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WG ECOSTAT report on common understanding of using mitigation measures for reaching Good Ecological Potential for Heavily Modified Water Bodies

Part 3: Impacted by drainage schemes

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Abstract

Hydromorphological alterations for drainage are widespread pressures on water bodies in Europe. Because of the importance of the water uses relying on drainage schemes, such as agriculture and urban areas, not all necessary restoration measures can be taken without significant adverse effect on the water use. Therefore many of the affected water bodies have been designated as heavily modified (HMWB). Still, in a substantial number of these water bodies, some mitigation measures should be taken to reach Good Ecological Potential (GEP).

This report presents responses of European countries on a detailed questionnaire distributed in 2015 on the impacts of land drainage on the water environment and the measures that can mitigate those impacts. The questionnaire also included questions on impacts of flood prevention, presented in the accompanying report "*Part 2: Impacted by flood protection structures*".

A key objective of the questionnaire was to compare the understanding of impacts caused by drainage to continuity, hydrological regime, morphological alterations and aquatic biology. Information was requested on 1) national definitions of drainage and existing guidelines, 2) water uses and regulatory regimes linked to drainage, 3) hydromorphological alterations due to drainage and their assessment, and 4) mitigation measures. A list of mitigation measures and their definition is presented. In total, 20 countries responded to the questions on land drainage.

Key findings of the exercise are as follows:

- Comparing the mitigation expected for good ecological potential by different countries provided a good basis for identifying similarities and differences between those countries' standards for good ecological potential. It also provided a valuable opportunity for the exchange of information.
- It is possible to reach a harmonized understanding between countries of the environmental objective for HMWBs impacted by drainage.
- There is no common EU wide definition of the term drainage, although a common understanding exists of what it entails.
- There are several methods to detect impacts from hydromorphological pressures and many countries do not have methods to detect all the parameters affected by drainage.
- There is no common understanding on minimum ecological requirements for GEP related to impacts from drainage.
- The standard for ecological potential seems to vary between water bodies and countries and few countries have a national definition on significant impact on water use.
- There are some indications that the majority of countries probably rule-out mitigation measures when considering (often site-specific) evaluating criteria.
- It would be interesting to compare different countries' national methods to a common and comparable set of water bodies/catchments impacted by drainage. Such an exercise would be valuable in further identifying and elaborating on emerging good practice, implementation of measures in practice and possibly also for handling multiple pressures and intercalibrated Ecological Quality Ratios/Methods related to e.g. pollution in a comparable way.

Key recommendations for next steps presented in the conclusions of this report include:

- A generalised framework for deciding on the mitigation required for good ecological potential should be developed to achieve further harmonisation of GEP. Such a generalised framework can be used to supplement CIS Guidance no. 4 on HMWB.
- The existing approach should be further developed to allow for harmonizing the levels/requirements of ecological potential based on mitigation measures.

- Future exercises under the Common Implementation Strategy should use the common technical terminology and mitigation measures provided in this report.
- Harmonized hydromorphological classification methods should be developed in order to have a comparable assessment of the hydromorphological alterations due to drainage, among the different countries.
- More common understanding on ecological minimum criteria for GEP should be developed.
- Countries should exchange and establish transparent criteria for deciding if mitigation would have a significant effect on drainage and benefits for society.
- Reasons for ruling out measures should be made clear and more transparent .
- It is recommended to compare the outcomes produced by countries' national methods by applying them to a comparable set of heavily modified water bodies included in generic cases. Consideration should then be given to incorporating the results of both exercises into a good practice guide.

1 Introduction

1.1 Scope of the report

This technical report documents the outcome of information exchange on Good Ecological Potential (GEP) carried out between 2013 and 2017, as a first step towards the intercomparison of ecological potential in the context of the Water Framework Directive (WFD) intercalibration exercise. Following a general introduction the report focuses on the use of mitigation measures for reaching GEP for heavily modified water bodies (HMWB) impacted by drainage schemes. The outcome of the information exchange which took place in parallel on Heavily Modified Water Bodies (HMWB) impacted by water storage and flood defences are presented in separate technical reports (Halleraker et al., 2016; Bussettini et al., 2018).

1.2 Key principles – Heavily Modified Water Bodies and Ecological Potential

Several key principles, conclusions and recommendations from Common Implementation Strategy (CIS) guidance and related CIS workshops on HMWBs are still highly relevant in the context of a common understanding on the use of mitigation measures, HMWBs designation and objective setting. The most important key principles are summarised in the following paragraphs.

CIS 2003 Guidance no. 4 on HMWB: The 2003 CIS guidance no. 4 on HMWBs (WFD CIS Guidance no 4, 2003) specifies a common understanding for the designation and classification of HMWBs (Figure 1) and defining GEP based on the biological quality elements. Since 2005, a number of CIS workshops have led to key conclusions and recommendations for best management practice for hydromorphology issues (available at CIRCABC).

CIS 2005 (Workshop on Hydromorphology): The Prague or the mitigation measure approach was agreed at the CIS workshop on Hydromorphology in 2005 as a valid method for defining GEP (Kampa and Kranz, 2005). The Prague or the mitigation measure approach bases the definition of GEP on the identification of mitigation measures. Starting from all measures that do not have a significant adverse effect on the water use, which reflects Maximum Ecological Potential (MEP), those measures are excluded that, in combination, are predicted to deliver only slight ecological improvement (Figure 2). GEP is then defined as the biological values that are expected from implementing the remaining identified mitigation measures. The main difference to the reference-based approach described in the CIS Guidance No 4 is that GEP is derived from the mitigation measures for maximum ecological potential and not from the biological quality element (BQE) values at maximum ecological potential. Both methods define BQE values for GEP.

Both WFD CIS Guidance no 4 (2003) and the outcome from the CIS 2005 workshop on hydromorphology state that GEP is not a "stand alone" objective, but is based on the mitigation measures in relation to the water use. It was therefore proposed to develop lists of relevant mitigation measures along with estimations of their effectiveness.

CIS 2009 (Workshop on HMWBs): Regarding significant adverse effect on use, it was agreed, it cannot mean "*no impact on use*" (key conclusion – kc 21). It was agreed that ecological continuum is a relevant consideration in defining GEP as well as MEP (kc 32). There was general agreement at this workshop that providing river continuity for fish migration is normally a necessary component of GEP (kc 33). Ecological quality at GEP may be more similar for some uses than others (kc 53).

CIS 2015 Guidance no. 31 on Eflows: The 2015 CIS guidance on Eflows (flow needed for reaching at least good ecological status) identified a series of overall key indications to tackle some critical aspects linked to the management and restoration of water bodies affected by hydrological pressures. However, the flow needs in HMWBs and thereby for reaching GEP was only briefly mentioned in the Eflows guidance (WFD CIS Guidance n. 31, 2015), with reference to the ongoing activity on ecological potential under WG ECOSTAT.

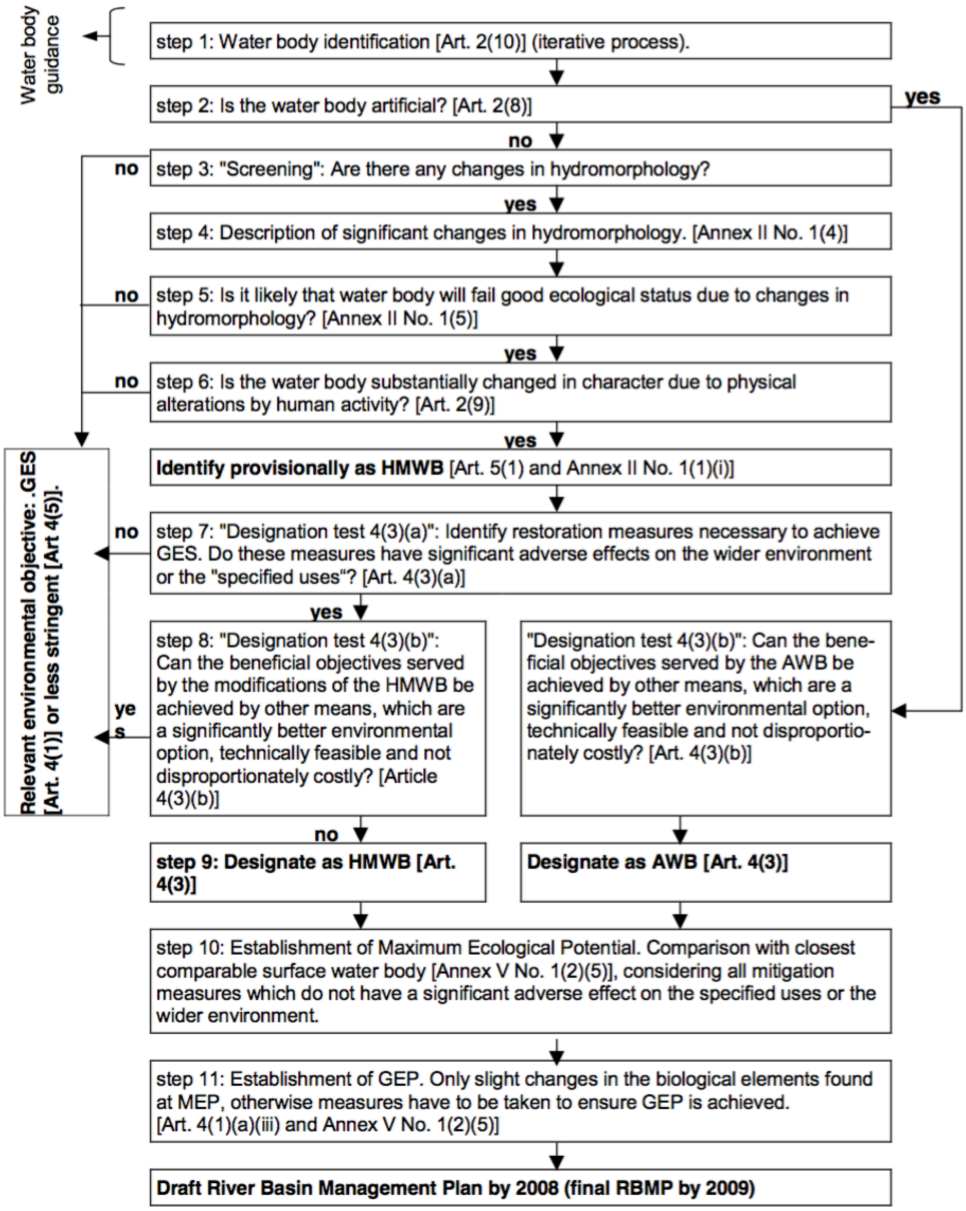

Figure 1. Steps of designation and classification of heavily modified and artificial water bodies

Source: WFD CIS Guidance no. 4 on HMWBs (2003)

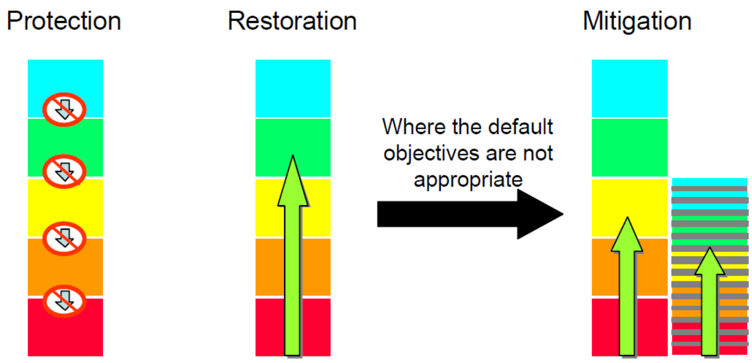

Figure 2. Mitigation measures and Good Ecological Potential

Source: Kampa and Kranz (2005)

1.3 Intercalibration of ecological status and potential

Intercalibration is a process aimed at achieving comparable good status and potential classification boundaries for the biological quality elements set in compliance with the WFD requirements. The requirement for intercalibration is specified in WFD Annex V 1.4.1. The intercalibration exercise is to be carried out by the Member States and facilitated by the Commission, with a deadline set for 2007. Intercalibration activities started soon after the WFD came into force in 2000, as a key activity under the Common Implementation Strategy (CIS). In practice the intercalibration exercise proved to be much more complicated than originally foreseen; by the 2007 deadline only a part of the work could be completed, and a second and even a third phase were necessary. Several CIS guidance documents describe the common understanding and agreed procedures:

- CIS Guidance No. 6 "Towards a guidance on establishment of the intercalibration network and the process of the intercalibration exercise" (2003);
- CIS Guidance No. 14 "Guidance on the intercalibration process 2004-2006" (2005);
- Updated CIS Guidance No. 14 "Guidance on the intercalibration process 2008-2011" (2011);
- CIS Guidance No. 30 "Procedure to fit new or updated classification methods to the results of a completed intercalibration exercise (2015).

During phase 1 (finalised in 2007) and phase 2 (2008-2011), the intercalibration exercise has focused on natural water body types[1], and the intercalibration guidance documents do not cover ecological potential: "*As in Phase 1, intercalibration in Phase 2 will focus on […] good ecological status. Good ecological potential (GEP) will not be intercalibrated […] in Phase 2 due to the complexity of defining GEP and the fact that the procedure how to intercalibrate GEP is not yet clear*" (CIS Guidance No. 14).

For natural waters, it has been possible to agree on a technical intercalibration process where Member States' classification methods are checked for their compliance with the normative definitions specified in WFD Annex V. Subsequently, the high-good and good-moderate boundaries are compared and harmonized either directly or by using a common metric. A common understanding of the type-specific reference conditions is a key prerequisite to carry out the comparability analysis for good status classification methods. An important part of intercalibration of natural waters has been to apply/agree

[1] An exception is the biological quality element phytoplankton as an indicator for the effects of nutrient pressure that has been intercalibrated for Mediterranean reservoirs

on common criteria for reference conditions. Results of the completed intercalibration exercises were published in COM Decisions 2008/915/EC (phase 1) and 2013/480/EU (phase 2). The current phase 3 (2012-2016) is aimed at completing intercalibration (IC) gaps for natural water body types, and to start addressing ecological potential.

The WFD specifies that, for MEP, "*the values of the relevant biological quality elements [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*" (WFD Annex V 1.2.5). GEP is defined as, "*There are slight changes in the values of the relevant biological quality elements as compared to the values found at maximum ecological potential"* (WFD Annex V 1.2.5). Intercalibration is ultimately about achieving comparability for good status and potential classification boundaries for the biological elements. The quality elements applicable to artificial and heavily modified surface water bodies shall be those applicable to whichever of the four natural surface water categories above most closely resembles the heavily modified or artificial water body concerned (WFD Annex V 1.1.5).

It is not possible to apply the intercalibration procedures that were developed for the natural water body types to heavily modified water bodies. The main reason is that setting good ecological potential boundaries for the biological quality elements cannot be seen separately from the HMWB designation process (Figure 1). This is further emphasized in WFD definition of maximum ecological potential for the hydromorphological elements, i.e. "*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*" (WFD Annex V 1.2.5). Boundaries for GEP for hydromorphological elements are "*consistent with the achievement of the values specified above [for GEP] for the biological quality element"* (WFD Annex V 1.2.5).

CIS ECOSTAT 2011 (Concept paper on Intercalibration of GEP): This concept paper, endorsed by the Water Directors, discusses possibilities for intercalibrating GEP in accordance with WFD requirements and provides recommendations on assessing and improving comparability of GEP assessments. A comprehensive intercalibration of GEP in the same form as undertaken for Good Ecological Status (GES) is not expected to be technically possible. The reasons for this are that:

- Member States' definitions of GEP will always be influenced by their national judgements about the significance, and hence acceptability, of adverse effects on the use (e.g. land drainage for agriculture) or on the wider environment;
- Scientific understanding of the ecological impact of hydromorphological alterations is less well developed than is the understanding of the impact of pollution;
- There is considerable variability in the nature and extent of hydromorphological alterations because of the wide range of uses for which water bodies have been designated as heavily modified and the wide variation in the associated hydromorphological modifications.

Therefore, alternative approaches to assessing and improving comparability are needed. The proposed pragmatic approach had the following three components:

a) Review of the current state of play in defining GEP taking into account the requirements of the WFD and existing guidance documents;

b) Development of a methodological framework for defining and assessing GEP taking into account the results of the review; and

c) Simple comparisons of GEP for common uses.

