FLOOD PREVENTION SCHEMES

Guidance for Local Authorities

natural scotland
SCOTTISH EXECUTIVE

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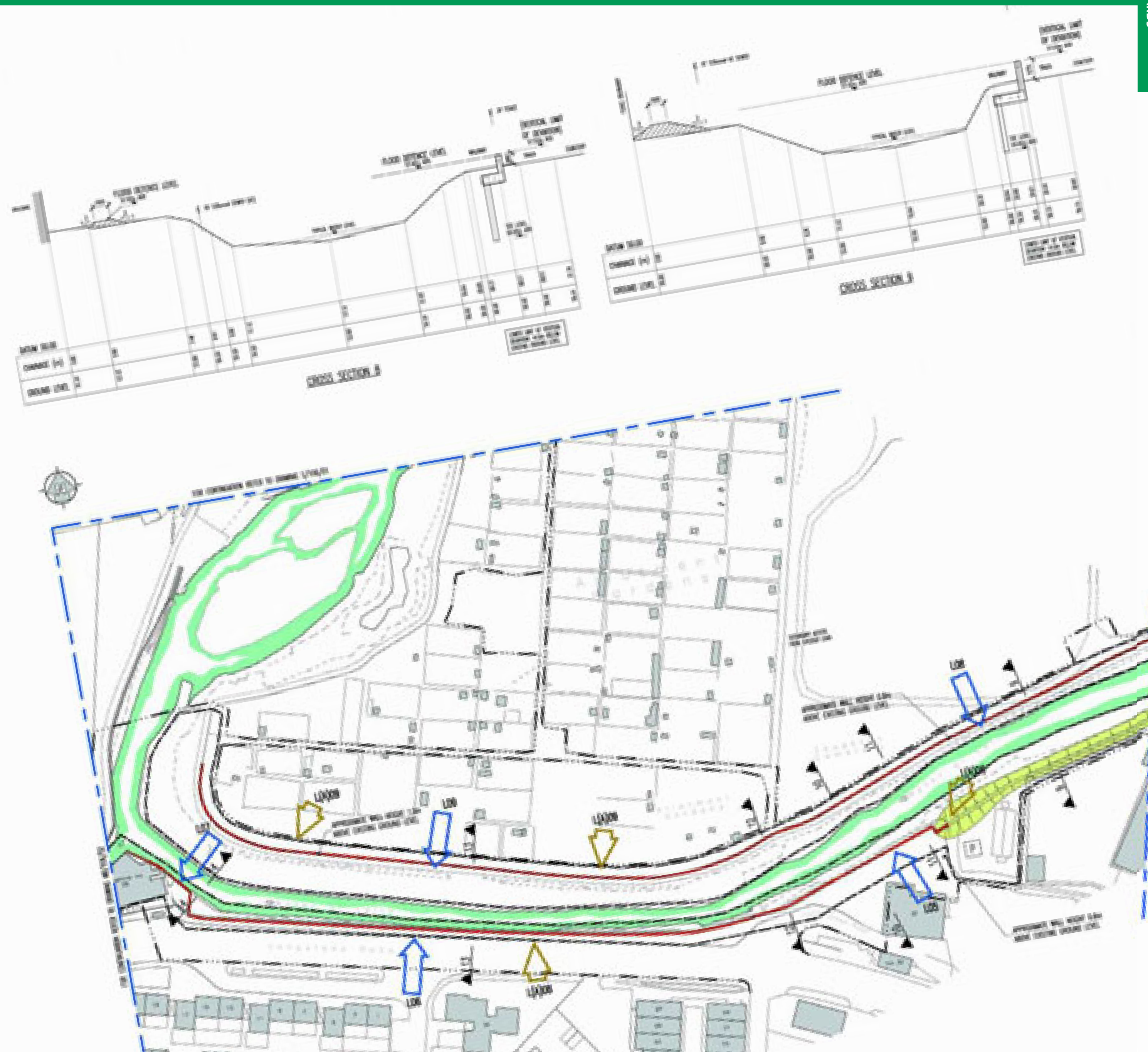

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Economic Appraisal

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Chapter 5

FLOOD PREVENTION SCHEMES: GUIDANCE FOR LOCAL AUTHORITIES

ECONOMIC APPRAISAL

CONTENTS

SECTION 1

INTRODUCTION

Scope

1.1 This chapter provides guidance for Scottish local authorities on the economic aspects of project appraisal for flood prevention schemes promoted under the Flood Prevention (Scotland) Act 1961. It identifies methods for valuing costs and impacts in monetary terms and sets out a recommended decision process, based on economic values. Good practice recommendations are shown in bold text.

1.2 The guidance assumes that the reader has prior knowledge of general benefit-cost analysis techniques, and should be read in conjunction with the other chapters. It is not intended to be followed mechanically, or to cover every possible eventuality. Appropriate specialist advice should be sought as necessary for the benefit-cost analyses of all schemes.

1.3 Unless otherwise stated, references in this chapter to economic values, whether in terms of costs, losses or benefits, assume that all components of economic value are taken into account. Such components can include social, political and environmental values (Annex B).

1.4 The document is based on the procedural guide, "Flood and Coastal Defence Project Appraisal Guidance, Economic Appraisal", published by the Ministry of Agriculture, Fisheries and Food, now the Department of Environment, Food and Rural Affairs (Defra) (reference 1). It incorporates and develops certain aspects of the guidance to local authorities given in the Scottish Executive's Note of 14 March 2003.

Background to benefit-cost analysis

1.5 In Scotland, the capital works undertaken by local authorities in respect of flood prevention schemes can attract substantial support from public funds in the form of grant assistance. To qualify for such support, schemes must, among other things, be subjected to economic appraisal, to ensure value for money and the achievement of other goals. The procedures for economic appraisal should be consistent with the 'Treasury Green Book' (reference 2).

1.6 The recommended approach is appraisal-led design. That is, the whole process of option development, refinement and choice should be carried out within a logical appraisal framework. Ideally, this should entail working from strategic assessments through to appraisal of the options for a particular project.

1.7 The key to application of benefit-cost analysis to flood prevention schemes is the management of risks. Such schemes reduce the probability or severity of future flood damage, compared to the pre-scheme situation. This change in probability may vary over time; for example, as an embankment erodes. No scheme can eliminate the possibility of flooding, and there can be no certainty about the timing of the next damaging event. Further discussion of issues related to the definition and evaluation of risk can be found in Chapter 6.

1.8 It should be emphasised that the aim of benefit-cost analysis is to provide a transparent and inclusive approach to decision-making which, as far as possible, takes all relevant factors into account. While some impacts cannot easily be valued in monetary terms, they should not be excluded from the appraisal.

1.9 Benefit-cost analysis is a useful tool for determining the most appropriate strategic approach, deciding whether it is worthwhile to undertake a scheme, and identifying and comparing scheme options. It should not be viewed as a hurdle. The analysis should stimulate the development of alternative solutions by clarifying the consequences of all options. Well-designed, it should ensure that schemes undertaken represent the best value for money, and that uneconomic schemes are identified at an early stage.

1.10 The design process is cyclic and iterative. It involves exploring the problem, generating options, and refining the selection progressively. This approach should also be applied to the benefit-cost analysis, to aid and guide the design towards the best solution.

Goals

1.11 Economic appraisals have several goals:

Best use of public money Demands for public funding always exceed the money available. It is therefore necessary to aim for economic efficiency in the investments that are made. This is achieved when the total of all forms of benefit is maximised relative to the resources used. The analysis should not be limited to the consideration of priced benefits and resources. It should, where appropriate, include unpriced benefits, such as the enjoyment gained from walks by a river, as well as the unpriced costs incurred, such as nuisance during construction.

Sustainability Sustainable schemes are those which take account of the interrelationships with other defences, developments and processes within a catchment, and which avoid as far as possible tying future generations into inflexible and expensive options (see Chapter 3). This can often be demonstrated in economic terms (paragraphs 5.20, 5.21).

Accountability A formal process of project appraisal can demonstrate that a wide range of different options has been considered transparently, and that the advantages and disadvantages of each have been properly considered. Appraisals also create an effective audit trail of decision-making.

Quality assurance Good quality appraisals save time and money by early rejection of unrealistic options; they increase certainty and confidence in the final outcome.

SECTION 2

THE APPRAISAL CONTEXT

Defining the problem

2.1 An appraisal should start with a clear statement of the problems to be tackled or the objectives to be achieved. These should be defined without prejudging the solution; for example, it is not acceptable to state that the objective is 'to replace existing flood defences with a 1 in 100 year design standard flood embankment'. Further, all social, environmental and economic issues should be taken into account. Major constraints affecting the options should also be stated.

2.2 An example of such a statement might be:-

'The town is prone to flash flooding with an annual probability of greater than 5% (that is, at return periods of less than 1 in 20 years); the area at risk covers 120 properties including some sheltered housing with a higher expectancy of risk to life. The problem is believed to have increased in recent years because of urbanisation of the catchment. Sections of the river border an SSSI.'

Strategic approach

2.3 Flood prevention schemes must meet certain basic criteria. Specifically, they should be technically sound, economically viable, and environmentally acceptable. To achieve these objectives, a strategic approach is desirable. Once broad solutions have been determined at the strategic level, the range of options to be considered on a project-specific basis will become clear. Guidance on strategic considerations is provided in Chapter 3.

Issues which cannot be incorporated into a benefit-cost analysis

2.4 A limitation of economic analysis is that it involves comparison of options in terms of a single objective, economic efficiency. There may be other objectives relevant to the choice; for example, the achievement of sustainable development and the promotion of sustainable flood management (Chapter 3). Further, there are some impacts that cannot be readily valued in economic terms and others which, for various reasons, may not be given their full weight in the analysis. It is, therefore, crucial to set out project objectives and to compare the options in terms of their contribution to the achievement of these objectives. If the contribution cannot be wholly quantified in economic terms, or does not affect economic efficiency, it is important that it be identified and stated.

2.5 Schemes may be affected by legal obligations under national and international law, which may constrain the appraisal process. For example, where the obligations involve requirements that must be met, it would be incorrect to test that position using economic analysis. Instead, the principles of cost-effectiveness would usually be more appropriate. A benefit-cost analysis may serve only to identify the least costly method of meeting the legal obligations.

Hazard management options

<u>Importance of a good choice of options</u>

2.6 Benefit-cost analysis can only identify the best of those options considered. A good appraisal will, therefore, encompass a wide range of management options, if only to rule out many of these at an early stage. A narrowly defined search may only identify the best of a poor set.

2.7 Options may reduce the risk of an event, or reduce the damages when an event occurs. Institutional or behavioural adaptations, such as relocation of some activities, or the temporary closure of roads when flood warnings are in force, may be considered in addition to the construction of works.

2.8 The form of the detailed analysis also depends on the situation and physical aspects of the land, whether or not there is an existing scheme, and whether there is a statutory requirement to maintain the watercourse. The residual life and standard of protection offered by any existing scheme should also be taken into account. These different conditions determine the appropriate 'do nothing' and 'do something' options (section 3).

Assessing risk to life

2.9 Deaths from flooding in the UK have fortunately been rare. However, this risk is always present. It is sensible, therefore, to assess whether floods in a particular situation pose an unusually high risk to life. Such a threat might occur with a rapid rise in floodwaters, accompanied by high flow velocities and deep water, particularly where this could result in the structural failure of buildings. Consequently, where structures such as flood embankments fail, or where flooding can occur in very small, steep catchments, special attention should be given to managing the risk.

Events exceeding scheme capacity

2.10 There is always the possibility that a more extreme flood than the design event will occur during the lifetime of a scheme. Consequently, appraisals should consider all events, not just those up to the design standard of protection.

Environmental protection

2.11 The water environment provides a range of habitats, which supports a wide variety of species and water-related uses. Changes to that environment, both locally for a scheme and in a wider national context, need to be taken into account in the appraisal process, particularly the ability to meet statutory environmental objectives. Further information is provided in Chapter 7.

Consultation

2.12 Consultation is a necessary part of most schemes. It is good practice to consult early in the scheme design, and to continue the process throughout the design work and implementation. This should enable a comprehensive consideration of the appropriate costs and benefits.

Multi-functional schemes

2.13 The development of strategic approaches to flood prevention may result in the promotion of a multi-functional project. At its simplest, such a project may involve 2 or more different structures, each with a different purpose, but built together to make savings in total construction costs. In this case, it would be reasonable to apportion these costs, and to appraise the flood defence function of the works separately.

2.14 However, the aim of promoting a multi-functional project will generally be to provide a range of facilities at a lower total cost than if each were provided separately. In this situation, when undertaking the benefit-cost analysis, all benefits and costs should be included and the question of who benefits and who pays can be ignored.

2.15 The question then arises of how to share the costs equitably between funders. Because the overall aim is to make more efficient use of resources, it is reasonable to assume that no party should pay more than the whole-life cost of meeting their specific requirements on a stand alone basis. The contributions should usually be based on the costs of the relevant major sections of the work. However, there may be situations where it will be more equitable to divide costs in the ratio of the major benefits, provided these can be determined on a consistent basis (see also paragraphs 5.9 and 5.10).

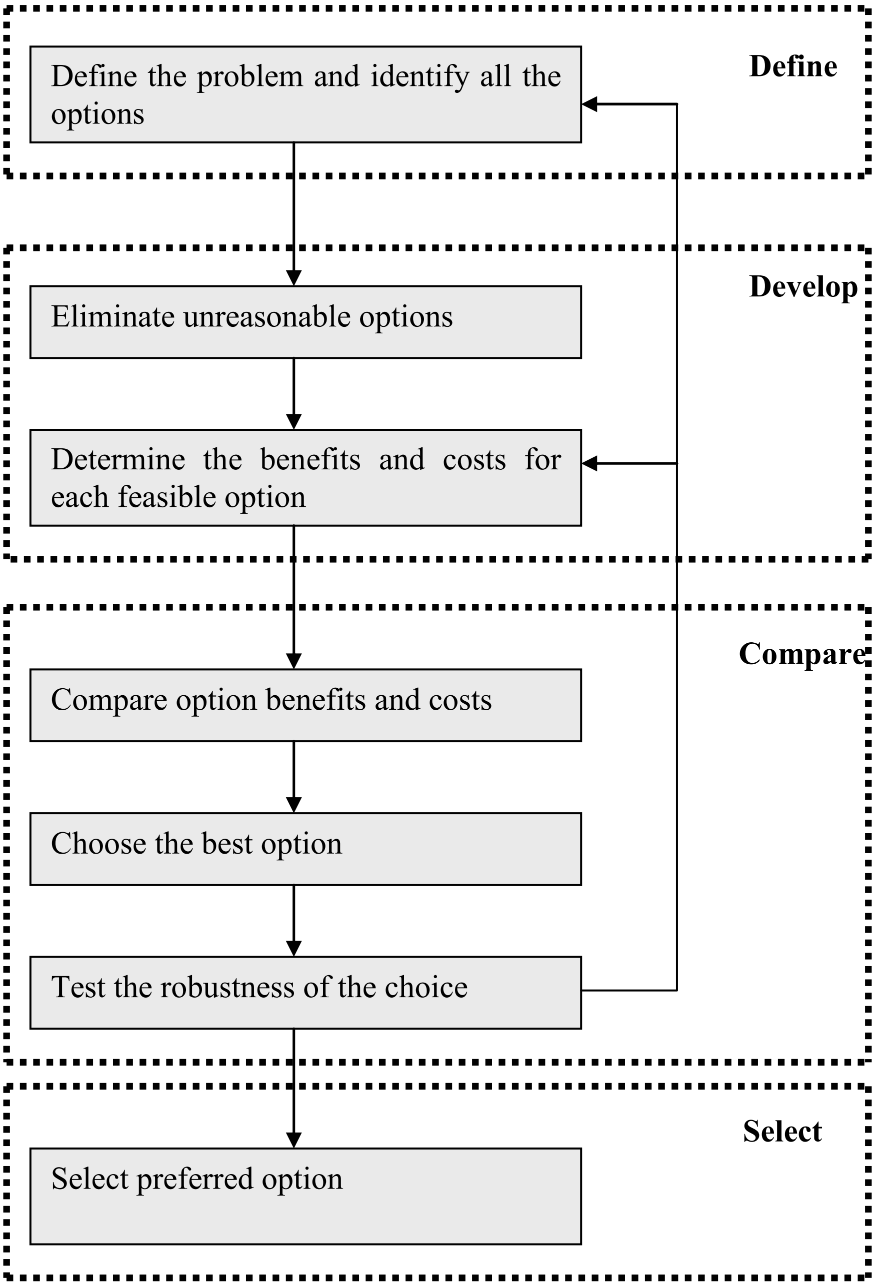
SECTION 3

STAGES IN A BENEFIT-COST ANALYSIS

Main stages

3.1 Figure 3.1 shows the main stages in a benefit-cost analysis. It also shows the iterative loops by which the identification of the 'do something' options, and the estimation of the benefits and costs of those options, can be progressively refined.

Figure 3.1 Main stages in a benefit – cost analysis



Identifying the 'do nothing' option

3.2 Benefits and costs for all 'do something' options should be compared with those of the 'do nothing' case. The latter provides a convenient common baseline against which the other options can be assessed. Scheme benefits are calculated from the losses avoided by carrying out the proposed works rather than doing nothing.

3.3 Identifying the 'do nothing' option correctly is therefore important to the analysis and needs careful consideration. Where there is no existing scheme, the 'do nothing' option is obvious; there is no intervention in natural processes.

3.4 Where there is an existing scheme, the 'do nothing' option will be to walk away and abandon all associated maintenance and repair, allowing nature to take its course. Simply continuing with maintenance and repair of the existing structure then becomes one of the 'do something' options.

3.5 While it might appear impossible for political or other reasons to abandon the area, this should mean that the advantages of preserving what is there are overwhelming. It should therefore be easy to demonstrate that continuing present practice is better than the 'do nothing' option. If this is not the case, the non-economic reasons for continuing must be carefully considered. For health and safety reasons, it may be necessary to take minimal steps to make any abandoned works safe and these costs should be taken into account.

3.6 In some cases, due to the statutory duty to maintain certain watercourses (Flood Prevention (Scotland) Act 1961, section 4B(1)), it may be necessary to use the 'do minimum' option as the baseline. Otherwise, this option will only be appropriate when there is interdependence between action on the site and other areas, such that the cost of analysing the 'do nothing' case is disproportionate compared to the size of the project.

3.7 **The 'do nothing' options should be:**

where there is an existing scheme, walk away: cease all maintenance, repairs and similar activities immediately;

where there is an existing scheme, and walking away is not permissible for legal or statutory reasons, adopt the 'do minimum' option;

where there is no existing scheme, do nothing; do not intervene in natural processes.

Identifying the 'do something' options

3.8 In the early stages of analysis, the range of options should be as wide as possible; the process of analysis may itself suggest new options. In terms of design standards, the guideline for grant purposes is protection against the 1 in 100 year flood event. However, this is not intended to constrain the design process. It is simply a practical benchmark to assist with the administration of the grant scheme. Different design standards should always be considered, including the guideline standard. Such an approach should help to justify departures from that standard.

3.9 The options selected should always[1] include the best solution in environmental terms, provided such a solution is technically feasible. ([1] The Water Framework Directive, Article 4(7), requires demonstration of disproportionate cost where the beneficial objectives served by the physical modification of a water body could be delivered by a significantly better environmental option that would minimise the risk of a deterioration in status.) The options should also include any reasonable proposals suggested by consultees.

