Interreg
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Danube Transnational Programme
DanubeSediment

Sediment Management Measures for the Danube

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Project Introduction

Sediments are a natural part of aquatic systems. During the past centuries, humans have strongly altered the Danube River. Riverbed straightening, hydropower dams and dikes have led to significant changes in the sediment load. This sediment imbalance contributes to flood risks, reduces navigation possibilities and hydropower production. It also leads to the loss of biodiversity within the Danube Basin.


The Danube by Hainburg, Austria. (Philipp Gmeiner/ IWA-BOKU)

To tackle these challenges, 14 project partners and 14 strategic partners came together in the DanubeSediment project. The partnership included numerous sectoral agencies, higher education institutions, hydropower companies, international organisations and nongovernmental organisations from nine Danube countries.

Closing knowledge gaps: In a first step, the project team collected sediment transport data in the Danube River and its main tributaries. This data provided the foundation for a Danube-wide sediment balance that analysed the sinks, sources and redistribution of sediment within the Danube - from the Black Forest to the Black Sea. In order to understand the impacts and risks of sediment deficit and erosion, the project partners analysed the key drivers and pressures causing sediment discontinuity.

Strengthening governance: One main project output is the Danube Sediment Management Guidance (DSMG). It contains recommendations for reducing the impact of a disturbed sediment balance, e.g. on the ecological status and on flood risk along the river. By feeding into the Danube River Management Plan (DRBMP) and the Danube Flood Risk Management Plan (DFRMP), issued by the International Commission for the Protection of the Danube River (ICPDR), the project directly contributes to transnational water management and flood risk prevention.

International Training Workshops supported the transfer of knowledge to key target groups throughout the Danube River Basin, for example hydropower, navigation, flood risk management and river basin management, which includes ecology. The project addressed these target groups individually in its second main project output: The Sediment Manual for Stakeholders. The document provides background information and concrete examples for implementing good practice measures in each field.

DanubeSediment was co-funded by the European Union ERDF and IPA funds in the frame of the Danube Transnational Programme. Further information on the project, news on events and project results are available here: www.interreg-danube.eu/danubesediment.

Project Reports

The DanubeSediment project was structured into six work packages. The main project publications are listed below.

A detailed list of all project activities and deliverables is available on our project website: www.interreg-danube.eu/approved-projects/danubesediment/outputs.

1) Sediment Monitoring in the Danube River
2) Analysis of Sediment Data Collected along the Danube
3) Handbook on Good Practices in Sediment Monitoring
4) Data Analyses for the Sediment Balance and Long-term Morphological Development of the Danube
5) Assessment of the Sediment Balance of the Danube
6) Long-term Morphological Development of the Danube in Relation to the Sediment Balance
7) Interactions of Key Drivers and Pressures on the Morphodynamics of the Danube
8) Risk Assessment Related to the Sediment Regime of the Danube
9) Sediment Management Measures for the Danube
10) Danube Sediment Management Guidance
11) Sediment Manual for Stakeholders

Sediment Management Measures for the Danube

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Introduction

Sediment data assessment along the Danube River and selected tributaries indicates a sediment regime that is disturbed at various scales as a direct effect of the various significant pressures caused by different drivers. In the report "Interactions of Key Drivers and Pressures on the Morphodynamics of the Danube", our project assessed drivers, which cause the alteration of the sediment regime. According to this assessment, the main key drivers "responsible" for the alteration of the sediment regime in Danube River Basin are navigation, flood protection and hydropower (see chapter 1 from report "Interactions of Key Drivers and Pressures on the Sediment Balance of the Danube").

Other significant contributions to the disturbance of the sediment transport are channel realignment, straightening and deepening of the river for navigation purposes (e.g. 87% of the Danube river total length is navigable), the building of chains of hydropower plants on the Upper Danube, the Gabčíkovo hydropower plant and Iron Gate I and II on the Middle and Lower Danube as well as flood protection engineering works along almost the entire Danube river.

Following the DPSIR-concept (Driver-Pressure-State-Impact-Response), the main significant pressures that affect the sediment balance and transport continuity have been identified as dams, weirs, ship locks, groynes, dredging to allow navigation and for ensuring flood protection, dredging for other purposes (i.e. industrial use, ecological restoration), river channel maintenance, regularization works of the river channel, and artificial channels for flood protection, navigation, diversion etc. (see chapter 2 from Report "Interactions of Key Drivers and Pressures on the Sediment Balance of the Danube").

The above-mentioned hydromorphological pressures have a direct impact on the hydromorphological and biological status of surface waters, e.g. dredging and sediment disposal can produce smothering of bed, respectively alteration of invertebrate communities.

In association with the disturbance of the sediment transport and balance, the project has performed a risk assessment for hydromorphology and ecology. The risk assessment includes the sediment related hydromorphological elements by taking into account the morphodynamic processes and the main biotic parameters that would be influenced due to changing of certain hydromorphological parameters (see Report "Risk Assessment Related to the Sediment Regime of the Danube").

The negatively affected morphodynamics lead to severe impacts on the type-specific aquatic communities and water dependent terrestrial ecosystems and thus on the water status. Consequently, in the frame of updating the Danube River Basin Management Plan, the alteration of the sediment balance has been identified as new sub-item of the Significant Water Management Issue "Hydromorphological alterations". This shows that an effective management of sediment in rivers is becoming increasingly important from an economic, social and environmental perspective.

The ICPDR's basin-wide vision is a balanced sediment regime with undisturbed sediment continuity. The balanced sediment regime enables the long-term provision of appropriate habitats for the type-specific aquatic communities and water dependent terrestrial ecosystems.

The processes controlling sediment transport and sedimentation are dynamic and highly variable. Therefore, an effective sediment management must be site specific, by acting on the level of each significant pressure and understanding the dominant spatial and temporal processes operating by the pressures at the basin-wide level.

Moving towards more sustainable sediment management, this project collected and assessed good practice and potential measures for sediment management. These measures were collected along the Danube River and its main tributaries (i.e. Isar, Inn, Traun, Enns, Morava, Lajta, Raba, Vah, Drava, Tisza, Sava, Velika Morava, Jiu, Iskar, Yantra, Arges, Ialomita, Siret, Prut). Some measures were also collected from outside of the Danube River Basin (e.g. Rhine).

After collecting and processing the good practice and potential sediment management measures in our project, we presented these measures to experts from throughout the Danube River Basin in the frame of "national stakeholder workshops". The experts gave our project team feedback on their experiences with the presented measures and gave us recommendations for including them in our project results, specifically the "Danube Sediment Management Manual". This Manual will entail good practice measures for improving the sediment regime and will address relevant target groups working in sediment management such as hydropower, flood protection, navigation and river basin management.

The results of the project will contribute to the preparation of the next update of the Danube RBMP, to achievement of objectives of the EU Water Framework Directive and update of the Danube Flood Risk Management Plan. The Danube Sediment Management Manual, as well as the Catalogue of Measures will help national authorities to improve sediment management, which will in turn contribute to the development of navigation, reduction of flood risks, and improvement of morphology and river ecology.

The implementation of measures and best practices for improving the sediment regime will be the task for other projects in the future.

1 Report on sediment management measures

1.1 Assessment of Good Practices and Potential Measures

1.1.1 General considerations

To achieve a balanced sediment regime along the Danube and its tributaries, an inventory of lighthouse projects and an assessment of already implemented measures is needed. This may constitute the basis for a future Danube-wide sediment approach. As a first step, the DanubeSediment project collected such measures in the frame of a catalogue of good practices of sediment management measures (see Chapter 2 and Annex 2). The inventory of measures indicates that there are different technical solutions that can be adapted to suit the conditions of a certain river section. Hence, different sections of this report present an array of sediment management measures for dealing with erosion and sedimentation.

The character of a good practice measure is generally validated via post-implementation monitoring of sediment transport in terms of suspended sediments or bedload. Good practices can also be the state-of-the-art measures that an authority or any other responsible entity considers a "good practice" (e.g. specific regulations, handbook, etc.).

There are many definitions of "what does good practice mean?", e.g. SEPA (Scottish Environmental Protection Agency) defines good practice as: "…the course of action which serves a demonstrated need, while minimising ecological harm, at a cost that is not disproportionately". This shows that a key aspect in the sediment context is to understand what is good practice. In order to take actions for improving the sediment regime it is important to understand the morphological process, and to identify the cause of the problem, because they treating the symptoms, we need to address and treat the sediment problem.

There are some cases of measures that improve the sediment balance but are not deemed as "good practice" because they have not yet been sufficiently tested or more research is needed. This does not mean that a measure should be excluded. Instead, we consider it to be a "potential measure" that may be applicable in future sediment management policy.