1.4 Mandate and scope of the information exchange on GEP mitigation measures

As one of the core activities for the CIS working group on Ecological Status (ECOSTAT) since 2013, a harmonized understanding of GEP, often mentioned as intercomparison, for HMWBs has been on the agenda. An ad-hoc group has been working on harmonising GEP mainly related to drainage schemes, consisting of national experts on hydromorphological issues and coordinated by a core group (the authors of this report).

The main aims of the information exchange on GEP for HMWBs impacted by drainage have been to:

1. Exchanging experience on GEP and hydromorphological alterations caused by drainage;
2. Finding suitable methods for assessing comparability (intercalibration);
3. Learning from each other to ensure common understanding;
4. Sorting out good management practice; and
5. Possibly defining best available mitigation measures for HMWBs due to drainage across Europe.

In order to reach that aim, the following related questions for rivers and lakes affected by drainage should be answered:

1. Do we design drainage related HMWB in a similar or comparable way?
2. Do we look at similar impacts, regarding type and scale?
3. Do our national mitigation measure libraries contain similar measures for these impacts?
4. Do we use comparable criteria to select/rule out mitigation measures?

An essential component of the work on harmonising the understanding of good ecological potential for water bodies impacted by drainage schemes has been information exchange templates circulated between participating countries and EEA to collect and compare data on available mitigation measures and approaches to defining GEP in relation to drainage schemes. Workshops based on the template results have been arranged to clarify terms and definitions, highlight where there is alignment, and where there are differences in approaches and to start to explore the reasons behind these. Presentations and documents related to the group's work are available on CIRCABC.

The following chapters present the outcome of this information exchange, in particular the results of the templates circulated to participating countries.

1.5 Report structure and content

The purpose of this report is to present the responses of European countries on the assessment of the impacts of drainage and the consideration of mitigation measures on land drainage, and draw relevant conclusions on the use of mitigation measures for reaching GEP. The focus of the report results is on natural water bodies and HMWB and not on artificial WBs.

The next chapter 2 presents key terminology relating to land drainage and GEP, followed by Chapter 3 presenting the structure of the questionnaire

Chapter 4 presents results of the questionnaire regarding drivers of land drainage and existing regulatory regimes. This is followed by Chapter 5 on the impacts of hydromorphological alterations due to drainage, Chapter 6 on the ability of national assessment to detect hydromorphological alterations, Chapter 7 on the relevance of drainage alterations on reaching GES, and Chapter 8 on the value of hydromorphological alterations to the water use. Chapter 9 examines in more depth the issue drainage maintenance, while Chapter 10 reports results on the designation of HMWB due to drainage.

Chapter 11 presents a list of mitigation measures on land drainage and results regarding their consideration and use across Europe.

Key conclusions and recommendations are provided in Chapter 12.

2 Drainage and impacts on water bodies

2.1 What is "drainage"?

Drainage is one of the water uses alongside water regulation and flood protection mentioned in the WFD Article 4.3 on environmental objectives and the designation of HMWB. It is also included in Annex II in respect to the impact of drainage on groundwater dynamics. Countries may thus designate a body of surface water as artificial or heavily modified if the changes to the hydromorphological characteristics of that body which would be necessary for achieving GES would have significant adverse effect on the use for which the drainage is applied.

There is no common EU wide definition of the term drainage, but it is often associated with man-made structures or alterations to water bodies to improve a specific land area for a certain purpose such as agriculture, forestry or coastal and urban development. In this report, the term drainage is mainly linked to agricultural drainage, and we hereby introduce a definition in table 1 of the term within the context of this report.

2.2 What are drainage schemes?

Drainage schemes can be associated with agricultural activities, forestry, urban development and infrastructures, as well as land reclamation projects. Mining may sometimes require drainage of ground water to reduce the inflow into a mine or a quarry, but these specific aspects are not covered within the content of this report. Drainage in peat production is part of the operation.

Agricultural drainage, also called field drainage, aims to keep a proper balance between available soil pore water and available pore air, the objectives being to reclaim and conserve land for agriculture, to increase crop yields, to permit the cultivation of more valuable crops, to allow the cultivation of more than one crop a year, and/or to reduce the costs of crop production in otherwise waterlogged land (Oosterbaan, 1994). In some situations, drainage can also result in multiple benefits regarding soil conservation, reduced soil compaction, and reduced soil erosion. Other positive effects due to drainage are reduction of the load of pesticides, herbicides and nutrients.

Agricultural drainage includes surface schemes, usually based on ditches and trenches or subsurface schemes, usually based on tile drains, rubble drains or mole drains (Figure 3). Drains typically end in an open channel or sometimes in a collector pipe system. In order to regulate the drainage, water levels in drainage systems can be controlled by check gates at the end of the system. Drainage pumps are used to lower the ground water level to a suitable depth in closed depressions where negative slopes make surface and subsurface drainage ineffective.

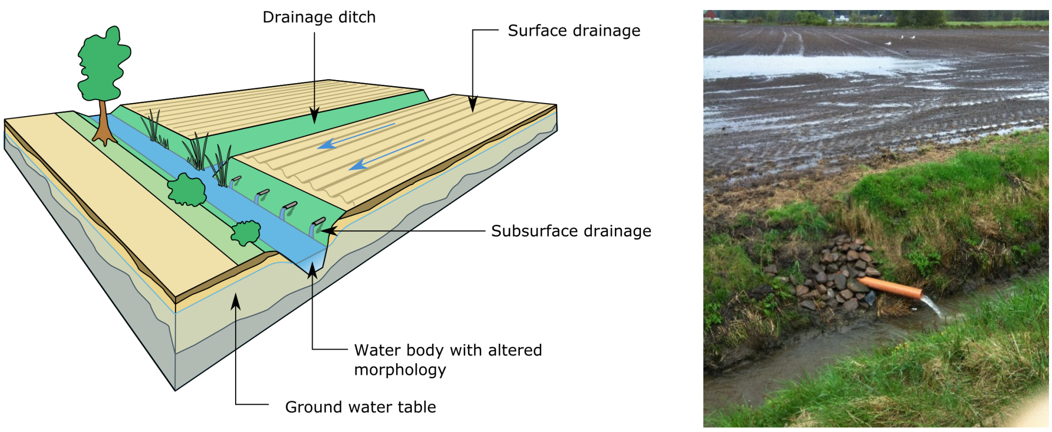

Figure 3. General sketch of agricultural drainage and an example of subsurface drainage entering a drainage ditch. Illustration: Johan Kling

Forestry drainage can be divided into normal ditches permanently lowering the groundwater table and protective drainage ditches which are mainly used in clear-cut areas. Forestry drainage may be especially important during planting phase and in cold areas to reduce frost heave of root systems and the plant.

Urban drainage[2] aim to lower the ground water table or to manage surface runoff from impermeable areas, with the use of pipes and culverts, drains, or artificial channels. The recipient may be a natural water body, an artificial channel or a storage reservoir. To have an efficient removal of storm water, some rivers are dredged and their morphology altered. Drainage systems aimed at flood protection are also considered in the "*WG ECOSTAT report on common understanding of using mitigation measures for reaching Good Ecological Potential for heavily modified water bodies. Part 2: Impacted by flood protection structures*" (Bussettini et al., 2018).

Infrastructures such as roads also often need drainage in the form of subsurface drainage pipes or in the form of ditches. The aim is to remove surface run-off from the road and to keep ground water table low to have a stable road bank. In northern Europe, keeping the groundwater table level low is important to reduce road damages due to frost heave.

Coastal land reclamation aims to create new land area in coastal waters for agriculture, urbanization, transportation (e.g. large ports and harbours), and energy production. It is very common along the entire European coastline, especially in estuaries, tidal flats or other flat areas close to the shoreline with high ground water table.

Land reclamation has also been carried out extensively in European rivers and floodplains. Typical situations include the modification of a river with multiple channels into a river with one single channel, or the combination of floodplain drainage with dikes for flood protection. Land reclamation also occurs around lakes, typically by lowering mean lake water level to gain land for agriculture, forestry or urbanization.

2.3 Key terms used in this report

Table 1 presents key technical terms and their definitions in the context of this report.

Table 1 Definitions of key technical terms in this report

Term	**Definition (in the context of this report)**
Backwater	Often called backwater inlet or backwater channel. A backwater is a part of a river in which there is little or no current. It refers either to a branch of a main river, which lies alongside it and then rejoins it, or to a body of water in a main river, backed up by the tide or by an obstruction such as a dam, lock or weir.

[2] Urban drainage does not include sewage system since this is managed in a separate system in most European urban areas. However accidental mixing of sewage and storm water may occur due to unnatural precipitation events, flooding or human errors.

Biological continuity	Biological continuity refers to the longitudinal dimension within the water body (river continuity) and the lateral dimension including interactions between the channel and the adjacent riparian zone and floodplains with its backwaters. It also refers to the temporal dimension of ecological systems, ranging from the time required to elicit a behavioural response to the time required for response on climate change or for evolutionary change. Biological continuity ensures that species can move freely between different habitats, improve population stability (gene flow), make populations less vulnerable for disturbance and allow colonisation.
Channelization / straightening	Straightening and sometimes widening and/or deepening of a river stretch in order to maximize drainage surplus water.
Ditches and trenches	A ditch is a small to moderate depression created to channel the water in a certain direction. They are man-made structures and are different from stream converted into a ditch-like morphology. Interception ditches cuts off ground water flow from higher grounds to lower parts of agricultural fields. Trenches are usually deeper and narrower compared to ditches.
Drains	Drains are subsurface drainage structures. They include for example tile drains composed by plastic, concrete or even brick tubes laid down in a trench at a proper depth and covered by soil. Rubble drains are similar but composed of rubble and stones. Mole drains are unlined channels formed in clay subsoil by pulling a ripper blade or leg, with a cylindrical foot on the bottom through the subsoil.
Drainage	The removal of excess water from the soil, either by a system of surface ditches (surface drainage), or by underground conduits (sub-surface drainage) if required by soil conditions and land contour, to lower the groundwater level.
Floodplain	An alluvial, flat surface adjacent to the river, created by lateral and vertical accretion under the present river flow and sediment regime. Flood plains along rivers are natural areas with interaction of surface water and ground water. Flood plains commonly have backwater swamps, wetlands and shallow ponds. The ground water table is often close to the soil surface.

Heavily Modified Water Bodies	Definition according to article 2.9 WFD. "Heavily modified water body means a body of surface water which as a result of physical alterations by human activity is substantially changed in character, as designated by the Member State in accordance with the provisions of Annex II." Water bodies identified as being at significant risk of failing to achieve GES because of modifications to their hydromorphological characteristics resulting from past engineering works, including impounding works, can be identified as heavily modified water bodies. In order for a water body to be designated heavily modified evidence is required to show that the water body would not achieve good status without measures being applied in relation to the modifications that have been made to the hydromorphological characteristics.
Land reclamation	Land reclamation is the process of creating new land from ocean, riverbeds, or lake beds by draining of submerged wetlands.
Mitigation measure	Physical or biological measure to mitigate ecological effects in an impacted water body (in this context: impacted by land drainage) leading to an improvement of the ecological conditions.
Ridges and furrows	Furrows are small, parallel channels, made to carry water in order to irrigate the crop or to drain excess water. The crop is usually grown on the ridges between the furrows. It is often used for crops that would be damaged by inundation, such as tomatoes, vegetables and potatoes.
Significant adverse effect on use	Adverse effect on the water use leads to the designation of HMWBs, here related to significant adverse effect upon the main purpose (driver) of land drainage such as agriculture and urban development.
Stormwater	Storm water is run-off from snow or rain on impermeable areas where infiltration into the ground is not high as in permeable areas. Due to rapid flooding and erosion, storm water may create serious damage or even health risk if not properly managed.
Sub-surface drainage	Subsurface drainage is mainly systems composed of different types of subsurface pathways (e.g. semi-permeable pipes) with much higher permeability compared with the surrounding soils.
Surface drainage	Surface drainage systems are mainly related to water logging on the field surface. Ditches, trenches, ridges and furrows in flat agricultural land are typical surface drainage systems.
Water logging	Waterlogging occurs whenever the soil is so wet that there is insufficient oxygen in the pore space for plant roots to be able to adequately respire.

2.4 HMWB designation due to drainage

Data reported in the context of the 1st draft RBMPs indicated that drainage (from agriculture but also other activities such as urbanisation) was the sixth reason to designate HMWB in Europe, after navigation, power generation, flood protection, water regulation and drinking water supply (Figure 4). More detailed observations are provided in chapter 10.

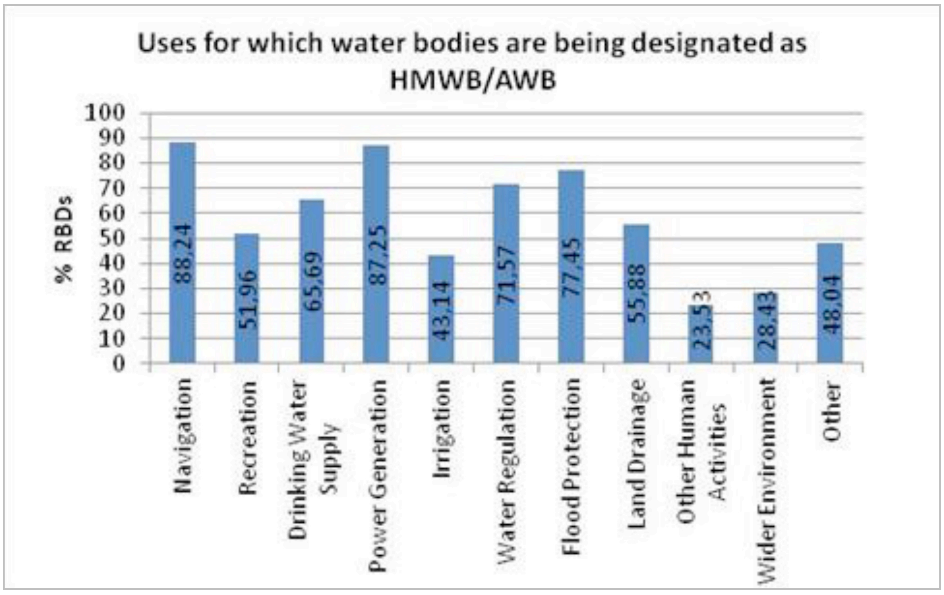

Figure 4. Uses for which water bodies were designated as heavily modified water bodies and artificial water bodies in the 1st RBMPs.

Source: RBMPs, from CSWD 2012

3 European questionnaire on drainage and GEP

This report presents responses of European countries on a detailed questionnaire distributed in 2015 on the impacts of drainage on the water environment and the consideration of mitigation measures on land drainage. The questionnaire also included questions on impacts of flood prevention and related mitigation measures. These results are presented in the accompanying report "*WG ECOSTAT report on common understanding of using mitigation measures for reaching Good Ecological Potential for heavily modified water bodies. Part 2: Impacted by flood protection structures*" (Bussettini et al., 2018).

The questionnaire on drainage was prepared by the ad hoc GEP/Drainage group of the CIS WG ECOSTAT together with ATG HYMO. 20 countries responded to the questionnaire. However, not all questions were answered by all countries. Thus, the total number of countries included in the results varies between topics and chapters.

3.1 Structure of the questionnaire

The questionnaire is based on the DPSIR model (driving forces, pressures, state, impacts, and responses) (Figure 5). In a series of Excel worksheets, information was requested on 1) national definitions of drainage and existing guidelines, 2) water uses and regulatory regimes linked to drainage, 3) hydromorphological alterations due to drainage and their assessment, and 4) mitigation measures.

Land drainage and the DPSIR concept

In a DPSIR context, which is the causal framework for describing the interactions between society and the environment (EEA), land drainage e.g. for agriculture or urban development represents a societal need, a "driving force". This need is put in place through drainage structures such as ditches, drains and pipes, which represent the hydromorphological pressures altering river hydromorphology and so impacting on ecological status. Mitigation measures are the responses to those impacts aimed to enhance the status.

