Chapter 6
Step 4: Scaling Complementary and Compensatory Remediation

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Abstract The purpose of the scaling step of the equivalency analysis is to determine the amount of remediation required to offset damages to natural resources or services. It involves calculating the benefits (credits) for relevant remediation options and determining how much of the selected remediation is required to generate sufficient credit to offset the damage (debit). The determination of how much of the selected remediation is required is called scaling. Estimating the costs of undertaking the necessary amount of remediation options is also discussed.

Keywords Scaling remediation · Remediation credit · Remediation costs

6.1 Introduction

The fourth step in performing an equivalency analysis involves scaling the benefits of remediation such that they offset the quantified environmental damage (debits). This step helps answer the question: 'How much remediation is necessary to compensate for the damage caused as a consequence of the incident?' Key steps in this portion of equivalency analysis include the following (see Box 6.1 for the key issues and Fig. 6.1 for key substeps):

- *Calculate per unit credits*. In this step, service gains of a remediation project are expressed in terms of each unit of service, resource, habitat, or value that is to be remediated, as quantified using the same metric(s) used to calculated debits from the damage.

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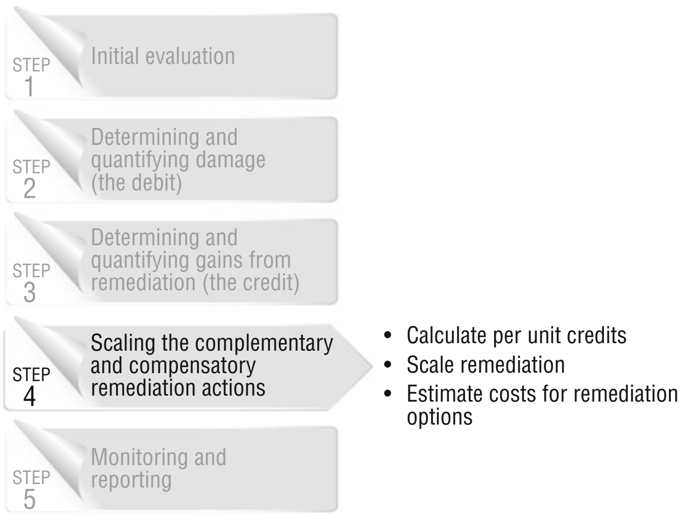

Fig. 6.1 Step 4 of equivalency analysis

- *Scale remediation*. Scaling remediation generally entails dividing the total debits by the per unit credits to determine how much remediation to provide.
- *Estimate costs for remediation options*. When using equivalency analysis, the cost of environmental liabilities includes the cost to implement and maintain the required remediation projects, as well as the cost of the efforts to undertake the equivalency analysis and the costs associated with planning, overseeing, and monitoring the remediation projects.

When scaling is undertaken, the credits from a remediation project should be quantified using the same metric(s) as used for the damage (debit) calculations (Chap. 5) so that the amount of remediation needed offsets the amount or extent of environmental damage.[1]

The general approach to scaling remediation is the same for Habitat Equivalency Analysis (HEA), Resource Equivalency Analysis (REA), and Value Equivalency Analysis (VEA), but the specifics differ slightly. For example, HEA and REA rely on non-monetary metrics (e.g., habitat services, number of resource units), while VEA relies on a monetary metric. However, in all cases, the scaling step is used to determine how much remediation is necessary, using the identified metrics, to offset the damages.

[1]For purposes of simplicity of exposition, throughout this chapter we present the discussion as if one type of remediation project is being implemented that is scalable to offset debits. In practice, multiple different remediation actions may be under consideration for use, and not all remediation projects may be completely scalable. The fundamentals of the approach described in this chapter still apply, however.