An Assessment of the scale and the significance of the problem and the interactions with the related driver(s) will help to determine whether or not sediment-related actions are required and it will ensure that any solution is suitable to the scale or magnitude of the problem.

It is important to recognise that any sediment-related measure must be designed to suit site-specific conditions. Thereby, it is essential for a good practice to consider a set of options to address any river engineering problem or need and to carry out an options appraisal. Without considering a range of options, it is not possible to determine if the selected approach represents the most suitable one.

Within the context of this report, a distinction is made between technical measures and non-technical measures. Technical measures, or structural measures, refer to physical construction, intervention, or to the application of engineering techniques or technology to improve the sediment regime. Non-technical measures instead are measures not involving physical construction and are of a legislative, administrative, organisational, economic or advisory nature. As such, non-technical measures serve to support the implementation of technical measures by creating incentives for the relevant players in order to modify their policy. One consequence of this is that non-technical measures could have a more long-term, more widespread effect than technical measures, and require coordination at a higher administrative level.

Both technical and non-technical should be considered in sediment management policy. Figure 1 presents a process for choosing good practice measures in a schematic way.

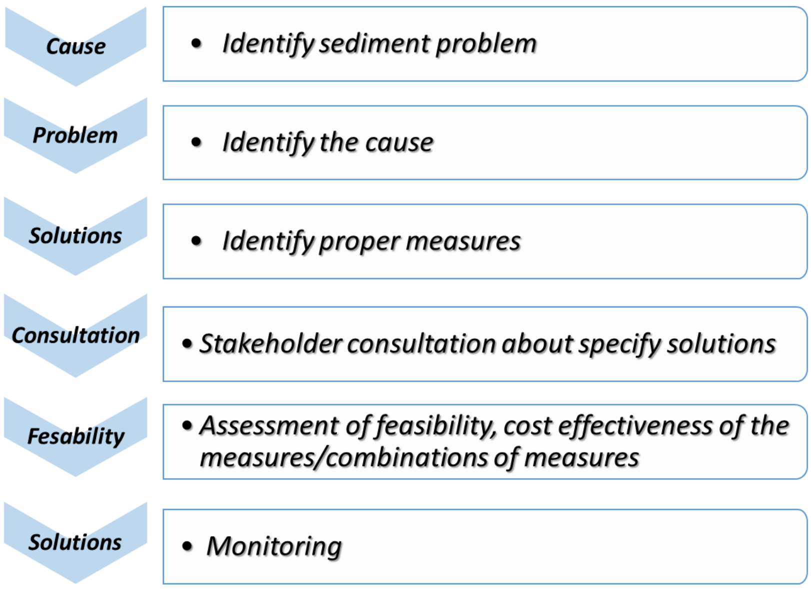

Figure 1: Sediment management measure good practice process

1.1.2 Methodological approach regarding the inventory of sediment management measures

The starting point of the inventory of the sediment management measures was the collection of factsheets. The project partners collected both good practice and potential measures on the Danube River, the major tributaries and some from outside the Danube River Basin i.e. on Rhine, Limmat and Albula River.

In order to have a uniform and proper assessment of the measures, the factsheet includes, besides general aspects, a set of key elements related to sediment measures. This begins with the morphological process (i.e. erosion or sedimentation) because of the alteration of the sediment regime, application area, then looks at the effect in terms of hydro- and morphodynamics of the river, sediment dynamics and ecology as well as the effects on water users and ecology. In addition, the qualitative assessment of cost effectiveness and the temporal and spatial scale has also been included as key elements (see Annex 1: Factsheets of best practice – template). The factsheet also includes descriptive elements like name of the project, aim and goal of the project, description of the measure, responsible authority, interrelation with other measures, related links, etc.

Figure 2 presents the main key elements addressed in the factsheet on good practice and potential measures.

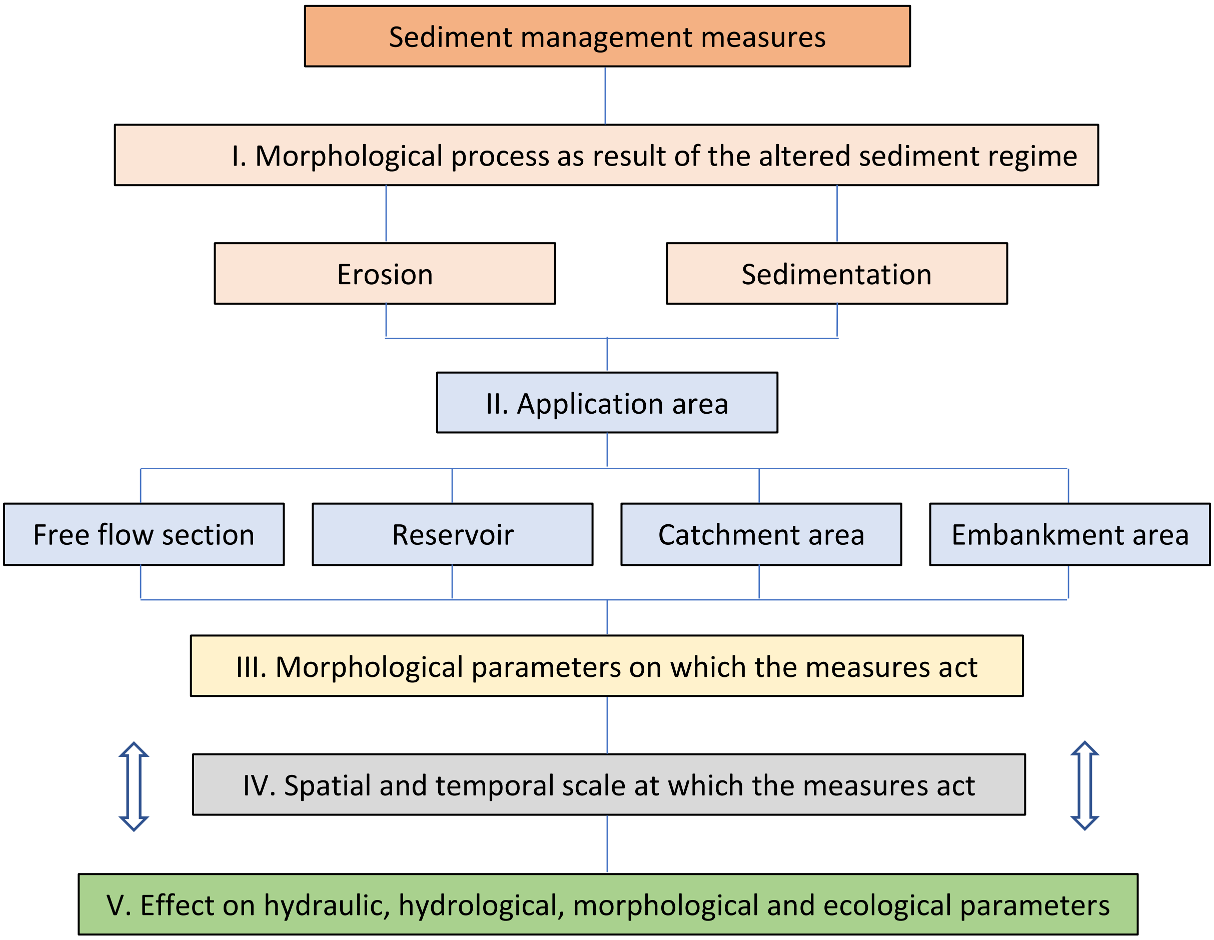

Figure 2: Key elements of the Factsheet for collecting sediment management best practices

The following sections (I-V) include a short description of the key elements, which characterise the good practice and potential measures examples. These key elements are included in the Factsheets (see sections 3.4; 4.2; 4.3; 4.9; 4.10) which practically defines the essence and relevance of the measures.

I. Morphological process as a result of the altered sediment regime

The interruption of longitudinal and lateral continuity by dams and weirs, flood protection and navigation embankment and regulating works directly influence the sediment deficit, which leads to riverbed *erosion*, especially downstream of barriers. On the other hand, we find significant *sedimentation* in several sections along the Danube and major tributaries. Sedimentation in reservoirs is one of the most pressing concerns presently facing river managers and it causes both upstream and downstream impacts, e.g. making the stretch unsuitable for navigation. To find out more about erosion and sedimentation in the Danube, see our project report “Assessment of the Sediment Balance of the Danube”. For these reasons, the changes in river processes (i.e. sediment transport – erosion/sedimentation problem) were chosen as a first key aspect in the sediment measures assessment process of our factsheet.