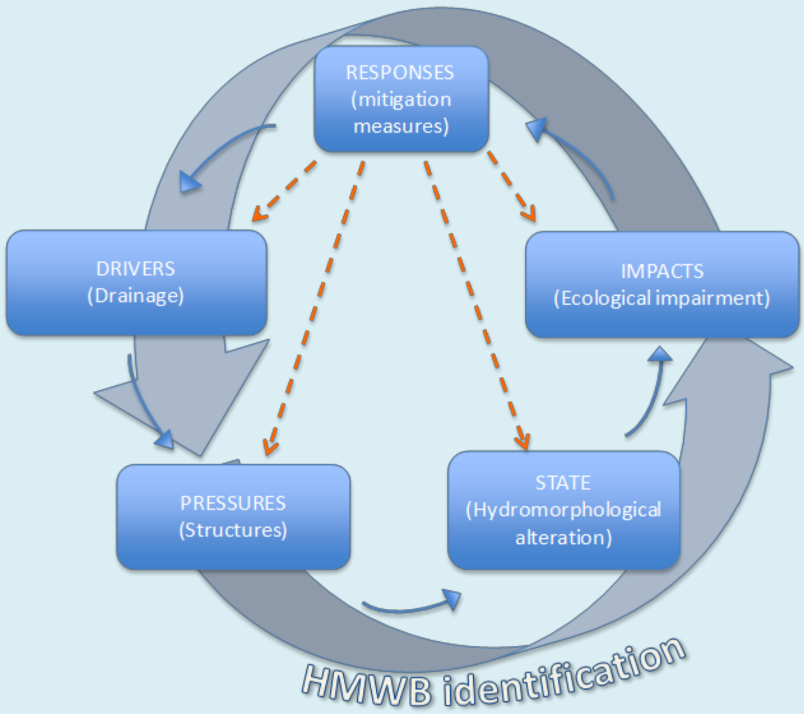

Figure 5. DPSIR schema for HMWB designation and deficits that leads to definition of mitigation measures needs

3.2 Issues covered through the questionnaire

The following issues were examined in the questionnaire (Table 2).

Table 2 Key topics examined through the questionnaire

General
Countries were asked if they designated HMWB and artificial water bodies impacted by drainage schemes (for each WB category), and whether national guidelines exist. They were also asked whether they have a legal definition of "drainage" and "significant adverse effects on land drainage".
Drainage –water use
Countries were asked to indicate what is included in the term drainage and how the benefits of drainage are defined in permits/licenses. They were also asked to indicate the main drivers for drainage in their territory, who "owns" or is responsible for drainage operations. A series of questions on the regulatory regime were asked, including whether the same legal requirements are applied to agricultural and urban drainage, whether there are environmental requirements imposed on drainage maintenance, who provide licenses for operations and for maintenance (where required). Finally, countries were asked to indicate what is considered a typical maintenance operation (e.g. removal of large woody debris, dredging of sediment, reshaping river cross section, reshaping plan form), their degree of usage and their degree of negative impact on ecological status.
Drainage –impact on hydro-morphology
25 types of drainage alterations (distinguished into three categories: alterations leading to impact on continuity, hydrology and morphology) were identified. Countries were asked to indicate whether the alteration commonly occur due to drainage in their territory, whether the alteration is picked up by the national assessment approach, what is the relative importance of the alteration for reaching GES, and what is the value of the alteration providing the water use.
Drainage –measures
18 types of mitigation measures were identified. Countries were asked to indicate, for each mitigation measure, whether it is included in their national library, what their assumed effectiveness for improving hydromorphology and biological quality is, and what the relative magnitude of their effect on water use is (in general term). A number of questions also related to the process of ruling out mitigation measures.

3.3 Scope of the report and results presented

This report focuses on land drainage, in particular agricultural land. Land reclamation and flood protection (including of agricultural land) is examined in the WG ECOSTAT report on "*common understanding of using mitigation measures for reaching Good Ecological Potential for heavily modified water bodies Part 2 –Impacted by flood protection*".

There are variations in the number of countries responding to individual questions. Each section and figure thus indicates which countries are included. Sometimes, countries did not select one of the pre-defined answers. This could have been interpreted in different ways: not relevant, not significant, mistake, etc. These answers are provided with the label "No answer".

We are also aware that all relevant mitigation measures that may be needed to fully mitigate (long term) impacts directly or indirectly from drainage are not covered in this report. This is partly due to terminology and/or main focus from a specific mitigation measure.

4 Drivers and pressures of land drainage

Part of the information exchange towards harmonized understanding of ecological potential is regarding drivers and pressures of land drainage. This information is used when assessing significant adverse effect on water use.

4.1 Definition of drainage

Countries were asked if there is a definition of "drainage" set out in legislation, guidance documents or other documents. Out of the 20 countries which answered this question, 8 countries indicated that they had a national definition and two countries referred to a definition based on CIS guidance document No 4. 9 countries indicated that no reference definition was used. The result suggests that there remain many countries with no definition of drainage in their legislation or guidance document.

Almost 70 % of the responding countries replied that the main goal of drainage is to improve a land area by increasing the depth to groundwater. In some countries (SE), also flood protection, especially in agricultural areas, and land reclamation (SE, EE, CZ, BG) are part of the term drainage.

4.2 Sectors and operators leading to land drainage

Figure 6 presents the main drivers of drainage identified by responding countries, and the body responsible for carrying out drainage operations. Overall:

- All countries replied that agriculture is one of the main drivers for drainage; this is followed by urban development and forestry with 16, 14 and 11 countries respectively. This suggests that these three sectors represent the main drivers for drainage in Europe.
- Less common drivers are mining and peat production which are mentioned by two countries each. Other drivers included land reclamation, navigation, recreation and wider environment (each mentioned once).
- 9 countries indicated that both landowners and public authorities are responsible for drainage operations. 4 countries indicated that only private landowners are responsible for drainage operations and 5 countries indicated that only public authorities are responsible for drainage operations. Local authorities were the most frequently mentioned, following by national and regional authorities.

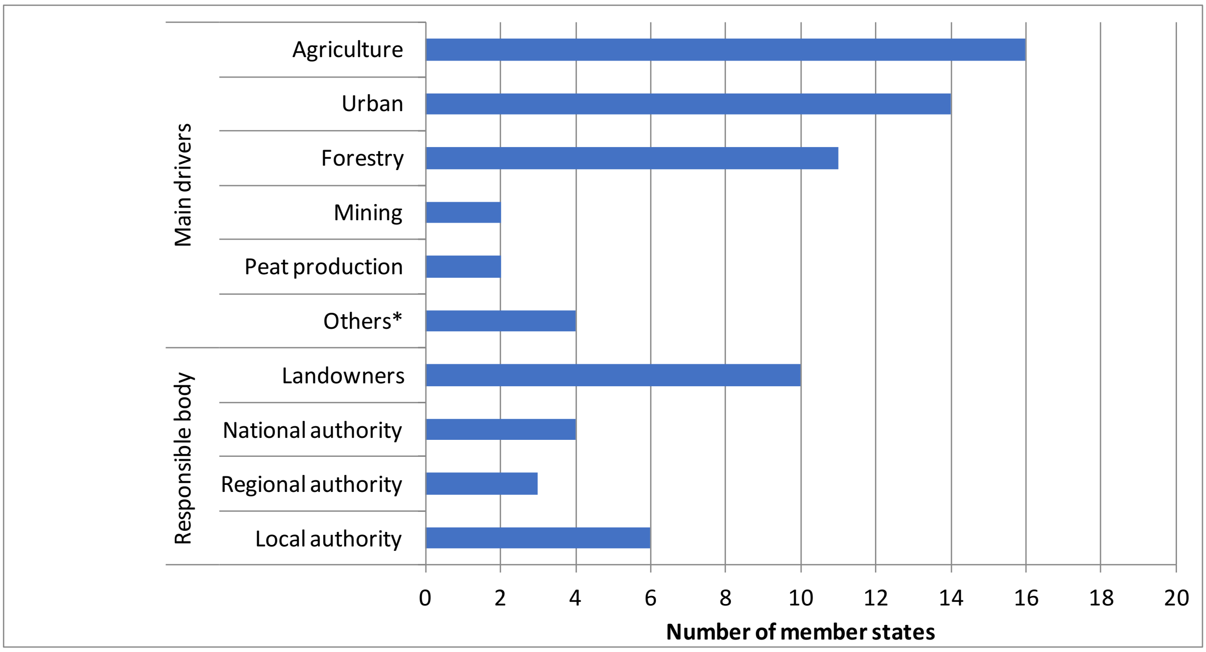

Figure 6. Main drivers and responsible actors for drainage operations

Notes: Multiple answers possible. Others refer to: land reclamation, navigation, recreation and wider environment (one member state each). 16 countries answered this question: BG; DE; DK; EE; HR; FI; IE; IT; LT; NL; NO; PT; RO; SE; SK; UK.

4.3 Pressures from drainage

There are several hydromorphological pressures due to land drainage. Artificial drainage alters the process and the pathways of the excess water removed from the land (Lambert et al., 2004). Drainage may include alterations to lake and stream hydrological regimes. In many cases, morphological alteration by reshaping the parts of the water body is required to reclaim naturally waterlogged land or to improve existing drainage conditions.

Hydromorphological pressures from drainage can be divided into primary, secondary and tertiary pressure:

- Primary pressures are direct impact or alteration of the hydromorphology of the water body. This can be removal of natural hydraulic limitations, channelization of rivers, or land reclamation in lakes and coastal areas.
- Secondary hydromorphological pressures are drainage pressures which do not directly influence the water body. This is typical for drainage in farmland, like ditches or piping which are connected to the water body but not directly altering the water body’s hydromorphology. The drainage has secondary effects like increasing the inflow of sediments in the water or changing the hydrological regime.
- Tertiary hydromorphological alteration due to drainage is reoccurring pressures with some specific interval due to maintenance operation. For example, maintenance of ditches may be as frequent as 1 to 5 years’ interval in agricultural ditches, whereas dredging streams may be more seldom.

The following alterations were included in the term drainage by the member states during the exchanges:

- Surface drainage leading to hydrological alteration and excess sediment
- Effects on continuity
- Lowering the groundwater table
- Impairing riparian and aquatic vegetation
- Subsurface drainage of land by subsurface with hydrological alteration
- Morphological alteration of rivers to improve drainage of land (e.g. lowering of the river bed by sediment removal; revetment of the channel, etc.)
- Increasing flow capacity by increased cross section area
- Increased slope of a river and decreased friction by removal of substrate, structures and large woody debris to maintain low water table in subsurface drainage
- Straightening of meandering rivers
- Putting river into culvert to improve drainage
- Relocation of rivers to increase farmable land or improve urbanisation
- Lowering lake and river water level
- Reclamation of land by dikes or similar structures

4.4 Legal requirements on drainage operation and maintenance

The legislation which authorizes drainage varies between countries. In most countries, there is a requirement to have some sort of license or permit to install new drainage operation. National, regional or local authorities are involved in most cases (11 out 16 countries) but other public bodies may be involved (e.g. environmental court, river basin authority, multiple authorities) (Figure 7). One member state replied there is no licensing system for drainage.

Only 31 % of responding countries (5 out of 16) require a permit for drainage maintenance, although environmental requirements are requested in more countries (50%, 8 out 16 countries) (Figure 8). In 3 countries, no license is required; however, if the maintenance leads to environmental damage, a new license may be required.

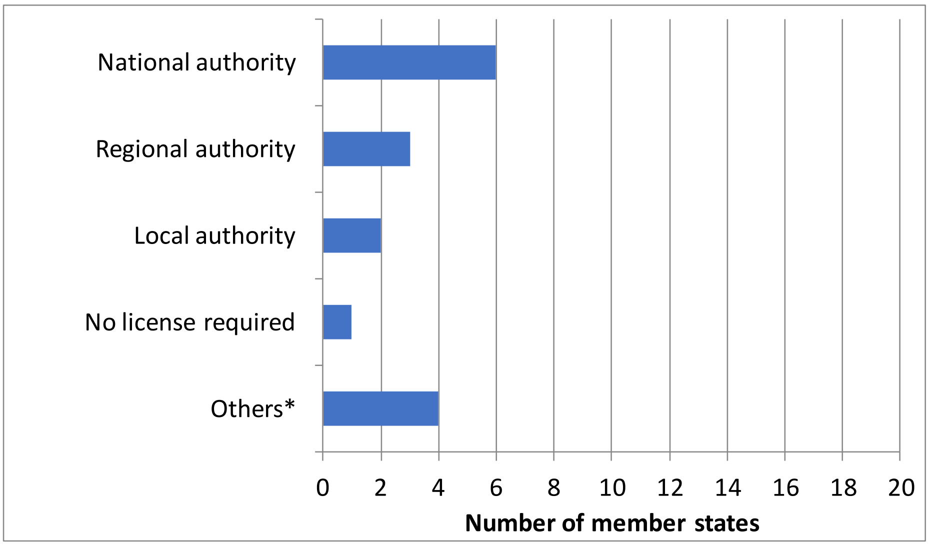

Figure 7. Responsible authorities for licensing drainage

Notes: Others refer to: environment court, river basin district, multiple authorities (one member state each). 16 countries answered this question: BG; DE; DK; EE; HR; FI; IE; IT; LT; NL; NO; PT; RO; SE; SK; UK.

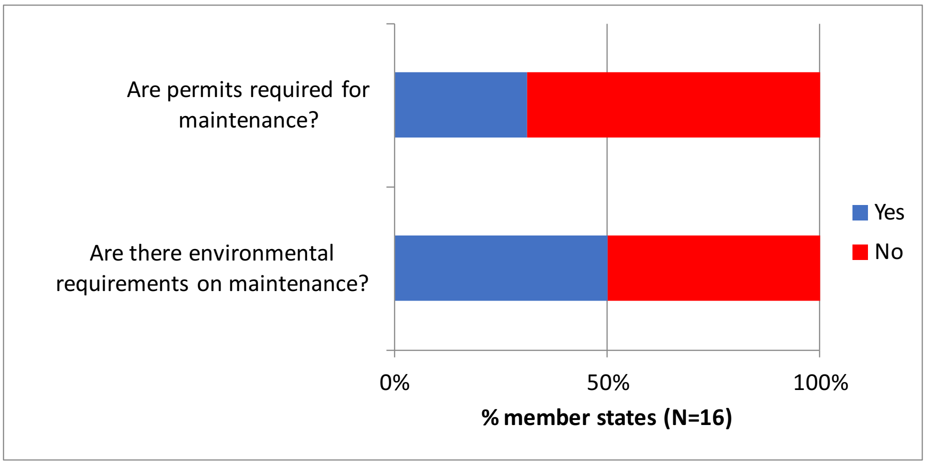

Figure 8. Legal requirements on the maintenance of drainage.

Notes: 16 countries answered this question: BG; DE; DK; EE; HR; FI; IE; IT; LT; NL; NO; PT; RO; SE; SK; UK

5 Hydromorphological alterations from land drainage

Part of the information exchange towards harmonized understanding of ecological potential is regarding hydromorphological alterations from land drainage. This information is used when assessing which changes to the hydromorphological characteristics of a specific water body would be necessary for achieving good ecological status or potential.

Countries report a wide range of impacts associated with land drainage pressures. Figure 9 presents the alterations considered by countries as commonly occurring in their country. It can be derived from this figure that countries consider a lot of hydromorphological alterations to water bodies in relation to land drainage. Commonly alterations are interlinked with each other and there may be more than one alteration in one water body. More specific observations are given below.