Box 6.1: Key issues and actions in Step 4: Scaling the complementary and compensatory remediation actions

The process of determining the amount of complementary and compensatory remediation that compensates for damage and interim loss is called scaling. Because scaling requires balancing the debit and credit sides of the equivalency equation, it generally requires two inputs: (1) the total discounted losses, or *total debits* (Chap. 4) and (2) the per unit present value gains, or *per unit credits*, of the remediation project. Remediation scaling then is achieved by dividing the total debits by the per unit credits, which gives you the appropriate amount (e.g., scaled amount) of remediation needed to offset the damage. This approach works for both monetary and non-monetary metrics. However, in the value-to-cost approach, scaling is simplified: the cost of remediation is set equal to the monetary amount of damage.

Step 4 also provides information on estimating the costs of remediation. The key elements of scaling complementary and compensatory remediation that should be considered in an assessment include the following (summarised briefly below):

- Calculating gains (credits) on a per unit basis for potential remediation options that pass the initial screening;
- Scaling remediation by dividing total debits by per unit credits to obtain the appropriate amount of remediation to offset damage; and
- Estimating costs for remediation options to provide an estimate of the costs of alternative remediation options, which can be useful in comparing across alternatives.

As with steps 2 and 3, uncertainty should be considered in scaling as well.

Estimating gains (credits) on a per unit basis conceptually is very similar to the process of estimating debits. For both monetary and non-monetary metrics, the approach entails identifying key assumptions about how the remediation project is expected to provide gains and then to sum these gains over the life of the project. The formula for estimating the per unit credit differs slightly depending on whether you are applying a non-monetary metric or a monetary metric.

Given an estimate of the per unit credits, the next step is scaling remediation. The formula is quite simple: total debits divided by per unit credits, adjusted on a present value basis. The result is the quantity of remediation, on a present value basis, that compensates for the total discounted present value of the damage. The only exception to this approach is the value-to-cost approach, which does not require an estimate of the (per unit) credits from remediation. Instead, the remediation is scaled based only on the extent of damage (debits). Illustrated examples of scaling remediation are provided for both a non-monetary metric (Sect. 6.3.3) and a monetary metric (Sect. 6.3.4).

Remediation costs include the cost of the remediation assessment, implementation, administration, operation, maintenance, and monitoring. These costs typically are both project- and site-specific.

6.2 Calculating Remediation Gains (Credits)

Although the total remediation benefits of a specific project can be calculated, many types of remediation projects have adjustable sizes, both in terms of geographic/temporal scope and intensity. For example, the number of hectares of forest revegetation, the intensity of wetland restoration projects or stream habitat improvements, the spatial or temporal extent of bird conservation measures, the amount of water quality improvements, or the number of migratory barriers removed all represent adjustable quanta of remediation alternatives. When a highly specified project hasn't been identified, the quantification of credits per unit of remediation therefore can be an efficient approach to scaling remediation and calculating the amount of remediation that might be undertaken to compensate for losses. *Per unit* credit calculation thus refers to the quantification of the service gains of a remediation project that are expressed in terms of each unit of service, resource, habitat, or value that is to be remediated, as quantified using the same metric(s) used to calculated debits from the damage. If the size or duration of a remediation project is adjustable, the amount of the remediation project can be scaled to fit the extent of damage.

6.2.1 *Per Unit Credits: Conceptual Approach with a Non-monetary Metric*

The conceptual approach to estimating per unit credits from a remediation option using a non-monetary metric is summarised by the following formula:

$$\sum_{t=0}^{t=n} \frac{(1 \times b_t)}{(1 \times r)^t}$$

where $\sum$ is the summation sign, $t = n$ is the end year, $t = 0$ is the start year, b_t is the degree of gain every year, r is the discount (or compound) rate, and t is any given year in the credit period (between 0 and n).

The inputs for this formula, which are described below, are very similar to those used for the debit formula in Chap. 4. For example, some of the inputs are necessarily the same (e.g., non-monetary metric to measure change, discount rate, and base year); other inputs are very similar in concept (e.g., degree of *gain* on the credit calculation is analogous to the degree of *loss* in the debit calculation). The inputs used in this formula are:

- *Start year* ($t = 0$). The year the remediation project begins providing environmental benefits.
- *End year* (n). The year the remediation project stops providing environmental benefits. In some cases, projects may provide benefits indefinitely. However, it

is still possible to estimate the *finite* benefits provided in such cases through the use of a positive discount rate.

