoirs/power stations in order to provide additional compensation flow in river channels since this would result in loss of generating capacity. However, the possibility of identifying any wastage of diverted water might be explored. A more constructive approach in the spirit of the Directive would embrace a principle of water trading. Possibilities for improving hydrological conditions for biota without impact on electricity generation schedules might then be explored in terms of temporal or spatial variation of compensation provisions, or even substitution of water sources at individual power stations – compensation water at one place or time could be traded for compensation at another place(s) or time(s).

For all aspects of ecological quality, the preferred ameliorative measures are those which simply involve changes in existing practice. As a second resort, measures with capital cost implications are considered to be admissible. Finally, measures with small (insignificant) effects on generation of electricity (and, therefore, of revenue) are not ruled out.

Rannoch group of HMWBs: potential effects of all mitigation

Loch Ericht Dam never spills and there is no provision for compensation flow in the River Ericht, so that temperature/hypolimnion effects cannot be invoked here. Neither the dam nor the catchwaters associated with the offtakes on the Allt Ghlas, Allt Loch Mhugaidh, Aulich and Killichonan Burns are fitted with fish passes, but it is uncertain whether salmonids would use these if they were provided because of the steepness of some of the streams. Fish access is, in any case, impeded by low flow conditions in all the HMWB streams, and the whole question of natural accessibility requires clarification. It is difficult to envisage how fish passage could be achieved without, at least, compensation releases. Any study should take into account the possibility that other species, even non-migratory ones, are impeded by the catchwater structures.

An interesting possibility for mitigation is offered by the arrangement at the Allt Ghlas intake. At present, this intake intercepts all flow up to the (unknown) capacity of the pipe connecting it to Loch Ericht, which is roughly 500m long, before spilling into the lower part of the Allt Ghlas and the River Ericht. It would seem to be worth examining the feasibility of replacing this pipe with a (larger capacity) flood diversion channel. The lowest flows in the Allt Ghlas would not be intercepted and would, in effect, provide a compensation flow to the River Ericht. The diversion channel would begin to take water at some predetermined flow rate (e.g. Q_{98}), and its design capacity should be such that it will collect the same quantity of water as delivered by the present arrangement during the course of each year. In effect, the lower most tranche of the flow duration curve would remain in the Allt Ghlas, and the lost water required for the power station would be collected from the upper part of the curve (presently lost as spill).

Since this arrangement would tend to increase fluctuations in storage (and thus water level) in Loch Ericht, an exercise to examine hydrological feasibility is required. It would also seem to be worth examining the possibility of additional water taken from the Allt Ghlas, while still providing an acceptable flow regime (baseflow with some superposed spate flow) there, and additional water traded against compensation in one or more of the other affected streams, or against complete release of, for instance, the Aulich Burn and/or the Allt Loch Mheugaidh.

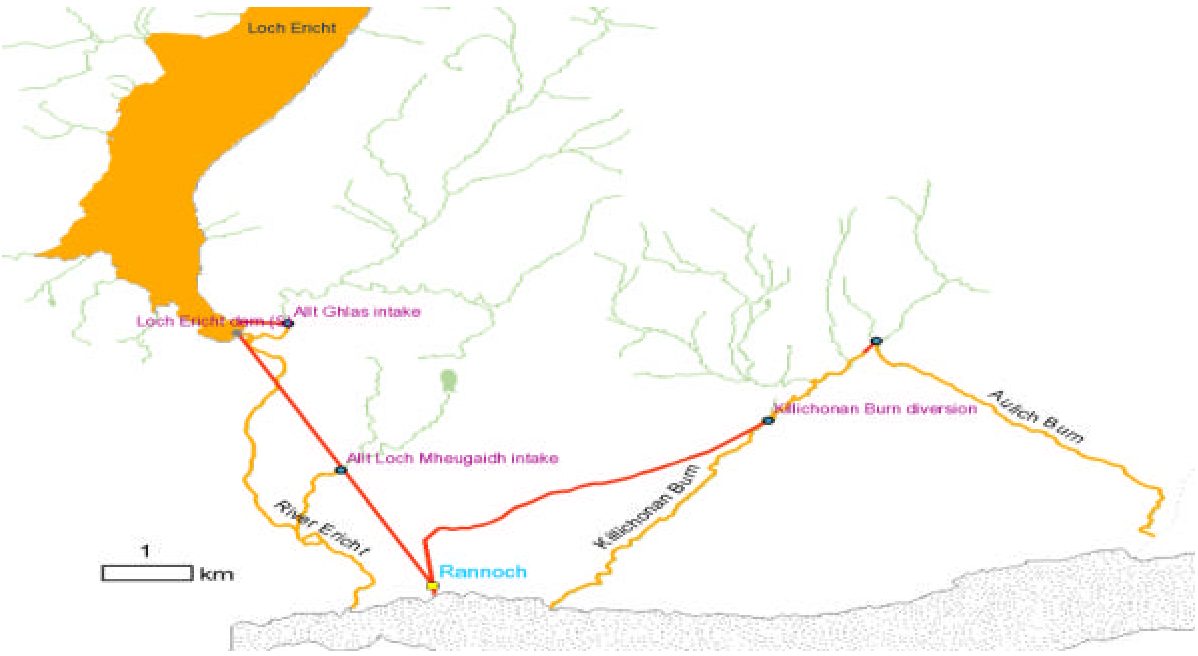

Figure 1: Rannoch HMWBs (gold) and structures (red lines, cyan and mauve labels).

For Loch Ericht itself, closer investigation of the apparent paucity of vegetation is required; the results may contribute to improving the calibration of the DHRAM methodology for lochs.

Potential General Conditions are defined as present conditions, where the Potential Hydromorphological Conditions incorporate adjustments to allow all fish species to pass freely through the system so far as natural accessibility will allow; to eliminate any deficiencies in sediment supply below the dam and catchwaters; and to provide the best possible hydrological regimes for biota within the constraint imposed by the existing schedule of demand for delivery of water to Rannoch Power Station.

Table 1: Potential effects of all mitigation at Rannoch HMWBs.

	POTENTIAL EFFECT ON BIOLOGICAL QUALITY ELEMENTS OF INDIVIDUAL WATER BODIES			
Mitigation	**Loch Ericht**	**R. Ericht/Allt Ghlas/ Allt L.Mheugaidh**	**Killichonan**	**Aulich**
	R01	R04/R02/R03	R07/R08	R05
* Modify regime of Loch Ericht to restore ecology	MP: increase in species and cover	none	none	none
* Install compensation flow at dam and catchwaters	none	BIF: Favoured F: access eased; increased spawning/feeding	BIF:R07 Favoured F: R07 access eased; increased spawning/feeding	BIF: Favoured F: access eased; increased spawning/feeding
* Import sediment to river and burns below dam/catchwaters	none	BIF: Favoured F: Increased spawning density	BIF:R07 Favoured F: R07 Increased spawning density	BIF: Favoured F: Increased spawning density
* Provide unimpeded passage for all fish species at dam and catchwaters	F: All spp. admitted; all spawning habitat exploited	F: All species able to pass catchwaters.	F: All species able to pass catchwater.	F: All species able to pass catchwater.

Key: MP: Macrophytes and Phytobenthos; BIF: benthic invertebrate fauna; F: fish. Asterisks indicate that further survey is necessary to confirm actual need before application of measures.

References	**Contact**
Black, A. R., O.M. Bragg, R.W. Duck, A.M. Findlay, N.D. Hanley, S.M. Morrocco, A.D. Reeves and J.S. Rowan (2002), Heavily Modified Waters in Europe - Case Study on the River Tummel, Geography Department, University of Dundee, and Department of Economics, University of Glasgow, Dundee and Glasgow.	**Black, A. R.,** **Geography Department, University of Dundee** **a.z.black@dundee.ac.uk**

4.1.3 ESTABLISHING MEP PHYSICO-CHEMICAL CONDITIONS (STEP 10.3)

The following example is given in this section:

1. Establishing MEP physico-chemical conditions in the River Tummel (Scotland, UK)

Example

1. Establishing MEP physico-chemical conditions in the River Tummel (Scotland, UK)

In the case study on the River Tummel (UK), the impact of weirs and dams on the temperature regime and possible mitigation measures was investigated in the context of setting MEP. This issue was also commented in the case study on the River Beiarn (NO), according to which water temperature is in many cases altered due to hydropower schemes.

Indeed, various effects on water quality likely to affect living organisms have been associated with hydropower operation. The effects centre around the fact that turbine intakes are often near the bottom of the reservoir where water quality conditions (e.g. aeration, temperature) may differ from those at the surface. Such effects are particularly marked when the reservoir is stratified; the water below the surface mixed layer is then relatively cold and dense with low dissolved oxygen (DO) concentration. Therefore, if the use of water for power generation is accepted as a reason to designate a water body as HMWB, the definition of MEP should accordingly consider the water temperature requirement. The example given here, however, has followed a strict interpretation of the WFD identifying mitigation measures for changed temperature (non modified temperature regime).

Some information on water temperature of the Errochty Water in the River Tummel system has been collected recently by Tay District Salmon Fisheries Board. When the reservoir is stratified, the compensation water is indeed relatively cool since it is drawn from the hypolimnion, and changes in water chemistry must be expected. Thus, the water in the river is unnaturally cold in spring and warm in winter, and the effect becomes attenuated downstream. Stratification of Loch Tummel is responsible for maintaining higher autumn temperatures in the River Tummel than in the Garry and may be responsible for observed differences in spawning times of autumn salmon between the Rivers Garry and Tummel (the optimum temperature for salmon spawning is 4-8°C). The result is likely to exaggerate a pre-existing natural one, since Loch Tummel predates the hydro scheme but has been enlarged and receives more water than under natural conditions.

Temperature effects have been investigated in the neighbouring River Lyon. Between March and July 2000, the water temperature below the Lubreoch hydro-power dam was more stable and consistently lower than temperatures downstream. By May 2001, it had reached only 8^{o}C despite warm weather which raised downstream temperatures as high as 15^{o}C. In general, the pattern of temperature variation below Lubreoch, where the flow regime is governed directly by the generation pattern at Lochay Power Station, was consistent with stratification of the reservoir during warm weather with intermittent mixing during cool spells. Impacts on ecology in the Lyon are severe, with proliferation of algae, changes in invertebrate fauna and poor performance of juvenile fish. These very recent observations from a nearby location indicate a risk of similar effects in parallel situations in the Tummel system, calling for vigilance or even a targeted field investigation.

Should any impacts be confirmed, mitigation would involve modification of the arrangements for release of water from the reservoir to draw as much as possible from the epilimnion rather than from the base of the dam, at least during periods of stratification. This would, presumably, require installation of a multi-level or adjustable draw-off facility (perhaps following the Temperature Control Devices developed by the US Bureau of Reclamation). For the present, however, the locations at which such effects are most likely to arise will simply be noted.

