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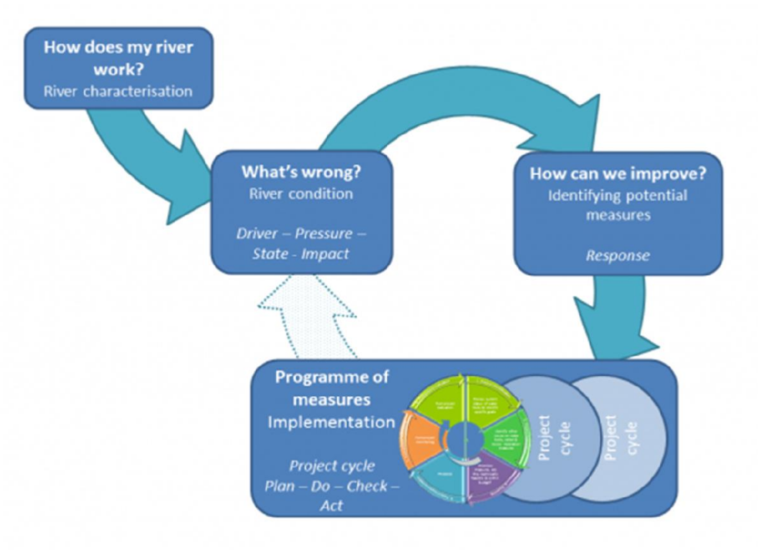
TOPIC: ENV.2011.2.1.2-1 Hydromorphology and ecological objectives of WFD
Collaborative project (large-scale integrating project)
Grant Agreement 282656
Duration: November 1, 2011 – October 31, 2015

REFORM

REstoring rivers FOR effective catchment Management



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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

The present report presents guidance and decision support for cost-effective river and floodplain restoration and its benefits. It serves as a portal to the web-based information system or wiki developed within REFORM and summarizes the contents, structure and functionality of this wiki. The wiki guides the planning process and design of cost-effective and hydromorphologically relevant restoration and its benefits. It has been structured around the phases of the river basin management planning cycle. A prerequisite of planning is a good understanding of how a river works and an evaluation of status by asking, “What’s wrong?” An integrated planning framework supports the design of river restoration measures and addresses the question, “How can we improve?”, including risk analysis, the wider benefits of restoration and the restoration potential of other human interventions. This framework is cyclic for both programmes of measures in entire river basins and the planning and evaluation of individual projects.

This report thus provides guidance on finding results of REFORM. All further details are given in the wiki, the REFORM deliverables and scientific publications.

Acknowledgements

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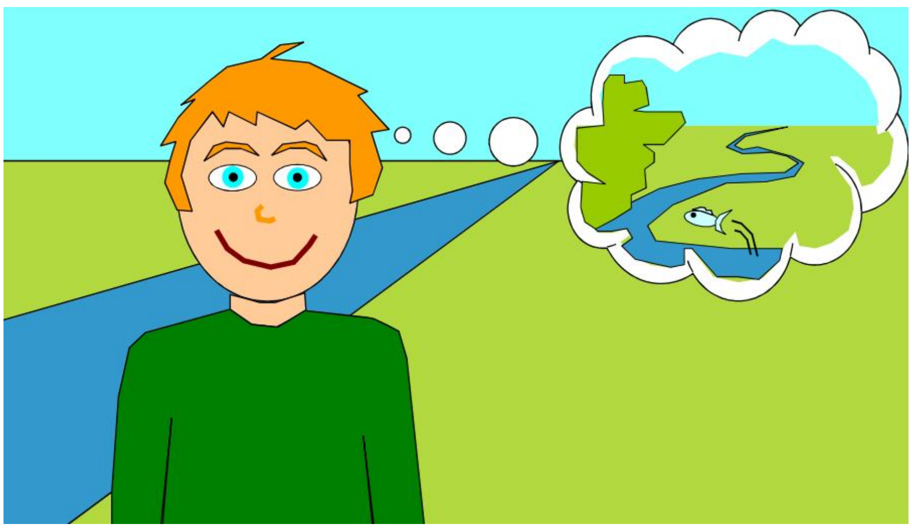
Table of Contents

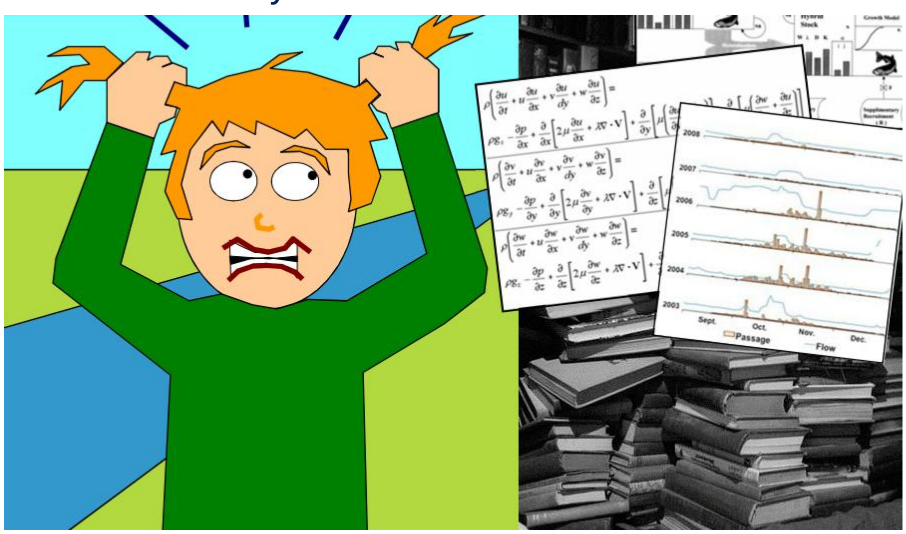
1. INTRODUCTION

The Water Framework Directive commits European Union member states to achieve good ecological and chemical status of all water bodies. Hydromorphological degradation is one of the causes why many rivers do not achieve this status, thus necessitating river restoration. This has promoted restoration activities and scientific research across Europe. Practitioners, however, face the difficulty of finding information on the experiences from restoration and the findings from research. That is why REFORM developed a web-based information system or "wiki":