- *One unit* (*1*). Represents the unit of remediation that can be adjusted, to offset the damage. This may represent a hectare of habitat, a resource such as a fish or bird, etc. In this formula, it is always set to 1 because we are estimating 'per unit' credits.
- *Present value multiplier (r).* As described previously (see Box 4.4), this multiplier adjusts the value of benefits into today's terms. In this case, future benefits are discounted back to present value terms. The discount rate should be the same on both the debit and credit calculations.
- *Degree of gain* (b_t). The degree of gain describes the same concept as the degree of loss in the debit calculation but refers to the *improvement* provided by the remediation project instead of the damage caused by the incident. It is often measured in percentage terms (e.g., percent increase in resources or services) or in number of resource units (e.g., numbers of fish, gallons of water). This rate of change into the future is analogous to the recovery rate on the debit side.

Additional assumptions that are not explicitly in the formula above but are nonetheless important inputs into this calculation include the following:

- *Metric*. The (non-monetary) metric used to measure the gain must be the same as the metric used in estimating the total debits (see Chap. 4 which reviews metric selection), or normalized using an appropriate adjustment scalar.
- *Base year*. The year used for the present value calculations. The year must always be the same as the base year used in the debit calculations.

The illustrative example in Sect. 6.3.3 demonstrates how these calculations might look for a sample HEA. The calculations would be very similar for an REA and therefore are not shown below.

6.2.2 Per Unit Credits: Conceptual Approach with a Monetary Metric

The per unit credits from remediation using a monetary metric are only relevant under the value-to-value framework, where the remediation gains in monetary terms must be quantified in order to scale remediation against losses denominated in a monetary metric. In the value-to-cost framework, the gains from remediation are not scaled through an equivalency analysis to the damage. Below we describe this relevant approach under both frameworks.

The following discussion uses *use* value (as opposed to *non-use* value) as the primary component of losses being valued. Alternatively, the non-use value, or total value, associated with a damaged resource may be compensated for through remediation projects. In these cases, the methods are the same, but the 'degree of gain in human use' would be replaced by the 'degree of gain in non-use or total value' below. (See Chap. 11, the BABE Forest Fires case study, as an example of the substitution of the per unit approach with a direct scaling approach, in which the overall debit value is calculated first and the overall required equivalent credit in environmental terms is estimated directly instead of inferring a per unit value).

Under the value-to-value framework where use value is the primary component, when a single type of remedial action that can be altered in size is being considered, per unit credits are calculated for the scaling process. The conceptual approach to estimating per unit credits from a remediation option using a monetary metric is summarised by the following formula:

$$\sum_{t=0}^{t=n} \frac{(1 \times q_t \times p_t)}{(1 \times r)^t}$$

where $\sum$ is the summation sign, $t = n$ is the end year, $t = 0$ is the start year, q_t is the degree of gain in human use every year, p_t is the degree of gain in economic value per unit of use every year, r is the discount (or compound) rate, and t is any given year in the credit period (between 0 and n).

The inputs are very similar to those used in the total debit calculation in Chap. 4. For example, some of the inputs are necessarily the *same* (e.g., monetary metric to measure change, discount rate and base year), while other inputs are *very similar* in concept (e.g., units of *gain* in human use on the credit calculation is analogous to the units of *loss* human use in the debit calculation). One key difference is the inclusion of the 'degree of gain in economic value'. This calculation is necessary on the credit side when using a monetary metric because it translates changes in resource improvements into the value that people place on that change (in a money measure) associated with that change. Inputs used in this formula include the following:

- *Start year* (*t = 0*). As above.
- *End year* (*n*). As above.
- *One unit* (*1*). Represents the unit of remediation that can be scaled, that is, adjusted, to offset the damage. In this *use* value example, it can represent a unit of human use (e.g., fishing trip, boating trip, recreational day at a beach). In this formula, it is always set to 1 because we are estimating 'per unit' credits.
- *Degree of gain in human use* (q_t). The improvement associated with human use of a natural resource following a remediation project. For example, if the primary human use is fishing, this may refer to an increase in fishing trips due to an increase in the number of fish caught (or size of fish) at a particular lake following a remediation project (e.g., habitat improvement). Estimating q_t requires knowing the change in the resource or service due to an incident, and what that change means in terms of human use. Where the metric for the former would be ecologically based as discussed in Chap. 4, the metric for the latter will be have to be discernible and hence valued by humans. For example, BOD (Biological Oxygen Demand) may be the correct ecological metric for the initial change in q_t to estimate the effect on fish populations, for the change in human use, the effect of the change in the fish

populations on the relevant recreational activities (if the fish is used for angling) or human health (if it is used a food source) needs to be identified.

- *Degree of gain in economic value* (p_t). The increase in value associated with human use of a natural resource following a remediation project. It translates the degree of gain in human use into an economic gain (measured by our monetary metric) which can be compared to the economic loss (measured by our monetary metric) from the damage. If the primary human use is fishing, this may refer to an increase in the value a fisherman associates with a fishing trip taken following a remediation project at a given location. This link between an increase in a resource measure (fish) to human value could be based on a review of the economic literature describing how fishermen value changes in fishing attributes or through a primary survey.
- *Present value multiplier* (r). As above.

6.3 Scaling Remediation

When scaling remediation, the objective is to determine how much remediation to provide using either a non-monetary metric, and thus HEA or REA, or a monetary metric, and therefore VEA. Below, we provide a description of remediation scaling for each type of equivalency analysis.

6.3.1 Scaling Remediation with Monetary and Non-monetary Metrics

Scaling remediation generally entails dividing the *total* debits by the *per unit* credits.[2] The output is the amount (magnitude) of remediation to provide today (and last for some time into the future[3]) that will offset the damage caused. Thus, a simple formula for scaling remediation is:

$$\begin{aligned}&\text{Total quantity of the remediation project to provide now}\\&\quad= \text{Total present value debits} \;/\; \text{present value per unit credits}\end{aligned}$$

In the case of a non-monetary metric, the number of units of remediation to provide would be the units of habitat, resources, or services that compensate for the damage, measured using the selected non-monetary metric(s).

[2]This same process can be applied when credits are not calculated on a unit basis by summing remediation project credits until the full debit is satisfied (see BABE Forest Fire case study in Chap. 11).

[3]How long the remediation benefits will last into the future is an important assumption to be made during an equivalency analysis.

In the case of a monetary metric using a value-to-value approach, the number of units of remediation to provide would be the value associated with the increase in human use (e.g., number of user days)[4] that comes from the remediation project (remember that when using this approach the remediation project must offset the value of the damage). Thus, the Competent Authority and/or responsible operator would need to undertake sufficient remediation to ensure the gain in value is equal to the loss in value. The cost of providing this amount of remediation, including the costs of operations, management, and monitoring, would represent a part of the environmental liability (the other part includes the cost of conducting the equivalency analysis, see Sect. 6.4). Note that this cost in monetary terms may be more or less than the value of the damage, depending on how the users of the resource value the remediation improvement.

6.3.2 Scaling Remediation Under a Value-to-Cost Framework

Scaling remediation under a value-to-cost framework is different. Instead of dividing the total debits by the per unit credits, the amount of remediation to provide is based only on the size of the damage (thus, no need to estimate per unit credits). The scaled amount of remedial actions to ensure equivalence between debits and credits is based on the total damage caused, rather than the value derived from the proposed remediation project (as is required under the value-to-value framework described above). That is, the remediation project is scaled so that its cost equals the total value of the damage. In practical terms, this means that the Competent Authority recovers the full value of the damage and uses these funds to implement a remediation project. Thus, the amount of remediation is scaled based on what it would cost to implement a remediation project that meets the criteria discussed in Sect. 5.2.2.

Note that both the value-to-value and value-to-cost frameworks are equally valid approaches for the purpose of equivalency analysis. The decision to use one or the other will depend upon the desires of the Competent Authority and the responsible operator. However, for damage cases under the Environmental Liability Directive, a specific hierarchy has been established that favours the use of value-to-value over value-to-cost.