In the case of the Gaur group of water bodies, the Potential General Conditions are defined as present conditions without acidification and with correction of any water temperature/hypolimnion effect below the dam. To this aim, mitigation measures for setting MEP at the River Gaur may include drawing compensation water at ambient temperature from the epilimnion. This would lead to reduced algal abundance, favour benthic invertebrates and re-synchronise fish spawing.

References	**Contact**
Black, A. R., O.M. Bragg, R.W. Duck, A.M. Findlay, N.D. Hanley, S.M. Morrocco, A.D. Reeves and J.S. Rowan (2002), Heavily Modified Waters in Europe - Case Study on the River Tummel, Geography Department, University of Dundee, and Department of Economics, University of Glasgow, Dundee and Glasgow.	**Black, A. R., Geography Department, University of Dundee** **a.z.black@dundee.ac.uk**

4.1.4 ESTABLISHING MEP BIOLOGICAL REQUIREMENTS (STEP 10.4)

MEP is intended to describe the best approximation to a natural aquatic ecosystem that could be achieved, given the hydromorphological characteristics that cannot be changed without significant adverse effects on the specified use or the wider environment. Accordingly, MEP biological conditions should reflect, as far as possible, those associated with the closest comparable water body type given the hydromorphological and resulting physico-chemical conditions at high ecological status to those established for MEP. The following examples are presented in this step:

1. Use of HMWB as most comparable water body and spatial network of sites meeting MEP criteria in the River Lozoya (Spain)
2. Definition of MEP on the basis of a comparable water body and expert-judgement in the River Hagmolen-Hegebeek (Netherlands)
3. Definition of MEP on the basis of modelling and existing natural site in the Forth Estuary (Scotland, UK)
4. Hindcasting modelling to set MEP values in the Lake Loosdrecht (Netherlands)

Examples

1. Use of HMWB as most comparable water body and spatial network of sites meeting MEP criteria in the River Lozoya (Spain)

Most comparable water body

The River Lozoya is an example of a Spanish river that has been significantly altered by the construction of a series of reservoirs, serving for nearly 50% of the total water supply to the metropolitan area of Madrid and to a lesser extent for hydropower generation (five hydropower plants). At present, roughly 50 % of the river's length is taken up by reservoirs.

The closest comparable water category for the reservoirs of the Lozoya watershed is that of a lake. In Spain, there are no large lakes; nevertheless, there are a great many small lakes and lagoons, mainly located in the Pyrenees and in other mountain ranges (Sierra Nevada, for example). The only two large lakes are Lake Sanabria (glacial lake) and Lake Banyoles (karstic lake). Spain is the Member State with the highest number of reservoirs (over 1,000), of which 100 have been extensively studied in two periods (1973/75 and 1987/88) to establish a regional limnology. Consequently, reference conditions have to be based not only on lake studies but also, and mainly, on reservoir studies (Margalef et al. 1976, Riera et al. 1990)[21].

According to classification of the Spanish reservoirs (see Table 1), River Lozoya reservoirs belong to those reservoirs of low water mineral content and alkalinity ≤ 1meq/L and are located in the eastern siliceous zone of the Iberian Peninsula. Furthermore, all reservoirs in the River Lozoya are mesotrophic with the exception of Pinilla, which is eutrophic.

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[21] Margalef, R., Planas, D, Armengol, J., Vidal, A., Prat, N., Guiset, A.., Toja, J & Estrada, M. (1976). Limnología de los embalses españoles. Dirección General de Obras Hidráulicas, Ministerio de Obras Públicas, Madrid, 422 pp.

Riera, J.L., Jaume, D., de Manuel, J., Morgui, J.A. & Armengol, J. (1990). Patterns of variation in the limnology of Spanish reservoirs: a regional study. Limnetica, 8: 111-123.

The most comparable water bodies to the Lozoya reservoirs have to be other Spanish reservoirs (i.e. closely comparable HMWB instead of natural ones), as they have been built in greatest profusion in Spain where natural lakes are scarce. To determine reference conditions, physicochemical quality (mineral water content and nutrient conditions) and hydromorphological (most frequent lacustrine environments in Spain) elements have been considered. The reference reservoirs most comparable to the Lozoya reservoirs are those oligotrophic ones with siliceous waters.

According to three recent studies, there are a few oligotrophic reservoirs in Spain and they represent between 7 and 28 % of the total. This variability depends on the systems studied and time periods considered; during dry periods, the percentage of eutrophic reservoirs increases, while during humid periods this percentage diminishes.

Table 1: Classification of Spanish reservoirs into four trophic categories according to three recent studies

Trophic status (%)	**Alvarez-Cobelas *et al.* (1992)[22]**	**Armengol & García (1997)[23]**	**Avilés *et al.* (1997)[24]**
Oligotrophic	7	28	26
Mesotrophic	23	22	34
Eutrophic	51	41	33
Hypereutrophic	19	9	7

Within the category of oligotrophic and siliceous reservoirs, three comparable reservoirs to the River Lozoya reservoirs have been chosen, due to similar morphometric and altitudinal characteristics (according to System A), (see also Table 2):

- Cernadilla (River Tera) would be comparable to El Atazar according to the morphometric characteristics (deep and with large water surface area) and altitudinal range.
- Camporredondo and Compuerto (River Carrión) and El Vado (River Jarama), with a smaller water surface area, but relatively deep, would be comparable to Riosequillo, Puentes Viejas and El Villar.

[22] Alvarez-Cobelas, M., Muñoz-Rubio, P., Rubio-Olmo, A. & Prat, N. (1992). Current state of eutrophication in Spanish inland waters. *Journal European Water Pollution Control*, 2: 27-32.

[23] Armengol, J. & García, J.C. (1997). Ecología de los embalses españoles. *Ecosistemas*, 20/21: 36-41.

[24] Avilés, J, Toro, M. & Peña, R. (1997). Indicators of aquatic ecosystems quality in Spain. *EurAqua Technical Review*, 4. Koblenz.

Table 2: Water bodies comparable to the river Lozoya reservoirs (oligotrophic and siliceous)

		Watershed (river)	Altitude (m)	Mean depth (m)	Surface (km^2)
Reservoirs	Camporredondo	Duero (Carrión)	1290	18.0	3.9
	Compuerto[25]	Duero (Carrión)	1221	25.3	3.8
	El Vado[26]	Tajo (Jarama)	924	19.0	3.0
	Cernadilla	Duero (Tera)	889	17.6	14.5
Lakes	Sanabria	Tera[27]	1000	35.0	3.2

Similarity of physico-chemical and morphological characteristics favours the comparison of ecological conditions between these water bodies and the River Lozoya reservoirs. Furthermore, geographical proximity (biogeographical constraints) with the River Lozoya watershed facilitates the comparison of biological communities (Figure 1):

- El Vado reservoir is within the same hydrographic watershed (Jarama, Tajo)
- The other reservoirs are located in a neighbouring watershed (Duero)

Lake Sanabria (glacial origin) might also be considered as a water body comparable to the Lozoya reservoirs as it is oligotrophic (1.5-18 µg/L of PRS and 5-15 m disk Secchi depth) and has siliceous (conductivity range of 13-18 µS/cm) and cold waters (4-20ºC of temperature). Moreover, the morphometric characteristics (mean depth of 35 m) and altitude (1000 m) are similar to those of the river Lozoya reservoirs. Lakes of glacial origin are those most comparable water bodies to reservoirs as they have a frontal moraine, which is comparable to a dam, and moreover, have a fluctuating, water level (for instance, Lake Baña in León). Nevertheless, the water outlet is located at the surface as opposed to the majority of reservoirs, whose outlets are located at high or intermediate depths.

Establishing MEP biological requirements

MEP values for the biological quality elements are based on the spatial network of sites set as most comparable water bodies for the Lozoya reservoirs. Table 3 shows that the biological quality elements used are those for lakes.

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25 oligotrophic according to data from Junta de Castilla y León (1989);

26 oligotrohic according to data from Cedex (1989) but mesotrophic according to Morguí (1991);

27 main tributary

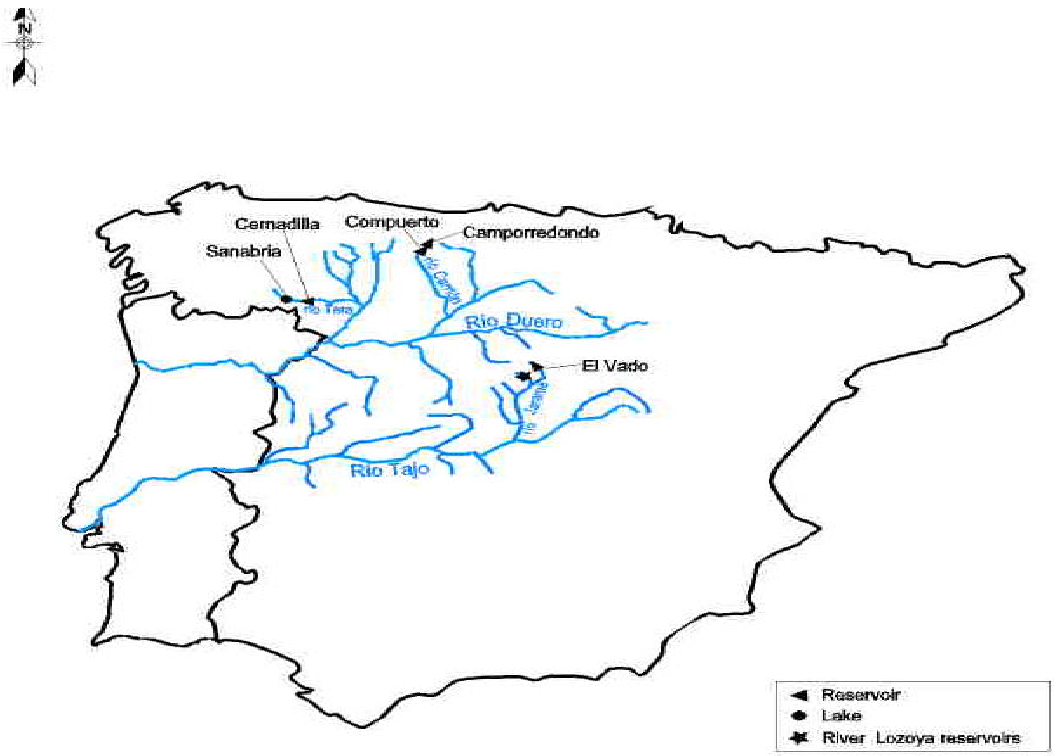

Figure 1: Location of the water bodies comparable to the river Lozoya reservoirs

Table 3: Biological quality elements for lakes

Biological quality elements
Composition, abundance and biomass of phytoplankton
Composition and abundance of macrophytes and phytobentos
Composition and abundance of benthic invertebrate fauna
Composition, abundance and age structure of fish fauna

Phytoplankton. The optimal phytoplanktonic community should correspond to that of oligotrophic and siliceous reservoirs (Margalef, 1976)[28] with diatom species such as *Melosira* (*Aulacoseira*) *distans* and *Tabellaria flocculosa*; and desmidiaceae such as *Cosmarium depressum*, *Spondylosium planum*, *Staurastrum gracile* and *S. mesikomerii*. Phytoplanktonic densities should be low (≤100 cells/ml).

