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REstoring rivers FOR effective catchment Management

Deliverable D6.1 Synthesis of interim results

Title Synthesis of interim results for practical application to support the compilation of the 2nd RBMPs

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Dissemination Level

PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Summary

REFORM (REstoring rivers FOR effective catchment Management) is targeted towards development of guidance and tools to make river restoration and mitigation measures more cost-effective and to support the second and future River Basin Management Plans (RBMPs) for implementation of the Water Framework Directive (WFD). The project runs from 1 November 2011 to 31 October 2015. Its final products will hence become available too late for the 2nd RBMPs that need to be completed by 2015. That is why deliverable D6.1 has been defined as a means to make interim results available at a time when they can still be used for the preparation of the 2nd RBMPs.

Accordingly, deliverable D6.1 provides a synthesis of interim results for practical application to support the compilation of the 2nd RBMPs. It synthesises the results of WP1 in particular. The interim results from work packages WP2 to WP5 are synthesised in a form which can be applied to support the compilation of the 2nd RBMPs. The report also presents a strategy for making the information available to practitioners in an accessible way. It thus serves as a stepping stone between the scientific results from the work packages and the final information for practical use by a wider audience. This stepping stone will be used itself within the project to discuss the clarity and the pertinence of work package outcomes as well as the appropriate ways of presentation.

The input for deliverable D6.1 is provided by the following deliverables:

- Deliverable D1.1: Review on eco-hydromorphological methods;
- Deliverable D1.2: Review on effects of pressures on hydromorphological variables and ecologically relevant processes;
- Deliverable D1.3: Review on ecological responses to hydromorphological degradation and restoration;
- Deliverable D2.1: Multi-scale framework and indicators of hydromorphological processes and forms;
- Deliverable D4.1: Field protocols and associated database;
- Deliverable D5.1: Review of methodologies for benchmarking and setting end-points for restoration projects.

The strategy for making the information available to practitioners rests on the set-up and population of a wiki, i.e. a thematic and well-designed open-access web-based knowledge management system and the communication through the newsletter, and directly to the appropriate stakeholder groups such the CIS working groups, the ECRR network and relevant groups in social media. The WIKI is an effective tool for linking science to practice.

Acknowledgements

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Table of Contents

1 Introduction

REFORM (REstoring rivers FOR effective catchment Management) is targeted towards development of guidance and tools to make river restoration and mitigation measures more cost-effective and to support the second and future River Basin Management Plans (RBMPs) for implementation of the Water Framework Directive (WFD). Aims of REFORM are (1) to provide a framework for improving the success of hydromorphological restoration measures, and (2) to assess more effectively the state of rivers, floodplains and connected groundwater systems.

The research activities within the project have been organized in three modules covering "natural processes", "degradation" and "restoration and mitigation". The work packages (WPs) are nested in these modules, cf. Fig. 1.1. The project started with a compilation and meta-analysis of existing knowledge (WP1), reported till now in deliverables D1.1, D1.2 and D1.3. This is followed by scientific data analyses addressing hydromorphological, ecological and socio-economic processes (WP2, WP3, WP4 and WP5), reported till now in deliverables D2.1, D4.1 and D5.1.

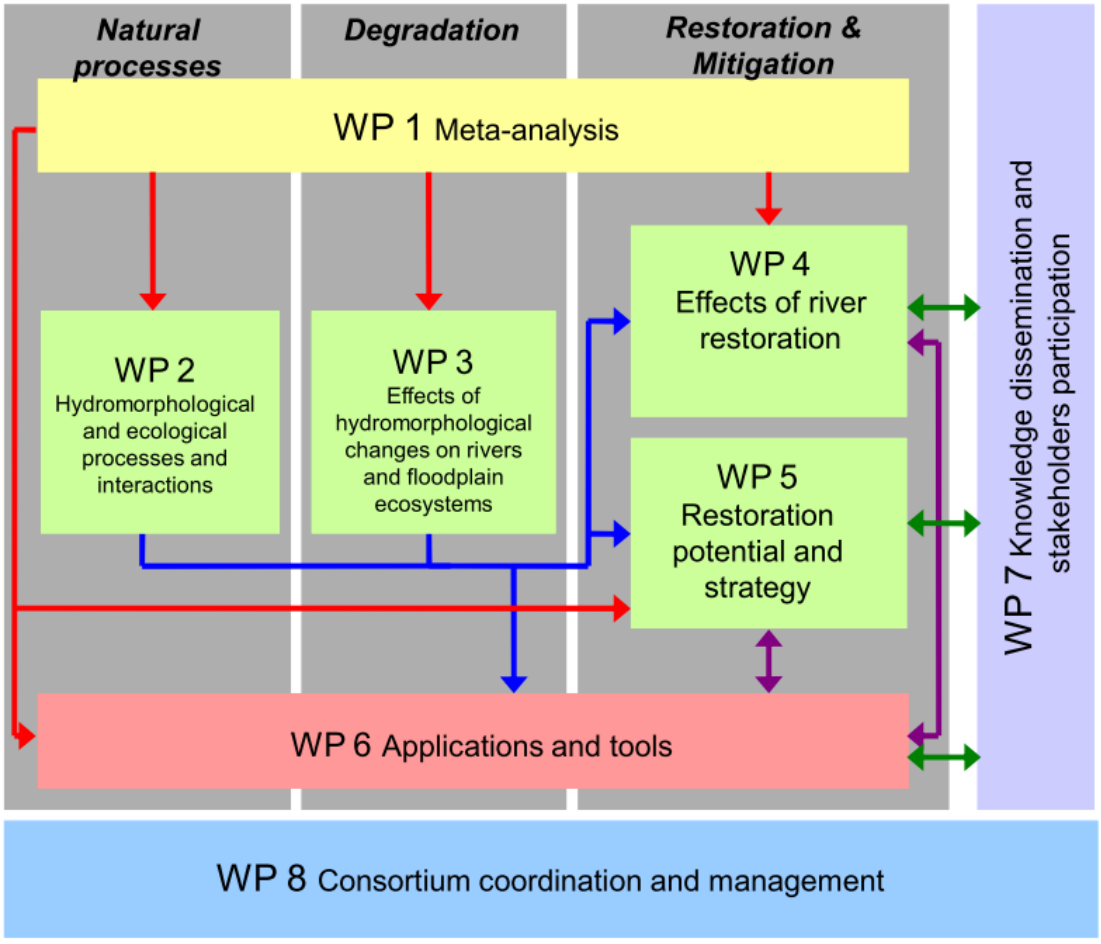

Figure 1.1 Work package structure of REFORM.

WP6 integrates the results from work packages 1 to 5 (WP1 – WP5) to develop methods, procedures, criteria and guidelines of practical applicability for stakeholders and river managers involved in monitoring and restoring the ecological quality, and the goods and services of rivers and floodplains. WP7 disseminates the knowledge developed in the project and actively involves stakeholders through questionnaires, interactive workshops and dissemination activities. WP8 has been set up for consortium co-ordination and project management.

The methods, procedures, criteria and guidelines developed by WP6 will help practitioners to:

- Assess the effects of hydromorphological pressures and restoration measures on river ecosystems and their goods and services;
- Assess the hydrological and morphological status of rivers in a more precise, comprehensive and cost-effective manner;
- Assess and synthesize the applicability of tools and models to support the assessment of hydromorphological state and ecological conditions of a river and prediction of possible impacts of restoration measures;
- Select the most cost-efficient restoration measures relative to particular catchment characteristics, states and processes, and other socio-economic activities and functions.

The present report, deliverable D6.1, synthesizes interim results of WP6 in order to make these results timely available for practical application to support the compilation of the second River Basin Management Plans (RBMPs). Moreover, the report presents a strategy for making the information available to practitioners in an accessible way. The central idea behind this strategy is the use of a wiki, i.e. a thematic and well-designed open-access web-based knowledge management system. This is an effective tool for linking science to practice. The wiki developed under REFORM builds upon the first-generation wiki for river restoration developed under the European FORECASTER project. The philosophy behind its design was to use the language of water management as the point of departure. The Water Framework Directive (WFD) terminology and categorization was used to design the structure for river typology, hydromorphological pressures, restoration and mitigation measures, and hydromorphological and biological quality elements. A straightforward and self-explanatory set-up prevented that users got lost and became discouraged and reluctant to explore the wiki. The FORECASTER and REFORM wikis have a simple multilayer approach linking geographical positioning with thematic clustering. A database holds the most essential facts meant to filter relevant case studies. The case-study wiki is the actual portal to inform users in brief, while links to background information allow multiple sources and forms of background information (DOI of peer-reviewed papers, photographs and movies, grey literature in multiple languages and web links).

The interim results in this report show which methods, procedures, criteria and guidelines are being developed in REFORM. This allows river basin managers to reconsider particular aspects of RBMPs while benefiting from the latest findings in the project. The interim results identify gaps in existing approaches and methodologies, and show the way

forward to fill these gaps. In this stage, nonetheless, final ready-to-use tools to fill these gaps are not available yet. Those will become available in the course of 2014 and 2015.

The river basin management planning process comprises nine identifiable components, with partly overlapping timing:

1. *Assessment of the current status of the river basin districts*: their characteristics, the impact of human activity and an economic analysis of water use;
2. *Setting environmental objectives for identified water bodies in the river basin districts*: including the establishment of reference standards and the classification of water bodies;
3. *Establishment of monitoring programmes for each water body*: to meet surveillance, operational and investigative needs;
4. *Gap analysis*: essentially determining for each water body any discrepancy between its existing status and that required under the WFD;
5. *Setting up programmes of measures*: the means by which water bodies' good status will be preserved or restored, as appropriate;
6. *Development of the river basin management plan*: essentially the pulling together of all the elements considered to date firstly in draft form for public consultation and then in final form for approval by Ministers;
7. *Public information and consultation*: the process by which stakeholders and the public are informed of progress with Directive implementation and consulted on the draft river basin management plans;
8. *Implementation of the programme of measures*: basically the period over which the measures in the plan are executed;
9. *Evaluation of effectiveness of the plan and the programme of measures*: the core of a six-yearly cycle of plan updates with the new plan being in place once the previous plan period is ended.

Six deliverables provide the input to the present synthesis of interim results. They are summarized in Sections 2.1 to 2.6 and support the river basin management planning process in the following ways:

- Deliverable D1.1: *Review on eco-hydromorphological methods*. This supports the assessment of the current status and the establishment of monitoring programmes in the RBMPs;
- Deliverable D1.2: *Review on effects of pressures on hydromorphological variables and ecologically relevant processes*. This supports the gap analysis in RBMPs addressing discrepancies between the existing status of water bodies and the status required according to the WFD;
- Deliverable D1.3: *Review on ecological responses to hydromorphological degradation and restoration*. This supports the gap analysis and the setting up of programmes of measures in the RBMPs;
- Deliverable D2.1: *Multi-scale framework and indicators of hydromorphological processes and forms*. This supports the classification of water bodies and the setting of corresponding environmental objectives in the RBMPs. The deeper hydromorphological insight provided by the framework enhances also the

assessment of the current status in RBMPs, in particular regarding the status of the hydromorphological quality elements;

- Deliverable D4.1: *Field protocols and associated database*. The results from testing the protocols in the case studies of the project will support the establishment of investigating monitoring programmes in the RBMPs to assess the effectiveness of measures;
- Deliverable D5.1: *Review of methodologies for benchmarking and setting end-points for restoration projects*. This supports the RBMP component of planning and evaluating the programme of measures.

2 Summary of early deliverables

2.1 Deliverable D1.1: Review on eco-hydromorphological methods

2.1.1 Objectives according to the Description of Work

Deliverable D1.1 "Review on eco-hydromorphological methods" is a summary report of the ecological and hydromorphological methods and metrics used in river management and restoration, with a hierarchy of ecologically relevant physical structures on different spatio-temporal scales and suggestion of a suitable eco-hydromorphological survey method. It derives from the activity carried out within Task 1.1 "Existing ecological and hydromorphological methods". This task regards a literature review of existing ecological and hydromorphological methods (indicators, tools and models) used in river management and restoration aiming to identify ecologically relevant physical structures on different spatial and temporal scales, and to understand and predict eco-hydromorphological responses to man-made physical change. The structure of D1.1 reflects the corresponding list of activities:

- Review existing methods, including all steps from field survey to data evaluation, all variables and processes involved and perform a critical analysis of the suitability of available models. This review is organized in two separate sections, one section on hydromorphological methods and one section on ecological methods;
- Compare existing methods to current hydromorphological theories at various spatial and temporal scales, to identify relevant, dynamic and potential parameters, processes, and data gaps;
- Review current metrics in use and add additional metrics if needed based on relevant bottlenecks for biota using results of current intercalibration works, ECOSTAT activities and analyses from Task 1.3. The deliverable identifies strengths, limitations and gaps, and provides recommendations for future progress in order to build the basis for improving existing or developing new assessment methods;
- Develop a process-based eco-hydromorphological framework and select indicators to generate new survey methods or improve existing eco-hydromorphological ones (input to Task 6.2).

2.1.2 Summary of results

Several ecological and hydromorphological assessment methods have been developed in different countries since the early 1980s, with notable differences in terms of aims, scales of application, and approaches. In many cases, strengths and limitations of the different types of methods are not yet sufficiently known, although they are widely used in some European countries. The objective of D1.1 is to provide an extensive overview on eco-hydromorphological assessment methods which are available for the implementation

of the WFD, and to identify strengths, limitations, gaps, possible integration of different approaches, and needs for future progress.

The main emphasis is on 'hydromorphological assessment methods', i.e. methods and procedures developed and used to characterize hydromorphological conditions and to classify the status of streams and rivers, including a review of indicators and parameters used within this context. According to the WFD, the assessment of stream hydromorphology requires the consideration of any modification to flow regime, sediment transport, river morphology, and lateral channel mobility.

After a preliminary review, five broad categories of hydromorphological assessment methods have been distinguished. Categories differ either according to the aim of the assessment (e.g. physical habitat, morphological or hydrological alterations, etc.) or the spatial context (e.g. channel vs. riparian zones) to which they are applied:

1. Physical habitat assessment, i.e. methods aiming to identify, survey and assess physical habitats;
2. Riparian habitat assessment, i.e. methods aiming to identify, survey and assess riparian habitats;
3. Morphological assessment, i.e. methods performing a geomorphological evaluation at broader spatial scales rather than a physical habitat assessment, incorporating morphological characteristics or human pressures;
4. Hydrological regime alteration assessment, i.e. specific methods for the assessment of hydrological regime alteration;
5. Longitudinal fish continuity assessment, i.e. specific methods for the assessment of the longitudinal continuity for fish communities.

For practical reasons, each method has been assigned to only one of the five categories, i.e. that category that best fits its characteristics, although some method might be classified in more than one category. This distinction enables a clear presentation of the main characteristics and scope of each method, as well as a better comparison between the methods.

The first stage was to review the general characteristics of a total of 139 methods (European and non-European). For each of the five categories defined above, the main information concerning each method has been summarized, allowing for a comparative analysis of the methods. The second stage of the review focussed on a selection of European methods (in total 21), i.e. those methods that have been formally approved or that are commonly used without formal approval by European countries for the implementation of the WFD. For each of these methods, deliverable D1.1 summarizes the scope, characteristics, recorded features and indicators, processes and strengths. It also presents a brief review of other tools and models used for a more detailed characterization, monitoring and analysis of physical habitats. Moreover, it reviews ecological assessment methods in use for determining the ecological status of European rivers. A total of 91 methods was considered, covering fish fauna, macrophytes, benthic diatoms, and benthic invertebrates from 27 European countries.

Based on the comprehensive review of existing methods, a series of strengths and limitations has been identified, first for each of the five categories of hydromorphological methods and then for the methods adopted by EU countries for the implementation of the WFD. This analysis reveals the main gap in most methods to be the insufficient consideration of physical processes in the assessment of hydromorphological conditions. With few exceptions, the hydromorphological analysis adopted in most EU countries is limited to a physical habitat assessment, which is only one component of an overall hydromorphological evaluation. This is an important limitation because a characterization of physical habitats alone does not provide sufficient understanding of alterations and their causes, i.e. insufficient understanding of pressure-response or cause-effect relationships. A good understanding is highly important for the successful implementation of restoration actions.

The Task 1.1 team thus recommends the development of a framework for integrated hydromorphological analysis, where the morphological and hydrological components (including functional vegetation) are key elements in the evaluation and classification of hydromorphological state and quality, while physical habitat and longitudinal fish continuity should represent additional components for a complete characterization of hydromorphological conditions.

An additional limitation was identified in the review of existing ecological methods. These methods are not able to assess the ecological response to hydromorphological pressures. Methods using fish fauna, macrophytes, and benthic invertebrates are not pressure-specific, which implies that they are not suitable for detecting ecological effects of hydromorphological pressures. Rather, they detect the effects of multiple pressures, for which hydromorphological pressures are only a part. Supplementary information characterising the pressures (hydromorphological and other) is required to identify problems and to plan appropriate measures.

2.1.3 Translation into form suitable for wiki

The five categories of hydromorphological methods in D1.1 are presented in the wiki as tools for the assessment of hydromorphological conditions. The structure of the presentation in D1.1 makes it easy to include the elements of each method in the wiki in a systematic manner:

- A brief summary of each chapter and section (a dotted box has been included at the top of each section);
- A figure highlighting the structure of method categories, in terms of spatial scales and context (Figure 2.1);
- A concise table listing the analysed methods for each country and category;
- Concise tables on the presence or absence of method characteristics, for each category of methods;
- Concise tables with descriptions of method characteristics, for European methods for implementation of the WFD;
- Tables listing the references and origins of analysed methods, for each category of methods.