3.10 Although it is good practice to start with a wide range of options for several different standards of defence, these can usually be reduced to a smaller range of standards and options for detailed analysis. For example, in economic terms, the solution with the lowest present-value cost will be the most cost-effective solution for any particular standard.

3.11 Alternative lines of defence should be considered, wherever feasible. Local protection works, or works which only protect particular areas of high value, should also be considered. These may include floor-raising and flood-proofing individual properties. In addition, remote protection should be examined; for example, by providing off-line storage/attenuation in the upper catchment.

3.12 **An appropriate range of options should be considered. These should normally include:**

- **different standards of protection;**
- **alternative alignments;**
- **different approaches to solution of the problem.**

Identifying the probabilities of failure

3.13 Changes in probability are central to the benefit-cost analysis. For flood prevention schemes, the 'do something' options reduce the probability of flooding. Commonly, the probability changes over time; for example, the likelihood that an existing flood embankment will fail may well increase with time. Climate change, development of catchments, and alterations in ground level may also change the probabilities of events of particular magnitudes. Chapter 6 provides guidance on the use of risk assessment in project appraisal, and the derivation of probability functions.

The nature of benefits and costs

3.14 Benefit-cost analysis is only concerned with changes in the total value of benefits and the total cost of the resources used. People will often adjust to a flood loss, and do so in a way that minimises their losses. If flooding closes a factory, production may be increased elsewhere. In such a case, the total national value remains the same. If the alteration simply varies the distribution of benefits and costs across the country, then no economic change occurs. Changes only in the distribution of consumption and resources are termed 'transfer payments' and should be excluded from the benefit-cost analysis (Annex A).

Boundaries of the benefit-cost analysis

3.15 Boundaries in space and time have to be drawn for any benefit-cost analysis. They should be set taking into account the consequences of the different options. It may not be possible to assess all such consequences, and a reasoned decision must therefore be made as to how far the process should be pursued. Options may have an influence outside the immediate area of the scheme but, in addition, their consequences may depend on factors outside the project boundary. For example, urbanisation of the upstream catchment could affect flood risk. The assumptions made about external conditions should be realistic, not simply convenient. Any significant impacts beyond the project boundary should be included.

The project domain

3.16 In some cases, the form of appraisal will depend on whether the solution is in fact a single scheme, or a series of independent projects. If the latter, a separate benefit-cost analysis should be carried out for each independent element. For example, if separate flood embankments are proposed for several different villages, the protection of each should be justified on its own. Where, however, it is possible to protect all the villages with a single scheme, such as a barrage, or flood storage reservoir, it is still necessary to consider the option of protecting each one individually. In this case, the aggregate costs and benefits of the best worthwhile individual protection schemes should be compared with those of the single scheme.

Phasing of a project

3.17 When a single scheme is phased, and there are no independent elements, the benefit-cost analysis should be carried out for the project as a single entity. However, a review of the justification of each stage of the phased works should also be undertaken.

3.18 As a scheme is progressed, the probability of a failure of one part of the scheme will change. It is this change in probability that should be used in the review of each stage of the works. Further, there are likely to be differences in the consequences of a failure, depending upon the particular works already completed.

Time span of the analysis

3.19 The appraisal period should reflect the physical life (with maintenance) of the longest-lived asset under consideration for a scheme. The presumption is that for most conventional schemes involving major earthworks, concrete or masonry structures, a 100-year timeframe will be appropriate. If, exceptionally, a shorter time horizon is used, terminal values may be applied to ensure that different options are evaluated on a comparable basis. These values should equate to the residual values of any assets, normally calculated using straight-line depreciation. Clearly all options should be evaluated over the same period.

Price basis

3.20 Benefit-cost analysis should be undertaken using real prices; that is, inflation is ignored where ‘inflation’ has the everyday meaning of the price of a resource increasing without its relative value also increasing. Commonly, the relative prices of the different streams of costs and benefits are assumed to be constant over time; this is generally a conservative practice. In reality, they may change over time.

3.21 Growth factors may be adopted to reflect predicted changes in relative prices or demand. However, if such factors are used for one stream of benefits or costs, they should logically be used for all streams. Since prices are relative, it follows that, over time, some will fall relative to others, in the same way that the real price of many electrical goods has fallen over the last 30 years.

Therefore, any use of selective growth factors should be considered carefully.

- **Inflation should be ignored in undertaking the analysis.**

- **Real prices should be used for all streams of benefits and costs.**

What is a benefit and what is a cost?

Treatment of negative costs and negative benefits

3.22 In deriving a benefit-cost ratio, there is no universally agreed basis for classifying a particular item as either a positive cost, or a negative benefit (disbenefit), or vice versa. While the particular approach adopted will have no effect on the net present value of an option, it can have a significant effect on the benefit-cost ratio. To ensure a consistent approach between options and schemes, it is important to have a common rule. The following conventions should therefore be adopted.

- **Any 'negative costs' should be regarded as benefits.**

- **Any 'negative benefits' should be regarded as costs.**

3.23 The benefit arising from a flood prevention scheme is the net difference between total present value damages with and without the scheme - that is, the damage avoided in comparison with the 'do nothing' option. Any negative benefit, or disbenefit, arising from the project represents a loss to society, and should therefore be treated as a scheme cost. Conversely, resources which become available to society as a result of project implementation should be regarded as a benefit. For example, if an option restricts the views of residents, the loss of amenity should be counted as a cost; if widening or dredging a river yields gravel which can be sold, this is a benefit.

Stocks and flows

3.24 When identifying and valuing the different streams of benefits and costs, it is helpful to think in terms of 'stocks' and 'flows'. It is easy to make the mistake of including the same benefit or cost twice because of a failure to distinguish sufficiently between the stock of some asset and the flow of resources, or consumption, which that stock generates. Typically, stocks give rise to some flow of consumption or resource so that the current capital value of the stock is determined by the discounted value of the future benefits, which flow from it. In some cases the flow diminishes the value of the stock value (eg mining coal necessarily diminishes the stock of coal) whereas in other cases it does not (eg catching fish at below the rate of replacement).

3.25 An appraisal can include either the stock value of a resource or the sum of all the flows that it yields but not both. However, the market value of a stock might not always fully reflect the value of the flow of services which it provides since these can include unpriced public goods, such as the provision of opportunities for enjoyment of the countryside. In such cases allowance can be made for these additional flow values, suitably discounted.

3.26 In some cases it may be easier to estimate the change in the annual flow of benefits from the stock than the change in the capital value of the stock. For instance, there is no obvious market price for a riverside park that might be destroyed through the construction of a flood prevention scheme. An estimate of the value placed by users on visits made to that park might represent a better approach to valuing its loss (section 4.2).

Level of detail

3.27 The level of detail in a benefit-cost analysis should be proportional to the scale of the project. For projects involving a small amount of expenditure, a detailed benefit-cost analysis may not be economically justified. Decisions will therefore be required on the appropriate level of detail, the streams of benefits and costs to be included, and the amount to be spent on the analysis.

3.28 For example, where appropriate, strategic and prefeasibility studies should be undertaken using readily available data, since the most expensive part of a benefit-cost analysis is data collection and collation. A simplified analysis should not, however, be interpreted as one that lacks economic rigour. This may include the simple technique of benefit transfer, which involves taking values derived in one context and applying them elsewhere; for example, taking the values of enjoyment for a visit to one river, and using them to estimate the value of visits to another.

3.29 For the more detailed design studies, the benefit-cost analysis should be sufficiently extensive to show with reasonable confidence whether or not it is worth adopting any of the 'do something' options. Ideally, the first streams of benefits and costs to be included should be those contributing the greatest proportion of the total. While it is not always possible to determine in advance which will be the largest, there are 2 areas which should generally be considered first. These are:

- benefits and costs which accrue earliest in the lifetime of the scheme; and
- those which have the highest probability of occurrence.

3.30 The cost of evaluating a stream of benefits and costs depends on the precision required. It also varies markedly according to the stream category (Table 3.1). For recreational benefits or non-use values, it will cost as much to evaluate these for a small scheme (or area) as a large one, since the costs are largely fixed. The assessment cost also depends on the extent to which standard data can be used, such as the depth-damage data for residential properties. Further, if the flood surface and topography are complex, evaluation costs will increase.

Table 3.1 Relative costs of evaluation

Benefit or cost stream	Relative cost of assessment
Flood prevention scheme: protecting residential plus some small commercial or industrial properties	□
Flood prevention scheme: protecting some large commercial or industrial properties	□ □
Traffic disruption	□ □
Recreation benefits	□ □ □ □
Environmental assets: replacement cost method	□ □
Environmental assets: evaluation of non-use value	□ □ □ □ □

Key: The greater the number of □, the greater the relative cost.

Post project evaluation

3.31 Post project evaluations demonstrate whether past investment has been worthwhile and has achieved its objectives. The exercise will be considerably eased if the fully documented original appraisal is readily available to evaluators. For example, it will be possible to compare actual performance against the sensitivity analysis in the benefit-cost appraisal. This will enable a check on the areas of greatest uncertainty, to see whether variations in practice are within predicted limits

3.32 In undertaking benefit-cost analysis as part of post project evaluation of flood prevention schemes it can be difficult to identify realised benefits, which are based on the avoidance of losses which would have occurred had the scheme not been implemented. Hence, it is difficult to determine whether the actual benefits are equal to those predicted. It will usually, therefore, be necessary to judge success on the accuracy of related predictions such as the costs of construction and maintenance, rates of environmental enhancement or measures of residual damage.

SECTION 4

ASSESSING THE BENEFITS

4.1 EVALUATION OF LOSSES

Domestic and other urban property

4.1.1 Permanent buildings at risk of total loss from flooding should usually be valued at their current market value, excluding any adjustment in value for the flood risk. For many strategic and preliminary studies, the mid-range of council tax bands, suitably adjusted from their 1991 price datum, can be used to estimate property values. Generally, property will be assumed to be written off if the mean annual maximum water level exceeds the floor level.

4.1.2 However, market values sometimes need adjustment. For example, for properties such as pubs and restaurants, the market value includes a significant factor for customer goodwill. This ‘goodwill’ element is a transfer, not an economic loss (Annex A). In other circumstances, if there is an excess supply of, say, some types of commercial property, such property would not be replaced if lost, and no economic loss would be incurred. It is also important to avoid double counting any waterside amenity element of market value. Further, in the case of loss through abandonment, it should be assumed that the contents of the buildings are removed before the building is lost. Consequently, all removable fixtures and fittings should be excluded from the valuation.

4.1.3 Where a flood has occurred recently, a record of the damages incurred will often be a good starting point for evaluation of losses. However, it is important that the limitations of such data are clearly understood. Actual damages will rarely be available for the required range of events. Where losses are recorded, these will often be in financial rather than economic terms, and values will have to be converted.

4.1.4 The Flood Hazard Research Centre produces some standard data on the losses to be expected for different types of property, according to the type of dwelling, its age and other aspects. Adjustment factors, which take account of the additional losses from saline flooding, are also available. Details on these data and factors can be found in the manuals listed at references 3-5. The manuals have been combined in reference 6, which is currently being reviewed.

4.1.5 For large industrial or commercial properties, or unusual properties such as listed buildings, it will often be necessary to carry out a site survey of the likely losses. A questionnaire can be used for this purpose (reference 5). In times of rapid obsolescence and replacement of many commercial and industrial buildings, effective life should be carefully considered when assessing the value of such properties.

4.1.6 An alternative to standard data is to commission surveys by loss adjusters. However, this is expensive. It is rarely justified unless the properties concerned are atypical and the use of standard data would likely give misleading results.

4.1.7 **From the foregoing:**

- **land and buildings should be valued in constant real prices in their current use;**

- **any ‘goodwill’ element in values for commercial premises should be excluded; and**
- **care should be exercised in the derivation of non-standard valuations.**

Temporary and semi-permanent structures

4.1.8 There are other cases where the real economic value of losses may be very different from current market values. For example, the economic value of a mobile home on a particular site is equivalent to the cost of moving it there and establishing the site, not the value of the unit itself, which could be retained if it were relocated elsewhere. Also, in assessing economic damages, caravans, mobile homes, chalets or other temporary buildings or structures should be considered as depreciating assets worth, on average, only half their replacement cost.

4.1.9 For the ‘do nothing’ case, it should normally be assumed that any caravan or mobile home could be relocated. The economic loss would then be limited to the cost of removal together with the loss of installed infrastructure, depreciated as appropriate. Where a site is to be protected, the ‘do something’ damages should be calculated in the normal way, taking into account the seasonal nature of occupation. Similar considerations will apply to other temporary or relatively short-life structures, such as most amusement park rides.

Infrastructure

4.1.10 The market value of a property can be expected to include the value of the immediate services; such local services have no economic value once the property is lost. However, separate valuations will usually be appropriate for infrastructure serving a wider area, including trunk sewers, main road and rail routes, major pipelines, cables, pumping plant and other such facilities. In general, the loss of such infrastructure can be treated as the cost of replacing the facilities elsewhere or rerouting them. Appropriate adjustments should be made for depreciation and obsolescence.

4.1.11 Embankments constructed primarily as flood defences have a functional value only in terms of the protection that they provide. Including a value for such assets is likely to lead to double counting. However, they may also have a use value for recreation, which may be taken into account.

Indirect losses

<u>Consumer losses</u>

4.1.12 If a shop or factory is flooded, the company will lose sales and its customers may be inconvenienced. Potentially, therefore, there are 2 forms of indirect losses: to the consumer, and to the supplier. In general, the loss to the consumer is the economic loss; that to the supplier is usually financial rather than economic. If consumers can buy the same goods at the same cost from an alternative supplier immediately, there is no loss to them. If they have to make do with inferior goods or incur higher costs, there may then be an economic loss. However, it will only be appropriate to evaluate this in special circumstances; for example, where long-term loss of a rural retail outlet is likely to involve significant extra travel.

<u>Supplier losses</u>

4.1.13 On the suppliers' side, if other shops or factories make up the consumers' purchases, this is simply a transfer unless those other shops or factories incur higher costs (Annex A). The sales lost by one company are gained by another. The only exception is when those purchases are made up by additional imports or lost exports. Indirect losses do not normally arise from disruption to commercial and retail activity because there are typically many alternative outlets offering the same services immediately. This need only be considered in exceptional circumstances, for example when highly specialised products are involved.

Traffic disruption

4.1.14 Disruption of road and rail networks, can result in significant indirect losses. For road networks, it will not generally be worth evaluating these unless a major through road is closed by at least the 1 in 10 year flood. If flooding occurs below the 5-year event, and a significant part of the network carrying through traffic is affected, the benefits of reducing disruption can be large, both in total and as a proportion of scheme benefits. Traffic that usually uses the roads will have to divert, and may have to travel further, and/or for longer, incurring both resource and time costs. Since the speed of traffic depends on volume, the normal traffic on the diversion routes will also travel more slowly, again increasing such costs.

4.1.15 Methods and guidance are available to help calculate the difference in the resource and time costs of using the road network under different flooding conditions, and to address the special problems of calculating the costs of flood-induced traffic disruption.

4.1.16 One problem is that of identifying the diversion routes. Another is that the progressive development of flooding may induce a cascade of traffic diversions as one road after another is closed. Further, standard volume-speed relationships are not intended for highly congested traffic, and their blind application can yield results which are not strictly applicable.

4.1.17 Where traffic disruption is likely to be severe and extend over a prolonged period, it may be more realistic (and more cost-effective for the appraisal) to equate the economic loss to the cost of reconstructing the road, or making sufficient improvements to alternative routes to avoid the cost of delays. This should be applied only where the present value is likely to be less than that of the long-term costs of disruption.

Socio-economic equity

4.1.18 A flood prevention scheme might have differential impacts on individuals, depending on aspects such as their income. It may therefore be necessary to consider the question of social equity. This can be achieved through a 'Distributional Impacts (DI)' analysis, which examines the distribution of costs or benefits of interventions across different income groups and social classes (reference 2). Interim advice on this topic has been produced by Defra (reference 7), and is summarised in paragraphs 4.1.19-4.1.23.

4.1.19 If a decision is made to assess DI, appraisers should be aware of the principle of diminishing marginal utility of additional consumption, whereby the impact of a project on an individual's wellbeing may vary according to his or her income; the rationale being that an extra pound will give more benefit to a person on a low income compared to someone on a high income. In other words, as income rises, its marginal value reduces. Consequently, a loss of £1000 will matter more to someone on a low income. For flood prevention schemes, DI analysis can be applied to the evaluated costs of avoided damage to residential property. The subsequent costs arising from the analysis may then be treated in the conventional manner.

4.1.20 The Treasury Green Book recommends that DI should be applied where it is necessary and practical to do so. Determining if it is 'necessary and practical', depends on a number of circumstances, including (i) whether a community at flood risk can be identified with reliable data and categorised according to their prosperity or social class; (ii) whether the assessment will contribute to an appraisal that demonstrates equity and fairness to people; and (iii) whether the time and effort in undertaking the assessment is proportional to the scale of the overall appraisal, either at a strategic or scheme level.

4.1.21 In addition, appraisers should consider whether they feel that in not undertaking the assessment, a strategy or scheme will still have an adverse differential impact on a particular group. A decision not to adjust explicitly for distributional impacts will require to be justified.

4.1.22 The following 2 steps set out the procedure for transposing the guidance on DI into flood defence investment:

Step 1 Analyse and understand the level of knowledge on the type, age and number of residential properties; the mix of social class groups and levels of income within an appraisal area. Take account of DI by following Step 2, if necessary and practical. If it is not necessary and practical, ignore Step 2 and use standard depth damage curves that focus on property type and age, only, without accounting for social class mix or income level.

Step 2 If proven necessary and practical, and good quality information is obtainable, Total Weighted Factors may be used by social class group as shown in Table 4.1. Those for social class groups C1 and C2 will generally have a negligible effect on the DI assessment. Hence, this approach is only recommended where AB or DE social class groups are predominant. The factors may then be applied to adjust the standard depth-damage curves, to obtain damages avoided taking account of DI.

Table 4.1: Total Weighted factors

Total weighted factors by social class group			
AB	C1	C2	DE
0.74	1.12	1.22	1.64

In the interest of transparency, both weighted and unweighted results should be routinely presented. Where results are sensitive to any weighting adjustment, a sensitivity analysis should be provided.

4.1.23 Where the quality of available information permits, appraisers should take account of DI in homogeneous areas or areas with a high proportion of rented accommodation. For the latter, the income level or class of the owner of the property should be used for assessing building damages, and that of the occupier used for the contents damages. The approach in Step 2 is suggested, but again only if a DI assessment is necessary and practical.

Non-monetary impacts on households

<u>Stress</u>

4.1.24 To householders, impacts of flooding such as increased stress, health effects and loss of memorabilia, can be as important as the direct material damages to their homes and their contents. Research has provided a method for quantifying these human related intangible impacts, as indicated in the recent interim guidance note produced by Defra (reference 7). In summary, the note states that the value of avoiding the health impacts of fluvial flooding is of the order of £200 per year per household. This is a weighted average derived from a wide range of responses. The note also provides a risk reduction matrix which can be used to calculate the value of health related benefits for different standards of scheme protection. The matrix is reproduced in Table 4.2. For example, the highlighted figure of £188 in the table represents the annual health related damages avoided, and hence the benefit per annum, per household, in moving from a pre-scheme situation where the standard of protection is 1 in 20 years to a scheme with a 1 in 100 year design standard.