Macrophytes. If hydromorphological conditions should enable the establishment of a macrophyte reference community, this should be composed of submerged macrophytes that thrive in stagnant areas in the fluvial sections of river Lozoya: *Ranunculus aquatilis*,

28 Margalef, R., Planas, D, Armengol, J., Vidal, A., Prat, N., Guiset, A.., Toja, J & Estrada, M. (1976). Limnología de los embalses españoles. Dirección General de Obras Hidráulicas, Ministerio de Obras Públicas, Madrid, 422 pp.

Ceratophyllum demersum and *Myriophillum verticillatum*. Macrophyte species associated with the reservoir littoral zone should be *Carex fusca*, *Scirpus*, *Juncus* and *Phragmites*, which nowadays are only present on the river banks of the regulated fluvial sections of the Lozoya.

Benthic invertebrate fauna. The profundal benthic reference community (invertebrates that inhabit fine sediments) should be composed of species characteristic of cold, low conductivity and oligotrophic waters; the last gives good oxygenation conditions in the hypolimnion and, therefore, in the sediment. Furthermore, in oligotrophic reservoirs, there is less phytoplanktonic density and therefore, less autochthonous organic matter supply to the sediment, which favours the presence of microcarnivorous (Tanypodinae chironomids) and detritivorous taxa (oligochaetes). Chironomid genera characteristic of cold, low conductivity and oligo-mesotrophic waters are: *Sergentia*, *Micropsectra* and *Tanytarsus*. Oligochaeta species characteristic of the same environmental conditions are: *Stylodrilus heringianus* –oligotrophic indicator species-, *Spirosperma velutinus* –cold water stenotherm species-, *Spirosperma ferox* and *Aulodrilus pluriseta*. The maximum annual density of benthic organisms should be relatively high (> 20,000 ind/m^2, in oligotrophic reservoirs from the river Duero watershed, 1989).

Fish fauna. Reference fish community in these reservoirs should be composed mainly of salmonids (*Salmo trutta*) and cyprinids such as *Chondrostoma polypelis*, *Leuciscus pyrenaicus* and *Rutilus arcasii*, accompanied by low densities of *Barbus bocagei*. This fish community should be characteristic of cold waters with a high oxygen content. In Spain, there are no fish species characteristic of standing waters because natural lakes are scarce and sparse. Therefore, the above mentioned species are characteristic of fluvial environments that colonise reservoirs. These species feed on benthic organisms, and consequently any mitigation measure that should enhance the presence of littoral zone vegetation should provide suitable habitats and food for the fish community.

References	Contact
Diaz, Jose-Antonio and Montserrat Real (2001), Heavily Modified Waters in Europe - Case Study on the river Lozoya (Tajo, Spain), Confederación Hidrográfica del Tajo, Calidad de Aguas and Limnos, S.A., Barcelona and Madrid.	**Real Montserrat, Limnos, S.A.,** **Montserrat_Real@URSCorp.com**

2. Definition of MEP on the basis of a comparable water body and expert-judgement in the River Hagmolen-Hegebeek (Netherlands)

This illustration describes the definition of the MEP of the Hagmolenbeek, a stream in the eastern part of the Netherlands on the basis of a comparable water body. The following selection criteria for the suitable comparable water body were used:

- Comparability with regard to the water category and type and general characteristics;
- The present hydromorphology should correspond with the MEP of the Hagmolenbeek. This means that the restoration measures of disproportionate costs or technical unfeasibility are not included; however, other possible mitigation measures are included.

For the selection of a comparable reference water body an inventory study has been used, which has been carried out by the local water board Regge & Dinkel (Schmidt, G., 1999)[29]. This inventory study describes and assesses the hydrology, morphology, water quality and biological parameters (macro-invertebrate and fish) of all streams in the management area of the water board. We selected the stream Ruenbergerbeek as a suitable comparable water body for the MEP of the Hagmolenbeek, because:

- Both streams are of the same type: the middle part of a slowly flowing lowland stream;
- The hydromorphology of the Ruenbergerbeek is comparable to the MEP of the Hagmolenbeek;
- The water quality of the Ruenbergerbeek is better than the present water quality of the normalised and canalised Hagmolenbeek, but the concentrations of various substances still exceed the values of the MEP of the Hagmolenbeek, namely the regional standards of negligible risk. We concluded that the Ruenbergerbeek is not a suitable comparable water body for the MEP with regard to the physico-chemical parameters.

The values of the biological parameters of the MEP of the Hagmolenbeek have been estimated on the basis of the hydromorphological and physico-chemical characteristics of the MEP of the Hagmolenbeek and the biological characteristics of the Ruenbergerbeek.

The ecological quality of the Ruenbergerbeek based on the macro-invertebrate assessment method EBEOSWA[30] fluctuates between moderate to very good (see Figure 1). Furthermore, a relatively large number of (very) rare macro-invertebrate species have been observed, which are indicative for unpolluted and oxygen-rich and fastly flowing water.

The present nutrient concentration of the Ruenbergerbeek exceeds the values of the MEP of the Hagmolenbeek, This means that the water quality belonging to the MEP of the Hagmolenbeek is better than the present water quality of the Ruenbergerbeek. It was

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29 Schmidt, G., 1999. De selectie van stromende waterparels in Twente. Waterschap Regge & Dinkel.

30 EBEOSWA is an assessment method for macro-invertebrates, delivering different yard-sticks for the factors hydrology, saproby, trophy, substrate and structure.

concluded on the basis of expert-judgement that the ecological status of the MEP of the Hagmolenbeek will probably improve slightly due to a better water quality. Therefore, the ecological status is considered to be good.

Concluding, expert-judgement will often be necessary to describe the MEP on the basis of the comparable water body, as it is difficult to find a water body that meets all criteria for all characteristics. In our illustration, the biological values of the Hagmolenbeek have been predicted on the basis of expert-judgement, the biological values of the comparable water body and the physico-chemical values of the MEP.

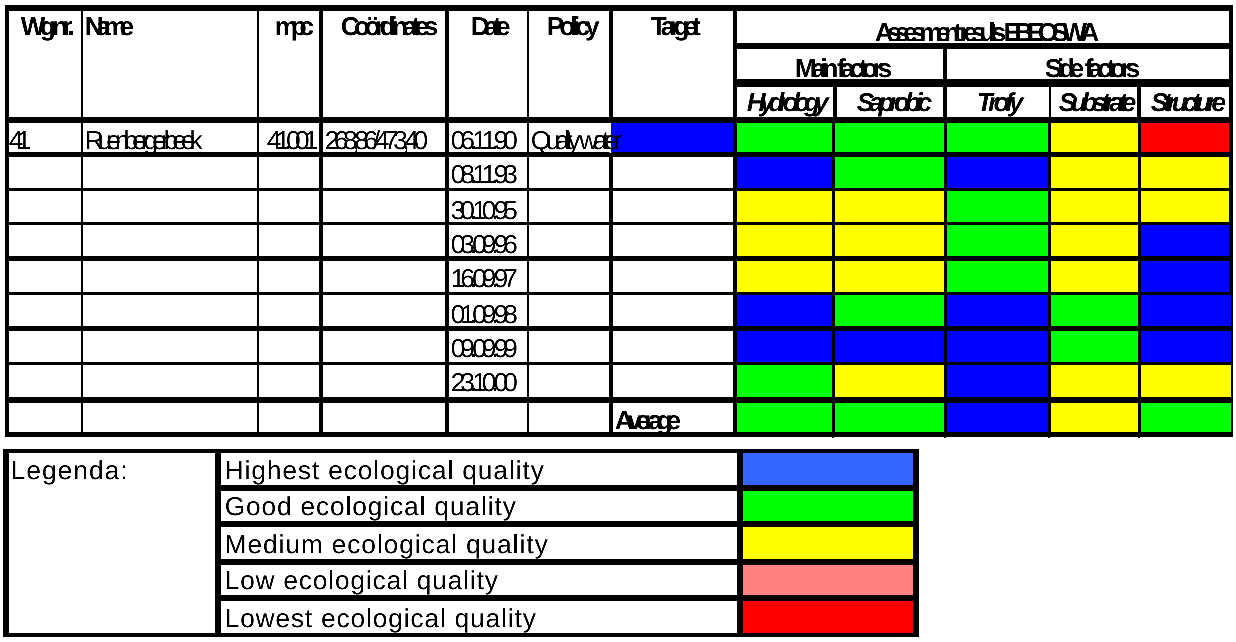

Figure 1: Overview of the ecological quality according to EBEOSWA at one measurement point in the Ruenbergerbeek over the period 1990-2000

References	**Contact**
Lorenz, C.M. (2001b), Heavily Modified Waters in Europe - Case Study on the Hagmolen-Hegebeek, Witteveen+Bos (W+B), Deventer. **Schmidt, G., 1999.** De selectie van stromende waterparels in Twente. Waterschap Regge & Dinkel. Almelo, the Netherlands.	**Lorenz, C.M., Witteveen & Bos, Deventer** **c.lorenz@witbo.nl**

3. Definition of MEP on the basis of modelling and existing natural site in the Forth Estuary (Scotland, UK)

In the HMWB case study on the Forth Estuary (water body B), a modelled comparable water body is used for MEP due to the lack of another estuary with similar physical characteristics to the Forth. Since the HMWB designation is based on morphological alterations to the boundary of the functional water body, the most appropriate assessment of the biological impacts of morphological changes alone might be physically based and expressed in terms of alteration in habitat extent. In this respect, it would seem that the best analogue for the estuary is a model based on the Forth itself with boundaries modified to represent the MEP condition. However, to set values for the biological elements at MEP, a combination of modelling and data from existing natural sites is used as explained below.

The locations and extents of uses and shoreline types included in the MEP model of Water Body B are shown in Figure 1 and Table 1. Areas shown in Table 1 are derived directly from Figure 1 for all surface types except mudflat and saltmarsh. For these, an adjustment has been applied to the direct measurements (in parentheses) to take account of existing saltmarsh.