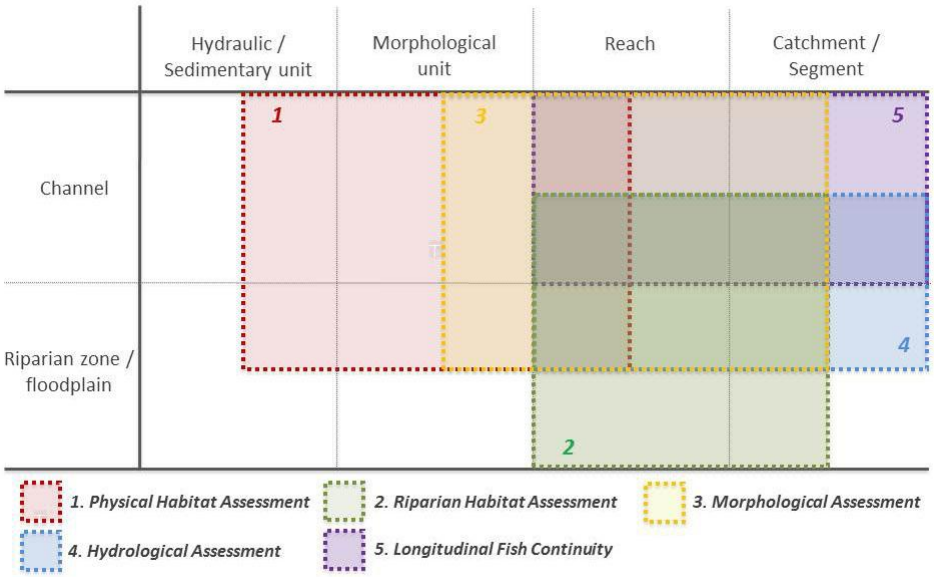

Figure 2.1 Spatial context, spatial scales and overlap between assessment method categories.

A sample output is given in Table 2.1, which gives an overview of one of the categories among the reviewed methods, i.e. category 3 regarding morphological assessment methods. Reference is made to D1.1 for overviews of other methods reviewed.

Table 2.1 Reviewed morphological assessment methods (category 3 in Fig. 2.1; for other categories see D1.1).

Morphological assessment methods				
	COUNTRY	CODE	KEY REFERENCES	ANALYZED REFERENCES
EU methods	Czech Rep.	HEM	Langhammer (2007)	Langhammer (2009); Matouskova et al. (2010)
	England	FA	Environment Agency (1998)	Branson (2005); Sear et al. (2008)
	England	SRH	Thorne (1998)	Original reference
	England	GAP	Sear et al. (2008)	Original reference
	England	MorphoAlt	EA TAM	Original reference
	France	SYRAH-CE	Chandesris et al. (2008)	Original reference
	France	AURAH-CE	Valette et al. (2010)	Original reference
	Italy	MQI	Rinaldi et al. (2013)	Original reference
	Poland	RHQ	Wyzga et al. (2009)	Original reference; Wyzga et al. (2009, 2012)
	Scotland	MImAS	UKTAG (2008)	Original reference; SEPA (2006)
	Spain	IHG	Ollero et al. (2007)	Original reference; Ollero et al. (2011)
	Spain	HIDRI-P1	Munné et al. (2006)	Original reference
Non-EU methods	Australia	RSF	Brierely & Fryirs (2005)	Brierley & Fryirs (2000); Fryirs (2003)
	South Africa	GI	Rowntree & Wadeson (2000)	Original reference; Rowntree & Ziervogel (1999)
	South Africa	GAI	Kleynhans et al. (2005)	Original reference; du Preez & Rowntree (2006)
	US	NCD	Rosgen (1996)	Rosgen (2006)
	US	WARSSS	Rosgen (2006)	Original reference
	US	CEM	Schumm et al. (1984); Simon & Hupp (1986)	Darby and Simon (1999); Simon et al. (2007)
	US	RGA	Moe (1999); Simon & Downs (1995)	CLOC (2011); Heeren et al. (2012); VANR (2010)
	US	SCS-RGA	MDEP (2009)	Original reference
	US	SCRS	Harrelson et al. (1994)	Original reference; McGinnity et al. (2005)
	US	CMA	OWEB (2000)	Original reference
	US	SAP	Starr (2009)	Original reference

Key outputs of deliverable D1.1 are already available in the wiki, accessible through the portal to hydromorphological assessment methods. Further links to subpages are available for each category of methods:

- European methods for WFD;
- Fish longitudinal continuity assessment;
- Hydrological regime assessment;
- Morphological assessment;
- Physical habitat assessment;
- Riparian habitat assessment.

2.2 Deliverable D1.2: Review on effects of pressures on hydromorphological variables and ecologically relevant processes

2.2.1 Objectives according to the Description of Work

Deliverable D1.2 "Review on effects of pressures on hydromorphological variables and ecologically relevant processes" is a summary report of the effects of pressures resulting both from degradation and restoration on hydromorphological variables and processes and the hierarchy of the most eco-hydromorphologically relevant impacts at various spatial and temporal scales.

2.2.2 Summary of results

European rivers have been altered by means of changing their morphology (straightening, training and canalization, disconnecting channels from flood plains, occupying riparian lands, building dams, weirs, bank reinforcements, etc.) in order to facilitate agriculture, transport and urbanization, to enable energy production and to provide protection against flooding. Also, water has been abstracted from rivers as a resource for irrigation and supply for urban and industrial needs, thus altering the natural flow regime. All these human activities have damaged fluvial habitats and have produced severe and significant impacts on the status of the aquatic ecosystems. These hydromorphological pressures are widely and commonly occurring pressures in European rivers, lakes and transitional waters, affecting more than 40% of all river and transitional water bodies.

Deliverable D1.2 is a bibliographic review concerning the effects of hydromorphological pressures on hydromorphological processes and variables resulting both from degradation and restoration. Based on this review, we aim to identify the most relevant hydromorphological effects of different types of hydromorphological pressures on fluvial systems across spatial and temporal scales, and, in particular, those effects that have a significant impact on aquatic biological elements. This bibliographic review also serves as a tool to identify gaps in present hydromorphological knowledge that is needed to improve

our understanding of the mechanisms that control degradation and restoration processes. In order to detect these gaps, D1.2 presents a conceptual scheme of the interactions between hydromorphological pressures, the main processes affected, and the resulting quantified changes on hydromorphological variables. The gaps are detected by comparing reference citation frequencies in relation to the different elements of this scheme.

The effects are analysed separately for each hydromorphological pressure. For this purpose deliverable D1.2 groups pressures into the following types:

- **Hydrological regime pressures in terms of water abstraction and flow regulation**: Here flow regulation includes hydrological regime modification (flow timing or quantity); hydropeaking; reservoir flushing; and sediment discharge;
- **River fragmentation pressures**
- **Morphological alteration pressures**: Impoundment; large dams and reservoirs; channelization (cross-section alteration and channel realignment); alteration of riparian vegetation; alteration of instream habitat; embankments, levees or dikes; sand and gravel extraction; and floodplain soil sealing and compaction;
- **Other elements and processes affected (physicochemical)**: Thermal changes; eutrophication (nutrient changes); and organic discharge.

For each pressure type the team developed a conceptual framework showing its explicit and direct effects on the processes and on the state variables. The main hydromorphological processes considered were:

- **Water flow dynamics**;
- **Sediment dynamics**: (a) sediment entrainment; (b) sediment transport; (c) sedimentation; (d) armouring;
- **Bank dynamics**: (a) bank erosion and failure; (b) bank stabilization;
- **Vegetation dynamics**: (a) vegetation encroachment; (b) vegetation uprooting; (c) vegetation recruitment;
- **Large-wood dynamics**: (a) large-wood entrainment; (b) large-wood transport; (c) large-wood deposition;
- **Aquifer dynamics**: (a) aquifer recharge; (b) aquifer discharge;
- **Other processes**: (a) Primary production; (b) heat exchanges; (c) reduction-oxidation reactions (redox).

A diagram has been developed for each pressure type, showing the direct effects on the main processes and state variables, along with the induced process changes with respect to hydromorphological variables. As an example, Figure 2.2 shows the diagram for the morphological alteration pressure of large dams and reservoirs.

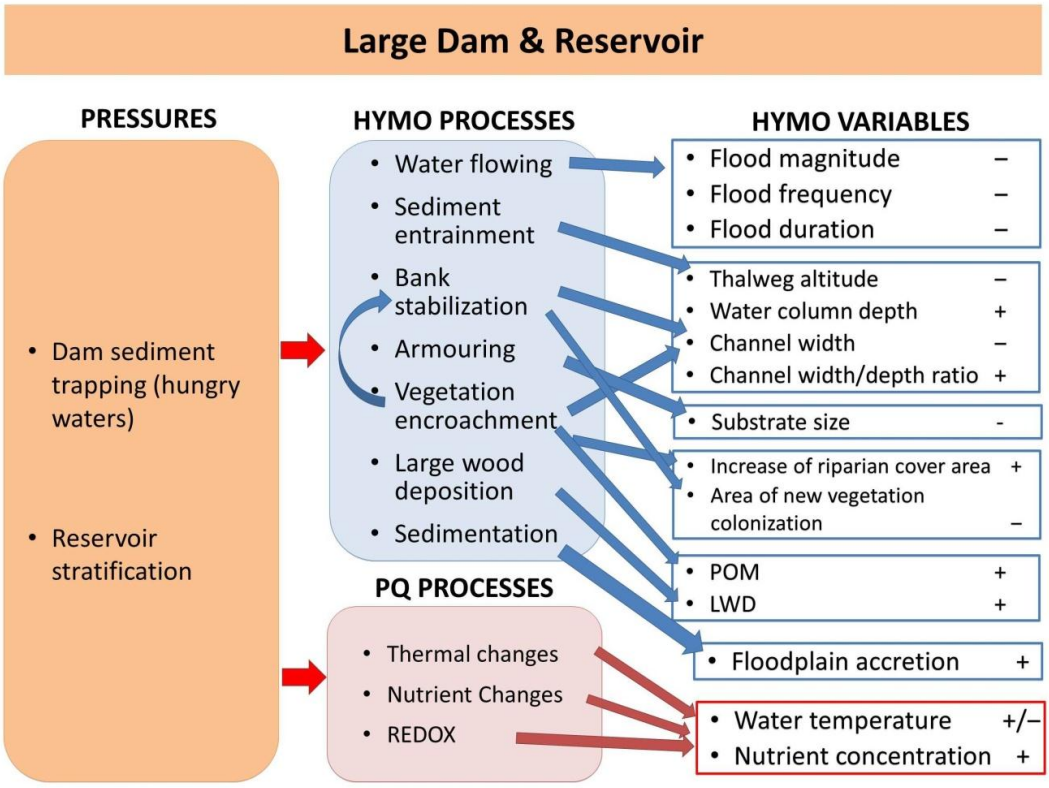

Figure 2.2 Conceptual framework of interactions between hydromorphological processes and variables caused by the morphological alteration pressure of large dams and reservoirs.

The quantitative variables are the variables that measure the intensity of the processes, and that are useful to monitor river changes and to evaluate pressure effects. In turn, these hydromorphological variables are the factors that provoke changes in the biological elements (impacts). Therefore care has been taken to select variables that are meaningful in relation to the biological elements, in order that impacts and recovery successes, such as degradation and improvement in ecological state, can be assessed and measured through changes in biotic components.

Main gaps in present hydromorphological knowledge have been detected though a comparison between issues found in literature and the conceptual scheme of the interactions between hydromorphological pressures, the main processes affected, and the resulting quantified changes of hydromorphological variables. These gaps present a focus for further research.

2.2.3 Translation into form suitable for wiki

The conceptual diagrams form concise representations of the effects of pressures. They will be pivotal elements of the pressures pages of the wiki. The diagrams, derived from reference citation frequencies regarding observations in the field, will be complemented in the wiki with physics-based diagrams of elementary hydromorphological responses to hydrological regime pressures and morphological alteration pressures. An example is given in Figure 2.3. The diagrams of elementary responses are based on the assumptions

of constant river plan form, no grain sorting, and no interactions with vegetation. They are hence merely building blocks for a mechanistic understanding of the conceptual diagrams, without capturing the full complexity of the latter.

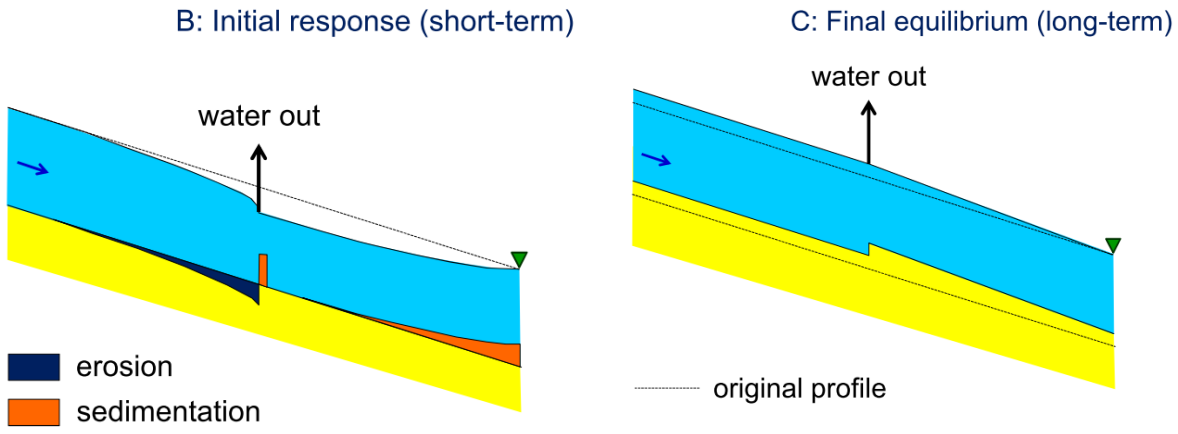

Figure 2.3 Physics-based diagram of elementary short-term and long-term hydromorphological responses to water abstraction.

2.3 Deliverable D1.3: Review on ecological responses to hydromorphological degradation and restoration

2.3.1 Objectives according to the Description of Work

Deliverable D1.3 "Review on ecological responses to hydromorphological degradation and restoration" is a summary report and a hierarchical classification of the known relations between hydromorphological changes and biotic responses of WFD relevant aquatic taxa with special reference to species tolerance curves and habitat bottlenecks. The main objective is to compile the available knowledge and data on quantitative and qualitative responses of biota to hydromorphological changes, including the potential effects of restoration.

2.3.2 Summary of results

The analyses have been strictly narrowed and conceptualised to the underlying mechanisms and bottlenecks in order to arrive at practical advice for river rehabilitation. This implied a focus on the most direct, measurable or assessable links between hydromorphological variables and biota. The analyses included:

- Identifying the relevant biological quality elements (BQE) of the WFD responding to hydromorphology;
- Identifying the key hydromorphological structures and variables;
- Identifying principal cause-effect chains for hydromorphology-biota interactions;

- Providing quantitative information and data for interaction strength, species requirements, species responses, tolerances, and limitations;
- Providing a contribution to the development of assessment and restoration evaluation tools as well as to an increased efficiency of measures.

Of the four mandatory BQEs of the WFD only macrophytes, benthic macroinvertebrates and fish respond sufficiently to hydromorphological changes to serve as indicator of hydromorphological degradation and as indicator of improvements or targets for hydromorphological rehabilitation of rivers.

Key biotic response chains have been developed to pragmatically simplify the complex interactions between various hydromorphological processes and variables to identify the key mechanisms and effects to which stream biota respond (Figure 2.4). Characteristic hydromorphological features and structures are primarily determined by the natural flow regime of a river, experienced by biota as **flow velocities** and **stream power**. Both maintain on one hand gravel sorting and coarse gravels. The latter emerged as key substrate indicating hydromorphological integrity with relevance to aquatic organisms. Correspondingly, taxa and species essentially depending on coarse gravel during their life cycle provide specific indicators for hydromorphological degradation and rehabilitation. On the other hand flow velocities and stream power set physical thresholds for habitat use and may become a limiting factor for species and life stages. Accordingly, data exploration and analyses were focused especially on species-specific responses to coarse substrates, reported gravel preferences as well as performance and thresholds in respect to flow velocity and stream power. However, quantifiable data on species response to hydromorphological changes are rather limited. Quantitative data on gravel size requirements were found for only 10 taxa out of about 500 described aquatic macrophytes species. Similarly, quantitative data on gravel size requirements were found for only 56 taxa out of more than 20,000 freshwater macroinvertebrates, and for only 28 taxa out of about 550 lamprey and fish species. Quantitative data on flow velocity thresholds were found for only 75 aquatic macrophyte taxa, for only 78 freshwater macroinvertebrate taxa, but for all fish taxa, the latter derived from regression functions based on total length.

Limiting effects from high flow velocities and stream power are naturally mitigated by habitat complexity providing shelter and refuges. Habitat complexity should be assessed at the spatial scale of functional process zones, i.e. at the reach scale of rivers, which requires biological indicators integrating at similar spatial scales.