II. Application area

Morphological changes as a result of continuous alteration of the Danube and its tributaries occur in the riverbed along the *free-flowing sections*, as well as in the *catchment area*, *reservoirs* and *embankment sections*. Sediment data assessment confirm both a sediment deficit, but also an increased sediment transport capacity in different free-flowing sections, especially in the embanked sections. A surplus of sediment is observed instead in the impounded sections.

Mitigation of the sediment transport alteration involves different types of measures for different locations, but also taking into consideration the effect of these measures on flood risk, navigation conditions, hydropower production and biodiversity. In the free-flowing sections for example, measures like reducing or optimising the riverbed protection structures or groynes can have a suitable effect on reducing the erosion, while maintaining suitable conditions for navigation. In another case, measures like flushing are efficient in relation with accumulated and deposited sediments in a hydropower plant (HPP) reservoir, thus contributing to the optimal functioning of the HPP.

III. Morphological parameters impacted by the measures

Engineering measures to manage and improve sediment transport are often very complex and they usually rely on the application of very case-specific solutions for sediment management in order to be sustainable.

A set of various key morphological parameters is implicitly interlinked with improving the sediment regime, be it erosion or sedimentation. These parameters are:

- changing in sediment regime;
- increase/decrease of bed resistance;
- reduction/increase the energy slope and
- minimisation/increase of bed shear stress.

For example, measures like granulometric bed improvement, i.e. the feeding of coarser material that is still in the natural grain size spectrum, lead to an increase of bed resistance and implicitly to the increase of sediment transport capacity and to a reduction of erosion. A similar effect could be reached by acting on the energy slope (increasing) and reducing the bed shear stress.

IV. Spatial and temporal impact of measures

Sustainable sediment management should consider different spatial and temporal scales. Different measures act in different ways and, as previously mentioned, an effective basin-wide sediment management requires a site-specific response. Just as the sediment transport processes are dynamic and highly variable in time and space, the measures have different effects in time and space, too.

Local, regional or transboundary effects characterise the spatial scale, whilst short, medium or long term characterise the temporal one.

For example, sediment related measures at the reservoir could have a local effect when talking about small reservoirs. The same measure in a very large reservoir can have a larger spatial effect. The same applies to measures undertaken in the free-flowing sections: increasing the sediment supply or regulation of the sediment dynamics at hydraulic structures (i.e. dams, weirs) has a local effect, whilst e.g. significant riverbank restoration or reconnection of the side arms could have a regional or even a transboundary effect.

At the same time, the temporal scale of each measure needs to be considered. Measures like stabilisation of the riverbed, regulation of the sediment supply act on a long-term scale. Measures like feeding to maintain the water level conditions in the navigation channel or refeeding dredged sediment in upstream sections to reduce the ongoing riverbed incision act on mid-term scale. The removal or sediment from a reservoir and re-introduction downstream of a dam usually has a short-term effect.

The examples mentioned above are not always the rule. They refer only to good practice measures collected in the project. The assessment of the spatial and temporal scale at which the measure acts on plays an important role when weighing the various decision-making parameters during the course of selecting an efficient combination of measures.

V. Effect on hydraulic, hydrological, morphological and ecological parameters

The goal of improving the sediment regime is directly linked to the effect that the sediment regime improvement measures have on different hydraulic, hydrological, morphological and ecological parameters (Figure 3).

For example, when flushing sediment through sluices, the *water level* in the reservoir is drawn down to allow for sediment-load inflow to pass the reservoir with a minimum of deposition.

Reducing stream *velocity* through engineering works implicitly reduces the erosive capacity of the stream. For example, by river widening works.

Optimising hydraulic structures contributes to the reduction of the transport capacity of rivers and implicitly to the reduction of the *bed shear stress*.

Anti-erosional measures like *removal of natural levees* have a high effect on a river's hydrodynamics by optimising the water level, flow velocity or shear stress (reduced at bank full discharge). Having in view the sediment dynamics and morphodynamics, the effect of this type of measure is medium.

Anti-sedimentation measures undertaken at the head of HPP reservoirs, for example by *construction of gravel bars and islands,* will slightly increase the water level, flow velocity and shear stress and implicitly the transport capacity of sediments.

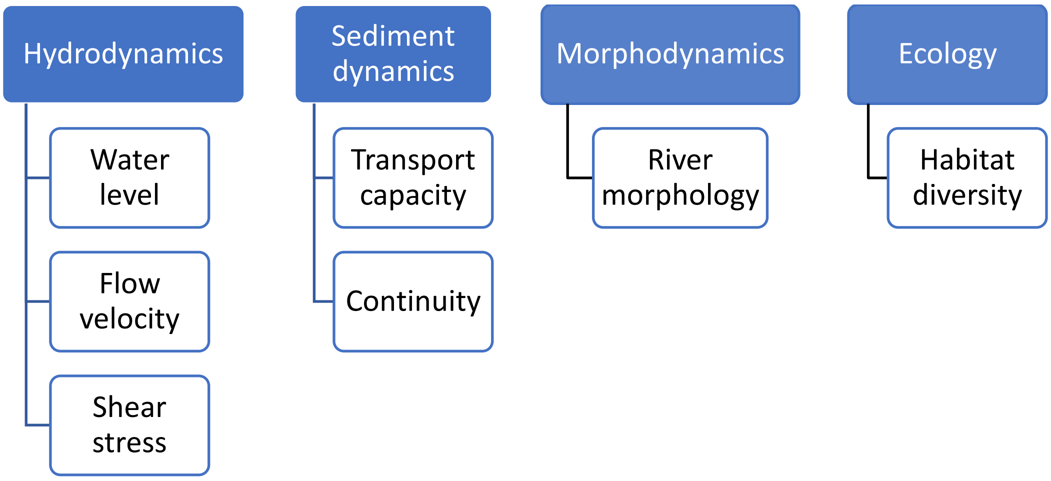

Figure 3: Categories of parameters affected by sediment regime improvement measures (included in section 4.10 of the Factsheet for collecting the measures, see Annex 1: Factsheet of best practice – template)

At the same time, navigation, hydropower or flood protection related infrastructure works impact the morphodynamics of a river, leading to negative effects, such as the deterioration of type-specific habitats and of the ecological status.

The riverbed substrate, the natural river bank, an adequate hydrological regime and a good water status support "biological quality elements" of a river (see Annex V of Water Framework Directive)[1]: fish, macrozoobenthos and macrophytes. According to this EU Directive, when planning sediment measures, one must take the ecological impact of a measure into account to improve and maintain the water status.

[1]Annex V of Water Framework Directive accessed on https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060

1.2 Categories of sediment management measures

Different site-specific sediment management measures, engineering solutions and several non-technical measures, defined as good practices or potential measures have been collected from in- and outside the Danube River Basin, including major selected tributaries mentioned in "Introductory note" (these main tributaries were also, considered in collecting data about drivers and pressures on sediment regime). All these measures are provided in the Catalogue of Measures and are organized in Annex 2.

This section provides an overview of so-called "generic measures" for improving the sediment regime. They have been synthesised based on the key information provided within the factsheets and grouped according to:

- morphological process for which the measures are addressed: anti-erosion vs. anti-sedimentation;
- location: free flowing sections, reservoir, catchment area, or embankment section;
- morphological parameters impacted by the measures (i.e. sediment regime, bed resistance, energy slope, bed shear stress).

Furthermore, the generic measures are presented in an illustrative way by providing indicative information in terms of effect on morphology and ecology.

The inventory of generic measures indicates that there are slightly more measures against sedimentation than ones for stopping bed erosion.

Considering anti-sedimentation measures: those applied at the reservoirs are the most common. This can be explained on the one hand by the significant volume of sediments trapped in the reservoirs, which serves as an important source to mitigate the sediment deficit downstream of the reservoir. On the other hand, the need to reduce the accumulation of sediment in the reservoirs, which affects the purpose of the reservoir (e.g. reduces hydropower generation).

Considering the anti-erosion measures, the inventory indicates a preponderant number of measures that aim to reduce riverbed erosion in the free-flowing sections. This is due to a variety of regulation works for flood protection and navigation, as well as commercial dredging, land use/agriculture and other infrastructure projects that occur in the free-slow sections and which increase riverbed erosion.

It should be highlighted from the beginning that the measures collected are in some cases part of more complex projects with multiple purposes and goals, among which there are measures in relation with the improvement of sediment regime. The following section aims to synthesise these measures (called "generic measures") together with those, which directly address the sediment regime.