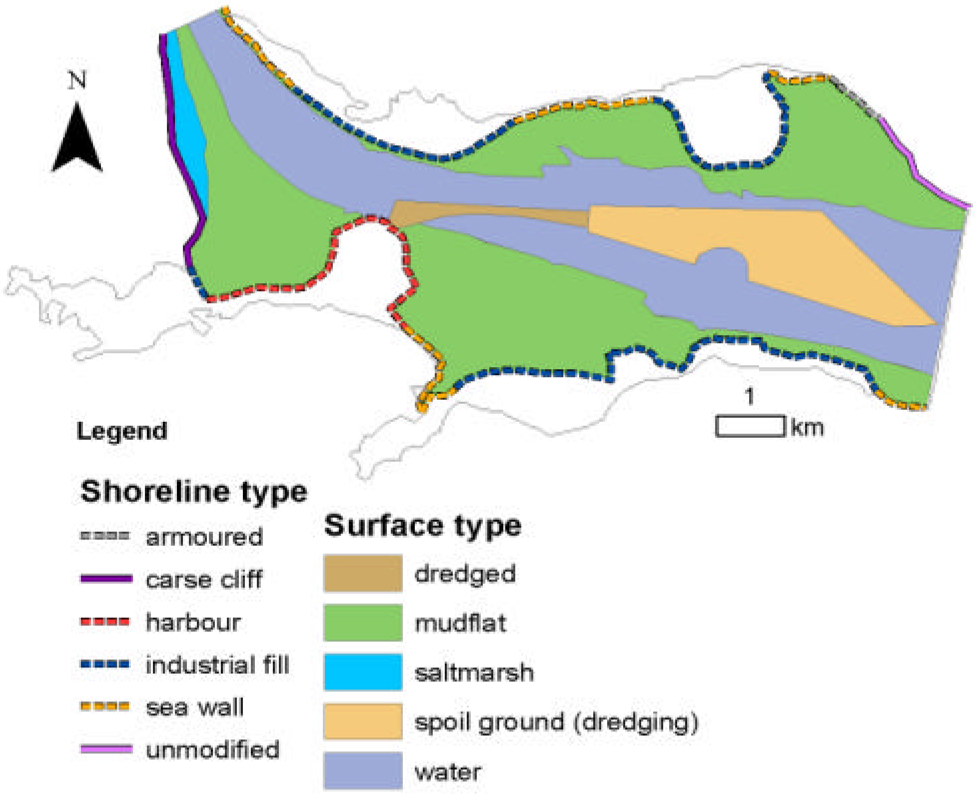

Figure 1: Water Body B at MEP

Table 1: Uses and shoreline types for Water Body B at MEP

Surface type	Area (km^2)		Shoreline type	Length (km)
dredged	0.64		unmodified	2.00
mudflat	18.38 (19.88)		Carse cliff	3.81
saltmarsh	2.39 (0.89)		armoured	1.01
spoil ground	4.34		sea wall	7.99
subtidal without direct impact	13.77		harbour	5.41
			industrial fill	15.73
Total	39.52		Total	35.94

Whilst this model provides a basis for defining habitat quantity (and by inference biotic quantities) at MEP, the problem of setting targets for biological quality remains. Again, the prospect of using the Forth Estuary itself as the basis for the analogue water body is attractive. For example, the mudflats of Torry Bay, although subject to the background physical and chemical environment, lack the local physicochemical impacts of the Culross, Skinflats and Kinneil mudflats so that their biota might be used to indicate MEP within existing water quality constraints.

For instance, regarding macrophytes, modelling data have been used to set the values at MEP and compare them with the present situation. The existing area of saltmarsh has been estimated at 0.25 km^2, which is 24% of the 1.04 km^2 total modelled for the MEP estuary (Table 18). However, detailed modelling of managed realignment at the site (Babtie 2001) indicates that the present area of saltmarsh is 33.3 ha and the potential gain 47.5 ha, against which 12 ha loss through erosion should be offset, giving a net gain of 35.5 ha and a total of 68.8 ha (0.7 km^2), over a 50 year timescale. On this basis, the EQR is calculated as (present area of saltmarsh / potential area of saltmarsh) = 33.3/68.8, or 0.48.

Benthic invertebrates have been identified as the appropriate quality indicators for the mudflats of Torry Bay, Culross Bay, Kinneil Kerse and the Skinflats intertidal zone. The invertebrate complement at Torry Bay is adopted as the MEP standard. However, no recent data for Torry Bay have been located, and the definitive (although 20 years old) study (Elliott 1979)[31] is not accessible at the time of writing, so that only a partial and out-of-date species list (from McLusky 1987)[32] can be quoted. These data are regarded as which are however sufficient to illustrate the calculation of the EQR values, likely to be unrealistically low. For each monitored site, the number ***C*** of taxa in common with Torry Bay, the number ***E*** of taxa

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[31] Elliott, M.E. (1979) Studies on the production ecology of several mollusc species in the estuarine Firth of Forth. Ph.D. theseis, University of Stirling.

[32] McLusky, D.S. (1987b). Intertidal habitats and benthic macrofauna of the Forth Estuary, Scotland. *Proceedings of the Royal Society of Edinburgh 93(B),* 389-399.

not recorded at Torry Bay ("exotic" taxa) and the number ***M*** of Torry Bay taxa that are missing are calculated. The EQR is then calculated as: **EQR** = ***C*** / (***M*** + ***C*** + ***E***).

Table 2: Derivation of preliminary EQR values for mudflat habitats.

Source of data	**McLusky (1987)**	**McLusky *et al.* (2000)**	**Ashman (2001)**	**Ashman (2001)**
Year	**Pre-1979**	**2000**	**2000**	**2000**
Sampling dates	unknown	19-28 July	1-3 July	1-3 July
Taxon SITE	TORRY BAY	KINNEIL	LONGANNET	SKINFLATS
Ampharete acutifrons				
Arenicola marina		x	x	x
Capitella capitata [agg.]				
Carcinus maenas				
Cerastoderma edule			x	
Chitons				
Copepod (Harpacticoid)				
Corophium volutator				
Diptera larva				
Enoplus brevis				
Eteone longa agg.				
Formanifera				
Gammarus sp.				
Hediste diversicolor				
Heterochaeta costata				
Hydrobia ulvae				
Macoma balthica				
Manayunkia aestuarina				
Marenzelleria viridis				
Mediomastus fragilis				
Mya arenaria		x	x	x
Mytilidae sp.				
Mytilus edulis				
Nematoda				
Nemertines				
Nephtys hombergii				
Nephtys sp.				
Nereis diversicolor			x	x
Oligochaeta				
Ophelia limacina				
Polydora cornuta				

Polydora sp.				
Pygospio elegans				
Retusa obtusa				
Scoloplos armiger				
Sphaerolaimus hirsutus				
Streblospio shrubsolii				
Tharyx 'A'				
Tubificoides benedii		x		
Tubificoides swirencoides				
Tubificoides sp.				
Number of taxa	10 (incomplete)	18	18	26
C : Number of taxa in common with standard: incomplete estimate	10	6	5 (18)	7 (13)
M : Number of missing taxa: incomplete estimate	0	3	4 (0)	3 (5)
E : Number of exotic taxa: maximum estimate	0	12	13 (0)	19 (13)
Preliminary **EQR: *C*/(*M*+*C*+ *E*)**	**1**	**0.29**	**0.23 (1)**	**0.24 (0.42)**

References	Contact
Black, A. R., O.M. Bragg, C.M. Caudwell, R.W. Duck, A.M. Findlay, N.D. Hanley, S.M. Morrocco, A.D. Reeves and J.S. Rowan (2002a), Heavily Modified Waters in Europe - Case Study on the Forth Estuary, Geography Department and Biological Sciences Institute, University of Dundee, and Department of Economics, University of Glasgow, Dundee and Glasgow.	**A.R. Black, Geography Department, University of Dundee,** **a.z.black@dundee.ac.uk**

4. Hindcasting modelling to set MEP values in the Lake Loosdrecht (Netherlands)

Lake Loosdrecht (10 km^2) has been selected as a typical example for a Dutch peat lake and is part of a system of shallow interconnected lakes in the centre of the Netherlands. While former industrial peat mining created the preconditions for the creation of the Lake, natural processes formed the present lake. It is heavily impacted by recreation, especially recreational shipping and by the construction of unnatural embankments to prevent further erosion of the peatbanks. A further problem is eutrophication and water quality.

The HMW designation shows that a return to the oligotrophic reference phase is not possible for Lake Loosdrecht. Therefore, the Maximum Ecological Potential will be based on phase 2 in the history of Lake Loosdrecht: the clear, mesotrophic lake dominated by macrophytes. The MEP will be described on the basis of historical data from phase 2 (1930-1955) in the history of Lake Loosdrecht. This phase is the period after the oligotrophic phase, which is the reference condition of the lake, and it is the phase before the eutrophication of the lake into a turbid, cyanobacteria dominated situation. The values of the biological and physico-chemical parameters during phase 2 are derived from the AMOEBE Loosdrecht (Hofstra & Van Liere, 1992). The AMOEBE is an ecological assessment instrument, which describes the ecological objective of Lake Loosdrecht (see table 1). The desired values presented in table 1 correspond to the values required for MEP. They are not based on measurements but have been estimated on the basis of historical information on biological elements. Therefore the approach used in this HMWB case study for the establishment of MEP biological requirements involves a hindcasting method using historical data.

Table 1: AMOEBE values of the biological and physico-chemical parameters during phase 2 of the history of Lake Loosdrecht, which is also the MEP (Hofstra & Van Liere, 1992).

Parameter	Present value (1990)	Desired value
Abiotic		
Transparency (yearly average, m)	0,4	1,9
Total P (yearly average, mgP/l)	0,1	0,0054
Soluble reactive P (yearly average, mgP/l)	0,002	0,0015
Mineral nitrogen (summer average, mgN/l)	0,840	0,238
Salinity (summer average, mg/l)	305	231
Oxygen (summer average, mgO_2/l)	10,4	11,0
Plankton		
Total zooplankton (carbon, mgC/l)	0,575	0,075
Total cyanobacteria (fresh weight, mg/l)	30,6	1,25
Total diatoms (fresh weight, mg/l)	0,81	0,06
Total green algae (fresh weight, mg/l)	0	0,48
Chlorophyll a (mg/l)	0,1	0,025
Vegetation		total covering according to Tansley (1946)
Characeae-group (4 species)	0	15
Potamegoton-group (10 species)	1	11
Menyanthes-group (7 species)	2	14
Thelypteris-group (15 species)	6	25
Nymphaea- group (7 species)	14	18

Butomus-group (6 species)	11	15
Caltha-group (10 species)	14	24
Fish		
Pike (fresh weight, kg/ha)	1	45
Bream (fresh weight, kg/ha)	180	50
Surroundings of lake		
Presence of helophytes and marsh vegetation	Absent due to fixed banks	Presence due to the existence of natural banks and marshes

References	Contact
Lorenz, C.M. in association with DWR and RIVM (2001), Heavily Modified Waters in Europe - Case Study on Lake Loosdrecht, Witteveen+Bos (W+B), DWR and RIVM, Deventer.	**Lorenz, C.M., Witteveen & Bos, Deventer** **c.lorenz@witbo.nl**

4.2 ESTABLISHING THE GOOD ECOLOGICAL POTENTIAL – GEP (STEP 11)

Regarding this step please refer to the respective section of the HMWB guidance document:

	Chapter	Sub-steps
HMWB-Guidance	6.3	11.1-11.4

The good ecological potential (GEP) is the environmental quality objective for HMWB and AWB. Risk of failure of the ecological objective for AWB and HMWB is assessed against GEP (see HMWB Guidance Annex II No. 1.4).