Summing up the conceptual considerations, the analyses of interactions between hydromorphology and biotic responses of plants, benthic invertebrates, and fish focuses in all taxa on: (i) identifying sensitive indicators essentially depending on or responding to coarse substrates which are maintained by stream power showing hydromorphological integrity, (ii) determining thresholds of physical forces (currents, shear stress, wake wash) which limit habitat use and suitability for species, age groups, and growth forms in plants, and (iii) improving the indication of complex responses to habitat heterogeneity and hydromorphological integrity at the reach scale by further exploring and improving the concept of river zonation qualifiers.

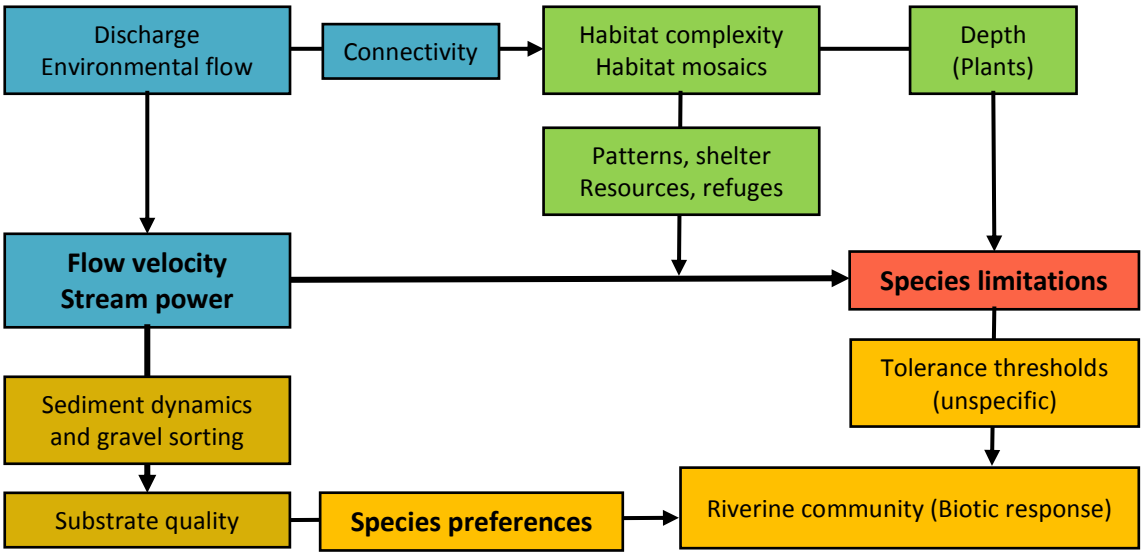

Figure 2.4 Conceptual flow chart of the basic elements and primary mediators of hydromorphology – aquatic biota interactions in rivers.

Macrophytes are considered as ecosystem engineers, which means that their occurrence, diversity, and distribution is still determined by abiotic factors and processes. Once established, however, macrophytes themselves actively affect local hydraulics, sediment dynamics, and fluvial landforms. The specific response of macrophytes to hydromorphological changes is rather weak, because nutrients, light, and turbidity are of similar significance for their growth and establishment. Data are provided for flow requirements and to a lesser extent substrate preferences of macrophytes. The most diverse plant communities, highest plant densities and largest varieties of growth forms are commonly reported from weakly flowing habitats (< 0.3 m s^{-1}) and stable, well rootable sandy substrates. Both requirements have limited discriminant power to detect hydromorphological degradations or to assess improvements by hydomorphological rehabilitation of rivers.

Benthic invertebrates are most widely used in environmental assessments and biomonitoring of human impacts. However, they respond nearly similarly to nutrients, nutrient inputs and resulting water quality alterations as to hydromorphological alterations. Correspondingly, pressures at larger spatial scales (land use, diffuse source pollution) are commonly reported as dominant impacts superimposing the specific response of benthic invertebrates to hydromorphological changes. Data are provided especially on the hydraulic habitat preferences of benthic invertebrates and their resistance to increased flow velocity and shear stress, but also on substrate preferences. Substrate size was a significant predictor of benthic invertebrate diversity and especially a high surface complexity of the particles was associated with high species richness. Physical and hydraulic habitat heterogeneity is the main structuring factor for benthic invertebrate communities, but other environmental triggers such as disturbances causing drift events, oxygen demands or the presence or absence of food resources might become controlling factors too. Plotting preferred substrate classes against shear stress

enabled identifying the invertebrate species for which the presence is not primarily determined by substrate or hydraulic preference.

Fish are the indicator organisms responding best to hydromorphological degradations. However, they integrate over larger spatial and temporal scales due to their mobility and longevity and should therefore be applied preferably at the reach scale. Data are provided especially on critical swimming performance of length classes, which determines physical thresholds for habitat use, and to a lesser extent on specific gravel size requirements for spawning. Open-substrate spawners can utilise a much broader variety of gravel calibres and substantially larger gravel diameters than brood hiders. However, a range in gravel size between 4 mm and 69 mm fits all. It is especially for fish that an indicator of preference for certain river reaches has been implemented and harmonised for 163 lampreys and fish species throughout Europe, which should allow for assessing hydromorphological habitat complexity as well as hydromorphological degradation and rehabilitation at the spatial scale of river reaches.

Uncertainties: Finally, a kind of uncertainty analysis is provided that refers in particular to uncertainties due to insufficient data. There are still huge knowledge gaps and widely insufficient data on specific ecological requirements and tolerances of lampreys and freshwater fish species, but also – to a much larger extent – on specific ecological requirements of macrophytes and benthic invertebrate species.

2.3.3 Translation into form suitable for wiki

Currently no elements from D1.3 are available in the REFORM wiki. In the near future, deliverable D1.3 will be presented in the wiki as a downloadable report. In addition, practitioners will be able to access relevant outputs through the link "Biological Quality" for the specific biological quality elements.

2.4 Deliverable D2.1: Multi-scale framework and indicators of hydromorphological processes and forms

2.4.1 Objectives according to the Description of Work

Deliverable D2.1 "Multi-scale framework and indicators of hydromorphological processes and forms" reports outputs from Tasks 2.1 and 2.2. It regards hydromorphological processes, forms and their relationships across scales, including methods for estimating the indicators and requirements for new data or survey approaches. This aims at filling the gap identified in deliverable D1.1 that most methods currently applied in European countries do not consider the physical processes sufficiently.

2.4.2 Summary of interim results

The multi-scale framework of D2.1 provides an approach to the assessment of hydromorphological processes and forms within river catchments. It aims to make best

use of currently available surveys of physical habitat, riparian habitat, morphological regime, hydrological regime and fish continuity, as well as readily-available (mainly free) Pan-European data sets. The framework guides users on:

- What information is required at which spatial scale in the context of the data sets that are available and any new data that may be needed;
- How the above information can be collected or generated, and how it can be analysed, in order to:
    - Describe and, crucially, explain variation in river character and behaviour within a catchment;
    - Provide users with a basis upon which they are able to understand past and present behaviour and to predict how a particular reach might react to changes (e.g. removal of local engineering modifications, flow regime naturalisation, reinstatement of longitudinal sediment connectivity);
    - Allow users to define potential, site-specific, "reference" conditions against which current hydromorphological and ecological conditions could be assessed.

The framework comprises five stages:

Stage 1: Definition of a hierarchy of spatial units. The units provide the framework within which relevant properties, forms and processes can be investigated to understand and assess hydromorphology and its potential impact on ecology (Figure 2.5). The units are arranged according to their relative size (indicative spatial scale) and persistence (indicative time scale). The reach is the key spatial scale at which the mosaic of features found within river channels and floodplains (i) responds to the cascade of influences from larger spatial scales and (ii) is influenced by interactions and feedbacks between geomorphic and hydraulic units and smaller elements such as plants, large wood and sediment particles within the reach.

Stage 2: Delineation methodology. For catchment assessment and management purposes, the aim is to subdivide the entire catchment into a complete set of units at all spatial scales from catchment to reach. In large catchments, this may not be possible, but it is necessary to subdivide the catchment to the scale of its major landscape units, after which representative subcatchments within each landscape unit can be analysed, delineating segments and reaches along the main channel and major tributaries for detailed analysis. For assessment of a particular reach or segment, a minimum assessment needs to focus on the specific reach or segment and larger spatial units that contain and are immediately upstream of the reach or segment under consideration.

Stage 3: Characterisation methodology. Characterisation of spatial units at the different scales attempts to draw together readily-available information, surveys, and data sets in ways that will promote understanding of the contemporary characteristics of the units and the linkages between them. Recommendations for characterisation take account of WFD requirements and make best use of existing pan-European and national data sets, including the outputs from physical habitat, riparian habitat, morphological, hydrological regime and fish continuity assessments, where they are available.

Stage 4: Indicators of contemporary condition. Based upon the information collected at the characterisation stage, key indicators of contemporary condition are identified at each spatial scale. In each case the degree to which these may be indicative of human alteration is also considered. The indicators include an 'Extended River

Typology', which applies to the reach scale and extends the current catchment-scale WFD typology.

Stage 5: Temporal dynamics. This last stage focuses mainly on the reach scale and assesses river dynamics and their sensitivity to particular controlling factors through three perspectives: the analysis of historical information, modelling approaches, and consideration of proximity to threshold conditions indicated by empirically-based formulae.

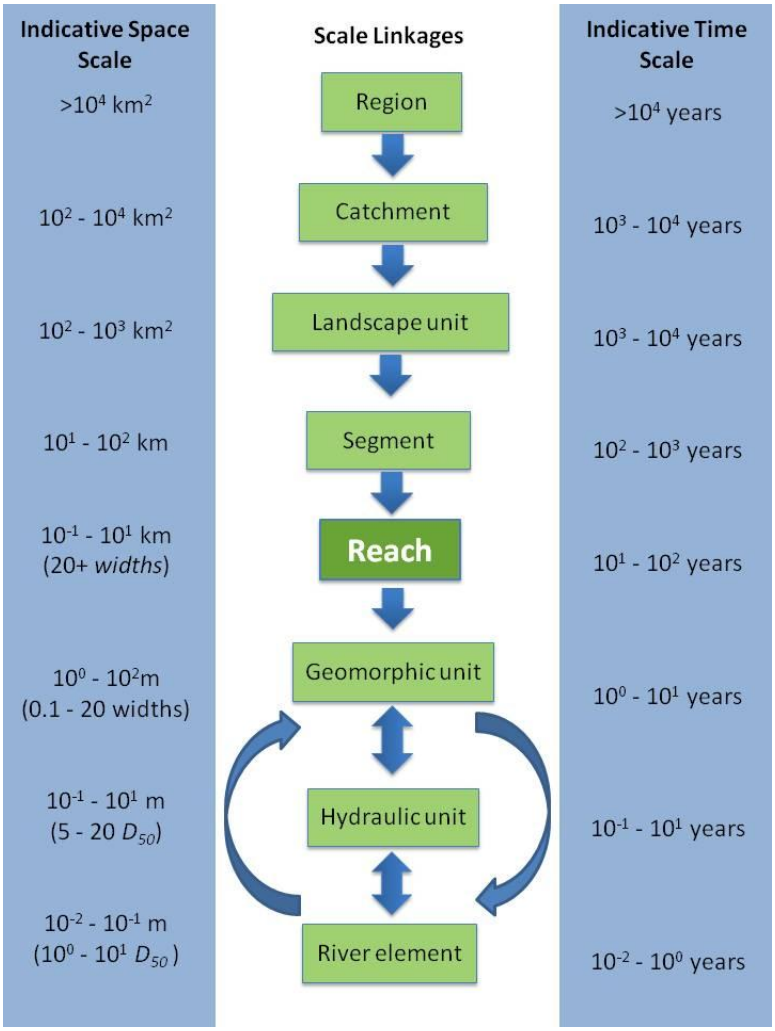

Figure 2.5 Hierarchy of spatial scales for the European Framework, including indicative spatial dimensions and timescales over which these units are likely to persist.

2.4.3 Translation into form suitable for wiki

Deliverable D2.1 will be presented in the REFORM wiki as an online framework to support methodologies of hydromorphological assessment, as an approach to understand hydromorphological processes at various temporal and spatial scales. Practitioners will access the deliverable outputs from the River Characterisation link on the REFORM wiki homepage. Once on the River Characterisation page, they will be presented with an overview of the hierarchical assessment framework and summaries of the key stages of analysis. The descriptions will be kept concise, supported by key figures to aid presentation of the topics and linked to PDFs of the full documentation. The

documentation will be divided into self-contained manuals for each of the key stages of the assessment, allowing practitioners to explore in detail specific aspects of the framework.

Deliverable 2.1 is currently available in the REFORM wiki in draft format. On the River Characterisation page, practitioners can read summaries of the framework and its stages, and can click on active links to the draft manuals. At present, the framework contains four of the five stages presented in Section 2.4.2: hierarchical definition, delineation of spatial units, characterisation, and indicators. However this structure will be modified and expanded in subsequent edits to accommodate a revised structure that will include temporal dynamics. There will also be expanded scientific descriptions of some elements in the form of Methodology Supplements and several case study applications of the proposed methods in the form of Methodology Illustrations. These elements are illustrated in Figure 2.6, where the blue squares are the wiki categories, red squares are content, and green squares are types of information. The orange square labelled practitioner summary will provide a brief entry point for those interested in using the methodology.

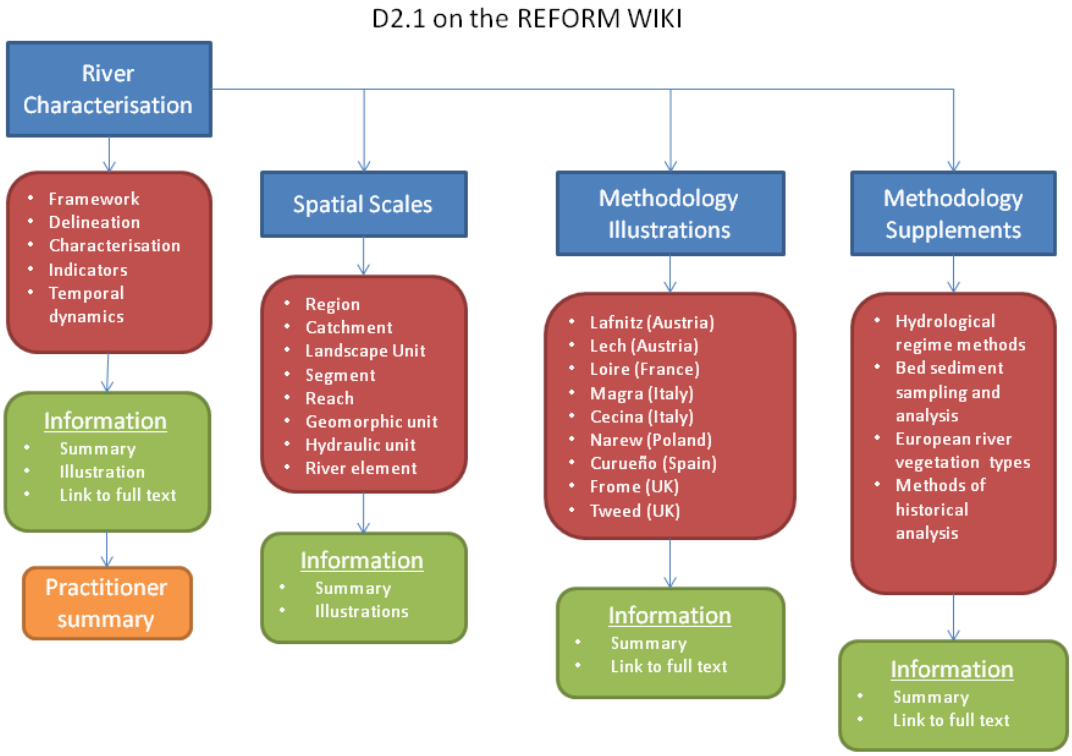

Figure 2.6 Planned structuring of information from D2.1 in the wiki

Sample outputs are already available in draft format on the River Characterisation wiki page. For example, the hierarchical framework (Figure 2.5) is illustrated. Further outputs will be developed, and captions will be revised to make them more self-explanatory.

Deliverable 2.1 can be accessed on the River Characterisation page. The spatial-scales subcategories are accessed from links at the bottom of that page. Brief descriptions have been included for spatial scales down to reach scale. Modelling approaches in

assessments of temporal dynamics will make use of the hydromorphological models compiled in the Tools pages of the wiki.

2.5 Deliverable D4.1: Field protocols and associated database

2.5.1 Objectives according to the Description of Work

Deliverable D4.1 "Field protocols and associated database" serves the preparation of the field studies in the paired river catchments of WP4. These field studies will use examples of restored sites in which either a single large-scale measure (flagship restoration site) or a set of smaller restoration measures (small restoration site) have been implemented. These restoration sites will be compared to "control sites" that are situated upstream and are still degraded (nested design). The field protocols of D4.1 serve as one of the components of the overall hydromorphological assessment developed in REFORM.

