WFD AND HYDROMORPHOLOGICAL PRESSURES

TECHNICAL REPORT

Good practice in managing the ecological impacts of hydropower schemes; flood protection works; and works designed to facilitate navigation under the Water Framework Directive

- November 2006 -

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Annexes

Separate document: ”Case Studies - potentially relevant to the improvement of ecological status/potential by restoration/mitigation measures”

1 Introduction

1.1 On December 22, 2000 the European Water Framework Directive (EU/60/2000, WFD) came into force setting a new frame towards the management of European river basins. The overall environmental objectives of the Water Framework Directive (WFD) for both surface waters and groundwater are:

- To aim to achieve good status for all surface water bodies by 2015
- To aim to achieve good chemical and quantitative status for all groundwater bodies by 2015

1.2 At the end of 2004 and in accordance with the requirements of the Water Framework Directive, Member States completed an analysis of pressures and impacts on the environmental quality of their surface waters and groundwater.

1.3 The results of this analysis showed that a significant number of surface water bodies across Europe are at risk of failing to achieve good ecological status, one of the main objectives of the Water Framework Directive. A high proportion of these water bodies were identified as being at risk or probably at risk because of alterations to their structural characteristics (i.e. their morphological characteristics) and associated impacts on their water flow and level regimes (i.e. their hydrological characteristics).

1.4 In addition, a high proportion of surface water bodies have been provisionally identified as heavily modified water bodies (HMWB) and to a less extent as artificial water bodies (AWB) (see Table 1). Heavily modified water bodies are substantially changed in character due to hydromorphological alterations, sometimes involving a change in category (e.g. a water body has changed from a river to a reservoir as a result of a dam). The specific objective for heavily modified and artificial water bodies is to achieve good ecological potential. Good ecological potential represents an ecological status slightly lower than the best one that could be achieved without significant adverse effects on the specified water uses dependent on the modifications or on the wider environment (Art. 4(3)(a) WFD).

Table 1: Results of the “article 5” report carried out by the Member States (Data from WRc Report version 2 – WRc 21st July 2006).

HMWBs of total WB	about 20 %
AWBs of total WB	about 4.5 %

1.5 The results of the analysis of pressures and impacts were not surprising. Some uses of surface water bodies depend on hydromorphological alterations to a greater or lesser extent. In addition those alterations often cause subsequent changes of the morphology which do not support or maintain the uses. Nevertheless, it is recognised that some sustainable uses may need hydromorphological alterations of water bodies to a certain extent.

1.6 Important uses of surface waters which may impact on hydromorphology include navigation, flood protection, activities for the purpose of which water is stored (drinking-water supply, power generation or irrigation) and recreation as specified in Art. 4(3)(a) of the WFD. Urbanisation is not specifically mentioned in the WFD. Urbanisation can be associated with modifications to surface waters for the purposes of flood defence, land drainage, erosion control and land claim. For the purposes of this report, urbanisation is considered as one of “other equally important sustainable human development activities“ referred to in Article 4(3) of the Directive. Specific hydromorphological alterations such as cross profile constructions in rivers (dams & weirs) and deepening or channelisation are necessary for certain uses. Those alterations may serve not only one but several uses, they are multipurpose alterations. For example, a particular dam and weir may often be used for navigation, flood protection and hydropower purposes.

1.7 Because of the large number of water bodies identified in the Art. 5 reports as being at risk due to hydromorphological alterations; because such risks have not been addressed in previous European environmental legislation; and because many of the water uses depending on hydromorphological alterations provide important economic, social and environmental benefits, the Water Directors agreed at their meeting in Luxembourg in June 2005 to start a new activity on hydromorphological alterations as part of the Common Implementation Strategy (CIS). The aims of the activity are:

- to identify how best to manage synergisms and antagonisms between the management of hydromorphological alterations in river basin management planning and the requirements of other policies & activities by appraising social, economic and environmental impacts and benefits;
- to exchange information on the assessment and management of hydromorphological pressures and impacts between Member States;

in order to promote common and comparable approaches to WFD implementation.

1.8 On the basis of the results of the pressure and impact analysis, the focus of the **CIS activity on hydromorphology** is on hydropower generation, navigation and flood protection. These important and widespread water uses are responsible for significant hydromorphological changes to Europe’s water bodies.

1.9 This technical report is an output of the CIS activity. It aims to provide a toolbox of prevention, mitigation and restoration measures, not only to the governmental bodies at different levels but also to water managers, operators and stakeholders. These measures cannot be compulsory for all projects and must be adapted individually to reflect the specific characteristics of the project concerned and of the affected water body or bodies.

1.10 In parallel to the technical report, a policy report on “WFD and Hydromorphology – Recommendations for better policy integration” has been developed. To have a more comprehensive understanding, it is thus recommended that the policy paper be read in conjunction with this technical report.

2 Purpose of the Report

2.1 The aim of this report is to provide guidance and good practice examples of how to prevent, remedy or mitigate the adverse ecological effects of human alterations to the structural and hydrological characteristics of surface water bodies in order to achieve the environmental objectives set by the WFD.

2.2 It is based on information gathered from a wide range of practitioners from across Europe. Its aim is to share this experience more widely among water managers. As well as assisting local managers, it is also hoped that the information contained in the report will help promote consistency in decision-making on how best to protect, enhance and restore surface water bodies (good practice) by showing that there are ways and means to reconcile social, ecological and economic concerns.

2.3 The focus of the report is on measures relevant to addressing the adverse effects of hydromorphological alterations typically associated with hydropower schemes, flood defence schemes and navigation. However, many other water uses involve similar sorts of alterations. Consequently, water managers and authorities will be able to draw conclusions on the information contained in this report in a wide range of decision-making situations.

2.4 The report addresses both current hydromorphological alterations and future pressures (e.g. planned infrastructure projects), which may impact the status of surface waters by altering their hydromorphology.

2.5 In the context of understanding of this document and according to the process of identification and designation of HMWB and AWB (see CIS Guidance Document No. 4), restoration measures mean measures necessary to ensure the hydromorphological conditions of a water body are consistent with the achievement of Good Ecological Status (GES). Measures that do not restore a water body to GES are referred to as mitigation measures. That includes measures to achieve Good Ecological Potential (GEP). All mitigation measures are to be identified to establish the Maximum Ecological Potential.

2.6 The criterion used in the HMWB and AWB Guidance to distinguish both types of measures is whether GES is reached (restoration) or is only approached (mitigation), for example:

1. Water level management in a lake is “restoration” when natural water level fluctuation is mimicked so that GES of macrophytes (and all other biological elements) will be met. However, when the ecological status improves, without reaching GES, the measure is “mitigation”.
2. A fish-ladder can mitigate the effect of a dam, but an efficient type may result in GES which makes it a restoration measure in some situations (e.g. on small weirs).
3. If in a water body with multi-modifications some are “restored”, while at least one can not be restored. This means that the overall state of the water body can not be restored to good. Therefore the impacts on the water body as a whole have only been mitigated.

2.7 These examples illustrate that the same measure can be in different circumstances ”restoration” or “mitigation”. For practical reasons the good practice examples in this report, delivered by case studies, do not therefore distinguish restoration from mitigation.

2.8 Beside the six main chapters, this report includes seven annexes and a separate comprehensive document with case studies. Annex I summarises the relevant requirements of the Water Framework Directive. An alternative approach to defining Maximum Ecological Potential (MEP) and Good Ecological Potential (GEP) is presented in Annex II. Annex III provides an overview of the effects of hydromorphological alterations on aquatic life and of criteria for the improvement of the ecology. Information on potential restoration and mitigation measures identified by Member States is given in Annex IV in form of literature and links. In addition Annex IV provides information on CIS guidance documents relevant for this report. In Annex V case studies demonstrate measures which might contribute towards the improvement of ecological status/potential by restoration/mitigation. The descriptions of the different case studies are summarised in a separate comprehensive document. A glossary for interpretation of the technical wording used is added as Annex VI. The members of the drafting group for this report are registered in Annex VII.

3 General approach to identifying measures

3.1 The first step in selecting appropriate measures is to identify the adverse ecological effects caused or likely to be caused by a particular modification of the hydromorphological characteristics of the water body or by a combination of modifications.

3.2 Human activities often result in several alterations. However, many physical modifications serve not only one but several uses: they are multipurpose modifications. For example, cross profile constructions in rivers (dams & weirs) and deepening or channelisation may be necessary for navigation, flood protection and/or hydropower purposes. Water bodies may become at risk of failing to achieve their environmental objectives due to hydromorphological changes, leading to ecological impacts (i.e. impacts on biological elements). Measures to improve the ecological status can not always clearly be related to one use or to one alteration. In practice, the relation between uses, alterations, state and measures can be complex. A general approach to identifying appropriate restoration measures for water bodies at risk of failing to achieve good status by 2015 due to hydromorphological changes is presented in Figure 1. In addition a comparable approach to identifying appropriate mitigation measures for heavily modified and artificial water bodies is presented in Figure 2.

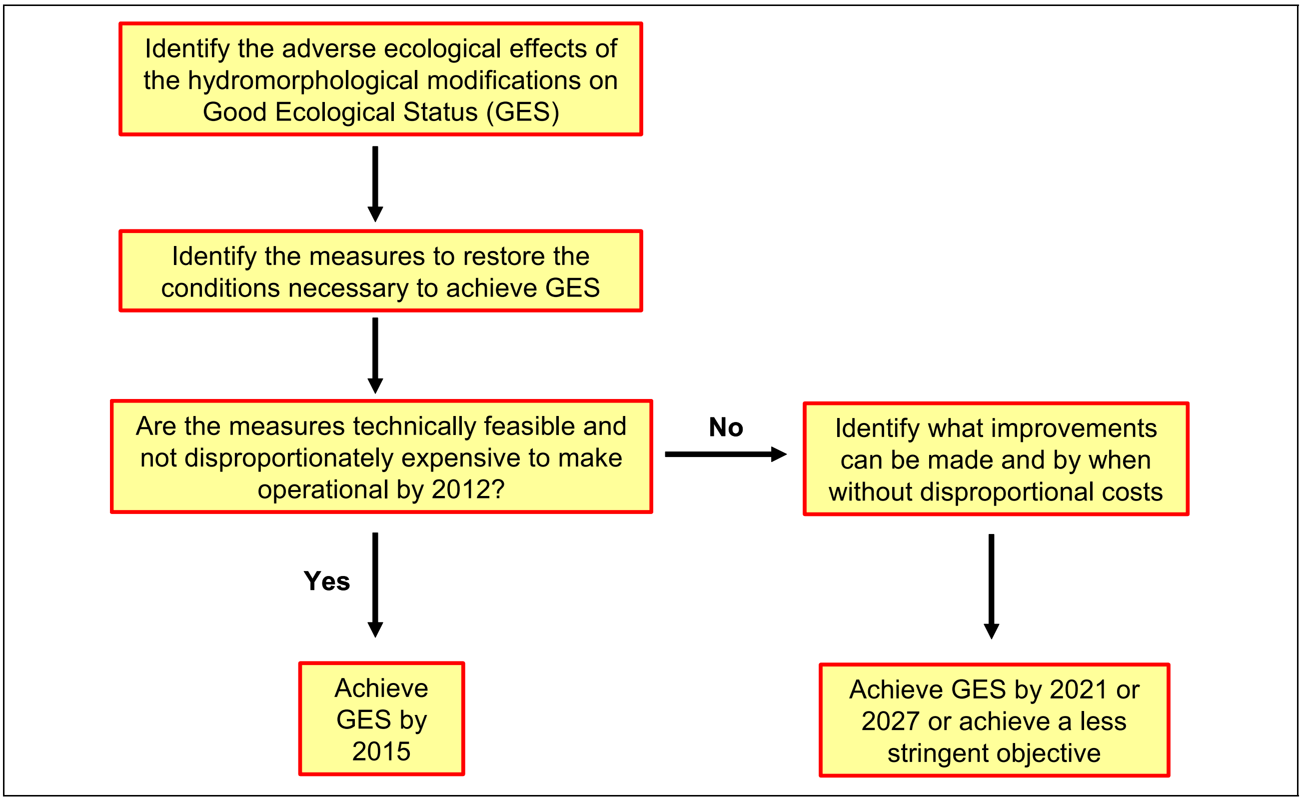


Figure 1: Selection of restoration measures and planning of objectives for water bodies at risk of failing to achieve GES by 2015 due to hydromorphological changes.

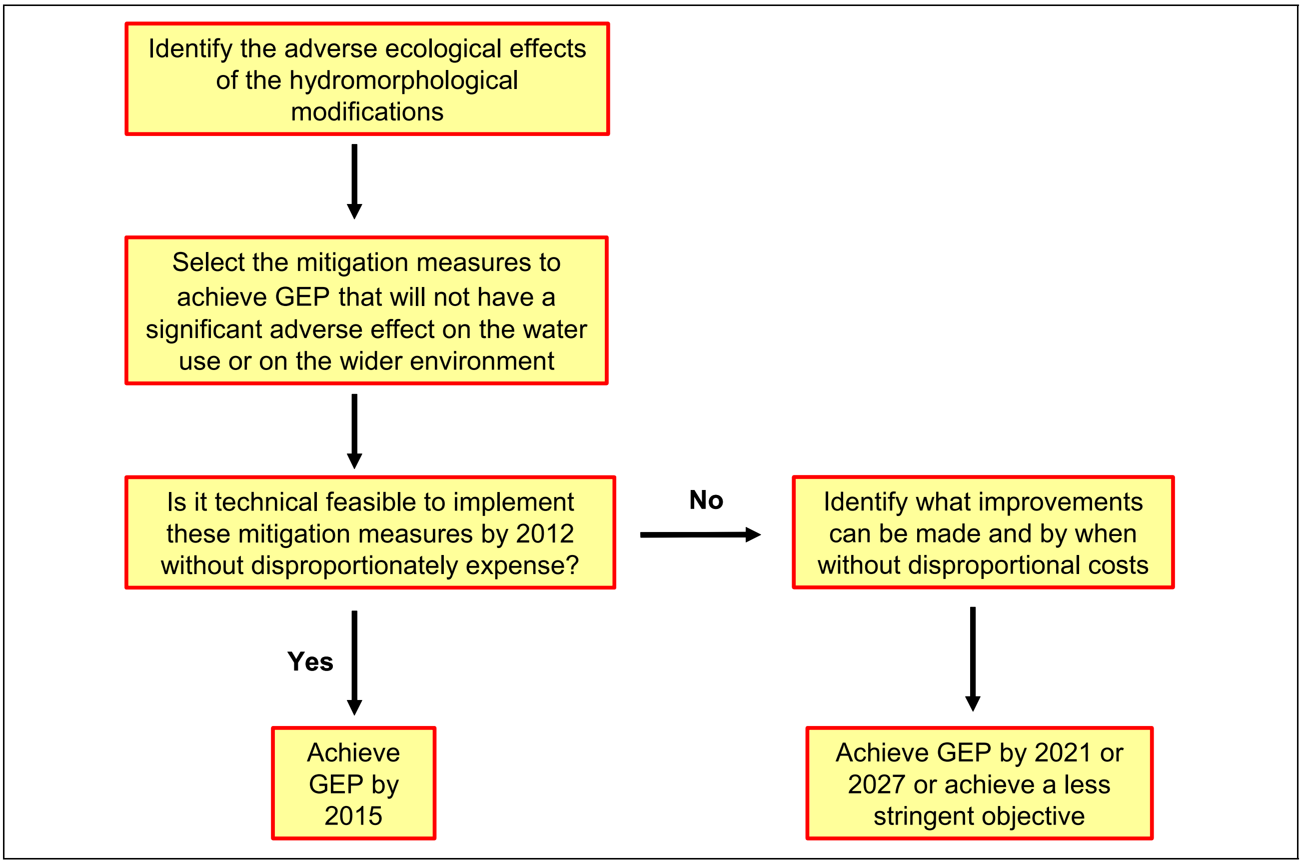


Figure 2: Selection of mitigation measures and planning of objectives for HMWB and AWB (in order to achieve GEP or a less stringent objective than GEP).

3.3 There exists an important difference between these approaches: while the biological values defining MEP and hence GEP depend on what mitigation measures it would be possible to take without significant adverse impacts on specified water uses or the wider environment, the values defining High Ecological Status (HES) and GES do not depend on any consideration of impact of the measures needed to achieve them. Socio-economic considerations shall not play a role in the definition of status classification systems (Objective Guidance Document, p. 11). In both cases, the technical and economic feasibility of the measures are taken into account when choosing the environmental objectives (GES or GEP in 2015, 2021 or 2027 or a less stringent objective).

3.4 Nevertheless, by definition, the environmental objectives assigned to AWB and HMWB expressed in terms of ecological potential take into account the physical modifications due to their designation. Therefore, only those measures that will not have a significant adverse effect on the use for which the body has been designated can be used in mitigating the adverse ecological effects of the modification.

3.5 For example, a dam required for hydropower generation is preventing the upstream and downstream movement of migratory fish through a heavily modified river. Removal of the dam to facilitate fish passage would have a significant adverse effect on hydropower generation. Consequently, the measure *'removing the dam'* cannot be identified as a mitigation measure.

3.6 The definition of GEP is recognised as a major technical challenge. In many cases current knowledge is insufficient to assess or model precisely the impacts of hydromorphological alterations on the biological quality elements. The same applies to mitigation measures involving physical modifications. This knowledge will be improved in coming years through research and monitoring (monitoring of water status/potential, assessment of the effects of measures, etc.). The approach to define GEP/MEP presented in Annex II tries to simplify the modelling needs, and has been proposed as alternative to the HMWB guidance method.

3.7 Both approaches are still somewhat theoretical. Their advantages and disadvantages are yet to be demonstrated. As with the approach described in the HMWB guidance document, the practical application of this alternative approach should deliver a definition of MEP and GEP and a classification system for HMWBs that is consistent with the requirements of Annex V of the WFD.

3.8 It is therefore recommended that further works is carried out on the application of the methods, and, once Member States have gained experience, further consideration is given to whether the methods need further development and improvement.