4.2.1 SUBSTEP 11.1

The establishment of good ecological potential for HMWB and AWB is principally based on **biological quality** elements (derived from MEP). GEP accomodates “slight changes” in the values of the biological elements from the MEP. The following examples illustrate this substep.

1. GEP as slight changes in the value of biological elements of MEP in the River Lozoya (Spain)

2. GEP as slight changes in the value of biological elements of MEP in the River Tummel (Scotland, UK)

Examples

1. GEP as slight changes in the value of biological elements of MEP in the River Lozoya (Spain)

The River Lozoya rises in the central mountain range in high altitude and cuts through a steep relief joining the River Jarama at 710 m a.s.l. The Jarama is a main tributary of the Tajo, the longest river in Spain with the greatest discharge capacity. Lozoya is an example of a Spanish river that has been significantly altered by the construction of a series of reservoirs, serving for nearly 50% of the total water supply for the metropolitan area of Madrid and, to a lesser extent, for hydropower generation (five hydropower plants). Nowadays, roughly fifty percent of the river's length is taken up by reservoirs.

The determination of good ecological potential in the River Lozoya reservoirs depends on the viability of the mitigation measures. These measures would reduce the trophic status of the reservoirs: (i) from eutrophic to mesotrophic (Pinilla), and (ii) from mesotrophic to oligotrophic (El Atazar), as it is the last in the multiple-reservoir series in which nutrients are progressively being trapped. The rest (Riosequillo, Puentes Viejas, El Villar), with the reduction of the trophic status, would remain within the mesotrophic category but without anoxia in the hypolimnion. This way, GEP (mesotrophic state) is determined as light deviation from the MEP of the Lozoya reservoirs (oligotrophic state).

Table 1: Good ecological potential according to physico-chemical and biological quality elements

	Physico-chemical quality elements	Biological quality elements			
	General conditions and specific pollutants	Phytoplankton	Macrophytes	Benthic invertebrate fauna	Fish fauna
Pinilla, Riosequillo, Puentes Viejas, El Villar	Mesotrophic conditions (without anoxia in the hypolimnion)	Community of cold, siliceous and mesotrophic waters	-	Community of cold, siliceous and mesotrophic waters	Community of cold, siliceous and mesotrophic waters
El Atazar	Oligotrophic conditions (same as for MEP)	Reference community (same as MEP)	-	Reference community (same as MEP)	Reference community (same as MEP)

The "slight deviations" from the maximum ecological potential for the values of each biological quality indicator are defined below with regards to each water body.

Table 2: Biological quality elements at GEP and MEP

GEP (as slight deviation from MEP)	MEP
Phytoplankton. The phytoplanktonic community expected in all reservoirs, except in El Atazar, should be characteristic of siliceous and mesotrophic waters (Margalef, 1976; group A in Sabater & Nolla, 1991), and should consist of diatom taxa such as *Melosira* (*Aulacoseira*) *distans*, *Tabellaria flocculosa*, *Fragilaria crotonensis*, with some chlorophyte taxa (*Dictyosphaerium pulchellum*), but desmidiaceae would be absent. The phytoplanktonic density should range from 100 and 10.000 cells/ml (mesotrophic reservoirs).	*Phytoplankton*. The optimal phytoplanktonic community should correspond to that of oligotrophic and siliceous reservoirs (Margalef, 1976; group A in Sabater & Nolla, 1991) with diatom species such as *Melosira* (*Aulacoseira*) *distans* and *Tabellaria flocculosa*; and desmidiaceae such as *Cosmarium depressum*, *Spondylosium planum*, *Staurastrum gracile* and *S. mesikomerii*. Phytoplanktonic densities should be low (≤100 cells/ml).
Macrophytes. Hydromorphological conditions do not allow the establishment of a macrophyte community in the littoral zone.	*Macrophytes*. If hydromorphological conditions should enable the establishment of a macrophyte reference community, this should be composed of submerged macrophytes that thrive in stagnant areas in the fluvial sections of river Lozoya: *Ranunculus aquatilis*, *Ceratophyllum demersum* and *Myriophillum verticillatum*. Macrophyte species associated with the reservoir littoral zone should be *Carex fusca*, *Scirpus*, *Juncus* and *Phragmites*, which nowadays are only present on the river banks of the regulated fluvial sections of the Lozoya.
Benthic invertebrate fauna. The benthic reference community should consist of characteristic species from mesotrophic reservoirs with cold waters and low mineral content, except in El Atazar (see reference community in Section 8.1). The slight increase in phytoplanktonic production in mesotrophic reservoirs with regards to oligotrophic ones would favour the presence of phytophagous chironomids (*Stictochironomus* and *Chironomus*), which would occur together with the reference taxa described in 8.1 in those reservoirs of intermediate depth (Pinilla). Among the oligochaetes cited in Section 8.1, other cosmopolitan and ubiquitous genera such as *Limnodrilus* spp. and *Tubifex tubifex*, would be present as well.	*Benthic invertebrate fauna*. The profundal benthic reference community (invertebrates that inhabit fine sediments) should be composed of species characteristic of cold, low conductivity and oligotrophic waters, the last gives good oxygenation conditions in the hypolimnion and, therefore, in the sediment. Furthermore, in oligotrophic reservoirs, there is less phytoplanktonic density and therefore, less autochthonous organic matter supply to the sediment, which favours the presence of microcarnivorous (Tanypodinae chironomids) and detritivorous taxa (oligochaetes). Chironomid genera characteristic of cold, low conductivity and oligo-mesotrophic waters are: *Sergentia*, *Micropsectra* and *Tanytarsus*. Oligochaeta species characteristic of the same environmental conditions are: *Stylodrilus heringianus* –oligotrophic indicator species-, *Spirosperma velutinus* –cold water stenotherm species-, *Spirosperma ferox* and *Aulodrilus pluriseta*. The maximum annual density of benthic organisms should be relatively high (> 20,000 ind/m^2, in oligotrophic reservoirs from the river Duero watershed, 1989).
Fish fauna. Fish community in mesotrophic reservoirs corresponds to that reference community described in Section 8.1 (*Salmo trutta*, *Chondrostoma polypelis*, *Leuciscus pyrenaicus* and *Rutilus arcasii*) but accompanied by high densities of *Barbus bocagei*.	*Fish fauna*. Reference fish community in these reservoirs should be composed mainly of salmonids (*Salmo trutta*) and cyprinids such as *Chondrostoma polypelis*, *Leuciscus pyrenaicus* and *Rutilus arcasii*, accompanied by low densities of *Barbus bocagei*. This fish community should be characteristic of cold waters with a high oxygen content. In Spain there are no fish species characteristic of standing waters because natural lakes are scarce and sparse. Therefore, the above mentioned species are characteristic of fluvial environments that colonise reservoirs. These species feed on benthic organisms and consequently any mitigation measure that should enhance the presence of littoral zone vegetation should provide suitable habitats and food for the fish community.

References	Contact
Diaz, Jose-Antonio and Montserrat Real, (2001), Heavily Modified Waters in Europe - <u>Case Study on the river Lozoya (Tajo, Spain),</u> Confederación Hidrográfica del Tajo, Calidad de Aguas and Limnos, S.A., Barcelona and Madrid.	**Real Montserrat, Limnos, S.A.,** **Montserrat_Real@URSCorp.com**

2. GEP as slight changes in the value of biological elements of MEP in the River Tummel (Scotland, UK)

The catchment of the River Tummel is located in the northern highlands of Scotland. It covers an area of 1,713 km^2 and reaches a peak altitude of 1,083 m a.s.l. The Tummel study area has a very low population density (less than 0.10 persons per hectare). The single pressure in the River Tummel Basin is a large-scale hydro-power generation by a scheme of five hydropower stations and an extensive channel system to direct water from other catchments towards the stations. Habitat creation associated with some water bodies in the hydropower scheme area is of acknowledged nature conservation value. These parts of the water bodies have been designated as Sites of Special Scientific Interest.

The uncertainties encountered in arriving at biological interpretations of MEP and in estimating EQRs preclude rigorous definition of GEP levels in terms of the biological quality elements. The case study on the River Tummel used the approach of setting GEP threshold value for the EQR. Initially, the scale from 0 to 1 might be divided into 4 equal intervals corresponding to the levels of ecological potential:

<u>Ecological potential</u>	<u>EQR range</u>
Maximum	1.00
Good	0.75-0.99
Moderate	0.50-0.74
Poor	0.25-0.49
Bad	0.00-0.24

Results of the intercalibration exercise (Annex V, part 1.4) may be helpful in this regard once available, but in the meantime the nominal values above were used for this study. The threshold value of 0.75 proposed is likely to require adjustment in the light of more detailed assessment of the effects of various measures on the ecology. Using this approach, the EQR of a water body has to be calculated to check if it meets GEP or not. For example, the EQR of the water body “TB 04” was calculated as shown in Table 1, comparing invertebrate taxa with those of an unimpacted water body (Allt Kinardochy).