Table 4.2 Intangible benefits associated with flood defence improvements (£ per annum per household)

Standard of protection **before** scheme – in terms of annual flood probability and (return period in years)		Standard of protection **after** scheme – in terms of annual flood probability and (return period in years)							
		0.007 (150)	0.008 (125)	0.010 (100)	0.013 (75)	0.020 (50)	0.033 (30)	0.05 (20)	0.1 (10)
1	(1)	£218	£215	£200	£153	£73	£25	£12	£5
0.1	(10)	£214	£210	£195	£148	£68	£21	£8	£0
0.05	(20)	£206	£202	**£188**	£141	£60	£13	£0	
0.033	(30)	£193	£189	£175	£128	£47	£0		
0.020	(50)	£145	£142	£127	£80	£0			
0.013	(75)	£65	£62	£47	£0				
0.010	(100)	£18	£15	£0					
0.008	(125)	£4	£0						

4.1.25 For areas of uniform flood risk, such as housing on level ground, damages are based on common standards of defence. Having identified the standards of protection before and after an option is implemented, Table 4.2 can be used to derive the annual intangible benefit per household. This can be applied to the total number of households (or residential properties) in the area to give the overall annual intangible benefits for a particular option. In areas where the risk varies greatly, such as sloping ground away from a river, damages are based on individual levels of property flood risk. This will require banding of the areas into different levels of existing protection, and the identification of the standards of protection being offered by the scheme to each band area. The table can then be used to evaluate the intangible benefits for the properties within each band.

4.1.26 The figures in Table 4.2 already take account of distributional impacts. Consequently, a DI analysis should not be applied to the results arising from the appraisal of intangible impacts.

Disruption

4.1.27 A partial measure of the disruption resulting from flooding can be given by the cost of renting a home equivalent to the one flooded, together with the cost of accelerating the drying-out process.

4.1.28 About 50% of households are vacated for an average of 30 days when flooding exceeds 30 centimetres (reference 1). The use of dehumidifier units is the best method of drying out properties, and hence of enabling repairs and redecoration. The rental of such units reduces the losses that would otherwise occur. The number of dehumidifiers required depends on the size of the property. Rental and electricity rates are used to calculate the costs. On average, 2 to 3 units are required for a period of 3 to 4 weeks.

4.1.29 If there are reasons to believe that the remaining non-monetary impacts will be unusually high, this aspect should be considered. For example, if a flood were to last several days or result in a significant risk to life, stress and health damages may be anticipated to be higher than average.

4.2 RECREATIONAL AND ENVIRONMENTAL VALUES

Recreation

4.2.1 Flood prevention schemes may affect the value of a river or coastal reach for recreational uses, including angling and informal recreation. Any significant associated gains or losses should, as far as possible, be included in the benefit-cost analysis. Where only marginal changes in recreation or amenity are likely, such valuations will seldom be worthwhile. If a scheme relies on a substantial element of recreational benefit for its justification, it should be treated as a multi-functional project (paragraphs 2.13-2.15).

4.2.2 The benefits of avoiding a loss in recreational value, or an increase in such value, can be calculated by (i) estimating the number of visits made to the site, and (ii) multiplying this by the change in the value of enjoyment per visit.

4.2.3 Thus, the number of visits made to a site is a primary indicator of the likely magnitude of the benefits. If there are no visitors, there are no benefits. Therefore, any analysis should start with a preliminary estimate of the number of visits made by adults. For rivers, where the number of visits is small, the estimates given in, for example, the Foundation for Water Research Manual on the benefits of surface water quality improvement can be used to estimate the order of magnitude of the recreational benefits (reference 8).

4.2.4 Where no comparable estimates of the annual number of visits to different types of site have been compiled, the simpler methods shown in Table 4.3 will have to be used. Early thought should be given to accurate estimation of the number of visits. The methods shown in the table are in decreasing order of accuracy.

Table 4.3 Methods of visitor estimation

Method	Comments
Long period counts using people counters	A number of infrared, or other automatic, counters are installed at least over the period of March to September in one year. The counters are manually calibrated; interview surveys are conducted to determine statistically how the number of adult visits relates to the number of passages recorded on a given day. An annual growth curve is then used to derive an estimate of the total number of adult visits made in that year.
Short period count	Counts are undertaken by hand over a period of days. An annual growth curve is then used to derive an estimate of the total number of adult visits made in that year.
Inferred estimate	The counted number of visits made to a related site (eg a car park or museum) is used to infer how many visits are made to the site. This requires estimating what proportion of all visitors to the site also visit the site for which counts are available.
Visitor equation	A number of equations have been developed which predict distance-frequency functions so that from census data on the population in different zones, a prediction can be made as to the number of visits generated by a site.
Informed estimate	The estimate of an informed person (eg car park attendant, park ranger) as to the number of adults visiting the site.
Average number of visits to equivalent sites	This benefit transfer approach is only suitable for prefeasibility and strategic studies. The number of adult visits made to the site is estimated as being of the same order as the number of visits made to an equivalent site. However, there are few sites for which good data are available and little research to enable the reliable identification of an 'equivalent' site.

4.2.5 Where recreational value is a significant part of the total benefits, a contingent valuation study may be necessary to derive a site-specific value of enjoyment. Some of the considerations for such studies are listed in Annex B. However, the difficulties and expense should not be underestimated.

Environmental and heritage issues

4.2.6 Most environmental assets have both use value (eg as measured through recreational use) and non-use values (eg existence value). These are described in more detail in Annex B.

4.2.7 Whether valued in monetary terms or not, environmental impacts should always be assessed. While in many cases sensitively designed schemes can make a significant contribution to the environment, there will often be choices to be made. It is probable that all the ‘do something’ options and the ‘do nothing’ option will have significant environmental consequences, positive or negative. Consequently, it is important to hold early consultations to establish environmental requirements and, in particular, the legislative ‘drivers’ (see Chapters 2 and 7). In some cases, protecting one site may have consequences for another, and a decision will have to be made on their relative values. In other cases, environmental losses may be unavoidable, for example, in reducing the risk of loss of life. However, an auditable record of the assessment and decision-making process will be required.

4.2.8 Where such choices have to be made, and in a number of other situations, it is desirable to place an explicit economic value on an environmental site or asset, in addition to any associated recreational value.

4.2.9 However, it should be recognised that it may not always be possible to express use and non-use values in monetary terms, or even to quantify them meaningfully in some other way. This should be taken into account in the overall appraisal.

4.2.10 **In general, the least contentious and lowest cost method of deriving a proxy for the lower bound economic value of an environmental or heritage asset, gained or lost as a result of a flood prevention scheme, can be taken as the lowest of:**

- **the cost of creating a similar site elsewhere of equivalent environmental value;**
- **the cost of relocating to another site (eg historic buildings or relocation of specially protected species);**
- **the cost of local protection (eg a local flood embankment).**

<u>Creation of equivalent sites</u>

4.2.11 The use of such proxy values, however, will depend on there being broad agreement that the value of the asset in question is at least equal to the lowest of these figures. The cost of re-creation, or removal, should be the expected present value economic cost only of those actions required to acquire the site and make the necessary changes. The normal expectation should be that long-term management costs would not change. However, such costs may need to take account of the likely success in achieving replacements of comparable quality and the time delay in their achievement. This is only strictly possible where assets are technically replaceable although, where protection can be amply justified on this basis alone, there is likely to be little benefit in applying more sophisticated valuation techniques.

4.2.12 For sites whose conservation is enjoyed by local populations only, the most appropriate valuation approach for benefit-cost analysis may be to use the value of the nearest equivalent local land in commercial use which could, in principle, be adapted as a replacement site. For example, grazing pasture or commercial woodland might provide proxy values for a local nature reserve. Clearly, this may not capture the whole value to the local community, and will not necessarily be appropriate for other decision-making purposes.

4.2.13 In certain exceptional circumstances, such economic valuations may not be appropriate. For example, an unusually high value may be placed on a feature specifically because of its particular position; or there may be some doubt as to whether the heritage value of a structure could really justify the high cost of its relocation. In such cases it may be necessary to obtain a valuation using other monetary based techniques as described in Annex B, or to apply other decision-making techniques.

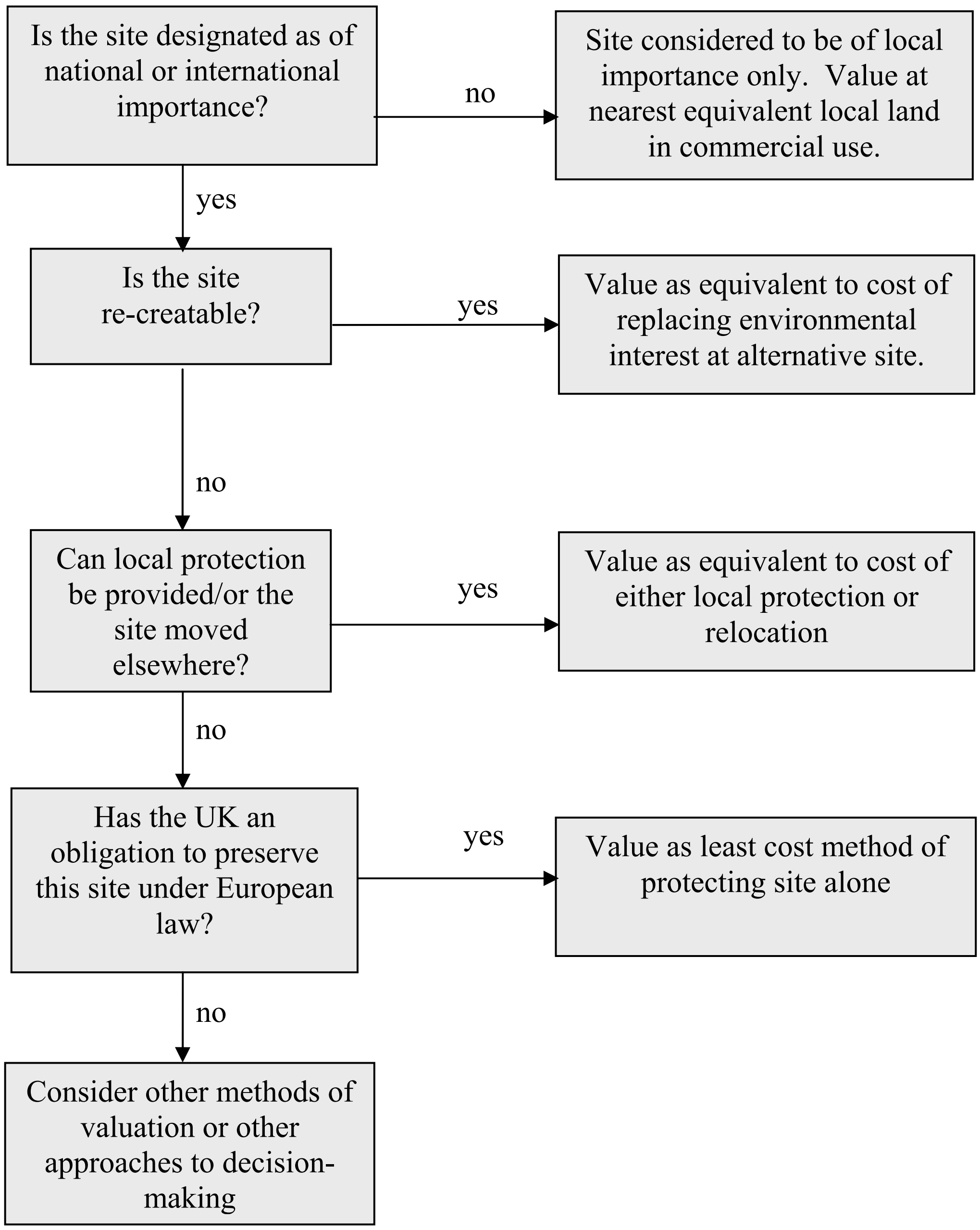
4.2.14 Nationally and internationally important sites and habitats, such as SSSIs, SPAs, SACs and Ramsar sites, may be considered to have a national economic value. The lower bound estimate of this should be calculated from the minimum cost of protecting the site *in situ* or, if lower, the cost of providing replacement habitat. It is important to stress that calculating the replacement cost does not imply that habitat replacement is the most appropriate option. It is simply a way of deriving what can be considered to be a minimum monetary estimate of the loss involved, or the benefit of protected habitat. In some cases, habitat replacement may be necessary, but for European sites in particular, there should normally be a presumption in favour of *in situ* protection of habitats.

4.2.15 For some sites it will be possible to put a non-use value on the benefits of protection. Methods of calculation are described in Annex B. However, this is likely to be difficult, expensive and potentially contentious, and will rarely be justified.

4.2.16 Where there are apparent environmental disbenefits to specific options, the least contentious method of valuation may be to include, as a cost, the present value of introducing compensating environmental enhancements, which most closely match those lost.

4.2.17 Figure 4.1 shows a decision tree, using the above approach, for the determination of minimum economic values in relation to environmental and heritage sites. Other decisions will relate more to marginal changes in environmental quality or individual environmental attributes, and these may require some adaptation of the approach. However, the general principles should be applied where possible. These issues will be discussed further in Chapter 7.

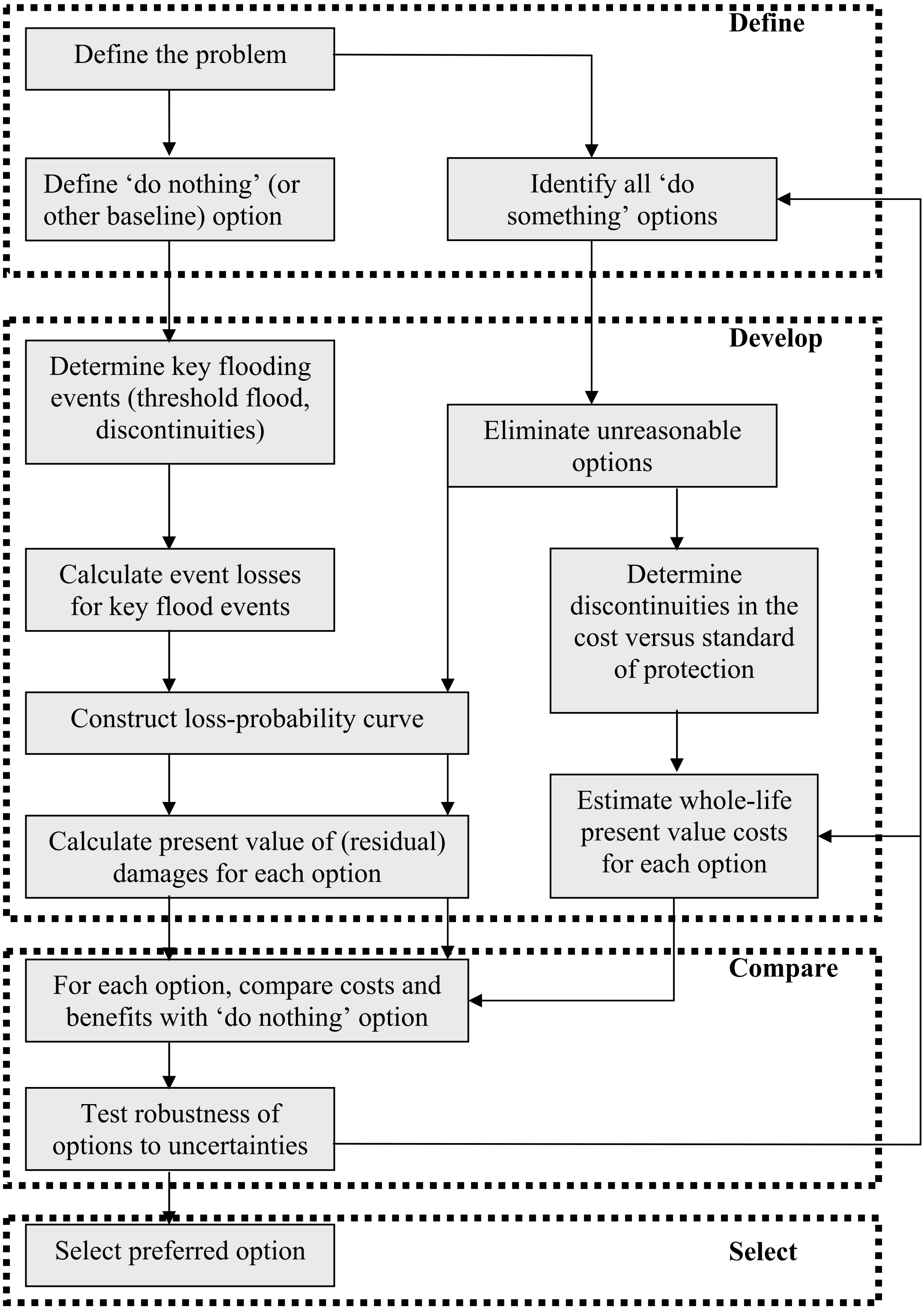
Figure 4.1 Decision tree for appraising proxy economic values of environmental and heritage sites at risk of loss or damage



4.3 FLOOD PREVENTION BENEFITS

4.3.1 The benefits of flood prevention schemes are calculated as the difference between the expected value of flood damage with the option being evaluated, compared with flood damage and losses in the 'do nothing' case. A summary of the procedural steps required is shown in Figure 4.2.

Figure 4.2 Framework flow chart for flood prevention appraisal



Damage calculation

4.3.2 The damages caused by a flood are a function of its depth, duration, velocity, and its sediment and pollutant loads. In the UK, floods are usually relatively short in duration and involve low velocities. Consequently, the primary determinant of the losses for a particular property is the depth of flooding. However, in some small flashy catchments, and where protective structures fail, flood velocities can be high. This may result in additional losses from partial or complete structural failure of properties.

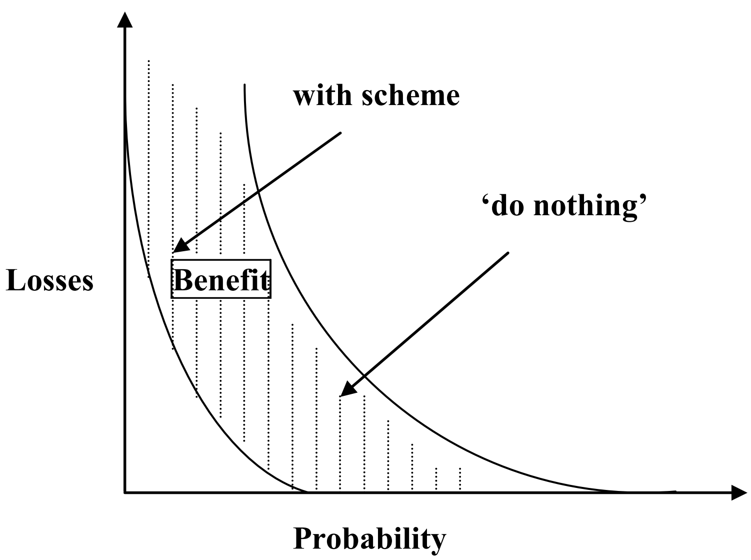
4.3.3 Sediment, debris and sewage borne by a flood may affect the costs of cleaning up after the event. Further, flooding by saltwater generally causes more damage than the equivalent depth of flooding by freshwater.

Calculating the benefits

Loss-probability relationship

4.3.4 The benefits of flood prevention are calculated as the expected value of annual flood losses averted. As floods are assumed to be random events, it is not possible to predict when they will occur. The expected value of annual flood losses is calculated as the probability of a range of events multiplied by the loss that such an event would incur. In practice, the losses are measured by the difference in the areas under loss-probability curves for the 'do nothing' and with scheme options. This difference in area is the expected value of the reduction in flood losses each year over the life of the scheme; the average annual benefits (Figure 4.3). These are discounted over the life of the scheme to give the present value of the benefits.