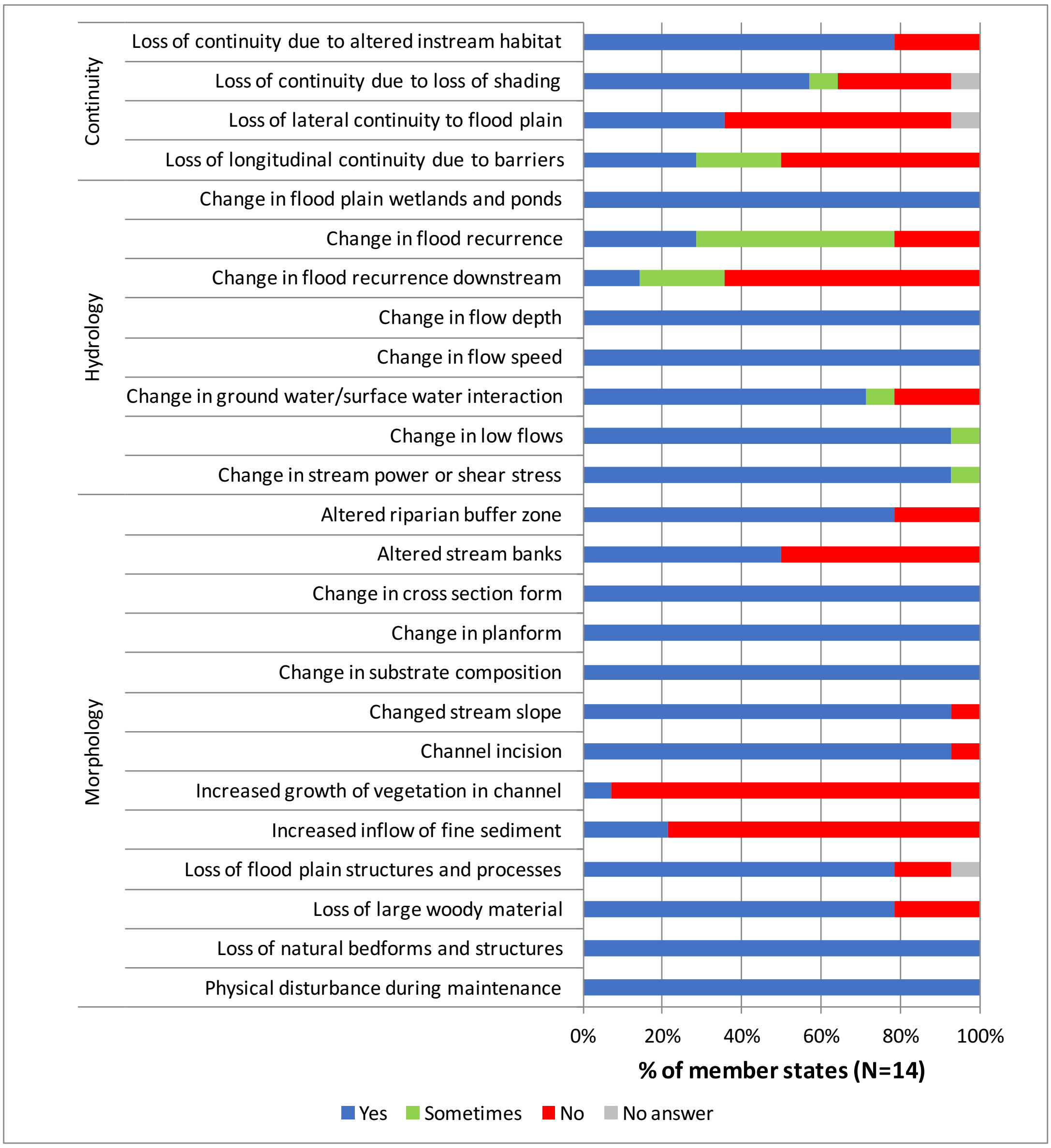

Figure 9. Alterations associated with land drainage

Notes: 14 countries included: BG; CZ; DE; DK; FI; HR; IE; IT; LT; NL; NO; PT; SK; UK

Loss of continuity

The most common impact mentioned by countries on (biological) continuity is due to altered instream habitat, followed by loss of shading. It is known from the literature that some fish species do not migrate if the channel is not shaded. This may not be the case for all fish species or other aquatic organisms. One country does not regard this as an impact on continuity and four countries suggest it sometimes occur.

Most countries consider that drainage pressures led to a loss of lateral continuity with the floodplain, while the loss of longitudinal continuity due to barriers seems to vary among countries. Loss of longitudinal continuity is usually associated with drainage channels regulated by small dams or pumps. Five countries replied that this is a common impact in the case of drainage; seven countries replied that it sometimes occurs; three countries replied it never occurs.

Hydrological regime

All countries replied that drainage has a negative effect on hydraulic condition mainly by changing flow depth and speed. All countries, except one, reported also changes in stream power and shear stresses. Stream power and shear stress are related and are responsible for channel erosion.

Countries replied that land drainage pressures can lead to changes in low flows and change in flood plain wetlands and ponds. 70 % of the countries replied that changes occur in the interaction between ground water and surface water.

Only two countries observe an impact on flood recurrence at the location or downstream of the land drainage schemes.

Morphological alteration

All countries reported that physical disturbance occurs due to maintenance operation of the drainage. It is common that drainage ditches and rivers regularly need to be dredged due to natural morphological changes. The entire channel may be affected during drainage maintenance.

A majority of countries also identified loss of bed forms and structures, change in substrate, and morphological changes in cross section form as a common impact of drainage. This may occur both during the construction phase of the drainage and during maintenance.

Channel incision and change in stream slope are frequent morphological alteration due to drainage. One country reported that it only occurs sometimes.

Changes in riparian buffer zone and the floodplain seem to be commonly related to drainage. In many countries this is the main purpose of drainage (i.e. to improve the land area surrounding a water body).

6 Ability of methods to detect hydromorphological alterations

Part of the information exchange towards harmonized understanding of ecological potential is about the ability of methods to detect hydromorphological alterations. This information is useful in understanding the countries' results, and sometimes differences, in assessing hydromorphological alterations from land drainage.

There are several methods to detect impacts from hydromorphological pressures (Figure 10). Some countries replied that almost all impacts could be detected, whereas some report that only a limited number of impacts can be picked up by their hydromorphological methods. Overall, almost one third of the countries do not have methods to detect all the parameters affected by drainage. More detailed observations are provided below.

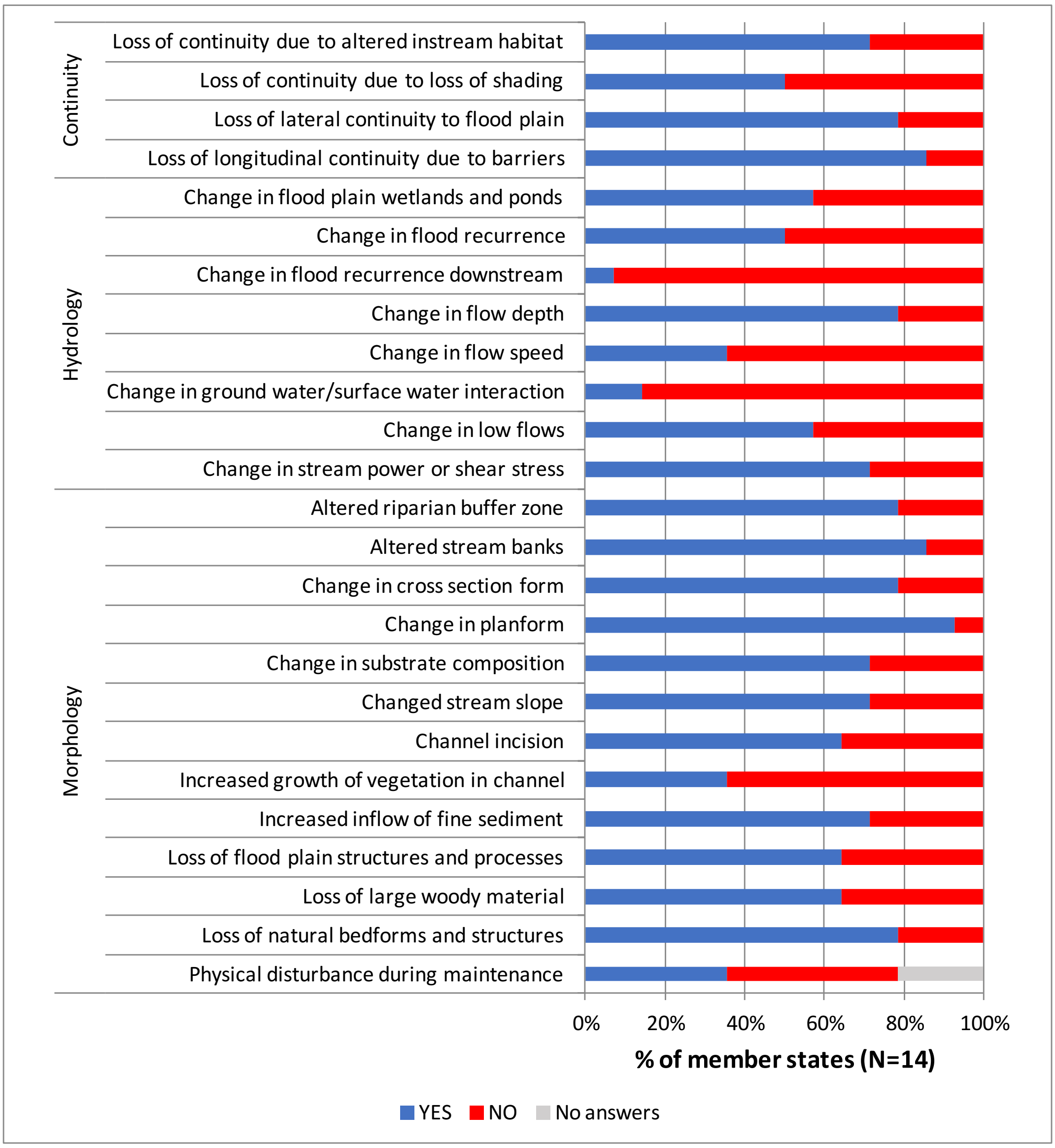

Figure 10. Ability of methods to detect hydromorphological impacts

Notes: 14 countries responded to this question: BG; CZ; DE; DK; FI; HR; IE; IT; LT; NL; NO; PT; SK; UK

Loss of continuity

Almost all countries report that their hydromorphological methods are enough to detect loss of longitudinal continuity. Most hydromorphological methods also appear to detect loss of lateral continuity with the flood plain or backwater.

Almost one third of the countries do not have a method that detects loss of continuity due to altered instream habitat and almost 50% of countries do not have methods to detect impacts related to the loss of shading.

Hydrological regime

Most countries report that direct hydraulic alterations in the channel, like flow depth, shear stresses and stream power are detected by hydromorphological methods. Fewer countries indicate having methods to detect a change in flow velocity. Furthermore, a majority of countries have methods to detect changes in flood plain wetlands and ponds, and changes in low flows and flood recurrence.

Few countries can measure interactions between ground water and surface water as well as change in flood occurrence downstream.

Morphological alteration

Change in planform and changes of the stream banks are detected by almost all countries. Approximately 80 % of the countries have methods which detect changes to riparian buffer zone, bed forms, and cross section form.

Fewer countries have methods detecting increased inflow of fine sediment, changes in substrate composition, and changes in stream slope. The two first impacts are interconnected since excess fine material tends to change the substrate in the channel or clogging coarse-grained streambeds. Change of stream slope may occur in drainage but not always.

A majority of countries indicated that they did not have any method to detect physical disturbances during maintenance and increased growth of vegetation in the channel. One explanation for the lack of methods on increased vegetation growth is that it is more related to eutrophication and not directly by hydromorphological pressures. It may also be a secondary result of decreased water depth and shear stresses due to drainage.

7 Relevance of drainage alterations for reaching good ecological status

Part of the information exchange towards harmonized understanding of ecological potential is about the relevance of drainage alterations for reaching GES. This information is used when assessing which changes to the hydromorphological characteristics of a specific water body would be necessary for achieving good ecological status or potential, and whether these changes would cause a significant adverse effect on water use, i.e. land drainage.

From the questionnaire results, it is clear that the view on how hydromorphology is used in the final classification of ecological status varies among the responding countries. This is reflected in the reply on the importance of different hydromorphological alterations for reaching GES (Figure 11). More detailed observations are provided below.

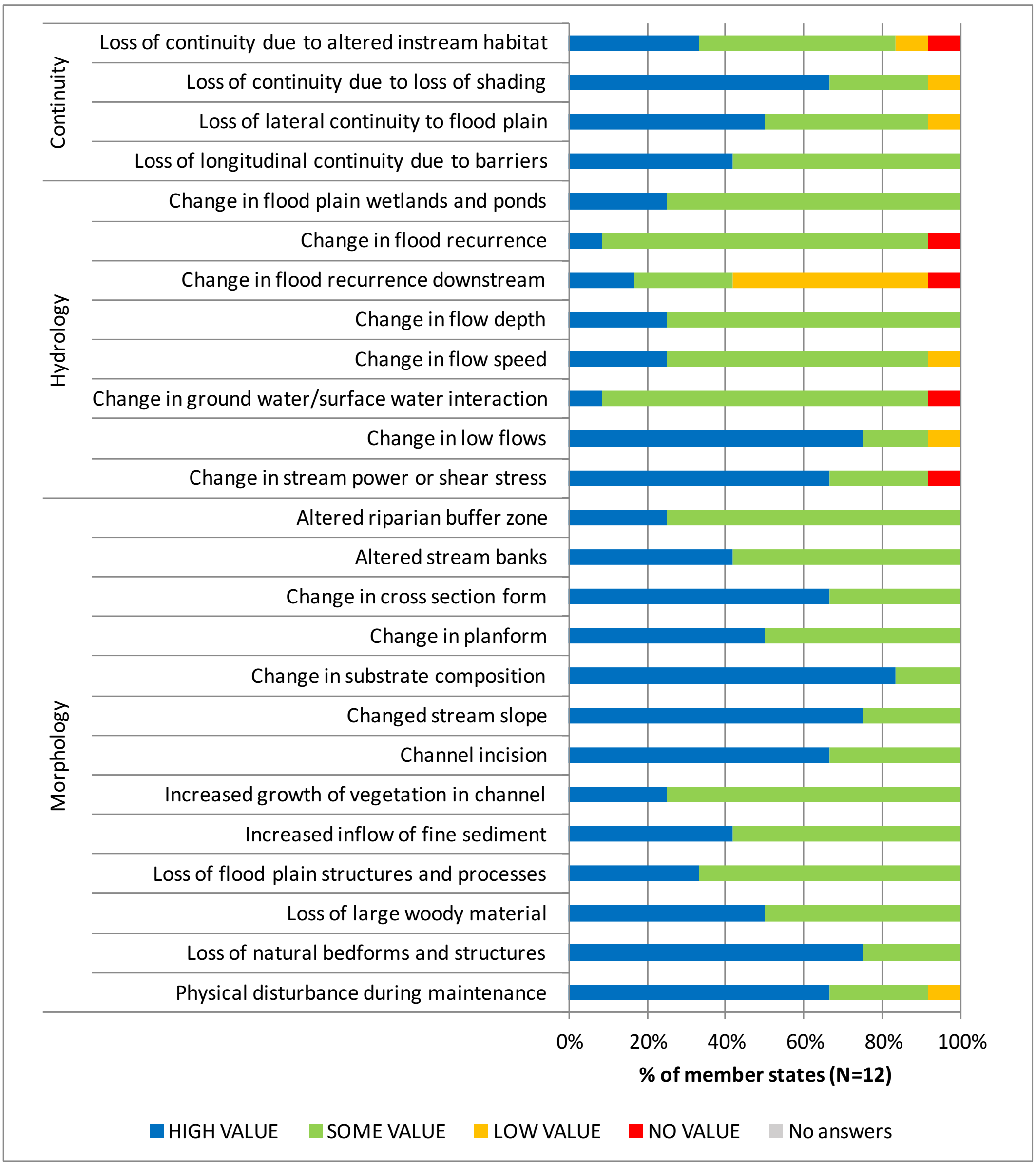

Figure 11. Relative importance of the alteration on reaching good ecological status

Notes: 12 countries have responded to this question: CZ; DE; DK; FI; HR; IE; IT; LT; NL; PT; SK; UK

Loss of continuity

Most countries replied that the loss of continuity due to shading is an important parameter for GES. Only one country replied it has low value for GES.

Loss of lateral continuity is either regarded as of high value (50 % of the countries) or of some value for reaching GES. Loss of longitudinal continuity due to barriers seems to be less important for GES. This might reflect that barriers are not as common in drainage as other water uses.

Loss of instream habitat is regarded by a majority of countries as having a high or some value for GES. Two countries regard it as low or no value.

Hydrological regime

Change in low flows and change in stream power/shear stresses are by most countries regarded as important parameters for reaching good ecological status. Both parameters reflect the hydraulic habitat in the water body.

A second group of parameters are classified by most countries as having some value for ecological status. These parameters are change in flood plain ponds and wetlands, flow depth, flow speed, change in ground water/surface water interaction and finally flood recurrence.

Morphological alteration

Morphological alteration due to drainage is in general regarded by countries as having either a high value or some value for reaching GES. One country indicated low value and none replied no value for any morphological parameters.

Parameters' describing the physical habitat seems to be a group of parameters which is regarded as important factors for reaching GES. This includes parameters like substrate, bed forms, change in stream slope, incision, and change in cross section. Most countries replied either high or some value of these parameters.