Table 1: Comparison of invertebrate taxa present in the River Tummel at Tummel Bridge with those in the Allt Kinardochy on 09 March 1999

Taxon	River Tummel at Tummel Bridge (TB04)	Allt Kinardochy (unimpacted)
Sericostomatidae		
Odontoceridae		
Planariidae		
Elminthidae		
Rhyacophilidae		
Tipulidae		
Gammaridae		
Perlidae		
Taeniopterygidae		
Nemouridae		
Limnephilidae		
Chloroperlidae		
Heptageniidae		
Perlodidae		
Baetidae		
Simuliidae		
Oligochaeta		
Chironomidae		
Leuctridae		
Elmidae		
Polycentropodidae		
Hydropsychidae		
Hydroptilidae		
Lepidostomatidae		
No. taxa	20	19
C : Common taxa	15	19
M : No.missing taxa	4	0
E : No. exotic taxa	5	0
EQR: *C*/(*M*+*C*+ *E*)	0.83	1.00

References	Contact
Black, A. R., O.M. Bragg, R.W. Duck, A.M. Findlay, N.D. Hanley, S.M. Morrocco, A.D. Reeves and J.S. Rowan (2002), Heavily Modified Waters in Europe - Case Study on the River Tummel, Geography Department, University of Dundee, and Department of Economics, University of Glasgow, Dundee and Glasgow.	**Black, A. R., Geography Department, University of Dundee** **a.z.black@dundee.ac.uk**

4.2.2 SUBSTEP 11.2

The **hydromorphological conditions** at GEP must be such as to support the achievement of the GEP biological values. This will require the identification of the hydromorphological conditions necessary to support the achievement of the GEP values for the biological quality elements, and in particular, the achievement of the values for those biological quality elements that are sensitive to hydromorphological alterations. The following example illustrate this substep.

1. Setting hydromorphological conditions at GEP in the Haringvliet Estuary (Netherlands)

Example

1. Setting hydromorphological conditions at GEP in the Haringvliet Estuary (Netherlands)

The Haringvliet Estuary represents an example of transitional waters strongly influenced by human activities and substantially changed character. The rivers Rhine and Meuse form a combined estuary in the south-west of the Netherlands. The northern outlet of the Estuary is the Rotterdam Waterway. The southern outlet is the so-called Haringvliet Estuary, which is the focus of this case study. After completion of the Haringvliet Dam in 1970, this area changed from a dynamic brackish tidal inlet into a semi-stagnant freshwater area. The flow regime is regulated by sluices to ensure a minimum water flow in the Rotterdam Waterway. Actually, there are plans to open/remove the Haringvliet Dam in the future in order to restore the estuary system.

For the Haringvliet Estuary, the establishment of biology at GEP was based on the ecological model used at the Environmental Impact Assessment (EIA) of the Haringvliet. The hydromorphology at GEP forms the basis for the new ecotopes. As described below, hydromorphological conditions have been modelled and clearly deviate from the ones at

MEP. At MEP, the present dam is still present but the sluices are fully opened. At GEP, the sluices are partially opened.

Hydrology

In GEP marine influences in the Haringvliet – Hollandsch Diep will be smaller than those at MEP. In Figure 1, the salt intrusion in the area (based on model calculations) is shown during normal tide situation and at mean water discharge of the river Rhine. This figure illustrates that the influence of sea water will be confined to the upper parts of the Haringvliet. During extreme low discharge, the influence of the sea will be excluded from the area by closure of the sluices.

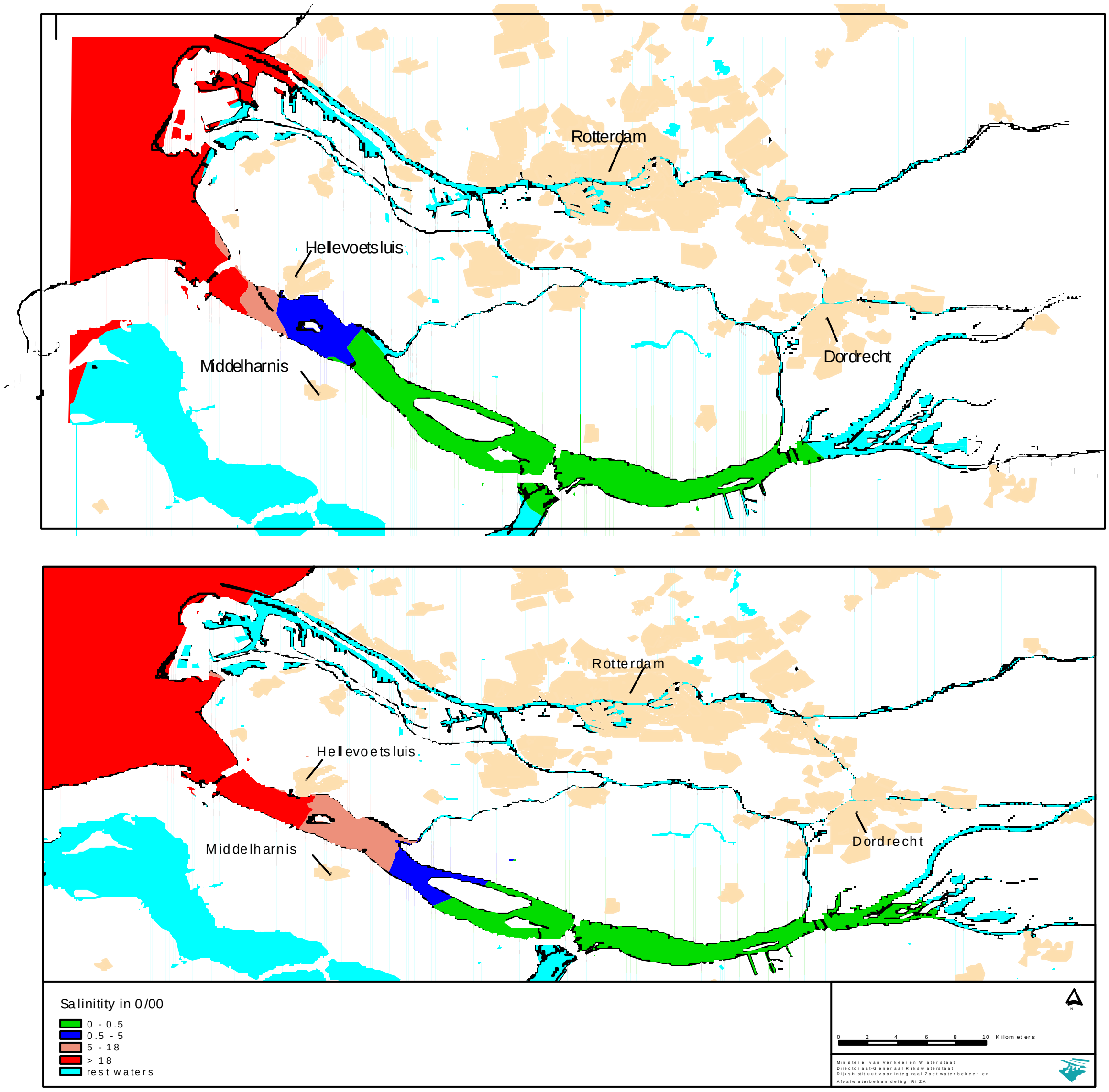

Figure 1: Salt intrusion at GEP during normal tide and upper figure: normal river discharge (2200 m^3/s) and lower figure: low river discharge (1000 m^3/s; after Bol and Kraak, 1998)

The effect of the partial opening of the sluices in GEP, presented in table 1, will lead to a smaller increase in the tidal amplitude and related parameters than for MEP, but it is still substantially higher than the present situation. A reversal of the current velocity is introduced in the area and, similar to MEP, maximum current velocities occur during flood. The values of maximum current velocity increase by 40 to 60% for the Haringvliet and the Biesbosch respectively. The tidal amplitude increases by 55 to 65%.

Table 1: Maximum current velocity, tidal volume, mean high water level (MHW), mean low water level (MLW) and tidal amplitude in Haringvliet, Hollandsch Diep and Brabantsche Biesbosch during normal tide and mean discharge of the river Rhine (2.200 m^3/s)

	MEP				
	Max current velocity (m/s)	**Tidal volume ($m^3 \times 10^6$)**	**MHW (m+NAP)**	**MLW (m+NAP)**	**tidal amplitude (m)**
Haringvliet	0.65	Pm	0.75	-0.15	0.90
Hollandsch Diep	0.60	Pm	1.00	-0.20	1.25
Brabantsche BB	0.65	pm	1.05	-0.25	1.30

Morphology

Like for MEP, an import of fine silty and muddy sediments from the sea is expected in the GEP-situation while the sand will not be able to pass the high ramp. It is rather uncertain to what level the suspended matter concentration will increase, although a rough estimate would be a maximum of 30% in the annual average concentration. Morphological calculations were carried out in case of partial opening of the sluices. Like for the MEP-situation, the change in the profile below mean water level is expected, due to a change in the hydrodynamics (compare Figure 2 with fig. 3). The figure illustrates that on a longer time scale the sedimentation front in the Hollandsch Diep shifts in a seaward direction when compared to the present situation for MEP. Eventually, the change in hydrodynamics will also lead to an increased sedimentation in the Haringvliet. The sedimentation in both the Hollandsch Diep and Haringvliet will, first of all, be confined to the deeper parts of the system (the former tidal channels and tidal gullys). It is doubfull whether sedimentation will increase onto the intertidal flats in such way that extension of this area can be expected, despite the increase in tidal amplitude. In this situation, the present day dredging activities will have to be maintained at a similar level.

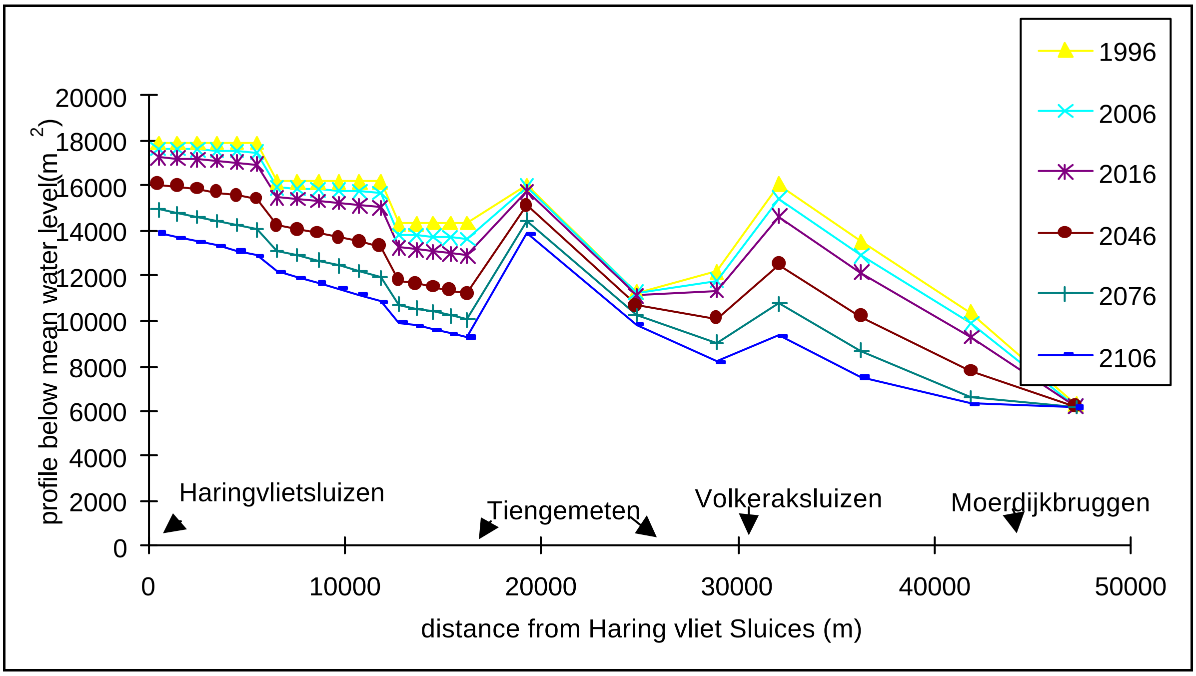

Figure 2: Morphological development of the profile below mean water level during GEP-situation (from Houwing et al., 1998)