[4]Depending on the resource, the number of user days may represent fishing trips to a river, number of boating days in a lake, or number of beach visits to a recreational beach. Depending on the type of damage, other units such as health impacts, crop value etc. can also be used.

6.3.3 Example: Scaling Remediation Using a Non-monetary Metric

To provide a numerical illustration of how to scale remediation, we use the example presented in Sect. 4.6.1. In that example, we assumed that 100 ha of land were damaged, leading to a loss of functional habitat services. We estimated the total debits to be 319.5 Discounted Service Hectare Years (DSHaYs) (see Sect. 4.6.1 and Table 4.1). For purposes of this illustration, we assume that a remediation project at a nearby location could provide improvements in functional habitat services that are similar to those that had been provided by the damaged land and the habitat improvements (credits) are quantified as described in Chap. 5. Below we identify the hypothetical assumptions for our illustrative scaling example (Table 6.1 summarises the calculations):

- *Start Year*. We assume remediation benefits are first realised in 2014.
- *End year*. We assume benefits from the remediation will stop being provided in 2068.
- *Unit* (*Table* 6.1, *column A*). Hectares of habitat functional services (i.e., unit = hectare).
- *Degree of gain* (*Table* 6.1, *column B*). We assume an ultimate 50% increase in provision of habitat relative to baseline. This gain is assumed to occur gradually in the first five years from 2014 to 2018 and then continue at a constant 50% increase for the next 50 years (at which point the habitat improvements return to the original baseline).
- *Present value multiplier* (*Table* 6.1, *column C*). We assume a 3% discount rate.
- *Metric*. The non-monetary metric is the same as in the debit calculations: hectares of habitat quality function.
- *Baseline*. We assume the baseline is the same as defined in the debit calculation. The implication is that the 50% degree of gain is relative to this condition.
- *Base year*. We assume 2012 is the base year for the analysis (same as the debit calculation), which means the present value multiplier is equal to 1 in that year.

Table 6.1 demonstrates how the per unit credits would be calculated for 1 ha of land that would provide habitat-related benefits for 55 years into the future. The per unit credit in each individual year is equal to the degree of gain in that year multiplied by the present value factor. The present value credits then are summed across the years during which the remedial project generates benefits to calculate the total present value of credits for each unit of remediation (1 ha in this examples) over the lifetime of the remediation project.[5] Thus, the increase in habitat quality services (over the baseline) measured in present value (2012) from the hypothetical

[5]If the benefits would have been provided indefinitely, the present value factor would—after about 100 years—become less than 0.01. In practical terms, this means that benefits occurring 100 years from now and into the future are essentially zero. Thus, we can still estimate a finite per unit credit for remediation projects with perpetual benefits.

Table 6.1 Illustrated example of per unit credit calculations using a non-monetary metric

Year	Unit (ha)	Degree of gain (e.g., % increase in species on site)	Present value multiplier[a]	Per unit credit[b] (DSHaYs)
	(A)	(B)	(C)	(D) = (A) × (B) × (C)
2014	1	10	0.94	0.09
2015	1	20	0.92	0.18
2016	1	30	0.89	0.27
2017	1	40	0.86	0.35
2018	1	50	0.84	0.42
⋮	⋮	⋮	⋮	⋮
2065	1	50	0.21	0.10
2066	1	50	0.20	0.10
2067	1	50	0.20	0.10
2068	1	50	0.19	0.10
Credit per hectare of land remediated				12.08

[a]Present value factor = $1/(1 + \text{discount rate})^{(\text{year}-\text{base year})}$, where discount rate = 3% and base year is 2012

[b]Per unit credit is calculated by multiplying percent gain by present value factor for each unit and for each year of the project

remediation project is equal to 12.08 DSHaYs per hectare of habitat remediation (sum of discounted unit in column (d) of Table 6.1).

