REMEDE

022787

REMEDE

Resource Equivalency Methods for Assessing Environmental Damage in the EU

Sixth Framework Programme

Priority 8.1 – 1.5

Deliverable 13: Toolkit (summary)

(Draft until approved by the European Commission)

Start date of project: 01/05/06 **Duration: 26 months**

Lead contractor organisation for this deliverable: eftec

Version 1

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
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)	

REMEDE TEAM

eftec

STRATUS CONSULTING

eco logic

UNIVERSITEIT GENT

UAB
Universitat Autònoma de Barcelona

Centre de Recerca Ecològica i Aplicacions Forestals
CREAF

SLU
Swedish University of Agricultural Sciences

Pro Biodiversity Service

SIGILLUM UNIVERSITATIS BOHEMIAE MERIDIONALIS

NORWEGIAN UNIVERSITY OF LIFE SCIENCES
MDCCCLIX

Jonathan Cox Associates
ecological consultancy

RSPB

Pels Rijcken
& Droogleever
Fortuijn advocaten
en notarissen

Vrije Universiteit amsterdam
Institute for Environmental Studies

Version 1

	Prepared by	Reviewed by	Approved by
NAME OF THE INDIVIDUAL	Ece Ozdemiroglu	Josh Lipton and David Chapman Jan-Bart Calewaert	Ece Ozdemiroglu
NAME OF THE PARTNER	eftec	Stratus Consulting University of Gent	eftec
DATE	6 March 2008	7 March 2008	7 March 2008

This version is revised to reflect the changes in the main Toolkit (D13).

Acknowledgements

This document is a summary of the main REMEDE Toolkit which has been co-authored by Dr Joshua Lipton, Dr Katherine LeJeune, Dr Jan-Bart Calewaert, Ms Ece Ozdemiroglu and contributed to by Dr David Chapman, Mr Jonathan Cox, Mr Scott Cole, Prof Pere Riera, Prof Colin Janssen and Prof Bengt Kristrom.

REMEDE receives research funding from the 6th Framework Programme of the European Commission. This report reflects the authors' views alone. The Community is not liable for any use that may be made of the information contained therein.

Table of Contents

1. Introduction 1

1.1 Background and Objectives 1

1.2 REMEDE Toolkit 2

2. Overview of Resource Equivalency Methods 3

3. REMEDE Toolkit for Resource Equivalency Analysis 7

3.1 Step 1: Initial Evaluation 10

3.2 Step 2: Determine the Damage (Debit) 11

3.3 Step 3: Determine the Environmental Benefits from Remediation (Credit) 14

3.4 Step 4: Scale Remediation 17

3.5 Step 5: Monitoring and Reporting 20

1. Introduction

This document is intended to provide a summary of the REMEDE Toolkit. Following this introduction, Section 2 presents an overview of resource equivalency methods to demonstrate key concepts and describes the scope of REMEDE. Section 3 takes the reader through the step-wise approach presented in the Toolkit and a hypothetical example illustrates some of the steps for one of the equivalency analyses.

REMEDE has produced several reports which are available to download from the project website at www.envliability.eu. Of these, the following are especially relevant to accompany this summary:

- Deliverable 5: Legal analysis;
- Deliverable 6A: Review report on resource equivalency methods and applications (the experience from the US);
- Deliverable 6B: Use of resource equivalency methods in environmental damage assessment in the EU with respect to the Habitats, Wild Birds and EIA Directives;
- Deliverable 13: REMEDE Toolkit; and
- Deliverable 12: case studies.

The Toolkit, together with several case studies that demonstrate its application in different damage and resource contexts as well as technical Annexes that provide further detailed information, will be published in early Summer 2008. To be kept informed of the developments please join the project's mailing list via the website.

1.1 Background and Objectives

On 30 April 2004, Directive 2004/35/EC on Environmental Liability with regard to the prevention and remedying of environmental damage entered into force[1]. The objective of the EU Environmental Liability Directive (ELD) is to establish a common framework for the prevention and remediation of environmental damage at a reasonable cost to society.

In the event of an incident (or an imminent threat of an incident) that causes environmental damage ELD requires the damage to be remediated so that the affected environment returns

[1] OJ 2004 L 143/56, 30.4.2004.

to its baseline. The Directive also requires that the public is compensated for the initial damage and the losses during the time the environment takes to recover back to baseline.

Annex II of the Directive recommends the use of **resource equivalency methods** (REM) in the assessment of environmental damage and selection of appropriate remediation projects. REM is a collection of methods and approaches that are used to determine the type and amount of resources and services that are lost over time as a result of an environmental damage, and the type and amount of actions that are needed to offset this loss.

Implementation of the ELD requires supporting information explaining the methods mentioned in Annex II, how and when to use them, and how much effort to spend on assessment. REMEDE (Resource Equivalency Methods for Assessing Environmental Damage in the EU) is funded under the 6th Framework Programme of the European Commission for this purpose, in particular to:

> *"develop, test and disseminate resource equivalency methods appropriate for determining the scale of complementary and compensatory remedial measures necessary to adequately offset environmental damage."*

In achieving this objective, the project:

> *"draws from US experience and that of EU Member States to apply and develop resource equivalency methods in accordance with the requirements of the Environmental Liability Directive, and the Environmental Impact Assessment, Habitats and Wild Birds Directives, in order that a standard Toolkit can be applied to all damage cases in the EU."*

Thus, the Toolkit is aimed at all who need to understand the implementation of ELD, and in particular Annex II of the Directive, as well as the concept of compensation under Habitats and Wild Birds Directives.

1.2 REMEDE Toolkit

Given a case of environmental damage requiring remediation or compensation under the above Directives, ELD requires two inter-related questions to be answered:

- What types of natural resources or services should be remediated?
- How much complementary and compensatory remediation is enough?