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

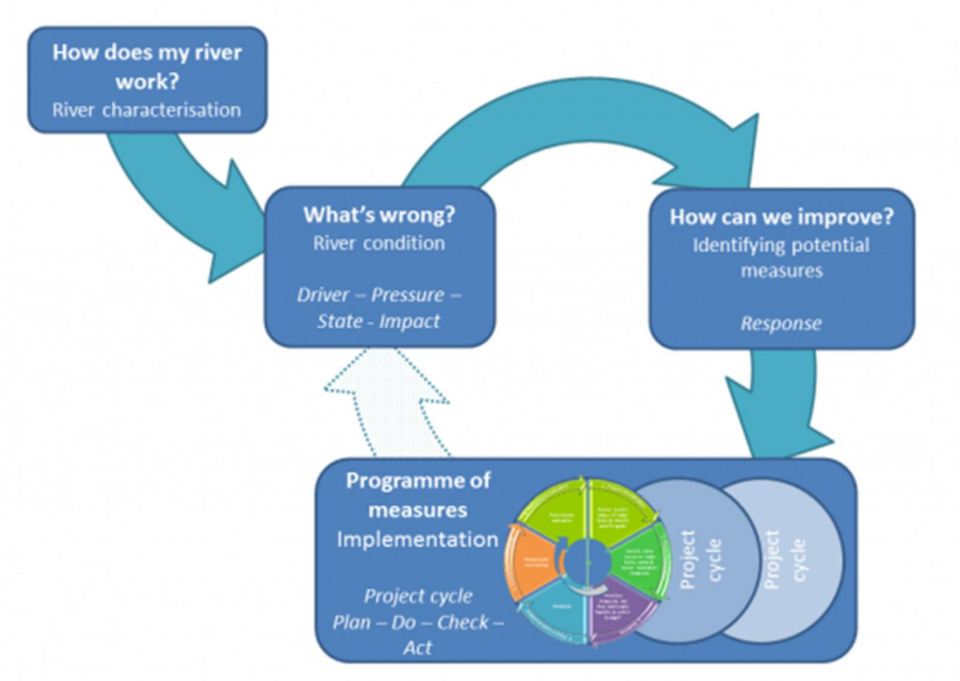


We may wish to restore a river ...



... but where do we find the knowledge?

The wiki guides the planning process and design of cost-effective and hydromorphologically relevant restoration and its benefits. The present report serves as a portal to the wiki. It summarizes the contents, structure and functionality of this web-based information system. The wiki is structured around the phases of the river basin management planning cycle. A prerequisite of planning is a good understanding of how a river works. Chapter 2 provides guidance for this. Chapter 3 guides the evaluation of status by asking the question, “What’s wrong?” Chapter 4 addresses the programme of measures by asking, “How can we improve?” , including risk analysis, the wider benefits of restoration and the restoration potential of other human interventions.

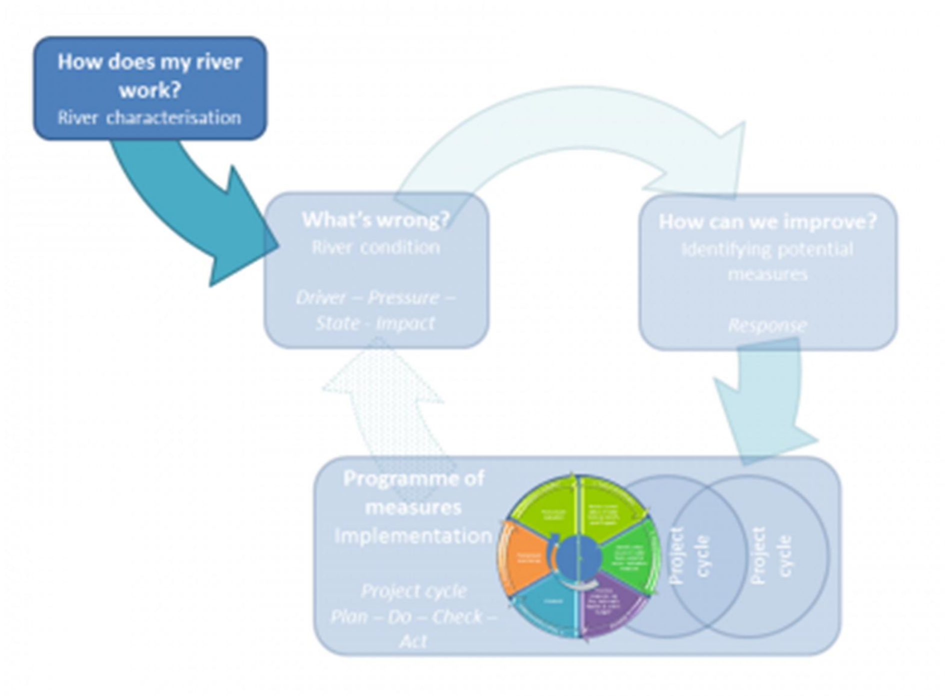


2. HOW DOES MY RIVER WORK?

2.1 Overview

Knowing how a river works is essential for achieving success in river restoration. It should be the first step in any restoration process, and the basis for any future river basin management plan. Important aspects are hydromorphology, the role of vegetation, and ecosystem services:

http://wiki.reformrivers.eu/index.php/How_does_my_river_work%3F

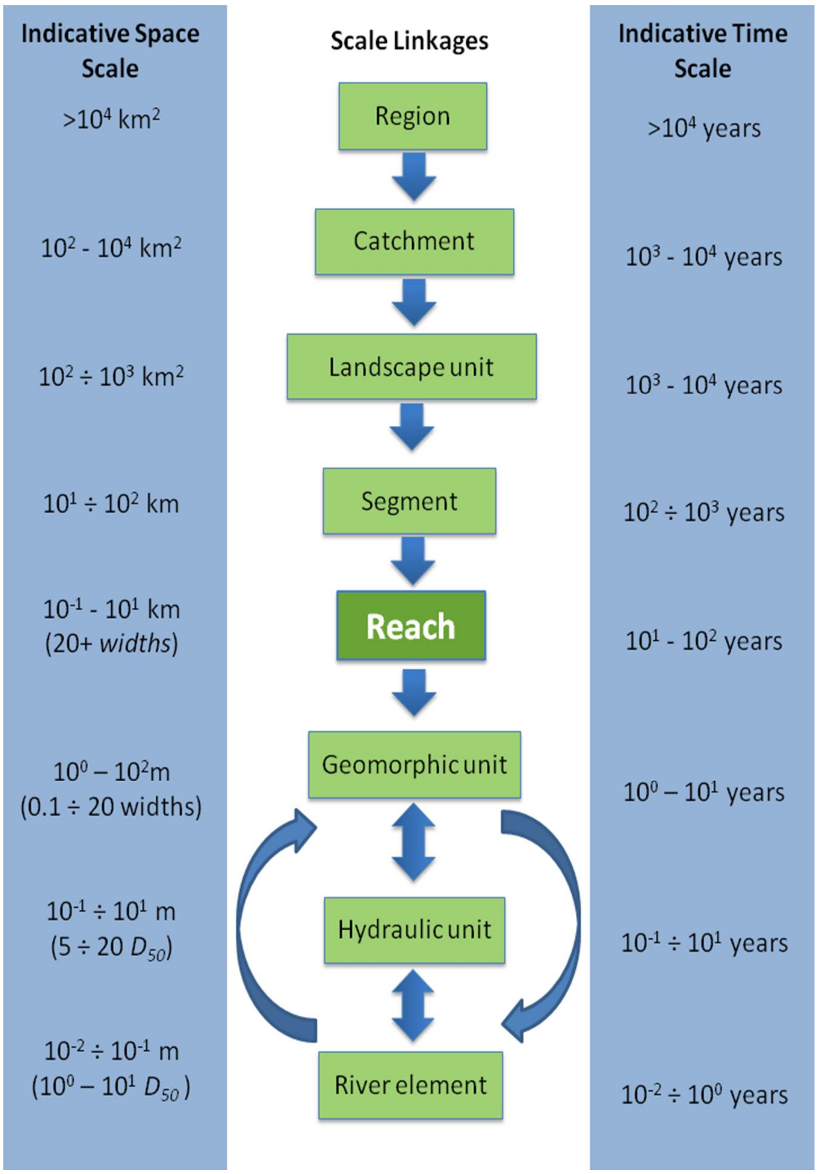


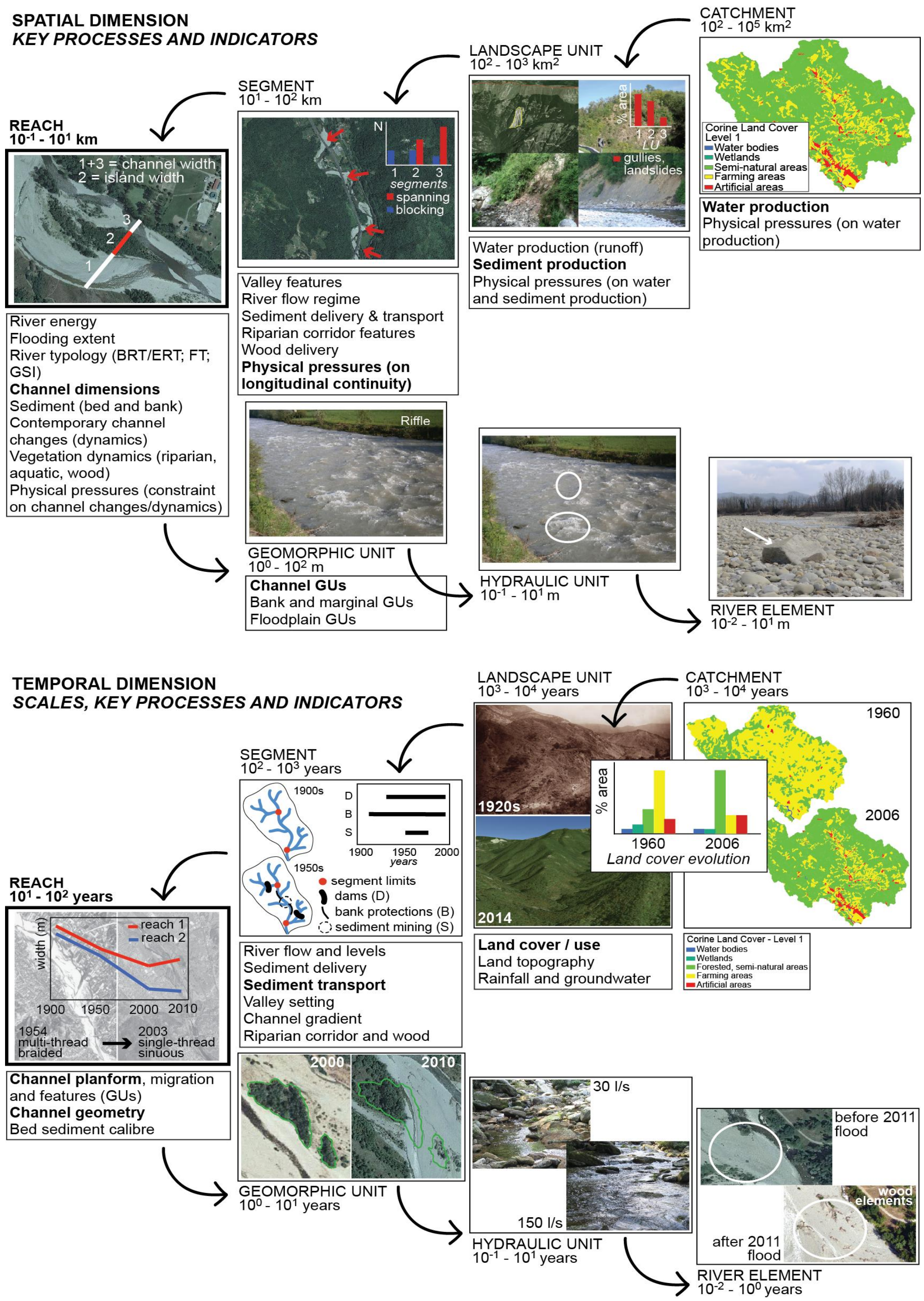
Hydromorphology:

Effective river restoration calls for an understanding of how rivers work. A key step for this is hydromorphological characterization, looking at rivers from a perspective that discloses the relevant processes and forms. Hydromorphology is a matter of water and sediment, but also of vegetation interacting with water and sediment. This makes both geomorphological and ecological processes relevant.

Hydromorphological characterization aims at capturing and explaining the complexity of hydrological, geomorphological and ecological processes that interact at many temporal and spatial scales. This is the key step in developing a fuller understanding of how a river functions physically, as a foundation for evaluating river conditions and developing a programme of restoration measures.

When thinking about a river, we usually imagine a reach of a few kilometres in length. This is the key spatial scale within a framework of spatial components of the river landscape. For characterizing the full complexity of rivers, however, it is useful to consider components larger and smaller than a reach too. A multiscale hierarchical framework for this helps in adopting the relevant spatial scales to describe specific river system characteristics.





Integration of spatial characteristics and their changes through time allows the investigator to identify which spatial units and temporal scales drive the relevant forms and processes. This is a basis for diagnosing causes and effects of the hydromorphological process cascade.

http://wiki.reformrivers.eu/index.php/Category:River_Characterisation

Role of vegetation:

Vegetation does not just depend on hydromorphology. It influences hydromorphology too and plays an active role in shaping a river. REFORM carried our research on the reciprocal relations between hydromorphology and vegetation. Understanding these relations can be a major factor in the success or failure of restoration projects:

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

Ecosystem services

A river forms an ecosystem that can be made suitable for many human uses. We call these uses “ecosystem services” as they are provided by the ecosystem. REFORM developed ways to valuate the services in a river system so we can assess the effects of river restoration on the services provided:

http://wiki.reformrivers.eu/index.php/Category:Ecosystem_Services

2.2 Tools

Hydromorphological processes are represented by a wide range of hydromorphological models:

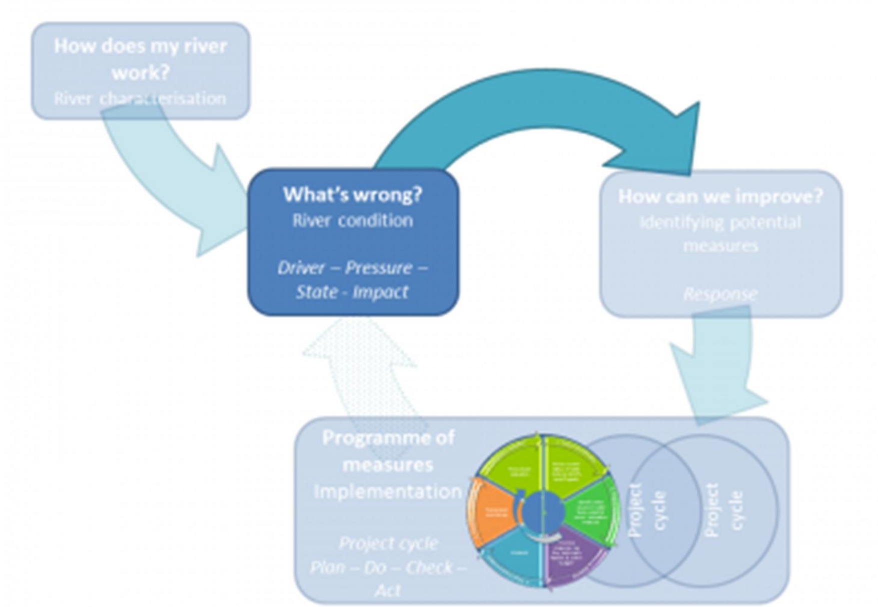
http://wiki.reformrivers.eu/index.php/Category:Hydromorphological_models

3. WHAT'S WRONG?

3.1 Overview

Once we know how our river works, we can assess what is wrong. This regards both hydromorphological quality and biological quality. Based on the outcomes of the REFORM project, we recommend using the hydromorphological assessment method for ecological class assessment directly, circumventing the use of biological indicators. Degradation of quality can be due to hydromorphological pressures, although it is often very difficult to single out the effects of these pressures compared to other pressures in a multi-stressor environment.