3.9 Hydromorphological alterations of surface water bodies related to the use can cause subsequent impacts on the ecological status of water bodies. For example the continuity of surface waters is often disrupted by weirs constructed for navigation or hydropower generation. Such structures usually disrupt natural sediment transport and the migration of fish. This can have considerable adverse effects on natural aquatic communities. The degree to which the adverse ecological effects of such structures can be mitigated is of high importance in determining the ecological status or potential achievable in the affected water bodies. In some cases, the construction of functioning fish ways and measures to promote natural bed load transportation may be sufficient to enable the achievement of good ecological status.

3.10 In many cases there will be a hierarchy of possible options for addressing the adverse ecological effects of a hydromorphological alteration (see also paragraphs 2.5 – 2.7). For a proposed new modification, options which prevent or avoid the impact should be explored first. In the event that an impact cannot be prevented, measures to mitigate it should be considered.

3.11 Where an existing physical alteration is affecting the hydromorphological and ecological conditions of a water body, options to restore the affected water body to GES should first be considered. If such restoration is not viable because it would be technically infeasible, disproportionately expensive, or result in significant adverse effects on the specified water uses or on the wider environment, mitigation measures aimed at reducing the environmental impacts of the physical alteration should be assessed. Such measures might include, for example, increased compensation flows or provision of fish passage to reduce the impacts of a weir.

3.12 In most of the cases, a single measure is not sufficient to remedy or alleviate negative ecological impacts due to hydromorphological alterations. In some cases a combination of measures alleviating negative impacts of hydromorphological alterations can include also other than hydromorphological measures. For example, navigation rules to avoid excessive wash or suction or, in the longer term, modifying the design of vessel hulls or propulsion systems, can help to mitigate river bank erosion and reduce the need for (further) hydromorphological intervention. In Finland, Norway and Sweden stocking of fish and their eggs has been used in many regulated water courses as a cost-efficient way to mitigate the impacts of reduced natural reproduction and therefore to improve the status of fish. In several countries removal of cyprinids has been used to stimulate zooplankton predation on phytoplankton and therefore returning the lake from the turbid to the clear water state. Stocking and removal of fish can be used to

- initiate the restoration of fish population and/or
- act as a mitigation measure for the impacts on fish populations of the physical alterations associated with heavily modified water bodies.

However, even though these measures can be useful mitigation measures (e.g. for supporting the preservation of endangered fish species), they do not provide a sustainable long term solution to meet GES. This is because they do not alleviate the hydromorphological alterations and their ecological impacts on other biological aquatic communities).

3.13 In considering restoration or mitigation options, it may be that more than one measure could achieve the same ecological improvement. In such cases, a judgement will need to be made about which option is most cost-effective (see Chapter 5). However, whilst both fish passes illustrated in Figure 3 would facilitate fish movement upstream and downstream, the benefits for the production and migration of macroinvertebrates and the value of the additional spawning areas provided by the more natural structure should also be considered.

Figure 3: Two types of functioning fish passes – the more natural- like bypass channel is more costly in this case but provides useful additional spawning ground.

3.14 Having selected measures that would most cost-effectively address the adverse effects of the modifications to a water body, consideration should be given to when, and if, it is practicable to implement those measures. For example, it may be technically infeasible or disproportionately expensive to implement all the identified measures in the first planning cycle but phasing the measures over two or more planning cycles may be practicable. Such decisions will determine the environmental objective applicable to the water body and will have to be specified in the River Basin Management Plan (see Figures 1 and 2).

4 Selection of appropriate measures considering site specific conditions

4.1 The precise definition of the measures appropriate in any given situation is likely to depend on the particular characteristics of the water body and the water use concerned.

4.2 As briefly mentioned above, the choice of the appropriate restoration and mitigation measures within the planning cycles in any particular case will depend on a number of site specific considerations. Specifically, the appropriate measures will depend on the adverse ecological effects of the physical modifications; on the effectiveness of the measures regarding in particular the improvements of the ecological condition; on the technical feasibility and the cost-effective analysis of implementing the measures at the site; and, in the case of designated HMWB or AWB, on the effects of the mitigation measures on those water uses responsible for the modifications and other uses dependent on the modification (e.g. bathing). In any case the efficiency of restoration and mitigation measures should be considered not only on a local water body scale but also at a river basin scale.

4.3 Hydropower installations, navigation activities and/or navigation infrastructure and flood defence works are typically associated with a range of hydromorphological alterations with potential adverse ecological consequences (examples see Figures 4 a-d). Often these equipments are used for different purposes. The actual extent of the alterations associated with any particular scheme will depend on the design characteristics and management of the scheme. Therefore the identification of appropriate measures depends more on the alterations that have been made than on the uses themselves. Moreover the degree of the adverse ecological effects of the alterations that are associated with a particular scheme will depend on the particular characteristics of the affected water body or bodies.

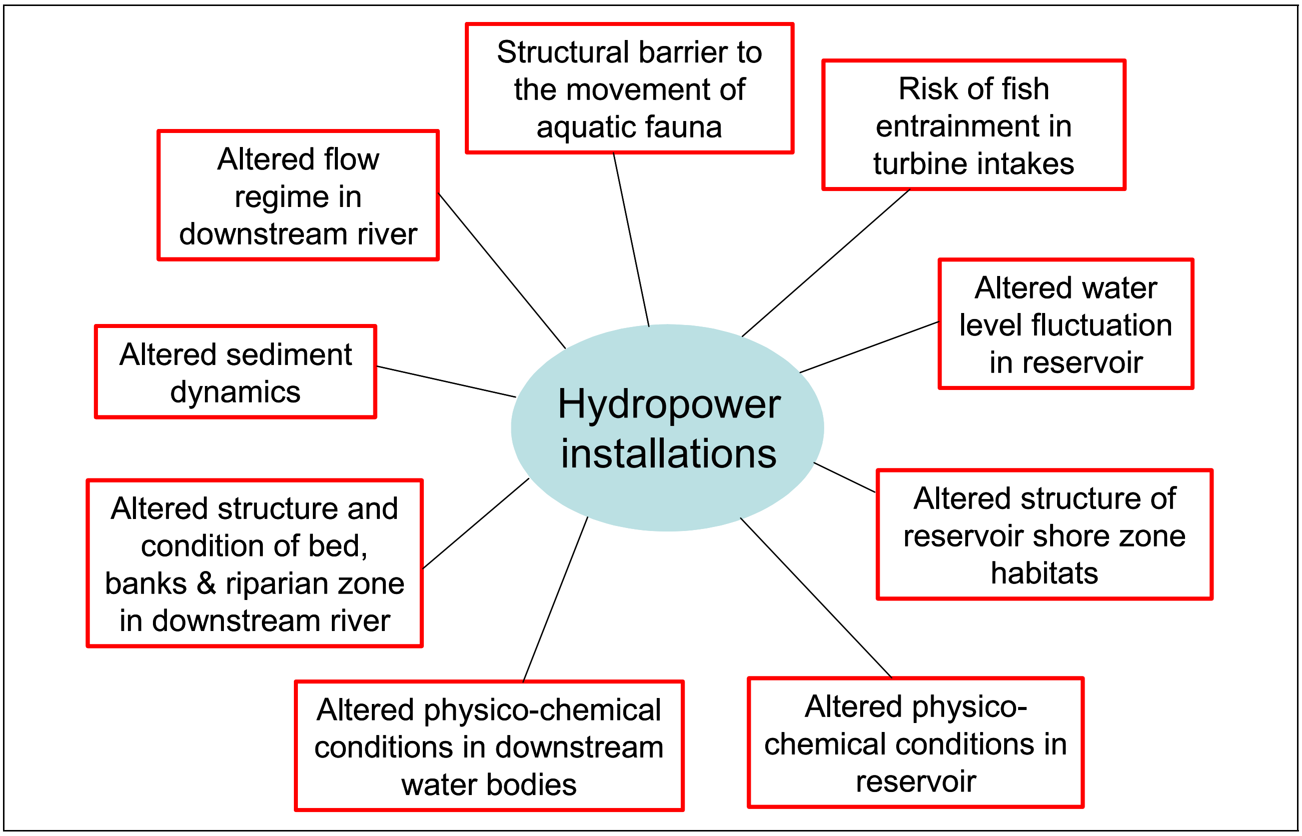


Figure 4a: Illustrative range of possible alterations typically associated with hydropower dams with subsequent biological alterations (More information available in Annex III).

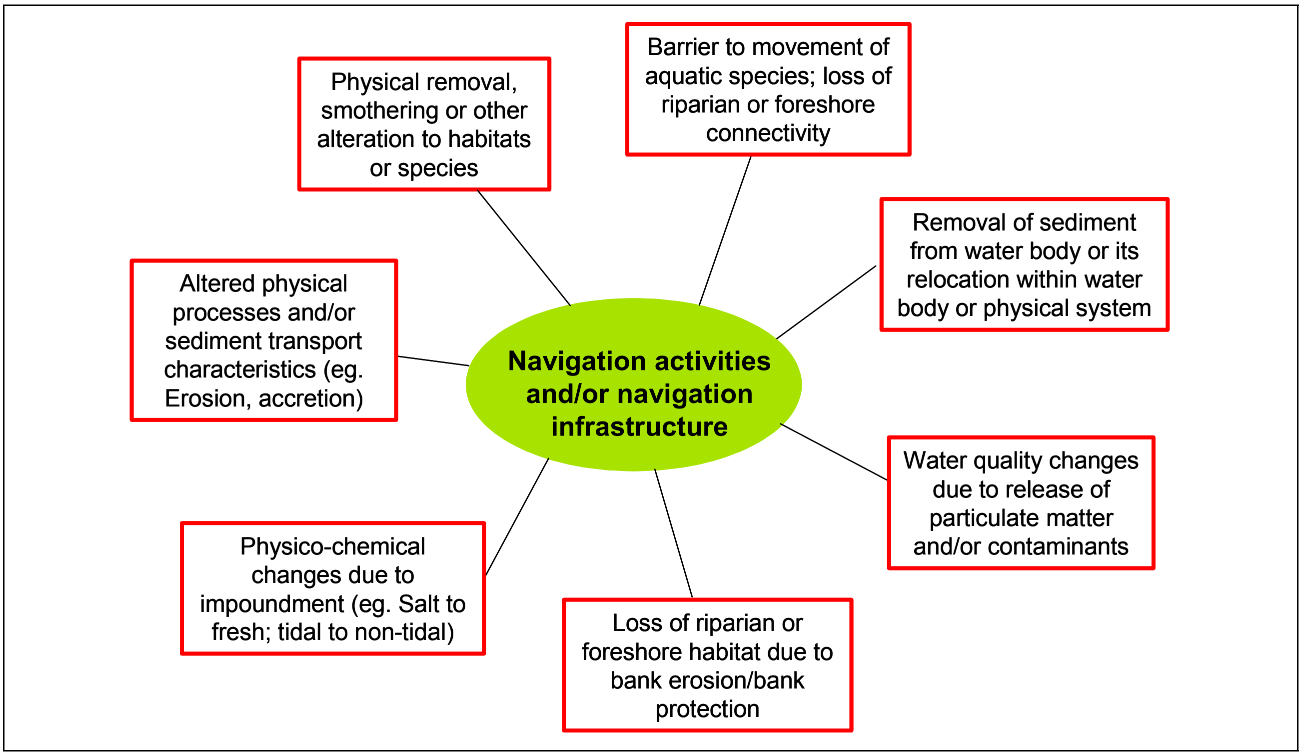


Figure 4b: Illustrative range of possible alterations typically associated with navigation activities and/or navigation infrastructure with subsequent biological alterations.

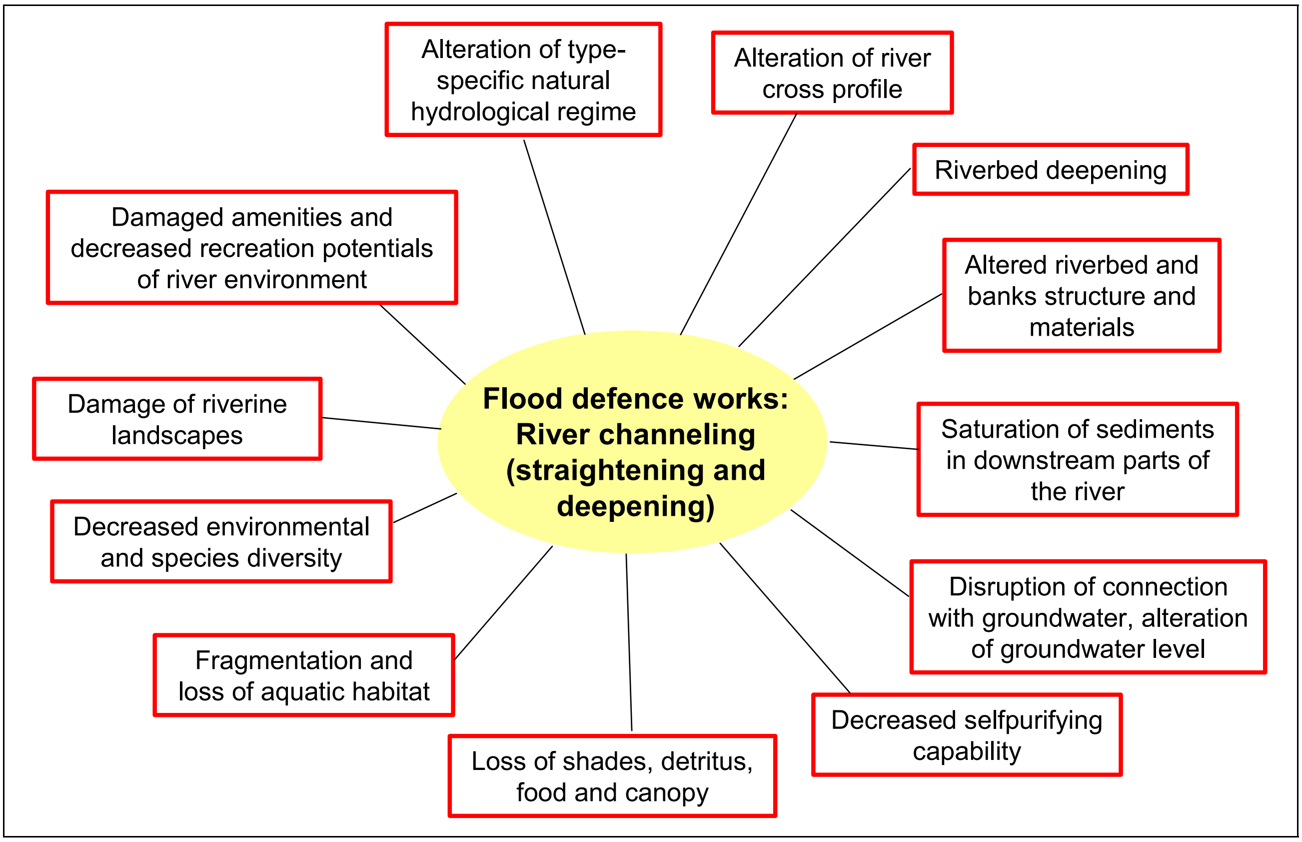


Figure 4c: Illustrative range of possible ecological alterations and impacts typically associated with flood defence works – river corridor channelling (straightening and deepening).

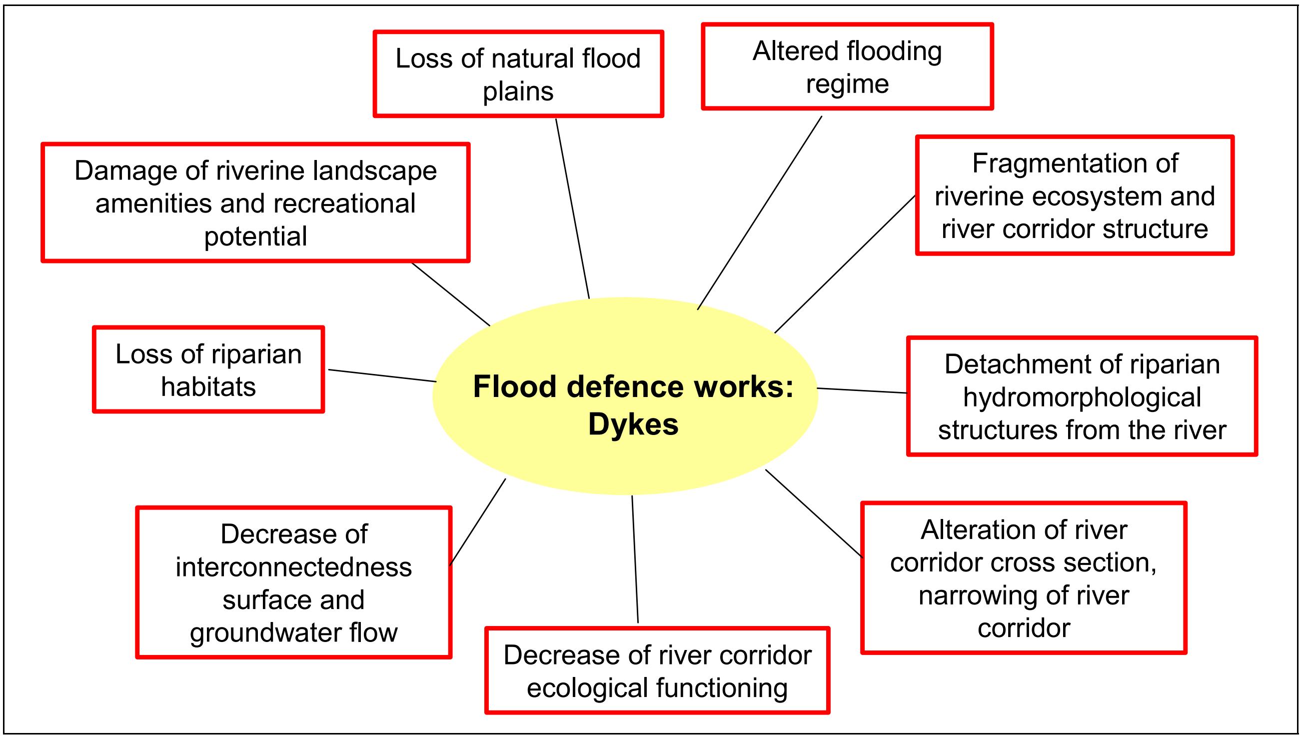


Figure 4d: Illustrative range of possible ecological alterations and impacts typically associated with flood defence works – dykes.