The Toolkit focuses on the second question and provides a framework of analysis and a structured and consistent approach to making and recording the necessary assumptions, selecting and analysing input information and interpreting the results. It requires prior scientific and economic knowledge of the users but helps them to tailor this knowledge to the requirements of the damage case in hand.

Resource equivalency methods are only one input to the process of deciding how remediation should proceed. There may be other considerations that Competent Authorities, operators or other stakeholders may wish to take into account for a given damage site. These site-specific considerations may also be taken into account in any negotiation toward a final remediation agreement to offset environmental damage. The Toolkit offers a common framework for all parties to work together. In fact, the Toolkit actively recommends that all parties do collaborate from the start for an efficient remediation outcome at the end.

2. Overview of Resource Equivalency Methods

Figure 1 shows a stylized picture of what an incident and its effects on the environment may look like over time. It is a simplified picture, but one the reader will find useful in understanding the terminology involved and the scope of REMEDE within the implementation of the ELD and other related Directives mentioned above.

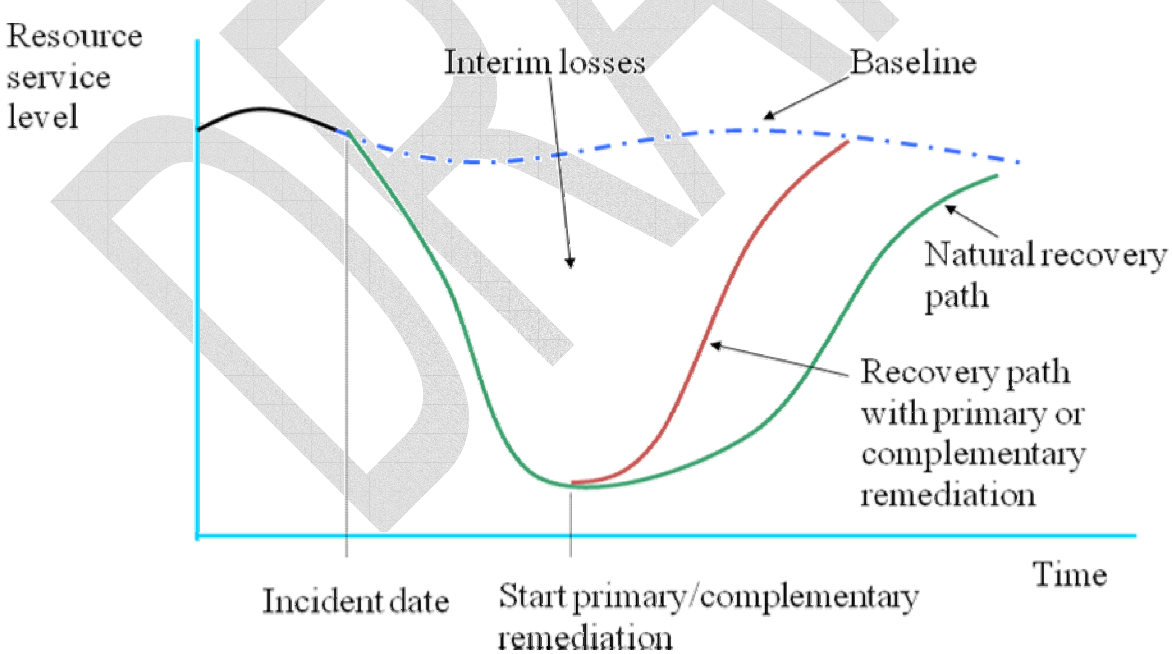

Figure 1: Anatomy of Environmental Damage

The y-axis of the graph in Figure 1 measures the quality and/or quantity of the natural resource affected. It can be measured in any unit, or **metric**, so long as both damages from the incident and benefits from remediation are estimated using the same metric. Selection of the metric determines the type of REM:

- If the metric is expressed in terms of resource units (such as number of fish or birds), the analysis that follows is called **Resource Equivalency Analysis (REA).** Here, damage is measured in terms of the reduction in the chosen resource units. The benefit of remediation is measured in terms of the increase in the chosen resource units.

- If the metric is expressed in terms of habitats and the ecosystem services[2] (e.g. provisioning, nutrient and carbon cycling, regulating etc.), the analysis that follows is called **Habitat Equivalency Analysis (HEA)**. Here damage is measured in a combination of the area of habitat(s) damaged and the degree of damage (in terms of the percentage reduction in the ecosystem services typically provided in the baseline). The benefit of remediation is measured in terms of area of habitat improved or recreated and/or provision of services improved.

- If the metric is expressed in terms of money, the analysis that follows is called **Value Equivalency Analysis (VEA)**. There are two variations to VEA. In the **value - to - value** variation, both damage and benefit of remediation are measured in terms of their economic value, i.e. in money units. In the **value - to - cost** variation, damage is measured in terms of the economic value lost. The remediation actions are then designed to cost at most as much as the monetary estimate of this value lost. 'Value' measured here refers to Total Economic Value of the environment based on individuals' preferences for the use they make of the environment and for other non-use reasons[3]. VEA is likely to be most appropriate when the nature, scale, or location of remediation projects differs from the specific resources and services damaged.

[2] Here we use the typology of ecosystem services by Millennium Ecosystem Services (2005). The changes in each and every service are not necessarily quantified but a proxy percentage loss or gain is preferred for ease of analysis. Millennium Ecosystem Assessment (2005), various reports, key summary to be found in *Living Beyond Our Means: Natural Assets and Human Well-being*, Millennium Ecosystem Assessment, available at http://www.millenniumassessment.org/en/index.aspx

[3] Total Economic Value is measured by individuals' willingness to pay (WTP) for an improvement or to avoid degradation in the quality and/or quantity of a resource or their willingness to accept compensation (WTA) to forgo an improvement or to tolerate degradation. There are several motivations for why individuals may have WTP and WTA for the environment: direct use value (consumption of resources or non-consumptive uses like recreation), indirect use value (ecosystem services that regulate the functioning of the environment), option value (for future uses of the environment) and non-use values (protecting the environment for others who make use of it now – altruistic value; for future generations – bequest value; and for the sake of the environment itself – existence value).