2.5.2 Summary of interim results

Deliverable D4.1 documents the abiotic and biotic parameters to be recorded at the case study sites and provides a description of the methods used within the project for field investigations in 2012 and 2013 including manuals, field forms and protocols. These are not the final methodologies of the project, but the methodologies to be tested. The final methodologies will be defined in WP6 and proposed in 2015. The following investigations will be performed at the case study sites:

- **Hydromorphological survey:** A CEN compliant physical-habitat survey method (adapted Austrian HyMo-survey method) will be applied in 4 sections per case study site;
- **Hydromorphological transect method:** Meso- and microhabitat composition will be measured at 10 transects per site;
- **Stable-isotopes:** The following groups will be sampled: periphyton; macrophytes; macroinvertebrates; stream-bed organic sediment (POM); riparian arthropods; terrestrial plants; terrestrial arthropods, and optional fish. The analysis aims at showing the effects of hydromorphological restoration on aquatic terrestrial linkages and on the complexity of food webs;
- **Fish:** The EFI+ manual will be the guiding line for fish sampling;
- **Macroinvertabrates:** The sampling of benthic invertebrates should follow an EU WFD compliant sampling protocol. Deliverable D4.1 recommends the multihabitat sampling standardized in the AQEM and STAR projects, which reflects the proportion of microhabitat types that are present with > 5% cover;
- **Macrophytes:** The survey of macrophytes includes all submerged, free-floating, amphibious and emergent angiosperms, liverworts and mosses and will be conducted in the main growing season (July to mid-September);
- **Riparian arthropods:** Riparian arthropods, especially carabid beetles, are good indicators for changing environmental conditions. They strongly benefit from the

creation of near-natural floodplain habitats including for instance unvegetated bars or vegetated swamps;

- **Riparian or floodplain vegetation:** This vegetation will be sampled in summer (June-July). Vegetation units will be classified to the order level at three hydromorphology survey transects. Within sample plots, plant species and their abundance will be sampled by estimating their coverage (~ abundance).

Deliverable D4.1 describes the selection procedure and final determination of the parameters and field methods, as well as the general sampling design and techniques. The site-specific record sets will be complemented by data at catchment scale. The integration of existing data is intended (1) as a substitute for data to be collected in the field (if current data on fish and invertebrates are available), and (2) as a data source to address additional questions, e.g. temporal developments. A database has been created for the management of the gathered data. It requires information entries on ten key subjects. Five subjects are abiotic: site information, hydromorphology, pressure types, restoration measure types, and physico-chemical data. The other five subjects are biotic: fish, invertebrates, macrophytes, riparian arthropods, and floodplain vegetation.

2.5.3 Translation into form suitable for wiki

Figure 2.7 shows how the information will be structured in the wiki.

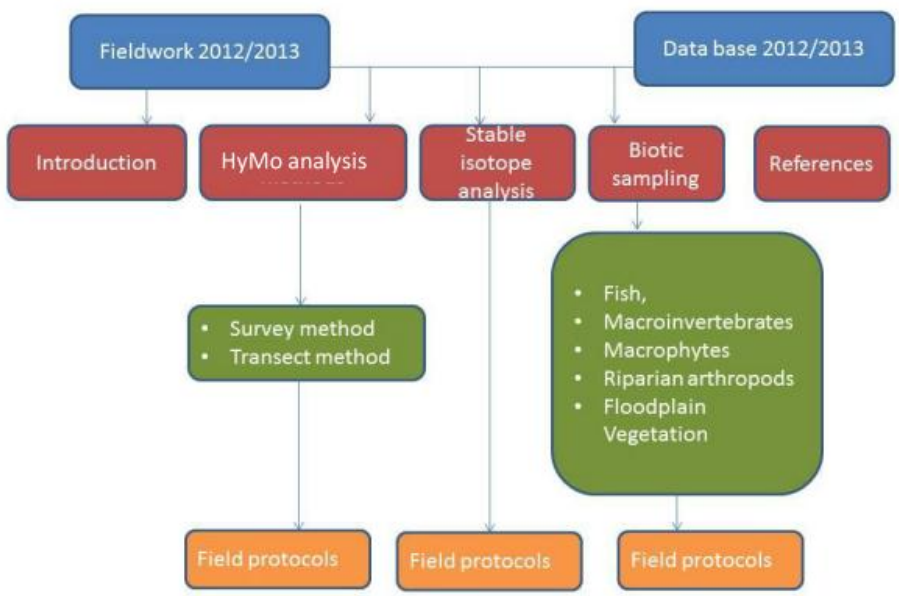

Figure 2.7 Planned structuring of information from D4.1 in the wiki

Furthermore, the information will be presented in concise tables and clear pictures. Several examples are given below. Links will be established to the descriptions of the case studies where the field protocols will be applied and evaluated.

Table 2.2 Sampling areas per survey target for field work at case-study sites.

	Sampling area	Sampling season
Hymo - survey	4x wetted channel width	Low flow in summer
Hymo - transect method: Channel features	The whole flood-prone area including aquatic, transient and terrestrial parts; in restored sections the terrestrial area comprises the bankfull discharge area, in degraded sections the area of high-water level ('flood marks'); maximum width of 200 m	Low flow in summer
Hymo - transect method: Microhabitats	Aquatic area	Low flow in summer
Macroinvertebrates	Aquatic area without oxbow lakes	Low flow in early summer (June to July)
Macrophytes	Aquatic area	Maximum growth in low-flow conditions (mid-summer)
Fish	Aquatic area (wadable and < 15 m width: whole channel surface; wadable and > 15 m width or boat fishing: partial sampling method)	Late summer - early autumn except non-permanent Mediterranean rivers in spring
Riparian arthropods	10 m strip of riparian areas	Late June (Mediterranean sites) to early August (Scandinavian sites)
Floodplain vegetation	The whole flood-prone area including aquatic, transient and terrestrial parts; in restored sections the terrestrial area comprises the bankfull discharge area, in degraded sections the area of high-water level ('flood marks'); maximum width of 200 m	Maximum growth in low-flow conditions
Stable isotopes	Aquatic, transient and terrestrial area; the terrestrial area comprises the whole flood-prone area + a strip across the edges of embankments for sampling of non-riparian beetles	Maximum of biomass

Table 2.3 Lengths of sampling sections

	wetted channel width < 50 m	wetted channel width > 50 m
Hymo - survey	4x100 m (4x200)*	4x500 m
Hymo - transect method	200 m	500 m
Macroinvertebrates	200 m	200 m
Macrophytes	200 m	200 m
Fish	10-20 times wetted channel width, with a minimum length of 100 m	
Riparian arthropods	200 m	500 m
Stable isotopes	200 m	500 m
Floodplain vegetation	200 m	500 m

*100 m if wetted channel width < 20 m, 200 m if wetted channel width > 20 m

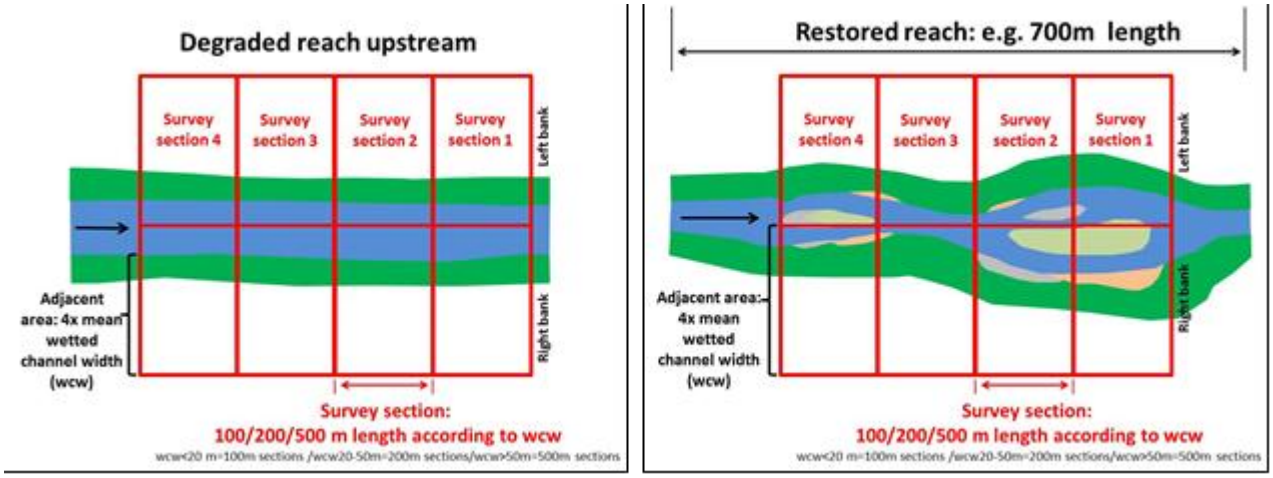

Figure 2.8 Investigation of four survey sections at degraded and restored site .

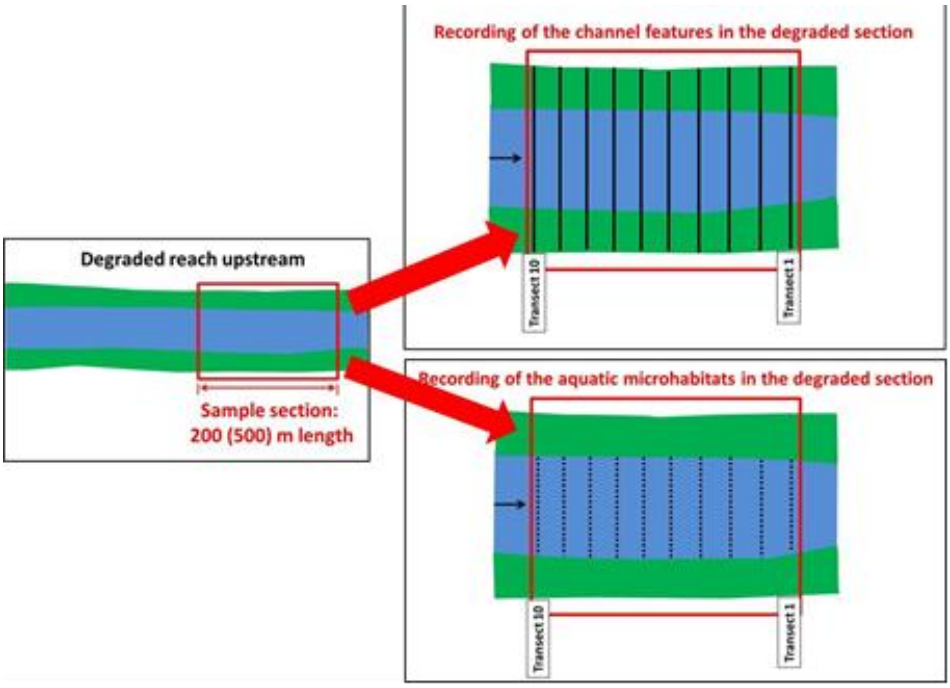

Figure 2.9 Sampling of channel features and aquatic microhabitats along ten transects in the degraded section (continuous black lines: transects for recording channel features; dotted black lines: transect segments for recording aquatic microhabitats).

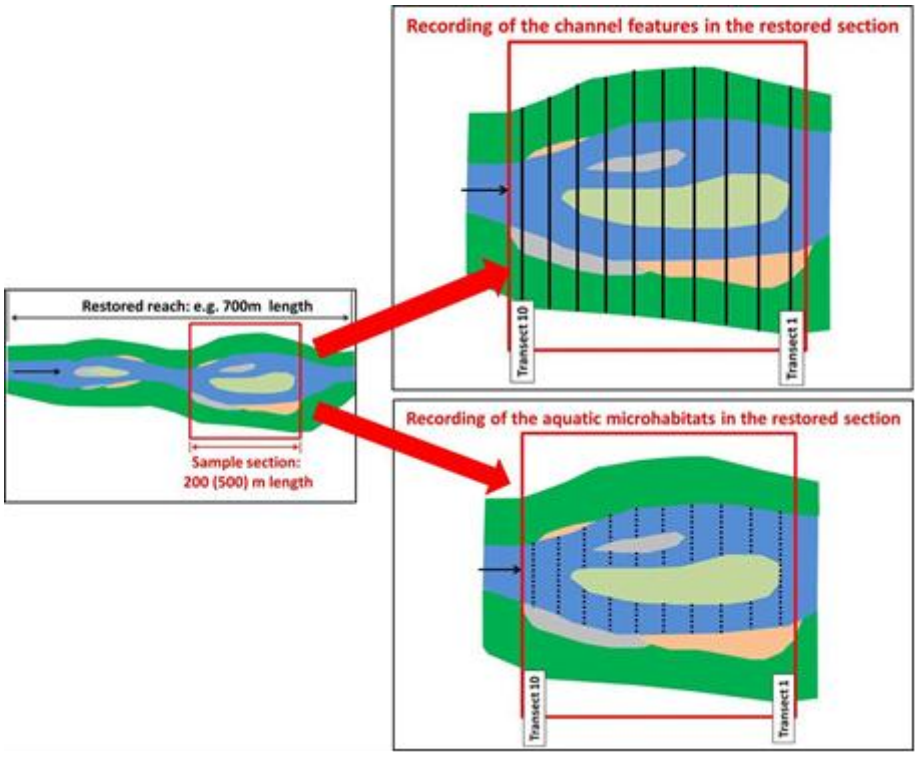

Figure 2.10 Sampling of channel features and aquatic microhabitats in the restored section (continuous black lines: transects for recording channel features; dotted black lines: transect segments for recording aquatic microhabitats).

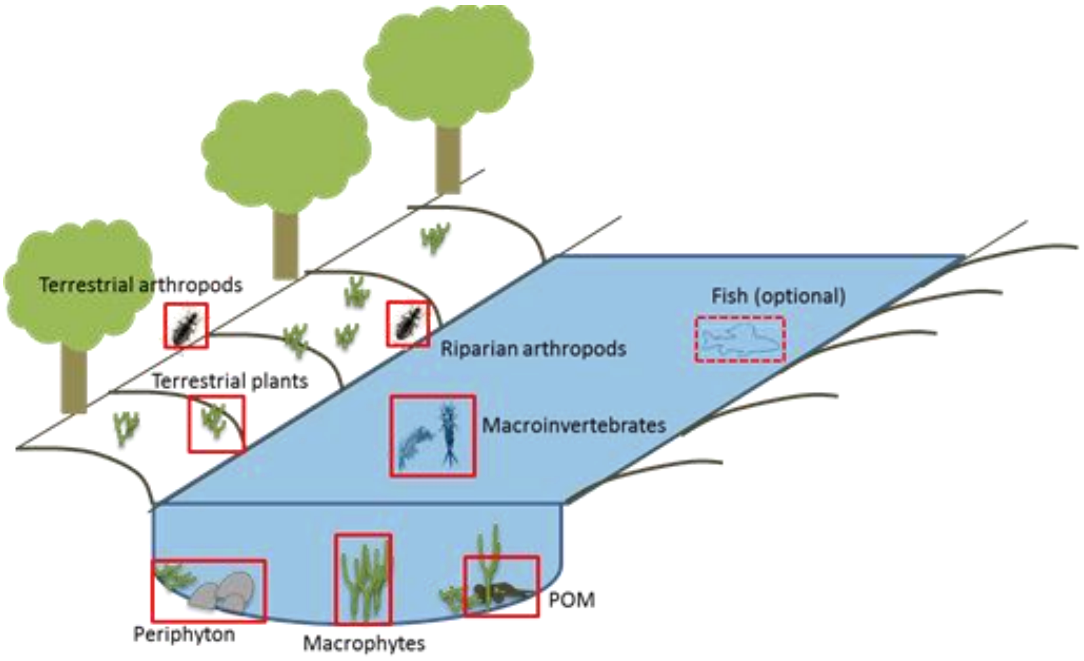

Figure 2.11 Overview of samples to be taken for stable-isotope analysis.

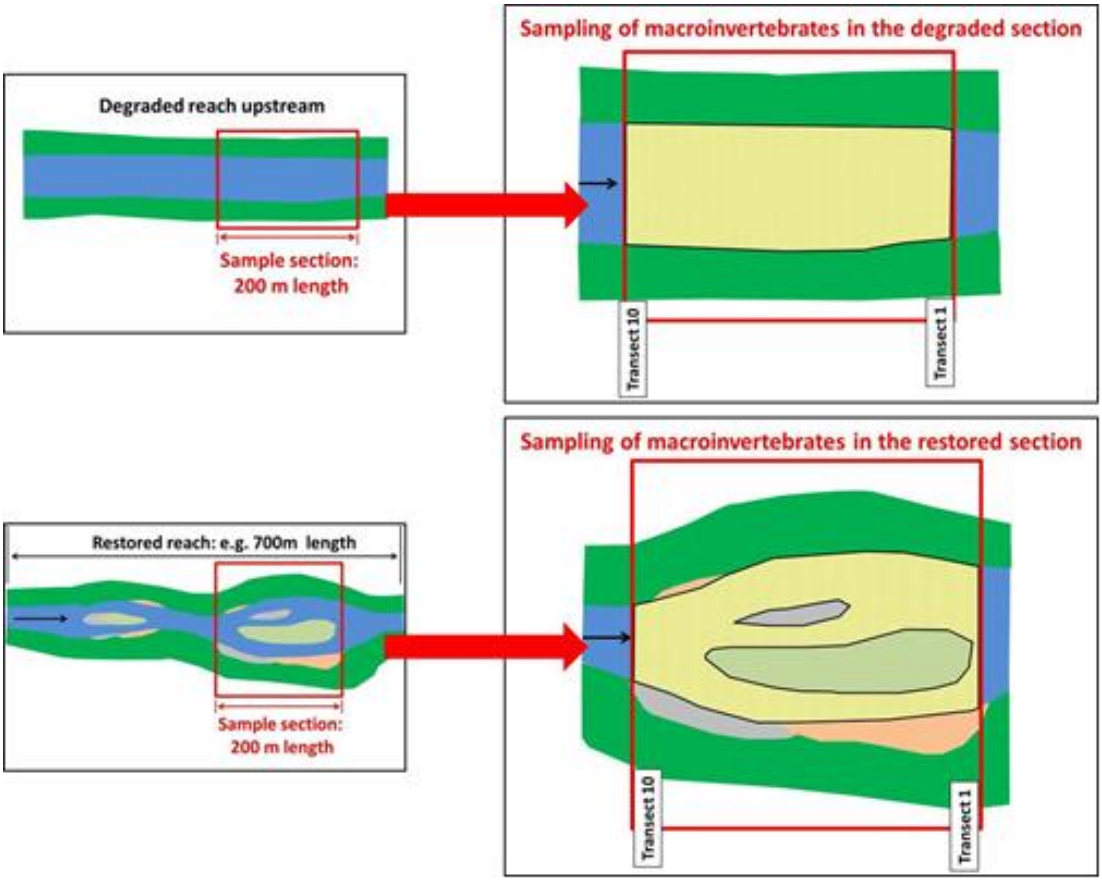

Figure 2.12 Sampling scheme for macroinvertebrates in the degraded and restored section (sample area is marked in yellow).