A second group of morphological parameters are change in planform and occurrence of large woody debris, which are regarded as parameters of high value or as some value according to the countries who replied.

The third group of parameters is dominated by some value for reaching GES and much less of high value. Several of these parameters are reflecting the terrestrial habitat surrounding the aquatic habitats for example, riparian buffer zone, flood plain structures and processes and stream banks morphology. In naturally unconfined or semi-confined rivers riparian and floodplains habitats are in fact among the key factors for reaching the GES. Increased inflow of fine sediment and growth of are is also parameters regarded as of some value for reaching GES.

8 Value of drainage alterations to the water use

Part of the information exchange towards harmonized understanding of ecological potential is about the value of drainage alterations to water use. This information is used when assessing if changes to the hydromorphological characteristics necessary for achieving good ecological status or potential would cause a significant adverse effect on land drainage and related drivers such as agriculture (food production) and urban development. Food production is considered as one of the benefits of land drainage.

Some changes in the hydromorphology of the water bodies will be needed to be a successful drainage operation. However, not all alterations are a necessity for a successful drainage operation. Figure 12 presents countries' views on the value of different types of hydromorphological alterations to the activity benefiting from land drainage.

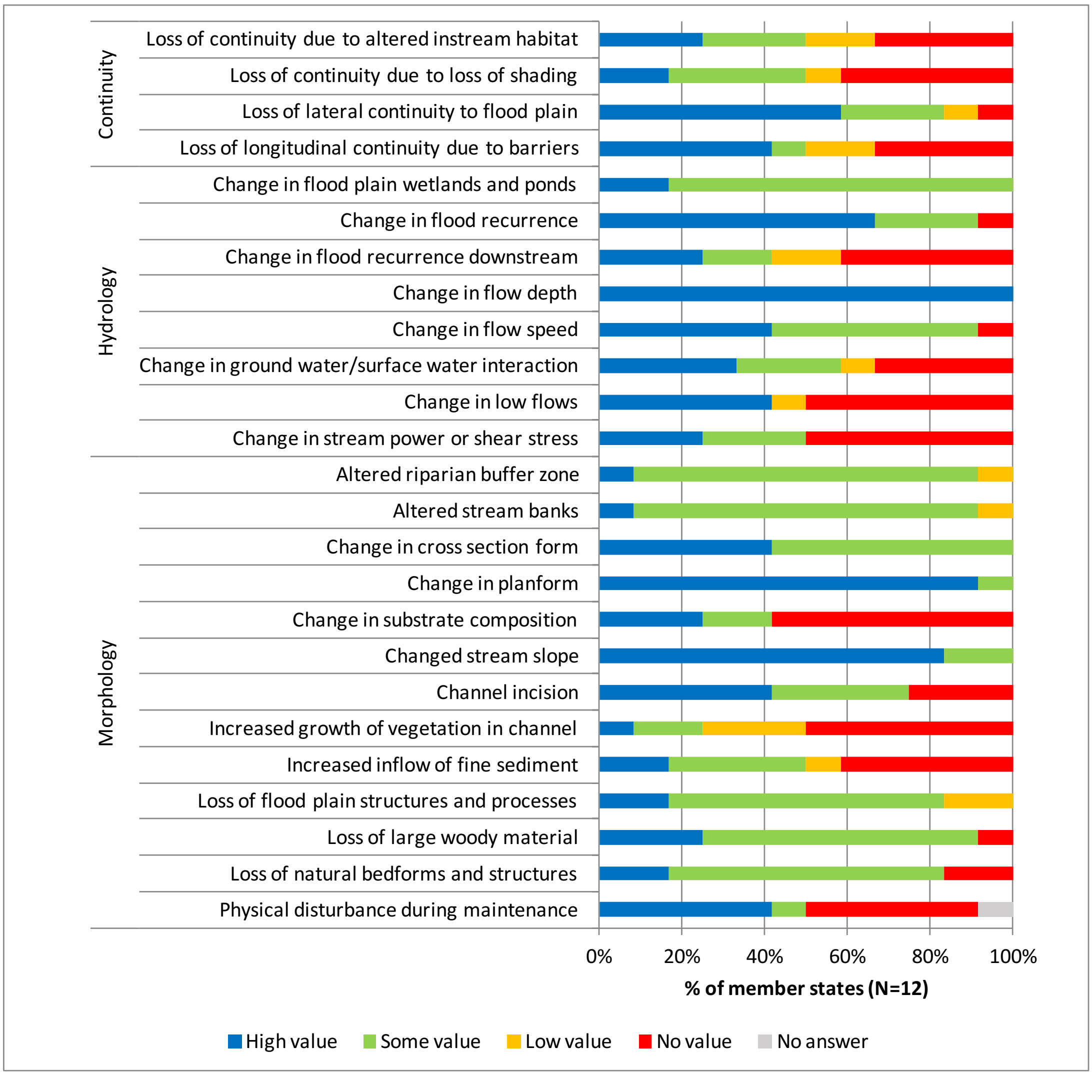

Figure 12. Land drainage results in alterations of hydromorphological elements of the water bodies. The value of these alterations for activities benefiting from land drainage is shown in the figure

*Notes: 12 countries answered this question**:** CZ; DE; DK; FI; HR; IE; IT; LT; NL; PT; SK; UK*

Loss of continuity

A majority of countries report that loss of lateral continuity is the most important continuity parameter for drainage, which is coherent with the idea that drainage is often required mainly to prevent waterlogging and flooding of riparian and floodplain areas.

Hydrological regime

All countries report change in flow depth as the most important parameter for drainage pressures. In many cases, drainage aims to achieve an increased depth of the groundwater table by lowering water levels in rivers.

Change in flood recurrence is the second most important hydrological parameter for drainage. This is a coherent result since land drainage close to a water body also aims to avoid regular flooding.

Change in floodplain wetlands and ponds are regarded of some value of drainage, which is also coherent since drainage aims to transform waterlogged and wet areas into usable land area for agricultural and other purposes.

No consistent responses between countries are reported for the remaining parameters.

Morphological alteration

Change in planform is regarded as the most important morphological parameter for drainage. Straightening of rivers increase in many cases the usable land area as well as decrease flood risk and support drainage in the surrounding land area.

Change in stream slope is also regarded as an important morphological parameter. In fact, most changes in planform will result in increased channel slope. Change in cross section form is also regarded by all countries as having high or some value for drainage. Increasing channel capacity and increasing depth are common goals in drainage.

Channel incision and physical disturbance during maintenance do not give a common viewpoint on their importance for drainage. Half the countries reply it is of high or some value, whereas the other group reply they have low or none value. These parameters need to be further elaborated.

Loss of bed forms, flood plain structures as well as altered riparian buffer zone and stream banks do not always provide high value for drainage, and their benefits will be site dependent. Similarly, increased inflow of sediment and increased growth of vegetation seems to have low or no value.

9 Maintenance operation

Part of the information exchange towards harmonized understanding of ecological potential is regarding maintenance operation. Maintenance operation of a drainage facility is necessary in order to ensure the functionality of the drainage. The maintenance operation itself can prevent the water body from achieving good ecological status or potential. Therefore, information regarding maintenance operation is important when assessing if changes to the hydromorphological characteristics necessary for achieving good ecological status or potential would cause a significant adverse effect on water use.

A secondary negative effect of drainage on the hydromorphology and ecological status is maintenance operation of a drainage facility. Not all drainage requires maintenance, for example piping. Open ditches nearly always require some maintenance since the cross section form is not natural and because of inflow of sediment and growth of vegetation. If the drainage is regarded as a highly important water use and cannot be removed, this may suggest the use of HMWB. In this case, reducing the negative impact of maintenance operation may be a priority.

9.1 Typical maintenance operation

Figure 13 presents the frequency with which countries applied some maintenance operations on land drainage.

The most typical maintenance operation is weed cutting according to responding countries. Removal of large woody debris also seems to be a common practice. This is followed by sediment dredging, although the frequency with which it is applied by countries varies widely.

Reshaping the river cross-section and reshaping the planform do not appear to be as regular. It is probably more related to the construction phase of the drainage scheme. Reshaping of cross section may occur if the river is dredged without concern to the stream banks.

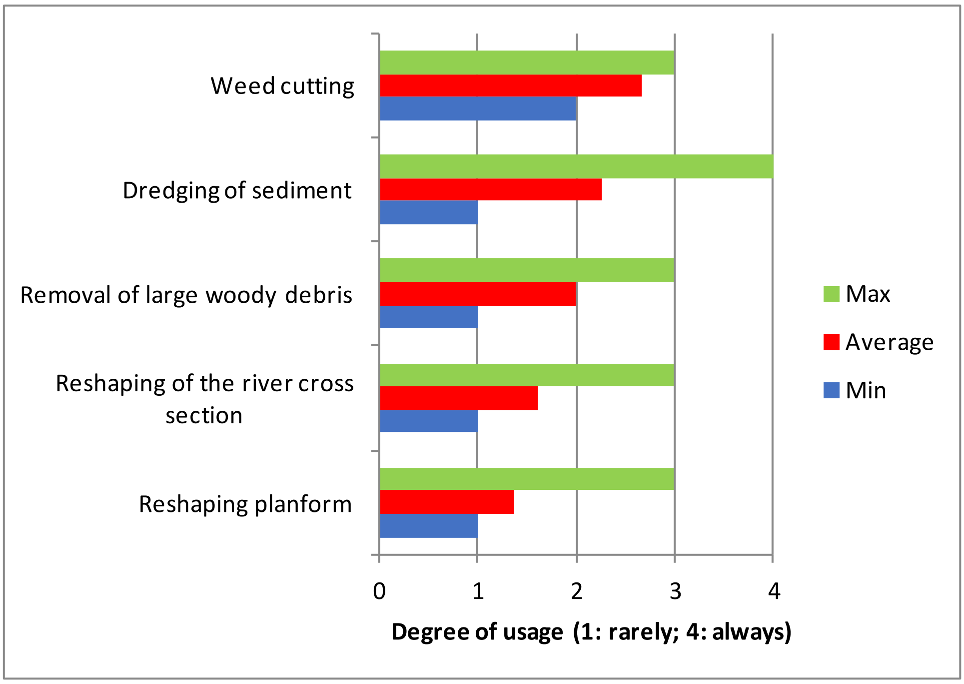

Figure 13. Degree of usage in typical maintenance operation of drainage

Notes: 15 countries responded to this question: BG; DE; DK; EE; HR; FI; IE; LT; NL; NO; PT; RO; SE; SK; UK

9.2 Impact on ecological status due to maintenance operation

Figure 14 presents the expected impact on ecological status of maintenance operation according to countries.

Almost all typical maintenance operations are reported to have a negative impact on good ecological status or potential. Dredging of sediment seems to have the largest impact on GES. This suggests mitigation measure should focus on reducing the inflow of sediment into the channel. Reducing the frequency of dredging can be beneficial both for achieving environmental goal as well as reducing the costs for the drainage operator.

Reshaping of cross section and reshaping river planform are also suggested to have large negative impacts on GES. They are not very common (see Figure 13 above) although they may occur at the same time as sediment dredging.

Weed cutting and removal of large woody debris appear to have slightly less impact on the water bodies according to the result.

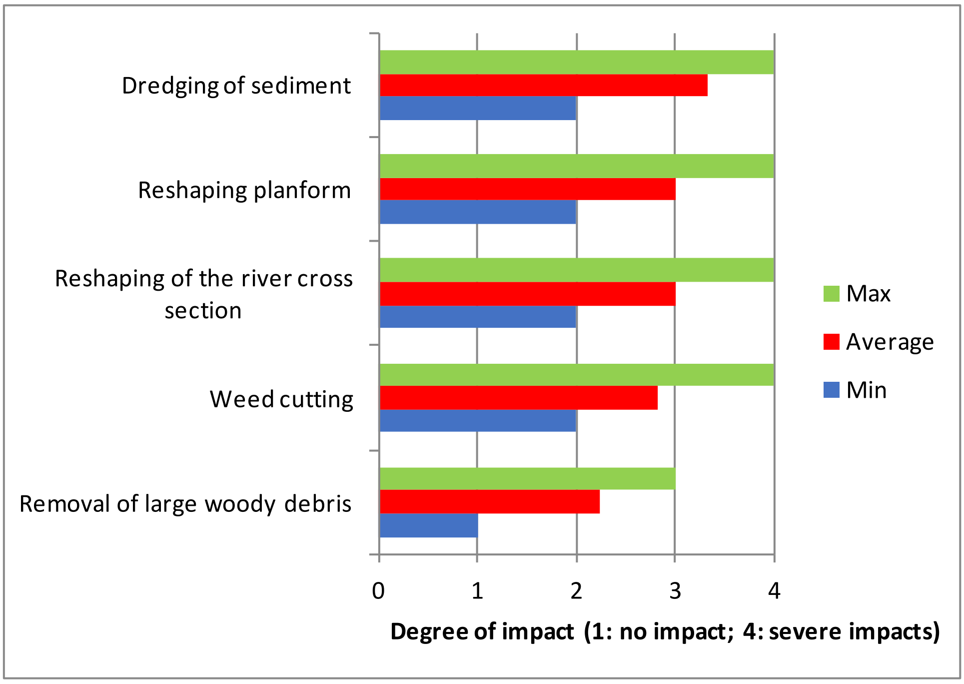

Figure 14. Impact of maintenance operation on good ecological status

Notes: 13 countries responded to this question: BG; DE; DK; EE; FI; IE; LT; NL; PT; RO; SE; SK; UK

10 Designation of heavily modified water bodies due to drainage

Part of the information exchange towards harmonized understanding of ecological potential is regarding the designation of heavily modified water bodies due to drainage.

In some cases, especially with respect to substantial hydromorphological alteration of the water body, HMWB might be considered according to Article 4.3 in the WFD. The recommendation on how to use this article is provided by CIS Guidance Document no.4. The result from the questionnaire shows that not all countries have designated HMWB due to drainage. There are several reasons behind this.

In some countries, especially in southern Europe, excess water is not the main problem for land use, but keeping the water in the landscape during drought periods. In other countries, the topography and soils types are not creating waterlogged conditions in large areas. The need for agricultural drainage probably varies from southern Europe with limited need to drain the soils to northern Europe with extensive need for drainage. However, urban and coastal drainage is probably more similar across Europe.

Another explanation for not using HWMB due to land drainage is the different national approaches in considering significant adverse effects on water use, in this case land drainage and related human activities such as agriculture (or urban development). Significant effect need to be compared to a baseline, which varies geographically and different scales. Our understanding is that national guidelines need to be developed for most countries.

10.1 Water category

The most common water category across water uses in Europe designated as HMWB is rivers (Figure 15). This includes straightened rivers or rivers that are reshaped like ditches.

Drainage related to lakes is less frequent. None of the responding countries appear to have designated coastal water bodies as HMWB due to drainage. The reason is probably that coastal water bodies are in general quite large and the drainage only affects a small part.

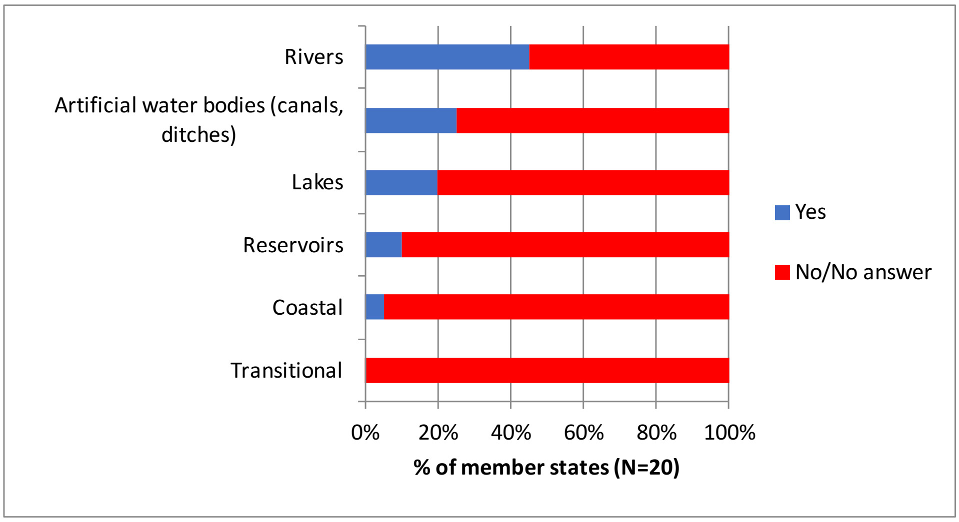

Figure 15. Number of countries who designated HMWB due to drainage (several drivers) in different water types

Notes: 20 countries included: AT; BG; CZ; DE; DK; EE; ES; FI; HR; IE; IT; LT; LU; NL; NO; PT; RO; SE; SK; UK

10.2 Significant adverse effect on water use

An important part in the designation of HMWB is to check whether measures to achieve GES will have a significant adverse effect on water use. This is a difficult task since the benefits of drainage varies considerably depending on whether the sector benefiting from drainage is e.g. agriculture or urban development. Furthermore, the evaluation of measures to achieve GES is often site-specific.