The generic measures have been grouped in relation with their main effect in terms of morphological parameters (i.e. change of sediment regime bed resistance, energy slope, riverbed shear stress). Based on the data collected in the Factsheets, the list below indicates which generic measure impacts which parameter the most. This does not exclude the complementary effect of a certain measure on the other parameters (Figures 4 and 5).

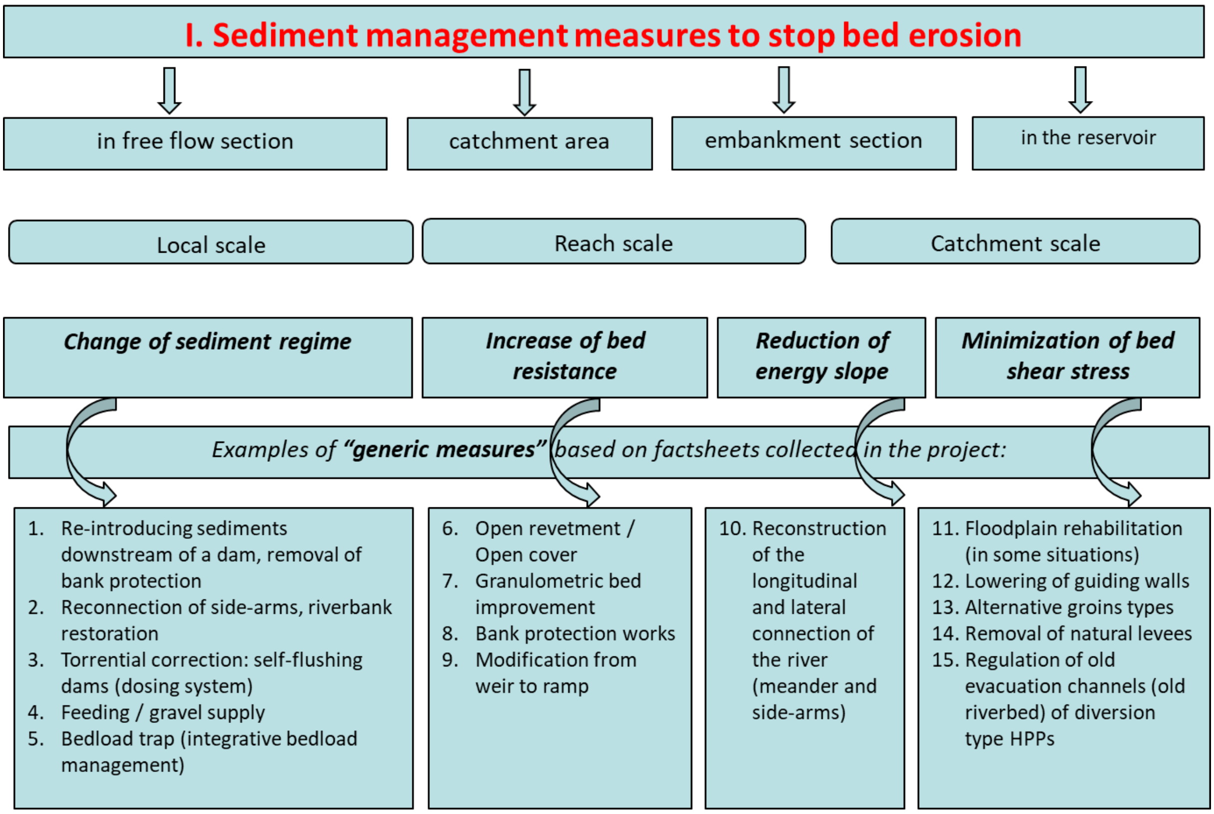

Figure 4: Sediment management "generic measures" to stop bed erosion (details are included in Table 1 - Section I and Annex 2: Catalogue of measures)

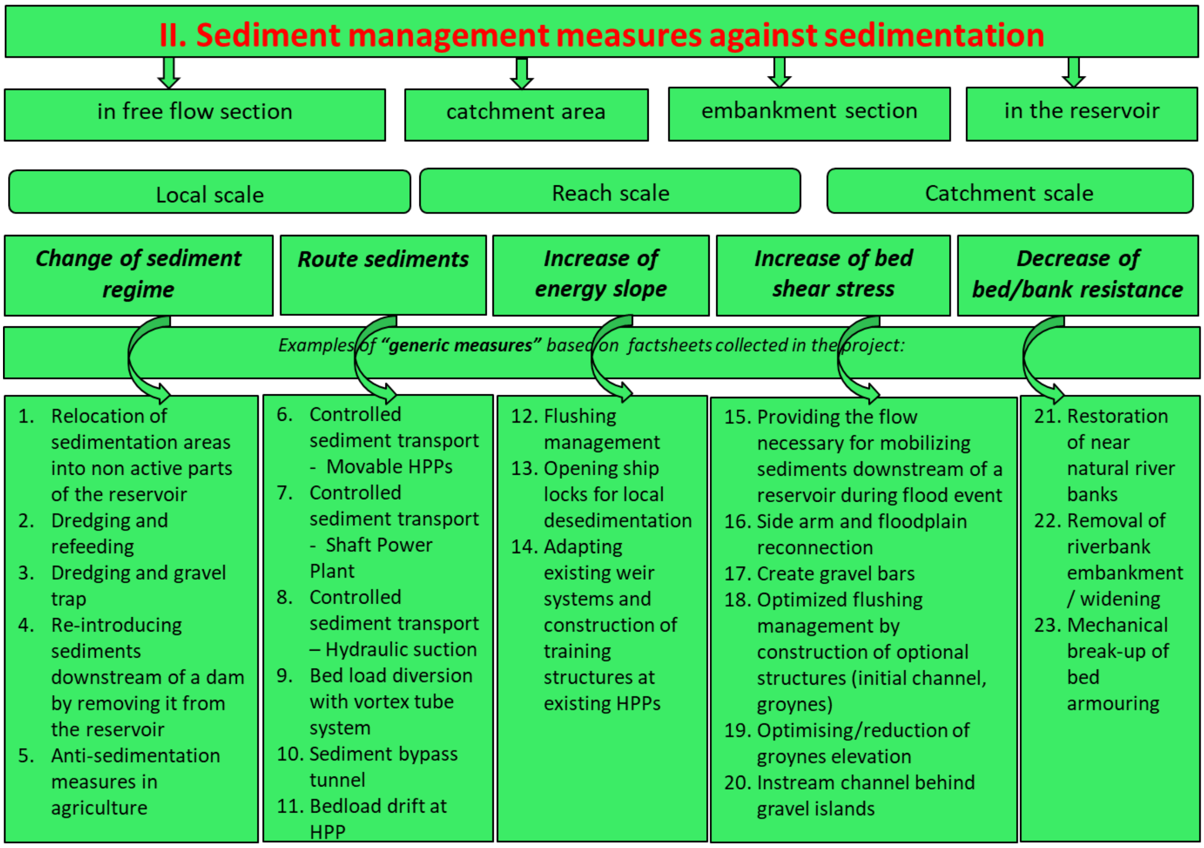

Figure 5: Sediment management "generic measures" against sedimentation (details are included in Table 1 - Section II and Annex 2: Catalogue of measures)

Table 1 gives an **overview** of generic measure types that were collected by our project partners. **All collected measures** are listed in Annex 2: Catalogue of measures; furthermore, **the details for each measure** are included in Annexes 3a and 3b: Factsheets regarding sediment management measures to stop bed erosion and against sedimentation.