4.4 For example, if migratory fish do not, because of natural reasons, access the part of the river system in which a dam is located (e.g. because of an impassable natural waterfall downstream), that dam will have no adverse effect on fish migration. Nevertheless, it may be relevant to implement a selection of measures in order to improve the ecological continuity of the river and the values of the biological elements, without adverse impacts on the specified uses of the water body.

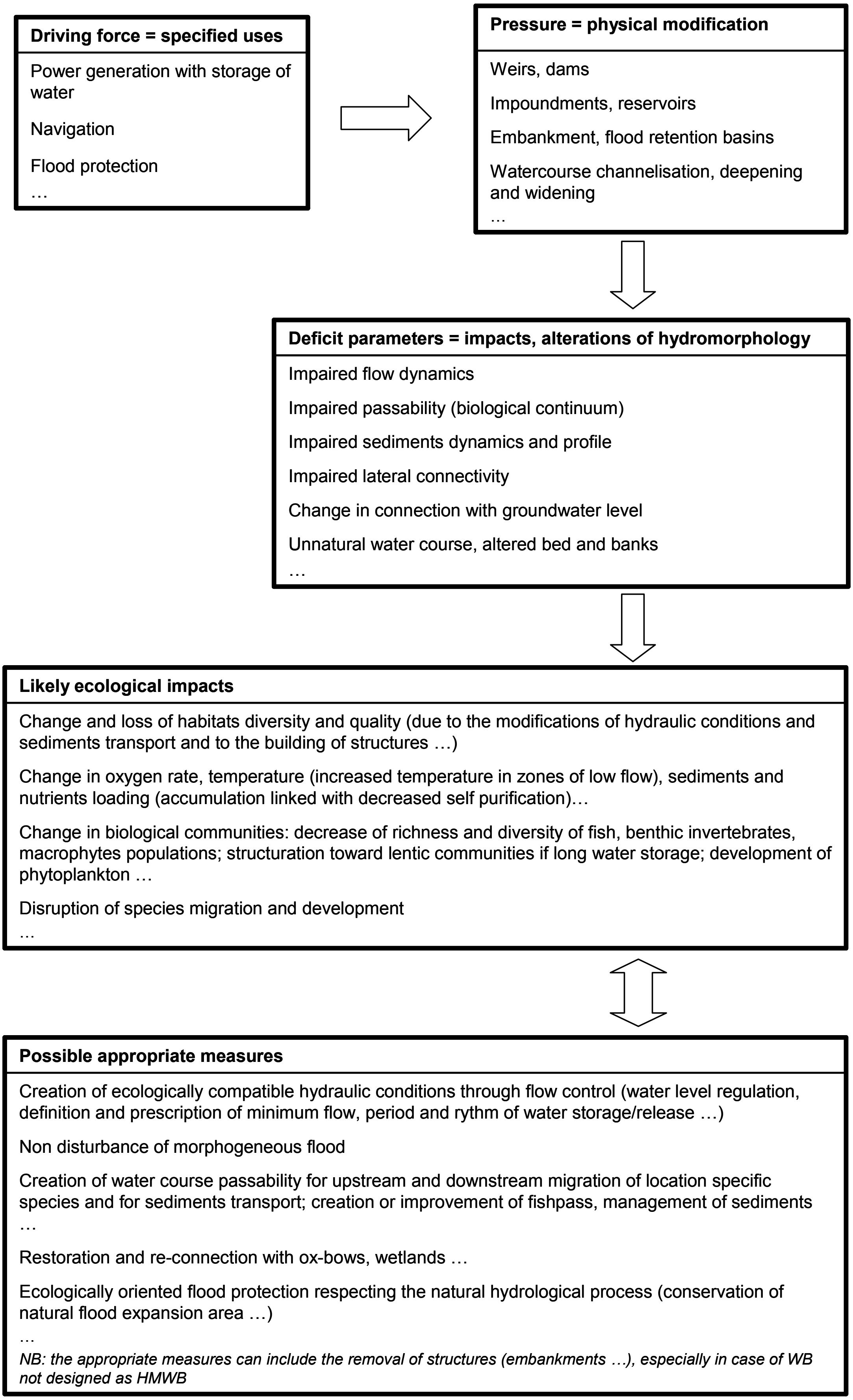
4.5 Figures 5, 6 and 7 illustrate the types of measures that may be appropriate in relation to some of the main hydromorphological alterations (water flow changes, sediments dynamics impairments and morphological changes) and their associated ecological impacts, due to the typical hydromorphological modification needed for particular water uses.

4.6 Because of site-specific dependencies discussed above, the selection of an appropriate measure or combination of measures will rely on water managers in local and regional authorities being able to determine what alterations are actually presenting a significant ecological risk and then identify the most appropriate and cost-effective measures that could be taken to prevent, remedy or mitigate these ecological risks. To do this they will also need to have a suitable knowledge and understanding of the potential effects of measures on the water use or uses that rely on the modifications. National guidance on how to assess environmental impact can support the water managers. Good communication between water users and water managers is also important.

4.7 For the purposes of river basin planning, water managers will need to identify as far as possible any restoration or mitigation measures still needed to achieve good ecological status or potential. Only those measures that are technically feasible and not disproportionately expensive to make operational within the timescale of the first river basin planning cycle will have to be included in the first river basin management plan.

4.8 The significance of the effect of a measure on a water use will depend on the particular design and operating needs of that water use. HMWB and AWB may have modifications that provide for a range of water uses. A measure that does not have significant adverse effects on one water use could be inappropriate because it has a significant adverse effect on another water use.

4.9 For example, a river channel has been deepened and widened for flood defence purposes. The adverse ecological effects of the modifications could be mitigated in this case without a significant reduction in the channels' capacity to convey flood water by the establishment of a two stage channel (i.e. a deeper central channel and shallower margins within the artificially widened channel). This measure would increase habitat diversity and allow rooted plants to grow in the shallower areas adjacent to the banks. However, if the channel is also being used for navigation, such a measure might have a significant adverse effect on the navigability of the channel and therefore be inappropriate.



Driving force = specified uses

Power generation with storage of water

Navigation

Flood protection

…

Pressure = physical modification

Weirs, dams

Impoundments, reservoirs

Embankment, flood retention basins

Watercourse channelisation, deepening and widening

…

Deficit parameters = impacts, alterations of hydromorphology

Impaired flow dynamics

Impaired passability (biological continuum)

Impaired sediments dynamics and profile

Impaired lateral connectivity

Change in connection with groundwater level

Unnatural water course, altered bed and banks

…

Likely ecological impacts

Change and loss of habitats diversity and quality (due to the modifications of hydraulic conditions and sediments transport and to the building of structures …)

Change in oxygen rate, temperature (increased temperature in zones of low flow), sediments and nutrients loading (accumulation linked with decreased self purification)…

Change in biological communities: decrease of richness and diversity of fish, benthic invertebrates, macrophytes populations; structuration toward lentic communities if long water storage; development of phytoplankton …

Disruption of species migration and development

…

Possible appropriate measures

Creation of ecologically compatible hydraulic conditions through flow control (water level regulation, definition and prescription of minimum flow, period and rythm of water storage/release …)

Non disturbance of morphogeneous flood

Creation of water course passability for upstream and downstream migration of location specific species and for sediments transport; creation or improvement of fishpass, management of sediments …

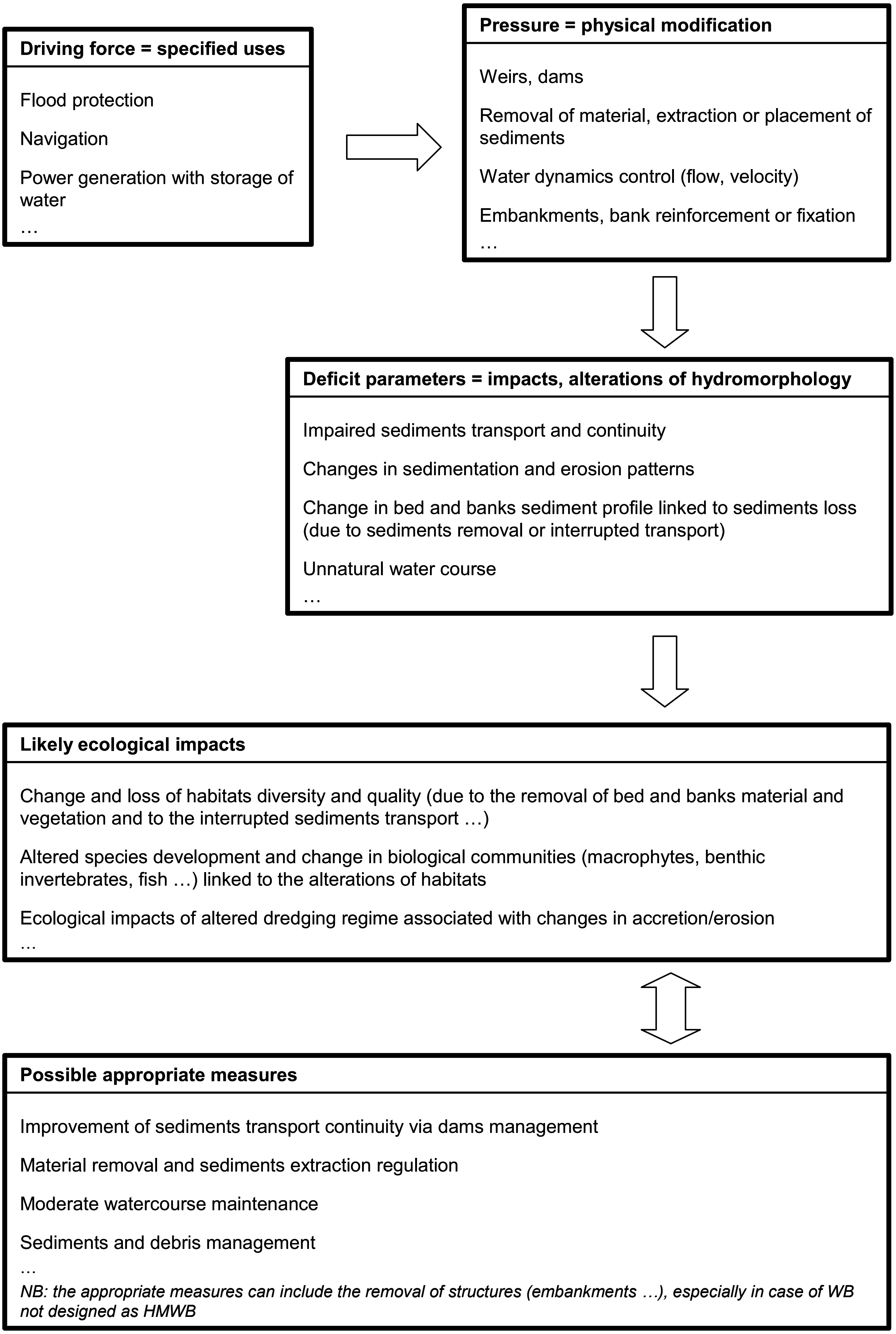
Restoration and re-connection with ox-bows, wetlands …

Ecologically oriented flood protection respecting the natural hydrological process (conservation of natural flood expansion area …)

…

NB: the appropriate measures can include the removal of structures (embankments …), especially in case of WB not designed as HMWB

Figure 5: Examples of measures for the pressure category “water flow changes” (river basin level).



Driving force = specified uses

Flood protection

Navigation

Power generation with storage of water

…

Pressure = physical modification

Weirs, dams

Removal of material, extraction or placement of sediments

Water dynamics control (flow, velocity)

Embankments, bank reinforcement or fixation

…

Deficit parameters = impacts, alterations of hydromorphology

Impaired sediments transport and continuity

Changes in sedimentation and erosion patterns

Change in bed and banks sediment profile linked to sediments loss (due to sediments removal or interrupted transport)

Unnatural water course

…

Likely ecological impacts

Change and loss of habitats diversity and quality (due to the removal of bed and banks material and vegetation and to the interrupted sediments transport …)

Altered species development and change in biological communities (macrophytes, benthic invertebrates, fish …) linked to the alterations of habitats

Ecological impacts of altered dredging regime associated with changes in accretion/erosion

…

Possible appropriate measures

Improvement of sediments transport continuity via dams management

Material removal and sediments extraction regulation

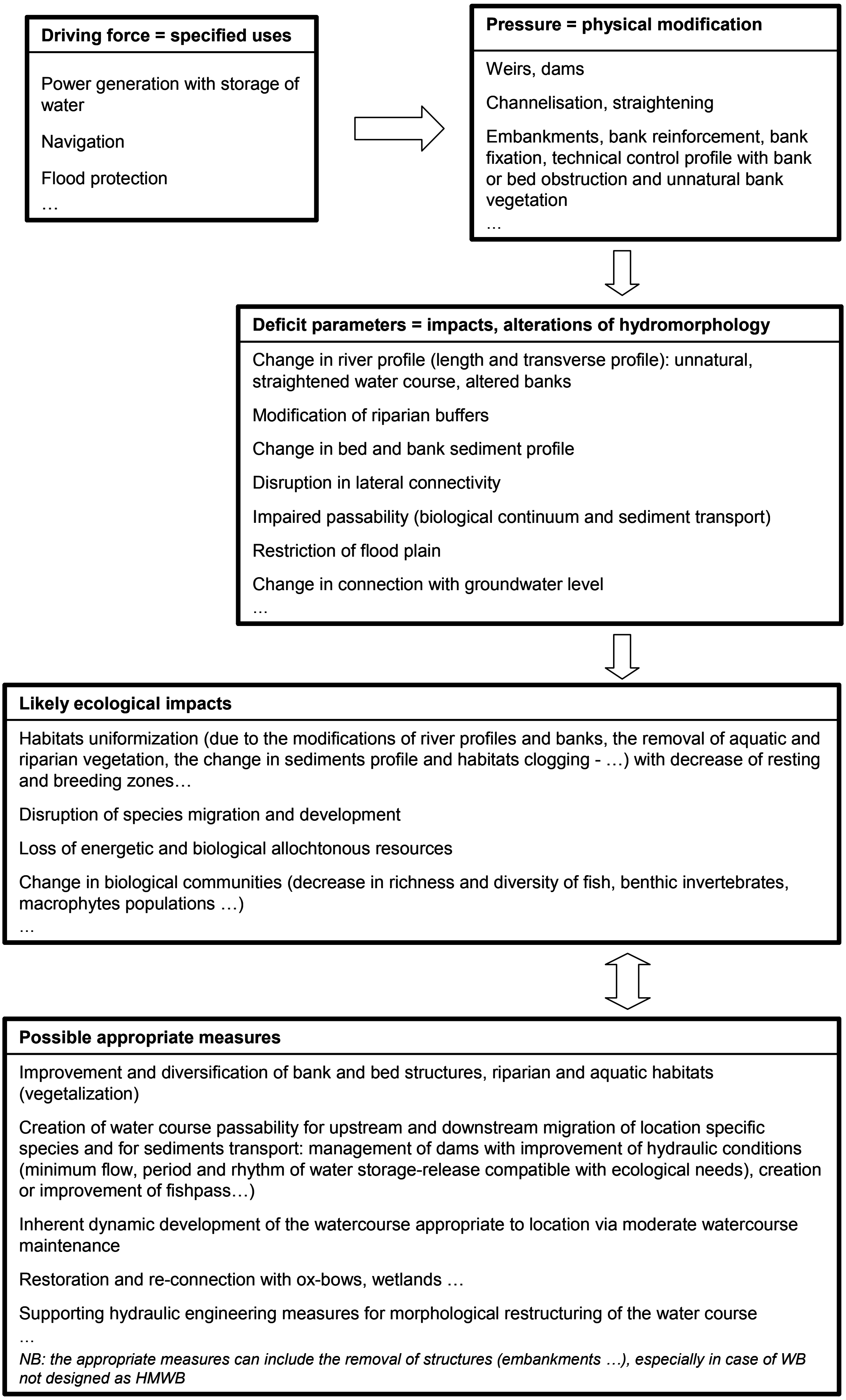
Moderate watercourse maintenance

Sediments and debris management

…

NB: the appropriate measures can include the removal of structures (embankments …), especially in case of WB not designed as HMWB

Figure 6: Examples of measures for the pressure category “sediment dynamics impairment” (river basin level).



Driving force = specified uses

Power generation with storage of water

Navigation

Flood protection

…

Pressure = physical modification

Weirs, dams

Channelisation, straightening

Embankments, bank reinforcement, bank fixation, technical control profile with bank or bed obstruction and unnatural bank vegetation

…

Deficit parameters = impacts, alterations of hydromorphology

Change in river profile (length and transverse profile): unnatural, straightened water course, altered banks

Modification of riparian buffers

Change in bed and bank sediment profile

Disruption in lateral connectivity

Impaired passability (biological continuum and sediment transport)

Restriction of flood plain

Change in connection with groundwater level

…

Likely ecological impacts

Habitats uniformization (due to the modifications of river profiles and banks, the removal of aquatic and riparian vegetation, the change in sediments profile and habitats clogging - …) with decrease of resting and breeding zones…

Disruption of species migration and development

Loss of energetic and biological allochtonous resources

Change in biological communities (decrease in richness and diversity of fish, benthic invertebrates, macrophytes populations …)

…

Possible appropriate measures

Improvement and diversification of bank and bed structures, riparian and aquatic habitats (vegetalization)

Creation of water course passability for upstream and downstream migration of location specific species and for sediments transport: management of dams with improvement of hydraulic conditions (minimum flow, period and rhythm of water storage-release compatible with ecological needs), creation or improvement of fishpass…)

Inherent dynamic development of the watercourse appropriate to location via moderate watercourse maintenance

Restoration and re-connection with ox-bows, wetlands …

Supporting hydraulic engineering measures for morphological restructuring of the water course

…

NB: the appropriate measures can include the removal of structures (embankments …), especially in case of WB not designed as HMWB

Figure 7: Examples of measures for the pressure category “morphological changes” (local level).