Since significant adverse effect on water use is an important parameter in the designations process of HMWB, countries were asked if they have developed national guidelines for this part (Figure 16).

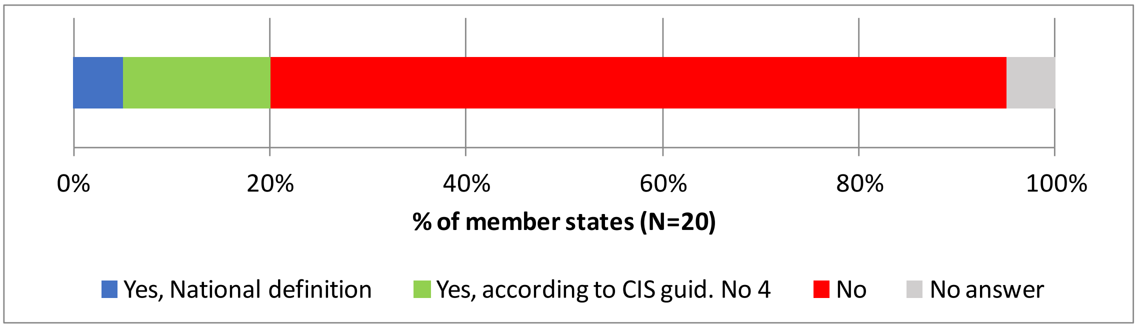

Figure 16. Number of countries who has developed national guidance document on significant adverse effect on water use related to drainage. 20 countries included: AT; BG; CZ; DE; DK; EE; ES; FI; HR; IE; IT; LT; LU; NL; NO; PT; RO; SE; SK; UK.

11 Key measures to mitigate impacts from land drainage

Part of the information exchange towards harmonized understanding of ecological potential is regarding relevant measures to mitigate (or fully restore) impacts from land drainage. It is only possible to harmonize ecological potential for HMWB designated for the same reason, in this context of this report mainly agricultural drainage. This information is important when assessing if changes to the hydromorphological characteristics necessary for achieving good ecological status or potential would cause a significant adverse effect on drainage and related human activity such as agriculture and food production.

11.1 Overview of mitigation measures

Measures mitigating the impacts of land drainage relate to actions that maximise improvements on biological continuity, and the hydrological and morphological condition of the water bodies. Mitigation measures may aim to improve the quality of aquatic and riparian habitats, fish spawning, migration and macroinvertebrates populations, as well as overall biodiversity by diversifying flow and erosion processes and morphological conditions.

Mitigation measures can also aim to mitigate impacts on flow dynamics and hydrological regimes, for example by decreasing the risk of rapid changes in stream flow, sustaining base flow in rivers during periods of lower rainfall, and optimising flow velocity associated with the influence of in-stream and riparian vegetation. Mitigation measures may also aim to improve sediment movement and the diversity of physical habitats in the water bodies, and reduce the loss of lateral continuity with the floodplain.

Table 3 presents the beneficial impacts of mitigation measures against the three impact categories.

Table 3 Measures for mitigating the impact of land drainage

Mitigation measures	**Biological continuity**	**Hydrological impacts**	**Morphological impacts**
Develop riparian forest	x	x	x
Introducing woody debris	x	x	x
Recreate gravel bar and riffles	x	x	x
Reconnect backwaters and wetlands	x	x	x
Improve water retention		x	
Ensure minimum flows	x	x	
Manage aquatic vegetation	x	x	x
Narrow widened water courses		x	x
Improve backwaters	x	x	x
Trap sediments from ditches and erosion			x
Constructed wetlands		x	x

Mitigation measures	Biological continuity	Hydrological impacts	Morphological impacts
Remove hard engineering			x
Increase bed complexity		x	x
Two stage ditches	x	x	x
Substrate improvement	x	x	x
River bed variation		x	x
Reduce impact of maintenance		x	x
Ochre reduction			x
Reopen and reconnect subsurface rivers/brooks from underground pipes	x	x	x
Restore natural wetlands or aquatic habitats	x	x	x
Buffer strips	x	x	x
Reduce sediment input		x	x
Remeandering watercourses		x	x

11.2 Description of key mitigation measures

The measures presented in the table above are described in more detail below. A link is provided to relevant external sources. These sources are not official European guidelines and documents; they are provided for informative use only.

Develop riparian forest

Planting and/or preserving riparian zones aims to improve channel stability, in-stream aquatic habitat and terrestrial biodiversity in the riparian zone. In relation to drainage impacts, riparian forests can shade the river for e.g. fish migration. Riparian planting can also increase infiltration and decrease sediment inputs to surface waters. Diverse ecological improvements may only be achieved over long time scales, and rehabilitation of streams is most successful when planting riparian zones from the headwaters down through the catchment and a continuous buffer length is achieved.

Further description: http://wiki.reformrivers.eu/index.php/Develop_riparian_forest

Introduce woody debris

Introducing large woody debris aims to increase flow diversity, diversify erosion and deposition processes and enrich substrate diversity, leading to improvements in stream morphology, biota (macroinvertebrates) and fish habitats and migration. Large wood has the largest effect in free flowing sections, but can also provide valuable habitat for fish and substrate for invertebrate species in impounded reaches. The measure can involve the active placement of artificially fixed wood structures in the stream or the loose introduction of large woods. It can be regarded as an interim measure prior to the establishment of a riparian forest providing natural input of large wood (recruitment).

Further information: http://wiki.reformrivers.eu/index.php/Introduce_large_wood

Recreate gravel bar and riffles

Recreating gravel bars and riffles aims to improve in-channel structure and substrate affected by channelization and cross-section alterations and alterations to in-stream habitats. It increases the diversity of physical habitats of the reach restored with beneficial effects for macroinvertebrate populations, and fish spawning and migration. To ensure that artificial bars and riffles are sustainable, it is necessary to periodically empty sediment traps upstream, to redistribute the gravel and to add new material when some of the gravel is eroded.

Further information: http://wiki.reformrivers.eu/index.php/Recreate_gravel_bar_and_riffles

Reconnect backwaters and wetlands

Reconnecting backwaters, such as oxbows and side channels, and wetlands aims to restore the lateral connectivity between the main river channel, the riparian area and the wider floodplain and to re-vitalise natural processes. It has benefits for the re-establishment of natural hydro-morphological features as well as the wetland specific aquatic biota such as phytoplankton, macrophytes and fish.

Further information:

http://wiki.reformrivers.eu/index.php/Reconnect_backwaters_and_wetlands#Reconnect_backwaters_and_wetlands

Improve water retention

Improving water retention involves a range of measures taken across the catchment (riparian areas, floodplain and wider land area) to increase water infiltration and reduce the effect of rapid discharges from drainage schemes. Creating retention basins and constructed wetland to capture stormwater and water at the outlets of drainage pipes can be effective means to retain water. Water retention can also be increased by restoring stream connectivity to floodplains by allowing lateral channel migration (removing bank fixation, set back embankments), widen rivers, lower river embankments, reconnect backwaters and wetlands, and restore wetlands. More widely across the catchment, reducing impervious surfaces, reducing agricultural soil compaction, decommissioning roads, and increase vegetated and forested areas can reduce run-off and discharges.

Further information: http://wiki.reformrivers.eu/index.php/Improve_water_retention

Ensure minimum flows

Ensuring a minimum flow aims to reduce the impact of lower water retention due to land drainage on hydrological and ecological functions in periods of low flows. Measures include increasing the connectivity of floodplain and stream channel in order to ensure water infiltration in the alluvial aquifer to sustain base flows in the drier season. Blocking drains can reduce discharge during periods of high precipitation, increase soil water storage, and increase groundwater recharge increasing base flow in streams. Creating detention ponds and basins or constructed wetlands at the outlet of drainage ditches and pipes can help store run-off when it rains, trap sediments and replenish groundwater sustaining low flows during drier periods.

Further information: http://wiki.reformrivers.eu/index.php/Ensure_minimum_flows

Manage aquatic vegetation

Managing vegetation aims to mitigate the negative effects of dredging or weed cutting on stream biota. It involves modifying weed-cutting practice to an acceptable level to ensure sufficient drainage while reducing level of physical disturbance and ensuring sufficient water depth and flow velocity for a more diverse in-stream habitat. It can be applied in lowland agricultural areas where options for stream restoration are limited. Preferably, riparian forested buffer strips should be restored to provide more ecological benefits (e.g. shading, input of organic material like leaves and large wood) and to develop more natural habitat conditions (given that the streams are naturally bordered by riparian forests).

Further information: http://wiki.reformrivers.eu/index.php/Modify_aquatic_vegetation_maintenance

Narrow widened water courses

Narrowing watercourses that were widened for drainage and flood protection purposes aims to increase water velocities and depth. The whole channel can be narrowed, if a decrease in discharge capacity and increase in overbank-flooding can be admitted. Alternatively, if discharge capacity cannot be markedly reduced, low-flow channels can be built to increase water depth and flow diversity in the given over-widened cross-section. Alternating deflectors (e.g. large wood) or berms (e.g. made of boulders) can be used to create a sinuous thalweg with higher flow velocities and water depth (similar to groynes in larger rivers). In addition, vegetation (aquatic or riparian) can be established on wing deflectors and berms to provide greater habitat diversity and shading.

Further information: http://wiki.reformrivers.eu/index.php/Narrow_water_courses#Narrow_water_courses

Improve backwaters

Improving backwaters involves habitat enhancement measures such as the reconnecting or the creating of lentic backwaters or small backwaters with low flow velocity. The creation of new floodplain waters with a permanent connection and a constant, moderate flow probably has the highest potential for supporting rheophilic fish community. Side arm structures in the more lentic central impoundment are mainly important for eurytopic species, but also host young age classes of rheophilic species, and provide sufficient prey fish for predators.

Further information: http://wiki.reformrivers.eu/index.php/Improve_backwaters

Trap sediments from ditches and erosion

Sediment capture ponds are engineered ponds placed in networks of ditches to slow the velocity of water and cause the deposition of suspended materials. Sediment capture ponds are most useful for managing the effects of ditch construction and maintenance, road work and final feeling. They are useful for capturing sediment in agricultural and forestry runoff. Sediment capture ponds have a limited lifespan, depending on how much suspended material is in the inflowing water. However, ponds can be maintained by removal of accumulated sediment.

Further information:

http://wiki.reformrivers.eu/index.php/Trap_sediments

http://nwrm.eu/measure/sediment-capture-ponds

Constructed wetlands

A constructed wetland is an artificial wetland area (ex. marsh, fen, and peatland), permanent or temporary, with static or flowing water, which provides water retention of water run-off from surrounding agricultural, forested and urban areas. Wetland construction and management can involve spatially large-scale technical measures (including the installation of ditches for rewetting or the cutback of dykes to enable flooding); or small-scale technical measures such as clearing trees. By retaining water, constructed wetlands can contribute to attenuate floods and decrease river flows, thus reducing the need for drainage works, such as river channel enlargement, to protect riparian land. They can enhance habitats and biodiversity, and also improve water quality by retaining polluted run-off water and sediments.

Further information: http://nwrm.eu/measure/wetland-restoration-and-management

Remove hard engineering

Removing hard engineering aims to improve in-stream, riparian and floodplain habitat quality by removing bank fixation and creating habitats such as semi-natural or artificial wetlands or the creation of new floodplain ponds or backwaters. Removal of bank fixation is a prerequisite for many other measures like re-meandering or widening as well as initiating later channel migration and dynamics.

Further information: http://wiki.reformrivers.eu/index.php/Remove_bank_fixation#Remove_bank_fixation

Increase bed complexity

Bed complexity can be increased by some of the mitigation measures presented above such as: introduce large wood; modify aquatic vegetation maintenance; recreate gravel bar and riffles and reduce impact of dredging. In addition, there are additional measures that can increase bed complexity, such as: add sediments; initiate natural channel dynamics to promote natural regeneration; remove or modify in-channel hydraulic structures; and remove sediments

Further information:

http://wiki.reformrivers.eu/index.php/Category:06._In-channel_structure_and_substrate_improvement

http://wiki.reformrivers.eu/index.php/Add_sediments

Two stage ditches

Two-stage ditches aim to maintain the drainage function of drainage ditches along agricultural field while ensuring improved ecological function. They are designed with a low flow channel, which provides better water depth during periods of low flow, and constructed benches on the channel, which provide cover and shade. The two-stage ditch profile provides increased sediment conveyance and sorting of fine sediment on the benches and coarser material in the bed, leading to increased ditch stability and reduced maintenance.

Further information:

https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/indiana/howwework/twostage-with-charts.pdf

Substrate improvement

Substrate improvement involves the placement of gravel material (primarily stone, gravel or wood) in either channelled or natural streams. The laying of the gravel materials may be substituted for material that has been removed through earlier excavation. By adding gravel material, the habitat heterogeneity of watercourses improves, which in many cases can result in better living conditions, especially for macro invertebrates and fish. If the laying of coarse material results in a greater variation in depths and water velocities and thus a greater variation in substrate types, positive effects on the plant communities can also be expected. The laying of stone and gravel has shown good results, especially for salmonids, but also for other fish species, such as lamprey. If a watercourse has a trout or salmon stock, good water quality and good slope but lacks substrate usable as spawning material for salmonids, this measure can cause a sharp increase in the density of salmonids. For many fish species, however, this should be seen as a relative local effect, as there should be shelter in many places in a watercourse to ensure full herd of fish. Although substrate improvement is a good measure for improving the biological conditions, it can, however not be ruled out that raising of the watercourse sediment due to placement of gravel may cause a minor increase on water levels.

Further information: http://dce2.au.dk/pub/SR86.pdf (in Danish)

River bed variation

River bed variation can be increased by different mitigation measures for river bed depth and width variation improvement. Some of those have been described previously: narrow water courses; remeander water courses; two-stage ditches; and constructed wetlands. In addition, there are additional measures that can increase river bed variation, such as: allow/increase lateral channel migration or river mobility; shallow water courses; and widen water courses.

Further information:

http://wiki.reformrivers.eu/index.php/Category:05._River_bed_depth_and_width_variation_improvement

Reduce impact of maintenance

Many streams, especially in the lowland regions, are located in agricultural areas. Due to the lack of riparian forests and shading as well as high nutrient inputs, excessive growth of aquatic vegetation is common. Maintenance of these streams usually includes the mechanical removal of aquatic vegetation several times per year to ensure the efficient drainage of agricultural areas, reduce sedimentation and flooding risks. To mitigate the negative effects of dredging or weed cutting, several guidelines recommend to leave some macrophytes, either on one or both sides of the channel or as alternating patches that induce a sinuous flow pattern and to cut the weeds in summer rather than in spring. The growth of aquatic macrophytes can be significantly reduced through an increase of shading that can help reducing the maintenance effort.

Further information: http://wiki.reformrivers.eu/index.php/Modify_aquatic_vegetation_maintenance

Ochre reduction

Establishment of ochre treatment plants are designed to prevent and reduce the harmful effect of ochre on biology in streams, lakes or the sea due to agricultural ditching and drainage activities. When establishing an ochre plant, the watercourse is led through an excavated basin, where a combination of long residence time, good oxygen conditions, possibly contact with vegetation and sedimentation basins ensure an oxygenation of the dissolved iron during the formation of ochre, as well as a collection of the precipitated ochre. Hereafter the water proceeds downstream to the natural water body. The plants have typically been established on smaller streams, as the establishment of such plants on larger rivers cannot be expected to be economically feasible. The plants have to be continuously applied and cleaned for sediment. Experiences shows that residence time should be more than 8 hours and that the most efficient treatment plants are full with macrophytes and have a pH above 6. The speed of the reaction of the harmful dissolved iron compounds is also dependent on the temperature and the oxygen content of the water. Ochre plants do not influence drainage of farmland. It can help removing the fine particles from the drainage water which can have a negative impact on the biology.