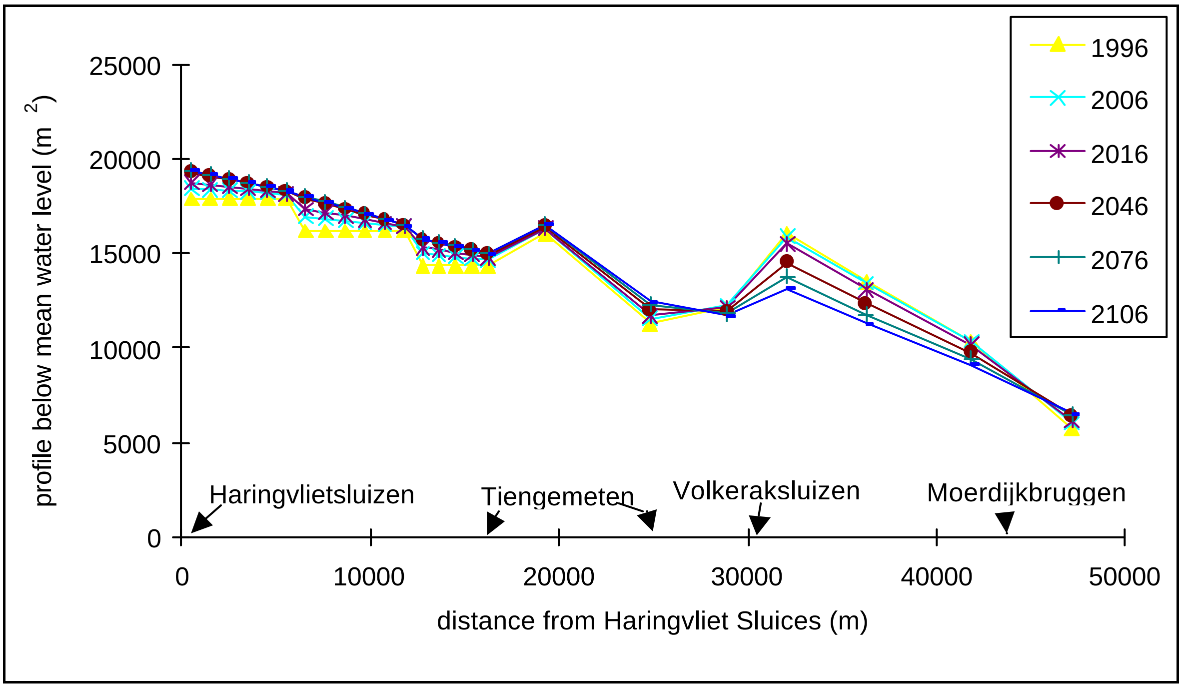

Figure 3: Morphological development of the profile below mean water level at MEP (from Houwing et al., 1998)

References	Contact
Backx, J.J.G.M., G. v.d. Berg, N. Geilen, A. de Hoog, EJ. Houwing, M. Ohm, M. van Oirschot and M. van Wijngaarden (2002), Heavily Modified Waters in Europe - Case Study on the Haringvliet Estuary, RIZA Dordrecht.	**J. Backx, RIZA** **J.Backx@riza.rws.minvenw.nl**

4.2.3 SUBSTEP 11.3 AND SUBSTEP 11.4

The values for the **general physico-chemical** quality elements at GEP are such as to support the achievement of the GEP biological values. It is also required that the values for the general physico-chemical quality elements at GEP are such as to ensure the functioning of the ecosystem [Annex V No. 1.2.5]. Accordingly, appropriate standards for these elements must be established.

GEP also requires compliance with environmental quality standards established for the **specific synthetic and non-synthetic pollutant** quality elements in accordance with the procedure set out in Annex V No. 1.2.6. The following example illustrates these substeps.

1. Physico-chemical quality elements and specific pollutants in the Haringvliet Estuary (Netherlands)

Example

1. Physico-chemical quality elements and specific pollutants in the Haringvliet Estuary (Netherlands)

To achieve GEP in the Haringvliet Estuary, Hollandsch Diep and Brabantsche Biesbosch, it is necessary that the general water quality characteristics (nutrient concentrations, temperature, oxygen content and pH) are sufficient to guarantee a naturally functioning ecosystem. In this case, the generic MPC (maximum permissible concentrations) values for nutrients, temperature, oxygen content and pH, as used in The Netherlands, were applied (see table 1).

With respect to specific synthetic and non-synthetic contaminants, in order to achieve GEP, concentrations should not exceed water quality criteria that have been determined using the procedure described in 1.2.6 of the Water Framework Directive. In this case, the water bodies in question should also comply with the MPC values for specific synthetic and non-synthetic contaminants, as used in The Netherlands (see Table 1).

Table 1: Indicative list of water quality criteria for achieving MEP and GEP (no MPC values for dissolved PCB's have been determined in The Netherlands)

General parameters		**MEP**	**GEP**
Total-N	mg P/L	0,05	0,15
Total-P	mg N/L	1	2,2
Temperature	ºC	< 25	< 25
Oxygen	mg/L	> 5	> 5
pH	-	6,5 – 9	6,5 - 9

Non-synthetic contaminants		**MEP**	**GEP**
Copper	μg/L	0,4	1,5
Zinc	μg/L	2,8	9,4
Mercury	μg/L	0,01	0,2
Cadmium	μg/L	0,08	0,4
Lead	μg/L	0,2	11
Nickel	μg/L	3,3	5,1
Synthetic contaminants			
Anthracene	ng/L	< d.l.	0,07
Benzo(a)anthracene	ng/L	< d.l.	0,01
Phenanthrene	ng/L	< d.l.	0,3
HCB	ng/L	< d.l.	9

d.l. lower than the detection limit for the contaminant concentration in water

References	**Contact**
Backx, J.J.G.M., G. v.d. Berg, N. Geilen, A. de Hoog, EJ. Houwing, M. Ohm, M. van Oirschot and M. van Wijngaarden (2002), Heavily Modified Waters in Europe - Case Study on the Haringvliet Estuary, RIZA Dordrecht.	**J. Backx, RIZA** **J.Backx@riza.rws.minvenw.nl**

4.3 REPORTING AND MAPPING FOR HMWB AND AWB

Regarding this issue please refer to the respective section of the HMWB guidance document:

	Chapter	Step
HMWB-Guidance	6.4	-

4.3.1 PROGRAMME OF MEASURES

HMWB and AWB are required to achieve "good ecological potential" (GEP) and good surface water chemical status. Member States must prevent deterioration from one status class to another, and aim to achieve GEP by 22nd December 2015 unless grounds for derogation are demonstrated.

Where the results of the monitoring programmes achieved on the Annex II risk assessments indicate that a HMWB or AWB is likely to fail to achieve GEP, Member States must establish an appropriate set of measures to improve the ecological potential of a water body with the aim of achieving GEP by 2015. Below you can find three examples on this issue.

1. Measures for achieving GEP in the River Dender (Belgium)
2. Measures for achieving GEP in the River Emån (Sweden)
3. Costs versus the likelihood to achieve ecological goals of MEP and GEP in the Haringfliet Estuary (Netherlands)

Examlpes

1. Measures for achieving GEP in the River Dender (Belgium)

The River Dender is influenced by different types of specified uses such as flood protection, navigation, urbanisation and agriculture as well as various physical alterations such as canalisation, straightening and dams. Due to the geology in the area, the stream discharge has a quick response to rainfall events. However, exceptional discharges in winter or in summertime are caused by canalisation and the locks. In the following paragraphs, the proposed basic and supplementary measures for achieving GEP in the Dender are presented.

Basic measures

In the case of the Dender, the measures for achieving GEP are the same as for MEP without the reduced tide. These measures can be seen as basic measures because they aim at enhancing the actual ecological quality. The measures proposed are applicable to a large river:

- *Connecting old meanders*: To increase structural variation, old disconnected meanders can be reconnected to the river. This gives possibilities to develop a rich vegetation of macrophytes to create shelter for spawning, feeding and hiding for fish.

- *Increasing structural diversity*: In rivers with a low structural diversity but with a sufficient flow (such as the water bodies designated as HMWB in this case: Dender6, Dender7 and Dender8), the construction of flow deflectors gives good results in increasing fish population and raising the variation of macrophyte communities. Another possibility is the construction of triangular rock deposits on alternating banks to imitate a winding river. The use of these deflectors have to be kept to a minimum in streams which by nature do not have such objects. It is only used for streams without the possibility to rewind on their own, such as the downstream section of the Dender.

- *Adjustment of the embankments*: Measures to create zones with lots of macrophytes are also possible, in order to create shelter for spawning and feeding. This can be done by removing the concrete embankments (or the wooden reinforcements) and replacing them by deposits of fractured rocks. This is supposedly the most ecological option to reinforce the banks and to prevent caving in and flooding. In these fractured rocks, it is possible for aquatic plants to grow roots and to fully cover the bank reinforcement after a while. An alternative option for this is the creation of a pre-bank reinforcement structure. This way a zone of calm water is formed between the real river bank and the secondary bank. This pre-bank structure protects that zone from waves caused by passing ships.

- *Solving fish migration bottlenecks*: Because the Dender has a connecting function (main migratory route, institute for nature conservation) and MEP includes ecological continuum, measures have to be taken to eliminate the migration bottlenecks. A diversion channel can be dug around the locks, which can be constructed as a winding river with a high fall and roughness. This adjacent channel is used by fish to travel around the lock, as well as for shelter and a spawning place for stream-loving species. To make it as natural as possible, it is important to use natural materials and local plants for decoration. A problem with such a channel is the amount of space needed for construction of it, especially in the residential or industrial area in the vicinity of the locks. If creating an adjacent channel isn't possible, other types of fish passages can be constructed, like fish ladders with V-shaped spillways.