Table 1: Overview of **sediment management** “**generic measures**“ to stop bed erosion (Section I) and against sedimentation (Section II)

Section I: Sediment management measures to stop bed erosion				
“Generic Measure” Type	**Morphologic parameters category improved**	**Main objectives and effects on ecological and hydromorphological parameters**	**Location of effect**	**Example(s) of measure(s) from Factsheets collected*)**
1. Re-introducing sediments downstream of a dam, removal of bank protection	Change of sediment regime	Re-introducing sediments downstream of dam/weir to ensure/restore the longitudinal continuity of sediments, to reduce erosion downstream of the dam or weir to stabilise the riverbed and groundwater level, to improve the connection with side arms and floodplains, and to improve the habitat diversity.	reservoir; main channel	E_FF_H_T_P02; E_FF_FP_T_GP05; E_FF_FP/N_D_P21 E_R_H_T_GP24; E_R_H_T_GP25; E_R_W_T_P26
2. Re-connection of side-arm system, riverbank restoration	Change of sediment regime Minimization of bed shear stress	The reconnection of the side-arm primarily leads to improved ecological conditions in these river systems. This measure creates new aquatic habitats and refugial areas, where organisms are protected against wave influences. Due to the permanent connection to the main channel, the water level, flow velocity, shear stress and transport capacity are increased. Morphodynamic processes are enhanced both in the side-arm and in the main channel, due to river bank restoration. This effect the sediment balance in the main channel by causing higher sediment input from the side-arm and the river banks. Furthermore, flood retention is increased, resulting in lower water levels in the main channel at high flows. Primarily benefits ecology and in a lesser degree sediment balance and flood protection.	river bank	E_R_N/H_D_P28; E_FF_FP/N_D_GP15; E_FF_FP/N_D_GP18; E_C_N_D_GP31;
3. Torrential correction: self-flushing dams (dosing system)	Change of sediment regime	These works are reactivating bedload transport, reducing the removal of bedload at the barrier/dam. Also, improves habitats.	main channel	E_FF_FP_T_P10

4. Feeding / gravel supply	Change of sediment regime	Feeding / gravel supply helps to stabilize the bed level, reduces erosion and ensures sediment supply / continuity.	main channel	E_FF_H_D_GP01
5. Bedload trap (integrative bedload management)	Change of sediment regime	The use of bed load traps as part of an integrative bed load management helps to maintain the fairway depth in the navigation channel by dynamically stabilizing the riverbed; refeeding the dredged sediments in the upstream parts reduces the ongoing riverbed incision. This makes only sense if there is a reservoir downstream, otherwise the downstream erosion will be increasing.	main channel	E_FF_N_D_GP13
6. Open revetment / Open cover	Increase of bed resistance	Open cover (or revetment): large stones, which are bigger than the existing bed material, are placed onto the riverbed, covering about half of the area. The stones increase the resistance for the water flow and protect the finer, natural bed material in their shelter zones. Acting on local scale and long term, effects are in improvement of ecology in the river and bed stabilisation.	main channel	E_FF_FP_T_GP07
7. Granulo-metric bed improve-ment	Increase of bed resistance	Granulometric bed improvement sustains riverbed stabilization (stop riverbed erosion), reduces maintenance for less ford dredging, increases low water level and a dynamic equilibrium.	main channel	E_FF_N/H_D_GP22; E_FF_N/H_D_GP23; E_R_N/H_D_GP27
8. Bank protection works	Increase of bed resistance	Construction and reconstruction of hydraulic regulation and protection structures will improve flood protection and stabilization of the flow and riverbanks	river bank	E_FF_FP_D_GP04; E_FF_FP_T_GP09; E_FF_N_D_GP14
9. Modifi-cation from weir to ramp	Increase of bed resistance	The weirs were usually built to slow down velocities and prevent bed erosion. However, weirs hindered upstream fish migration and downstream sediment continuity. Therefore, the weirs can be removed and replaced by a ramp.	main channel	E_FF_FP_T_GP08

10. Recon-struction of the longitudinal and lateral connection of the river (meander and side-arms)	Reduction of energy slope Reduced shear stress in main channel	Side-arms shape the landscape through erosion and sedimen-tation. Measure will ensure permanent connection of the side-arm system (at low flow), will improve the ecological conditions (esp. at the river banks and side arms), having effect on sediment budget in the side-arm system. Also, will offer protection against wave influence.	floodplain	E_FF_FP/N_D_GP16; E_FF_FP/N_D_GP17; E_E_H/FP_T_GP33
11. Floodplain rehabilitation (in some situations)	Minimization of bed shear stress	Increase the hydro-morphological dynamics of the river, which stimulate the movement of bed load and decrease the deepening of the riverbed.	floodplain, main channel	E_FF_FP_D_GP03; E_FF_FP_T_GP06; E_FF_FP/N_D_GP19; E_C_FP_T_GP30; E_C_A_T_P32
12. Lowering of guiding walls	Minimization of bed shear stress	Lowering of the guide wall leads to the reduction of the incision of the riverbed (reduced erosion).	main channel	E_FF_N_D_GP12
13. Alternative groyne types	Minimization of bed shear stress	Alternative groyne types help to reduce incision in the riverbed (reduced erosion), to reduce groyne field effects (less sedimen-tation), to increase hydromorpho-logical dynamics on the shores, to restore river banks (side erosion due to higher shear stress along the river bank) and to improve the ecological conditions (improving the diversity of the aquatic habitat through the near shore flow).	main channel	E_FF_N_D_GP11
14. Removal of natural levees	Minimization of bed shear stress	Removal of natural levees acts for increase discharge capacity (flood protection), increase sediment input, reduce the incision of the riverbed by reducing shear stresses and the natural morpho-logical development of the bank zones (morphodynamics). Removal of levees (revitalising the floodplain) improves flood protection by enabling the water more width (during average flood events) and reconnect of the floodplain (i.e. enabling a natural hydraulic floodplain dynamic) supports the protection of the soft wood forest and the remaining native black poplar population	main channel, floodplain	E_FF_FP/N_D_P20; E_FF_A/H_D_GP34

15. Regulation of old evacuation channels (old riverbed) of diversion type HPPs	Minimization of bed shear stress	Preventing the reservoirs from getting filled up with gravel downstream and improving the sediment transport capacity. Also, preventing the channel from getting overgrown with vegetation and raising the groundwater level, increasing flow capacity.	reservoir	E_C_FP_T_GP29

*) The Factsheets are centralized in Annex 2: Catalogue of measures and detailed in Annex 3a: Factsheets regarding sediment management measures to stop bed erosion (see related codes).

Section II: Sediment management measures against sedimentation				
Measure Type	**Morphologic parameters category improved**	**Main objectives and effects on ecological and hydromorphological parameters**	**Location of effect**	**Examples of measures from Factsheets collected**)**
1. Relocation of sedimentation areas into non active parts of the reservoir	Change of sediment regime	Re-introducing sediment downstream of dam by removing it from reservoir improve sediment continuity and contribute to riverbed stability.	reservoir	S_R_FP/N_D_GP63
2. Dredging and refeeding	Change of sediment regime	Dredging to maintain navigation conditions and to maintain adequate flood protection conditions. This measure is only recommended if the dredged material is reintroduced in the river system (if possible upstream).	main channel	S_FF_N_D_GP40; S_FF_N_D_GP42; S_R_N_D_GP62; S_E_H/FP_T_GP70; S_R_H/FP_D_GP65
3. Dredging and gravel trap	Change of sediment regime	Dredging and gravel traps help protect against flooding by reducing high water levels and ensuring sediment transport by preventing sediment from entering the HPP chain. This measure is only recommended if the dredged material is reintroduced in the river system. Traps can be implemented if there is a further reservoir downstream, otherwise riverbed erosion might be increased downstream.	main channel	S_R_H_T_GP52

4. Reintro-ducing sediment downstream of dam by removing it from reservoir	Change sediment regime	Re-introducing sediment downstream of dam by removing it from reservoir ensures sediment transport continuity and riverbed stability.	reservoir; main channel	S_R_H/FP_T_GP67
5. Anti-sedimentation measure in agriculture	Change of sediment regime	Aims to create permanent riparian buffer strips in agricultural areas, they are also called "green strips for protect-tion of water bodies and soil." The measure aims to slow down runoff and input von fine material and nutrients and contribute to flood protection	floodplain	S_C_A_T_GP71; S_C_A_T_GP72; S_C_A_O_P73
6. Controlled sediment trans-port - Movable hydropower plant	Route sediments	The use of movable hydropower plant can support the sediment continuity and migration of fish.	main channel	S_FF_H_T_GP35
7. Controlled sediment transport Shaft-Hydro-power Plant	Route sediments	The innovative concept combines energy production, downstream fish migration and sediment continuity due to a movable sluice gate.	main channel	S_FF_H_T_GP36
8. Controlled sediment transport Hydraulic suction	Route sediments	Hydraulic suction reintro-duces sediment downstream by removing it from reservoir and thus ensures continuous sediment transfer.	main channel	S_R_H_O_GP58
9. Bed load diversion with a vortex tube system	Route sediments	Bed load diversion with a vortex tube system increases the sediment transport continuity.	main channel	S_FF_H_O_GP37
10. Sediment Bypass Tunnels (SBTs)	Route sediments	The concept is to divert inflowing sediment to the downstream river reach without deposition in the reservoir. This will highly improve the river morpho-dynamics (substrate and river structure). SBTs prevent reservoir sedimentation, restore the sediment continuity and enhance the quality and quantity of the affected benthic habitats (downstream).	main channel	S_R_H_O_GP59