In all of the above analyses, the resources that are actually damaged and those that are used for remediation are likely to be of different kinds and in different locations. The "equivalency" between these differences is what lies in the heart of the REM and are further explained below.

The x-axis of the graph in Figure 1 shows the change in the quality and quantity of the natural resource/service affected over **time**. The environment varies over time due to natural and human-made factors and so does its recovery after an incident. Just as REM tries to make different resource types comparable, it also tries to make past, current and future losses and gains comparable. Changes that happen in the past or the future are not valued (whatever the metric used) in the same way as those that happen today. There are two main reasons for this difference. The first is the individuals' *time preference,* which means, all things equal, individuals prefer to consume now (today), rather than wait (until tomorrow). The second reason for this difference is *cost of capital* – the resources (money or other) that are available today can be used (invested or processed) to generate further benefits which would be lost if they are not available until next year or further into the future.

Thus, we need a procedure to ensure that environmental damage and gains from remediation that occur at different points in time are compared on an equal basis. A **present value multiplier** is used for this as further described and illustrated in Section 3.

The first solid then dashed line at the top of Figure 1 shows the **baseline**. Baseline reflects the condition of the resource and its associated services (including the physical, biological, or ecological functions of a resource, as well as any use or nonuse human services provided by the resource) had the damage not occurred. Data permitting, a dynamic picture of the baseline over time may better reflect baseline conditions in some settings than a static analysis. In Figure 1, a more or less flat baseline is shown, implying that the conditions would not have varied substantially had the damage not occurred. Under different conditions, baseline could be declining – demonstrating a decreasing quality and/or quantity of the environment (e.g. in an already polluted environment). Baseline could also be increasing – demonstrating an improving quality and/or quantity of the environment (e.g. due to better implementation of environmental regulations).

REMEDE does not specify which shape of baseline applies in which case – in fact such a specification cannot be made ex-ante due to its site-specific nature. However, the Toolkit recommends approaches to identify what the baseline conditions are likely to be in a given case. These involve using (i) existing environmental and economic data; (ii) environmental modeling approaches, and (iii) data from representative reference-sites that are sufficiently similar to the damaged environment to enable reasonable estimation of baseline conditions.

Figure 1 also shows an 'incident date'. This point represents the onset of environmental damage and typically represents the **base year** for any analysis. It should be noted that the ELD becomes applicable if the Competent Authority deems environmental damage to be 'significant'. Determination of such significance is outside the scope of REMEDE, and application of the Toolkit assumes that ELD (or other relevant Directives) have been deemed to be applicable. In the context of EIA, Habitats and Wild Birds Directives, an incident is a planned activity that will take place in some future date.

As soon as the ELD is deemed to apply, it requires the implementation of **primary remediation**. Primary remediation includes any remedial measures which return the damaged natural resources and/or impaired ecosystem services to (or towards) baseline conditions. The selection of primary remediation measures is outside the scope of REMEDE since they typically refer to clean-up and on-site restoration activities. Such actions generally are focused on direct remediation of the same resources as those damaged; hence, 'equivalency' is not required. In the context of EIA, Habitats and Wild Birds Directives, primary remediation measures correspond to mitigation actions which are also outside the scope of REMEDE. The Toolkit does, however, provide users with quantitative methods to consider the scale and efficacy of primary remediation in assessing the need for additional compensation.

Where primary remediation measures do not result in fully remediating the damage natural resources and/or ecosystem services back to baseline conditions, further **complementary remediation** measures are required. These are most likely to involve remediation of similar resources offsite, or remediation of resources that differ somewhat from the damaged resources. Thus, an equivalency between the damage and the benefits provided by the complementary remediation needs to be established. The REM approaches covered in REMEDE can be used to help select the type and define the scale of complementary remediation measures.

Primary and complementary remediation measures need not require human intervention. **Natural recovery** can and should be considered as a remediation option. Green and red lines in Figure 1 show these possible remediation options. The assumptions and analyses about the rate of recovery of the damaged resource and/or rate of improvement in the remediated resource (if different from the damaged resource) determine the shape of these lines.

Figure 1 shows that recovery of the resource back to baseline takes time during which there will be loss of resources and services. This is referred to as **interim loss**. In Figure 1, this is the area under the baseline curve and above the primary / complementary recovery curve. In cases where it is not technically feasible for the resource to recover back to baseline, the interim loss continues into perpetuity.

The ELD requires that interim losses are compensated. Remedial measures designed to address interim losses are referred to as **compensatory remediation**. Compensatory remediation measures are most likely to be of different kind to damaged resources and off the damaged site. Thus, an equivalency between the damage and the benefits from compensatory remediation needs to be established. REM covered in REMEDE can be used to select the type and scale of compensatory remediation measures.

3. REMEDE Toolkit for Resource Equivalency Analysis

In the language of REM (and hence REMEDE Toolkit), **the debit** refers to an expression of the loss suffered due to environmental damage. The debit is often multi-dimensional, since an environmental damage can have adverse impacts on many species, habitats, ecosystem functions, and human use and non-use values. In addition, the spatial and temporal extent of the damage and degree of the damage can vary depending on how damage is measured.

Typically in a HEA or REA, one or more measures are defined to serve as indices of keystone resources or services that were damaged. In choosing the metric for the debit, an assumption is made that remediation that addresses the chosen metrics will collaterally address the aspects of debit that were not specifically treated in the equivalency analysis.

The credit in an equivalency analysis is the amount of resource or service benefit that will be gained through complementary and compensatory remediation. An off-site project (or suite of projects) is designed and implemented to enhance the resources and services that were damaged. The number, type and size of projects are scaled so that the expected amount of benefit generated approximately equals the debit, quantified in terms of the same metric used to quantify the debit.