Scaling remediation requires that the total debit be divided by the per unit credits. The total debit was estimated in Sect. 4.6.1 to be 319.5 DSHaYs. The per unit credits were estimated above to be 12.08 DSHaYs per unit. Thus, to offset the total loss of 319.5 DSHaYs with the example remediation project, 26.5 ha of remediation would be required, i.e., 319.5 DSHYs/12.08 DSHYs per hectare restored = 26.5 ha.

Therefore, the amount of hectares to be provided each year, that is, remediated this year and then made available for a period of 55 years that will compensate the total interim loss of habitat, is approximately 26.5 ha.

In this example, the remediation required consists of a smaller area (26.5 ha) than the damaged land (100 ha). Although this seems counterintuitive, this is a result of the summation over time and the services provided by habitats over time. In our example, the debit occurs over a period of nine years, with services reduced by 50% for the first five years, and then improves linearly over the final four years back to a baseline level (Table 4.1). As shown in Table 6.1, the credit occurs over a much longer period of 55 years, with services improving linearly over the first four years to 50% in the fifth year, and continuing at a 50% improvement over pre-remediation conditions for 50 years. Although the credit is discounted by 3% each year, the longer time that services are provided by the remediation means that a smaller area is needed to compensate for the debit.

6.3.4 Example: Scaling Remediation Using a Monetary Metric

In our simple VEA example from Chap. 4, we assumed that a popular fishing area was contaminated by a chemical release, which led to a loss of 200 fishing trips per year for a three-year period and a diminished experience for the 100 fishing trips per year that continued at the site for a three year period. With our assumptions, we calculated the total debit to be a discounted lost value (DLV) of €18,938 (see Sect. 4.6.2 and Table 4.2).

Using the value-to-cost approach, scaling would proceed as follows: the Competent Authority would recover the €18,938 from the responsible operator and use that to implement compensatory remedial actions. These actions might include actions such as fish stocking, improving public access to fishing areas, or habitat improvements designed to improve the fishing experience (e.g., improve catch rates, average fish size, or quarry species mixes). Importantly, the amount of remediation would be scaled such that the total cost would not exceed €18,938. In other words, the value-to-cost framework ensures equivalence between the debits and credits by assuming that *the cost of remediation* equals the total debits.

Using the value-to-value approach, the Competent Authority would also recover funds that would be used to implement similar types of remediation. However, the scaled amount of funds used for this remediation would be based on the value the anglers derive from the proposed remediation project, rather than being based on the value of the damage. In other words, the value-to-value framework ensures equivalence between the debits and credits by assuming *the amount of remediation* should be based on the increase in value provided by the remediation project.

To scale the appropriate amount of remedial actions in the value-to-value approach, we follow the methodology described above for non-monetary metrics by estimating the per unit credits and dividing them into the total debits.

Below we identify hypothetical assumptions for this illustrative example, based on the scenario described in Sect. 6.3.3 (Table 6.2 summarises the calculations).

- *Start year*. We assume remediation benefits are first realised in 2014.
- *End year*. We assume benefits will stop being provided in 2068.
- *Unit* (*Table* 6.2*, column A*). We scale the number of fishing trips to the damaged area, that is, unit = fishing trip.
- *Degree of gain in human use* (*Table* 6.2*, column B*). Increased catch rates typically improve the value of recreational fishing. We assume that a proposed remediation project improves the catch rate by 25% to anglers by increasing fish stocks through habitat improvements. We assume this occurs gradually over a five-year period from 2014 to 2018 and then continues to provide that same service gain for the next 50 years, at which point the incremental benefits are no longer achieved.
- *Degree of gain in economic value* (*Table* 6.2, *column C*). To translate this gain in human use into an economic gain (measured by our monetary metric), we make an assumption about the economic value per trip (in real cases, this

Table 6.2 Illustrative example of per unit credit calculations using a monetary metric