11. Bedload drift at HPP	Route sediments	The bedload drift at HPP helps stabilize the bed / the roughness of the raised bed and improve the habitat (grain sizes are transported from the middle to the course).	main channel	S_R_H_T_GP54
12. Flushing management	Increase the energy slope	Flushing management improves continuity (reducing sedimentation in the reservoir and erosion in the downstream reach), increases flood protection by restored reservoir capacity, prevents clogging and supports the restoration of spawning habitats. In case of flood protection, the use of flushing management reduces high water levels.	reservoir	S_R_H_T_GP51; S_R_H_T_GP57; S_R_H_D_P61; S_R_H/FP_D_GP69
13. Opening of ship locks for local desedimentation	Increase of energy slope	Opening of ship locks for local desedimentation improve continuity sediment transport (reducing sedimentation in the reservoir and erosion in the downstream reach).	reservoir	S_R_H_D_P60
14. Adapting the existing weir system and construction of training structures at the HPP	Increase of the energy slope	Adaptation of the existing weir system and the construction of training structures to HPP leads to flood protection by regulating flow /discharge and continuity of sediments by enhancing the bedload transport through HPP.	main channel	S_R_H/FP_T_GP66
15. Providing the flow necessary for mobilizing sediments downstream of a reservoir during flood event	Increase of bed share stress	According to the Weir Operating Regulations, segment gates must be opened in case of a flood event. These regulations contain specifics for the water level lowering at the HPP, as soon as the upstream regulation water level rises above a defined limit value. Opening the weir fields leads to increased shear stresses	reservoir; main channel	S_R_H_T_GP55; S_R_H_T_GP56; S_FF_FP_T_P39; (S_R_H_D_P61)

		and flow velocities in the reservoir. As a result, sediments are remobilized and transported out of the reservoir. Continuity is enhanced, leading to an improved sediment balance in the downstream reach. Benefits for sediment regime and flood protection. By the remobilization of deposited sediments in the reservoir, the continuity of suspended sediments is improved.		
16. Side-arm and floodplain re-connection	Increase Bed shear stress in the floodplain and decrease bed shear stress in the main channel	Side-arm and floodplain re-connection enhance stream habitat, re-establish flood and groundwater dynamics and improve longitudinal connectivity via fish pass (stream). This measure can increase the erosion capacity in the floodplain, thus reduce the sedimentation.	floodplain; river bank	S_FF_H/FP_D_P48
17. Create gravel bars	Increase of bed share stress	Constructed for protection of sediment biotope within the reservoir. The gravel bars offer succession areas for different plants in the wetlands. Thus, a significant ecological upgrading of the macrozoobenthos can be achieved. New refugee's habitats are created where fish are protected against vessel-induced waves.	reservoir	S_R_H/FP_D_GP64
18. Optimized flushing management by construction of optional structures (initial channel, groynes)	Increase of bed shear stress	Flushing efficiency can be increased by the construction of initial channels and groynes. These structures, situated at the head of the reservoir and enhance the sediment transport through the reservoir and reduce the sediment deposition at higher discharges and higher sediment inflow rates. An initial channel can be located	reservoir	S_R_H_T_GP53

		near the weir or at the head of the reservoir. The flushing channel may enhance the sediment transport if cohesive sediments or clogged riverbeds occur. The deposited sediments are eroded not only retrogressive but also lateral to the initial channel. The optimized flushing management leads to the improvement of the continuity by reducing the sedimentation in the reservoirs and the downstream erosion, by increasing the protection against floods by the restored capacity of the reservoir and the prevention of the colonization and the restoration of the habitats of deposit.		
19. Optimising reduction of groynes elevation	Increase of bed shear stress	The bed share stress is reduced in the main channel and increase in the groynes field and near bank/riparian area	main channel	S_FF_FP_D_GP38; S_FF_N_D_GP43
20. In-stream side channel behind gravel islands	Increase of bed shear stress	In-stream side channel behind gravel islands leads to the improvement of ecological conditions (diversity of aquatic habitat through the stream near the shores, refugial habitats for protection against the effects of waves induced by ships) reducing the effects of the groynes field (less sedimentation) and the increased hydromorphological dynamics in the banks.	main channel; river bank	S_FF_N_D_GP41; S_FF_D_D_GP44
21. Restoration of near natural river banks	Decrease of bed/bank resistance	Implementation of hydrotechnical works and measures on the existing hydrographic networks for establishing conditions of	river bank; floodplain	S_FF_D_T_GP47; S_R_H_D_GP49; S_R_H_D_GP50;

		previous river banks and even wetlands, as well as previous natural conditions important for biodiversity of the areas, conservation of floodplains and water habitat conditions.		
22. Removal of riverbank embankments / widening	Decrease of bed/bank resistance	Contributing to restore the near natural river banks and stabilisation of riverbed and previous natural conditions.	river bank, embankment (dikes) sector	S_E_H_T_P68
23. Mechanical break-up of bed armouring	Decrease of bed/bank resistance	The mechanical break-up of bed armouring maintains the continuity of the sediments, diverse habitats with adequate levels of oxygen and ensuring capacity of cross-section in case of flooding.	main channel	S_FF_D_T_GP45; S_FF_D_T_GP46

**) The Factsheets are centralized in Annex 2: Catalogue of measures and detailed in Annex 3b: Factsheets regarding sediment management measures against sedimentation (see related codes).

Considering the location, the assessment of sediment good practice and potential measures indicates that most of the measures are located in the free flow section, especially on the main channel and floodplain area and addresses both anti-erosion and anti-sedimentation. Measures undertaken at the reservoirs are also present in a relatively important number mostly related to optimising the river dam or weir hydraulic equipment, but also measures related to an improvement of the morphological conditions at the riverbed and the river bank.

Considering the temporal and spatial scale, most of the collected measures with long term effect are those related to reduction of erosion which mostly has a local effect. Measures with a medium or short-term effect located on regional or river basin scale have been also collected.

2 Catalogue of sediment management measures

2.1 Catalogue structure

2.1.1 Background and EU / ICPDR context

Examples of sediment improvement related measures have been assessed in the frame of different actions either we consider the EU or more specific Danube basin wide context. The Common Implementation Strategy, EU Projects, but also River Basin Management Plans coordinated by ICPDR and background technical documents make reference to measures for improvement the sediment regime.

- EU Context

In the European Union, water management is regulated via Water Framework Directive (WFD, formally Directive 2000/60/EC) that was adopted in October 2000. Adjacent documents regulate the implementation of the WFD, e.g. the EU CIS Guidance Document No. 4. Thus, the EU CIS Guidance Document No. 4 - *Steps for defining and assessing ecological potential for improving comparability of Heavily Modified Water Bodies* was updated in 2019, emphasising the importance of mitigation measures for achieving and definition of maximum (MEP) and Good Ecological Potential (GEP)[2].

Regarding the identification of mitigation measures, the need was expressed for a "best environmental practices" guidance for different types of modifications related to different users. To support this, a library of good practice mitigation measures for HMWB has been set up in the updating of EU CIS Guidance Document No. 4 - *Steps for defining and assessing ecological potential for improving comparability of Heavily Modified Water Bodies* in 2019. The library describes the typical implications of different types of physical modification and suggests relevance of mitigation measures to address typical effects in each water category (rivers, lakes/reservoirs, transitional/coastal waters). The library includes key 145 groups of mitigation measures, which are expected to be considered for ecological 146 improvements in order to address certain modifications (CIS Guidance 4).

The impact on sediment dynamics caused by hydrological or morphological alteration makes sediment management to one of the key measures to reach the Good Ecological Potential[3].

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[2] https://circabc.europa.eu/sd/a/f9b057f4-4a91-46a3-b69a-e23b4cada8ef/Guidance%20No%204%20-%20heavily%20modified%20water%20bodies%20-%20HMWB%20(WG%202.2).pdf

[3] https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp

- Project REFORM

Measures for improving the sediment regime were also addressed in the frame of the REFORM project (*REstoring rivers FOR effective catchment Management*). The project underlines the key role of bedload transport and sediment dynamics in forming fluvial habitats and includes sediment flow quantity improvement in the frame of factsheets for collecting different restoration measures[4].

- Natural Water Retention Measures

The Natural Water Retention Measure (NWRM) platform includes a catalogue of measures and a catalogue of case studies. The catalogue of measures of the NWRM is sorted by sector. It has been developed in the NWRM project, represents a comprehensive but non prescriptive wide range of measures, and there may be other or similar measures that could also be classified as NWRM. Sediment related measures could be found under hydromorphology.