Ensuring equivalency between the debit and credit is conceptually quite simple:

- Add up all the losses (debits) caused by the damage;
- Determine the amount of benefit expected per unit of remediation (credits); and
- Divide the debit by the per-unit credit to get the total amount of remediation needed.

However, in practice, ecosystems are complex, and understanding and quantifying the impact of an environmental damage can be difficult. In addition, quantifying the benefit that will be provided over time by a remediation project can be difficult. Therefore, quantifying the debit and credit typically requires expertise and professional judgment on the part of the equivalency analysis team. Such a team might include biologists, ecologists, toxicologists, chemists, hydrologists, economists, recreation managers, and other environmental specialists whose knowledge is relevant to the type of resources and services damaged.

There are five basic steps in implementing the REM which apply all approaches.

Step 1: Initial evaluation is performed to determine whether an equivalency analysis should be conducted and, if so, the appropriate scale and content of the analysis.

Step 2: Determine the environmental damage (debit). In this step, damaged resources, habitats and/or services are identified and quantified relative to baseline conditions. The causes of damage are determined. Finally, the benefits of primary remediation are determined and the total debit (net of primary remediation) is quantified.

Step 3: Determine the environmental benefit from remediation (credit). Credits are determined by identifying and evaluating potential remediation alternatives and by calculating the benefits that will be gained by implementing complementary and/or compensatory remediation projects.

Step 4: Scale remediation. The final step in the equivalency analysis *per se* is determining the scale or quantity of the remediation project(s) to implement. Scaling is performed so that, over time, the discounted flow of services from the remediation projects (credits) is equal to the loss (debits).

Step 5: Monitoring and reporting. After the equivalency analysis is performed and remediation projects are selected and scaled, a remediation plan is prepared that includes project goals, implementation details, engineering plans and designs, and biological plans and designs. The remediation plan also includes procedures and schedules for monitoring the recovery of resources and services following implementation, and evaluating the project's success.

Selecting an equivalency method, debit and credit metrics, and appropriate remediation often can be an iterative process. The analyst (or analyst team) might initially select one equivalency approach, and later, when more information is available about the nature of the loss or opportunities for remediation, might decide that another equivalency method is more likely to allow scaling of an appropriate amount or type of credit.

Likewise, selecting a metric or metrics to quantify loss and gain, and deciding upon credible and logically consistent approaches to describing loss and gain trajectories, service losses and gains anticipated, and baseline conditions can also be iterative. There is no objective standard for any of these components of an equivalency analysis – **the 'right' approach is the one that achieves an appropriate amount and type of remediation most effectively**.

Regardless of the REM approach used, each step entails uncertainty either due to lack of data or incompleteness of our scientific and economic understanding of the way the environment functions. This is further discussed in Step 3.

Figure 2 shows the break-down of the five basic steps which also corresponds to the sub-sections of the Toolkit.