Year	Unit (fishing trips)	Degree of gain in human use (% increase in catch rate)	Degree of gain in economic value due to increase in human use (€) (10% of base value of fishing trip (€25))	Present value multiplier[a]	Per fishing trip credit[b] (€)
	(A)	(B)	(C)	(D)	(E) = (A) × (B) × (C) × (D)
2014	1	5	0.50	0.94	0.47
2015	1	10	1.00	0.92	0.92
2016	1	15	1.50	0.89	1.33
2017	1	20	2.00	0.86	1.73
2018	1	25	2.50	0.84	2.09
2019	1	25	2.50	0.81	2.03
2020	1	25	2.50	0.79	1.97
⋮	⋮	⋮	⋮	⋮	⋮
2064	1	25	2.50	0.22	0.54
2065	1	25	2.50	0.21	0.52
2066	1	25	2.50	0.20	0.51
2067	1	25	2.50	0.20	0.49
2068	1	25	2.50	0.19	0.48
Credit (value) per trip from the remediation project					€60.40

Notes [a]Present value factor = 1/(1 + discount rate)$^{(\text{year}-\text{base year})}$, where discount rate is 3% and base year is 2012

[b]Per unit credit is calculated by multiplying degree of gain in human use by degree of gain in economic value by present value factor for each unit and for each year of the project. All are expressed per 1 fishing trip

To shorten the table, some of the results were omitted and substituted by the ellipsis

assumption should be based on studies from the literature or primary economic research). We assume that increasing the catch rate by 25% would increase the value of a fishing trip by 10% of the original value of the trip, or €2.50 (current value is €25) per trip. Because this benefit is dependent upon the gain in human use, its trajectory over time mirrors the gradual increase over five years, then becomes constant for the next 50 years.

- *Present value multiplier* (*Table 6.2, column D*). We assume a 3% discount rate.
- *Metric*. The monetary metric is the value of the human use of the resource. On the debit side, this was the value of the loss. Here it represents the value of the gain in human use due to the remediation project, that is, the 25% increase in catch rate (€2.50 per trip).
- *Baseline*. We assume the baseline is the same as that defined in the debit calculation. The implication is that the gain in human use (catch rate) is relative to this condition.
- *Base year*. We assume 2012 is the base year for the analysis (same as the debit calculation).

When fully implemented in 2014, this remediation project would improve the value of a recreational fishing trip by €2.50. Using the same implementation schedule as the gain in human use (i.e., gradually reaching the maximum level in five years and then providing constant gains for the next 50 years), Table 6.2 shows the calculations to determine the increase in value of a single fishing trip. Column (E) is the credit per trip and is equal to the number of trips (A) times the degree of gain in human use (B) times the degree of gain in economic value (C) times the present value factor (D). Thus the increase in value (over the baseline of €25) associated with increasing one fishing trip annually due to the remediation project is €60.40, measured in present value (2012) (sum of discounted unit benefits in column (D) of Table 6.2).

We then scale remediation to ensure the value-benefits of the remediation project is equal to the value of the loss, providing us the number of *improved* recreational trips that will offset the loss. Thus, we divide the total debit (€18,938) by the per unit credit (€60.40) and determine that remediation must provide sufficient improvements such that the 25% increase in catch rate is realised on approximately 314 recreational fishing trips annually (€18,938/€60.40 per trip = 314 trips).

In the value-to-value calculations above, the Competent Authority would determine the cost to undertake the required habitat improvements to increase fish stock so that recreational anglers would realise a 25% increase in catch rates. The cost to implement those habitat improvements would then form the basis of the liability claim.

6.4 Estimating Costs of Remediation Options

The total cost of environmental liabilities using an equivalency analysis is equal to the sum of the cost of the efforts to undertake the equivalency analysis, the cost to implement and maintain the required remediation projects, and the costs associated with planning, overseeing, and monitoring the remediation projects. The cost of analysis may include staff costs of the Competent Authority and possibly the costs of hiring external experts (e.g., ecologists, economists, lawyers). Here we focus on the cost of the remediation project because of its importance in comparing different remediation options. In other words, some projects may provide the same level of complementary or compensatory remediation but differ in their costs.

6.4.1 Remediation Cost Components

The results of an equivalency analysis can be presented in terms of the amount and type of required remediation or the cost of implementing the required remediation. Unit costs of the required scale of remediation may include:

- Project design (including scientific or engineering design, permitting, surveying, and other related design costs),
- Project implementation,
- Project administration,
- Operations and maintenance,
- Failure contingency,
- Monitoring and reporting expenditures, and
- Oversight costs by the Competent Authority.