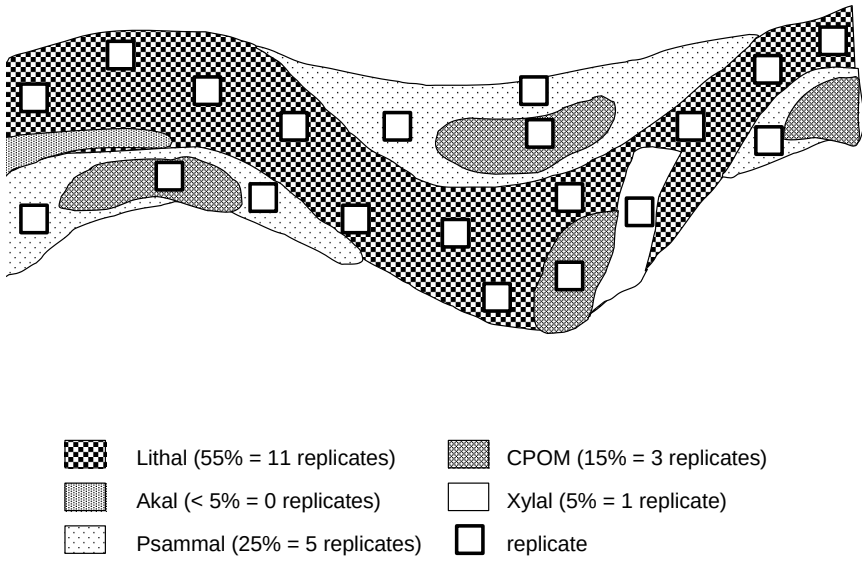

Figure 2.13 Example of "sampling unit" position in a theoretical sampling section according to the multihabitat sampling method applied in the AQEM and STAR projects.

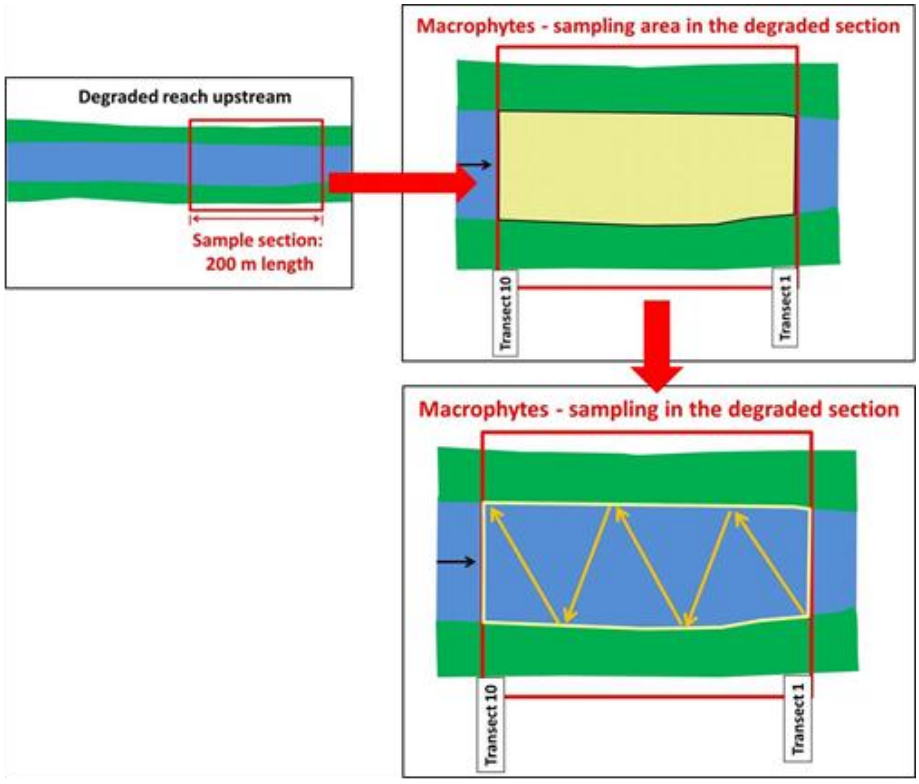

Figure 2.14 Sampling of macrophytes in a degraded section (sample area is marked in yellow; orange arrows show the way of wading).

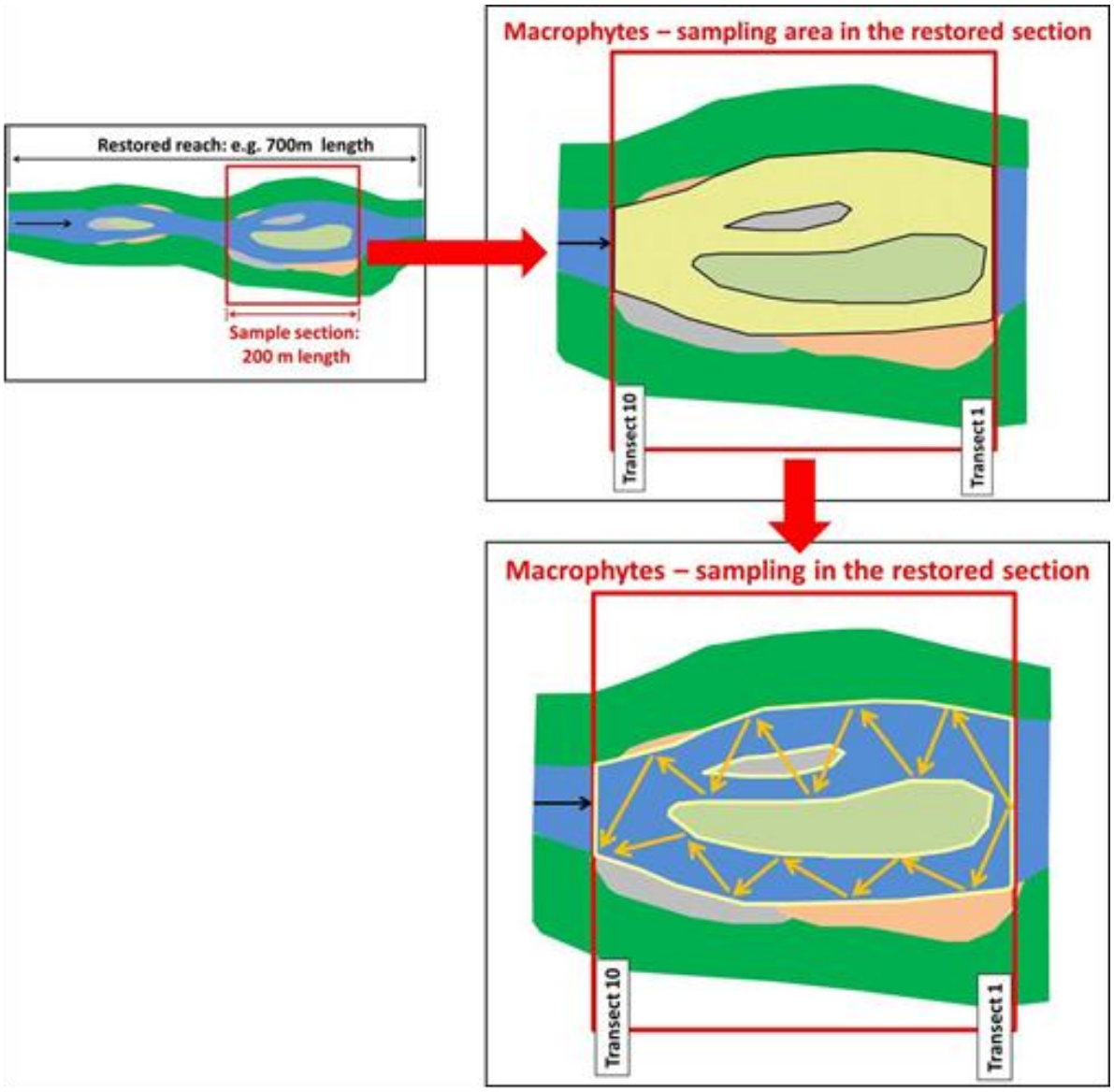

Figure 2.15 Sampling of macrophytes in a restored section (sample area is marked in yellow; orange arrows show the way of wading).

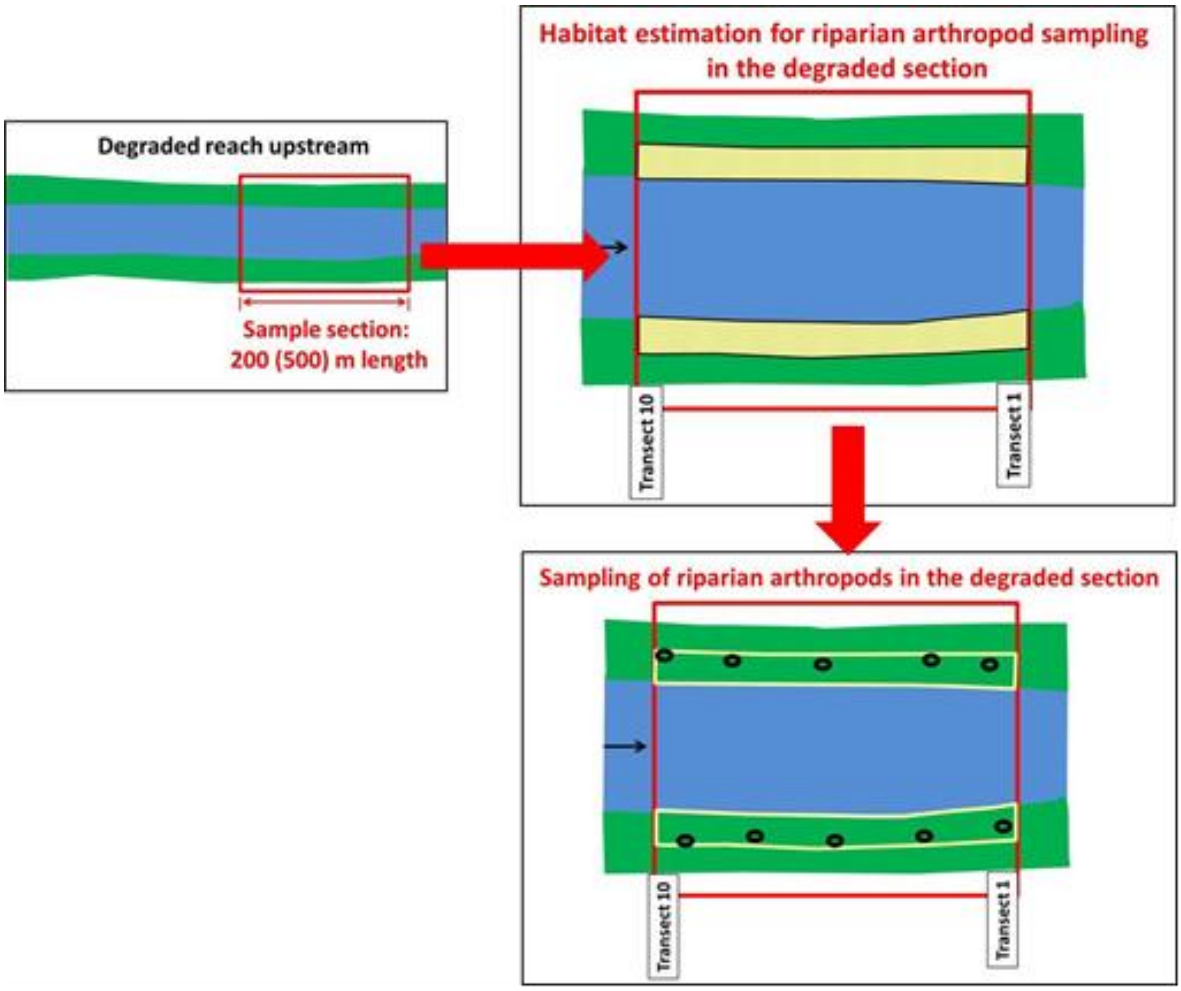

Figure 2.16 Habitat estimation and sampling of riparian arthropods in a degraded section (sample area is marked in yellow; black rings = pitfall traps).

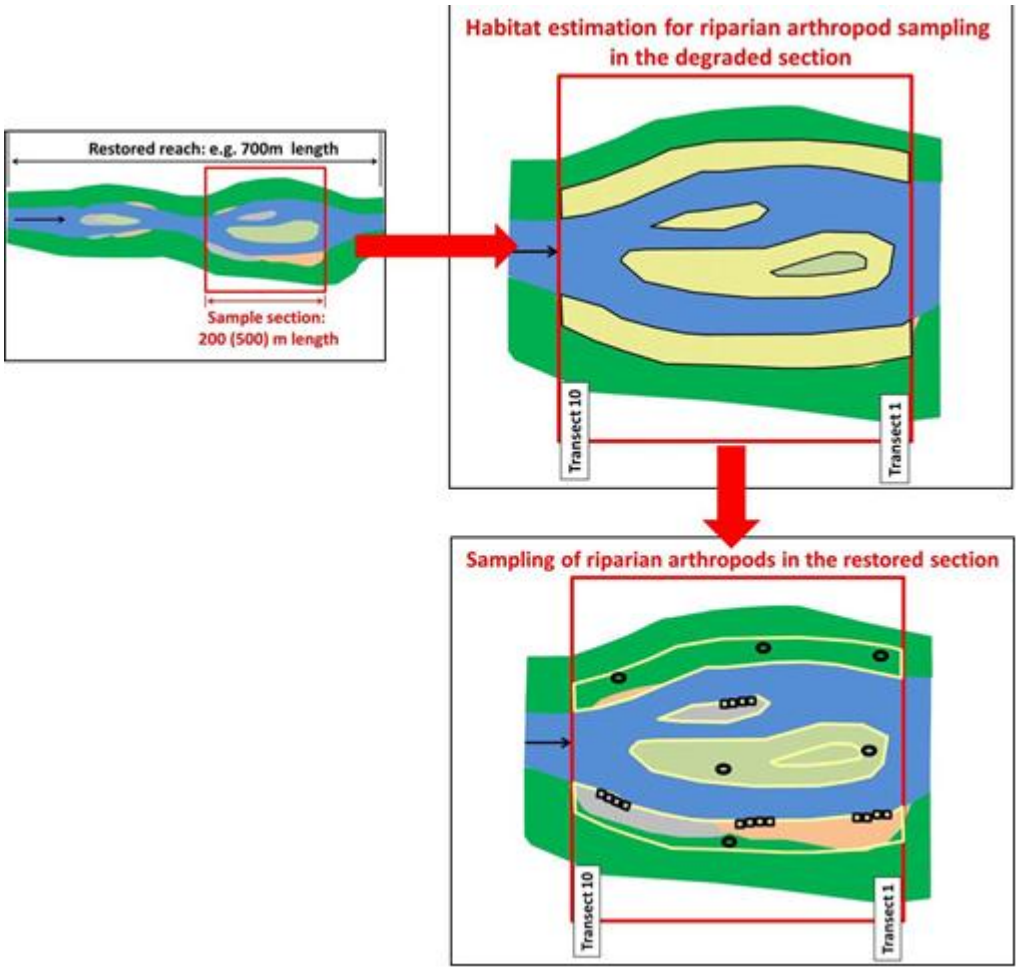

Figure 2.17 Habitat estimation and sampling of riparian arthropods in a restored section (sample area is marked in yellow; black rings = pitfall traps, row of black quadrats = hand collections).