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

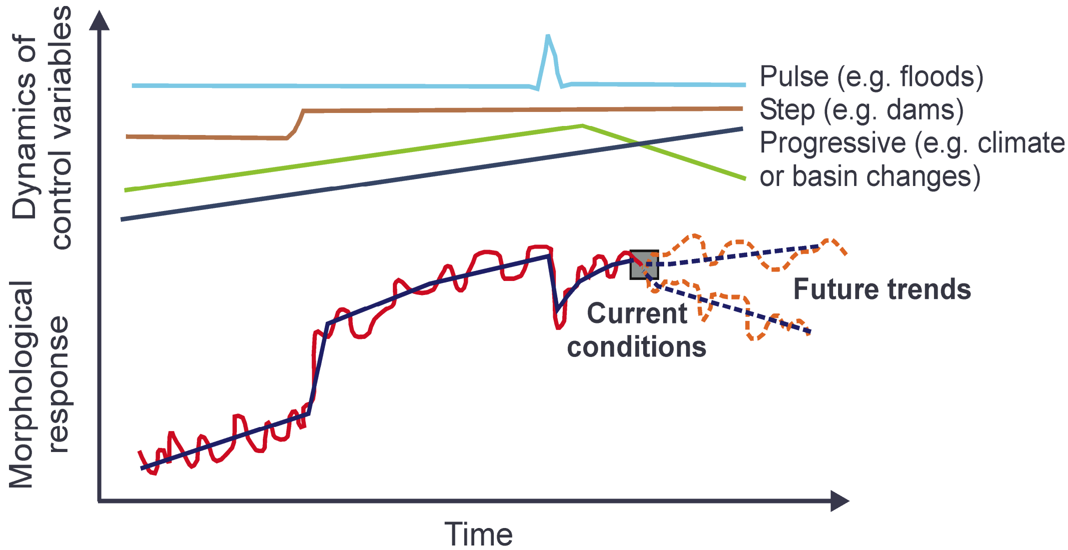


Hydromorphological quality:

REFORM developed a coherent set of methods and tools for practical assessment and monitoring of hydromorphological conditions. The spatial and temporal contexts are based on the multiscale hierarchical framework for river characterization. The overall framework incorporates four stages:

1. Delineation and characterization of the river system
2. Assessment of past temporal changes and current river conditions
3. Assessment of future trends
4. Identification of management actions.

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



Biological quality:

The ecological status of a river can be assessed by evaluating indicators for the composition, abundance, species diversity or absence of various groups of organisms known as “biological quality elements”. Four biological quality elements are used for rivers: algae (phytobenthos), macrophytes, macroinvertebrates and fish.

BQE	Sampling method (often CEN standards)	HYMO diagnostics?
Algae (diatoms)	Single stones/macrophytes	No
Macroinvertebrates	1-3 m^2 stratified by «habitat» types along 20 to 50 m «reaches»	Yes e.g. LIFE, DFI, Mesh **but none intercalibrated**
Macrophytes	Reach scale assessments (50-100 m); coverage and species/taxa composition	No
Fish	Reaches (100 m or more)	Partly – the guilds approach relates to overall HYMO conditions

Algae appear to be the least suitable of the biological quality elements. As a biological quality element, they primarily relate to very small scales and substrate-specific sampling. Moreover, most methods in Europe use only the algae group of diatoms, and not algae with larger growth forms such as for instance filamentous green algae. Macroinvertebrates are slightly better as indicators of hydromorphological degradation, but they appear sensitive to multiple stressors. It is thus almost impossible to single out the effects of hydromorphological conditions on community composition. As was the case for algae, macroinvertebrates are usually sampled at a relatively small scale and often on specific substrates, making any linkages to hydromorphological degradation on larger scales spurious. Among the biological quality elements for which specific metrics have been developed, macroinvertebrates represent the only elements that are sensitive to hydromorphological and hydrological degradation. However, these metrics have not been intercalibrated and tend to respond in a manner similar to the response of metrics sensitive to other stressors. Macrophytes show more potential. For certain river types it must be possible to develop robust metrics that will be sensitive to hydromorphological degradation. Additionally, the key role of aquatic and riparian vegetation in shaping hydromorphological processes offers an additional argument for increased focus on this biological quality element in indicator development. Fish appears to be the most promising biological quality element. It can be used to detect hydromorphological stress, although a need remains to develop more stressor-specific metrics.

With the current level of knowledge, it remains difficult to use biological quality elements for detecting hydromorphological degradation. Therefore REFORM recommends using the hydromorphological method directly for ecological class assessment, circumventing the use of biological indicators.

REFORM prepared a systematic overview of pressures, linked to various case-study examples:

http://wiki.reformrivers.eu/index.php/Category:Pressures

3.2 *Tools*

REFORM developed three methods for hydromorphological assessment: MQI, MQIm and GUS.

REFORM also reviewed existing hydromorphological assessment methods. They can be divided into 5 categories:

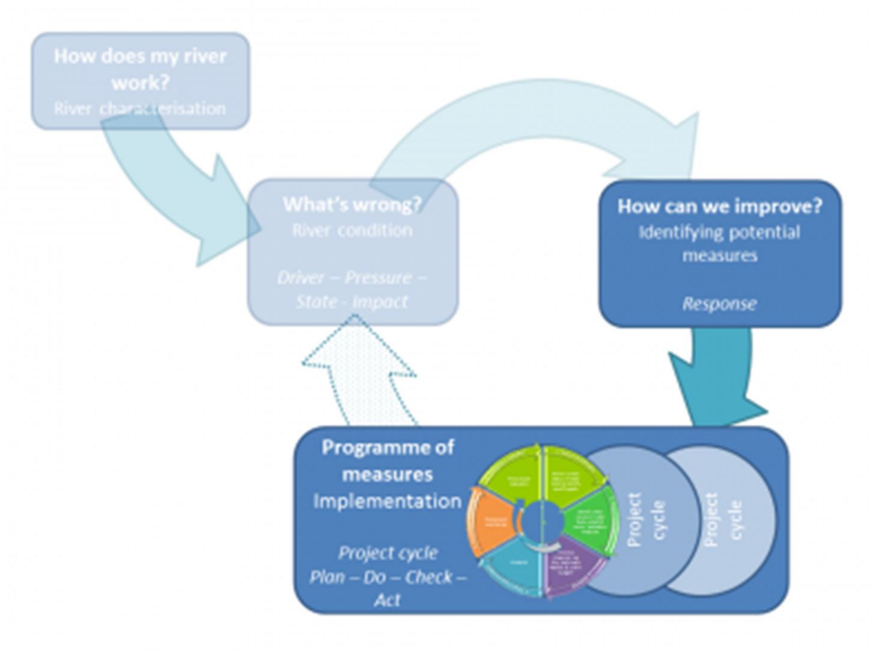
1. Physical habitat assessment
2. Riparian habitat assessment
3. Morphological assessment
4. Hydrological regime assessment
5. Fish longitudinal continuity assessment

http://wiki.reformrivers.eu/index.php/Category:Hydromorphological_assessment_methods