Further information: http://mst.dk/media/121281/12-status-for-okkerrensning-vurdering-af-behovene-for-og-effekterne-af-alternative-rensningsmetoder-for-okker.pdf (in Danish).

Reopen and reconnect subsurface rivers/brooks from underground pipes

Reopen and reconnect subsurface rivers or brooks from underground pipes aims to increase the area of limnic habitats. The mitigation measure also aims to restore the lateral connectivity between the main river channel, the riparian area and the wider floodplain and to re-vitalise natural processes. It has benefits for the re-establishment of natural hydro-morphological features as well as the wetland specific aquatic biota such as phytoplankton, macrophytes and fish.

Further information: http://wiki.reformrivers.eu/index.php/Modify_culverts,_syphons,_piped_streams

Restore natural wetlands or aquatic habitats

Restoring degraded wetlands and other aquatic habitats aims to recreate their natural storage and infiltration capacities. The measure can thus contribute to mitigate a number of hydrological impacts related to drainage, including restoring groundwater levels and slowing water flow. Restored wetlands and aquatic habitats can also regulate sediment flows in particular by reducing loads through reduce flow and increased sedimentation. Furthermore, restored wetlands create natural habitats that can improve biological processes and fish population. Side benefits include increased denitrification, absorption of nutrients by the vegetation and improved water quality.

Further information: nwrm.eu/measure/wetland-restoration-and-management

Buffer strips

Vegetated and woodland buffer areas can be placed in and around cropped fields and alongside watercourses in order to reduce run-off and trap suspended sediment. The buffer strips can also serve in reducing run-off and trapping agricultural nitrates. Their efficiency can be higher if the trapped nitrates (embedded in plants' tissue) is removed and utilized (e.g. as organic fertilizer) outside the river valleys. Otherwise part of the trapped nitrates may eventually reach watercourse as an end result of decaying of plant matter. A distinction can be made between 'edge-of-field' buffer strips which are placed around fields and along watercourses and 'in-field' buffer strips which are positioned within cropped fields. Buffer strips can consist of natural meadows and tall for communities or forests and tree plantings, which compose riparian woodland buffers. The recommended width of riparian buffers to filter fine sediments increases with slope, flow, decreases with particle size. As a consequence, the recommended buffer with is highly variable (3-200 m) but a minimum width of 15-30 m seems to be sufficient to provide the multiple functions of riparian buffers under most circumstances.

Further information: http://nwrm.eu/measure/buffer-strips-and-hedges

Reduce sediment input

Reducing sediment input (e.g. drainage pipes and ditches) can be achieved by promoting changes in land use management (e.g. no-tillage farming, cover crops, buffer strips), by stabilising bank erosion, and by securing the area around the water intakes to increase sedimentation of soil (and particle-bound nutrients) before the drainage water enters the drains. Restoration measures to limit excess bank erosion are especially important in gravel-bed rivers where fine sediment is clogging interstitial spaces and altering habitat for fish and macroinvertebrates.

Further information: http://wiki.reformrivers.eu/index.php/Reduce_undesired_sediment_input

Remeandering watercourses

Remeandering aims to change the shape of a channel (sinuosity and profile) from an unnatural channelized shape to a natural or near-natural shape. This measure refers to the remeandering of straightened river channels, through both creation of a new meandering course and reconnection of cut off meanders. Remeandering can take place in a passive way (ceasing stream maintenance) or active way. In general, passive restoration programs entail no direct human intervention. However, cessation of disturbances, in view of the many pressures on rivers, can be insufficient in which case active restoration is required. Remeandering is applicable to river systems that would naturally be expected to have a meandering planform but have been modified.

Further information:

http://wiki.reformrivers.eu/index.php/Remeander_water_courses

http://ec.europa.eu/environment/archives/water/implrep2007/background.htm

11.3 Mitigation measures related to drainage: presence in national libraries [3]

Figure 17 presents the percentage of countries including different types of mitigation measures in their national library. The majority of countries which responded to the questionnaire (~80%) include measures aiming to improve the morphological and continuity conditions in the river (e.g. river bed variation, substrate improvement, recreate bars and riffles). Fewer countries include riparian habitat restoration measures (e.g. wetlands, introduce woody debris) and mitigation of maintenance operations.

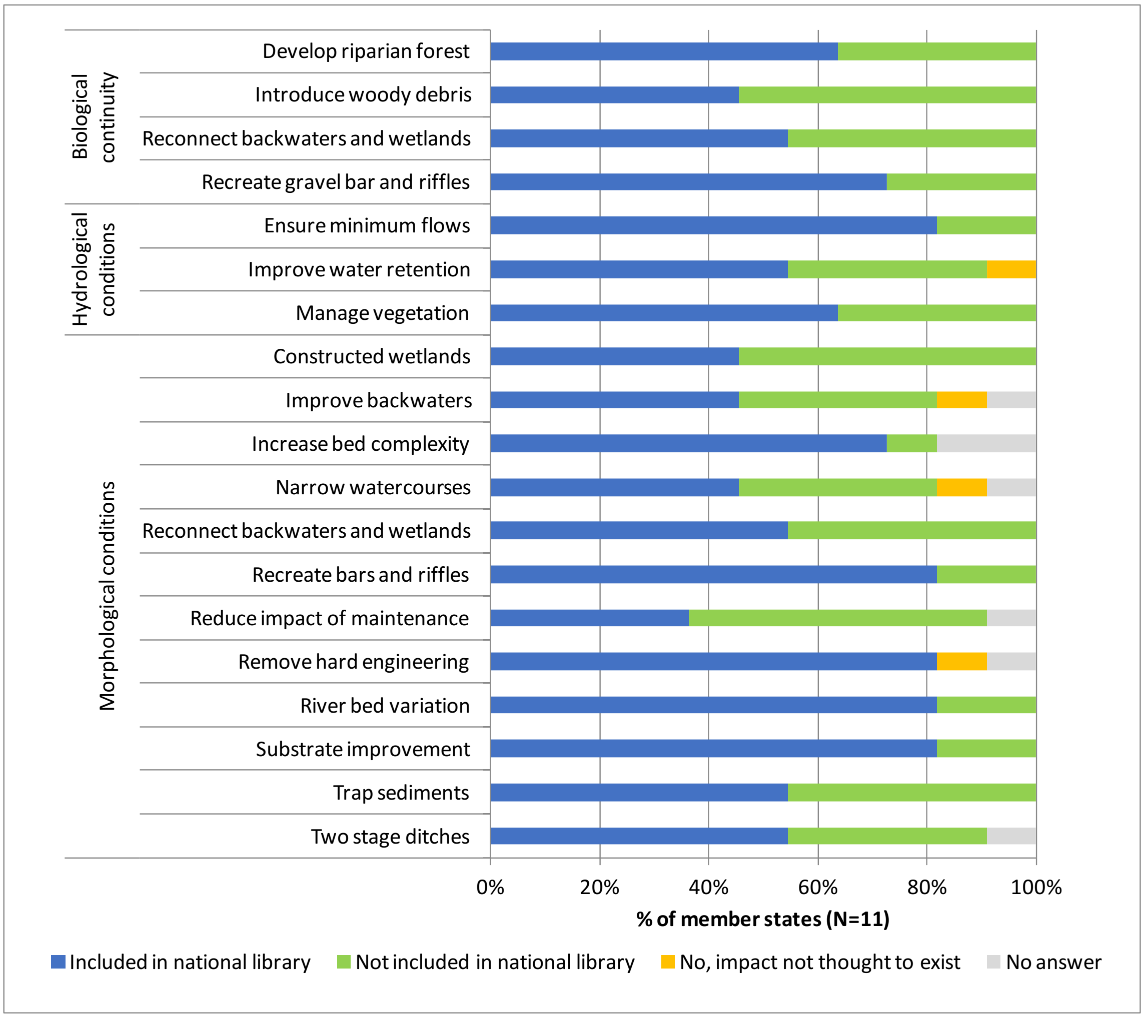

Figure 17. Inclusion of mitigation measures in national libraries

Notes: 11 countries responded to this question: DE, DK, FI, IE, IT, LT, NL, NO, PT, SK, UK

[3] The list of measures presented in Figure 18, 19 and 20 do not match the list of measures in Chapter 11.2. Additional measures were added during the information exchange after the questionnaire was prepared.

11.4 Ecological effectiveness of mitigation measures

Figure 18 presents the effectiveness of different types of mitigation measures as perceived by respondents. The most effective measures for mitigating the impact of land drainage are deemed to be river bed variation measures together with the removal of hard engineering and the reconnection of backwaters and wetlands. Most measures are perceived to have high or some value in mitigating the impact of land drainage in at least half up to 2/3 of the responding countries. There are a large number N/A; however, it is not clear if it is an omission by the country or whether it was not deemed relevant (= no value).

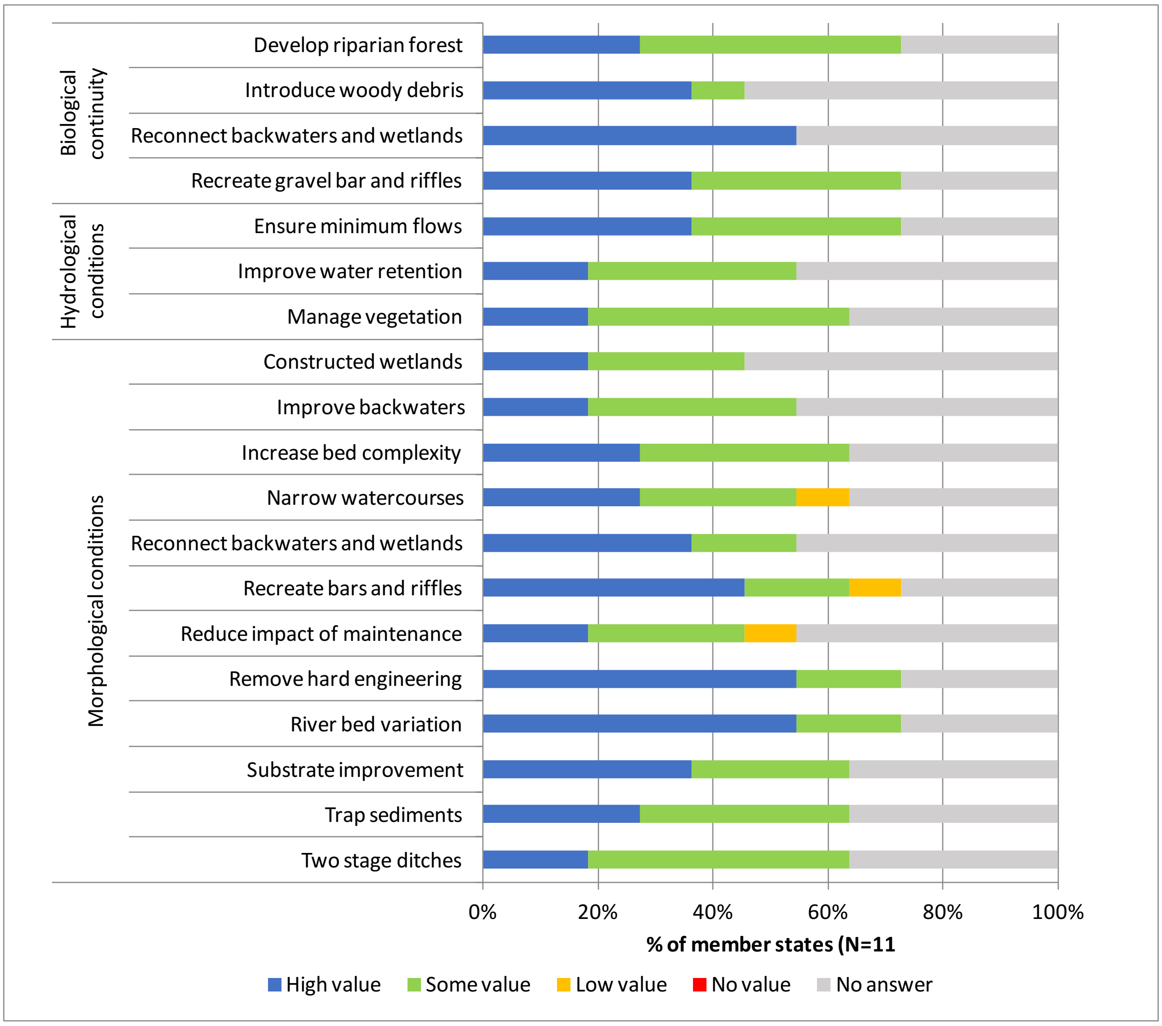

Figure 18. Assumed ecological effectiveness of the measure for improving hydromorphology and biological quality

Notes: no country has answered "no value" option. 11 countries responded to this question: DE, DK, FI, IE, IT, LT, NL, NO, PT, SK, UK

11.5 Effects of mitigation measures on land drainage

Figure 19 presents the perceived magnitude of adverse effects on land drainage of different mitigation measures. Most measures are deemed to have some to low effect on water use. There are a large number N/A; however, it is not clear if it is an omission by the country or whether it was not deemed relevant (= no value).

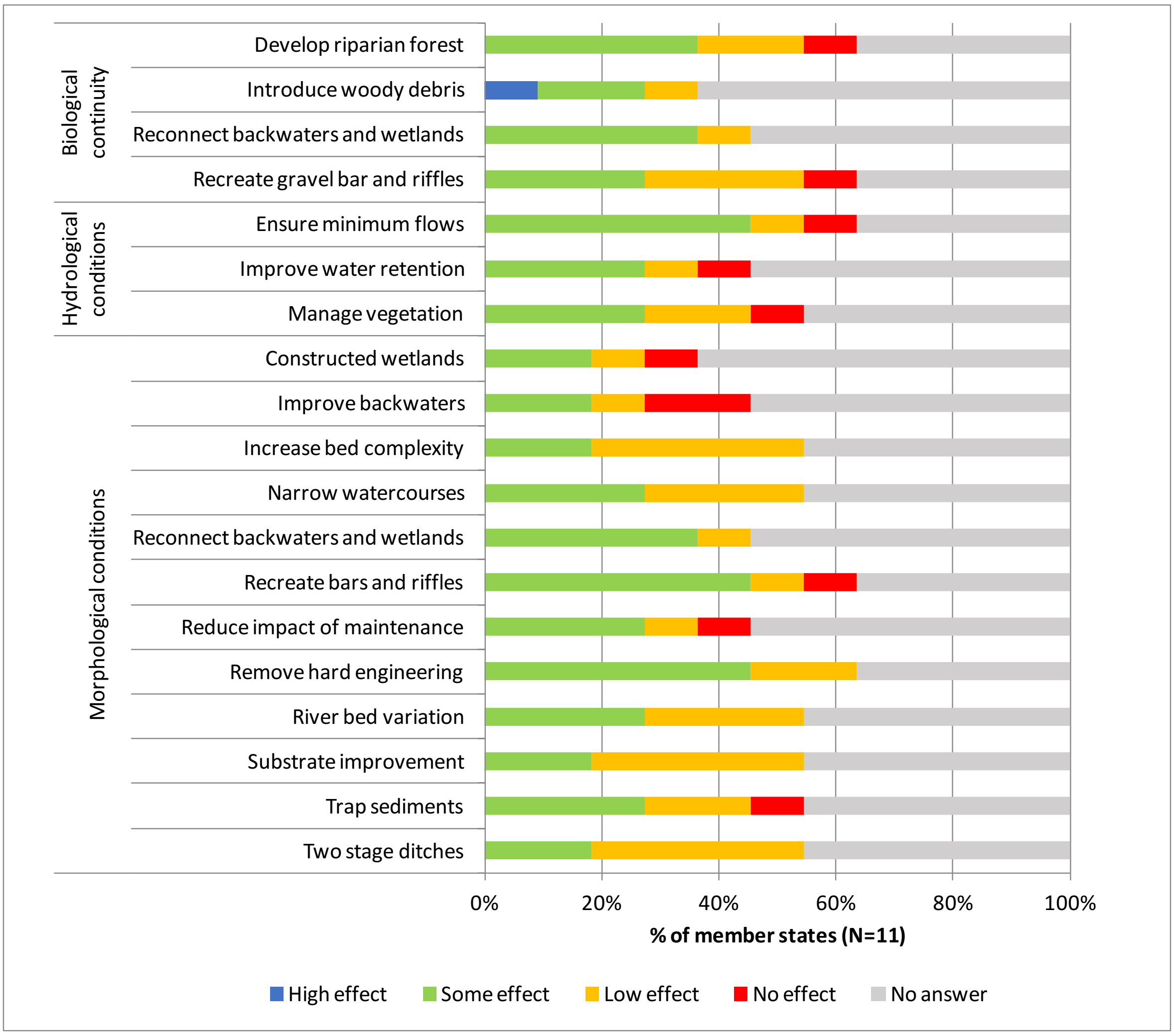

Figure 19. Perceived relative magnitude of adverse effect on drainage (water use)

Notes: 11 countries responded to this question: DE, DK, FI, IE, IT, LT, NL, NO, PT, SK, UK

11.6 Reasons for ruling out measures

In the questionnaire, countries were asked to indicate if they ruled out measures based on a series of evaluating criteria. However, there were few replies to these questions and not all options were systematically filled-in. Responses thus appeared inconsistent or incomplete. As a result, no figures were prepared. Nevertheless, the sample of responses may indicate that the majority of countries probably rule-out mitigation measures when considering the evaluating criteria. More information exchange between countries on these aspects is recommended.