Figure 4.3 Determination of average annual benefits



Changes over time

4.3.5 Studies suggest that our climate is changing, and that this could have a negative impact on future coastal and river flooding, through rising sea levels and changing rainfall patterns. This is discussed more fully in Chapter 4. As indicated there, the projected impacts have high levels of uncertainty and, until more definite information is available, they are best examined as part of the overall sensitivity analysis (paragraphs 6.10-6.14). Further guidance on dealing with climate change risk is given in Chapter 6.

4.3.6 Where changes are anticipated in the expected probabilities of flooding over the life of a scheme, it is necessary to calculate a number of different average annual benefits corresponding to the different conditions. As noted above, such changes could include those associated with climate. Physical changes in the catchment could also affect probabilities. Further, changes over time in the use of the flood plain may alter the losses expected from a flood of a given magnitude. In such cases, average annual benefits should be calculated for appropriate years, and values interpolated for intervening periods.

The upper limit to losses

4.3.7 Care should be exercised where the total present value of losses exceeds the current write-off value of the asset. In the case of domestic or commercial property, it will usually be prudent to assume that the long-term economic loss cannot exceed the current capital value of the property. In the case of other assets, such as roads, railway lines, pipelines or cables, some very large values can be generated for long-term disruption. It will often then be reasonable to assume that the maximum economic benefit derived from flood defence is equal to the economic cost, depreciated to allow for the age of the existing asset, of reconstructing an equivalent facility at a higher level, or on an alternative alignment, which avoids the flood risk.

Sampling the return periods

4.3.8 The loss-probability curve is generally calculated using only a very small sample of the possible return period events that might be considered. The overall form of the curve, and the area under it, is derived by drawing straight lines between the calculated points. This can, potentially, result in wrong estimates of the area under the curve (Figure 4.4). In this illustration, the choice of return periods, when compared to the 'true' relationship, has resulted in a significant overestimate of the overall losses.

Approximation of loss curves

4.3.9 Determining how many and which return periods to include is a sampling problem. The aim is to obtain a reasonably close approximation to the loss-probability curve representing an infinite number of return period events if these were to be modelled. The ideal return period events to use are those located at discontinuities on the curve.

High probability events

4.3.10 First, it is important to locate the return period of the threshold flood event: that is, the most extreme flood that does not cause any damage. Secondly, engineering judgment should be used to assess where the discontinuities are likely to be. For example, they can be expected to occur when an existing natural or man-made structure is overtopped, or a culvert or bridge reaches its capacity.

Thirdly, the greatest proportion of benefits generally arises from the shorter return period floods. Consequently, the sampling should usually be biased towards these events. A few judiciously chosen events at appropriate points of discontinuity will generally produce a more realistic result than a larger number at standard intervals.

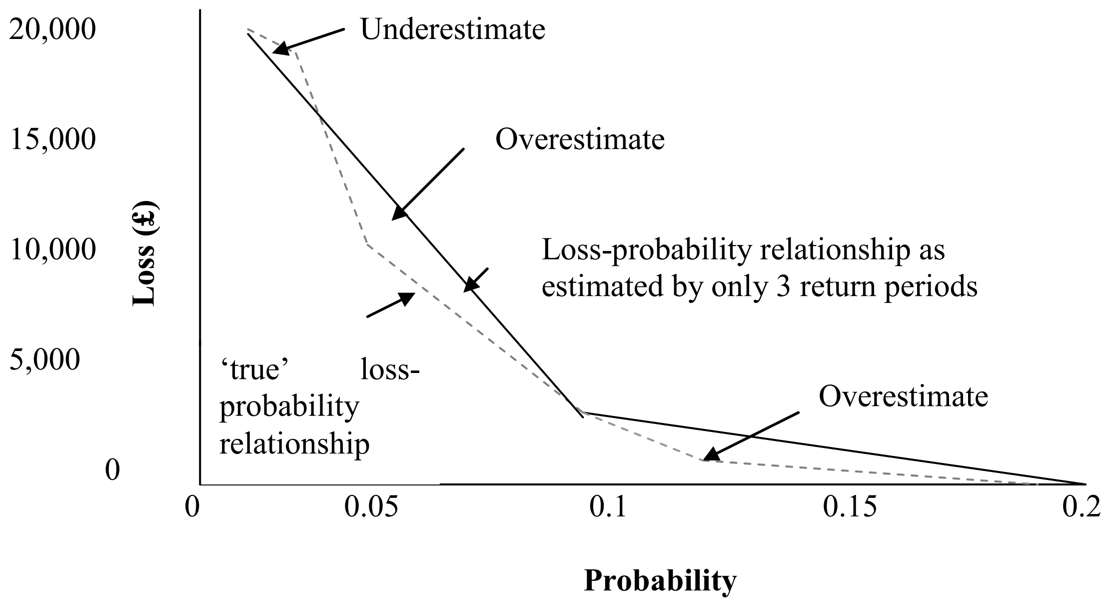
4.3.11 If a software package is being used to calculate the flood losses, it is simple to plot a flood-stage/damages curve for a large number of flood stages. Discontinuities on the curve indicate those events that should be included, provided the information that produced the discontinuities is accurately provided in the data input.

4.3.12 **In terms of good practice:**

- **the benefits should be calculated using a minimum of 3 events and the choice of those events should be considered carefully;**

- **one of these events should normally be the threshold flood event.**

Figure 4.4 Accuracy of estimation of the loss-probability curve



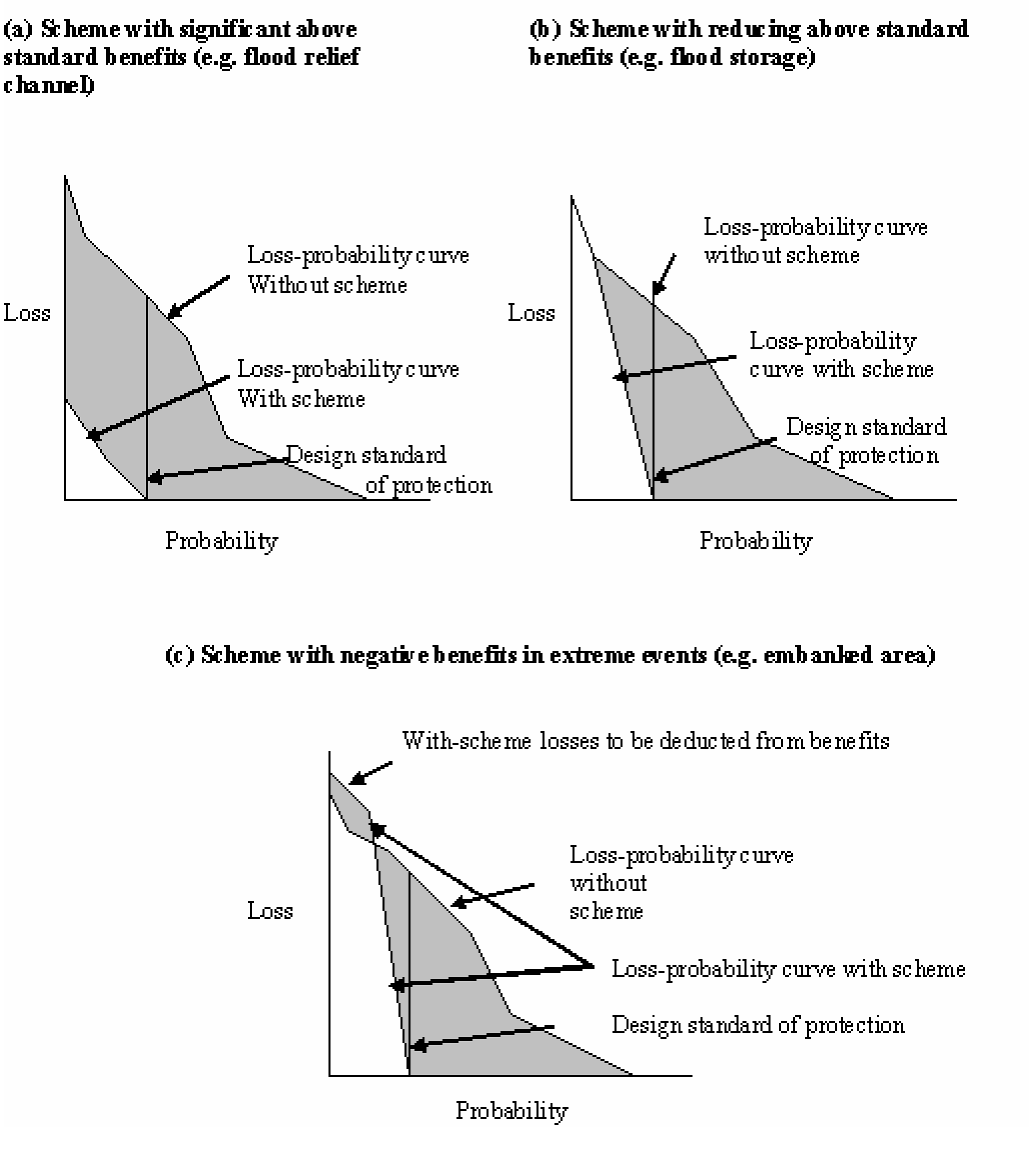
Above-design-standard benefits

4.3.13 The notional standard of protection (design standard) afforded by a flood prevention scheme will usually be defined in terms of the onset of significant losses. However, many such schemes will have some effect on the losses from all floods, even the most extreme, and all of these impacts should be taken into account. While it may not always be practical to model the extent of flooding from all events up to the probable maximum flood, it should be possible to draw logical inferences as to how the scheme will respond to such larger events. From this, the likely shape of the loss-probability curve can be estimated. It is important to ensure that the range of events considered is appropriate for fair comparison of all options.

4.3.14 For example, schemes that increase the capacity of a river channel will result in less water flowing out of the bank for all events with the scheme than without. Consequently, the losses from any particular event with the scheme, should never exceed those without the scheme, and will normally be less. Two examples are illustrated in Figures 4.5(a) and 4.5(b). In both cases the shaded areas represent the total average annual benefits.

4.3.15 For other schemes, for example those involving walls and embankments that may be overtopped, losses in less probable events can be more severe than if no scheme existed. The duration of flooding may be increased, or the velocities of flow resulting from a failure may be greater than from the natural rate of rise of the flood (Figure 4.5(c)). In this case the negative benefits above the design standard should be subtracted to derive the net average annual benefits.

Figure 4.5 Estimation of above design standard benefits



4.3.16 For some schemes, above-design-standard benefits can be a significant proportion of total benefits. They will also have an impact on the incremental benefits of different design standard options. For instance, part of the incremental benefits of a nominal 100-year return period scheme may already be realised in the benefits of the 50-year return period scheme. This illustrates the importance of considering the full range of benefits in all decision-making.

Development benefits

4.3.17 Any benefits arising from potential new development, including the intensification of existing uses, should normally be excluded unless construction has commenced. The primary reason for this is to ensure that schemes are designed primarily to protect existing buildings and their users from flood risk rather than large areas of undeveloped brownfield land. Where works are proposed for economic regeneration or similar purposes, other sources of funding may be available.

Freeboard

4.3.18 Freeboard should only be used to take account of uncertainty in scheme performance. The use of indiscriminate standard freeboard allowances can lead to problems, particularly in relation to differential standards of protection. Ideally, defence crest levels should be determined from a risk-based approach (Chapter 6). It will then be possible to extend the risk analysis into the economic appraisal to determine the benefit of raising or lowering the actual height of defences.

4.3.19 In the absence of a rigorous risk analysis, appropriate methods should be used to determine a most likely range of defence levels for each return period. Where the height of the defence (including freeboard) is then designed to accommodate such uncertainty, the benefits of the defence should be those appropriate to the calculated design standard.

4.3.20 For example, if a defence is constructed on the basis of a 100-year standard, but with an additional crest height to allow for uncertainty in the hydrology and hydraulic analysis, the only benefits to accrue should be those appropriate to the 100-year standard (ie 0.01 probability of overtopping). This topic is discussed further in reference 10.

Simplified assessment

4.3.21 For very small schemes, or preliminary studies, properties can be grouped for the purposes of damage estimation. Estimates can then be used of the likely average depth of flooding in each group of properties. This procedure should be applied for each of a minimum of 2 flood events above the threshold flood. The average loss for a residential property at each of those depths, multiplied by the number of properties in each group, can then be used to derive the loss-probability curve. For a very basic assessment, it is possible to consider the average benefit of protecting a residential property. An analysis of the benefits of flood prevention schemes suggests an average annual flood damage of between £3,000 and £8,000 per property in a moderately vulnerable area (reference 1).

Use of software packages

4.3.22 A variety of dedicated software packages for flood alleviation benefit assessments is available and spreadsheets can also be used (reference 1), particularly for the smaller and simpler schemes. In addition to reducing simple arithmetic errors, a virtue of these systems is in archiving data and recording the bases of different assessments. They also allow rapid recalculations, as the assessment is progressively refined during the course of the project.

Validating the inputs

4.3.23 Mistakes can easily arise when entering large quantities of data. It is therefore important to check for obvious errors in the input files. In particular, discrepancies in property floor levels, areas and grid references may lead to large errors. Scatter plots and frequency distributions are quick and simple ways of picking up extreme values, and hence checking for potential input errors. Some programs can be set only to accept locally valid ranges of values.

Checking results

4.3.24 The results of a program also need to be validated. Particular care should be taken where simplified loss models are effectively required to act as overland flow models, converting flood level data for points along the river channel to flood depths for particular properties. Ideally, an overland flow model would be used to generate these depths, to take account of local topography. This is often not possible and, consequently, engineering judgment combined with local knowledge should be used to make reasonable estimates of the correct flood depths.

SECTION 5

COMPARING COSTS AND BENEFITS

Estimating the costs

Whole-life costs

5.1 For any economic appraisal, the anticipated benefits of a scheme must be compared with its expected whole-life costs. All relevant capital, maintenance and running costs must be included. Maintenance estimates should allow for storm damage repairs and, where significant, decommissioning costs.

5.2 Only benefits and costs resulting from implementing each option should be considered. The appraisal should exclude 'sunk' costs, which have already been incurred, such as previous investments in defences and expenditure on feasibility studies.

Discontinuities in costs

5.3 In the same way as benefits may vary in a stepped fashion, option costs are also likely to increase in specific increments. For example, this could occur where the form of construction needs to change to accommodate a higher water level for an increased standard of service. The points at which these steps occur should be examined in detail, to assess the range of option standards where benefits may have increased without increased costs.

Residual values

5.4 Some assets may have a lifetime beyond that used in the analysis. The residual values should be taken into account in the estimation of costs and benefits only where this is required to ensure equality of assessment between different options. A straight-line depreciation over the asset life, which presupposes a decision to continue using the asset, will usually be appropriate.

Rates and prices

5.5 Estimates should reflect the nature and scope of the work to be constructed. Aspects to be considered should include site conditions, location, size, complexity, risks, programming and timing constraints, availability of resources, construction methodology, specification and conditions of contract. Wherever possible the estimate should be based on appropriate cost data from historical tenders, published articles and estimating price books, estimates and quotations from companies for specialist work, and the estimator's own experience.

5.6 Where less common items constitute a significant part of the overall cost, it is often necessary to make a careful assessment of quotations and estimates obtained from operators with commercial experience in that sector.

Price indices

5.7 The base year used for pricing should always be stated. When data are not available for that particular year, it may be necessary to use appropriate indices to convert historical prices to the same base. At feasibility level, costs and benefits can generally be indexed using the all-items index of retail prices. For construction costs, the public works non-road index is appropriate for most uses.

5.8 Particular components may constitute a large proportion of a project cost, or the cost of those components may be expected to vary in real terms over time. In such cases, sensitivity analysis should be used to explore the implications for option choice.

Other cost elements

Contributions from others

5.9 When considering project costs, it may be incorrect to deduct payments from developers, highway authorities or other contributors. Generally, such windfalls only affect the distribution of costs and not the total resources required for the project. If the associated benefits were excluded from the appraisal, it would be reasonable also to exclude the contributions. However, particularly when those contributions come from other budgets of public money, it is preferable to include all benefits and costs. In this way the benefit-cost analysis will demonstrate whether the project as a whole is justified.

5.10 When the contributor is a commercial organisation, it may be prepared to pay on the basis of the financial benefits to that organisation, which may be greater than the economic benefits. For example, the owner of a supermarket might be prepared to contribute an amount which reflects not just the direct losses that would be experienced from flooding, but also the loss of trade where in economic terms the loss is simply a transfer payment. The economic implications of such contributions therefore need careful consideration, having regard to the particular circumstances.

Negative costs

5.11 Sales that offset the costs of construction are to be treated as benefits of the scheme. For example, the sale of sand or gravel excavated as part of a channel widening scheme, or charges raised for the incorporation into the scheme of arisings from others, should be treated as a benefit (paragraphs 3.22, 3.23).

Negative benefits

5.12 Disbenefits such as noise and disruption caused by project works, and obstructions to views, should be treated as costs (paragraph 3.23). In general, however, they are likely to be better handled as part of the consultation process and environmental appraisal, through which ameliorating actions are likely to be identified and included in scheme costs. If not, the costing of the disbenefits is likely to be disproportionate to their magnitude. Their value will only require consideration when there are significant differences of impact between different groups or between different options.

Treatment of project risk

5.13 There is a widely recognised, general tendency for appraisers to be overly optimistic in their early assessment of project costs, time-scales and benefits, when these are compared with final outturn values. This is termed “Optimism Bias”. Prior to the revision in 2003 of the Treasury Green Book, this bias was taken into account in a generalised way through a percentage premium included within the test discount rate. HM Treasury have *unbundled* the issue from the discount rate, which has been reduced from a flat 6% to a variable 3.5% (reference 2). Consequently, an explicit consideration of Optimism Bias is required through (i) the application of suitable uplift factors to early best estimates of project costs, and (ii) sensitivity analysis of predicted benefits and project time-scales.

5.14 The **best estimate** for any project should be the appraiser’s assessment of the most likely outturn costs of the project. These should include, for example, all labour, materials, supervision, land purchase, compensation, access costs and contractors’ overheads associated with both temporary and permanent works, and all long-term costs associated with operation and maintenance. Where the estimator judges that additional sums are likely to be required for particular areas of work, for example, for dealing with poor ground conditions, these should be included, but general contingencies should be estimated as part of the process of deriving the optimism bias adjustment. All elements of the estimate should be based on experience of projects of similar character and should recognise the likely difficulties involved in carrying out works in particular circumstances, for example, the high cost of working in confined spaces or within, or adjacent to, private properties in urban areas.

5.15 Sensitivity analysis of **benefits and project time-scales** is an important element of best practice. However, the new approach to Optimism Bias in **cost estimates** requires a strengthened procedure. Best practice guidance in relation to strategy and scheme costs is set out below. This develops the interim guidance issued by the Executive to local authorities in March 2003 (reference 11).

- <u>Strategy costs (initial feasibility stage)</u>
  At this stage it is assumed that no detailed design has been carried out and that, therefore, cost estimates are based on broad assumptions about the scope and nature of the work.

Step 1: For each option, identify best estimates of all capital, operating and maintenance costs given current information.