4. HOW CAN WE IMPROVE?

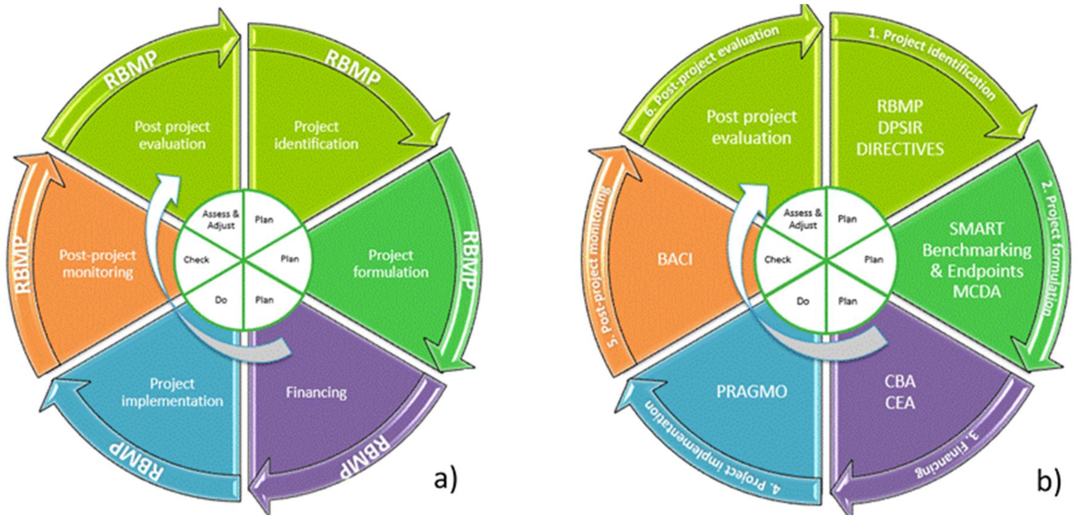
4.1 Overview

An integrated planning framework supports the design of river restoration measures. This framework is cyclic for both entire river basins (catchments) and individual projects.



Restoration planning at a catchment scale has six main steps:

1. River characterization.
2. River condition.
3. River restoration potential. The effects on biota are higher in gravel-bed mountain rivers with low land-use pressure.
4. Programme of measures. There is no single “best measure”, but widening generally has a high effect. Restoring specific habitats is more important than merely increasing habitat diversity.
5. Project identification. Small restoration projects do work, but larger projects with a long-term plan are recommended.
6. The project cycle for the planning of individual projects.



The planning of individual river restoration projects sets project objectives to improve ecological status at a local scale (figure panel b) whilst keeping the project in a river basin or catchment context (figure panel a). The project cycle in the figure follows the basic PDCA (Plan, Do, Check, Act) structure, but includes more detailed planning phases in the first part. Having identified the project within planning at the catchment scale, the following five phases play a key role:

1. Project formulation
2. Financing
3. Project implementation
4. Post-project monitoring
5. Post-project evaluation

Terrestrial and semi-aquatic species benefit most from restoration. The result is a higher number of individuals rather than new species. Specific traits or species are affected rather than the mere number of total species.

Restoration pays, because it increases ecosystem services.

http://wiki.reformrivers.eu/index.php/How_can_we_improve%3F

REFORM prepared a systematic overview of measures, linked to various case-study examples.

http://wiki.reformrivers.eu/index.php/Category:Measures

4.2 Tools

The following planning tools support risk analysis and valuation of the wider benefits of restoration and the restoration potential of other human interventions.

http://wiki.reformrivers.eu/index.php/Category:Planning_tools

DPSIR framework: Driver – Pressures – State – Impact – Response

The DPSIR framework is a holistic approach that identifies key relationships between society and the environment. It supports managers in their decision making, especially to structure and communicate policy relevant restoration projects. Drivers are the key demands by society such as agricultural and urban land use, flood protection, inland navigation and hydropower. These drivers are responsible for pressures that cause biological and abiotic state changes and further impacts within the river system:

- Abiotic state – reflects the magnitude, frequency and concentration of the environment including:
    - Physical variables – climate variables (air and sea temperature, precipitation, storms & hurricanes, drought);
    - Chemical variables – contaminants, nutrients, pH, atmospheric CO_2 levels, salinity. The abiotic environment determines the survival, growth, and distribution of living organisms in the biological state;
- Biological state – includes the biological components of the ecosystem and their interactions;
- Living habitat – is generally defined by the ecosystem of interest.

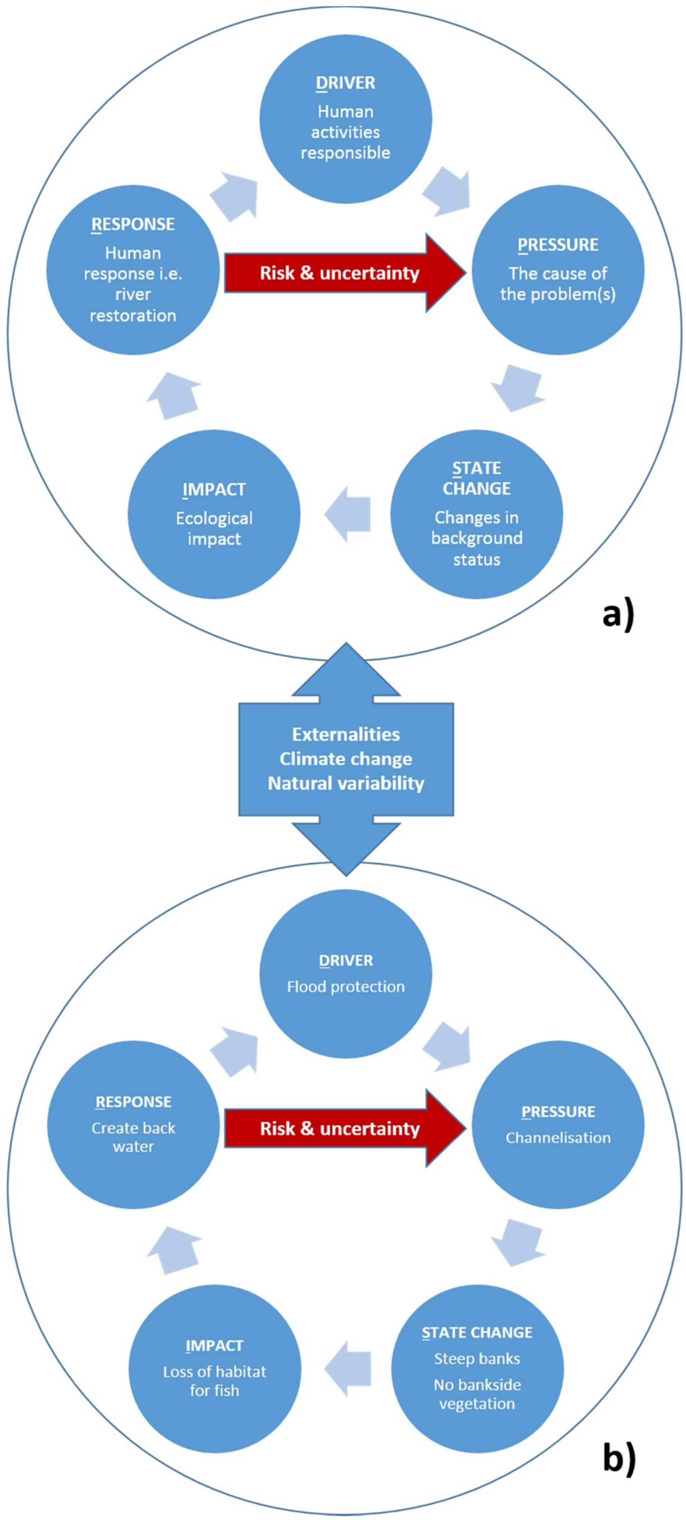
Natural variability, invasive species and climate change are indirect pressures that can also cause changes in river state and combine with pressures from human activities to intensify impacts on the ecosystem. The DPSIR approach disentangles these knock-on effects and identifies mitigation response to the impacts on ecosystem services and ecosystem function through the application of river restoration to prevent or improve state changes in the environment.