5 Cost-effectiveness of measures

5.1 Information on the cost and effectiveness of different measure options provides a means of comparing the relative cost efficiency of those options. Such information will therefore provide the basis for making judgements about the combination of measures that will produce a given improvement most cost-effectively.

5.2 The following information on a measure or combination of measures is likely to be useful when making comparisons with other measures or combinations of measures.

(a) The ecological improvement expected from the measure (ecological efficiency) and its contribution to achieving good ecological status or good ecological potential
(b) The likelihood that the measure will deliver the expected ecological improvement
(c) The length of time before the ecological improvement is expected to occur (e.g. could it deliver the improvements by 2015)
(d) The lifetime of the measure
(e) The costs of the measure (capital and running costs)
(f) Any other potentially significant positive or negative impacts (e.g. energy; landscape; employment and other user interests)

5.3 Involving water users and other stakeholders in the identification of cost-effective measure options can help identify practical solutions and improve the effectiveness of the selected measures by increasing stakeholders' understanding of, and support for, them.

6 Recommendations and conclusions

6.1 The aim of this report is to provide water managers and decision makers with information to help select locally appropriate measures to deal with hydrological and/or morphological pressures (see Figure 8) and help other interested parties to understand the process. After identifying the environmentally relevant impacts of the physical modification it is possible to identify the deficit parameters and then the corresponding measures. The implementation of the measures should be followed by a monitoring phase in order to check the effectiveness on biological function. The results of the monitoring allow to review the measures to improve their efficiency. The results can also feed into the generic list of potential measures. As examples Figures 5, 6 and 7 show measures for the typical pressures ”water flow changes”, “sediment dynamics impairment” and “morphological changes”. In these Figures the measures are outlined briefly in a few key words. In addition the information is given in form of generic information on different measures (see Annex IV) and in illustrated case study examples of their application (see Annex V and separate document).

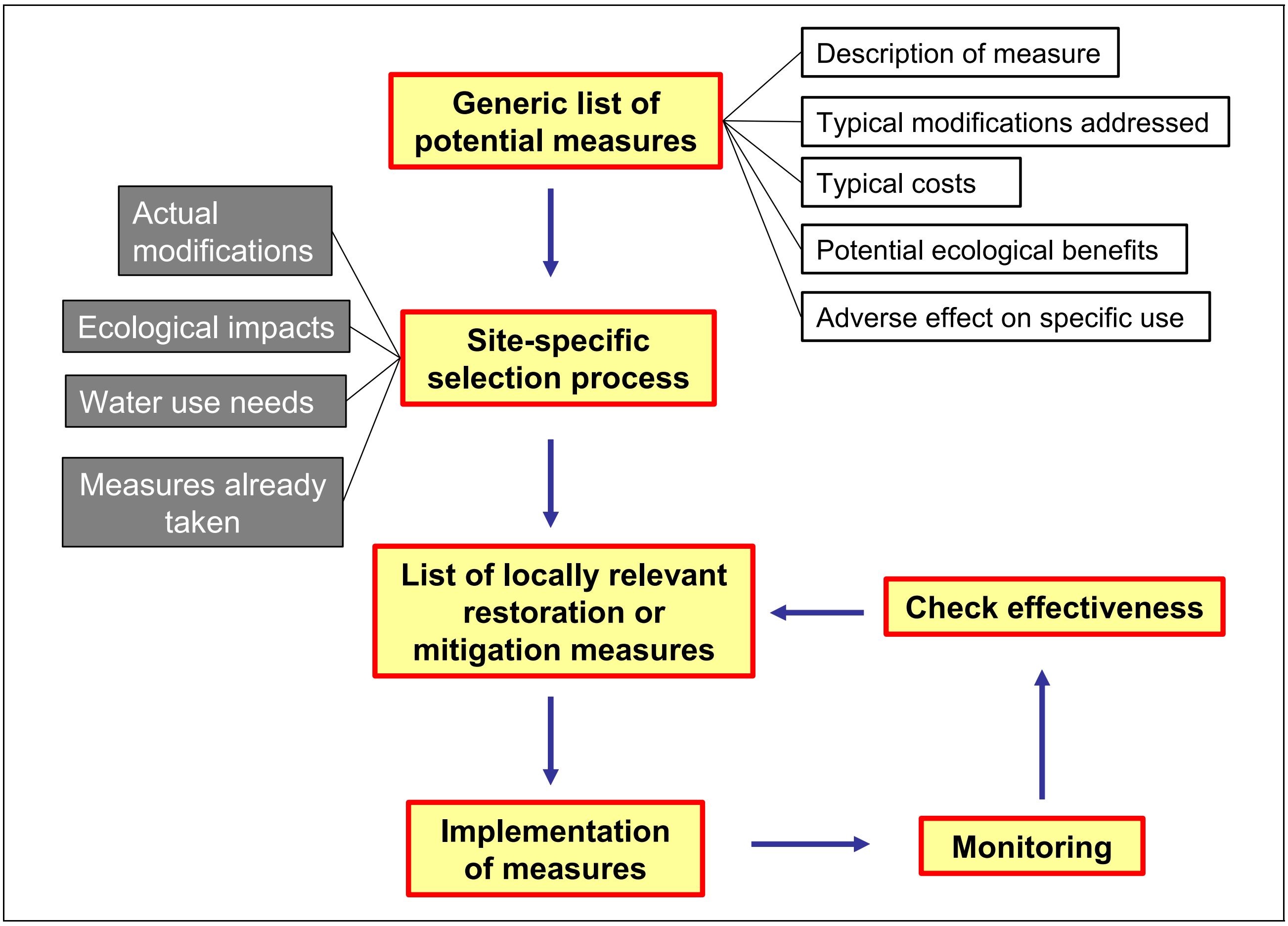


Figure 8: The role of a generic list of potential measures in measure selection.

6.2 The measures contained in this report may be able to prevent or remedy an adverse ecological effect of a modification in some cases whilst only being able to partially mitigate the effect of the modification in other cases.

6.3 Moreover, the information in this report may be used when considering either present physical modifications impacting the ecological state of water bodies or future modifications planned as part of a proposed new development.

6.4 In general, it will be cheaper to incorporate measures into the design of a new development than it will be to retrofit those same measures into an existing modification. This may mean that the impacts resulting from a new water use activity can be prevented or mitigated to a greater extent than the impacts of comparable existing activities.

6.5 With regard to new development, there may also be scope to reduce its impact by directing such developments to areas in which the characteristics of the water environment are such that the modifications necessary for the development have less of an impact than they would in other areas. Indeed, depending on the particular user requirements, some new water use development may be able to take place without causing deterioration of status. In practice, it will be of benefit to all concerned to provide information about the

WFD requirements and start discussion with stakeholders in the early stages of the development of a new project.

6.6 Notwithstanding the above discussion about minimising the effects of new modifications, it is also important that adequate attention be paid to identifying existing or historic modifications which are now redundant or obsolete. In particular, such ‘legacy’ issues should be highlighted during the river basin planning process and possible measures to deal with them (including, if appropriate, relevant funding mechanisms) should be proposed.

6.7 A collection of case studies was compiled as part of the CIS activity on hydromorphology and is published in ***“Case Studies – potentially relevant to the improvement of ecological status/potential by restoration/mitigation measures”.***

6.8 The case studies describe examples of measures which Member States have taken, or are planning to take, to improve the ecological status or potential of water bodies whose hydromorphological characteristics have been altered for the purposes of flood defence, navigation and/or hydropower. The studies illustrate a broad range of practical restoration/mitigation techniques, many of which have been implemented without significant adverse effects on the uses.

6.9 The case studies show that there is already an understanding of the relationship between hydromorphological changes and ecological impacts. This understanding is expected to substantially improve through practical experience of implementing the Water Framework Directive.

6.10 In particular, improvements in the understanding of the ecological efficiency of hydromorphological restoration/mitigation measures will help Member States make better judgements about the most cost-effective measures to take.

6.11 In several case studies, significant ecological improvements have been identified at the location of the measure. However, it was unclear whether these improvements were sufficient to improve the overall status of the water body.

6.12 It is recommended that, as Member States’ experience of implementation grows, further workshops are organised under the Common Implementation Strategy to exchange information on:

- The ecological efficiency of different hydromorphological restoration/mitigation measures; and
- The scale of improvement necessary to benefit the ecological status of water bodies.

6.13 In order to support the further exchange of information between the Member States, it is also planned to maintain the Case Study on the internet as “living document” and to add new case studies in due course.

ANNEX I

Relevant requirements of the Water Framework Directive regarding Hydromorphology

For surface waters the overall aim of the Water Framework Directive (WFD) is for Member States to prevent deterioration of the status of all bodies of surface water and to achieve “good ecological status” and “good surface water chemical status” in all bodies of surface water by 2015.

The values of the hydromorphological quality elements must be taken into account when assigning water bodies to the high ecological status class (HES) and the maximum ecological potential class (MEP), i.e. when downgrading from high ecological status or maximum ecological potential to good ecological status/potential. For HES, the values for the hydromorphological quality elements correspond totally or nearly totally to undisturbed conditions. For MEP, the hydromorphological conditions are consistent with the only impacts on the surface water body being those resulting from the artificial or heavily modified characteristics of the water body once all mitigation measures have been taken to ensure the best approximation to ecological continuum, in particular with respect to migration of fauna and appropriate spawning and breeding grounds. The mitigation measures should not include those that would have a significant adverse effect on the specified uses of the water body or the wider environment.

For all other status/potential classes, the hydromorphological elements are required to have “conditions consistent with the achievement of the values specified [in Tables 1.2.1 - 1.2.5 WFD] for the biological quality elements.” (cf. Table I.1). Therefore, the assignment of water bodies to the good, moderate, poor or bad ecological status/ecological potential classes may be made on the basis of the monitoring results for the biological quality elements and also, in the case of the good ecological status/potential the physico-chemical quality elements. This is because if the biological quality element values relevant to good, moderate, poor or bad status/potential are achieved, then by definition the condition of the hydromorphological quality elements must be consistent with that achievement and would not affect the classification of ecological status/potential.

Table I.1: Hydromorphological quality elements to be used for the assessment of ecological status/potential based on the list in Annex V, 1.1, WFD.

HYDROMORPHOLOGICAL ELEMENTS SUPPORTING THE BIOLOGICAL ELEMENTS			
Rivers	***Lakes***	***Transitional waters***	***Coastal waters***
• *Hydrological regime* ➔ *quantity and dynamics of water flow* ➔ *connection to ground water bodies*	• *Hydrological regime* ➔ *quantity and dynamics of water flow* ➔ *residence time* ➔ *connection to the groundwater body*	• *Tidal regime* ➔ *freshwater flow* ➔ *wave exposure*	• *Tidal regime* ➔ *direction of dominant currents* ➔ *wave exposure*
• *River continuity* • *Morphological conditions* ➔ *river depth and width variation* ➔ *structure and substrate of the river bed* ➔ *structure of the riparian zone*	• *Morphological conditions* ➔ *lake depth variation* ➔ *quantity, structure and substrate of the lake bed* ➔ *structure of the lake shore*	• *Morphological conditions* ➔ *depth variation* ➔ *quantity, structure and substrate of the bed* ➔ *structure of the intertidal zone*	• *Morphological conditions* ➔ *depth variation* ➔ *structure and substrate of the coastal bed* ➔ *structure of the intertidal zone*

ANNEX II
Alternative methodology for defining Good Ecological Potential (GEP) for Heavily Modified Water Bodies (HMWB) and Artificial Water Bodies (AWB)

1.0 Introduction

1.1 Steps 10 and 11 in the Common Implementation Strategy Guidance Document Number 4 on the identification and designation of HMWB and AWB[1] describe a method for defining maximum ecological potential and good ecological potential. This Annex describes an alternative approach.

1.2 The method described here is expected to offer a more practical approach. This will be particularly so where maximum ecological potential (MEP) differs from water body to water body or where there is a lack of monitoring data from which to derive a sufficiently reliable estimate of the biological values expected at MEP and good ecological potential (GEP). However, both approaches are still somewhat theoretical. Their advantages and disadvantages are yet to be demonstrated The ecological conditions defined for GEP are expected to be the same whichever method is used, i.e. the results of both methods should be comparable.

1.3 Both approaches are still somewhat theoretical. Their advantages and disadvantages are yet to be demonstrated. Practical experience of defining GEP is currently very limited, the definition of GEP seems to be very complex. In the course of implementation, knowledge and understanding will increase enabling the further development and improvement of the approaches. Member States may also identify other alternative approaches. Where Member States wish, new approaches can be discussed in the Common Implementation Strategy and, if appropriate, included in future CIS guidance.

1.4 Defining GEP is a necessary step before heavily modified or artificial water bodies can be classified and before objectives can be set for them as part of the river basin management planning process.

1.5 For further information on all other aspects of the identification or designation of heavily modified water bodies, the reader should refer to the CIS Guidance Document No. 4 mentioned above.

2.0 Background

2.1 Good ecological potential is defined in the Annex V 1.2.5 to the Water Framework Directive as an ecological state in which "*there are slight changes in the values of the relevant biological quality elements as compared to the values found at maximum ecological potential*".

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[1] http://europa.eu.int/comm/environment/water/water-framework/guidance_documents.html

2.2 The values for the biological quality elements at MEP should reflect, "*as far as possible, those associated with the closest comparable surface water body type, given the physical conditions which result from the artificial or heavily modified characteristics of the water body"*. The definition recognises that the MEP biological values (a) depend on the MEP hydromorphological conditions and (b) may be different from those of the any natural surface water body type because no such natural type is completely comparable.

2.3 The Directive defines the MEP hydromorphological conditions as those "*consistent with the only impacts on the surface water body being those resulting from the artificial or heavily modified characteristics of the water body once all mitigation measures have been taken to ensure the best approximation to ecological continuum, in particular with respect to migration of fauna and appropriate spawning and breeding grounds".*

2.4 The mitigation measures referred to in the definition of MEP hydromorphological conditions are limited to those that would not have a significant adverse effect on (a) the wider environment or (b) the use or uses that are dependent on the modified characteristics. The purpose of designation of a water body as a HMWB or AWB would be defeated if mitigation measures that would have such adverse effects were included.

2.5 This also means that GEP cannot represent a state that could only be achieved using measures that would have a significant adverse effect on the wider environment or on the use or uses justifying designation in accordance with Article 4.3.

2.6 GEP therefore represents a state in which the ecological potential of a water body is falling only slightly short of the maximum it could achieve without significant adverse effects on the wider environment or on the relevant water use or uses. An assessment of disproportionate costs of the mitigation measures should not be considered.

2.7 In contrast, the definition of good ecological status is independent of any consideration of impact of the measures that may be needed to achieve it. Costs of these measures are also not considered.

3.0 Technical difficulties with the approach defined in CIS Guidance Document No. 4

3.1 The generic steps relevant to defining GEP and described in the CIS Guidance Document No.4 can be summarised as in Figure II.1 below.

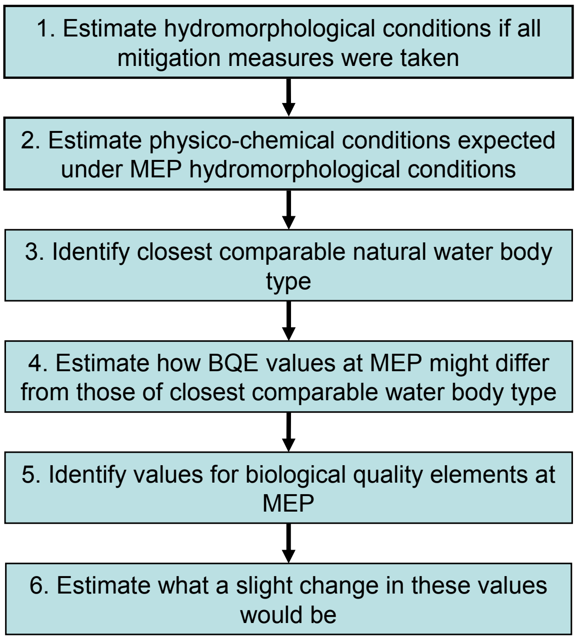

Figure II.1: Steps in defining GEP as described in the CIS Guidance Document No. 4.

3.2 Because the MEP hydromorphological characteristics can be quite unlike the reference hydromorphological characteristics of any natural surface water body type, the estimation of the MEP biological values (step 4 and 5 in Figure II.1) will often depend on modelling or expert judgement. The reliability of such estimates will depend on the availability and quality of the monitoring data used to develop and validate the models or judgements. The reference conditions for the closest comparable surface water body type may themselves have been derived by modelling or expert judgement. Errors are likely to be compounded when such reference conditions are used as the basis for estimating MEP biological values. Where few water bodies share the same MEP hydromorphological characteristics or where no or only a few water bodies are at MEP, data with which to validate estimated MEP values will be limited or absent.

3.3 In circumstances where there are no closely comparable natural surface water bodies, the Guidance Document No. 4 notes that it may be possible to use other similar HMWBs, which are at, or close to, MEP, in defining MEP values. Where the other HMWBs are close to MEP, this would include modelling the effect of taking ‘all mitigation measures’.

3.4 The estimation of the GEP biological values using the existing approach will also rely on predictive modelling or expert judgement if there are few HMWBs or AWBs with the same or very similar modified characteristics. Again the reliability of such approaches will depend on the availability and quality of monitoring data that can be used to build and validate the models or judgements.

3.5 Once the GEP biological values have been defined, Member States will have to assess what mitigation measures would be needed achieve them if they are not already being achieved. This step is again reliant on good modelling and expert judgement.

3.6 Technically the approach is complicated and highly reliant on good predictive modelling or expert judgement. Any errors in the estimates made in each of the steps will tend to sum. This compounding of errors could result in a definition of GEP that cannot be achieved without significant adverse effects on a relevant water use or that fails to reflect the level of ambition intended by the Directive.

4.0 Description of alternative approach

4.1 The method described below defines GEP relevant to those biological quality elements and physico-chemical quality elements that are so affected by the heavily modified characteristics that they cannot achieve their GES values without measures being taken that would have a significant adverse effect on the wider environment or on a use of the water body that is reliant on the modifications. For other quality elements, their values at GEP are expected to be the same as their GES values prior to the hydromorphological modifications.