Step 2: Take a **starting** value for Optimism Bias of **60%** of total Present Value costs (including capital, operating and maintenance costs over the whole life of the option). This percentage reflects the current view of the average cost uplift from strategy/pre-feasibility stage to the final account stage.

Step 3: Study Annex C, which sets out the current view of the key components of risk that make up the overall 60% factor. Assess whether the contributions of these components should be higher or lower for the particular situation under consideration. Where demonstrable action has been taken to minimise individual risks, a case can be made to reduce the relevant component(s). Conversely, where the project is considered to be more risky than average in certain areas, perhaps because of innovation, say, the relevant risk component contributions should be increased. In the absence of evidence either way, the default risk component percentages (Annex C values) should be left unchanged.

Step 4: Rework the overall Optimism Bias factor based on any revisions to risk components. Apply the revised Optimism Bias factor as a percentage uplift to total Present Value costs (in place of any contingency estimate).As an alternative, where a full "Monte Carlo" type risk evaluation has been undertaken, then the 95% confidence level estimate should be used to derive the optimism bias factor. Where any present value costs are not included in the risk approach these should be adjusted using the above approach and added to the 95% confidence risk based result.

- <u>Scheme costs (detailed design stage)</u>
  To reach this stage it is assumed that appropriate site investigations and detailed design of the main works have been carried out, so that major cost items are based on detailed assessments of works required from substantially complete working drawings and specifications.

Proceed as for strategy costs, but use a starting Optimism Bias factor of **30%** and the relevant risk component guidelines in Annex C.

Discounting and economic efficiency

5.16 To test the economic efficiency of different options on a comparable basis, it is necessary to discount all of the costs and benefits of the scheme, from the time they arise in the future, to their present value. The test discount rates specified in the Treasury Green Book are 3.5% for years 0-30, 3% for years 31-75, and 2.5% thereafter (reference 2).

5.17 The convention that should be adopted is to take all costs and benefits in any given year as accruing at the midpoint of that year, and to discount all these streams back to their present value at mid-year 0. This is the time at which capital expenditure is also to be taken to start to accrue.

5.18 **In terms of good practice:**

• the test discount rates specified by the Treasury are to be used for all streams of benefits and costs;

• each and every benefit and cost should be taken to accrue in the middle of the year when it occurs, and

• present values should be calculated as at the mid-year of year 0.

5.19 The economic efficiency of options can be assessed by comparing their benefit-cost ratios (ie the present value of benefits divided by the present value of costs), and their net present values (ie the present value of benefits less the present value of costs).

5.20 Where different options offering different standards of protection are compared, the incremental benefit-cost ratio of the higher standard of protection equals the increase in benefits resulting from that higher standard divided by the additional cost.

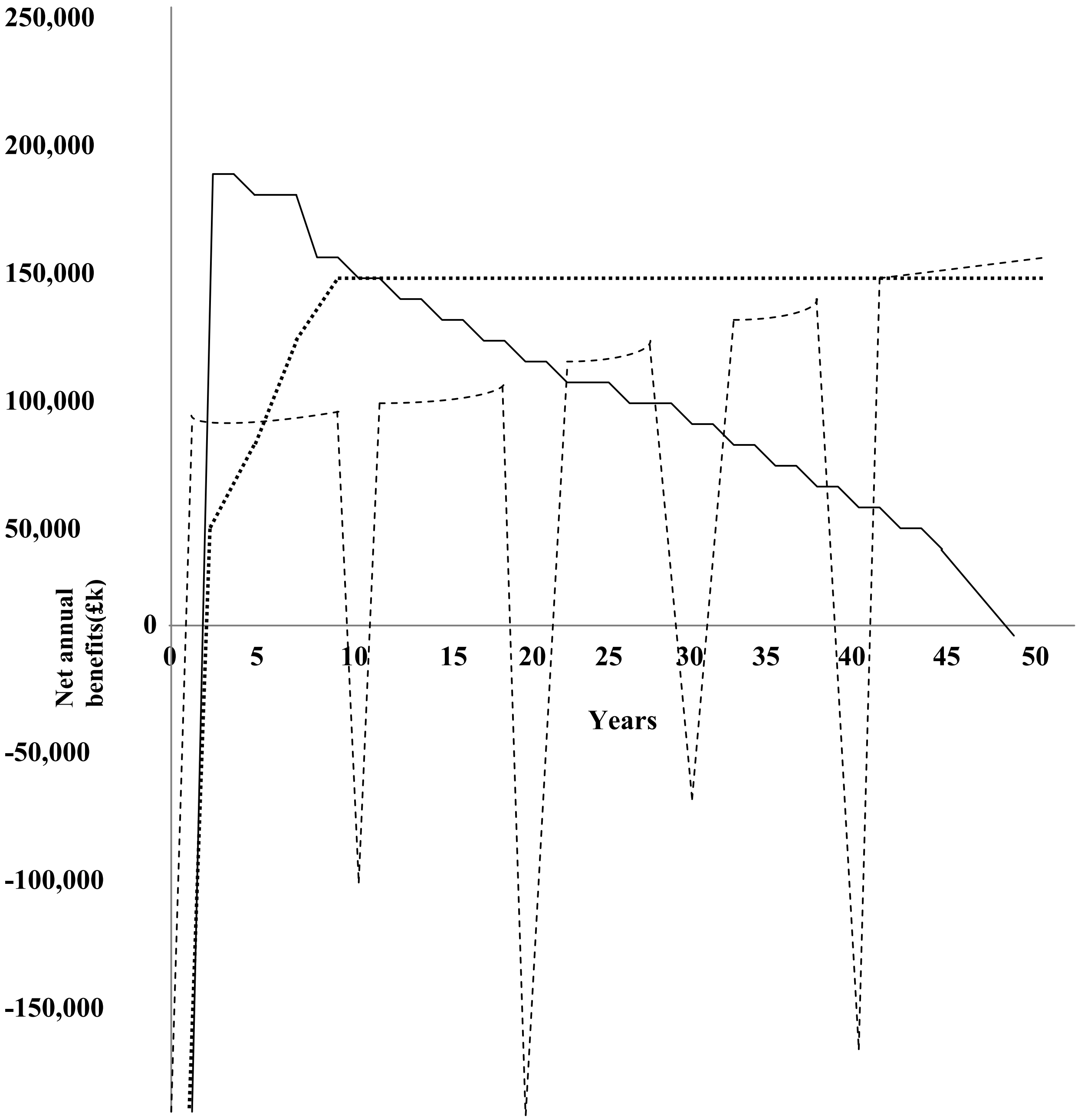
5.21 Because of the limitations inherent in comparing schemes by use of a single indicator, it is good practice to plot the changes in the different streams of benefits and costs over time. Discontinuities are either a sign of a change in conditions or an arithmetic error.

Economic sustainability

5.22 The economic sustainability of different options can be examined by plotting the distribution of net annual benefits over time. For example, Figure 5.1 shows 3 options with very different distributions of net annual benefits (ie the difference between expected annual benefits and costs for each year of the scheme life) but very similar benefit-cost ratios and net present values (NPVs). Option 1 has (marginally) both the highest benefit-cost ratio and NPV. However, unlike the other 2 options, the net annual benefits of option 1 are negative in the long run. With option 2 there are some significant initial costs and the benefits are not immediately realised in full, but in the long-term stable benefits are achieved. Option 3, shows increasing benefits over time but also high recurrent costs.

5.23 In such a case it would not be appropriate to attach significant weight to the relatively minor differences in benefit-cost ratio or NPV but rather to examine the wider area of economic sustainability. This might include at least an outline appraisal over a longer time period so that longer-term gains and losses can be taken into account.

Figure 5.1 Comparison of options with different expenditure profiles



Option 1 (high capital costs; low operating costs) - NPV = £1,319,490; B/C = 2.49:1
Option 2 (high capital costs; high running costs) - NPV = £1,237,902; B/C = 2.43:1
Option 3 (low capital cost; high operating/replacement) - NPV = £1,124,544; B/C = 2.40:1
(NPV = net present value; B/C = benefit-cost ratio)

SECTION 6

CHOOSING THE OPTION

Introduction

6.1 Flood prevention schemes made by local authorities and submitted to the Scottish Executive for grant assistance must provide value for money. The funds available for such assistance are set with reference to the schemes in the Scottish programme, and to the demands of other programmes. Consequently, the funds are not limitless.

6.2 Historically, the number of schemes has averaged less than 2 per annum. With such low numbers, and the comparatively low level of capital expenditure, it has been possible to manage the grant scheme within available resources. However, the flood defence programme has been expanding, thereby increasing the pressure to obtain best value for money for the programme as a whole.

6.3 A practical way of ensuring best value for money, which may be applied on a project-by-project basis, is to maximise the benefit-cost ratio of those schemes being funded while seeking to achieve an appropriate standard of protection for the type of land in question. The procedure for achieving this, the decision process, is set out below.

Standards

6.4 To qualify for grant assistance, it is expected that flood prevention schemes in Scotland will continue to be designed to withstand, at least, a 1 in 100 year flood event. As noted in paragraph 3.8, this guideline standard is not intended to prejudge or otherwise constrain the appraisal process. It does not preclude the adoption of a higher standard where justified, nor indeed a lower one. However, experience over many years in Scotland has shown that a 1 in 100 year standard is appropriate for the protection of non-agricultural land. Such a standard reflects reasonable public expectations in relation to residential and other urban property. Further, it lies within the return period range of 50-200 years, which is the indicative standard in England and Wales for the protection of intensively developed urban areas against fluvial flooding. Against that background, a 1 in 100 year standard is a reasonable starting point, and provides a practical benchmark to assist with the administration of the grant scheme. This does not negate the need to appraise different standards in addition to the guideline value.

The decision process

6.5 The objective of this section is to guide flood defence practitioners in the choice of the most appropriate scheme option. It is appropriate only for the consideration of alternative standards of defence. It assumes that alternative design options will be separately considered to determine the least whole-life cost to achieve any particular design standard. In addition, it should be noted that the method is dependent on the sensible determination of discontinuities in both the benefit-probability and cost-probability curves (section 4.3).

Steps in decision-making

6.6 The starting point is the concept of benefit-cost ratio, both overall and on an incremental basis. The maximisation of this ratio often indicates the most economically worthwhile scheme but should be considered in the following steps to take account of reasonable expectations of standards of protection.

(1) Examine the benefit-cost ratios of all options. If none is at least unity, reconsider the scope of the options and recommence this process, or abandon the proposal.

(2) Identify the option with the highest benefit-cost ratio. The standard of protection for this option will fall below, at or above the guideline of 1 in 100 years. Where it falls below, consideration can be given to alternative options to come closer to achieving the guideline standard provided the incremental benefit-cost ratio is robustly greater than unity. Consideration can be given to options up to an indicative maximum of 1 in 200 years, provided the incremental benefit-cost ratio is competitive with that likely to be achieved if the additional costs were invested in other schemes. Any further increase in standard should only be considered if the additional benefits by far outweigh the additional costs. Such considerations should follow the steps set out at (3)(a), (3)(b) and (3)(c) below.

(3) The aim of this step is to provide best value for money while achieving the most appropriate standard of defence.

(a) Scheme with maximum benefit-cost ratio lies below guideline standard of 1 in 100 years.

Consider the option with the next higher standard and determine whether its incremental benefit-cost ratio is robustly greater than unity. If this is the case, proceed to the next higher standard option. Continue the process until either:

- the incremental ratio is no longer robustly greater than unity, at which point the process ends; or

- until the guideline standard is reached. Then proceed to (3)(b).

(b) Selected scheme lies at or above the guideline standard but below the indicative maximum.

Consider the option with the next higher standard and determine whether its incremental benefit-cost ratio compares with other nationally funded schemes. If this is the case proceed to the next higher standard option. Continue the process until either:

- the incremental ratio is no longer comparable with other nationally funded schemes, at which point the process ends; or

- the indicative maximum standard is reached. Then proceed to (3)(c).

(c) Selected scheme up to this point exceeds the indicative maximum standard.

Consider a higher standard scheme only if this yields an incremental benefit-cost ratio that is exceptional and, certainly, significantly higher than the benefit-cost ratios of independent schemes competing for funds.

6.7 It should be noted that incremental benefit-cost ratios can be sensitive to the choice of interval and spuriously high or low individual values should not be allowed to mislead. In each case it is important to compare 2 viable options. Further, where the best scheme choice is dependent on incremental ratios that are marginally greater than unity, a sensitivity analysis might be required to assess whether the choice would be worthwhile.

6.8 The recommendations arrived at from the above process may well be the final choice. However, it is recognised that benefit-cost analysis is but one tool available to aid decision-making. An authority may be justified in proceeding with an alternative where other exceptional factors influence choice. These could include:

- uncertainty regarding the economic outcomes of a particular option which it has not been possible to incorporate adequately into the preceding analysis (see Chapter 6);
- environmental considerations for which it has not been possible to assign monetary values;
- development plan policies and other material planning considerations;
- availability of funds (affordability).

6.9 It should be emphasised that the exercise is not about the manipulation of figures. Rather, what is required is a reasoned interpretation of the information produced from the appraisal.

Sensitivity analysis and robustness testing

6.10 Within economic appraisal, the purpose of sensitivity analysis and robustness testing is to determine whether, within the reasonable bounds of confidence, and for the various assumptions made:

- the scheme is economically worthwhile;
- the economic return is likely to be achieved;
- the option choice is robust.

6.11 It is therefore important to determine those factors that would impact on any investment decision. If, for example, the benefit-cost ratio is highest for an option where there is significant uncertainty, it may be better to pursue an alternative with a lower, but more certain outcome. Chapter 6 incorporates a framework for evaluating such risks.

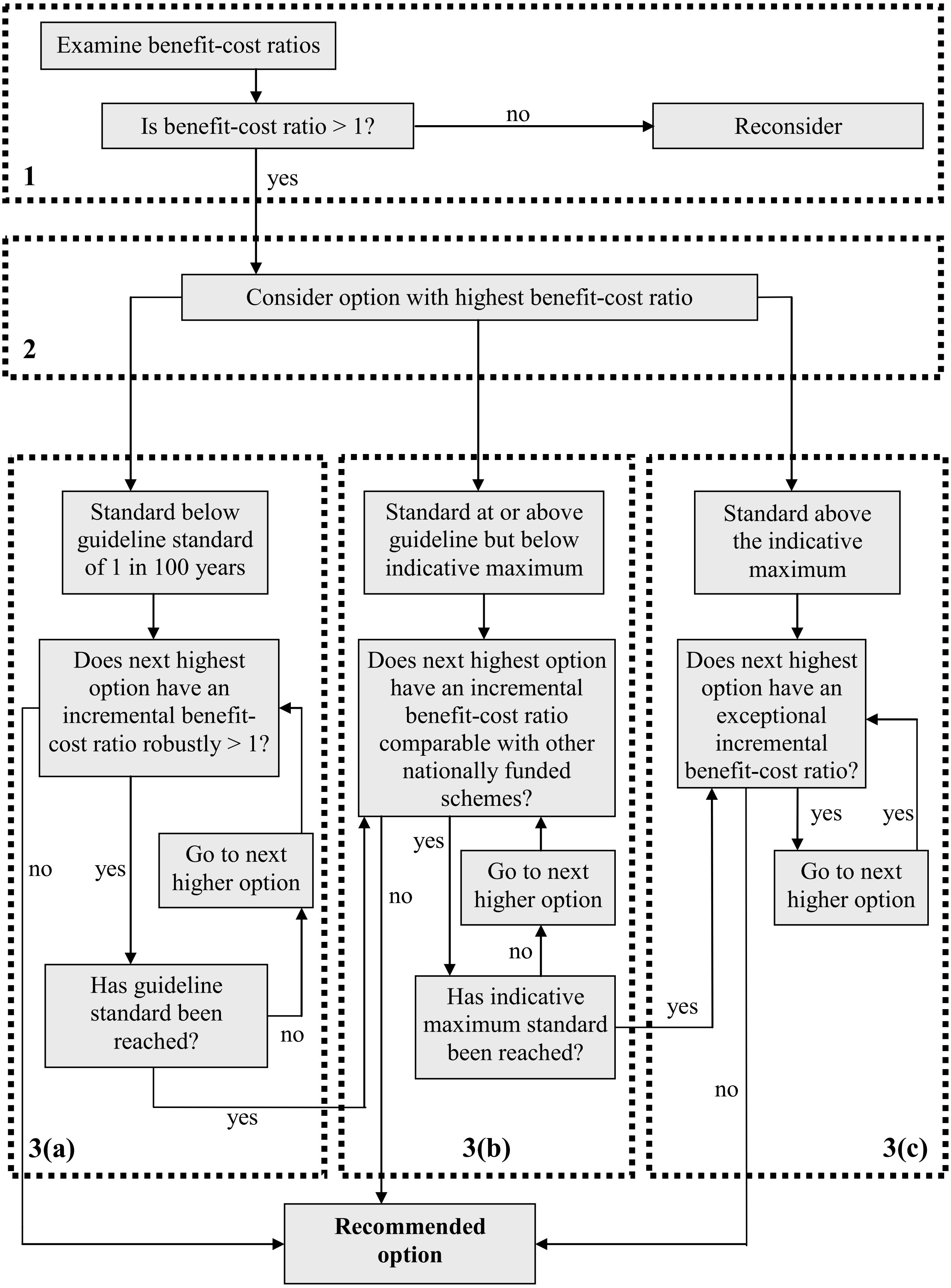
6.12 Having determined the most important factors, assessments of uncertainty should be made on the basis of experience and judgment. As a general guide, a range of possibilities should be considered for items such as:

- costs (whole-life capital, maintenance and management);
- threshold of flooding (many schemes will be sensitive to assumptions about the level, and hence frequency, at which flood damage commences);
- calculation of extremes and their probabilities;
- changes to major beneficiaries (for example, a major business in the benefit area could cease trading or relocate).

6.13 Even where it is not possible to quantify the uncertainty associated with each variable, it should be possible to identify a reasonable range of possibilities. All major risks should be considered both singly and in combination.

6.14 For major projects it is particularly important to identify switching points where a change in the assumptions would alter the option choice. Informed judgments can then be made of the relative likelihood of the different outcomes, to determine the best option.

Figure 6.1 The decision process



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GLOSSARY OF TERMS

Above-design-standard benefits	The benefits from reductions in flood losses from events which exceed the design standard of protection, expressed as an annual average benefit.
Appraisal	The process of defining objectives, examining options and weighing up the costs, benefits, risks and uncertainties before a decision is made.
Benefits	Those positive quantifiable and unquantifiable changes that a project will produce.
Benefit-cost ratio	The ratio of the present value of benefits to the present value of the costs.
Contingent valuation method	A valuation methodology which uses questionnaire techniques to elicit valuations using respondents' willingness to pay for an environmental improvement.
Discounting	The procedure used to arrive at the sum of either costs or benefits over the lifetime of a project using a discount rate to scale down future benefits and costs. The effect of using a discount rate is to reduce the value of projected future costs or benefits to their values as seen from the present day.
Economic appraisal	An appraisal that takes into account a wide range of costs and benefits, generally those which can be valued in money terms.
Incremental benefit-cost ratio	The ratio of the additional benefit to the additional cost, when 2 options are compared.
Intangibles	Those costs, benefits and risks that are difficult to quantify but which are nevertheless relevant for the decision making process. Usually applied to non-monetary impacts.
Market price	The price for which a good is bought and sold in a market. If restrictive conditions are satisfied, this price may be used to estimate the economic value of the good. Otherwise, the market price may need to be corrected, and a 'shadow price' derived, in order to estimate the economic value of the good.