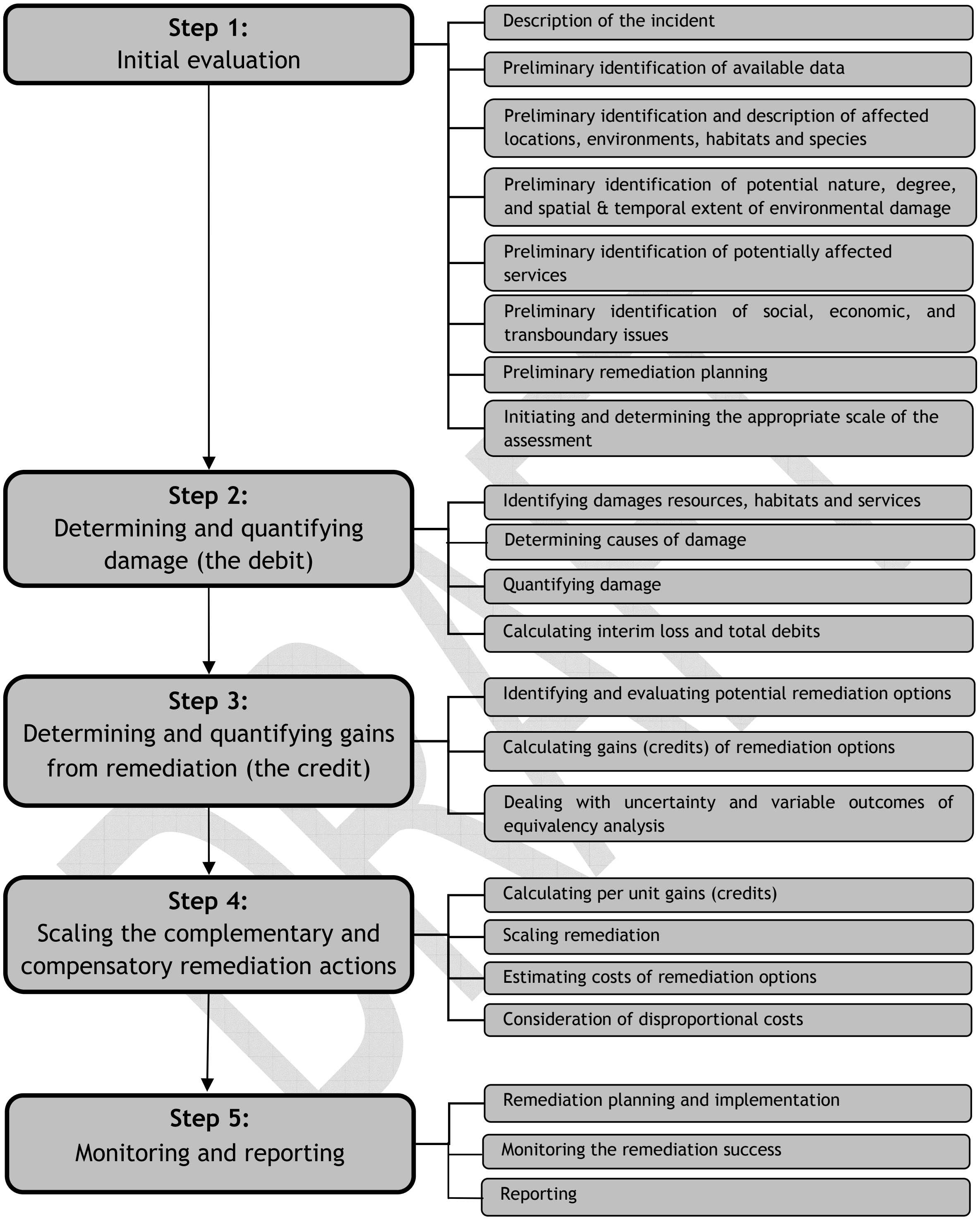

Figure 2: The Steps of a Resource Equivalency Method – and the REMEDE Toolkit Outline

3.1 Step 1: Initial Evaluation

The objective of the initial evaluation is to determine whether an equivalency analysis should be performed and, if so, the appropriate level of detail for the analysis. Determination of whether an equivalency analysis should be initiated and the **appropriate level of effort** will include a preliminary determination of:

- The severity of the incident;
- The degree, extent and duration of damage;
- The availability of data;
- The ease and cost of additional data collection;
- The degree of precision required for the specific case;
- The scale and recovery rate of complementary and compensatory remediation, and
- Other factors that may be considered by the Competent Authority.

In cases where the spatial and temporal extent and degree of damage are small, and where resources will rapidly return to baseline condition (with or without primary remediation), resource equivalency analyses could also be small-scale. Such small scale assessments may rely on readily available existing data, models, or simplifying assumptions or formulas.

Where the damage is more complex, likely to cause cascading or persistent adverse effects, cannot be addressed through primary remediation or simply cannot be addressed quickly, more detailed, comprehensive analyses might be needed. Comprehensive assessments may require time consuming, or costly data collection and analysis, including design and implementation of field or laboratory studies to understand the extent of the damage, and feasibility studies to select appropriate remediation projects or methods.

In addition, the **appropriate legal framework** (ELD, Habitats Directive or other) to be applied should be determined. While the legal framework does not make a difference to the implementation of the REM, it may influence the negotiations around the remediation option and hence the result of the REM.

If primary remediation is undertaken, the results, schedules and projected outcomes of this should also be considered during the initial evaluation. While **primary remediation** is outside the scope of this Toolkit, remedial responses are integrated and potentially interactive. Thus, the scale and success of primary remediation affects the amount and timing of interim losses and hence the need for complementary and compensatory remediation.

The initial evaluation may also involve identification of the **relevant stakeholders** (including the Competent Authorities, their implementation agencies, operators and others) that should be either involved in or informed of the equivalency analysis, identification of stakeholders who might be involved in a public consultation process, and establishment of cooperative relationships between responsible parties and Competent Authorities.

The main elements of an initial evaluation are listed below. The Toolkit describes each in detail. Importantly, each incident will be unique, so these details are intended to guide and not to prescribe:

- Description of the incident;
- Preliminary identification of available data;
- Preliminary identification and description of affected locations, environments, habitats and species;
- Preliminary identification of nature, degree, spatial and temporal extent of damages incurred or anticipated;
- Preliminary identification of potentially affected services, including ecosystem services and human use/non-use services;
- Preliminary identification of social, economic, transboundary issues;
- Preliminary remediation planning, and
- Initiating and determining the appropriate scale of the assessment.

All of the initial and following assessments are based on available data (which may or may not be complete) and knowledge about how the environmental resources function, change as a result of an incident, and recover. Using monetary metrics adds further uncertainty to the assessment through the limited evidence for use and non-use values held by individuals affected by the damage or benefiting from remediation. Outcomes of remediation projects are often uncertain because implementation in the 'real world' is subject to natural and anthropogenic stressors that complicate or slow recovery and that cannot be fully predicted at the analysis stage.

3.2 Step 2: Determine the Damage (Debit)

The purpose of damage determination and quantification is to establish an amount of lost resource or service over time that should be offset by remediation projects. This involves determining the causes, degree, spatial and temporal extent, and nature of damages. In some cases existing data are sufficient to quantify damages; in other cases, studies must be conducted to gather the necessary data.

Damage studies should be designed to produce scientifically rigorous, high quality data and to answer questions relevant to the equivalency analysis. Studies should not be designed primarily to answer questions that are of purely scientific interest. However, analysts should not hesitate to conduct investigations of an exacting scientific nature, because without correct quantitative information about damages, equivalency analysis is unlikely to provide for the 'right' amount of remediation.

This step is conducted through:

- Identifying damaged resources, habitats and services;
- Determining causes of damage;
- Quantifying damage by comparing the level of resource and service quality post-incident to the level under baseline conditions; and
- Calculating the total damage (debits) including the interim loss, which includes consideration of the time required for full return to baseline conditions (or determination that the baseline conditions will never be met).

Key elements of damage determination and quantification that should be considered in an assessment include the following.

During the **identification of damaged resources, habitats and services**, data and information from the preliminary evaluation and additional data collected are analysed to produce a logical and credible estimate of the types of resources or habitats damaged, and the services normally provided by the resources or habitats. The damage determination may address not just ecological harm and associated service losses, but social and economic factors (use and non-use values) that depend on the ecological integrity of the resources in question.

When identifying damaged resources, habitats and services, scientific and other data about the condition of the site and characteristics of impacts are typically evaluated to assess stressors, exposure and receptors involved in the damage.