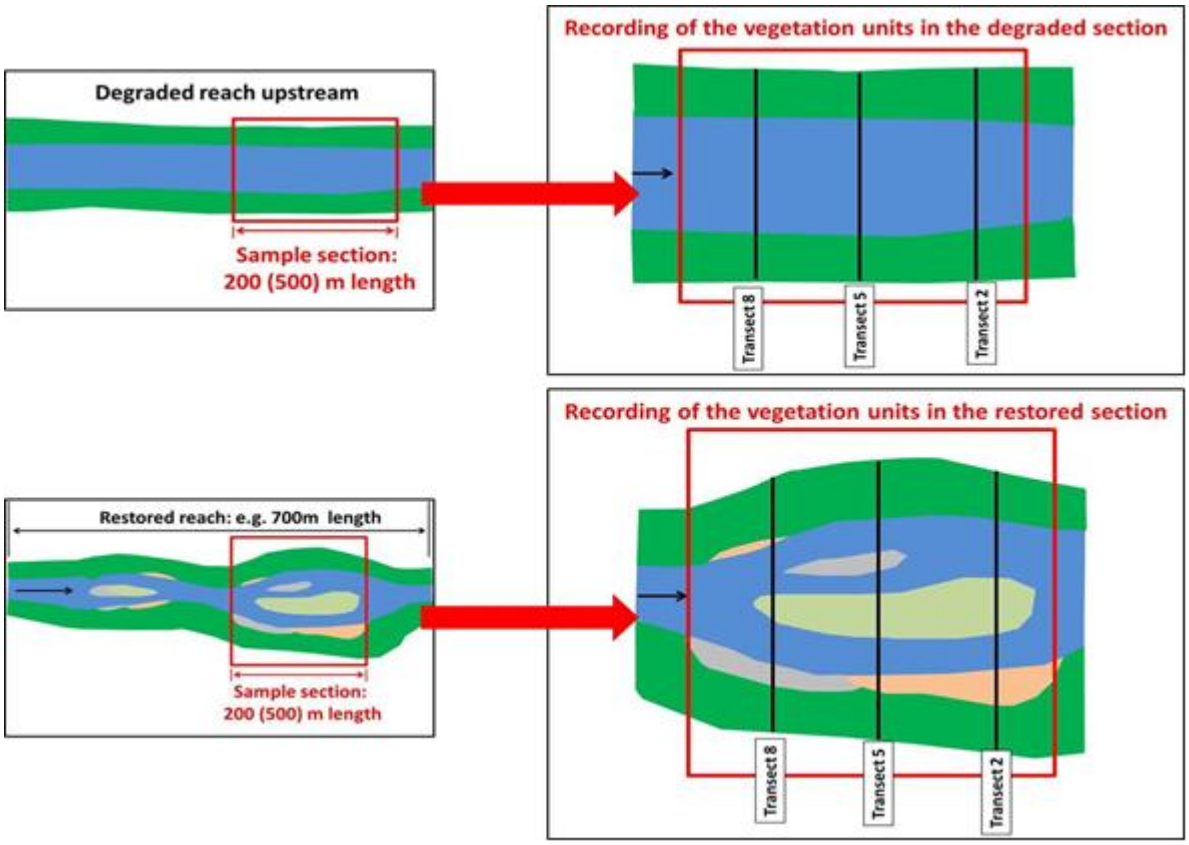

Figure 2.18 Sampling of floodplain vegetation units along three transects per section; black lines mark the three chosen transects.

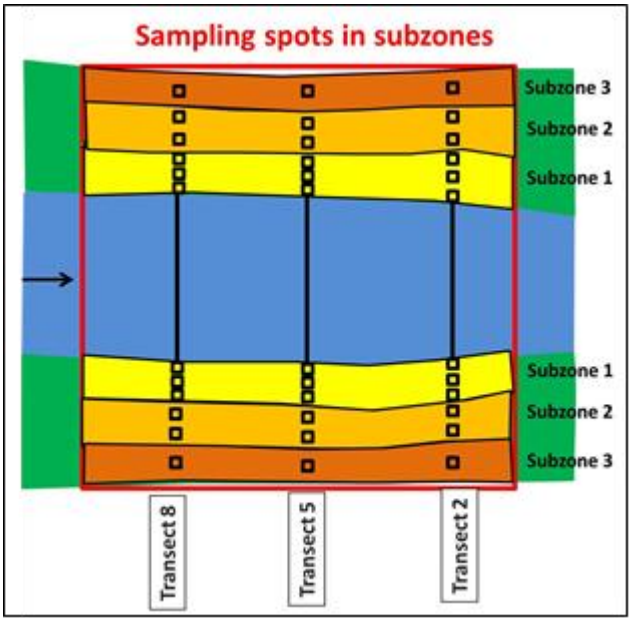

Figure 2.19 Sampling section of floodplain vegetation with sample plots in subzones 1-3 (black quadrats = sample plots).

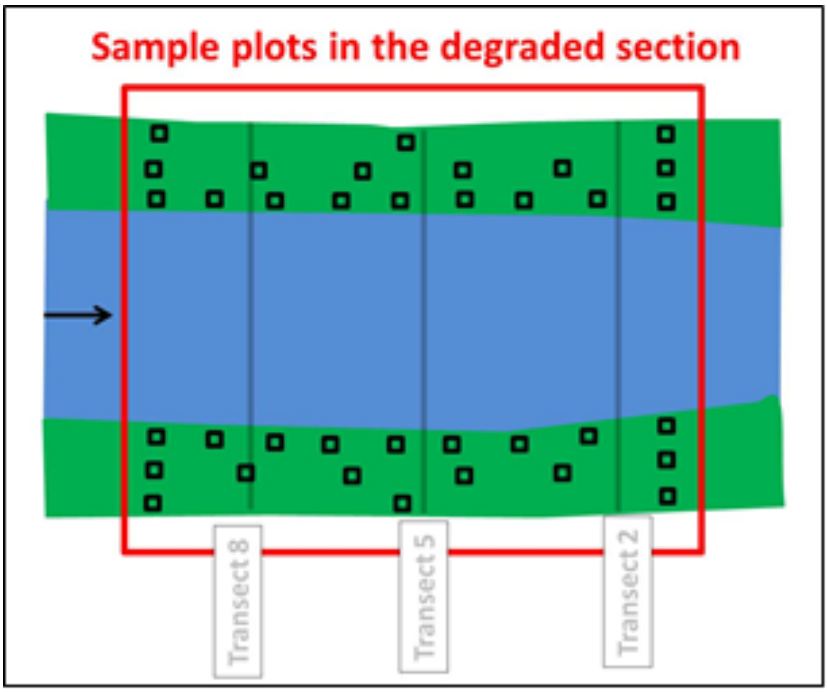

Figure 2.20 Sample section of floodplain vegetation with sample plots without reference to transects in case of floodplain width < 5 m at each side of the main channel (black quadrats = sample plots).

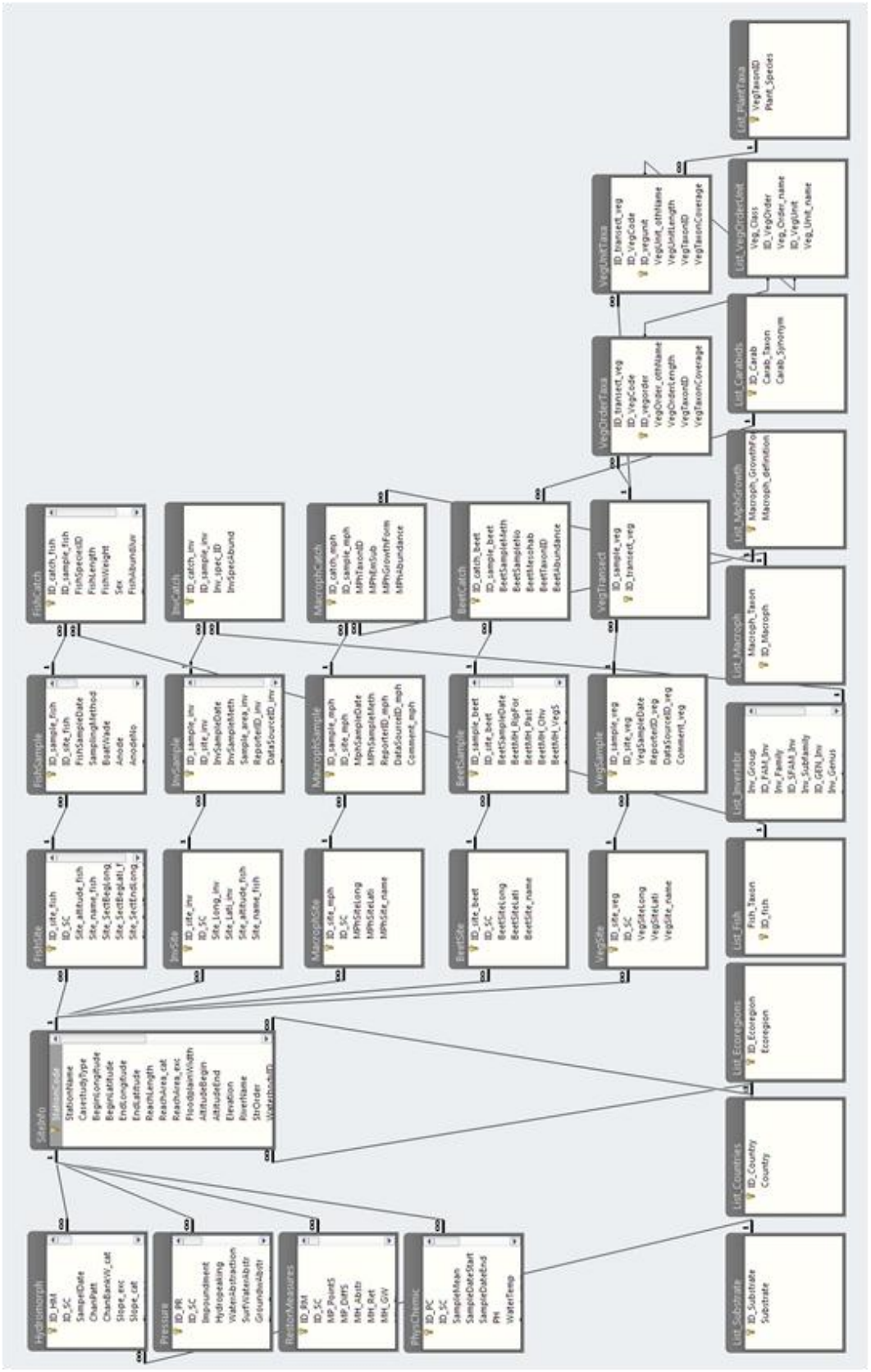

Figure 2.21 Relationships between several tables for the case-study database in Microsoft Access.

2.6 Deliverable D5.1: Review of methodologies for benchmarking and setting end-points for restoration projects

2.6.1 Objectives according to the Description of Work

Deliverable D5.1 "Review of methodologies for benchmarking and setting end-points for restoration projects" analyses metadata to quantify strategic end-points that are consistent with WFD objectives and can serve to evaluate the outcomes of restoration measures and the development of a protocol to set realistic quantifiable end-points for restoration projects.

2.6.2 Summary of interim results

With an increasing emphasis on river restoration, comes a need for new techniques and guidance. These are tools to assess stream and watershed condition, to identify factors degrading aquatic habitats, to select appropriate restoration actions, and to monitor and evaluate restoration actions at appropriate scales. Unfortunately, despite the rapid increase in river restoration projects, little is known about the effectiveness of these efforts. Restoration outcomes are often not fully evaluated in terms of success or reasons for success or failure. This seems an anomaly if restoration measures are to be carried out in an efficient and cost effective manner. REFORM strives to meet this need by developing a protocol for benchmarking and setting specific and measurable targets for restoration and mitigation.

Despite large economic investments in what has been called the *"restoration economy"*, many practitioners do not follow a systematic approach for planning restoration projects. As a result, many restoration efforts fail or fall short of their objectives, if objectives have been explicitly formulated. This often appears not to be the case. Some of the most common problems or reasons for failure include:

- Not addressing the root cause of habitat degradation;
- Not establishing reference condition benchmarks and success evaluation end-points against which to measure success;
- Inadequate monitoring or appraisal of restoration projects to determine project effectiveness;
- Upstream processes or downstream barriers to connectivity and habitat degradation that affect ecosystem functioning;
- Inappropriate uses of common restoration techniques ("one size fits all");
- No or an inconsistent approach for sequencing or prioritizing projects;
- Improper evaluation of project outcomes (real cost-benefit analysis);
- Poor or improper project design;
- Failure to get adequate support from public and private organizations.

To overcome these challenges and problems requires a decision support framework that will aid the development of restoration programmes or projects. One of the first steps in

this framework must be to establish benchmark conditions against which to target restoration measures. This requires i) assessment of catchment status and identifying restoration needs before selecting appropriate restoration actions to address those needs, ii) identifying a prioritization strategy and prioritizing actions, and iii) developing a monitoring and evaluation programme. The latter requires that objectives of the restoration programme are established against which the success can be measured. These targets or end-points of any restoration project should be specific, measureable, attainable, relevant and timely.

This work should take place within the context of the RBMPs for the WFD. Nevertheless, it is our impression that this diagnosis is inadequately specified and insufficiently quantified to identify the causes and bottlenecks of degradation. Thus, it does not necessarily help plan the most effective ways for improvement. Goals and objectives need to be set at multiple stages of the restoration process. There are multiple steps within each stage, but the initial stage is to identify end-points and benchmarks against which to measure performance. This needs to be reviewed against reference conditions, to determine appropriate targets for restoration, rehabilitation and mitigation activities. Unfortunately, this step is often missing from most restoration planning, although excellent examples exist on which to base the process).

To support this process, REFORM has developed a protocol in WP5 for restoration project planning that incorporates benchmarking and setting specific and measurable targets for restoration and mitigation measures (Fig. 2.22). The approach uses project management techniques to solve problems and produce a strategy for the execution of appropriate projects to meet specific environmental and social objectives. It provides knowledge of the technical policy and background to conflicts of multiple users of resources and develops a plan for comparison of status with objectives. Such resource planning should become an integral part of the river basin management, and full consultation with all aquatic user groups is essential to promote optimal, sustainable use of the water body whilst meeting WFD targets.

In using this strategy it is important to recognise that each restoration scheme proposal should be treated individually as no situation is alike. It is therefore impossible to provide threshold criteria on which to make decisions. In addition, sufficient information should be provided to evaluate the overall risk of a scheme not having environmental, economic and social benefits that is commensurate with costs. The decision support tools allow the proposal to be evaluated at different levels and stages and will effectively curtail a proposal at an early stage should the proposal be potentially impractical or unviable. The challenges faced to achieve sustainable river basin management include:

- proper valuation of resources and ecosystem services;
- precautionary approaches and principles;
- adaptive management systems;
- participation and commitment of all stakeholders;
- appropriate science and integrated management and approaches;
- reversal of the burden of proof - those exploiting the resources must demonstrate no ecological long-term changes (conservation-first perspective, precautionary principle);

- applying a stakeholder approach to decision making that recognises a larger set of beneficiaries.

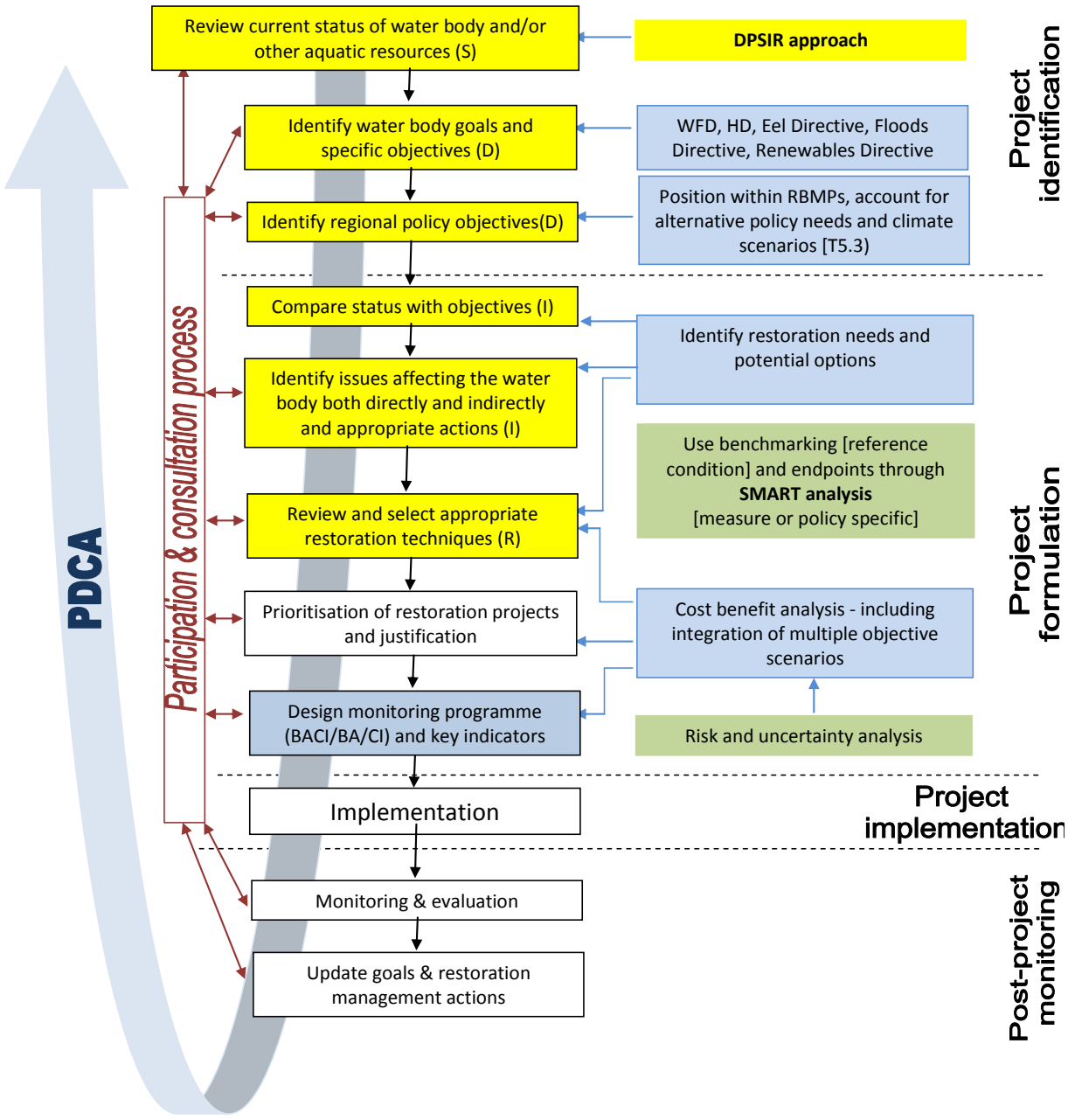

Figure 2.22 Proposed planning protocol for restoration projects - yellow coloured boxes represent steps in the DPSIR approach to management intervention.