4.2 Figure II.2 summarises the main steps involved in the alternative approach to defining GEP (left side of Figure) and compares this with the main steps in the approach set out in CIS Guidance Document No. 4 (right side of Figure).

4.3 The first step of the alternative approach is similar to that of the approach in CIS Guidance Document No. 4. All mitigation measures are identified that would (a) deliver ecological improvements; (b) not have a significant adverse effect on the wider environment; and (c) not have a significant adverse impact on a water use that relies on the heavily modified or artificial characteristics.

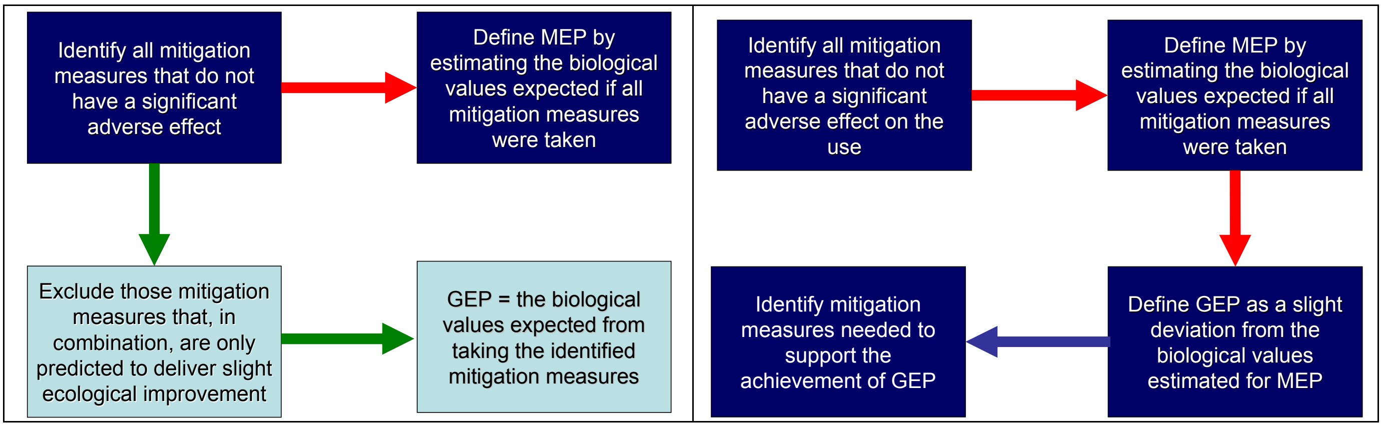

Figure II.2: Steps involved in defining GEP using alternative approach (left side) compared to the relevant steps in the approach described in CIS Guidance Document No. 4 (right side); red arrows: steps following CIS method, green arrows: modifications of CIS method.

4.4 As in the original CIS method, the mitigation measures may be identified on a water body by water body basis or identified for groups of water bodies. In the latter case, the heavily modified or artificial characteristics of the water bodies must be sufficiently similar for the same set of mitigation measures to be relevant to each of the bodies. The needs of the relevant water uses must also be sufficiently similar for the mitigation measures not to have significant adverse impacts on the uses.

4.5 The alternative approach provides for the estimation of the MEP biological values using either the same method as the original approach or by estimating the improvements in the current values of the biological quality elements that could be achieved if all the identified mitigation measures were taken.

4.6 In contrast to the original approach, the reliability of the alternative approach's definition of GEP does not depend on the reliability of the estimated MEP biological values. GEP is defined as the ecological conditions expected when all the mitigation measures are taken except those that in combination would only deliver slight ecological improvements to the heavily modified or artificial water body[2].

4.7 The closest comparable water body type is used to help frame the direction of improvement that should be sought through the mitigation measures, bearing in mind the constraints imposed by the needs of the water use or uses. For monitoring purposes, the parameters indicative of the biological elements (i.e. metrics) that Member States are using to assess the status of water bodies of the closest comparable type can also be calculated for heavily modified or artificial water bodies.

4.8 The technical focus of the approach is on identifying ecologically-effective mitigation measures that are compatible with the water use or uses and that do not have significant adverse effects on the wider environment. The ecological conditions predicted to result from these mitigation measures are used to estimate the values of the biological quality elements at GEP.

4.9 The approach is technically less complicated as the values identified for GEP do not rely on the accuracy and precision of the estimated values for the MEP biological quality elements. This makes the alternative approach's definition of GEP less prone to error since there are fewer steps dependent on modelling or expert judgement. One consequence of this is that the method will not result in a definition of GEP that cannot be achieved without significant adverse effects on the relevant uses or the wider environment. Member States may also find it a more practical means of defining GEP and the associated mitigation measures for HMWBs and AWBs within the time constraints of the river basin planning process.

4.10 Under both approaches the gap between MEP and GEP in ecological quality terms will be slight. Ecologically, GEP will represent the same level of ambition whichever of the two approaches is used.

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[2] Note: It may be that all such mitigation measures are already in place in a water body. Where this is the case, the water body would be expected to be at good ecological potential provided there are no other significant impacts (e.g. pollution problems)

4.11 It should be noted that the alternative method does not define the mitigation measures that have to be included in the programmes of measures. The mitigation measures included in any programme of measures will depend on the objective set for the water body[3] and the combination of measures Member States consider to be a cost-effective way of achieving that objective defined with the River Basin Management Plans.

5.0 Comparability issues

5.1 The purpose of setting out guidance on how to derive MEP and GEP is to promote comparability and consistency across Member States. This does not mean however that the values of the biological quality elements at GEP will be same in each HMWB or AWB. This will depend on the similarity of the MEP hydromorphological and physico-chemical characteristics of different HMWBs. Where these characteristics are very similar, the HMWBs can be considered to be of the same ‘type’ and their MEP and GEP biological values will be equivalent.

5.2 Where the heavily modified characteristics and the extent to which they can be mitigated without such adverse effects differs from water body to water body, the ecological conditions expected at good ecological potential will also differ. The choice of method for defining GEP is will not have any bearing on this.

5.3 The alternative approach allows Member States to discuss, and share experiences of, the mitigation measures they have considered and the reasons why they have excluded or included them in defining GEP. This will promote comparability of in the way GEP is defined even though the values of the quality elements at GEP in any particular water body will depend on the characteristics and uses of that water body.

6.0 Conclusions

6.1 The method for defining MEP and GEP described in CIS Guidance Document No. 4 and the alternative approach presented here provide different but technically sound approaches to defining MEP and GEP.

6.2 Both methods are expected to deliver the same level of ambition for GEP.

6.3 Member States can choose the method most suited to their circumstances or use a combination of both. Further methods may be identified as implementation progresses.

6.4 The approach introduced in this paper has the advantages over the original CIS approach of relative simplicity and a reduced risk of identifying unnecessary or inadequate mitigation measures. This is important given the time constraints imposed by the river basin management planning process. Where technical resources are limited or ecological data to derive and validate estimates of MEP are unavailable, it may prove more practicable for Member States to use the alternative approach.

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[3] See CIS paper on Environmental Objectives Under the Water Framework Directive

6.5 Nevertheless both approaches are still somewhat theoretical. Their advantages and disadvantages are yet to be demonstrated. Practical experience of defining GEP is currently very limited, the definition of GEP seems to be very complex. In the course of implementation, knowledge and understanding will increase enabling the further development and improvement of the approaches. Member States may also identify other alternative approaches. Where Member States wish, new approaches can be discussed in the Common Implementation Strategy and, if appropriate, included in future CIS guidance.

ANNEX III
Morphological alterations:
Ecological impacts and criteria for status improvement

The purpose of this annex is to introduce the main impacts of different kind of hydromorphological pressures and if possible provide criteria for impact assessment. Although the amount of knowledge about the link between hydromorphological changes and ecological impacts is growing there is still a lack of data in this field. The ecological impact of measures is often site specific. Furthermore, in heavily modified and artificial water bodies the possible measures depend on the adverse effect on specific use, which is very site specific. Taken all this into account it is not possible to give exact generic criteria, which could be used under all circumstances. Nevertheless some examples of criteria for assessment of impacts are provided, which obviously and directly influence biology and therefore ecological status or potential. These criteria are understood as indicating when biological elements could meet GES or measures could be effectively able to mitigate impacts in order to meet GEP. These criteria could be qualitative descriptions or sometimes also threshold values.

1 Description of hydromorphological alterations and their impacts

Table III.1 summarises the hydromorphological alterations typically associated with different water uses and their subsequent impacts on hydromorphology.

Table III.1: Overview of hydromorphological alterations typically associated with different water uses and their subsequent impacts (x = more relevant; (x) = less relevant).

	Specified uses (= driving force)					**Impacts on hydromorphology: deteriorations, impairments of hydromorphological conditions (= deficit parameters)**						
Physical modifications (= pressure)	Navigation	Water regulation, flood protection	Activities for which water is stored, transferred or bypassed			Disruption in river or estuary continuum & sediment profile	Change in hydrological regime: low / reduced or increased flow, artificial discharge and level regime	Change in (soil) erosion / sediment transport / silting	Change in river profile (length and transverse profile)	Disruption in lateral connectivity, detachment of oxbow lakes / wetlands	Restriction / loss of flood plains or intertidal area	Change in connection with groundwater, alteration of groundwater level
			Power generation	Water supply	Irrigation							
Cross profile construction (dams, weirs, locks, impoundments)	x	x	x	x	x	x	x	x	x	x	x[1]	x
Longitudinal profile construction (dykes)	(x)	x					x		x	x	x	x
Channelisation, straightening	x	(x)	(x)	x	x	(x)	x	x	x	x	(x)	x
Bank reinforcement, bank fixation, embankments (training wall, breakwater, groynes etc.)	x	(x)	(x)	(x)		x	x	x	x	x		
Deepening (channel maintenance, dredging, removal or replacement of material)	x	(x)	(x)		(x)	(x)	x	x	x			x
Intakes, transfers and bypasses of water (tunnels etc.)			x	x	x	x	x					

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[1] The construction of tidal barrages (eg. Cardiff Bay barrage) can lead to significant loss of intertidal area (ie. conversion to sub-tidal)

2 Use of impact criteria in the design of typical mitigation and restoration measures: general considerations

2.1 Disruption of river and sediment continuum

Dams, weirs, locks, impoundments, water bypass tunnels, bank reinforcements and other constructions are built for navigation, water regulation, flood protection, power generation, water supply and irrigation. These constructions disrupt the ecological water and sediment continuum of rivers.

Weirs and dams should be passable by the naturally occurring migratory fish and invertebrate species (up- and downstream) as well enabling downstream transport of organic and inorganic sediments and naturally swimming items (e.g. deadwood). Ecologically compatible hydraulic conditions should be maintained through flow control (minimum flow, period and rhythm of water storage and release). The following text describes criteria for these demands.

2.1.1 Upstream migration of fish

In order for fish to negotiate dams and weirs, they must be able to migrate through the flowing water in a way that is consistent with their natural behaviour and physiological characteristics without expending undue amounts of time or energy. Bypass channels with appropriately structured, continuous and rough beds and sufficient water flow should be provided for invertebrate species when possible. For example, German and Austrian data showed that potamal fish species cannot pass heights higher than 10 – 30 cm and rhithral fish species cannot pass heights higher than 30 – 100 cm. In case of mitigation (GEP) these possibilities should be examined.

2.1.2 Downstream migration of fish

At a chain of weirs and turbines the fish population can only survive, if a distinct percentage of the downstream migrating abundance survives. The appropriate percentage depends on the species, e.g. it was assessed that the eel population will only survive, if 50% of the natural number of eel reaches the sea. Fish can migrate safely downstream if they are not harmed at water intakes, i.e. do not pass through them at all and are instead guided through a bypass beneath a plant's hydro mechanical installation. However, in view of the widely divergent conditions obtaining at hydropower plants, no "all sizes fits all" bypass solution can be applied. So far, physical barriers that are designed with a specific flow velocity and flow angle in mind and with fish-friendly intake bar spacing in conjunction with an appropriate bypass have proven to be most effective where the hydromorphological and biological characteristics make them a suitable solution. Many barriers that are currently under development select only certain species owing to the excessive flow velocities involved and the fact that various species exhibit widely divergent behaviours. Hence, fish safeguards and bypasses should be built, according to existing studies demonstrating their abilities to meet future requirements and having the specific species characteristics, specific local conditions, specific management goals and a specific watercourse firmly in mind. For surface water with water discharge < 20 m^3/s the maximum screen bar distance should not exceed for adult potamodromus fish species 20 mm, for catadromus fish species (e.g. eel) 15 mm and for anadromus fish species (e.g. smolt of salmon and trout) 10 mm.

The reservoirs and slow flowing zones upstream a dam have a “lake effect”, that cause delay of the downstream migration to the sea and increased predation of salmon and trout smolt. If the smolt does not enter the sea at the right time it will not survive in the sea. In “lake-like” water bodies the fish community is changed to a lake species composition – usually richer in the number of predatory species. In German risk analysis water bodies were assessed to be at risk to fail good status, if the length of reservoirs and slow flowing zones exceeds 20% of the water body.

One way to improve downstream migration is by selecting or designing fish-friendly turbines. The mortality rates of fish that swim into hydroelectric turbines may be decreased by modifying blade wheel diameter, the number of blades, turbine RPM (rotor revolutions per minute), and blade wheel and turbine stator angle.

Other mitigation measures to enhance river continuity, especially for fish, are:

- habitat restoration, building spawning and breeding areas,
- catching and moving fish or catching fish and moving fish sperm and spawn to appropriate spawning areas.

These measures have no or only minor adverse effect on specific uses.

2.1.3 Sediment/Debris management

In addition to the realization of structural measures that permit the conveyance of bedload and organic floating material in relatively large dams, a sediment/debris management plan could also contribute to an ecological improvement. It can consist of elements such as the following: striking a balance between projected bedload volumes (and the attendant characteristic grain sizes) and the transport capacities afforded by the envisaged measures (e.g. dam management and cleaning); controlled input of additional debris beneath weirs to prevent erosion. In the interest of avoiding degradation of (a) the ecological status of downstream river segments and (b) the quality of uses bedload management plans could define the timing and implementation of debris management measures in light of the following variables: fish and other aquatic life ecology, site characteristics, watercourse quality and flow conditions.

Dam management refers to non-debris related measures realized in dams for the purpose of improving dam hydromorphology and the interplay between watercourses and floodplain. The wide range of measures that are available in this domain can potentially improve ecological status or potential.

Sediment management should aim at:

- passing through floating deadwood and bed load downstream the dam,
- maintaining downstream amount and grain size distribution of bed load consistent with the transport capacity of the downstream flow.

2.2 Importance of flow dynamics, variation and changes in river profile and sediment transport in the design of restoration/mitigation measures

Riverine ecosystems, both in stream and flood plains, are susceptible to changes in the morphology of the river and its flow regime. Under undisturbed conditions the river has maximized its morphological variability in response to the natural fluctuations in the flow. Associated spatial and temporal velocity distributions enable the river to transmit the accompanying sediment load and establish a dynamic stability while retaining a complex of pools, riffles, runs glides and meandering pattern and sustaining bed material heterogeneity. The variability in flow depths, velocities and bed material sizes within a reach is the basis of the natural habitats and their variation and controls therefore the biodiversity of the river reach. Thus the flow dynamic is recognized as a heart-beating of ecosystem. Although the restoration of natural flow dynamics is seen as the most vital step, it is an often neglected aspect in river rehabilitation.

Morphological modifications, through combinations of widening, dredging and straightening and/or the construction of dams, weirs, locks and flood levees or flow modifications, which alter the magnitude, velocity pattern, frequency and duration of flows, can affect a river's ability to transport the sediment load and nutrients supplied from its catchment. Local reduction in a river’s transport capacity or an increased sediment supply causes sedimentation (widened and dredged rivers, water impoundments, flow division into multiple channels, below degrading reaches, etc.) while an increased transport capacity or reduced sediment supply causes bed degradation and bank erosion (straightened reaches, downstream from dams and weirs, below aggrading reaches, etc). Any instability that is initiated can require continued and expensive maintenance to sustain the required river functions, particularly if the river's ability to self stabilise is denied by such action.

2.2.1 Flow dynamics and sediment transport

Rehabilitation of highly impacted rivers to achieve genuine ecological improvement (GES/GEP) is possible provided that it is based on an understanding of natural river processes and their interaction with the ecological functioning of the river ecosystem (river basin, riverine zone, river channel/ flood plain). *Adhoc* measures taken in ignorance of these processes are unlikely to be successful or, indeed, sustainable. Sediment transport is a key issue. On rivers that actively transport bed material it is necessary to ensure that the morphological and/or flow modifications proposed to rehabilitate the river will re-establish the natural sediment transport continuity of the river. On rivers which do not transport bed material, namely passive ones[1] (many small lowland rivers in Europe), sediment transport will only be an issue if the modifications initiate transport. This illustrates why rivers can respond differently to the same modifications and emphasizes the danger of copying rehabilitation procedures from case studies unless the rivers are of the same type and comparable size.

Flow hydraulics also have to be considered to ensure that the rehabilitation measures implemented are in harmony with the river. The principle is to harness the energy within the flow and use it to recreate the morphological variability associated with its type of river. This can be achieved by non structural measures or, possibly, by using structures to initiate or accelerate the required ecological improvements (GES/GEP) or to artificially create greater habitat diversity. Before the measures are implemented, it is essential to ensure they do not adversely affect sediment transport through the reach. Re-establishing the longstream and lateral hydraulic continuity/connectivity of heavily modified rivers is a major issue that needs addressing in order to achieve GES/GEP.

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[1] ***Passive rivers*** – smaller rivers, especially those flowing over coarser material (gravel), rarely if ever transport bed material load

Active rivers - mostly lowland rivers, which generate sufficient stream power to transport large amounts of bed material load, particularly if the river bed is composed of fine sediments (sand, fine gravel)

Measures to restore nearly natural conditions could include:

- removal of structures from the channel: weirs, barriers, bank reinforcement,
- reconnection of meander bends or side arms,
- lowering of river banks and
- channel narrowing etc.