During the **determination of the causes of the damage** phase, the analyst must define, to the extent practicable, the causal linkage between the incident and the resulting damage. The use of scientific data from the literature, logical analysis, modelling and deductive reasoning are essential to the characterisation of causality.

During **quantification of the damage**, the (spatial and temporal) extent and the degree of the damage and service loss relative to baseline conditions are determined. Approaches to estimating the extent and degree of damage and service loss can include the use of chemical, toxicological, biological, or economic data, geographic information systems, environmental risk assessments and modelling. The Toolkit provides an Annex containing suggestions for factors that need to be taken into account when assessing and quantifying damage to different types of environmental media and resources.

The expression of the degree of damage to the resource or to the services provided by the resource involves two important aspects: the expression is done relative to baseline conditions and is typically in terms of one or more quantification metrics that are used to quantify the adverse effects of the incident and scale the remediation.

Baseline conditions are the conditions of the resource without the incident in question. The Toolkit lists readily identifiable sources of data that may be useful to help determine baseline for those resources that are regularly monitored for legal and/or research purposes at least at the European level. In the absence of baseline data, data from similar sites unaffected by the incident (reference sites/conditions), or modelled conditions, can be used instead. Reference sites should be selected such that they match the damaged site as closely as possible in terms of the important characteristics of the latter (e.g. similar stream size, elevation, orientation, and bordering land uses; similar bay or estuarine shape, bathymetry, currents, fringing habitats, and bordering land uses; or similar geology, geochemistry, hydrology, and soil types). For social and economic baseline conditions, reference sites provide similar human use services, such as fishing and other recreational use and non-use attributes, and should be located in a similar or comparable location relative to population centres that were affected by the incident, i.e. consider similarity of access, scarcity, and regional importance.

Metrics, as mentioned above, range from easily measured, quantitative attributes (e.g. population density or user visits), to more conceptual or qualitative attributes and in some cases to complex indexes. For an equivalency analysis, the metric must be the same on the loss and gain sides of the equation. If a composite index is used as a metric, the analysis needs to be transparent about which components of the index are improving (or declining) if the index on the whole improves due to remediation (or declines due to damage). Otherwise, the overall change in the index may mask possibly opposing changes in the individual components.

When damages have been quantified, the next step is the calculation of interim losses and the total debits. Interim losses are calculated by estimating the degree of resource or service loss each year between the time the damage occurs and the time that the resources and services are restored to baseline conditions. The degree of loss each year of the damaged area is summed (and discounted) to give the total debit. Calculating interim losses and total debits requires knowledge about the benefits and potential collateral damage of primary remediation and associated (natural and remediated) recovery rates. The Toolkit shows how to sum and discount damages across a finite time as well as across perpetuity in cases where the baseline is not reached.

Table 1 presents an illustration of how debit can be estimated over time using a Habitat Equivalency Analysis (HEA). Column (a) shows the spatial extent (i.e., the area impacted) – in this example 100 hectares of a given habitat is damaged. Column (b) shows the degree of service loss as a percentage – in this example the initial damage is 50% in the first year, in time declining to a 0% loss. Column (c) shows the present value multiplier which is based on a 3% discount rate (as illustration not as the recommended discount rate). The annual debit is calculated by multiplying these three columns together. Summing them gives the total debit during the time the habitat is damaged. The total HEA debit for this hectare is calculated in **'discounted service hectare-years'** (DSHaYs) (hectares multiplied by service loss and discounted over time) which is the main metric used in HEA. This total debit of 319.5 DSHaYs is used later in Step 4 to demonstrate how to scale offsetting remediation for this simple example.

Table 1: Illustrated example of DEBIT calculations using a non-monetary metric

Year	Spatial Extent (hectares) (a)	Percent service loss (b)	Present value factor[1] (c)	Debit (DSHaYs) (d = a x b x c)
2007 (base year)	100	50%	1	50.00
2008	100	50%	0.97	48.50
2009	100	50%	0.94	47.00
2010	100	50%	0.92	45.76
2011	100	50%	0.89	44.42
2012	100	40%	0.86	34.50
2013	100	30%	0.84	25.12
2014	100	20%	0.81	16.26
2015	100	10%	0.79	7.89
2016	100	0%	0.77	0.00
2017	100	0%	0.74	0.00
	Total Debit in "Discounted Service Hectare Years" or DSHaYs			**319.5**

1. Present value factor = 1 / (1+ discount rate)^{year}. In this example, the discount rate is 3 % and the base year is selected to be 2007.

3.3 Step 3: Determine the Environmental Benefits from Remediation (Credit)

The purpose of this step is to identify the extent of gains provided by remediation project options. In the case of a non-monetary metric, this implies ecological gains such as improved habitat services or increases in the population of a specific species. In the case of a monetary metric, this may require identification of gains in terms of human use and non-use values. Information about these gains are needed in order to determine how much remediation is needed (i.e., scaled) in Step 4 such that the damage (Step 2) is adequately offset.

Step 3 of the Toolkit includes two major analyses:

- **Identifying and evaluating potential remediation options** selects feasible project(s) that will offset the damages identified in the previous step from a range of potential ones, and

- **Calculating the service gains (credits)** for each of the feasible remediation options in order to *quantitatively* compare these gains to the losses identified in the previous step.

At the same time as the work on determining the debits progresses, efforts to **identify and evaluate potentially suitable complementary and compensatory remediation** projects should begin. Potential projects are screened against a range of selection criteria. Once a set of acceptable projects is selected, the benefits anticipated from each project are identified and quantified in terms of the metric used on the loss (debit) side of the analysis. A general overview of the process is as follows:

- Establish criteria for evaluating remediation options for each type of damage and service loss;
- Develop a list or database of potential remediation options;
- Apply evaluation criteria to identify potential remediation actions that meet pass-fail criteria, and then to rank the remaining actions;
- Choose appropriate metrics for comparing remediation gains (credits) with losses (debits); and
- Develop information about unit costs for priority remediation actions. Costs should account for the implementation and administration of the action, as well as operation, maintenance, and monitoring expenditures required to ensure that the project provides the benefits incorporated in the equivalency analysis. This is further developed in Step 4.