Proper valuation of resources and ecosystem services is addressed within REFORM. An analytical framework has been developed for the estimation of ecosystem services delivered by restored and non-restored river corridors, i.e. the active river channel and its accompanying valley floor. The Millennium Ecosystem Assessment approach towards ecosystem services is adopted, but with a focus on final services, i.e. only those services are quantified that provide a net benefit to societal beneficiaries. A long-list of services

potentially provided by European rivers is provided and linked qualitatively to a river style typology developed in deliverable D2.1 to present the major services potentially provided by European rivers and their floodplains.

The appropriate spatial scale for a quantification of services provided is defined as that of a reach. Hence the method should cover extents of ~ 10 km and grains of ~ 100 m. From the reach, aggregation upwards to segments and catchments is feasible. The consolidated land cover classification of CORINE can serve to provide the mappable units, but requires additional fine-grained detail to specify the different habitats (or landscape elements, as specified in EUNIS) present in a reach as a mapped unit. The analytical framework starts from the mapped mosaic of habitat units within a reach and lists the potentially delivered services by each habitat. Subsequently, the exercise is re-iterated to assess whether a service is only provided at a larger scale by a combination of landscape elements, or over the full length and width of the floodplain and stream that can only be appreciated as a landscape. Then services are summed across the reach, generally as fluxes in biophysical units, and brought under the same denominator of economic value using benefit transfer functions. For several cultural services that have no market, direct field surveys using questionnaires are proposed. Such economic valuation methodologies for different services are briefly justified and procedures are outlined.

2.6.3 Translation into form suitable for wiki

As yet no steps have been made to translate the results from deliverable D5.1 into a form suitable for the wiki.

3 Detailed description of the structure of the wiki

3.1 Introduction

The REFORM wiki has a pivotal role in the translation of scientific outcomes to practical guidance for practitioners. The tool is based on a combination of a wiki proper and a database including geographical data (geo-wiki). This makes the tool flexible in the uptake of newly generated knowledge. Both REFORM partners and end-users (mainly river basin managers and water practitioners) will be able to contribute when additional information needs become apparent. The users will be able to upload their experiences and case studies according to a guided procedure and interactively discuss the best ways to restore rivers under the RBMPs.

Case study descriptions are in English while background information can be in either English or national languages. REFORM will facilitate this through an extensive glossary of terms in all languages of the consortium.

The description of work of REFORM summarises the contents of Task 6.4 as follows: "An information system (geo-wiki database developed by the IWRM-Net project FORECASTER) will be improved and adapted to help river restoration practitioners with the selection of appropriate measures, with the aim to provide information on the applicability and probability of success of given measures for particular catchment characteristics. The tool will present information about effectiveness of river restoration projects throughout Europe".

Each project will serve as a case study providing information about catchment characteristics, measures implemented, observed improvements in hydromorphological and ecological status, sustainability of these measures, scale of the project, and socio-economic benefits. Specific tasks are: to design an appropriate layout for the system in consultation with applied partners and end-users in the workshops; to populate the database with the information compiled in WP1 and WP4 on all restoration projects; and to fill in or update the wiki pages for hydromorphological pressures and restoration measures with the information compiled in WP1 and information derived from WP3 to WP5.

Figure 3.1 Screenshot of the Reform Rivers Wiki.

At the stakeholder conference (26–27 February 2013 in Brussels), the REFORM wiki was presented as one of the major dissemination tools for the knowledge generated in the REFORM project. Figure 3.1 shows the main menu view of the REFORM wiki. The wiki has been specifically designed to present the river restoration content as structured and as much to the point as possible. For that, the implementation consists of internet technologies: a wiki, a database (such as for case studies) and a geographical information part. The next sections describe the contents and detail the technical implementation.

3.2 Overview of wiki contents

The wiki is based on several bodies of information: case studies and attached documents; detailed descriptions of WFD elements; lists of pressures and restoration measures, and tools that help practitioners understand and quantify pressure effects and solutions. Using the wiki, end-users will be able to build upon existing knowledge and dissipate new knowledge by entering information from new case studies gathered in EU countries. The wiki is written in the language of the WFD and is in its core based on the wiki developed within the FORECASTER project.

The contents shown in the main menu (see left menu items in Figure 3.1) are detailed in Table 3.1. They show the main structure of the knowledge base of the wiki.

Table 3.1 Description of the wiki structure and its contents. Blue underscored items in the table are clickable and contain a direct link to the wiki.

Main menu item	Description
Homepage	Is the main entry page stating the aim and providing a general description of the wiki.
REFORM	Provides more detailed information on the REFORM project, showing links to the REFORM website.
River Characterisation	Describes the multi-scale hierarchical framework developed in REFORM. It is developed to establish standard river types and their associated processes. The characterisation helps the end-users understand the effects of pressures and measures as well select appropriate monitoring options and indices to capture relevant fluvial processes.
Pressures	Gives an overview and detailed information on hydromorphological pressure categories and individual pressures. Each individual pressure is described (under construction) and automatically linked to case studies in which it is addressed.
Measures	Gives an overview and detailed information on hydromorphological measure categories and individual measures. Each individual measure is described (under construction) and automatically linked to case studies in which it is applied.
Tools	Gives an overview of available tools, momentarily mainly hydro-morphological assessment methods and hydrological and hydromorphological models. Each tool is summarised and its applicability linked to scale and river characterisation types, WFD hydromorphological quality elements, WFD biological quality elements, pressures and measures.
Case studies	Shows the entries in the case study database both on a zoomable interactive map and in an alphabetical list. The map entries can be filtered on pressure type, measure type, presence of an evaluation, hydromorphological and biological quality elements addressed, ecosystem services, and EU policies addressed.
Biological Quality	Shows the WFD biological quality elements such as aquatic plants, macro invertebrates and fish. Every quality element is described and linked to case studies in which it is addressed.
HYMO Quality	Shows the WFD hydromorphological quality elements. Every quality element is described and linked to case studies in which it is addressed.

Ecosystem Services	Describes the ecosystem services of river systems, and links these services to the river characterisation types (under construction).
EU Directives	Describes relevant EU directives relating to hydromorphology and ecology in river systems, notably the Water Framework Directive, the Habitat Directive and the Floods directive.
Database	Links to the database section of the wiki. It enables certified users to add case studies, add tools, add pressure and measure types, edit the river characterisation types and more. More information can be found in the technical section of this chapter.
Related Sites	Gives relevant links to other information sources.
Contact Information	Gives contact information of REFORM and links to the REFORM main website.

The wiki contents are under development during most of the REFORM project because the project's results are added when they become available. The work is carried out in collaboration with the EU funded RESTORE project, in which a large project database is built up. REFORM provides possibilities to interlink between the RESTORE database and the REFORM wiki, especially when case studies overlap. REFORM does not aim at having the most extensive list of case studies, but at having a representative high-quality selection across countries, measure types and pressure types.

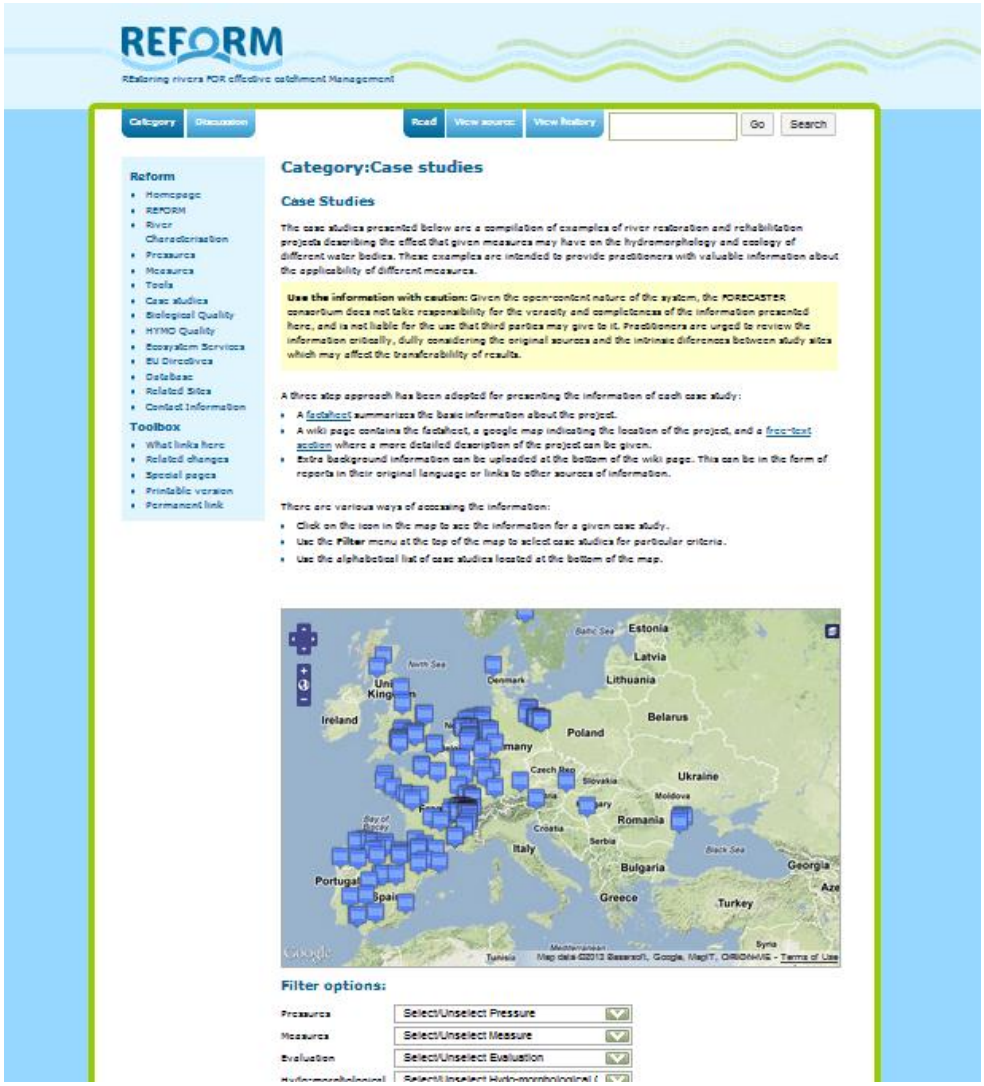

Figure 3.2 Case study page of the REFORM wiki, with a map showing the river restoration case studies.

Figure 3.2 shows an example of the main case-study view. Case studies inform the end-user of the nature and results of existing cases across Europe (although technically the system is not limited to Europe). The user can either browse an alphabetical list or filter the case studies shown on a zoomable map. Filtering is possible, for example, on the WFD biological en hydromorphological elements addressed, on the type of pressure mitigated or the type of measure applied. As the map is linked to Google maps, the end-user can view the project in high detail on aerial imagery. Once a case study of interest has been found, clicking the icon links to detailed information of the case-study, see for instance the example of Gameren in Figure 3.3.

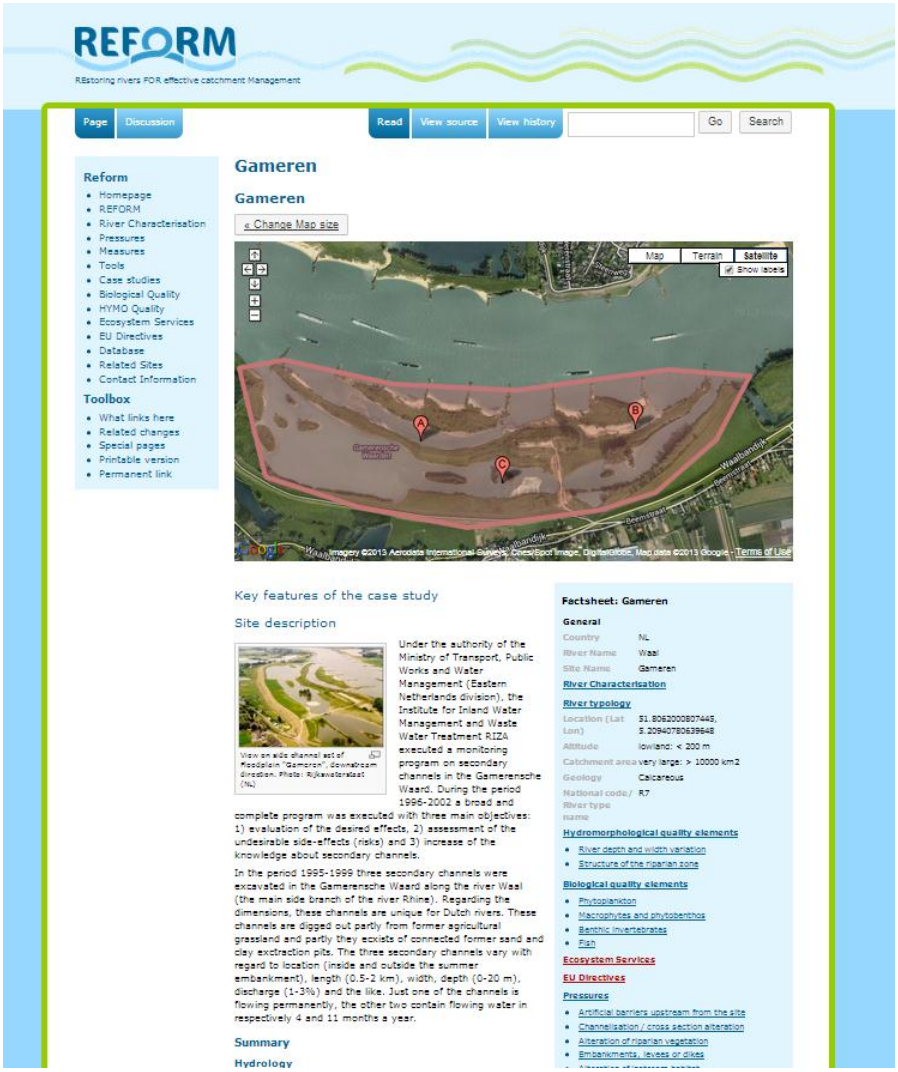

Figure 3.3 Gameren: example of detailed information on a case study. The right column shows standardised information entered into the database. The left column is wiki-based free text following standardised headers.

The information on case studies consists of factual information entered in the database, see the table left in the screenshot of Figure 3.3, descriptive information entered in the wiki, and attached documents. The descriptive information is free text but is structured by fixed section headers, uniform across all case studies. The factual information extracted from the database makes it possible to create interactive links to other wiki sections that characterise the case study such as the river type, the scale covered by the case study, the type of pressures addressed, the measures applied, the biological and hydromorphological WFD elements restored, etc. The technical section provides an overview of implemented wiki internal database links. As an example, you can select a case study, read it and click on a pressure in the case studies' factual table to find the pressure description and other case studies addressing the same pressure.

3.3 Technical structure

The concept of a Wiki has been popularised by Wikipedia and we apply that same technology in our REFORM wiki, see for more information: http://www.mediawiki.org/wiki/MediaWiki. Additionally, we included interactive maps showing river restoration projects across Europe that are directly linked to background knowledge within the wiki though a database. The database makes it possible to create interactive links between different elements in the wiki. For example, suppose the user wants to see all existing case studies that address the pressure "Channelisation / cross section alteration". Clicking on Pressures and subsequently on Channelisation / cross section alteration leads to the desired information. The page lists "Case studies where this pressure is present", which comprise all current cases that address this particular pressure. The database allows automatic updating of these links when for example a new case study is entered in the database.

Figure 3.4 shows the currently implemented links within the relational database. This "live link" feature enables the end-user to look up a restoration project and to immediately find other projects that address for example the same pressure, apply the same measure or evaluated the same biological component. Each newly added project is immediately linked into this structure and hence searchable. For now, adding projects and knowledge is limited to REFORM members, but this will be open to others in due time. The knowledge components shown in Figure 3.4 are based on the contents of work packages in the REFORM project.