Net present value (NPV)	The stream of all benefits net of all costs for each year of the project's life discounted back to the present date.
Non-monetary impacts	Used to describe those impacts of flooding on households which do not have direct financial impacts.
Non-use value	The value that people hold for an environmental resource which is not attributable to their direct use of the resource for commercial or recreational purposes. Otherwise known as intrinsic value.
Post project evaluation	A procedure to review the performance of a project with respect to its original objectives and the manner in which the project was carried out.
Present value	The value of a stream of benefits or costs when discounted back to the present time.
Ramsar site	Internationally important wetland, designated under the Convention on Wetlands of International Importance (Ramsar, Iran, 1971).
Return period	The average length of time separating flood events of a similar magnitude: a 100-year flood will occur on average once in every 100 years.
Risk assessment	Consideration of the risks inherent in a project, leading to the development of actions to control them (see Chapter 6).
Special Area of Conservation	An internationally important habitat or species **(SAC)** designated under the EC Habitats Directive.
Sensitivity analysis	Analysis of the effects on an appraisal of varying the projected values of important variables.
Special Protection Area (SPA)	Internationally important site designated under the EC Wild Birds Directive.
Sunk costs	A cost incurred in the past and which cannot be recovered whatever decision is taken now. Consequently, sunk costs are omitted in benefit-cost analyses.
Sustainability	The degree to which flood defence solutions avoid tying future generations into inflexible and/or expensive or environmentally damaging

options for defence. This will usually include consideration of interrelationships with other defences and likely developments and processes within a catchment. It will also take account of long-term demands for non-renewable materials.

Transfer payment

A payment which has no impact in terms of an economic analysis (see Annex A for a full definition). Examples are most tax payments and general subsidies.

Whole-life costs

The total costs associated with a scheme for its full design and potential residual life span, taking proper account of all aspects of design, construction, maintenance and external impacts. A particularly useful approach in helping to determine economic sustainability when used to compare the relative costs of long-life schemes such as flood defences, and where decisions need to be made between short-term capital costs and long-term maintenance costs.

Willingness to pay

The amount an individual is prepared to pay in order to obtain a given improvement in utility, expressed through the contingent valuation method.

ANNEX A

TRANSFER PAYMENTS

Transfer payments

When does a change result only in a transfer payment?

A1 Benefit-cost analysis is concerned with national economic efficiency where efficiency is, in effect, the ratio of the value of outputs (consumption) to inputs (resources). These inputs are yielded both from stock (eg engineering plant, buildings) and from flows (eg electricity, labour).

A2 A transfer payment occurs when a change simply affects either who gets the consumption or who provides the resources, but there is no change in the national total of either all the consumption, or all the resources required to generate that consumption.

Test for a transfer payment

A3 Will there be any change either or both in the total value of UK consumption, or in the resources required to provide that consumption? If not, then only a transfer payment is involved.

A4 When a physical object is damaged or destroyed by a flood, a transfer payment is not involved since maintaining current levels of consumption will require the replacement of that object. There will be distributional consequences as well (eg builders will get more work) but the test is whether there will be a change in the total level of consumption or the resources required, including the need to repair or replace stocks which have been damaged or destroyed.

Examples of a transfer payment

A5 Examples are:

- VAT and excise duties are always transfer payments and must be netted out of the analysis. If less petrol is sold, then the Exchequer will simply find different ways of raising taxes.

- If a hotel or pub were lost, the trade would simply transfer to other outlets, the value of any such 'goodwill' element in the market price must therefore be netted out of the analysis.

- Losses of trade to commercial or retail outlets will be a transfer payment except in the circumstances given below.

Examples of changes which are not a transfer payment

A6 In some cases, a levy is made in respect of negative externalities, a 'green tax', which is intended to reflect a real economic cost, although otherwise it appears identical to other forms of taxation such as VAT. If, for example, a charge were to be levied on aggregates which reflected the real environmental damage caused by aggregate extraction, this would reflect the additional economic loss resulting from mineral workings. Therefore, an increase in aggregate extraction would result in additional economic losses to the country, in addition to the resource costs of extraction and transportation. Landfill taxes are also a 'green tax' and represent a real economic cost. Ideally, where appropriate, these additional economic losses should be quantified and included in the analysis. However, this is unlikely to be practical for most flood prevention schemes and it will normally be reasonable to use the tax rates as a surrogate for the real economic loss in any analysis.

A7 Losses of trade to commerce and retail outlets result in real losses if consumers cannot obtain equivalent goods at the same time and at the same cost. If all 3 conditions do not hold, an economic loss is involved. However, the normal expectation is that consumers will be able to obtain equivalent goods at no extra cost and therefore any differences will not be worth evaluating.

A8 The test can also be applied to non-priced goods, such as visits to a riverside park. If consumers can go somewhere else and get the same amount of enjoyment at no extra cost, the change in visiting results in no real economic cost. If they cannot, the net value of the loss in enjoyment, plus any increase in cost to the visitor measures the economic loss.

ANNEX B

COMPONENTS OF ECONOMIC VALUE AND ENVIRONMENTAL ASSETS

Introduction

B1 Economic value is determined by individual preferences and, where there is a market in the goods or services in question, can generally be taken as the market price, at least as a first approximation. Many goods and services, however, have no market price, either because they are provided 'freely' by the state, such as defence, law enforcement and street lighting, or are otherwise freely available to all, such as a panoramic view. However, such goods still have an economic value. In the appraisal of flood prevention schemes it is the valuation of environmental or recreational assets for which there is no readily available market price that is likely to prove problematic. On top of the economic value deriving from the direct use of an unpriced asset, there are other components of economic value which might arise in some cases. These are:

- a *functional value*, where an asset serves a number of functions and yields benefits other than those deriving from its direct use by 'consumers';
- an *option value* given to maintaining the option of being able to use the asset in the future, although it is not currently used;
- an *existence* (often termed a 'non-use' or 'passive use') value representing a value which people attach to the continued existence of an asset for the benefit of current or future generations, even though they make no direct use of it themselves.

B2 Care always needs to be taken to avoid double counting by estimating total economic value in one way and then adding on some components which have already been implicitly included within the calculation.

The need to derive existence values

B3 In principle, all of these elements should be appraised when valuing changes to an unpriced environmental or other asset which arise as a result of carrying out - or not carrying out - any flood prevention scheme. In practice, however, it is likely to be changes in the use and functional value of the asset that will dominate. Three questions should be addressed initially.

(1) Under what circumstances is it necessary to appraise existence values?

(2) How can it be done?

(3) Is it likely to affect the result of the benefit-cost analysis if it is done?

B4 If the answer to the third question is 'No', so that the inclusion of existence value is unlikely to have any bearing on the outcome of the analysis, the first 2 questions become entirely academic. The use of existence values in practical contexts will, moreover, carry a considerable degree of uncertainty. Consequently, any estimates are likely to prove contentious. This is particularly so since those schemes where existence values are likely to have an important bearing on the final choice of option tend themselves to be contentious. Hence, rather than including explicit existence values within the benefit-cost analysis, it may be preferable to adopt the pragmatic approach of attempting to quantify, in non-monetary terms, the relative impact of existence values on the options under consideration, on the basis of consultations with interest groups and the wider public. Consideration can then be given as to how large the implicit monetary values would have to be to affect the choice of scheme, and whether such values are plausible on the basis of the information deriving from the consultation process. With the direct attribution of monetary values to existence values there is a danger of discussions becoming sidetracked into philosophical arguments about whether a monetary value ought to be attached to the environmental asset in question as well as methodological arguments about the adequacy of the particular technique used to derive that value.

B5 The results of any study of existence values will, however, generally be less contentious if there is a consensus that some 'do something' option is preferable to the baseline alternative so that the question essentially reduces to one of deciding whether it is worth spending a particular sum of money.

B6 There are 2 circumstances when it may be necessary to include an assessment of existence value. These are:

(1) where a proposed scheme protects only an environmental asset from loss or damage;

(2) where a proposed scheme would protect an environmental asset, amongst other properties, but the readily valued benefits are not sufficient on their own to justify a scheme.

B7 Even here it might be more helpful to look first at alternatives, such as the cost of replacing the asset or of its local protection, before embarking on an appraisal of existence values. Seeking to appraise the existence value of losses or damage to environmental assets, arising as a consequence of one or more of the 'do something' options, however, is unlikely to be helpful in reaching a decision on the best option. If such losses are unavoidable then, through discussion with interested parties, the scope for compensatory works should be explored.

Determining existence value

B8 If it does prove necessary to appraise the existence value of some change in environmental assets, then a methodology such as contingent valuation (Mitchell and Carson, reference 16) or conjoint analysis (Louviere, reference 15) should be used to derive this value. Such a study needs to be carried out by well-qualified practitioners and is liable to be quite expensive (>£50,000) taking some time (> 6 months) to complete. Ideally, in advance of the main fieldwork, qualitative studies will be undertaken, for example, using focus groups (Krueger 1988, reference 14). Such studies should seek to explore exactly what it is that the public values, or for which they are prepared to pay, and why they are prepared to pay. It is a useful opportunity to gain an understanding of how the public defines the decision that must be made, and how they believe it ought to be made. Again, in a main contingent valuation or conjoint analysis study itself, emphasis should be put on gaining an understanding of how different members of the public approach the choice. Additionally, it will be helpful to discuss the formulation of the study with interested parties, including the statutory consultees.

B9 One of the major issues in studies of existence value has been whether a value for the particular site is being obtained or something rather more ill-defined, such as a preparedness to pay for environmental protection as a whole. Care therefore needs to be taken that the values elicited from any study are specific to the asset in question, and do not relate to that type of asset in a more generic sense. For example, if an existence value for a SSSI is being sought, the interview schedule should be designed so that a clear distinction can be made between a preparedness to pay to preserve the specific SSSI and SSSIs in general.

B10 Another major issue in appraising existence value is the specification of the appropriate population. What are the geographical boundaries defining the population that is deemed to place an existence value on the asset and, by implication, which population is prepared to pay for it? It clearly makes a profound difference to the calculation of the existence benefit of protecting a site if an average existence value (the sample mean amount for individual preparedness to pay) of £1.60 a year relates to the population of the entire country, or only the population living within 5 kilometres of the site in question. The identification of the appropriate population is often neglected so that a relatively small monetary value (mean individual preparedness to pay), ends up being multiplied by a very large but essentially arbitrary population figure.

B11 This question can first be explored through the qualitative studies; for instance, by selecting the samples for the studies from populations living at various distances from the site in question. Secondly, the population to which the mean preparedness to pay is applied should not be wider than the population that was sampled in the quantitative study. Thus, if only people living within 10 kilometres of the site were interviewed, then it is a conservative assumption that people living further away are not prepared to pay to protect the site. Within the sample, it may be worthwhile exploring whether there is any relationship between the distance individuals live from the site and either the likelihood that they are prepared to pay at all, or the total amount they are prepared to pay. Where there is such a relationship, the population mean should be calculated by the appropriate weighting by distance.

B12 The individual figures found in the study will be intended to reflect the total economic value, both use and existence, of the site to the particular individual. Usually, they will contribute some use value to some individuals that will have been valued by other means. If so, this element must be removed from the sample estimates, to leave only existence value, and hence avoid double-counting of use values within the benefit-cost analysis. If it is assumed that the only difference between 'users' and 'non-users' is that one group uses the site and the others do not, users should be expected to be more likely to be prepared to pay, and to pay more, than non-users. This difference should be equal to the use value of the site to those users. Therefore, on this argument, the mean sample preparedness to pay of non-users can be used as the basis for generalising to the relevant population. However, the argument depends on the validity of the assumed sole difference between users and non-users, which must be checked. It is also necessary to determine whether there is a statistically significant difference between the preparedness to pay of the 2 groups.

Guidance for contingent valuation and other studies

B13 In general, both the contingent valuation and conjoint analysis techniques should be treated as experimental methods rather than routine tools. Consequently, it is necessary to establish the validity of the results, particularly that individual differences in preparedness to pay reflect those differences which are expected theoretically. Equally, because they are experimental techniques, it would be undesirable to set such restrictive rules as to inhibit innovation and the development of improved methodologies. Therefore, other than the adoption of social survey good practice, the rules below define what should be achieved, rather than prescribe the means to achieve those ends.

B14 The minimum requirements for a contingent valuation or conjoint analysis study are:-

- Sample size should be a minimum of 500 individuals.

- This shall be a random sample of the population to which it is intended to generalise the results.

- Professional quality fieldwork is required, complying with the Interviewer Quality Control Scheme and the Code of Conduct of the Association of Market Survey Organisations. This fieldwork should normally be undertaken by a specialist fieldwork organisation.

- Personal interviews with respondents are required rather than postal surveys or telephone interviews.

- The results may not be generalised to a wider geographical population than that included in the sample.

- The effects of distance on both the probability that an individual is prepared to pay and the amount that an individual is prepared to pay shall be analysed.

- The ‘use value’ component of preparedness to pay shall be removed from preparedness to pay when estimating existence value.

- The likelihood that an individual is prepared to pay, and the amount that an individual is prepared to pay, shall be reported separately.

- Since theory predicts that both the likelihood an individual is prepared to pay and the amount that such an individual is prepared to pay depend upon a number of factors, notably income, the extent to which the results are consistent with theory shall be reported.

- A report of the reasons why the values obtained can be treated as specific to the site in question is required.

Further reading

B15 There are many books and publications available on this topic but references 12 to 16 provide a selection of texts, including those referenced in this Annex. Bateman and Willis (reference 12) provide a good review of the state of the art in theory and methodology and Burgess, Clark and Harrison (reference 13) give a critical examination of how people actually respond in a contingent valuation study seeking to derive an existence value for a specific site.

ANNEX C

OPTIMISM BIAS DATA FOR FLOOD PREVENTION COSTS

The following data and other details have been abstracted from the note issued by Defra to operating authorities in March 2003 (reference 11).

Starting (upper bound) Optimism Bias factor for	**Strategy** costs (pre-feasibility stage):	**60%**
“ “ “ “ “ “ “	**Scheme** costs (detailed design stage):	**30%**

The risk components contributing to the above factors are detailed in the following table.

Risk components contributing to above factors (%, summing to 100 – see next page for definitions)		Average % for flood defence projects
Procurement	Late contractor involvement in design	1
	Dispute and claims occurred	11
	Other	1
Project specific	Design complexity	4
	Degree of innovation	4
	Environmental impact	13
	Other	9
Client specific	Inadequacy of the Business Case	23
	Funding availability	2
	Project management team	1
	Poor project intelligence	8
Environment	Public relations	5
	Site characteristics	4
External influences	Economic	5
	Legislation/regulations	4
	Technology	4
	Other	1

The risk components (except for those described “Other”) may be reduced for individual strategies or schemes if demonstrable action to minimise risks has been taken, or other evidence is provided that risks are not applicable to the degree indicated. In which case, the revised sum of risk components should be divided by 100 and multiplied by either 60 or 30 to obtain the new Optimism Bias factor.

<u>Example of Optimism Bias approach:</u> After an assessment of risk components, the “environmental impact” component for a strategy plan is halved (ie reduced by 6.5). The new optimism bias factor equals:

(100-6.5)/100 x 60 = 56

So the best estimate of Present Value strategy costs is increased by 56%, with this adjustment applying to operating and maintenance expenditure as well as capital expenditure.

Definitions of risk components

Procurement	Late contractor involvement in design	Late involvement of the contractor in the design leads to redesign or problems during construction.
	Dispute and claims occurred	Disputes and claims occur where no mechanisms exist to manage effectively adversarial relationships between project stakeholders.
	Other	Other factors that relate to procurement which affect the final project cost.
Project specific	Design complexity	The complexity of design (including requirements, specifications and detailed design) requires significant management, impacting on final project costs.
	Degree of innovation	The degree of innovation required due to the nature of the project requires unproven methods to be used.
	Environmental impact	The project has a major impact on its adjacent area leading to objection from neighbours and the general public.
	Other	Other project specific factors which affect the final project cost.
Client specific	Inadequacy of Business Case	The project scope changes as a result of the poor quality of requirement specifications and inadequate project scope definition.
	Funding availability	Project delays or changes in scope occur as a result of the availability of funding.
	Project management team	The project management team’s capabilities and/or experience impact on final project costs.
	Poor project intelligence	The quality of initial project intelligence (eg preliminary site investigation, user requirements surveys etc) impacts on the occurrence of unforeseen problems and costs.
Environment	Public relations	A high level of effort is required to address public concern about the project, which impacts on the final project cost.
	Site characteristics	The characteristics of the proposed environment for the project are highly sensitive to the project’s environmental impacts (eg greenfield site with badger setts, or contaminated brownfield site).
External influences	Economic	The project costs are sensitive to economic influences such as higher-than-expected construction cost inflation, oil price shocks etc.
	Legislation/regulations	The project costs are sensitive to legislation and regulation changes, eg health and safety and building regulations.
	Technology	The project costs are sensitive to technological advancements, eg the effects of obsolescence.
	Other	Other external influencing factors which affect the final project cost.

CHAPTER SIX

Approaches To Risk

Photograph © Renfrewshire Council

Chapter 6

FLOOD PREVENTION SCHEMES GUIDANCE FOR LOCAL AUTHORITIES

APPROACHES TO RISK

CONTENTS

SECTION 1

INTRODUCTION

Scope of guidance

1.1 This chapter provides guidance for Scottish local authorities on the risk assessment aspects of project appraisal for flood prevention schemes promoted under the Flood Prevention (Scotland) Act 1961. It aims to enhance decision-making for investment in such schemes through improved methods of risk assessment. No fundamentally new concepts are involved.

1.2 The guidance assumes that the reader has prior knowledge of general risk and sensitivity analysis techniques within project appraisal, and should be read in conjunction with the other chapters. It is not intended to be followed rigidly, or to cover every aspect of risk analysis. In particular, the guidance is not a methodological manual for risk assessment. Appropriate specialist advice should be sought as necessary.

1.3 The primary topic covered is risk assessment and its part in the project appraisal process. Risk management aspects are also discussed, but only where these are relevant to project appraisal. Various methods and techniques are outlined, and these are covered more fully in the references.

1.4 The document is based on the procedural guide, "Flood and Coastal Defence Project Appraisal Guidance, Approaches to Risk", published by the Ministry of Agriculture, Fisheries and Food, now the Department of Environment, Food and Rural Affairs (reference 24).

Background to risk assessment

1.5 Historically, design practice for flood prevention schemes has been largely deterministic, with some sensitivity analysis, but little application of probabilistic approaches. In a purely deterministic analysis, a unique set of input parameters is used in a model to obtain a unique value for the system response. However, there is now a move towards risk-based design within a probabilistic framework.

1.6 In a probabilistic analysis, a full range of input values is tested, each one weighted by the probability of it being encountered. This approach takes account of both the consequences and probability of failure. It allows for uncertainty, rather than the approach where data and prediction/design methods are assumed to be known precisely.

1.7 Risk assessment methods are available at different levels of sophistication - from broad brush approaches using risk registers (section 2) to more specialised techniques such as event/fault trees and multi-criteria tools (section 3). The methods should be soundly based, but not over-complicated. In particular, they should be cost-effective, appropriate and targeted.

Advantages of risk assessment and risk management

1.8 Risk based methods enable the consideration of end consequences. For example, they consider not just the likelihood of high water levels against flood defences, but also the probability of their failure, and the consequent harm to people and property.