Although some criteria for evaluation of potential remediation projects are the same for each case, evaluation criteria and their interpretation typically vary between sites, depending on site-specific issues, opportunities, and constraints. Different criteria or categories of criteria could be weighted more heavily to emphasise project characteristics of greatest value to the parties. Despite this site-specificity of criteria, there are some fundamental principles and considerations, including the following that need to be taken into account:

- Remediation for damage or loss of habitats through the creation of a new or replacement habitat can be complex and difficult to realise in practice. As an alternative, it is often much more feasible to attempt to restore an existing habitat or habitats of the same (or similar) type as that which has been damaged or destroyed.

- The approach to selecting remediation projects will be greatly influenced by the context of the habitat that has been damaged or destroyed (e.g. is it part of a Natura 2000 site, what is the level of fragmentation/isolation?).

- A remediation project needs to be **additional** to the current environmental management efforts. For example, designating a given area as a new nature reserve to compensate for damage to or loss of an existing site can be considered, but only if the unprotected habitat is under threat, this threat is real and imminent, and would not have been countered by any other protective measure.

- Environmental damage will often impact upon a number of different protected species. Therefore, developing a remediation package to meet the needs of this diversity of species presents a number of challenges and will need to consider the ecological requirements of each species.

- A project targeting remediation of the same type of habitat that was damaged, but in a different location, often does not provide services identical to those lost (e.g., the habitat at the remediation site might be more or less accessible to a target species). A possible approach to evaluate relative project benefits across habitats or locations is the use of '**scalars**' (or scaling factors) to assign preference weights.

- In compensating for human use and non-use losses, it is rarely appropriate to conduct remediation far from the damage site. This risks benefiting people that were not harmed by the loss, at the expense of individuals who experienced the loss.

Other issues that might arise in identifying appropriate remediation projects include compensating for cultural, social, or economic losses that are difficult to describe or quantify. An economic valuation or equivalency method that estimates people's preferences for services provided by natural resources might need to be used to fully compensate for such losses.

Once preferred projects are identified out of a long list of options, they can be given additional attention needed to prepare more detailed project descriptions, evaluate potential benefits, including the type, degree, and timing of benefits, and the relative 'fit' of the project in terms of its overall equivalency. **Project descriptions** may evolve from initial short, one-sentence descriptions to more detailed descriptions addressing project objectives; actions required to implement the project; potential project size (minimum, maximum); anticipated benefits and the time estimated to achieve the benefits; ongoing operation and maintenance activities required to sustain the project or its benefits; approximate cost required for initial implementation and ongoing operation and maintenance; permitting requirements; potential administrative (or other) obstacles; potential collateral/ancillary benefits or damages associated with the project; and a monitoring and evaluation plan. The Toolkit provides detailed evaluation criteria for the selection of suitable remediation options.

The second part of Step 3 includes the **calculation of service gains (credits) of remediation options**. This requires developing a similar set of information as quantifying damage (debits). Key elements of quantification of the credits are:

Determine the degree of service improvement over time in a manner similar to determining the degree of service impairment on the damage side. The degree of service improvement is calculated by estimating the current and post-implementation value of the metric. Importantly, service gains from compensatory (and, if relevant, complementary) remediation are estimated relative to the baseline conditions taking note of geographical proximity of remediation to damaged site; degrees of similarity between damaged and remediated resources and other ecological, cultural, social and economic factors. The Toolkit provides further detail on these factors.

Determine recovery curves reflecting the anticipated timing and degree of productivity of the remediation actions in terms of the chosen metric. The time course of benefit accrual (or service provision) following remediation can be described as a linear function, or as a non-linear function if data are available to describe such a trajectory. Modelling can be conducted to estimate the time required for the remediated resources or habitats to provide full benefits. The estimate of recovery should take into account natural stressors and disturbances that might reasonably be expected to affect the recovery rate, and corrective and maintenance actions that would be taken to bolster project success in future years. The time taken to recovery, in return, will determine the size of the interim loss.

Both of the analyses above should incorporate the degree of success (or probability of failure) of the remediation project(s) chosen. This could be done either by allowing contingencies in the size of the remediation project or allowing further budgets for remediation actions that can be undertaken in the same sized remediation. Alternatively, the probability of success can be incorporated in the credit estimates so that the estimates in effect 'expected credit' (credit multiplied by probability of success).

3.4 Step 4: Scale Remediation

The credits from a remediation project must be identified such that the amount of remediation provided can be adjusted to offset the amount or extent of environmental damage. This is referred to as "scaling". The ability to adjust the amount of remediation provided is crucial to the resource equivalency process and applies to all types of resource equivalency methods. The general approach to scaling relies on the (same) environmental metric used previously to measure the environmental damage (total debits).

Step 4 includes the following four actions:

- **Estimating gains (credits) per unit of remediation** (e.g. service gains per hectare of new habitat created) for all relevant remediation options that meet the basic criteria outlined in the Toolkit. This might include, for example, the improvement in habitat services *per* *hectare* of remediated land (HEA) or the improvement of fishing experience *per fishing trip* (VEA).