- ICPDR context

Having in view the provisions of the Danube River Protection Convention, the major legal instrument for cooperation and transboundary water management in the Danube River Basin. ICPDR is the platform for the implementation of all transboundary aspects of the EU Water Framework Directive (WFD). Danube River Basin Management Plan as the key planning instrument in the frame of WFD implementation include measures adressed to hydromorphological alterations. Restoring/improving the longitudinal connectivity are part of these measures.

Hereby the Danube Sediment Project will contribute the work for the successful implementation of the EU WFD. The Catalogue of good practices and potential measures will come to complete the Joint Programme of Measures in the DRBMP Update 2027 by providing relevant examoples of improving the sediment regime as base for identification future actions.

The DanubeSediment Catalogue (Annex 2) on sediment management measures proposes a set of more detailed examples of improving the sediment regime, representing a comprehensive but non prescriptive wide range of measures.

2.1.2 How and when to use the Catalogue of Good Practices

To ensure a sustainable and equitable use of waters in the Danube River Basin, further information exchange is key to enable the Danubian countries to learn from each other's good practices and experiences in the field of sediment management.

[4] https://reformrivers.eu/start

The further river basin management planning policy should take into account all relevant factors: water, biodiversity but also the needs for navigation, hydropower or flood protection.

The "Catalogue of good practices for sediment management" presents selected examples of good practices and provide examples from Danube River Basin, but also a few from outside of DRB (details are included in Annex 2: Catalogue of measures).

The Catalogue will:

- support Danube countries in understanding the needs and requirements for improving the sediment regime measures, having in the view it's continuously alteration;
- suggest methods and approaches that are available for improving sediment regime;
- provide examples of improving sediment regime in Danube River Basin on Danube River, Major selected tributaries (Isar, Inn, Salzach Wertach, Saalach, Drava, Sava, Mur, Iskar, Yantra, Iskar), but also outside of Danube River Basin on rivers Rhein Limmat, Albula.

The catalogue is neither prescriptive nor mandatory and presents only "representative examples" of improving the sediment regime in the Danube River Basin selected on the basis of key elements set under (see sub-chapter 1.1.2).

Furthermore, in Figure 6, based on details included in all factsheets collected, is presented the distribution of drivers or combinations of drivers to whom the measures collected are addressed.

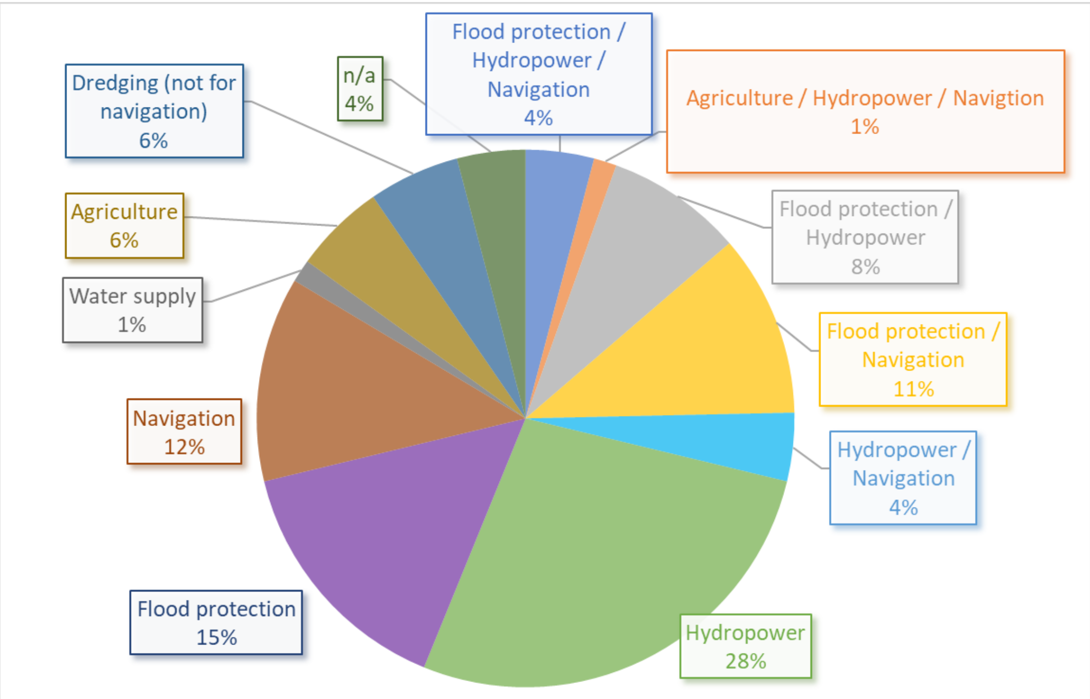

Figure 6: Drivers or combinations of drivers to whom the measures collected are addressed

The main users of the Catalogue will be:

- Danube Basin Countries' responsible authorities in charge of water resource and flood risk management;
- main water users in the frame of their environmental policy;
- research community.

The information on sediment management measures to improve the sediment regime along the Danube and tributaries could also be of interest for the following readers:

- private sector, in particular water resource and flood risk management experts and advisors;
- utility networks and critical infrastructure operators;
- insurance and real estate business sectors;
- other organisations/institutions from private or public sectors.

Annex 2: Catalogue of measures includes the details for all 73 measures collected, organised in two sections, including synthetic data about location, objectives, spatial-temporal scale, effect in morphological and ecological domains, etc.:

Section I: Sediment management measures to stop bed erosion (includes 34 factsheets coded, details are in Annex 3a – Factsheets regarding sediment management measures to stop bed erosion);

Section II: Sediment management measures against sedimentation (includes 39 factsheets coded, details are in Annex 3b – Factsheets regarding sediment management measures against sedimentation).

Here is presented the algorithm for code (Table 2) used for coding and organizing the measures from the Catalogue:

Table 2: Symbology used for description of the code

Measure type	Location	Driver	Stream	Counting the measure
E – anti-erosion **S** – stop sedimentation	**FF** – free flow section **R** – reservoir **C** – catchment area **E** – embankment section	**H** – Hydropower **N** – Navigation **FP** – Flood Protection **A** – Agriculture **D** – Dredging (not for navigation) **W** – Water supply **N/H** – Navigation + Hydropower **H/FP** – Hydropower + Flood Protection **FP/N** – Flood Protection + Navigation	**D** – Danube River **T** – tributaries **O** – outside Danube basin	GP**01**…xx – Good Practice* P**xx**…xy – Potential Measure* **The counting is continous.*

Example 1: code **E-FF-N-D-GP03**, it means an anti-erosional measure (E), located on free flow (FF), driver addressed on Navigation (N), located on Danube River (D) and considered as good practice (GP), being the 3rd in the centralized Catalogue (03).

Example 2: code **S-R-H_N-D-GP02**, it means an anti-sedimentation measure (S), located on reservoir (R), combination of driver addressed on are Hydropower and Navigation (H_N), located on Danube River (D) and considered as good practice (GP), being the 2nd in the centralized Catalogue (02).

Example 3: code **S-C-A-O-P73**, it means an anti-sedimentation measure (S), located in catchment area (C), driver addressed on Agriculture (A), located on Outside Danube River (O) and considered as potential measure (P), being the 73th in the centralized Catalogue (73).

All factsheets are coded, organized and included in Annex 3a: Factsheets regarding sediment management measures to stop bed erosion (33 factsheets) and Annex 3b: Factsheets regarding sediment management measures against sedimentation (40 factsheets).

2.2 Cost Effectiveness Analysis (CEA) in sediment measures context

2.2.1 Introduction

The basic concept of the cost-effectiveness analysis is in itself straight forward, i.e. identifying the measures for reaching a given objective (Improving the sediment transport in our case) in the most cost-effective way. In other terms, Cost Effectiveness Analysis (CEA) is an appraisal technique that provides a ranking of different specific measures on the basis of their costs and effectiveness, where the most cost effective has the highest ranking. In this way the CEA will provide additional information to aid decision-makers in the process of selecting and implementing specific measures.

Considering the present inventory of sediment management measures (good practices and potential measures), the use of a classical ranking method based on individual scores could mislead the policy makers in the decisions on adopting and implementing a certain measure. This is mainly due to level of details for the components of cost effectiveness analysis (e.g. quantifying the effects, accurate assessment of the costs.

In conclusion, this section of the report just proposes to briefly realize an overview on the main elements of the cost effectiveness analysis, their qualitative way of assessment and providing few relevant examples from the fact sheets.

- Key Elements of CEA

Three main steps comprise a cost effectiveness analysis:

- Identification as far as possible of an extensive set of measures;
- Assessment of the effects undertaken the goal of measure;
- Assessment of costs.