DPSIR Methods:

1) Complete a DPSIR table listing all drivers present, the pressures they create, the resulting state changes, subsequent impacts and potential rehabilitation measures.

Driver	Pressure	State	Impact	Response
E.g. Flood protection	*Channelization*	*Steep banks and simplification of the channel*	*Loss of lateral connectivity*	*Connect floodplain by disused gravel pits*

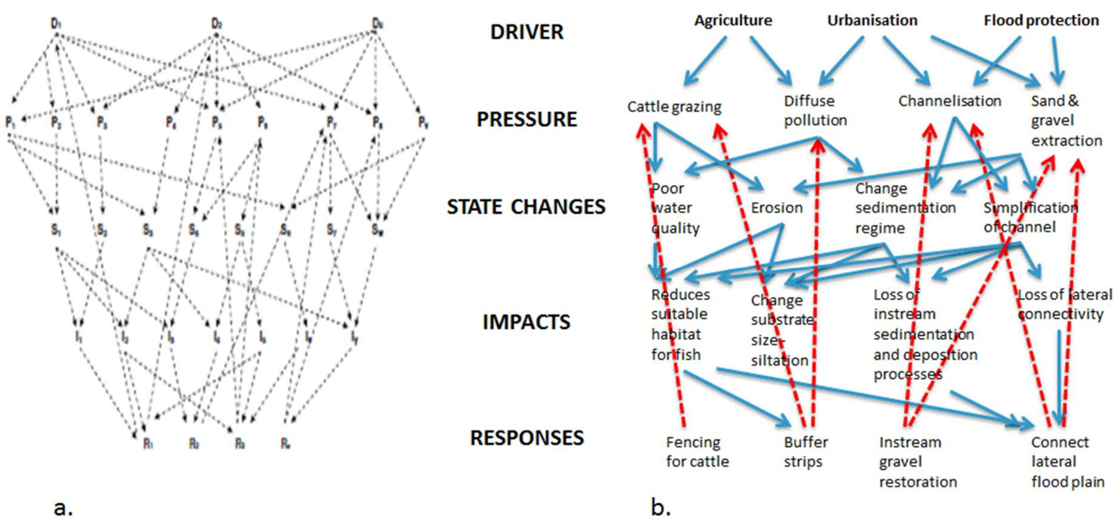
2) Create single cyclic DPSIR frameworks to understand the interactions, linkages and feedback loops for a given driver and pressures. A feedback loop between human response (river restoration) and pressures identifies the need to review the chosen rehabilitation measure and its effect on ecological risk and uncertainty.



(Atkins et al, 2011)

3) Create DPSIR concept map. A DPSIR map of concepts visually aids the decision maker to see complex interactions between all stages in the DPSIR framework. It

demonstrates how actions cannot be dealt with in isolation by identifying which activities interact with, or impact upon other activities. The term 'concept' is the sequence of interactions within the DPSIR and can span single or multiple sectors or drivers. The generic DPSIR concept map is intended to serve as a starting point from which users may remove or add components relating to their system and chosen restoration. Components can be removed or added to create different concepts to see specific problems in the system and how they can be overcome with restoration with little impact on human uses and to hopefully produce multiple benefits.



(Atkins et al, 2011)

4) Apply nested DPSIR framework. The nested DPSIR framework is a development of the original DPSIR and is an integrated approach that can assist decision makers when capturing key relationships between society and the environment. It nests many single DPSIR cycles for multiple drivers. The framework allows complex interactions between pressures, impacts and responses to be visualised for multiple drivers. Integrating these interactions allows users to explore relationships and identify measures that can produce win-win scenarios.

http://wiki.reformrivers.eu/images/3/32/REFORM_Tool_box_DPSIR.pdf

WISE conflict, resolution and prioritization matrices

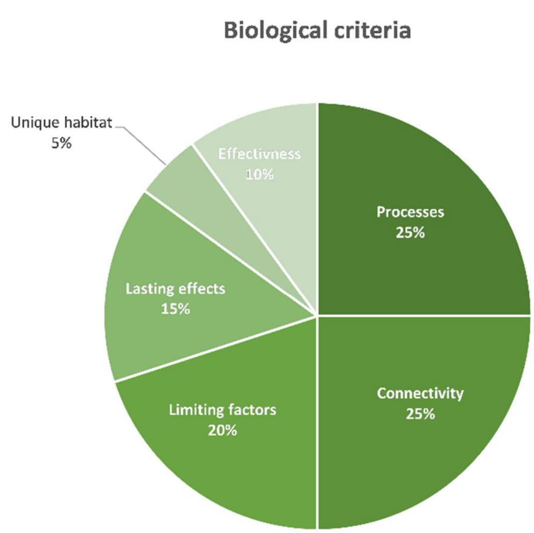
The prioritisation process scores the top restoration actions to be considered based on a series of ecological and socio-economic criteria. In turn, the development of the initial list of potential restoration actions is based on watershed assessment through the DPSIR table nested DPSIR approach.