- **Scaling remediation** is the process of determining how much remediation to provide. It is equal to the total debit divided by the per unit credits. While the general approach to scaling is the same across different type of equivalency analyses, some specifics differ. For example, the HEA and REA approaches rely on non-monetary metrics (e.g., habitat services, number of resource units, etc), while a VEA relies on a monetary metric. In addition, within the VEA framework, there are two additional considerations. First, one must decide which value is most important: use value or non-use value. The second consideration under a VEA, is to determine which of two alternative, but equally valid, approaches will be used, namely, a value-to-value or value-to-cost approach. Under the former, scaling proceeds as described above (divide total debits by per unit credits). Under the latter, the consideration of "per unit" credits is not relevant, as remediation is scaled based only on the cost of remediation project.
- **Estimating costs for remediation options** provides cost estimates for alternative remediation options, which can be useful in comparing across alternatives. Remediation costs are estimated by summing the different costs associated with the remediation assessment, implementation and monitoring. The key categories of costs include implementation, administration, operation, maintenance, and monitoring expenditures. These costs are very site-specific but detailed descriptions of what type of costs should be considered are given in the Toolkit. Importantly, the remediation costs will always be an underestimate of environmental liability because they exclude the cost of assessment itself (i.e. the time and expertise involved in developing the ecological and economic assumptions that stand behind the resource equivalency analysis), which should also be considered.
- **Considering disproportionate costs** entails analysing whether the estimated remediation costs may be disproportionate in comparison to the remediation benefits obtained and/or relative cost burden on responsible party (or parties). Neither ELD nor the Water Framework Directive, which also uses the term, offer a clear definition of 'disproportionate'. Instead, Member States may choose to define their own criteria for disproportionality, even though the Toolkit provides further discussion on this. The practical implication is that if costs are considered disproportionate, the Competent Authority can decide that no further remedial actions are required or the scale of the remediation needs to be reduced.

Table 2 demonstrates how the "per unit" credits would be calculated for 1 hectare of land (Column (a)) that would provide habitat services for 55 years into the future (using the Habitat Equivalency Analysis as in Step 2). The per unit credit is simply the degree of gain (in Column (b)) multiplied by the present value factor (times 1 unit). The rows are summed across the years to the get the total per unit credit during the lifetime of the remediation project.[4] Thus the increase in habitat services due to this particular remediation option (over the baseline) measured in present value (2007) due to the remediation project is just over 12 DSHaYs.

Table 2: Illustrated example of PER UNIT CREDIT calculations using a non-monetary metric				
Year	**Unit** *(number of hectares)*	**Degree of gain** *(% increase in species on site)*	**Present value factor**[1]	**Per Unit Credit (DSHaYs)**
Column	**(a)**	**(b)**	**(c)**	**(d = a x b x c)**
2009	1	10%	0.94	0.09
2010	1	20%	0.92	0.18
2011	1	30%	0.89	0.27
2012	1	40%	0.86	0.35
2013	1	50%	0.84	0.42
. . .		. . .	. . .	. . .
2060	1	50%	0.21	0.10
2061	1	50%	0.20	0.10
2062	1	50%	0.20	0.10
2063	1	50%	0.19	0.10
			Credit per hectare of land remediated	**12.08**

1. Present value factor = 1 / (1+ discount rate)^{year}. In this example, the discount rate is 3 % and the base year is selected to be 2007.

Below we use the debit estimate from Table 1 in Step 2 (319.5 DSHaYs) and the per unit estimate from Table 2 above to estimate the size of the remediation needed (in this case size of the habitat to be created).

Scaled remediation	= 319.5 DSHaYs ÷ 12.08 DSHaYs per (one) hectare
	= **26.5 hectares** (units) of remediation to provide

The illustration assumes that the habitat used for remediation is the same or sufficiently similar to the one assumed to be damaged in the illustration for Step 2.

[4] If the benefits would have been provided indefinitely, we can still estimate a finite per unit credit for remediation projects with perpetual benefits.

3.5 Step 5: Monitoring and Reporting

After the equivalency analysis is performed and remediation projects are selected and scaled, a **remediation plan**, which builds on information gathered during the equivalency analysis, should be prepared. This plan should include project goals, implementation details, engineering plans and designs, and biological plans and designs. Development of remediation plans may be iterative, and may include:

- Intended outcome(s) of the remediation (project goals);
- How the specific activities will contribute to the intended outcomes (including engineering and biological plans and designs);
- The anticipated time period of remediation actions;
- The anticipated duration of ecological recovery;
- The performance standards to be used to gauge project progress and success;
- Monitoring plans;
- Any potential risks to human health, society, culture, or the environment;
- How corrective actions will be taken, if necessary;
- Any ongoing operations and management necessary to ensure project objectives; and
- Project costs, including monitoring, oversight, operations, and management.

Specialised literature, existing general guideline documents and Member States' requirements should be consulted for additional information on the preparation of remediation plans.

Monitoring should be conducted at regular intervals that are determined based on biological, chemical, physical, social, or economic factors important to the determination of success. The metric originally used to quantify debit and credit should still be of substantial value in evaluating project success and benefits achieved. A graph of the metric over time ideally will match the credit model. Deviations can help inform future equivalency analyses. Monitoring plans should be designed to consider a reasonable range of natural variability, including factors such as seasonal variations in hydrographs, wildlife migrations, growing seasons, tidal cycles, and, potentially, human uses.

Reporting on a case-by-case basis is not a requirement of the ELD. However, since monitoring and evaluation are the only means by which Competent Authorities can demonstrate that they have protected the public's natural resources, reporting the results of monitoring and evaluation is crucial. Monitoring and reporting will also contribute to the communication of the remediation actions and outcomes to the affected public.

Whether publicly available or not, reports should include a description of the project, project goals, the anticipated recovery and benefits trajectory, data collected as part of the monitoring, and a synthesis and interpretation of the monitoring data. Any corrective actions taken or anticipated should be reported, and the degree of resource recovery and/or services recovery to baseline conditions, and relative to the anticipated recovery trajectory, should be described. In addition, an efficient EU-level reporting mechanism would allow Member States to benefit/learn from remediation experiences in other countries. In this context, ensuring EU level reporting of Member States follow up on remediation usage and success (e.g. efficacy, recovery outcomes and key parameters) to a central EU database might be a valuable contribution. The project's current website could be developed to act as such a dissemination portal.