- Identification as far as possible of an extensive set of measures

The inventory of measures performed in the frame of ***DanubeSediment*** project provides a wide range of specific sediment management measures either technical (engineering) measures, but also non-technical, i.e. of administrative, institutional or legislative nature. As previously described these measures have been classified as good practices and potential measures for improving the sediment regime.

2.2.2 Assessment of the effects

In general, the effects should be related to the aim of the measure, respectively to the improvement of sediment transport. In fact, a complex set of parameters compose this effect, which are described in the previous sections: hydraulic, hydrological, morphological and ecological.

As part of the factsheets for collecting the measures, the effect has been addressed in a qualitative manner by ranking it for each measure in: High, Medium or Low. Hence, for each individual measure the effect is evaluated for each individual parameter, which define the sediment processes, i.e. hydrodynamics, sediment dynamics, morphodynamics and ecology.

In Tables 3 and 4 there are two examples which illustrate the qualitative assessment of the effect.

Table 3: Anti-erosion measure example: Removal of natural levees

	Parameter	Short description	Effect*
Hydrodynamics:	water level	reduced at bankfull discharge -> earlier floodplain inundation	H
	flow velocity	reduced at bankfull discharge due to decreased hydraulic radius	H
	shear stress	reduced at bankfull discharge due to decreased hydraulic radius	H
Sediment dynamics:	transport capacity	reduced at bankfull discharge due to decreased hydraulic radius	M
	continuity	-	
Morphodynamics:	substrate	increased morphodynamics at the banks	M
Ecology:	habitat diversity	increased habitat diversity at the banks	M

*H – high; M – medium.

Table 4: Measure against sedimentation example: Opening of ship locks for local desedimentation

	Parameter	Effect*			
Hydro-dynamics:		Upstream		Downstream	
	water level	decreased	M	increased	L
	flow velocity	increased	H	decreased	L
	shear stress	increased	H	decreased	L
Sediment dynamics:	transport capacity	increased	L	increased	L
	continuity	increased	M	increased	L
Morpho-dynamics:	substrate	increased morphodynamics	M	increased morphodynamics	L
Ecology:	habitat diversity	restoring spawning habitats by preventing colmation	L	increased	L

*H – high; M – medium; L – low.

- Assessment of the costs

In the frame of CEA, the costs should be addressed to financial costs. In economic terms, financial costs represent the costs of providing and administering a service. They include beside the capital costs all operation and maintenance costs. It is estimated that a monetary assessment of financial costs of the measures will be in most cases difficult. Cost elements (maintenance, construction) are included in the factsheets, and in cases where cost information could be obtained, they were provided, for example for measures which were already implemented.

For the rest, a qualitative approach has been used that assesses the cost effectiveness in the same way as the assessment of the effects (High, Medium, Low). This qualitative approach admits a certain level of uncertainty, since every implemented measure is case-specific in terms of costs. This is the reason for not ranking the measures in terms of a classical CEA.

A detailed assessment of the costs could be further performed based on proper feasibility studies. This would require a larger pool of staff and sufficient time to collect the necessary information on the costs associated with each measure.

Conclusions

The morphological processes erosion and sedimentation, which result from the alteration of the sediment regime, set the key elements of sediment measures and the two major categories: measures against sedimentation and measures to stop bed erosion. Thus, morphological parameters, on which the measures act, are implicitly interlinked with improving the sediment regime, be it erosion or sedimentation (changing in sediment regime; increase/decrease of bed resistance; reduction/increase the energy slope and minimization/increase of bed shear stress).

The interruption of the longitudinal and lateral continuity by dams and weirs, flood protection and navigation embankment and regulation works as well as reduced sediment discharge directly influence the sediment deficit, which leads to riverbed erosion, especially downstream of the barriers. On the other hand, sedimentation is also significant in several sections along the Danube River and its major tributaries. Sedimentation in reservoirs is probably the most pressing concern facing river managers in present, and cause both upstream and downstream impacts. The sedimentation of water stretches can also make them unsuitable for navigation without regular dredging work.

The inventory of measures performed in the frame of the DanubeSediment project provides a wide range of specific sediment management measures both technical (engineering) and non-technical, i.e. of administrative, institutional or legislative nature.

In summary, we collected over 70 individual measures to improve the sediment regime from throughout the Danube River Basin and beyond. The examples we collected are in some cases part of more complex projects with multiple purposes and goals, among which there are measures in relation with the improvement of sediment regime. After comparing the examples, we condensed them into 38 generic measure types (15 regarding stop bed erosion and 23 against sedimentation, see Table 1).

The collection of measures indicates that there are different technical and non-technical solutions that can be adapted to suit to the conditions of a certain area. We recommend working with the inventory as follows: When choosing a measure that can solve a certain sediment problem, one needs to analyse the site-specific conditions and the effects that the measure would have at that exact location. The inventory shows that many measures are still in the phase of being developed (i.e. potential measures) and each measure needs to be adapted to the exact location and river conditions. At this point, all relevant stakeholders should be involved in the process, regarding their expertise and specific interests. Their cooperation is crucial to determine the feasibility of a measure. This can be done with CEA, physical and numerical modelling etc. You can find a list of experts working in river and sediment modelling in the Danube Region in the River Model Network collected by the DanubeSediment project).

In general, this report and the adjacent catalogue (Annex 2) and factsheets (Annexes 3a/b) aim to reach decision-makers and practitioners working in sediment management. In order to improve sediment management, it is essential that all Danubian countries work together on finding common solutions that will benefit both humans and nature in the Danube River Basin.

Further recommendations for transnational sediment management of the Danube and the main results of our DanubeSediment project can be found in the two main publications, the “Sediment Manual for Stakeholders” and the “Danube Sediment Management Guidance”.

List of Abbreviations

Art. - article
APSFR - Areas with Potential Significant Flood Risk
AT - Austria
BG - Bulgaria
BME - Budapest University of Technology and Economics
BOKU - University of Natural Resources and Life Science
BQEs - Biological Quality Elements
CEA - Cost Effectiveness Analysis
CEN - European Committee for Standardization
CIS - Common Implementation Strategy
DBA - Danube Basin Analysis
DE - Germany
DPSIR - Drivers-Pressures-State-Impact-Response
DRB - Danube River Basin
DRBD - Danube River Basin District
DRBMP - Danube River Basin District Management Plan
DRPC - Danube River Protection Convention
EAEMDR - Executive Agency "Exploration and Maintenance of the Danube River"
EEA - European Environment Agency
ERDF - European Regional Development Fund
EQS - Environmental Quality Standard
EU - European Union
EUSDR - EU Strategy for the Danube Region
FD - EU Floods Directive 2007/60/EC
FP EG - Flood Protection Experts Group
FRMP - Flood Risk Management Plan
GES - Good Ecological Status
GDP - Gross Domestic Product
GLC - Global Land Cover
HPP - Hydroelectric power plant
HR - Croatia
HRVODE - Hrvatske vode (Croatian Waters)
HU - Hungary
HYMO EG - Hydromophology Experts Group
IAD - International Association for Danube Research
ICPDR - International Commission for the Protection of the Danube River
IPA - Instrument for Pre-Accession Assistance

IPCC SRES - Intergovernmental Panel on Climate Change - Special Report on Emissions Scenarios
IzVRS - Institute for water of the Republic of Slovenia
JCI - Jaroslav Černi Institute for the Development of Water Resources
JDS - Joint Danube Survey
JRC - Joint Research Centre
LfU - Bavarian Environment Agency
NARW - National Administration "Romanian Waters"
NIHWM - National Institute of Hydrology and Water Management
NIMH-BAS - National Institute of Meteorology and Hydrology – Bulgarian Academy of Sciences
Non-EU - non-European Union Member State
NUV 2 - RBMP - 2nd River Basin Management Plan in Slovenia
NWRM - Natural Water Retention Measure
OECD - Organisation for Economic Co-operation and Development
PA - Priority Area
PPs - Project Partners
PSR - Pressure-State-Response
QEs - Quality Elements
REFORM - Restoring rivers for effective catchment Management project
RBM - River Basin Management
RBMP - River Basin Management Plan
RBSP - River Basin-Specific Pollutants
Rkm - River kilometre
RO - Romania
RS - Republic of Serbia
SAMS - Sustainable Asset Management System
SEPA - Scotish Environmental Protection Agency
SK - Slovak Republic
SI - Slovenia
SWMIs - Significant Water Management Issues
TEN-T - Trans-European Network - Transport
TUM - Technical University of Munich, Hydraulic Research and Water Resources Management
VUVH - Water Research Institute (Slovakia)
WFD - EU Water Framework Directive 2000/60/EC
WP - Work Package
WPLs - Work Package Leaders

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