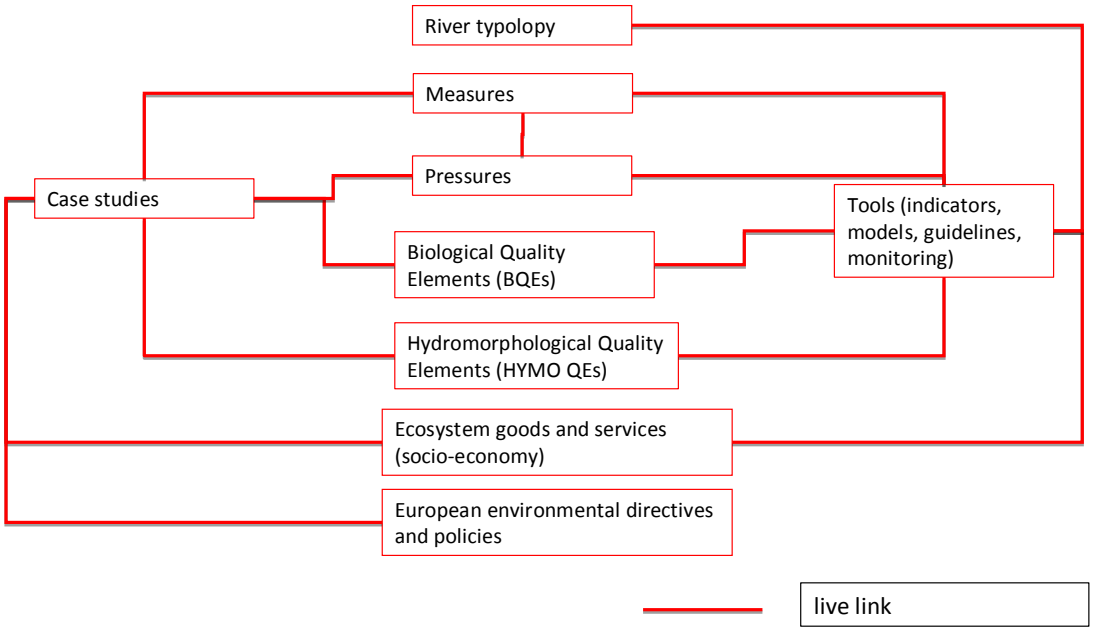

Figure 3.4 Internal structure of the wiki, showing "live links" between the knowledge components.

Certified users, who can apply for this feature by email, will be granted permission for access to the database. Figure 3.5 shows the switchboard. From here the user can access existing database entries and put in new entries in the following categories: case studies;

pressures; measures; measures & pressures; ecosystem goods and services; tools; and river characterisation.

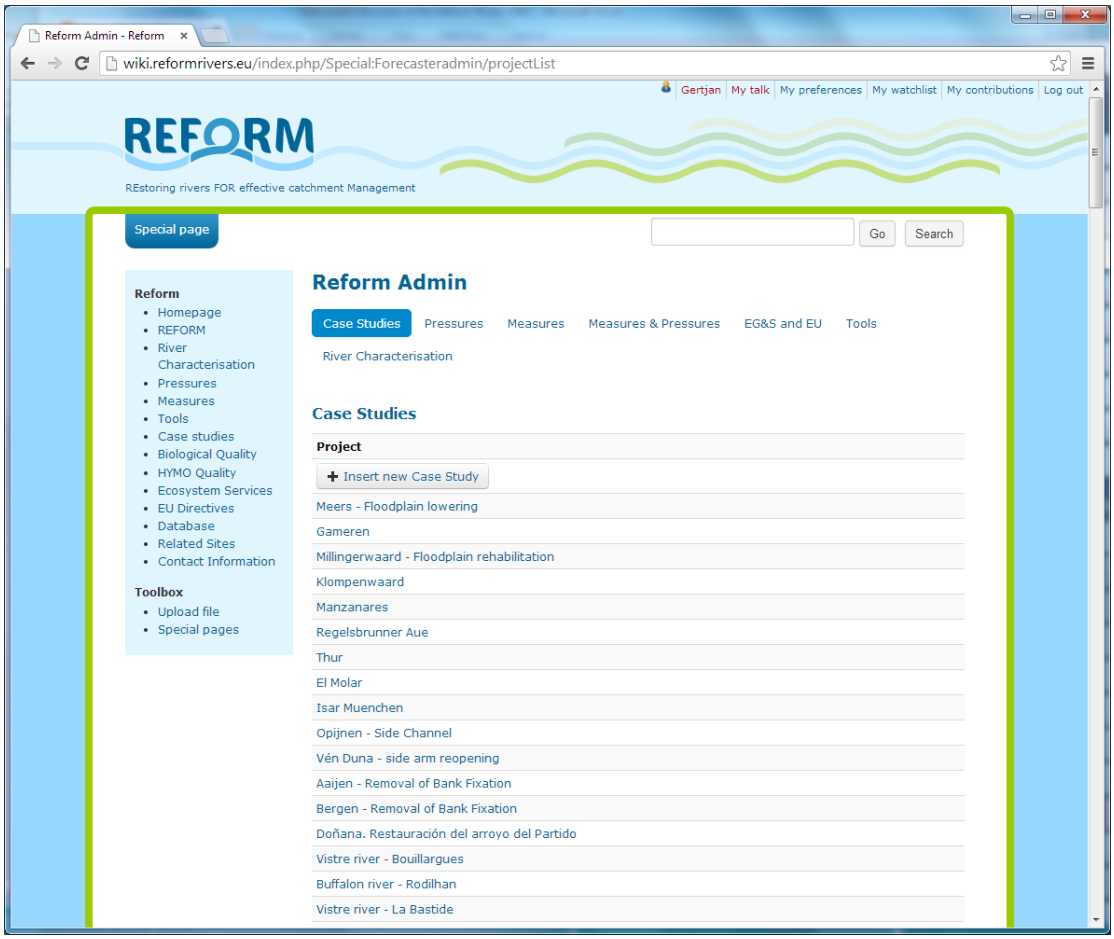

Figure 3.5 The switchboard, showing the database components that are linked according to the scheme in Figure 3.3.

The categories of the switchboard are the same as the ones described in Table 3.1, except for the "measures & pressures" category. This is a table linking measures to the pressures they mitigate, in effect creating a live link between categories. Try for instance http://wiki.reformrivers.eu/index.php/Introduce_large_wood and search for the section "Pressures that can be addressed by this measure".

Figure 3.6 shows an example of the feature to add new items for the category Tools through the buttons "Insert new tools category" and "Insert new tool". Other categories have similar possibilities of adding new categories and individual items.

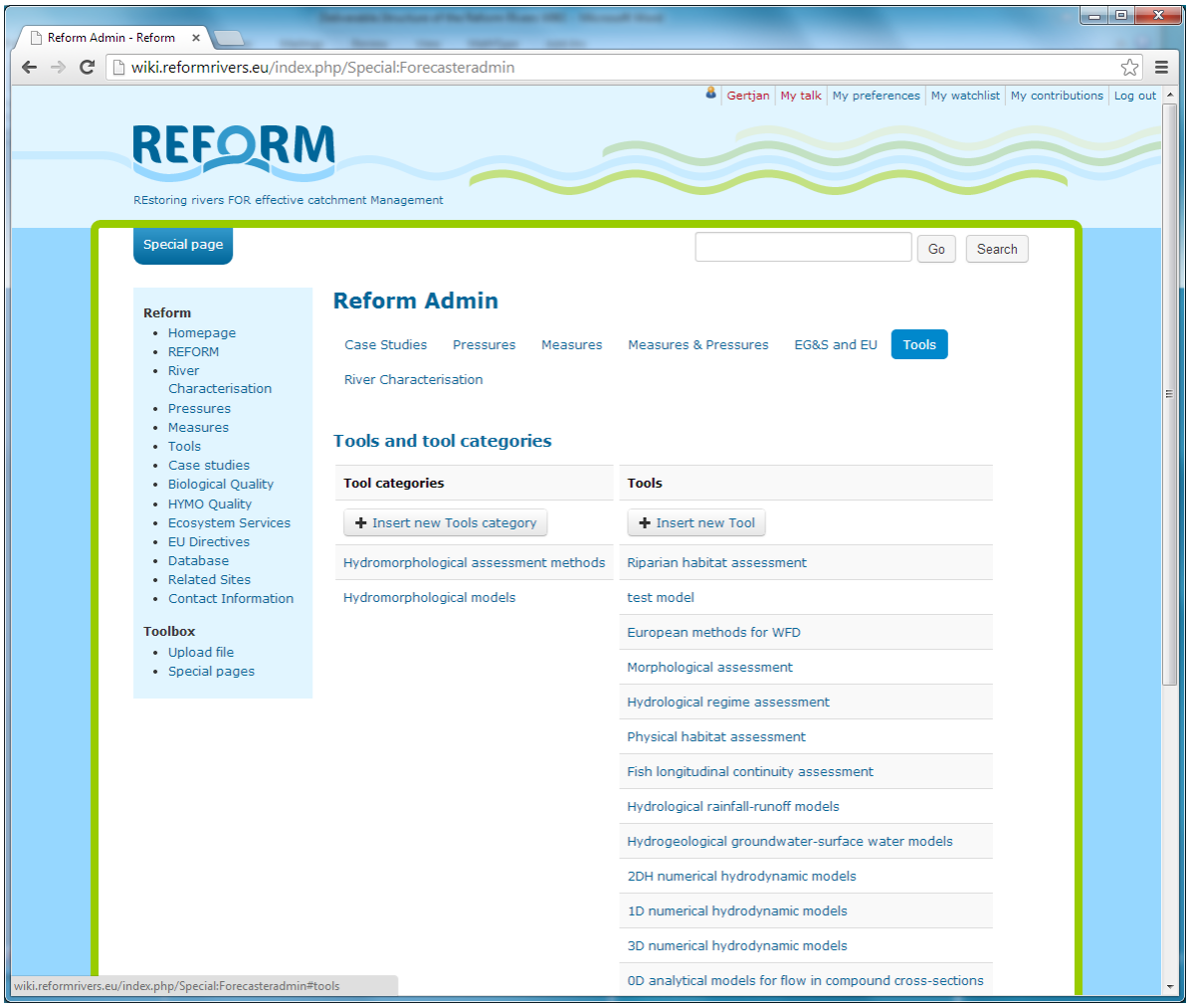

Figure 3.6 Possibilities to add new tool categories and individual tools.

Once a new item has been added, for example a new case study, the database forms ask the user specific information that allows the live links shown in figure 3.4. For example, links between specific pressures, measures and a case study can simply be checked in the case study form of the database. Figure 3.7 shows an example. The list is automatically changed when new pressures or measures are added. However, the pressure & measure list is fixed because adding new pressures and measures has the drawback that the newly added pressure or measure has to be checked for all existing case-study database entries.

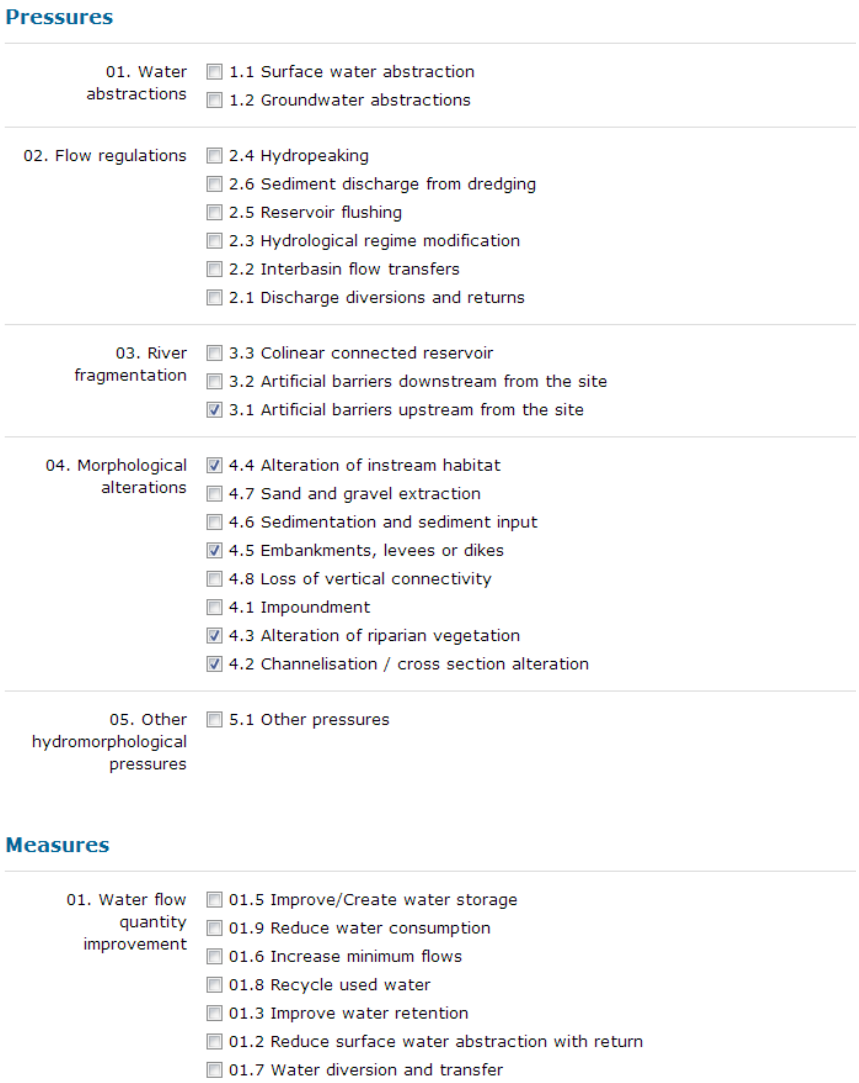

Figure 3.7 Example of database input form designed as a checklist to link pressures and measures (partly shown) to a case study.

The database entries of the case study additionally allow the user to filter the case studies on pressure type, measure type, presence of an evaluation, type of WFD hydro-morphological quality element, type of WFD biological quality element, and in the future ecosystem services and EU policies that apply (see Figure 3.8).

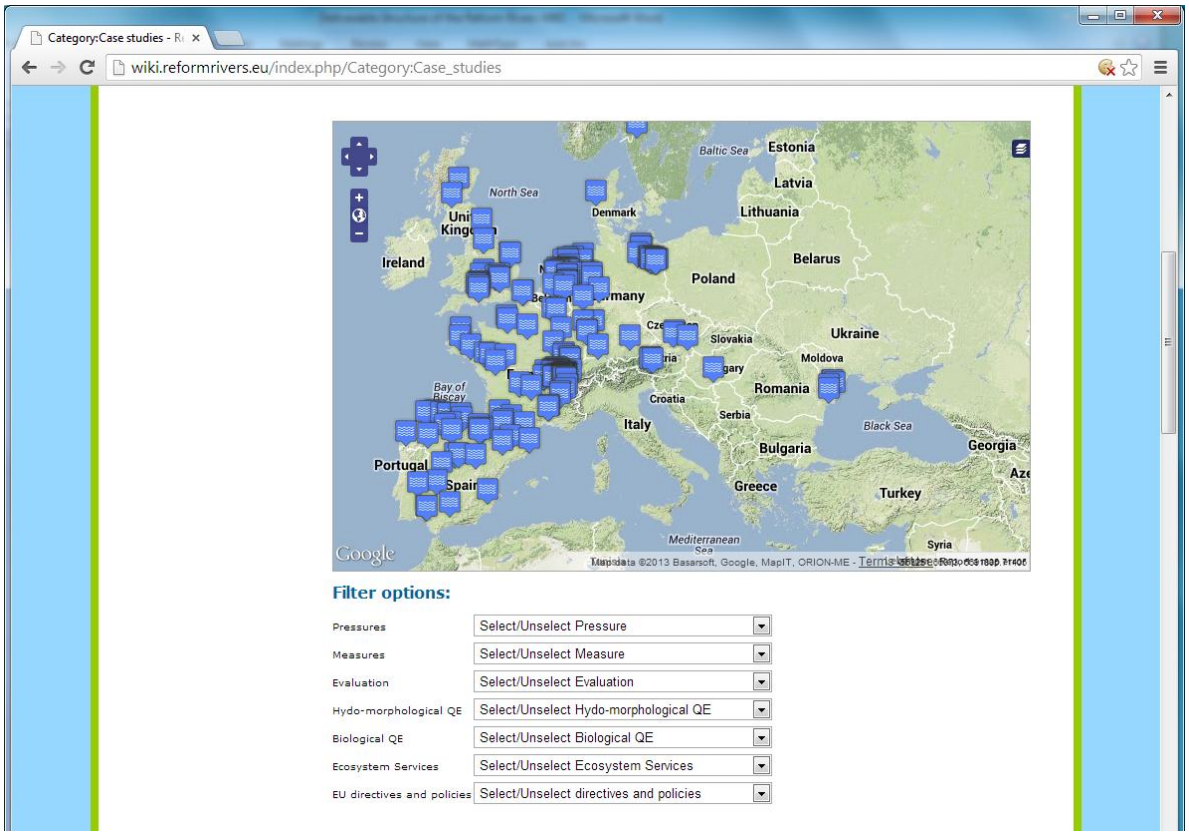

Figure 3.8 Filter options of case studies.

3.4 Remaining work

The wiki regards a work in progress. As knowledge becomes available in the REFORM project (till October 2015), it will be entered in a condensed form to fit the wiki structure. The aim is not to include complete reports or their contents, but to extract the minimum information needed to help guide the end-user to knowledge of relevant case studies, appropriate tools and background information. The power of the wiki is its structure and how it uses the REFORM internal structure of work packages and their final results.

The life of the wiki after 2015 will be guaranteed by finding a host among end-user organizations. Several institutes and organizations have already expressed their interest to host and maintain the REFORM wiki.