Within an altered morphology the following structural measures are probably appropriate:

- angled short groynes,
- cross-vanes,
- j-hook vanes,
- deflectors and
- fish passes, etc..

Current knowledge of river mechanics, geomorphology, aquatic ecology and river engineering is sufficiently advanced to enable viable solutions to be applied. It can also be used to explain why *adhoc* designs that simply aim to maximize habitat diversity fail and, thereby, to prevent costly mistakes.

Negative ecological and hydromorphological impacts of hydropower, navigation and flood alleviation schemes can be minimized by implementation of restoration measures based on understanding of river processes (*flow dynamics, sediment transport*) without the need for trial and error procedures. Usually a complex of restoration/mitigation measures has to be taken to achieve ecological improvement (GES/GEP) thus mutual interaction between them and the resulting synergistic effect have to be considered. This requires more systematic approach included in restoration strategy.

2.2.2 Minimum flow

In order to meet the criteria of good ecological status or potential, the minimum flow should at least leave water in the river (except in naturally dry falling rivers) and aim at maintaining and restoring the river’s type-specific aquatic community; promote the continuity of the original river bed, as well as the bypass at its termination; achieve nearly natural flow dynamics and groundwater status in floodplain; and maintain distinct water exchange zones. Instead of gathering statical data on minimum flow, the feasibility of implementing an ecological control mechanism for minimum dynamic flow should be ascertained. This mechanism should maintain a constant and inflow-driven minimum flow, or should at least be seasonally controlled and meet the aforementioned criteria. A river’s ecological status or potential can be ameliorated through the realization of measures that upgrade watercourse structures along original riverbeds in the light of site-specific characteristics, management goals, and minimum flow data, consideration should be given to site-specific characteristics.

2.2.3 Discharge regime:

Rapidly varying flows can be generated in a hydropower facility (hydro peaking). This gives rise to conditions that are deleterious to watercourse hydromorphology and aquatic biota downstreams, thus jeopardizing the goal of achieving good ecological status or potential. Hence, such artificial discharge regimes should be avoided for ecological reasons. However, if artificial discharge regimes cannot be avoided entirely, the ecological status of the water body/water bodies affected can still be improved through operational modifications (e.g. downstream “buffer” reservoirs) that attenuate the volume and frequency of artificially generated abrupt waves and avoid unduly precipitous water level fluctuations.

2.3 Change in river profile, lateral connectivity, flood plains and groundwater

Measures for cross profile constructions, dykes, channelisation, bank reinforcement, bank fixation, embankments and deepening change the length and transverse river profile and disrupt connectivity with oxbow lakes, wetlands, flood plains, intertidal areas and groundwater. Due to the changes in profile type specific river habitats disappear. Disruptions of lateral connectivity trench habitats of organisms and separate habitats of different stages in the live of organisms (e.g. spawning grounds of fish from habitats of adults). Disconnection of groundwater affects groundwater hydrological status and groundwater dependent ecosystems.

2.3.1 Riparian corridors

Rivers need a “development corridor” in their valley to develop lateral shape and movement. Only in a sufficient wide corridor the river is able to develop type specific structures, like meanders, slip-of and undercut slopes as well as bank and bed erosion structures with their different habitats. These habitats could be based on rocky, gravel, sand or mud substrate (if type specific). They are dependent on the flow energy at the place and move when the river moves during each flood within the corridor.

The width of the semi-natural corridor depends on the size of the river (e.g. the bed width of its semi-natural profile) and its curvature, i.e. its disposition to meander.

- The bed width of the semi-natural profile is usually wider than the anthropogenic altered bed width: In cohesive substrate by a factor of 2; in non-cohesive substrate by a factor of 3. A factor of five applies if the river type forms several beds and oxbow lakes.
- The width of the needed riparian corridor is wider than the semi-natural bed width: For stretched rivers by a factor of 1.5 - 2; for slightly meandering rivers by a factor of 3 – 5 and for heavily meandering rivers by a factor of about 10.

2.3.2 Dam management

Dams and hydropower plants should be designed and constructed in such a way as to respect and promote the interplay between watercourse and floodplain ecology, which can be improved using appropriate technical and other measures involving the inundation of actual or potential floodplain for relatively lengthy periods under the relevant flow conditions.

3 Use of impact criteria in the design of typical mitigation and restoration measures: Example: Port and navigation-related hydromorphological pressures

The following text introduces some of the issues associated with the following physical modifications, which are often necessary to sustain navigation and port uses:

1. dredging and placement or disposal of sediment in the aquatic environment

2. impoundment and abstraction
3. bank protection, bank erosion
4. flow/sediment control structures (eg. groynes, training walls)
5. reclamation, channel straightening

The environmental criteria to be considered in determining the possible nature and extent of any impacts, and hence possible restoration or mitigation measures, are summarised in each case.

At this generic level, broadly similar issues apply to inland and maritime, commercial and recreational navigation. However, the appropriateness of a particular restoration or mitigation measure will depend entirely on the nature and significance of the impact, as well as the physical characteristics of the water body in question. Site specific investigations will, therefore, usually be required before a decision on the suitability of a particular measure can be determined. This is particularly the case in coastal and estuarine water bodies where understanding the dynamic nature of the natural processes operating - and hence the potential consequences of any change - will be vital if restoration or mitigation measures are to be implemented successfully.

Finally, the importance of dredging to the provision and maintenance of safe navigation is worth stressing. Every year, CEDA estimate that approximately 200 million cubic metres of sediments are dredged from Europe’s navigable rivers, estuaries and canals. Much of this material is subsequently placed (or disposed) elsewhere in the aquatic environment, often in water bodies covered by the WFD. Effective sediment management is therefore crucial if WFD objectives are to be met whilst also maintaining safe navigation.

3.1 Impacts on water bodies associated with dredging/deepening, sediment removal and sediment placement

When considering the possible impacts of dredging, a key question is whether the anticipated impacts are temporary, short term and naturally reversible (ie. will the system revert to its previous state without further intervention and without measurable medium-long term consequences)? If so, mitigation measures may not be required. The following discussion highlights possible mitigation or restoration measures which might be applied in the event that adverse impacts are anticipated

Questions requiring consideration include:

- *are **sensitive species** or communities (eg. eelgrasses; shellfish beds; juvenile or migrating fish) naturally present in the river type to be dredged and/or area affected by plume, or at the placement site (for example, causing impacts due to removal, alteration or smothering)?*
- *could dredging or disposal lead to the release of **particulate matter** and/or contaminants?*
- *(how) should dredged material be retained within the water body or local environment so as to **sustain** ecological interests?*
- *is there a possibility of using dredged material **beneficially** (eg. for beach nourishment or foreshore recharge)?*

The significance of impacts will depend on a wide variety of factors relating to the natural environment as well as to the nature of the dredging or disposal operation. Of particular importance in estuaries will be the background levels, and natural variations in levels, of suspended sediments as these can differ by many orders of magnitude - not only between but also within estuaries (eg. according to tidal conditions). Another consideration is that the ecological impacts of capital dredging (to create a new channel or enlarge or deepen an existing channel) usually differ from those of maintenance dredging (ie. part of a regular maintenance operation to remove natural accretions of sediment in an already dredged location). Capital dredging usually changes the hydraulic conditions and often creates a necessity for maintenance dredging.

Depending on the nature and scale of any impacts, possible mitigation measures could include:

- **planning** measures, like minimisation of dredging needs through vessel traffic management or vessel modification, selection of suitable placements sites (eg. retain material within system, beneficial placement of material), special exclusion zones;
- **equipment-related** measures, including selection of the appropriate dredging plant, or use of special equipment; and/or
- **institutional** measures, for example tidal or seasonal timing restrictions on activity, restrictions on location of dredging operation or disposal activity, constraints on the operation of the dredger, etc.

Whilst there is a very broad range of possible management options, selection of an appropriate measure(s) will be very case specific: good management practice should only be determined after assessment of the problem, examination of alternative practices, and appropriate stakeholder participation.

‘Best Management Practices Applied to Dredging and Dredged Material Disposal Projects for the Protection of the Environment’ are the subject of a current PIANC Working Group, the report of which is expected to be published in 2007.

Finally, it is worth noting that in any case where the restoration of a previously dredged area is necessary, such areas could be expected to infill naturally.

3.2 Impacts associated with abstraction, impoundment and flow manipulation associated with the construction and operation of docks, locks, barrages, etc.

Questions requiring consideration include:

- *will there be or has there been a significant change in the characteristics of the water body (eg. from salt to fresh water; from tidal to non-tidal waters; from flowing to standing water; is the water level and its changes artificially maintained)?*
- *will there be adverse consequences for aquatic species and habitats?*
- *what upstream or downstream impacts are associated with the abstraction, transfer and/or impoundment of water?*
- *does the structure prevent the passage of migratory species?*

Possible mitigation or restoration measures include:

- if there is no longer a specified use, and if it does not cause unacceptable physical consequences elsewhere in the water body/physical system, **remove** the (impounding) **structure**

- investigate measures to **restore original** levels of **salinity** and/or to **restore tidal influence** (viability depends on whether maintained water level is for aesthetic reasons or reasons of navigational safety)
- other measures possibly as for hydropower (eg. maintaining flow levels downstream, fish ladders, etc.)

3.3 Impacts on riparian zones or intertidal areas, for example due to shore-parallel structures, bank protection works, or bank erosion resulting from boat wash

Questions requiring consideration include:

- *what implications do the existing or proposed physical modifications have for longshore connectivity, the riparian corridor, wetlands, floodplains or intertidal areas, groundwater and wildlife areas?*
- *do the existing or proposed physical modifications affect river type specific habitats or species especially potentially sensitive ones (eg. impacts of removal, smothering, erosion)?*
- *are there other (additional) pressures on the overall habitat/ecological resource (eg. due to other uses, climate change, sea level rise, coastal squeeze…)*

Possible restoration or mitigation measures (or alternatives to hard engineering solutions) include:

- if there are no unacceptable physical consequences elsewhere in the water body/physical system, **removal** or **modification** of the engineering structure, or reinstatement of the alteration
- **realignment** of banks to facilitate the restoration of riparian or intertidal habitat
- creation of a submerged or partly-submerged **berm** or placement of another structure in front of the embankment **to absorb wave energy** and hence reduce erosion
- recovery of the natural riparian corridor with its natural river movement and habitats
- use of alternative ‘**green’ bank protection techniques** including geotextiles, willow spiling or other products/systems which promote the establishment of riparian vegetation
- where appropriate, application and/or (better) enforcement of **traffic/navigation rules** requiring skippers to avoid excessive wash or suction, e.g. speed limits
- promoting **change of behaviour** of skippers to better recognise the need to protect the environment, via adapted training and education, undertaking awareness campaigns, etc.
- **design modifications** to vessels. For example the design of the hull and/or propulsion system to reduce boat wash may be medium-long term solutions but such measures require further research before they can be made operational to support the goals of the WFD

3.4 Impacts on riparian zones, intertidal areas or water body bed caused by flow and/or sediment control structures (eg. training walls, groynes, breakwaters)

Questions requiring consideration as for shore parallel structures (3) plus:

- *will/does the modification affect natural processes (up- or down-stream), for example hydrology, morphology, or sediment transport?*

Possible restoration or mitigation measures include:

- if there are no unacceptable physical consequences elsewhere in the water body/physical system, **removal** or **realignment** of the structure causing deterioration or failure to meet good status.
- introduce sediment **bypassing** procedures to restore downstream sediment supply or to limit upstream accumulation

3.5 Impacts on habitats/aquatic systems due to reclamation, channel straightening and other physical removal of aquatic habitat

Questions requiring consideration generally as for shore parallel and flow/sediment control structures.

Possible restoration or mitigation measures include:

- if there are no unacceptable physical consequences elsewhere in the water body/physical system, **reinstate flow** to meander or remove or realign reclamation.
- restore **connectivity** across/past the affected area (eg. by creating foreshore habitat in front of reclaimed area)

References:

Koed, A., Jepsen, N., Aarestrup, K., Nielsen, C. (2002). *Initial mortality of radio-tagged Atlantic salmon (Salmo salar L.) smolts following release downstream of a hydropower station.* Hydrobiologia 483, 31-37.

Jepsen, N., Aarestrup, K., Økland, F., Rasmussen, G. (1998). *Survival of radio-tagged Atlantic salmon (Salmo salar L.) and trout (Salmo trutta L.) smolts passing a reservoir during seaward migration.* Hydrobiologia 371/372, 347-375.

German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2006). *Guidelines for hydropower tarifes – charged by new and modernized hydropower plants under Germany's Renewable Energy Sources Act*. Berlin. http://www.bmu.de/english/renewable_energy/downloads/doc/37533.php

Ministry of the Environment and Conservation, Agriculture and Consumer Protection of the State of North Rine-Westphalia (2005).*Handbuch Querbauwerke*. Düsseldorf

LAWA (2002). *German Guidance Document for the implementation of the EC Water Framework Directive.* http://www.wasserblick.net/servlet/is/2888/

Example: Environmental goals for fish in some typical Norwegian HMWB

The table represents a simplified picture and should preferably be adjusted before use. Water temperature, height above sea level and lake/reservoir morphology are important factors to be included in a more thorough analysis. This may not necessarily mean that the table will be more difficult to use.

The environmental goals for fish have been developed based on the fact that hydropower regulations in rivers and lakes usually represent problems for trout, salmon and eel, whereas fish species such as perch, pike, white fish (gwyniad) and arctic char usually survive without specific measures. Water bodies with salmon and eel are, however, not treated in this table.

Type of water body	Example of environmental goals based on measures
Isolated section of creek or river with minimum flow requirements (Isolated means that the fish cannot migrate to adjacent reservoirs/lakes) In clear waters low in calcium, with trout and possibly minnow.	**Hydromorphological goal:** Elements of the natural habitat should be preserved (pool and chute) **Environmental goal - fish:** Stationary, self-reproducing stock of trout with regular recruitment (natural age structure), and without mortality caused by non-biotic factors (such as frozen riverbed, stranded fish due to sudden water flow reductions) **Practical expectations:** Stationary stock of trout with common size of catched fish of about 25 cm. Total production (kg/area) depends on the creek/river area in question, quality is dependent on recruitment, nutrient supply and catch rates.
Creek or river with minimum flow requirements, adjacent to lakes/reservoir(s). (Fish may migrate to lake/reservoir) In clear waters low in calcium, with trout and possibly minnow.	**Hydromorphological goal:** Elements of the natural habitat should be preserved (pool and chute) **Environmental goal - fish:** i) Stationary trout in the river/creek, and ii) Migrating trout between river and adjacent lake/reservoir. Stable trout recruitment (natural age structure) without mortality caused by hydromorphological factors (e.g. frozen riverbed, stranded fish due to sudden water flow reductions) **Practical expectations:** Stationary trout stock: Common size of catched fish of about 25 cm. Total production (kg/area) depends on the creek/river area in question. Production of migrating trout stock will occur in the adjacent lake/reservoir, and will therefore depend on fish types and population, recruitment, catch rates and nutrient supply. i) Trout, minnow ii) Trout, minnow, arctic char iii) Trout, minnow, arctic char, white fish (gwyniad) iv) Trout, minnow, white fish and possibly arctic char and perch

	Measures (such as small weirs, changed water flow) must be evaluated in terms of the danger of increasing the minnow stock, as well as increased siltation and periphyton growth.
Reservoir (originally lake) with a regulation level above 10 meter, with trout and arctic char, and possibly also minnow	**Environmental goal - fish:** Good quality on trout and arctic char. Trout should have a good growth pattern up to 25-35 cm, with red meat. Arctic char should have a good growth pattern up to 20-30 cm. Both species should have natural recruitment. **Practical expectations:** Common size on catched fish about 25-35 cm (trout) and 20-30 cm (arctic char). Necessary to ensure stable recruitment of trout; and to control the recruitment of arctic char. Total production (number and kg of fish) will depend on the area/volume of the reservoir during the production period, regulation level and nutrient status, but the potential for good quality of both species is realistic. Some large individuals of fish-eating trout are expected. **Measures**: Ensure that trout may access creeks for spawning; ensure survival of roe, and appropriate habitat for young fish in running water. Appropriate fishing strategy to balance the relationship between arctic char and trout. The recruitment of arctic char may be regulated by drying out the spawning grounds. Appropriate management requires that the main limitation factors are understood.
Reservoir (originally lake) with a regulation level above 10 meter, with trout, arctic char, and white fish; possibly also minnow	**Environmental goal - fish:** Self-reproducing trout stock of medium quality, with some larger, fish-eating individuals, but a good, dense population cannot be expected. Depending on reservoir morphology, at least one of the two other species (arctic char and white fish) should have good quality. **Practical expectations:** Common size of trout up to 25 cm, some larger, fish-eating individuals. In shallow lakes, white fish is expected to dominate, whereas arctic char will be sparse. In deep lakes white fish and arctic char may co-exist, but the quality of both is expected to be below average. **Measures:** Ensure that trout may access creeks for spawning, ensure survival of roe, and appropriate habitat for young fish in running water. Appropriate catch/fishing strategy to balance the relationship between the species; involving extensive fishing of arctic char and gwyniad.

Reservoir that originally was a river – with trout and minnow. Reservoirs created by a dam in a river will usually be highly productive, and will have a biological potential somewhere between a lake and a river.	**Environmental goal, fish:** Self-reproducing stock of trout, where the amount and quality will depend on the overall fish community in the reservoir, as follows: i) Trout and minnow: Large production of trout of good quality ii) Trout, minnow, and arctic char: Large production of trout of good quality iii) Trout, minnow, arctic char, white fish: Some trout of varying quality, large production of white fish of very good quality. iv) Trout, minnow, white fish, arctic char, perch and northern pike: Very sparse stock of trout, large production of white fish, perch and northern pike. **Practical expectations:** With increasing number of fish species in the reservoir, trout will seek to running waters, primarily in the upper reaches of the reservoir and in tributaries, and perch and white fish will dominate the fish community. **Measures:** Ensure that trout may access the main river for spawning; ensure survival of roe, and appropriate habitat for young fish in running water. Appropriate fishing strategy to balance the fish community, which will probably imply intensified fishing of all other species than trout. Fishing of large pike and large perch should increase recruitment and give a denser population of these two species. Very important to ensure nutrient-poor water and a littoral zone with limited amount of swamp vegetation.