12 Conclusions and recommendations

A key objective of the exchange of information between European countries on the approaches to achieve good ecological potential in water bodies affected by drainage has been to undertake a comparison of the understanding of drainage related alterations of river continuity, hydrological regime and morphological conditions that lead to impacts on biology. An overview of the measures to mitigate this impact is presented. In the following, we summarise the main findings and other important issues related to the comparability of GEP. As there are still differences in the interpretation of several issues by the responding countries, and the findings reported are based on a 2015 questionnaire with a not so high response, caution is needed when interpreting the results of this exercise.

12.1 Harmonized understanding of GEP

Comparing the information provided by countries and looking at the measures indicated to mitigate impacts from drainage provides a valuable opportunity for the exchange of information. There seems to be a good basis for identifying similarities and differences between countries' standards for GEP. Where impacts are similar, GEP is likely to be comparable. Therefore, it is concluded that a harmonized understanding of the environmental objective for HMWBs impacted by drainage is possible. However to really harmonize GEP itself might be a step too far as it is often site-specific and dependent of water body characteristics (as for other types of HMWBs).

Recommendation 1: A generalised framework for deciding on the mitigation required for good ecological potential (flow-chart describing the relevant considerations to be used in this decision-making process) can be developed to achieve further harmonisation of GEP. Such a generalised framework can be used to supplement CIS Guidance no. 4 on HMWB.

Recommendation 2: It is recommended in the upcoming work to further develop the existing approach that allows for harmonizing the levels/requirements of ecological potential based on mitigation measures.

12.2 Common terminology

There is no common EU wide definition of the term drainage, but it is often associated with manmade structures or alterations to water bodies to lower groundwater levels in a specific land area for a certain purpose. In this report the term drainage is mainly linked to agricultural drainage. The description of the key terms, drainage schemes and relevant mitigation measures in this report gives the countries enough common ground for harmonized understanding.

Recommendation 3: It is recommended that in any future exercises under the Common Implementation Strategy the common technical terminology and mitigation measures from this report is used.

12.3 Harmonized hydromorphological classification methods

There are several methods to detect impacts from hydromorphological pressures but almost one third of the countries do not have methods to detect all the parameters affected by drainage.

Recommendation 4: It is recommended to have harmonized hydromorphological classification methods in order to have a comparable assessment of the hydromorphological alterations due to drainage, among the different countries.

12.4 Minimum requirements for GEP

There is no common understanding on minimum ecological requirements for GEP related to impact from drainage. Some countries argue that the WFD has an expectation that there is an approximation to ecological continuum at GEP. Other countries argue that a significant effect on the benefits served by drainage can lead to a not or barely functioning ecosystem.

Recommendation 5: Minimum ecological requirement for GEP is an issue that needs further clarification. More common understanding on ecological minimum criteria for GEP should be developed.

12.5 Clarify criteria for determining significant adverse effects on water use

The standard for ecological potential seems to vary between water bodies and countries. One potential reason is that it depends on what can be done by way of restoration measures or improvement to the hydromorphological characteristics of the water body, without a significant adverse effect on the benefits served by drainage. Consequently, decisions on when such adverse effects are significant vs non-significant are crucial for common implementation. However, few countries have a national definition on significant impact on water use.

Recommendation 6: It is recommended that each country exchange approaches and establishes transparent criteria for deciding if mitigation would have a significant effect on drainage and benefits for society thereof.

12.6 Reason for ruling out measures

Based on the results from this questionnaire, no common understanding is apparent on how and why mitigation measures are ruled out. There are some indications that the majority of countries probably rule-out mitigation measures when considering (often site-specific) evaluating criteria.

Recommendation 8: It is recommended that the reasons for ruling out measures are made clear and transparent for better harmonization also on this step for setting GEP.

12.7 Applying national methods to a common set of HMWBs

The conclusion of the exercise presented in this report is that there are emerging good practices for setting GEP for water bodies impacted by drainage (see examples in the Annex from the Netherlands and Germany). It would be interesting to compare different countries' national methods to a common and comparable set of water bodies/catchments impacted by drainage. It is likely that a set of generic cases (type of modification/river characteristics) such as the ongoing work on water storage will be needed to agree upon in the context of land drainage. Such an exercise would also be valuable in further identifying and elaborating on emerging good practice, implementation of measures in practice and possibly also for handling multiple pressures and intercalibrated Ecological Quality Ratios/Methods related to e.g. pollution in a comparable way.

Recommendation 9: It is recommended that the Common Implementation Strategy agrees to an exercise to compare the outcomes produced by countries' national methods by applying them to a comparable set of heavily modified water bodies included in generic cases. Consideration should then be given to incorporating the results of both exercises into a good practice guide. There is probably a need to supplement CIS Guidance no. 4 on HMWB with an appendix based on this exercise, to ensure common environmental requirements in HMWBs.

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14 Annexes

14.1 Example 1: Groote Molenbeek, The Netherlands

General description

The Groote Molenbeek ("large millbrook") is a 30 km long slow flowing stream in a sandy area in the southern part of the Netherlands. It is a tributary of the river Meuse. Before 1850 the western part of the catchment was a raised bog, which was reclaimed for agriculture. Around the 1950s the Groote Molenbeek is channelized in order to drain the agricultural fields in spring. This rapid drainage caused water shortages in summer. To mitigate this water shortage inlet from the river Meuse via a channel was made possible


Status of the water body, and how is it assessed?

The water body Groote Molenbeek is designed as a Heavily Modified Water Body (HMWB), because large parts of the water body are channelized and impounded. As the raised bog cannot be restored within reasonable time (it takes approximately 5000 years to restore a raised bog), restoration to a natural condition and achievement of good ecological status(GES) values is impossible. In the table below an analysis is shown on the Ecological Key Factors (EKF, see http://edepot.wur.nl/418301 for a description of this method). For each Key factor a desired value to reach natural conditions (GES) is set. Next the achievable value is determined for this water body, this are the values for GEP-conditions.

Key factor	**Pressure**	**SI**	**Desired value = GES**	**Achievable value = GEP**	**Current value**
Light climate	shadowing	%	> 40	30	7.5
	Maintenance intensity	%	< 50	50	95
Discharge dynamics	Flow variation	-	"a lot"	Moderate	"no"
	Average current (summer)	cm/s	> 18	23	21
Substrate diversity	Wet-cross section	-	Free meandering	Free meandering	Canalize d

	Sinuosity	-	> 1.25	1.1	1
Organic matter	Biochemical Oxygen Demand (BOD)	mg/l	< 3	1.25	?
Nutrient load	Total phosphorus (summer average)	mg P/l	< 0.11	0.11	?
	Total nitrogen (summer average)	mg N/l	< 2.3	5	?
Continuity	Number of weirs	#		1 (with fishladder)	3
	Impoundment	%	< 25	10	75
	Fish migration	-	Good	Good	No

How is a measure chosen?

A list of measures potentially able to tackle the main problems in the water body was developed during a workshop with hydrologists, ecologists and maintenance employees from the water management authority. These measures consisted of:

- Recovery of natural discharge dynamics
    - Remeandering and redesign wet cross-section
    - Removal of weirs
- Reduction of nutrient loading
- Other improvements of design and maintenance
    - Planting trees of natural growth for shadowing
    - Extensive maintenance/mowing

How is the significant effect on use determined?

During the same workshop, the effect of the measures on water use was determined based on expert opinion. The backbone in the problem to achieve GES values in the Groote Molenbeek was that the hydrology of the system was severely changed. The area used to have natural raised bogs and high ground water levels and as consequence a relative constant discharge in the connecting rivers, such as the Groote Molenbeek. Nowadays the raised bogs have largely been disappeared or are hydrologically isolated, and cannot function anymore as a sponge. Water from the Meuse is artificially pumped to this system, to maintain some discharge in summer. Many uses including agriculture and housing are served by these changes. It is clear that the whole hydrology (including landscape) is so modified that it cannot be restored. In most Dutch cases, the use and its effect on the use is so large that national or specific criteria for 'significant impact on use' are not considered as a helpful tool. For each water body, the significant effect on use is described and publicly available in fact sheets. Please see: www.waterkwaliteitsportaal.nl/Beheer/Rapportage/Publiek?viewName=Factsheets&jaar=2015&maand=December.

How is GEP derived?

The "WFD-explorer" (https://publicwiki.deltares.nl/display/KRWV/KRW-Verkenner) is used to calculate the effect of the measures in terms of Environmental Quality Ratio

(EQRs). This is based on statistical relationships between ecological quality and environmental factors, including cases where environmental factors are changes by measures taken in the past. GEP can be based on this calculation.

Water body	**Expected state after implementation of measures**		
	Benthic flora	**Invertebrate fauna**	**Fish**
Groote Molenbeek	0.54	0.61	0.40

Results on monitoring of effectiveness

The measures presented above have been taken in parts of the Groote Molenbeek, in particular remeandering and alteration of the wet cross-section in combination with the creation of flow-dynamics by placing of woody debris. These improvements in hydromorphology resulted in the recovery of natural processes, with benefits on the ecology. Monitoring of sections of the Groote Molenbeek where restoration measures have been taken to create a free meandering stream show a recovery of the invertebrate fauna to an EQR of 0.63 whereas the canalized section has an EQR of 0.43.

14.2 Example 2: Wagenfelder Aue, Germany (Lower Saxony)

General description

The water body 'Wagenfelder Aue' is located in the North German Plain and belongs to the mid-sized sand and loam-dominated lowland streams (German type 15). The river catchment is characterised by agricultural land use (73% cropland). The water body is straightened and deepened to guarantee optimal land drainage for intensive agriculture. This features a technical standard profile of uniform width and a bed protected by rocks or other materials to amour shorelines, often covered with fine sediments. Various weirs constrain the ecological connectivity. Elevated nutrient concentrations (phosphorus) and lacking riparian shading cause excessive macrophyte growth that, together with frequent impoundments, decreases flow velocity. This occasionally leads to oxygen deficits on the channel bed. Intensive maintenance is relevant at the whole water body.

Status of the water body, and how is it assessed?

The water body is identified as heavily modified based on hydromorphological assessment results. The current ecological status is bad due to assessment results of benthic invertebrates; GES cannot be achieved without significant adverse effects on the use.

How is a measure chosen?

The national method consists of the following three main steps:

Step 1: Assigning the HMWB case group

The water body is assigned to the case group of 'lowland streams with land drainage'.

Step 2: Assessment of ecological potential

The benthic invertebrate fauna at the Wagenfelder Aue reveals bad ecological potential. This mainly results from the absence of type-specific species and a high proportion of littoral-preferring taxa. The occurrence of freshwater leech (*Erpobdella octoculata*), water sowbug (*Asellus aquaticus*) and sludge worms (Tubificidae) indicate the temporary oxygen deficits on the stream bed.

The water body reveals moderate ecological potential according to the fish fauna. This quality element shows low species richness and a low amount of rheophilic species, indicating impounded conditions. Migratory species are lacking, and disturbance indicators (e.g. spined loach) are frequently occurring.

According to the one-out all-out principle the water body's ecological potential is bad. Therefore, appropriate mitigation measures are selected in the following step.

<u>Step 3: Deriving mitigation measures</u>

The selection of potential measures for achieving GEP is based on the case group 'Lowland stream with land drainage'. This case group contains general measures that are suitable to reach GEP on a conceptual level for water bodies with land drainage as the main use.

A selection of detailed single measures has to be done for the implementation of concrete measures. This is part of an individual River Basin Management decision and not part of the national method.

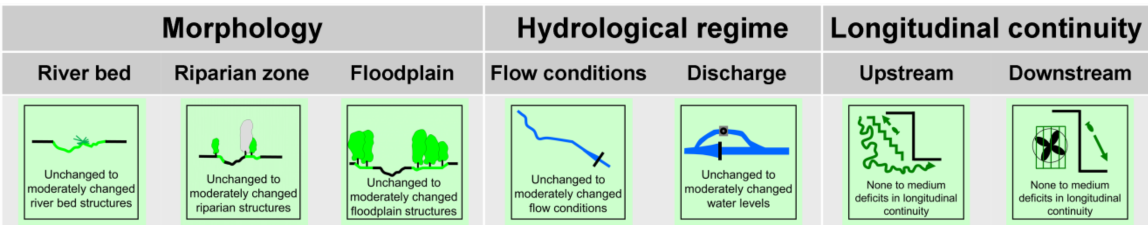
How is the significant effect on use determined?

Significance is determined based on a functional criterion that focuses on the drainage ability of the water body. Therefore, all measures that do not have a significant adverse effect on the drainage function are relevant for defining GEP. This set includes all measures that do not considerably rise the river bed level or decrease the hydraulic capacity of the profile.

How is GEP derived?

GEP is derived by using the case group 'Lowland stream with land drainage', that is comparable to a river type that includes the usage aspects of HMWB assessment. This case group contains especially measures and habitat conditions at Maximum Ecological Potential (MEP), habitat conditions and key factors at GEP as well as EQR values for Biological Quality Elements (fish, benthic invertebrates) that define GEP and general measures suitable for reaching GEP on a conceptual level.

According to the water body of the Wagenfelder Aue GEP anticipates not more than moderately changed morphology, hydrological regime and longitudinal continuity of the water body:



For achieving the GEP the following key factors are decisive:

- Near-natural bed substrate (sand, gravel and woody debris);
- Low amount of technical bank fixation using allochthonous material;
- Native trees/shrubs (at least on the banks);
- Natural variation in channel depth (featuring riffles and pools);
- Constructing/developing secondary floodplain (occasional);
- Floodplain elements (occasional);
- Self-dynamic river development;
- Ecological river maintenance;
- Longitudinal continuity.

To develop these key factors, emphasis shall be placed on re-establishing the natural flow conditions. Measures to enhance the river habitat structures are also vital. These include the removal of bed fixation, introduction of woody debris and, in particular, the instalment of riparian buffers. In principle, constructing a secondary floodplain is a technically feasible measure that could be implemented occasionally at the Wagenfelder Aue. By removing of the weirs the longitudinal continuity can be restored. Implementing an ecological maintenance scheme at this water body provides additional benefits for development of hydromorphological habitat parameters and biota.

Results on monitoring of effectiveness

Hydromorphological measures have not been implemented at the river stretch so far. Therefore, no monitoring results on effectiveness of measures are available yet.

However, based on the existing nutrient load, GEP will probably not be reached by implementing the mentioned hydromorphological measures without improving the nutrient values. Therefore, measures for reducing the nutrient load have a high priority.

For more information:

http://www.laenderfinanzierungsprogramm.de/cms/WaBoAb_prod/WaBoAb/Vorhaben/LAWA/Vorhaben_des_Ausschusses_Oberflaechengewaesser_und_Kuestengewaesser/O_1.13/index.jsp (in German)

List of abbreviations

BQE: Biological Quality Element

CIS: Common Implementation Strategy

DPSIR: Driving forces, pressures, state, impacts, and responses

EQR: Ecological Quality Ratio

GEP: Good Ecological Potential

GES: Good Ecological Status

HMWB: Heavily Modified Water Bodies

MEP: Maximum Ecological Potential

WFD: Water Framework Directive

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