1.9 Risk assessment facilitates decision-making - hazards, risks and assumptions are documented, and can be communicated to relevant stakeholders. It provides a basis for risk to be recognised explicitly, and reduced, shared, transferred or accepted. It also reduces the chance of surprise.

1.10 Risk management provides a common approach for the comparison of different responses to uncertainty - for example, choices between provision of increased safety margin; development of contingency plans; adoption of a different (more robust) option; or deferment to carry out more studies and collect further data.

General aspects of risk

1.11 Risk is concerned mainly with (i) the likelihood of future events, and (ii) their possible consequences or impacts. When combined or multiplied together, these 2 aspects give a measure of the scale or significance of the risk.

1.12 Risk is often taken to refer to a harmful or detrimental outcome. However, both negative and positive impacts should be considered. The guidance treats risk holistically, embracing all stages in the implementation of flood prevention schemes.

1.13 It is useful to think of risk in terms of sources, pathways and receptors. The source is generally a hazard such as a storm event, and the receptors include people and assets potentially at harm from associated flooding. The pathway is the set of mechanisms that could trigger the harm. For a community behind a sea wall, a pathway might be overtopping, followed by overland flow, ponding, and consequent flooding. There may be several pathways. For example, an embankment may be overtopped or breached or both, and the location of the breach may be uncertain.

1.14 Probabilistic representations of risk have been used for many years: engineers and managers are familiar with the concept of 'return period' as a measure of the likelihood that a given parameter, such as river level, will be exceeded. Sound decision-making, taking into account a large number of uncertainties, over a wide range of scheme types, requires a more rigorous assessment of risk.

SECTION 2

USING RISK ASSESSMENT WITHIN PROJECT APPRAISAL

Introduction

2.1 There is wide acceptance that significant benefits can be gained from a more systematic approach to the assessment and management of risks. Risk assessment has often been applied instinctively; risks have remained implicit, and have been managed by judgment informed by experience. The assessment should, instead, make the risks explicit, formally describing them and making them easier to manage.

2.2 Risk assessment should be a 'live' process intimately connected with the study or project. It should be reviewed and reconsidered as the project proceeds, to account for any changes in design or intention. Associated documents, such as risk registers, should be available to those responsible for any subsequent stages of project development.

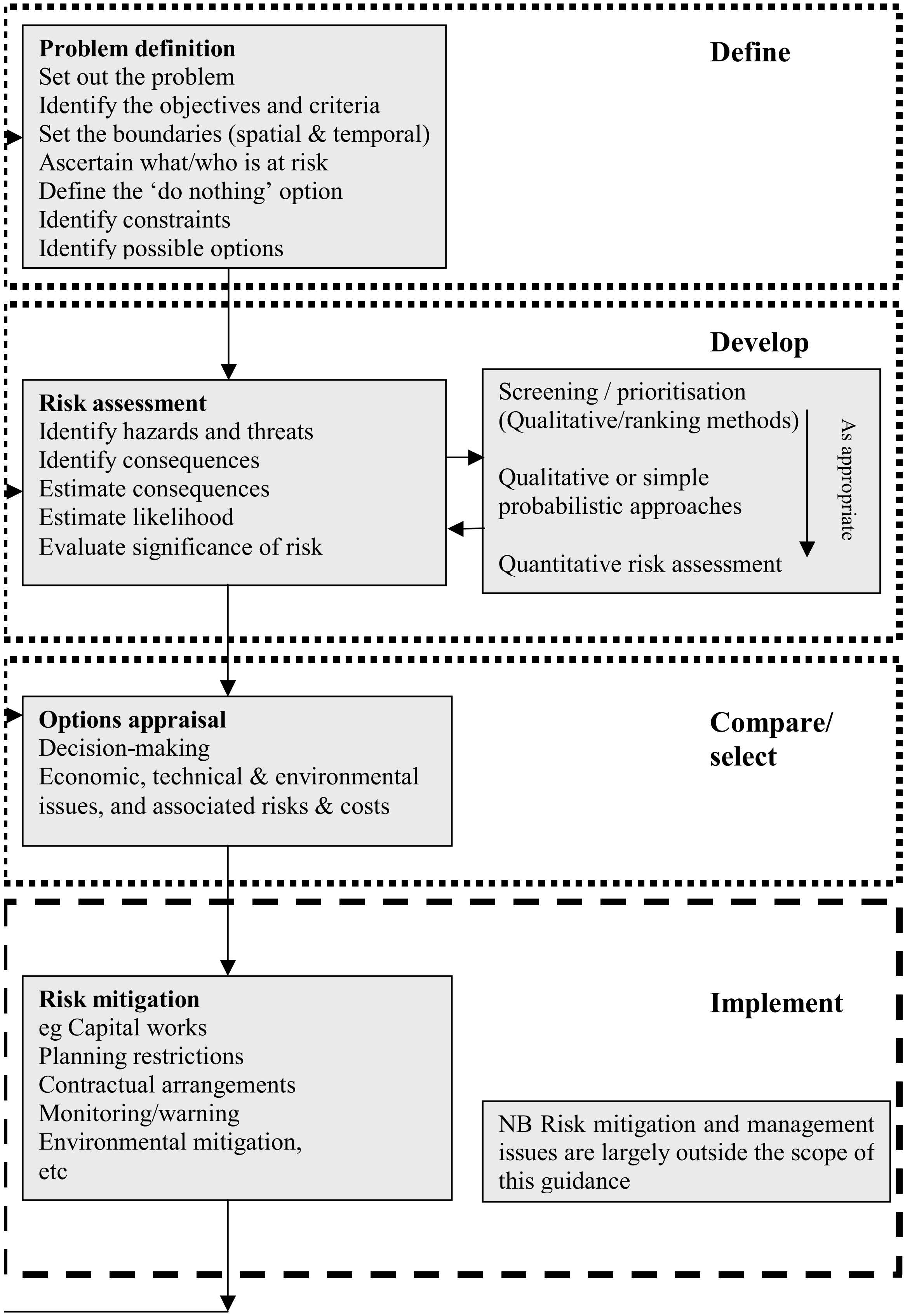
2.3 It is vital that the appraisal is linked to reality. An assessment that predicts severe flooding every year when no floods have occurred for 30 years is probably wrong. Similarly, input data should be carefully reviewed and cross-checked with similar data for nearby areas. This should provide some basis for estimating the likely uncertainty in the inputs.

2.4 Bounds have been established on what constitutes an acceptable health and safety risk (references 13 to 16). Acceptability is generally considered to be dependent on (i) the degree of control an individual has over the risk; (ii) the familiarity of the risk; and (iii) the number of individuals who may be killed or injured in any one incident. While these issues have not generally featured in appraisals of flood prevention schemes, they could be a legitimate consideration at some sites, and should be addressed in risk assessments in such cases.

Risk assessment framework

2.5 Figure 2.1 shows a flow chart framework for risk assessment within project appraisal.

Figure 2.1 Framework for risk assessment and management within project appraisal



2.6 Risks need to be considered as an integral part of the project appraisal process. That process, and hence risk assessment, should be carried out for all stages of a project. These may include large-scale planning and strategic studies (Chapter 3), in addition to the scheme development and design stage.

2.7 For the particular stage under consideration, it is important to define the objectives and aims of the programme or project; identify constraints; and determine options. The risk assessment should, for example, identify all significant hazards or threats to the objectives; estimate the likelihood and consequences of outcomes; and evaluate the importance, or significance of risks. Risks should be assessed for all options. Different options may involve different hazards and threats. They may also be affected by uncertainties to differing extents.

Approaches

2.8 There are various approaches to risk assessment, depending on the specific application. Guidance on this aspect is given in Table 2.1. The initial approach should be at a broad-brush level to identify, without complication, the key risks, issues and solutions. From the table, the most appropriate initial method is 'risk screening', using checklists and risk registers. This is a qualitative method. A ranking of risks using qualitative scales provides sufficient information for many decisions. This approach can highlight areas where detailed quantitative analyses are necessary. Such analyses require more specialised techniques and these are discussed separately in section 3.

Table 2.1 Risk assessment approaches

Approach	**Risk screening**	**Qualitative risk estimation**	**Quantitative risk assessment**
Tools	Check lists, risk registers	Scoring and weighting (also known as multi-criteria approaches and multi-attribute techniques)	Fault trees, decision trees, Monte Carlo modelling
Scope	Broad	Specific	Specific
Nature	Qualitative	Qualitative	Quantitative
Applications for flood defence	All, for audit purposes Generally, check lists will assist with hazard identification Construction Risks	Catchment management plans Strategic plans (with 'tangible'and 'intangible impacts)[1]	Strategic plans (with mainly 'tangible' impacts)[1] Schemes (design and appraisal)

[1] 'Intangible' impacts are impacts beyond those associated with damage to property, infrastructure, etc (ie 'tangible' impacts). They include damage to areas of environmental significance, impacts on recreational usage, high levels of stress, etc (Chapter 5).

2.9 A tiered approach is recommended for the structuring of risk assessments. This begins with the broadest view of the problem or issue. Next, all risks that could have a bearing on the issue should be identified. Some of these may prove to be insignificant and may be eliminated. The next logical step is to identify the most important risks among those remaining, usually by assessing the associated likelihoods and consequences.

Risk registers

2.10 Risk registers help to identify hazards, to record information about risks, and to document decisions taken. They also help to manage the risks, and are suitable for a wide range of projects, from large-scale planning to scheme implementation. The structure of the register should reflect the overall risk assessment and management process. An example format is given in Table 2.2. Issues affecting compilation of the register are discussed in paragraphs 2.11-2.25.

Table 2.2. Example of a format for a risk register

Project No.		Project Manager				
Project Name						
Brief Project Description						
Risks (identification)	Probability	Consequence	Assessment	Mitigation	Action by	Residual Risk
1	**2**	**3**	**4**	**5**	**6**	**7**

Risk identification (column 1, Table 2.2)

2.11 Guidance on the identification of risks is given in Annex A, which lists a number of risk categories as follows:-

- Funding
- Statutory framework
- Socio-economic framework
- Management of project development
- Strategic
- Impact of natural processes
- Performance of existing works
- Ecology, heritage and amenity
- Human intervention
- Design parameters
- Knowledge of principles/methods
- Scheme performance and response

- Procurement and construction
- Operation and maintenance

2.12 Some of the categories are non-project specific, a number are concerned with project development, and others are related to project implementation. The categories, and examples of associated risk areas, are considered in more detail in Annex A. It should be noted that the risk areas given in the annex are indicative. They will not be relevant to all projects. Further, the extent to which each needs to be considered will vary from project to project. Specific risks within each area are not given due to their potentially large number, and the fact that many would be project specific. Approaches such as 'brainstorming' should be used to ensure that all relevant areas are covered.

2.13 Risk assessment in large-scale planning and strategic studies needs to be commensurate with the decisions being taken, and the level of information available. All major risk areas should be identified, but it is likely that many will remain to be considered and resolved at the more detailed design stage.

<u>Probability assessment (column 2, Table 2.2)</u>

2.14 The probability of each risk needs to be identified. As a first stage, this may reflect the judgment of a knowledgeable individual or panel, based on best available information. The probability may be rated in one of a number of 'bands'. At its simplest, these may be ranked in High/Medium/Low categories. Alternatively, probability may be given on a scale of 1 to 5. Table 2.3 shows a suggested 5 point scale (see also reference 2).

Table 2.3 Suggested 5 point scale for assessing probability

Likelihood	Guidance	Frequency of occurrence
Frequent	Likely to occur many times during the period of concern	100/N
Probable	Several times during the period of concern	10/N
Occasional	Some time during the period of concern	1/N
Remote	Unlikely but possible (eg one in 10 times the duration of concern)	1/10N
Improbable	Can be assumed, for most purposes, that it will not occur	1/100N

NB: In the table, N is the period of concern. For a flood prevention scheme design, N may represent 100 years, while for a storm during construction its value may be one year. There is, of course, no reason not to use actual estimated probabilities where they are available, even in the initial risk register, rather than a scale or category. Use of probabilities may be more transparent, and will be an eventual goal for most significant risk areas in the later stages of assessment.

2.15 Where a scheme involves a number of individual lengths or phases, the failure probability of the system will depend on the failure probabilities for each part. It will also depend on the relationship between the parts; that is, whether they are dependent or independent. The assessment of probabilities in such situations may require expert judgment, modelling or other specialised techniques as described in section 3. This too may be required when assessing breach probabilities and their change over time.

Evaluation of consequences (columns 3,4, Table 2.2)

2.16 The consequences associated with flood defence include those in the economic, environmental, and social categories. They may not be confined to the area of the engineering works. For example, there could be significant impacts in distant downstream locations. Both remote and local impacts need to be identified.

2.17 Consequences and impacts also need to be evaluated. As with probabilities, it may be appropriate to use actual consequences (eg monetary values) where available, rather than a scaled version (eg very high, high, medium, and low).

2.18 Scales for probabilities and consequences should be similar, and designed so that their combination reflects the desired weighting. An example of how risks may be characterised and ranked in terms of probability and consequence (when these are quantified) is given in Table 2.4.

Table 2.4 Example of risk ranking in terms of probability and consequence

Risk	**Probability of occurrence**	**Consequence (anticipated cost if risk arises) (£K)**	**Risk value (£K)**	**(Rank)**
R1 Contaminated ground	5%	10	0.5	(4)
R2 Dewatering - property damage	25%	400	100	(1)
R3 Mine shaft collapse	5%	500	25	(2)
R4 Severe flooding	1%	100	1	(3)

This approach can be used to assess the acceptability and response to the risk; for example, it may be judged that risk R2 is unacceptable, and must be removed by changing the scheme concept or method. Risk R3 may be judged undesirable, and risk mitigation investigated and implemented as appropriate. Risk R4 may be accepted on the basis of low probability, and the cost of reducing flooding, but managed by detection and warning. Risk R1 may be accepted and dealt with if it arises.

2.19 The importance of particular risks will vary according to the stage of the appraisal. For example, strategic risks will command a very high priority during strategic studies, but only a medium priority in the context of scheme implementation, since major issues should already have been considered. On the other hand, procurement risks will have a very low priority during any large-scale planning stage, whereas they will be high priority at scheme stage.

2.20 Probabilistic analysis of consequences can add another dimension to appraisal. In certain situations, this may provide useful insights. However, it will often contribute little to achieving the overall project objectives. Under most circumstances, it is therefore preferable to adopt conventional methods of assessing consequences, and avoid quantitative analysis.

<u>Mitigation measures and residual risks (columns 5,6,7, Table 2.2)</u>

2.21 Mitigation measures are generally designed to reduce either the probability or consequence of a risk. There are many types of such measures and it is not possible to give a definitive list. However, the risk register and associated analysis should help to identify those that are most appropriate.

2.22 Some mitigation measures may remove the risk entirely; others may reduce it, leaving a residual probability and consequence. The importance of this must be assessed. If the residual risk is too high to be accepted, other mitigation measures should be considered.

2.23 Mitigation measures should be justified by their impact on the risk. In some cases, this will be directly measurable in economic or financial terms. Their effectiveness can be investigated by comparing the cost (ie expected value) of the risk without the mitigation measure, against the cost of the residual risk plus the mitigation measure.

2.24 Where risks and costs cannot be easily quantified, mitigation action may be justified on the basis of judgment. As well as reducing the mean or expected cost of risk, mitigation measures may also reduce the associated uncertainty. This may be important, particularly for complex risks with uncertain or unpredictable consequences. In these cases, it may be better to implement measures to control the risk and reduce the uncertainty. The register enables an auditable record of responsibility for mitigation actions.

2.25 It may seem difficult to estimate probabilities and consequences in the risk register, even with a relatively coarse scoring system. However, even where there is great uncertainty, the register is still a useful tool to establish and monitor appropriate mitigation measures, although judgment will be needed to decide the appropriate level of resources to mitigate unquantified risk

Dealing with climate change

2.26 There is, currently, reasonable agreement that, due to climate change, relative sea levels will rise over time, though the rate of rise is less certain. There is much less certainty regarding other potential impacts, such as the frequency, duration or intensity of storms and the consequences for extreme wave activity or river run-off. The indications are that such storm activity may well increase, but quantification of the impacts is difficult.

2.27 The predicted increases in sea levels and peak flows discussed in Chapter 4 are based on a recent study by the Babtie Group for the Scottish Executive and have high levels of uncertainty (reference 25). In addition, there is considerable variation in the magnitude of the increases depending on factors such as geographical location, the time frame under consideration, and the nature of the flooding, that is whether it is fluvial or coastal. It is therefore difficult to recommend robust climate change scenarios for the purpose of risk assessment.

2.28 In the future, it may be possible to make recommendations for the adjustment of input rainfall to flood event or continuous simulation models to take account of climate change, but this is not currently feasible. As an interim measure, for proposed flood prevention schemes in east and southwest Scotland, it would be reasonable to include in a sensitivity analysis an assessment of the impact of progressively increasing, over the next 50 years, the flow estimates in the flood frequency curve by up to 15% due to climate change, along with other considerations of uncertainty. In north and northwest Scotland, the predicted increases in peak flows are relatively small and do not appear to justify a detailed risk analysis. However, if a proposed scheme in that area, or in other parts of the country, is likely to be affected by an increase in sea levels, it may be appropriate to conduct a similar sensitivity analysis, consistent with the predicted increases and timescales referred to in Chapter 4.

SECTION 3

MORE SPECIALISED TOOLS AND TECHNIQUES

Introduction

3.1 The risk register approach described in the previous section should be the first step in risk analysis. However, many areas of risk assessment are only partly covered by such an approach. Particular risks may require more specialised methods of analysis. A decision to use such methods will be influenced by a number of factors, including the following:-

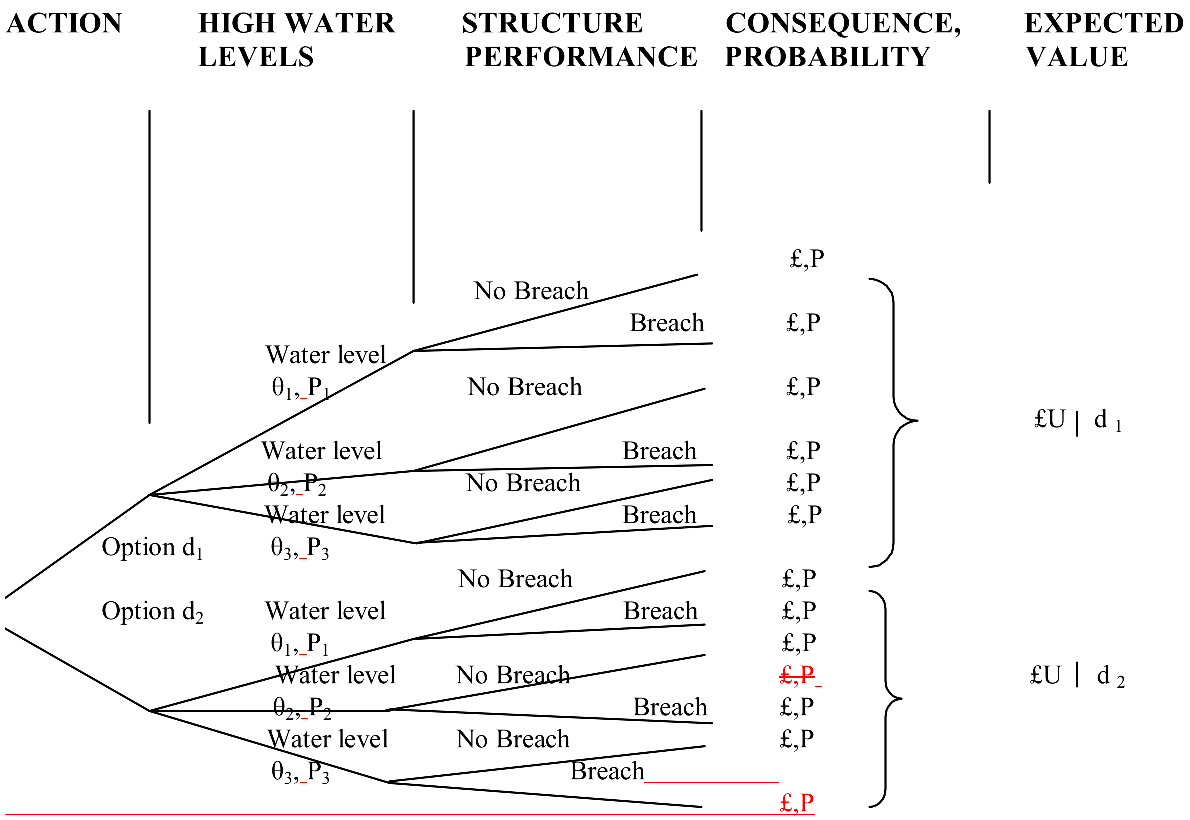
- A meaningful investment appraisal will often require detailed, quantitative, analysis of risks and uncertainties. For example, assessment of breach probability by quantitative analysis of the loads, such as water levels, waves, and the strength of the structure.
- Systems may be complex with interactions that are not easily dealt with by the risk register.
- Some risks may have common causes of failure which can only be addressed by more sophisticated methods.
- The balance between different types of impact may need to be considered in more specialised ways.
- Uncertainty may need to be reduced by more detailed investigation and analysis.
- Appraisal needs to consider changes over time, many years into the future, and more complex approaches may be required to track the changes in time, and to analyse decisions required now and in the future.