Two more types of reservoirs have been given environmental goals, i.e., reservoirs with a regulation level below 3-5 meters, and reservoirs with trout, perch and pike as part of the fish community. These goals have, however, not yet been translated.

ANNEX IV
Potential restoration and mitigation measures and their cost-effectiveness

EU Guidance Documents on WFD

No.	Title
1	Economics and the Environment - The Implementation Challenge of the Water Framework Directive *WATECO* (2003)
2	Identification of Water Bodies (2003)
3	Analysis of Pressures and Impacts - *Impress* (2003)
4	Identification and Designation of Heavily Modified and Artificial Water Bodies – HMWB (2003)
5	Transitional and Coastal Waters – Typology, Reference Conditions and Classifications Systems – COAST (2003)
6	Towards Guidance on Establishment of the Intercalibration Network and the Process on the Intercalibration Exercise – *Intercalibration* (2003)
7	Monitoring under the Water Framework Directive – *Monitoring* (2003)
8	Public Participation in Relation to the Water Framework Directive – *Public Participation* (2003)
9	Implementing the Geographical Information System Elements (GIS) of the Water Framework of the Water Framework Directive – *GIS* (2003)
10	Rivers and Lakes – Typology, Reference Conditions and Classification Systems – *REFCOND* (2003)
11	Planning Processes – *Planning Processes* (2003)
12	The Role of Wetlands in the Water Framework Directive – *Wetlands* (2003)
13	Overall Approach to the Classification of Ecological Status and Ecological Potential – *Classification* (2005)
14	Guidance on the Intercalibration Process 2004 – 2006 – *Intercalibration 2004-2006* (2005)

Download under:

http://forum.europa.eu.int/Public/irc/env/wfd/library?l=/framework_directive/guidance_documents/

Information on potential restoration and mitigation measures identified by Member States

Overview on potential measures		
Country	**Literature and links**	**Pressures/Driving Forces and Short Content Description**
DE	http://www.umweltdaten.de/publikationen/fpdf-l/2743.pdf	All pressures and driving forces Cost-effectiveness of most important measures for WFD programmes (English)
NL	http://www.iksr.org/uploads/media/rz_engl_lachs2020_net.pdf	Rhine & Salmon 2020 “A programme for migratory fish in the Rhine system”(English)
PIANC	www.pianc.org/download03 (Please contact wfd@pianc.info for getting access)	- Guidelines for sustainable inland waterways and navigation - Ecological and engineering guidelines for wetland restoration - Bird habitat management in ports and waterways - Recreational navigation and nature
WWF	http://www.eawag.ch http://www.oekostrom.eawag.ch http://levis.sggw.waw.pl/ecoflood www.rivermanagement.ch	

Generic Lists of Mitigating Measures for Water Bodies Heavily Modified by Hydropower (drafted by summarising general experience from Norway)

Illustrative application of methodology in creating a generic list of possible measures (based on Norwegian experience)

The following colour coding has been used to illustrate typical experience gained in Norway on the ecological significance and cost efficiency of each measure in general. Please note that the table is intended only to illustrate a methodology currently being tested in Norway, and does not automatically summarise the final grading of each measure

Colour 1	**Ecological Significance**
🟩	Generally positive experience with few negative side-effects
🟨	Mixed experience or some negative side effects. Needs site-specific studies
⬜	New or untested measure. Insufficient data to make a judgement. Needs research
🟧	Some poor experience, or serious negative side-effects. Only used in special circumstances

Colour 2	**Preliminary grading according to COST EFFICIENCY in improving ecological status**
🟦	Regarded as generally cost-efficient approach to improving status
🟦	Often cost-efficient approach but requires case by case documentation
⬜	New or untested measure, or insufficient data to make a judgement. Needs further analysis
🟪	Not generally regarded as cost-efficient in improving status in general, except in special circumstances

Table M1 LAKES (RESERVOIRS)

	Main group of mitigating measures		Sub-Group for mitigating measure	Main intention of measure	Specific target species or ecological effect	Likely ecologically beneficial effects	Typical cost efficiency or effect on water use
M1	**Stocking of fish**	**M1a**	Trout	Better fish stocks	Support natural recruitment	Can result in many small fish	Neutral for production
		M1b	Salmon and sea-trout	Better fish stocks	Support natural recruitment		
		M1c	Reestablishing fish species	Improve natural biodiversity	Marflo (food for fish)	🟨	
					Mysis (food for fish)	Invasive species replaced natural biodiversity	
		M1d	Intensive fishing of invasive species	Reduce invasive species domination	Minnows reduces competition for endemic species (trout)	Positive if species was introduced	
		M1e	Manipulation of age distribution	Control of toxicity	Hg accumulation in old pike	🟨	
				More natural distribution	Support sik contra trout		
M2	**New limitations on drawdown levels**	**M2a**	Seasonal restrictions imposed	Flood control Landscape and fisheries	Fishing, ice cover etc Natural litoral zone production Reduced algæ in eutrophic lakes	🟩	**Very negative for Production, especially winter security**
		M2b	Limited rate of drawdown	Reduce beach erosion	Reduce turbidity and scour of building foundations etc	🟩	Slightly negative for production (reduced flexibility)
M3	**Cut-off weirs constructed in shallow parts**	**M3a**	Completely isolated hydraulically from main reservoir	Restore natural conditions behind weir	Only restoration behind the Weir. Reservoir unchanged	🟩	Positive for recreation and landscape Neutral for production
		M3b	Weir connected to reservoir by overflow	As above + restores conditions in reservoir	Attempts to improve fish stocks	🟩	
M4	**Habitat manipulations In reservoir and brook deltas**	**M4a**	Coconut matting & planting vegetation in littoral zone	Reduces erosion by waves	Stability of littoral zone	🟩	Neutral for production Expensive for entire littoral. zone
		M4b	Spreading gravel for spawning	Improved spawning in reservoir	Whitefish (gwiniad) and other lake spawners	🟩	🟦

		M4c	Digging deep channels & vegetation clearance	Restores migration routes out of reservoir	Salmon and trout	🟩	🟦
M5	**Liming and fertilising**	**M5a**	Liming (Ca) and fertilising (N or P)	Reduces acidic or oligotrophic state	Reduces acidification Improves food production	Can be negative for w. bodies downstream.	Negative if river vegetation increases unusually

Table E1 RIVERS – Measures which do not intentionally alter substrate or water body

	Main group of mitigating measures		Sub-Group for mitigating measure	Main intention of measure	Specific target species or ecological effect	Likely ecologically beneficial effects	Typical cost efficiency or effect on water use
E1	**Fish Stocking** *Intended to support one specific species (often Salmon or trout)*	**E1a**	Roe	Better fish stocks	Supports natural recruitment Choice of age determined by site conditions.	Can result in many small fish Can reduce biodiversity	Neutral for production
		E1b	Fry				
		E1c	Fry with feeding started				
		E1d	Yearlings				
		E1e	Fingerlings/smolt				
		E1f	Full-grown fish			Highly debatable	
E2	**Fish ladders** *Help upstream migration of anadrome species*	**E2a**	Box type fishladder	Permits upstream migration	Better access to new spawning grounds	No alternatives	**Slightly negative for production**
		E2b	Other types				
		E2c	Other types				
		E2d	Other types				
		E2e	Other types				
		E2f	Other types				
		E2g	Other types				
		E2f	Scaring devices preventing fish from entering tailrace			Only a supplement to fish ladders	Neutral for production
E3	**Alter upstream regulation levels/strategy** *Measures originating upstream*	**E3a**	Two intakes at different levels in reservoir	Alter water temperature drawn off from reservoir	Fish, ice cover, fog	Raising temp.above 7 C favours salmon	Neutral for production
		E3b	Seasonal variations in reservoir use	Mimic natural hydrology downstream	Mostly fish	🟩	**Negative for production**
		E3c	Geometry of brook intakes altered,	Reduce air entrainment	Reduce nitrogen saturation		🟦
		E3d	Location of tailrace outlet	Avoid supersaturated N_2 kill	Fish around tailrace		

RIVERS (cont.) Measures which intentionally alter substrate/water body (without affecting power production)

	Main group of mitigating measures		Sub-Group for mitigating measure	Main intention of measure	Specific target species or ecological effect	Likely ecologically beneficial effects	Typical cost efficiency or effect on water use
E4	**Minimum flow release**	**E4a**	Stable flow over summer	Maintain wet section of river, thereby some benthos, fish and plant habitat retained Better recipient for waste discharge	Ecological continuum Better water quality	🟩	**Negative for production**
		E4b	Variable flows designed for downstream ecology	As for E4a, plus better habitat for young fish, easier migration			**Negative for production**
E5	**Other flow release**	**E5a**	Artificial flood releases	Timely migration of salmon	Upstream migration	Often ineffective for salmon	**Very Negative for production**
				Timely migration of sea-trout		Functions better for sea-trout	
		E5b	Releases aimed at triggering migrations	Migration of anadrome fish	Timely migration Mimics natural flow variation Avoid smolt kills on passing turbines	🟨	**Negative for production**
		E5c	Artificial scouring floods	Clearing mud and vegetation	Better spawning conditions	Exposes gravel substrate (spawning)	🟪
		E5d	Artificial scouring floods with winter freezing of roots	Clearing of extreme growth of e.g. *Juncos Ulbosus*	Plant root disruption	As above, but debris collects downstream	**Very Negative for production**
E6	**Overflow weirs**	**E6a**	Standard "pool-type" (simple)	Larger water surface and wet area (better landscape)	Habitat for benthos and fish, birds etc.,	Favours species adapted to stiller waters	Cheap and cost-effective alternative to larger minimum flow
		E6b	Syvde- type weirs	As above but permits migration upstream	Habitat variation for migrating fish	As above, permits migration upstream	🟦
		E6c	Cell-type weirs	Easier migration and better natural habitat	Habitat variation for migrating fish	Less erosion, more natural looking	🟦

E7	**Habitat adjustments**	**E7a**	Establish hiding and resting places for fish	Better habitat for fish	species of large fish	🟩	🟦	
		E7b	Dig deep channels	Better habitat for fish	As above			
		E7c	Remove natural barriers	Easier migration	As above			
		E7d	Spread gravel for spawning	Better spawning grounds	Better recruitment			
		E7e	Raking of substrate	Better spawning grounds	of salmon and trout		🟦	
		E7f	Mechanical clearing of invasive vegetation	Reestablish natural vegetation diversity	Keep invasive species down	🟨	🟦	Often needs repeating
E8	**Secure bird nests/other measures for one species**	**E8a**	Secure bird nests/other measures for one species	Support for one species	Dippers	🟨	🟦	

ANNEX V
List of case studies potentially relevant to the improvement of ecological status/potential by restoration/mitigation measures

More information can be found in the separate document “Case Studies – potentially relevant to the improvement of ecological status/potential by restoration/mitigation measures”.

Flood protection:

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
F 1 01	Construction of a bank protection to prevent erosion of salt marshes (Oosterschelde estuary, SW Netherlands)	NL	Changes in hydromorphological conditions (tidal range and silt supply) due to the construction of a storm-surge barrier and dams	Stop erosion of salt marshes by a low dam	high
F 1 02	Restoration of a brackish water reduced tidal area with natural abiotic and biotic processes	NL	Dyke between polder and sea	Installation of exchange between salt and freshwater habitat by culvert	medium
F 1 03	Creation of intertidal habitat as part of a flood risk reduction scheme, Essex, Eastern England	UK	Technical flood defence (bulkhead) – Loss of habitat	Creation of new intertidal habitats	high
F 1 04	Habitat creation at Freiston Shore, the Wash, England	UK	Dyke, constraint on freshwater/saline habitat transition, regional loss of habitat	Creation of breaches in the sea wall in order to open the site to tidal action	high
F 2 01	Manshanden fishway for pumping stations	NL	Dykes – pumping stations for water level management, damage of fish – no biological continuum	Installation of behavioural barrier and fish friendly pumping device (Manshanden fishway)	high
F 3 01	Restoration of the Jeseniscica River	SI	River straightening, bank reinforcement, cross sectional and longitudinal profile alteration	Renaturation of the river	medium

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
F 3 02	Connection of a sandpit and creation of dynamic oxbow lake along the Ijssel, a branch of the Rhine	NL	Winter and summer embankments, bank reinforcement, floodplain aggregation	Creation of a side channel with a permanent connection to the river, breach in summer dike, removal of riprap	high
F 3 03	Creation of side channels along the Rhine	NL	Winter and summer embankments, bank reinforcement	Creation of three side channels, rehabilitation of riparian zone	high
F 3 04	Symbiosis as the basis for a natural system of flood risk management in the Dijle valley, Flanders/Belgium	BE	River channel normalisation	Restore the natural flooding system (removal of drain ditches)	high
F 3 05	Restoration of the River Brent	UK	River straightening, river deepening, concrete channel ecological deficiency, habitat destruction and no landscape or visual amenity value as a result of construction of an artificial channel, disconnecting the river from its natural floodplain	Removal of artificial concrete banks, restoration of the meandering planform of the river, creation of backwater habitat	high
F 3 06	Restoration of the Bear Brook	UK	Brook straightening, deepening and agricultural siltation. Poor ecological value, habitat destruction and channel disconnected from its natural floodplain.	Restoration of sinuous course, design of shallow bank slopes	high

Hydropower:

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
H 2 01	Minimum flow requirements and new small weirs in a 5 km long river section in River Numedalslaagen	NO	Cross profile construction; no environmental flow requirements	Installation of minimum water flow, reconstruction of weirs	high
H 2 02	Mitigation measures in and downstream of Halnefjorden Reservoir in River Numedalslaagen	NO	Cross profile construction; no minimum flow requirements; erosion of the littoral zone	Installation of minimum water flow, Installation of fish pass, erosion protection	high
H 2 03	Dam removal on the Mirna River	SI	Damming; interruption in the river continuum	Removing of obsolete dam and construction of rocky glide	medium
H 2 04	Restoration of migration path on the Sava River, Tacen	SI	Damming; interruption in the river continuum	Reconstruction of dam and construction of rocky glide	high
H 2 05	Removal of barriers for fish migration in Norralaån, Sweden	SE	Damming; interruption of river continuum	Installation and reconstruction of fish passes, removal of dam and plant	high
H 2 06	Fishway as a mitigation measure	FI	Damming; interruption of river continuum and habitat loss	Installation of fishways	medium-low
H 2 07	Replacement construction of a large scale hydropower plant – Rheinfelden (High Rhine)	DE	Dam; impaired continuity; loss of the specific riverine habitats	Installation of a bypass channel, fish ladders, removal of bank reinforcement, improvement of habitat structures	medium
H2 08	Hydropower plant Albbruck-Dogern	DE/ EUR	Dam; insufficient residual water flow; interrupted continuum and fish migration	Installation of dynamic minimum water flow, creation of a fish ladder	high
H2 09	Hydropower plant Gottfrieding	DE/ EUR	Dam; interrupted continuum and fish migration	Creation of a concept study for positioning a fish bypass	medium
H 2 10	KW Steinbach Refurbishment -Optimizing energy generation and ecological measures	AT/ EUR	Cross profile construction; disruption in river continuum	Providing fish migration by establishing a vertical-slot-fish-ladder	high
H 2 11	KW Agonitz Refurbishment - Optimizing energy generation and ecological measures	AT/ EUR	Cross profile construction; disruption in river continuum	Establishing a fish bypass designed as combination of natural-like-rivulet and vertical-slot-fish-ladder.	high

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
H 2 12	Fishway as a mitigation measure	FI	Damming; interruption in the river continuum	Installation of fish ladder	medium-low
H 2 13	Minimum water discharges	FR/ EUR	Dams; deterioration of habitats of trouts	Increasing of minimum discharge downstream of dam from 1/40 of the mean annual discharge of the river to 1/10	medium
H 2 14	Optimizing the minimum flow in the Maronne river for migrating fish species	FR	Dams; impaired flow dynamics; change in habitat diversity and quality; disruption in river continuum and lateral connectivity	Installation of a minimum flow	high
H 2 15	Bypass channels at the short-term regulated River Oulujoki	FI	Damming; hydromorphological changes affecting habitat and species diversity	Consideration of the installation of bypass channels to both- create rapid-like streams and continuity; stream habitat restoration	medium-low
H 2 16	Catch and transport of migrating fishes	FR/ EUR	Multiple obstacles limiting fish migration (loss of ecological continuity at the dams)	Catch and transport (by van) of migrating species	medium
H 2 17	Fish compensation measures in the regulated River Klarälven	SE/ EUR	Damming; hydromorphological changes affecting habitat and species diversity	Fish stocking; restoration and installation of fishways in tributaries	high
H 2 18	Hydroecological diagnosis and hydropower installations management – the case of La Fontaulière	FR	Dam; impaired flow dynamics; disruption in river biological continuum and lateral connectivity	Comparison of artificial regimes, optimization of minimum flow & ratio between hydropeaking and base flow	high
H 2 19	Minimum flow requirements and reconstruction of riverbed after canalization and overgrowing in Børselva river, northern Norway	NO	No environmental flow requirements, hence none or low water discharge downstream of the dam; canalisation and eutrophication; heavy impact on biology at site; reduced floods, less water and high increased amount of nutrients	Minimum continuous flow requirements and restoration measures to optimize the physical and ecological conditions for wildlife and river biota	high

H 2 20	Restoring the Loire. The “Plan Loire Grandeur Nature”	FR/WWF	Dams, dykes; decrease in migratory fish species	Restoration programme (e.g. removal of dams; building of fish ladders)	high

Navigation:

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
N 2 01	Bed load management in the river Elbe	DE	River training by groynes, dyke construction, impounding; increased sediment transport capacity	Bed load supply	low – high
N 2 02	Modification of groynes at Elbe riverbanks – ecological investigations on the impact of construction on habitats and distribution of species	DE	Cross profile construction (groynes); loss of structural diversity along riverbanks	Modification of groynes	low – high
N 3 01	Establishment of a floodplain-typical island habitat dominated by the dynamics of varying river stages with an adjacent floodway	DE	Changed routing; loss of typical floodplain sites dominated by the dynamics of varying river stages	Enlargement of the flood spillway and connecting it with the River Moselle for water exchange above mean-flow levels	high
N 3 02	Controlling water levels in river-training projects to preserve floodplain habitats. The example of the Öberauer Schleife (cut-off meander)	DE	Changed routing; loss of typical floodplain sites with characteristic water-level variations	Preserving essential elements of the hydrological dynamics in the floodplain by artificial floods and low-water stages	high
N 3 03	Irrigation System in the riparian woodland between Korneuburg and Altenwörth (Danube river)	AT/ EUR	Changed routing; riverbed erosion, decreasing groundwater level	Installation of a bypass channel (irrigation system)	high
N 3 04	Reconnection of oxbow lakes/ wetlands	SK	Straightening of the river channel, bank reinforcement, uniform shape of river channel	Four meanders in three localities were reconnected with the river channel	-
N 3 05	Groundwater management	AT/ EUR	Changed routing; sinking groundwater level	Establishment of a groundwater management	high
N 4 01	Removal of a bank reinforcement on a slip-off slope of the Lower Rhine	DE	Bank reinforcement; loss of structural diversity	Removal of bank reinforcement	high

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
N 4 02	Interruption of a bank reinforcement on the bank of the limnetic tidal river Elbe	DE	Bank reinforcement; loss of structural diversity	Interruption of bank reinforcement	medium
N 4 03	Removal of a bank revetment in several sections of the limnetic tidal river Elbe	DE	Bank reinforcement; loss of structural diversity	Removal of bank revetment	high
N 4 04	Establishment of a shallow water zone protected against the impact of ship-induced waves	DE	Bank reinforcement; loss of characteristic bank zones	Construction of training wall parallel to the bank with connection to the river flow	high
N 4 05	Establishment of a shallow water zone protected against the impact of ship-induced waves, vegetation-free gravel and pebble areas and succession zones. New harbour Würzburg. River Main	DE	Bank reinforcement; loss of characteristic river and floodplain habitats	Establishment of shallow-water zones with connection to the River Main	high
N 4 06	Improving the structural diversity of river banks by creating a bypass (floodway) in order to promote shallow waters and protect banks against impacts of ship-induced waves	DE	Bank reinforcement; loss of natural river banks; impacts on fish and macrozoobenthos communities	Establishment of an artificial water body (oxbow) in the floodplain with a connection to the River Main	medium
N 5 01	Water column recharge of dredged material to sustain protected intertidal habitats	UK/ NAVI	Dredging; removal of sediment from estuarine system	Restoring and mitigating the effects of dredging on the intertidal mudflats	high
N 5 02	Accountability in maintenance dredging decision making	UK/ NAVI	Maintenance dredging	Development of a transparent decision making framework	high
N 5 03	Morphological management in estuaries conciliating nature preservation and port accessibility	NL/ NAVI	Sediment removal associated with maintenance dredging and capital dredging	Precise placement of dredged material using a diffuser	high
N 3 01	Establishment of a floodplain-typical island habitat dominated by the dynamics of varying river stages with an adjacent floodway	DE	Loss of typical floodplain sites dominated by the dynamics of varying river stages	Enlargement of the flood spillway and connecting it with the River Moselle for water exchange above mean-flow levels	high
N 3 02	Controlling water levels in river-training projects to preserve floodplain habitats. The example of the Öberauer Schleife (oxbow lake)	DE	Loss of typical floodplain sites with characteristic water-level variations	Preserving essential elements of the hydrological dynamics in the floodplain by artificial floods and low-water stages	high

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
N 3 03	Groundwater management	AT/ EUR	River regulation, river erosion due to channelization	Establishment of a groundwater management	-
N 3 04	Irrigation System in the riparian woodland between Korneuburg and Altenwörth (Danube river)	AT/ EUR	River regulation	Installation of a bypass channel (irrigation system)	-
N 3 05	Reconnection of ox-bow lakes/ wetlands	SK	Straightening of the river channel, bank reinforcement, uniform shape of river channel	Four meanders in three localities were reconnected with the river channel	-
N 4 01	Removal of a bank reinforcement on a slip-off slope of the Lower Rhine	DE	Bank Reinforcement	Removal	high
N 4 02	Interruption of a bank reinforcement on the bank of the limnetic tidal river Elbe	DE	Bank Reinforcement	Interruption	medium
N 4 03	Removal of a bank revetment in several sections of the limnetic tidal river Elbe	DE	Bank Reinforcement	Removal	high
N 4 04	Establishment of a shallow water zone protected against the impact of ship-induced waves	DE	Loss of characteristic bank zones	Construction of training wall parallel to the bank with connection to the river flow	high
N 4 05	Establishment of a shallow water zone protected against the impact of ship-induced waves, vegetation-free gravel and pebble areas and succession zones. New harbour Würzburg. River Main	DE	Loss of characteristic bank zones	Establishment of shallow-water zones with connection to the River Main	high
N 4 06	Improving the structural diversity of river banks by creating a bypass (floodway) in order to promote shallow waters and protect banks against impacts of ship-induced waves	DE	Loss of floodplain-typical landscape structures	Establishment of an artificial water body (oxbow) in the floodplain with a connection to the River Main	medium
N 5 01	Water column recharge of dredged material to sustain protected intertidal habitats	UK/ NAVI	Dredging; removal of sediment from estuarine system	Restoring and mitigating the effects of dredging on the intertidal mudflats	high
N 5 02	Accountability in maintenance dredging decision making	UK/ NAVI	Maintenance dredging	Development of a transparent decision making framework	high

N 5 03	Morphological management in estuaries conciliating nature preservation and port accessibility	NL/ NAVI	Sediment removal associated with maintenance dredging and capital dredging	Precise placement of dredged material using a diffuser	high

Other driving force:

Number	Title of case study	Country	Pressure & Impact	Measure	Ecological efficiency
o 2 01	Restoration of sediment flow control dam on the Kokra River	SI	Damming; interruption in river continuum	Construction of a fishway	medium
o 3 01	Doñana wetland	ES/ WWF	Mining, agriculture; water quality and wetland degradation, heavy alteration of river dynamics	Restoration of the ecological and hydromorphological dynamics of the water streams draining into the wetland	high

ANNEX VI
Glossary

Abiotic
Non-living characteristic or element of the environment. Usually refers to the physical and chemical components of an organism’s environment.

Abstraction
The deliberate removal of water from a water body, either surface or groundwater.

Alluvium
Sediments deposited by erosional processes, usually by streams.

Alteration
See ‘Modification’ and ‘Physical alteration’

Anadromous
Refers to species that live in the ocean and ascend rivers to spawn.

Aquatic
Refers to an organism that lives in water or is dependent on water (as a medium) for its survival.

Artificial water body (pursuant to the Water Framework Directive)
A body of surface water created by human activity.

Backwater
(1) A small, generally shallow body of water attached to the main channel, with little or no current of its own. (2) Water backed up or retarded in its course as compared with its normal or natural condition of flow.

Bedload
Solid material that a watercourse transports to or near to its bed via a rolling or jumping action.

Benthos
All aquatic organisms which live on, in or near the bottom of water bodies.

Biocoenose
A community of organisms whose composition and aspect is determined by the properties of the environment and by the relations of the organisms to each other.

Biodiversity
1) Genetic diversity: the variation between individuals and between populations within a species; species diversity: the different types of plants, animals and other life forms within a region; community or ecosystem diversity: the variety of habitats found within an area (grassland, marsh and woodland for instance)
2) An umbrella term to describe collectively the variety and variability of nature. It encompasses three basic levels of organisation in living systems: the genetic, species and ecosystem levels.

Biological continuity
Refers to the capacity of an ecosystem to enable aquatic species, as well as species that live around water such as beavers and otters, to successfully undertake characteristic, species-specific migration behaviours.

Biotope
Well-defined geographical area, characterised by specific ecological conditions (soil, climate, etc.), which physically supports the organism that live there (biocoenosis).

Body of surface water (pursuant to the Water Framework Directive)
A discrete and significant element of surface water such as a lake, a reservoir, a stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water.

Bypass
A channel at a hydropower facility that circumvents the facility's turbines and allows for safe passage of fish migrating downstream in the underwater current at the facility dams and weirs.

Bypass channel
A stream like channel enabling fish and invertebrate species migrating upstream to circumvent an obstruction such as a dam.

Catadromous
Refers to fish species such as eels that live in freshwater but migrate to the ocean to spawn.

Catchment area
(1) An area from which surface runoff is carried away by a single drainage system. (2) The area of land bounded by watersheds draining into a river, basin or reservoir.

Change
See 'Modification'.

Channelisation
The modification of a natural river channel; may include deepening, widening, or straightening.

Compensation flow
This is the agreed minimum water flow required below intake or dam structures.

Cost-benefit analysis
The evaluation of an investment project from the viewpoint of economy as a whole by comparing the effects of undertaking the project with not doing so.

Cost-effectiveness analysis
An analysis of the costs of alternative programmes designed to meet given objectives. The programme which costs least will be the most cost effective.

Dam
Structure built across a stream, river, or estuary to retain water.

Debris input
Increasing the volume of debris available for transport by adding controlled amounts of debris with the appropriate particle size, for purposes of forestalling erosion in relatively long stretches of watercourse.

Debris transport
Debris transported through a specific watercourse segment within a specific unit of time.

Drainage
The natural or artificial removal of surplus groundwater and surface water and dissolved salts from the land. In the case of natural drainage excess waters flow from the fields to lakes, swamps, streams and rivers. Artificial drainage removes surplus groundwater or surface water by means of sub surface or surface conduits to enhance for instance agricultural production.

Dredging
The excavation and removal of material from the bed of a river, harbour, lake or sea by dredger, dragline or scoop.

Drift
The totality of all living and dead organic and inorganic particles suspended in flowing water.

Ecological status (pursuant to the Water Framework Directive)
An expression of the quality of the structure and functioning of aquatic ecosystems associated with surface water bodies, classified in accordance with Annex V of the Water Framework Directive.

Ecosystem
System in which, by the interaction between the different organisms present and their environment, there is an interchange of materials and energy.

Embankment
Fill material, usually earth or rock, placed with sloping sides and usually with length greater than height. All dams are types of embankments.

Environmental objectives (pursuant to the Water Framework Directive)
Means the objectives set out in Article 4 of the Water Framework Directive.

Erosion
The process by which the banks and bottom of a water body are worn away by the action of water.

Eutrophication
Excessive enrichment of water by nutrients leading to the unduly abundant growth of algae and other forms of plant life.

Fish ladder
A technical construction with a series of steps with flowing water and pools enabling fish and invertebrate species migrating upstream to circumvent an obstruction such as a dam by leaping from step to step.

Floodplain
Nearly level land along a stream flooded only when the streamflow exceeds the water carrying capacity of the channel.

Flow
(1) The surface and subsurface gravity flow of water. (2) The volume of water that flows through a specific area during the applicable time unit and that is allocated to a catchment area.

Good ecological potential (pursuant to the Water Framework Directive)
The status of a heavily modified or an artificial body of water, so classified in accordance with the relevant provisions of Annex V of the Water Framework Directive.

Good ecological status (pursuant to the Water Framework Directive)
The status of a body of surface water, so classified in accordance with Annex V of the Water Framework Directive.

Good surface water chemical status (pursuant to the Water Framework Directive)
The chemical status required to meet the environmental objectives for surface waters established in Article 4(1)(a) WFD, that is the chemical status achieved by a body of surface water in which concentrations of pollutants do not exceed the environmental quality standards established in

Annex IX WFD and under Article 16(7) WFD, and under other relevant Community legislation setting environmental quality standards at Community level.

Groynes
A man-made structure, usually formed of large boulders, designed to direct or control the flow of water in a river. A groyne can also act as a kind of ponding weir to create, or enhance, water depth in the river channel above it.

Habitat
Area in which a specific animal or plant species regularly occurs.

Heavily modified water body (pursuant to the Water Framework Directive)
A body of surface water which as a result of physical alterations by human activity is substantially changed in character.

Hydrological continuum
Spatial, temporal and functional interrelationships within flowing waters or stretches thereof.

Hydromorphology
The physical characteristics of the shape, the boundaries and the content of a water body. The hydromorphological quality elements for classification of ecological status are listed in Annex V 1.1 and are further defined in Annex V 1.2 of the Water Framework Directive.

Hydropower facility
A facility that generates electricity by transforming specific energy in water to mechanical energy in a turbine that drives an electric generator.

Impact (from IMPRESS guidance)
In the context of WFD [Annex II No. 1.5] it is a change to the value of the quality elements resulting from one or a number of pressures, which potentially lead to failing the environmental objectives set in Article 4.

Impoundment
A body of water confined by a dam, dike, floodgate or other barrier.

Macrophytes
Individual plants that are easily visible with the naked eye, algae not included.

Macrozoobenthos
Animal life in or on the bottom that is easily visible to the naked eye.

Meander
Sinuous shaped stream channel. Usually found in streams flowing over a very shallow elevation grade.

Mitigation measures
Measures to improve the status of the water body while keeping the existing modifications for their intended “specified uses” (e.g. creation of habitat diversity within the constraints of flood embankments, bank re-profiling etc.).

Modification (from HMWB Guidance)
Change (or changes) made to the surface water body by human activity (which may result in failing to meet good ecological status). Each modification will have a current or historical “specified use” (such as straightening for navigation, or construction of flood banks for flood defence).

Morphology
An element of physical geography. The study of forms and structures.

Nearly natural
Any natural element or area of the environment containing a largely intact biotic community (whether prior to or following anthropogenic alteration) living in a suitable area that demonstrably displays the characteristic features and structures for its typology.

Oxbow
Abandoned part of a former meander, left when the stream cuts a new, shorter channel.

Physical alterations (from HMWB Guidance)
Modification of the hydromorphology of a water body by human activity (see also ‘Modification’).

Phytoplankton
Unicellular algae and cyanobacteria, both solitary and colonial, that live, at least for part of their lifecycle, in the water column of surface water bodies.

Pool
A spatially delineated deepening in a water body bed characterised by reduced water flows.

Potamal
The low-land and slow flowing river section.

Potamodrous
Refers to fish species e.g. brown trout that live in freshwater and migrate into small headwater streams to spawn.

Pressure
The direct effect of the driver (e.g., an effect that causes a change in flow or a change in the water chemistry of surface and groundwater bodies).

Pressure water
Water that appears behind a levee immediately following an inundation event owing to the fact that air stored in the ground is pressed out.

Pumped storage power station
A hydropower facility that pumps water into a reservoir whose contents are used in the event of increased demand for electricity.

Reference conditions (from REFCOND Guidance)
For any surface water body type reference conditions or high ecological status is a state in the present or in the past where there are no, or only minor, changes to the values of the hydromorphological, physico-chemical, and biological quality elements which would be found in the absence of anthropogenic disturbance. Reference conditions should be represented by values of the biological quality elements in calculation of ecological quality ratios and the subsequent classification of ecological status.

Renewable energy
Renewable energy means hydropower (including the energy generated by its waves, tides, salts and flows), wind energy, solar energy, geothermal energy, biomass energy (including biogas, landfill gas and sludge gas), as well as energy derived from biodegradable household and industrial waste.

Reservoir
A pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.

Revetment
A natural (grass, aquatic plants, etc.) or artificial (concrete, stone, asphalt, earth, san bag, etc.) covering (facing) to protect an embankment (raised structure made of soil, rock or other material) or other structure (such as a cliff) against erosion by wave action or currents.

Rheophilic
Refers to species that prefer running water.

Rhithral
Midsection of the river, also referred to as the Salmonidazone. Also stream primarily fed by rain and snowmelt runoff.

River basin
The area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta.

River Basin Management Plan
A plan that must be produced for each River Basin District within a Member State in accordance with Article 13 WFD. The plan shall include the information detailed in Annex VII WFD.

Scour
Erosion of bed or beach material close to a structure due to wave or river action.

Sedimentation
Process of settling and depositing by gravity of suspended matter in water.

Semiaquatic species
Species that live both near and in water.

Silting
The deposition of silt from a body of standing water; choking, filling, or covering by stream-deposited silt that occurs in a place of retarded flow or behind a dam or reservoir. The term often includes particles from clay to sand-size.

Slip-off slope
Inner bank (convex bank) of a river curve, primarily composed of sediment

Spawning ground
Geographic area where shedding and fertilization of eggs takes place.

Specified use (from HMWB Guidance)
Water uses as described in Art. 4(3)(a)(ii)-(v) WFD.

Substrate
'Supporting surface' on which an organism grows. The substrate may simply provide structural support, or may provide water and nutrients. A substrate may be inorganic, such as rock or soil, or it may be organic, such as wood.

Suspended material
Solids that remain on the in suspension owing to the turbulence of flowing water.

Tail-bay
A short stretch of open water between the power house and the adjoining open river.

Translatory waves
A quick change in depth of water in an open channel caused by a sudden flow increase or decrease occasioned by a closed turbine or other factor.

Tributary streams
Small streams that enter into the main stream.

Undercut Bank
Steep bank found on the inside of stream meanders. Formed by the erosion that occurs when a stream channel moves horizontally.

Water Framework Directive
Directive 2000/60/EC establishing a framework for the Community action in the field of water policy. It aims to secure the ecological, quantitative and qualitative functions of water. It requires that all impacts on water will have to be analysed and actions will have to be taken within river basin management plans.

Water use (pursuant to the Water Framework Directive)
Water services together with any other activity identified under Article 5 and Annex II WFD having a significant impact on the status of water.

Weir
A structure that is built in a flowing body of water, that is equipped with fixed or movable closure mechanisms and that is used to raise the water level and for other purposes.

Wetland
Habitat characterized by water and containing characteristic plants and animals. Other wetland features include reedbeds, marshes, fens and transition mires, swamps, highmoors and riverine forests.

Wider environment (from HMWB Guidance)
The natural environment and the human environment including archaeology, heritage, landscape and geomorphology.

ANNEX VII
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