Supplementary Measures

The previous measures all affect the physical stress factors of the River Dender. It is obvious that these measures on their own can't achieve a large improvement of the ecological quality if the water quality doesn't change. Therefore, supplementary measures are proposed.

An important measure is to decrease the impact of waste water discharges in the Dender. These discharges do not only have effects on the flow rate of the river, but they also have negative effects on the water quality itself. The water quality in the downstream sections of the Dender is poor, due to the toxicity level of the discharges. This has to be improved, otherwise the basic measures to boost macrophyte development and fish population won't reach the objectives intended.

When the previous measures are taken, an additional measure is the introduction of fish species in the Dender. To have a chance of success, first structural quality (shelter, spawning place, fish passages) and water quality (decreasing pollution) have to be improved.

References	Contact
Vandaele, Karel, Ingrid De Bruyne, Gert Pauwels, Isabelle Willems and Thierry Warmoes (2002), Heavily Modified Waters in Europe - Case Study on the Dender river, the Mark river and Bellebeek river in Flanders, Soresma, environmental consultants and Flemish Environmental Agency, Leuven and Antwerp.	**Karel Vandaele, SORESMA** **Karel.vandaele@soresma.be**

2. Measures for achieving GEP in the River Emån (Sweden)

The River Emån is the largest river in south-eastern Sweden and is heavily affected by over forty hydropower plants along its course. In the sub-basin (River Solgenån) where the case study has focused, there are three large hydropower plants, hindering the migration of *Salmo trutta*. Here the appropriate set of measures (proposed basic and supplementary) for achieving Good Ecological Potential are outlined.

Basic Measures

According to the WFD, the relevant basic measures for this case study are surveillance of pressures on the hydromorphology, recovery of costs for water services and the measures necessary to fulfil the requirements of the directives listed in Annex VI part A. Out of the directives mentioned in Annex VI part A, only those considering physical and hydromorphological modification are regarded in this case study, since only those kinds of modifications are studied. The following measures are demanded to fulfil the requirements of the WFD:

• *Careful analysis before more water withdrawals are allowed*. Both the Water Framework Directive and the Environment Impact Assessment Directive should be used by the assessment of the impacts of new water withdrawals. It is important to find out whether a new water withdrawal would risk the fulfilment of the good ecological potential. Since the highest possible minimum tapping of 5 % is much lower than the ecologically optimal minimum release, there is a risk that a water withdrawal might have a considerable effect in this area.

• *The costs for the water services could be gathered in trust funds* . The hydropower companies could pay an amount of money each year or as a lump sum. These trust funds could finance for example, ecosystem restoration and protection, and public education. It is suggested that these funds are managed and the money distributed, by an advisory council with members such as environmental authorities, NGO's and others concerned.

• According to the *Birds Directive* (79/409/EEC) article 4: ”The species mentioned in Annex I shall be the subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution”. Out of the bird species mentioned in Annex I, the following species are likely to be found in water body 3: black-throated diver, whooper swan, smew, osprey, crane, wood sandpiper, common tern and kingfisher. The mitigation measurements that would be necessary in order to protect these species are a minimum tapping to improve the environment in the old, dry river channels, and gradual increases/decreases, when the tapping is changed.

• The aim of the *Habitats Directive* (92/43/EEC) is ”to contribute towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora”. A European ecological network of areas is, at the moment, set up under the title of Natura 2000. River Solgenån (lower) has not been chosen to be one of the Natura 2000 areas, but Lake Solgen is a Natura 2000 area. According to the Water Framework Directive article 4.8, the measurements to achieve a good ecological potential must not risk the achieving of the aims of the WFD or other EU-legislation in adjacent waters. As a consequence, the mitigation measurements in water body 3 to achieve a good ecological potential must not risk the aims of the Habitat Directive in water body 1 (Lake Solgen).

Supplementary Measures

The definition of supplementary measures is found in the WFD article 11.4 and part B of Annex VI. The following supplementary measures have been suggested for this case study:

• The criteria for *environmental management standards*, such as ISO 14 000, could in the case of the certification of hydropower companies, be complemented with the requirements of the WFD. It is suggested that MEP should be fulfilled for those hydropower plants situated in areas classified as HMWB in order to achieve an environmental certificate. For those hydropower plants situated in areas not classified as HMWB, at least a good ecological status should be achieved and maintained in order to achieve an environmental certificate.

• A very important part of the work with the WFD is to *inform the public*. One of the sub-catchments of the River Eman could be used as a demonstration site for public information and involvement. This area could be restored and carefully monitored in order to investigate the effects of the restorations. Such a project could be a co-operation between the county administrative board and district authorities in the study area, such as already existing networks like the Emå-project and the Emån water society, NGO's and others. Apart from demonstration of river restoration and investigation of the effects, the aims of such a project should be to inform the public about the WFD, the pressures on rivers and what can be done. The project could be financed by money from the trust funds suggested as one of the basic measurements.

• *Time-limited licenses for hydropower plants* are used in the US. These licences include environmental requirements and have to be renewed every 30 to 50 years. When an application for a re-licensing is made, the licensee has to provide a description of the financing and the environmental impacts of the project. Both the concerned authorities and the public get an opportunity to review the plan and, for example, suggest additional measurements to mitigate the environmental impacts. It is suggested that this method should be used also in the case of Eman and in EU countries in general.

• *Water-saving measures* for industries and agriculture could also be useful in order to maintain a good ecological potential. The regulation of Lake Solgen does not only function as a reservoir for the hydropower plants, but also as one of the reservoirs for the rest of the River Emån. Water-saving measurements could, for that reason, result in a lower regulation of Lake Solgen and more water in Solgenån (lower) and a better environment in water body 3.

References	Contact
Weichelt, Anna-Karin (2001), Heavily Modified Waters in Europe - Case Study on the Emån river, Sweden, County Administrative Board Jönköping, Jönköping.	**Anna-Karin Weichelt, County Administrative Board Jönköping** **Lansstyrelsen@f.lst.se**

3. Costs versus the likelihood to achieve ecological goals of MEP and GEP in the Haringvliet Estuary (Netherlands)

The (economic) costs of measures versus the (ecological) benefits can be a way to define the practicability of measures. Such an ecological cost-benefit analyses was worked out in more detail in the case study on the Haringvliet Estuary and will be presented as an example here.

For the Haringvliet, the main mitigation measure is a re-opening of sluices in a dam, which nowadays separates the former estuary from the sea. Such measures would initiate salt intrusion and tidal motion in the currently low dynamic, fresh water system of lakes. However, mitigation measures for defining MEP should not have a significant adverse effect in the uses. The effects that the proposed mitigation measures will have on the use of the fresh water supply, intensively used for drinking water and agriculture, need to be compensated. Such costs were also taken into account in quoting the total costs. Another issue is that the polluted sediments in the basin need to be remediated before the sluices are opened, to prevent these sediments from being eroded and transported to the North Sea.

Two scenarios for sluice management were defined: in MEP sluices are maximally opened and only used as a storm surge barrier, whereas in GEP a more moderate sluices management is implemented. Consequently, the most important difference between MEP and GEP is that the impacts on the uses (fresh water supply) are much more significant in MEP, with likewise consequences for the costs. The costs involved in carrying out the measures for MEP and GEP were quoted as presented in the table below.

It should be pointed out that the costs of the measures themselves (opening the present sluices) are not taken into account in setting the standards for the hydromorphological quality elements at MEP. Opening the sluices costs practically „nothing“. The costs of the mitigation measures for the use function, such as altenative drinking water supplies, are, however, taken into account.

Table 1: Measures and costs to achieve MEP and GEP

Masures to achieve MEP and/or GEP	**Estimated costs for MEP (millions €)**	**Estimated costs for potential GEP (millions €)**
Dredging contaminated sediments Haringvliet	512	512
Benefits from national policy for dredging Haringvliet	170	170
Total costs for mitigating measures	342	342
Compensating uses	1	2
Agricultural water supply	410	118
Drinking-water supply	15	15
Fisheries	1.5	1.0
Recreation	15	14
Navigation	21	19
Other uses	4	1
Total costs for alternative water uses	**466**	**168**
Total estimated economic costs	**808**	**510**

To scale these costs with the achieved ecological restoration for each of the WFD objectives, the expected ecological restoration was estimated for each of the environmental objectives. HES was defined as the situation with sediment remediation over the whole of the estuary, whereas it was assumed that only with a partial remediation GES will be achieved. With respect to the ecological recovery, HES is considered a 100% recovery and the present situation no recovery.

In the figure below, the costs and effects of the WFD aims are compared. The figure illustrates that for GEP the ecological restoration achieved is quite high already (70-80%), while the costs are almost 50% lower than those to be invested for MEP. This scenario can, therefore, be considered [1)] a slight ecological deviation to MEP (80% ecological restoration in stead of 90%), in which [2)] the ecological continuum especially for fish migration is restored (sluices are still opened) and in which [3)] costs are much lower than for MEP.

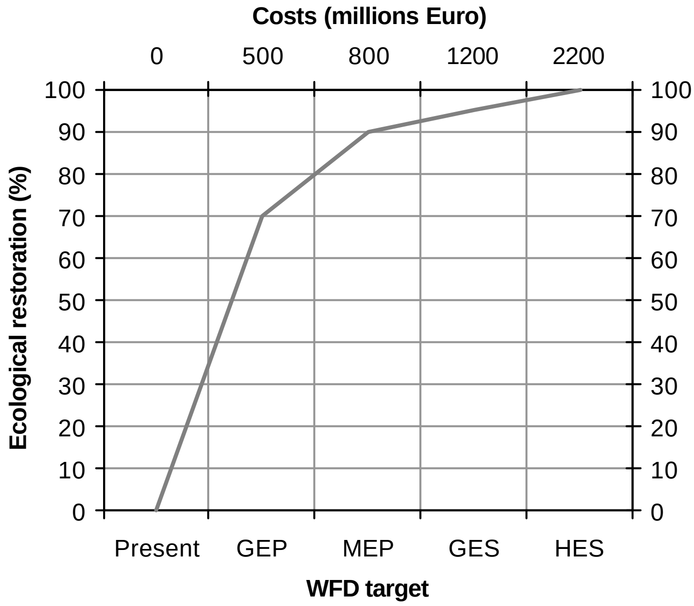

Figure 1: Costs of GEP, MEP, GES and HES

References	Contact
Backx, J.J.G.M., G. v.d. Berg, N. Geilen, A. de Hoog, EJ. Houwing, M. Ohm, M. van Oirschot and M. van Wijngaarden (2002), Heavily Modified Waters in Europe - Case Study on the Haringvliet Estuary, RIZA Dordrecht.	**J. Backx, RIZA** **J.Backx@riza.rws.minvenw.nl**