The costs of remediation projects are project specific, but some general considerations on potential cost components are provided in Table 6.3.

6.4.2 *Estimating Remediation Costs*

Cost estimation requires diligence by those managing the remediation project in order to ensure all cost categories are covered. It is important that scientists and engineers responsible for designing the project provide input to, or at least verify, cost estimates (GHK 2006, eftec 2010).

Cost information typically may be obtained by:

- Developing site-specific remediation costs;
- Acquiring representative costs of similar projects (keeping in mind potential differences related to site location, local economic factors, similarity of resources or projects); and
- Other such factors that may influence variations in project costs or through discussions with experts in ecological remediation and engineering design.

One approach to estimating costs is to rely on actual cost information from previous projects that are similar to the selected remediation alternatives. Cost information can be found in the literature, from documentation of previously conducted projects, or from established cost estimate tables available in some Member States. Important considerations when using the ‘cost transfer’ approach based on similar projects are (1) to standardise the costs on a per unit or per area basis to control for project size and (2) to ensure characteristics other than size of the documented project(s) are similar to the one under consideration. In addition to project size, other criteria for evaluating similarity might include climate, topography, region (labour and capital costs across regions), time, and other relevant factors.

Note that uncertainty in the cost components of the claim is not addressed in detail in this document. However, the typical approach, which is the addition of a flat-rate contingency to monitoring and oversight costs, is discussed in Sect. 4.2.3 of the United States National Oceanic and Atmospheric Administration Technical paper 99-1 (NOAA 1999). Diekmann and Featherman (1998) also discuss possible ways to assess cost uncertainty.

Table 6.3 Important cost components when estimating remediation cost

Cost	Description
Planning	lanning and design of the remediation project. This may include preliminary ecological (or economic) surveys to identify extent of damage (or loss of value or welfare) and ecological (or economic) surveys to count or assess post-incident ecological data (or loss of value or welfare). This cost component can be subdivided into two parts: • *Initial design, surveying, and plan preparation* covers those aspects of work that are necessary prior to preparing a final executable remediation plan. It should also include the costs of REA. • *Final plan preparation* covers the preparation of a final remediation plan including, as necessary, any public outreach and comment, design drawings, engineering models, survey results, mobilisation schedules, and other required plan elements.
Acquisition of permits	The acquisition of any necessary legal access, permitting requirements, or other such obligations that may be necessary to conduct remediation work
Acquisition of land	Land acquisition costs can cover any necessary costs to acquire property easements, rights-of-use, or other legal instruments needed to implement remediation actions and subsequent operations, monitoring, or adaptive management actions
Implementation	Implementation costs cover the fundamental elements of remediation implementation, including all labour, materials, transport, infrastructure development, site management and oversight, and supplies needed during the implementation process
Operations and maintenance	Operations and maintenance costs cover all costs required to run and manage the project, including necessary labour, equipment, materials, and supplies for these operations. Often this component is expressed as an annual cost of operating and/or maintaining the implemented activity (e.g., annual removal of sediments from constructed drains)
Oversight	Oversight covers any cost associated with necessary oversight of remediation projects by Competent Authorities. This cost component most likely consists of labour costs and administrative overhead costs, that is the additional cost (on top of labour costs) to account for ongoing expense of operating the organisation (rent, communication costs, utilities, permits, insurance, etc.)
Monitoring and reporting	Monitoring and reporting covers all necessary monitoring and reporting costs, including costs of labour, materials, supplies, and information dissemination
Failure contingency	The contingency cost component covers all necessary and appropriate contingency costs that apply to uncertainties associated with remediation project execution. The purpose is to account for unexpected/random events that increase actual costs over planned costs (e.g., bad weather). Often this cost component consists of a standard percentage amount that is added to the best cost estimate (e.g., all costs mentioned above). General practice is to assume an additional 20–40% of total estimated costs as 'contingency costs'

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