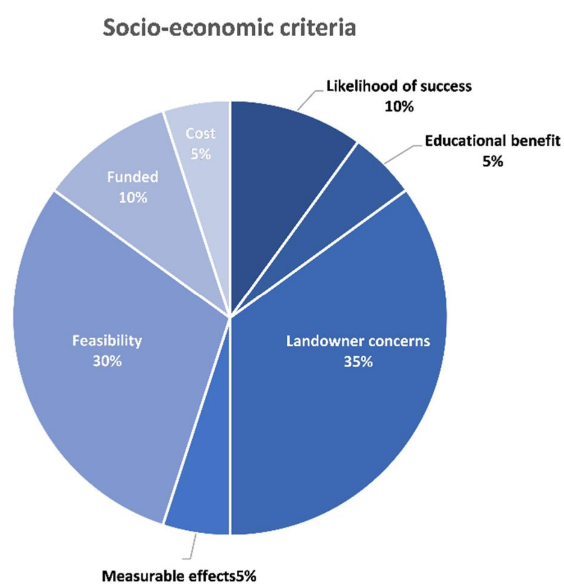
– Step 1: DPSIR, identification of prioritization criteria
– Step 2: Biological criteria and socio-economic criteria (collection of criteria constitutes a filter)
– Step 3: Restoration actions are scored based on the degree in which they satisfy each criterion

Biological criteria	Socio-economic criteria
– Restore watershed processes – Restore or improve watershed connectivity – Remove limiting factors – Have long lasting effects – Restore or expand unique habitat – Have well proven effectiveness	– Have a high likelihood of success – Provide educational benefits – Address landowner concerns – Have measurable effects – Are likely to be feasible – Are likely to be funded – Have an acceptable cost/benefit ratio

Examples of criteria (Giannico & O'Hanley, 2015)

A group of experts and stakeholders should jointly decide on the importance of each biological and socio-economic criterion by weighing each criterion within each category. It is essential that each criterion has a definition to ensure all decision makers understand the same meaning. For example, 'connectivity' – the action improves or re-establishes habitat connectivity'. In addition, a scoring system and definitions need to be produced and where possible, definitions should be quantitative values such as endpoints.





(Giannico & O'Hanley, 2015)

http://wiki.reformrivers.eu/images/7/75/REFORM_Tool_box_Conflict_resolution_and_prioritization_matrix.pdf

Setting SMART project objectives and the RRC monitoring planner

SMART project objectives:

- Specific (concrete, detailed, well defined)
- Measurable (quantity, comparison)
- Achievable (feasible, actionable)
- Realistic (considering resources)
- Time-Bound (a defined time line)

http://wiki.reformrivers.eu/images/1/17/REFORM_Tool_box_setting_SMART_objectives.pdf

SMART can also be applied when setting monitoring objectives. Further information:

www.therrc.co.uk/PRAGMO/PRAGMO_2012-01-24.pdf

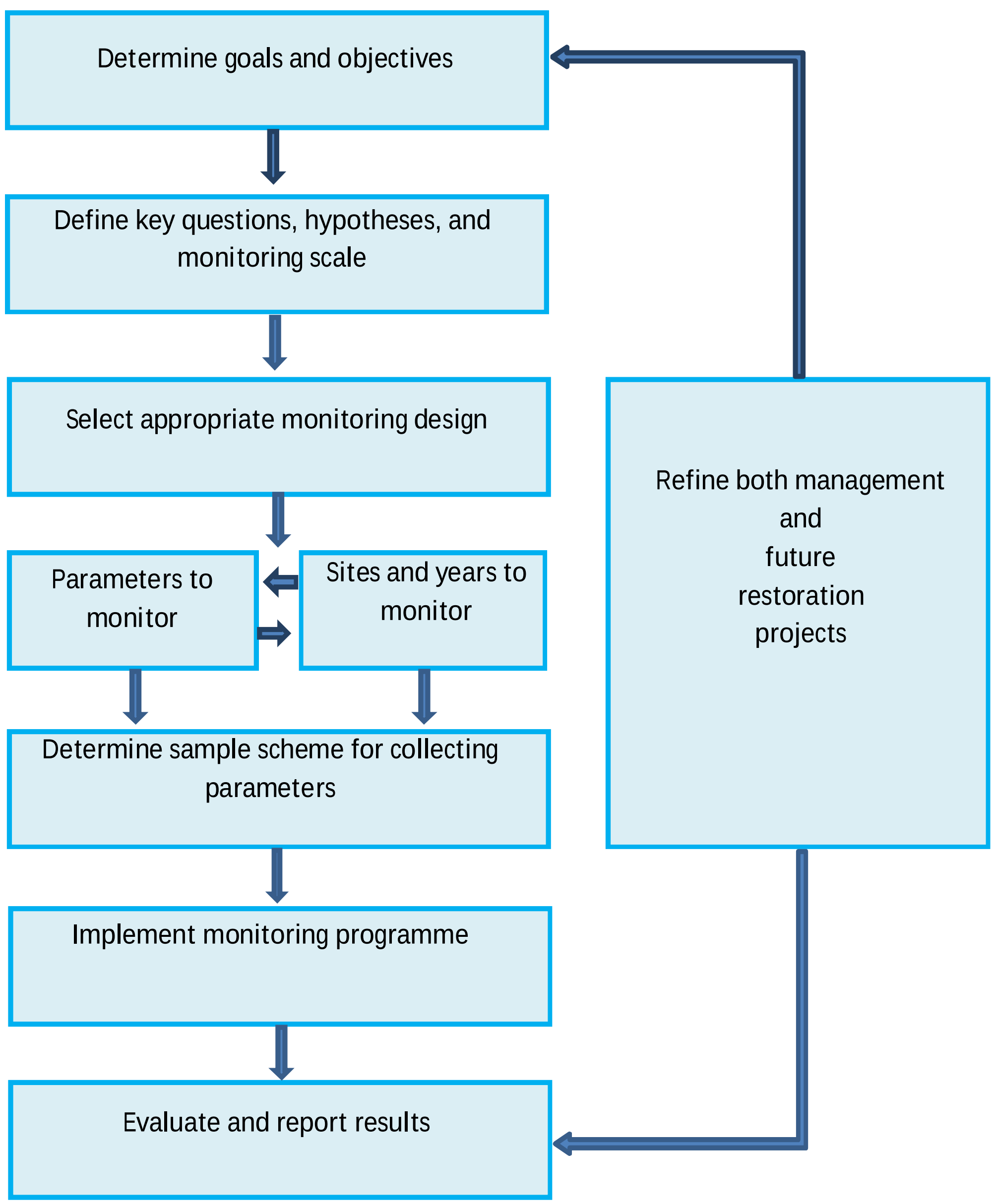
The River Restoration Centre has developed a monitoring planner to help practitioners structure and organise monitoring strategies. It contains examples and is freely available online:

http://www.therrc.co.uk/monitoring-planner

Monitoring design

A monitoring design is a continuous process and should take place at several stages throughout the project cycle. Spatial and temporal extent and resolution of the monitoring will account for:

- Target species or communities and their response to changes in habitat
- Natural variability in species population dynamics
- Natural variation due to weather, predation, disease, etc.
- Lag times associated with the response to rehabilitation activities



(Roni & Beechie, 2013)

Monitoring assessment techniques:

1) Before/After (BA) monitoring: before and after rehabilitation at a single site
2) Before/After and Control/Impact (BACI) monitoring: before and after rehabilitation at the restored site and at a control site
3) Repeated BACI monitoring: BACI monitoring at several restored sites, in addition to several control sites
4) Post-treatment monitoring: after restoration at a restored site and at a control site, focusing on spatial rather than temporal replication.

http://wiki.reformrivers.eu/images/6/60/REFORM_Tool_box_monitoring_design.pdf

Benchmarks and endpoints

Setting benchmarks and end points that are linked to clearly defined project goals is a valuable approach to help determine the measure of success within river rehabilitation. They place a level of quality to rehabilitation that can be used as a standard when comparing other things against which to measure performance.

Benchmarks are measurable targets for restoring degraded sections of river. They are representative sites with similar characteristics within the same river or catchment, but they differ from the degraded sections by having the required ecological status and being relatively undisturbed. Setting benchmarks draws on the assessment of catchment status and identifies restoration needs before selecting appropriate restoration actions to address those needs.

Endpoints are target levels of restoration. They can be ecological, social or physico-chemical, and are usually linked closely to project objectives. Given that benchmark standards cannot always be achieved, especially on urban rivers, endpoints will assist in moving restoration effort towards benchmark standards through application of the SMART approach.

The process of benchmarking can be broken down into a number of steps:

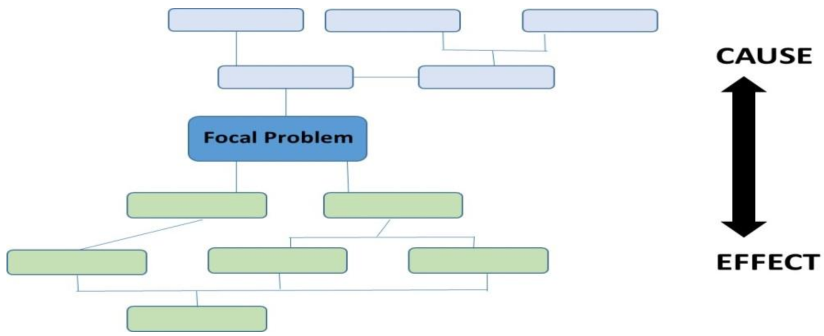
- Reference condition: Establishing reference conditions according to the multiscale hierarchical framework for hydromorphological river characterization;
- Expectation: Establishing endpoints for characteristics of concern that reflect the overall restoration goal;
- Baseline condition: Identifying hydromorphological limitations and processes that constrain recovery and exploring the restoration potential to establish endpoint target conditions.

Once the endpoints have been established, these restoration targets need integration into wider catchment-based activities to deliver win-win scenarios (e.g. flood mitigation, hydropower, agriculture, navigation), taking due account of the cost and benefits, specifically in relation to ecosystem services delivery. In this way the most effective measures can be identified to meet specific objectives.

http://wiki.reformrivers.eu/images/f/fb/REFORM_Tool_box_benchmark_and_endpoints.pdf

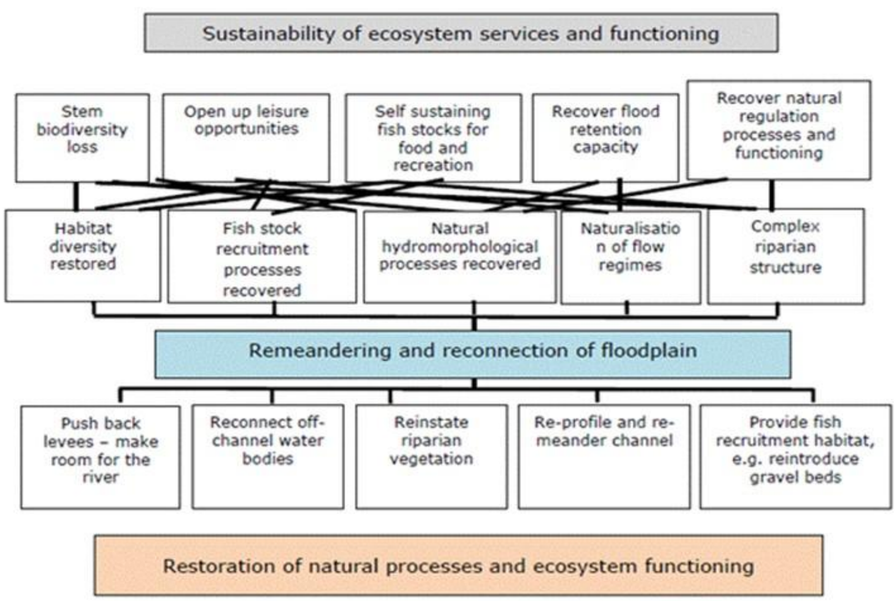
Problem tree analysis and tree of objectives

A problem tree analysis can be used to review the causes and effects of key issues for rehabilitation measures. Conflicts between user groups can be highlighted. Throughout the analysis there is a need for comprehensive discussion with stakeholders to understand their needs, motives and drivers.



An objective tree is closely linked to a problem tree and can be created by rephrasing each of the problems into desirable outcomes. In this way the root causes and consequences are turned into root solutions. This process is designed to help the project manager think about the key aspects of the river restoration project and about what the project is setting out to achieve.

http://wiki.reformrivers.eu/images/4/40/REFORM_Tool_box_problem_tree_analysis.pdf



Logical framework approach

The logical framework consists of a 4 x 5 matrix, listing the (i) goal, (ii) purpose, (iii) outputs, and (iv) activities. The rows are (i) summaries of the objectives at each level, (ii) performance indicators for achievement of those objectives, (iii) the sources needed to verify the indicators, and (iv) the important assumptions for moving from one level of objectives to the next.

PROJECT STRUCTURE	Measurable indicators	Means of verification	External factors and assumptions
GOAL: sectoral objectives			
PURPOSE: specific objectives			
OUTPUTS			
ACTIVITIES			

http://wiki.reformrivers.eu/images/3/32/REFORM_Tool_box_logical_framework_approach.pdf

Multiple-criteria decision analysis (MCDA)

Multi-criteria decision analysis (MCDA) is a framework for rational decision support by "value-focused thinking". The underlying concept is to quantify the objectives of the decision maker as a function of system attributes by value or utility functions, to predict the outcome of these attributes for all decision alternatives, and to evaluate the value or utility function at the predicted attributes to rank the alternatives according to the expected fulfilment of the objectives. The application of such a framework in environmental management is useful as societal decisions must be communicated and justified to the public.

In the case of river rehabilitation, this framework can be applied for decision support of local rehabilitation alternatives at the reach scale or for prioritization of rehabilitation actions at the catchment or administrative region scale. Value functions are elicited from stakeholders. Effects of rehabilitation alternatives are predicted using expert assessment, transfer of experience from other sites, and knowledge documented in the literature. The resulting rankings of alternatives for the value functions of different stakeholders serve then as a basis for supporting rational decision making.

To facilitate this process, REFORM developed three R packages:

- utility: R package for constructing, visualizing and evaluating value and utility functions
  https://cran.r-project.org/web/packages/utility/index.html
- ecoval: R package implementing ecological river assessment procedures
  https://cran.r-project.org/web/packages/ecoval/index.html
- riverval: R-package for analysis of attributes at the catchment or regional scale
  https://cran.r-project.org/web/packages/rivernet/index.html

Risk and uncertainty analysis

There are two important sources of uncertainty: uncertainty about scientific predictions of outcomes, and uncertainty about the preferences of the society elicited from inquiries or stakeholders. For stakeholders it is not only difficult to be aware of their own preferences and to be able to quantify them, but also to understand their own risk attitude. Clearly separating scientific predictions and societal valuations is an essential element of any decision support procedure.

Uncertainty about scientific predictions can be addressed by probability distributions and scenarios; uncertainty about societal preferences are often better addressed by sensitivity analyses of the ranking of the alternatives resulting from combining predictions of the outcomes of decision alternatives with preferences.

Communication of uncertainty is a key element of any communication of scientific predictions. Visualization of uncertainty ranges can support this task. Lack of communication of scientific uncertainty in the past led to a reduction of trust of stakeholders to scientists.