3.2 The results of the more specialised methods may be fed back to the risk register - in terms of (i) more reliable and accurate estimates of likelihood and probabilities, (ii) design or justification of mitigation measures, or (iii) review of the risks identified and more complete descriptions of their occurrence and interactions.

Event and fault trees

3.3 Event and fault trees are a primary tool for understanding the components of a problem, and combining probabilities in a logical manner. A diagrammatic example is shown in Figure 3.1. Here, a decision between options involves a range of possible consequences depending on (i) the maximum high water level encountered, and (ii) the performance of the structure during that high water event. In the example, the structure performance is represented by the probability of a breach developing. The expected value of each option can be calculated reflecting the probabilities and consequences of the outcomes.

Figure 3.1 Decision/event tree for comparing options with uncertainty



Multi-criteria approaches

3.4 It is often assumed that the consequences of adopting any option can be condensed to a single, usually monetary, value. This is the situation addressed in economic appraisal of projects, and will be the most usual context in which risk-based decision-making is adopted. For large-scale planning decisions, and during early stages of strategy development and project appraisal, it may not be possible or appropriate to express all of an option's attributes on a single, economic scale. Under these circumstances, so-called multi-criteria or multi-attribute methods can help in screening all the options. They can also help to build consensus between project participants who may have divergent objectives.

3.5 A multi-criteria matrix is illustrated in Table 3.1. The performance of each of the options d_1, $d_{2,...}$ d_l is scored against criteria A_1, A_2,... A_n. Thus the score of option d_1 against criterion A_1 is a_{11}, and so on. If a weight is applied to each of the attributes, a unified score for each of the options can be computed. This forms a basis for selecting the preferred option or, perhaps more often, to screen out those options which are not worth pursuing further.

Table 3.1 Multiple criteria matrix

	Criteria	**A_1**	**A_2**		**A_n**
d_1		a_{11}	a_{12}	…	a_{1n}
d_2		a_{21}	a_{22}	…	a_{2n}
		.	.	…	.
		.	.	…	.
Options					
		.	.	…	.
d_l		a_{l1}	a_{l2}	…	a_{ln}

3.6 Since multi-criteria methods are most usually applied at the large-scale planning stage, or during pre-feasibility studies, information relating to the future performance of options is at its most scarce, and uncertainty at its most acute. Uncertainty may be accounted for by defining criteria against which an option can be judged. For example, environmental impacts might be simply scored: 1 (no impact), 2 (medium impact) or 3 (high or unknown impact). Another approach is to incorporate uncertainty as a criterion. For example, in relation to flooding, a simple scoring system might be: 1 (low uncertainty - over 30 years of records and validated modelling); 2 (some uncertainty - less than 30 years of records and limited modelling); or 3 (high uncertainty - very limited data available).

3.7 Where the uncertainty in the scores applied to each option is great, it may be appropriate to assess the options under a range of different possible future states of nature $\theta_1, \theta_2, \ldots \theta_m$. This will extend the table into a third dimension, which can be readily achieved using spreadsheets.

Sensitivity testing

3.8 Sensitivity testing is most useful when used to demonstrate the robustness of a preferred option. It involves examining a number of scenarios without attaching probabilities. Nonetheless, it enables an initial study of the potential consequences of uncertainty in future performance. It will often be appropriate to conduct some sensitivity tests before embarking on more thorough probabilistic methods.

3.9 Sensitivity testing can be used to assess the extent to which key variables can change before a different preferred option is identified. The likelihood of that change actually occurring will then require some judgment. Sensitivity testing usually involves varying each parameter in turn, with other parameters set at their 'best estimate' values.

3.10 The findings of sensitivity tests will therefore give a rather uncertain indication of the robustness of a preferred option. Further probabilistic analysis will often be justified for those aspects shown to be critical to decision-making.

Assessing probabilities

Introduction

3.11 Probability can be defined in many ways. The probability of an outcome is the relative proportion or frequency of events leading to that outcome, out of all possible events. For some systems, such as a lottery draw, or the throwing of dice, probability can be calculated directly and precisely from the properties of the system. For other systems, such as the weather, it is not possible to define all discrete conditions or states. The probability of rain cannot be calculated directly, but must be estimated in some way, from data, or modelling, or both. The probability will be approximate, not exact.

3.12 Probabilities may change with time; for example, due to climate change. It is worth noting that probabilities themselves may be uncertain, and that a range of probability values may need to be examined for sensitivity purposes.

3.13 The 'encounter' probability is useful for communicating risk levels. It is less likely to be misunderstood than return period. It can be calculated from the equation,

$$P = 1 - (1 - 1/T)^N$$

where P is the probability, T is the return period of the design flood in number of years, and N is the particular time period of interest, also in number of years. For example, for schemes designed to withstand a flood with a return period of 100 years, there is a 0.63 probability (or 63% chance) that the design flood, or a more severe event, will be encountered within a period of 100 years.

3.14 Risk based decision-making requires a set of probabilities describing the relative likelihood of a range of future scenarios. This may entail:

- a model of the system of interest (paragraphs 3.15-3.18);
- some input probability distributions (paragraphs 3.19-3.21); and
- a method of integrating such distributions into the model (paragraphs 3.22-3.2.25).

Modelling the system

3.15 Understanding the system under appraisal, particularly its possible modes of failure, is an essential aspect of any risk assessment. Analysis by experts will be the starting point, often resulting in sketches of potential failure mechanisms. Although it may not prove necessary or possible to analyse them all, it is important to state the mechanism explicitly before excluding it from further analysis. This process is in many ways analogous to the generation of a risk register (section 2).

3.16 Having described the behaviour of the system in qualitative terms, it is necessary to develop a model suitable for quantitative analysis of probabilities. Fault tree analysis has proved its effectiveness in many disciplines. It involves identifying a specific state of a system (usually a failure state), and analysing all ways in which it can be reached. This type of analysis is particularly useful for mechanical and electrical systems such as floodgates, where components are fitted together in a clearly identifiable way, and where statistical failure rates are generally well documented. It enables critical elements to be identified and, if necessary, reinforced or duplicated, to improve the reliability of the whole system. Fault trees are therefore suitable for analysis of some aspects of flood defence systems. They are less applicable where failure mechanisms interact and are characterised by progressive cycles of decay rather than by discrete failure events.

3.17 Rather than working back from a defined failure mechanism (as in fault tree analysis), the overall behaviour of a system can be analysed by working through the events which may occur due to the loads on the system. This approach is particularly useful where there are only one or 2 key loads. In flood engineering, a statistical distribution of the key hydraulic loads will usually be available. This can be used as a direct input for a quantitative event tree analysis.

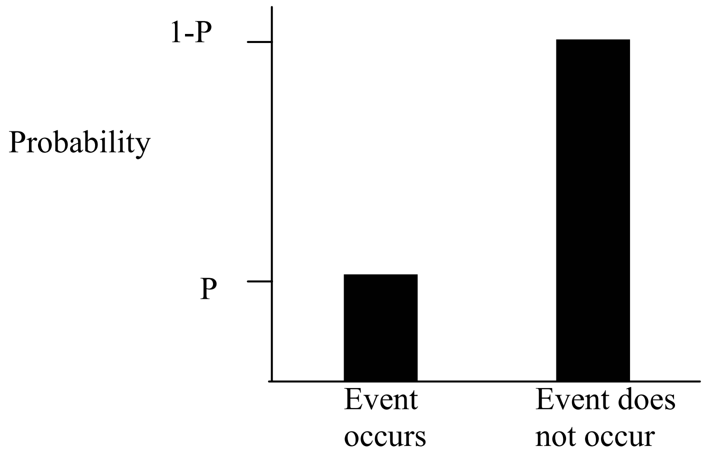
3.18 Event tree and fault tree analyses address failure at a particular point in time. However, the system will also be subject to long-term changes due to materials decay, embankment settlement, and the variation of the loads themselves. It is important to address such changes in an appraisal. This can be achieved by (i) analysing system failure at several discrete moments during the life of the scheme and interpolating; and (ii) simulating the behaviour of the whole system over the life of the scheme and directly obtaining whole-life predictions.

<u>Obtaining input probability distributions</u>

3.19 A quantitative risk analysis requires input probability distributions for the model. For example, for flood prevention schemes in tidal areas, this may require probability distributions for wave heights and tide levels. Distributions can be discrete (Figure 3.2), or continuous (Figure 3.3).

Figure 3.2 Examples of discrete probability distributions

Event probability: eg likelihood of unforeseen ground conditions during construction is low, or 5%.



Discrete probability distribution: eg probabilities of None, Low, Moderate and High flood severity at a site within the next year.

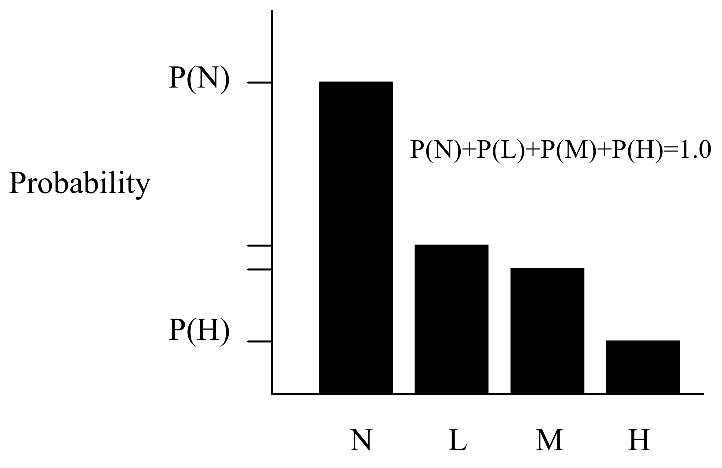
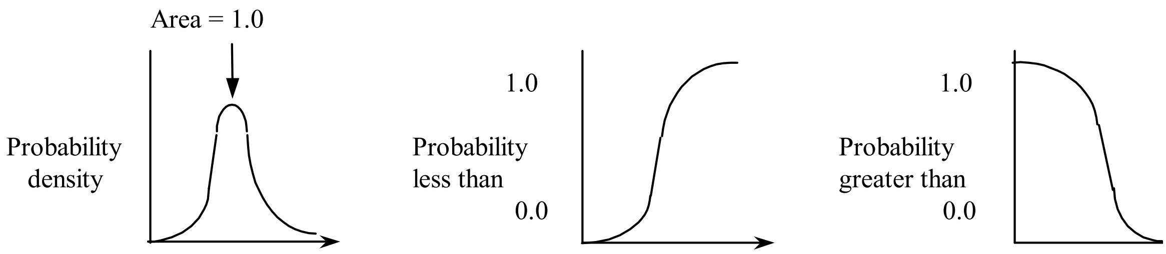


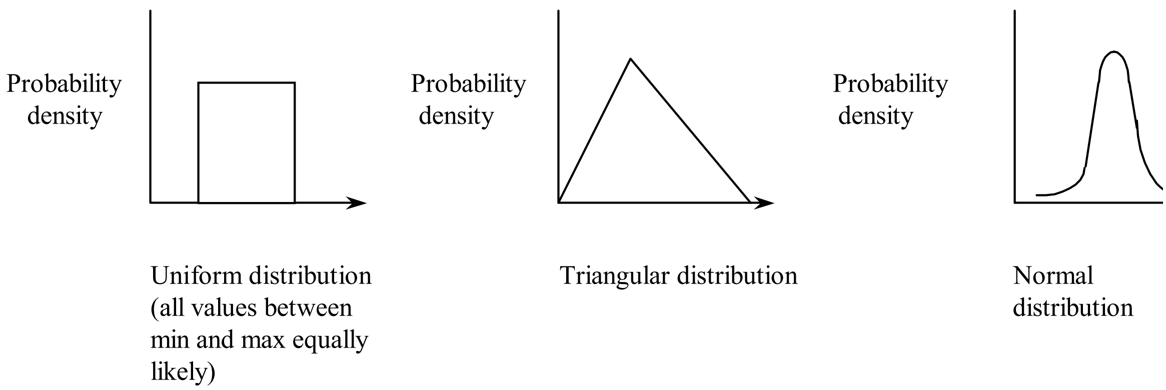
Figure 3.3 Examples of continuous probability distributions

Continuous probability distribution:
(eg estimate of residual life of a structure, estimate of soil strength)

- Three ways to show the same probability distribution:



- Three example probability distributions:



3.20 Most analyses will have more than one input distribution. The correlation between the input variables should always be explicitly considered, even if only in a summary statement that they are independent. In some circumstances, such as waves/tide levels at the coast, and waves/tide levels/fluvial flows in estuaries, the input distributions will not be independent. Estimation of joint distributions may be required (reference 22).

3.21 In the development of probabilities it is important to (i) include all possible events and always confirm that the total probability equals one; (ii) be clear whether probabilities are conditional on other events (eg probability of breaching may be conditional on a given high water level); and (iii) always consider whether probabilistic variables are dependent and use the correlation where appropriate.

Integrating probability distributions

3.22 In a deterministic analysis of a system, a unique set of input parameters is used in the model to obtain a unique value for the system response. In a probabilistic analysis, a full range of input values is tested, each one weighted by the probability of it being encountered. The analysis should consider every possible input condition likely to make a significant contribution to the response. This requires a method for integrating the contributions.

3.23 In some cases, it is possible to use *analytical* methods of integration. The scope for such methods can be extended by making assumptions about the form of the relevant distributions at the point where the system will fail (reference 23). However, *numerical* methods are of more general applicability. There are 2 categories: (i) methods based on approximating the continuous input distribution as a discrete distribution, and systematically working through every discrete input condition; and (ii) methods based on random sampling from the input distribution ('Monte Carlo integration').

3.24 Monte Carlo integration proceeds by conducting a large number of *realisations* of the model, each one with randomly sampled input parameters. In each realisation, a single point is selected at random from the input distribution. The system response to these input conditions is then calculated. Thus, each realisation is a conventional deterministic analysis. By repeating the process many times, taking values from the whole range of inputs, the output distribution is built up. The accuracy of the method depends on the number of simulations performed. As the number increases, the output distribution converges towards that which would be obtained with an analytical integration, if such an integration were possible.

3.25 It is important to state explicitly the assumed correlation between input variables. The supporting evidence for the assumptions should also be stated.

Use of probabilities from expert judgment

3.26 While it is preferable to use probabilities derived from quantitative or statistical analysis, there may be situations where this is not possible and an element of expert judgment is inevitable. Even a seemingly quantitative statistical analysis is based on judgments, in respect of the data to be admitted and its applicability to the particular problem.

3.27 There is an ample literature to show that expert judgments, and specifically subjective judgments of probabilities, can be prone to bias. In project appraisal, it is important to avoid such bias as far as possible. Good practice guidelines are:

(i) *Precisely define the events to which the expert is being asked to attach probabilities.* The analyst should ensure the expert is attaching an accurate meaning to the event for which a probability is being elicited. It should be made clear whether exceedance or encounter probabilities are being sought. The distinction between cumulative probabilities over a number of years and annual probabilities should also be made clear. Similarly, if the probability of failure is being considered, the circumstances that constitute such failure should be carefully defined. For example, depending on the circumstances, this could be the first crack in a flood wall, the onset of wave overtopping, or the initiation of flood damage to property.

(ii) *Structure the problem logically with the help of event trees.* In complex situations, it will be very difficult for experts to handle the multiplicity of factors which determine the probability of system failure. It is often preferable, therefore, to decompose the problem using event trees, and to seek expert judgment on the constituent scenarios.

(iii) *Use any available quantitative data to inform the expert judgment.* In many studies, even if a full probabilistic analysis is constrained, there is often some statistical data which should be incorporated in the analysis. For example, it is usually possible to obtain statistics for the occurrence of extreme storms which initiate defence failure. This information can be used at one node in an event tree, and the expert can then be asked for the conditional probability of failure given that a specified storm or number of storms has occurred.

(iv) *Check the expert testimony for inconsistencies.* By logically structuring the probability information being requested, and obtaining several judgments on different aspects of a problem, it is possible to check for inconsistencies in the expert testimony. Where discrepancies are found to exist, work with the expert to develop a more coherent set of probabilities.

(v) *Make use of peer review.* Judgments should be subjected to critical review by the expert's peer group. The effort and cost of these reviews increases with the rigour of the method and the number of experts involved.

(vi) *Document all the evidence upon which the expert judgment was based.* Expert judgments of probabilities are based on evidence, which will range from specific analysis, data and historic evidence for the particular site, to the tacit knowledge of the expert. The expert judgment should, as far as possible, be made transparent by documenting the sources of evidence, and the associated processes.

(vii) *Use expert judgments of bounds on probabilities or 'most likely', 'best' and 'worst' estimates rather than point estimates.* Experts in flood engineering will themselves willingly acknowledge the uncertainty inherent in probabilistic predictions. This should be expressed in terms of a probability distribution (often based on 3 estimates: 'most likely', 'best', and 'worst'. Alternatively, the bounds on the estimate may be treated separately in the analysis, to indicate the sensitivity of the final decision to the expert's uncertainty.

Probabilistic discounting

<u>Introduction</u>

3.28 Much of the uncertainty in flood engineering relates to events which are likely to occur in the future, but the exact time is far from certain. Situations of this type are well suited to probabilistic treatment.

3.29 Uncertainty in the timing of a future event, can be a significant issue in economic terms. A good example is the impact which the residual life of a flood defence can have on the economic appraisal of the 'do nothing' option. If the residual life is short, a variation of only a few years can radically change the economic case for replacement. Yet experienced engineers will readily admit potential variability in residual life estimates. Under these circumstances, it is advisable to treat predictions in probabilistic terms. This involves establishing a probability distribution of the year in which a critical event will take place, and using this in a discount table. The approach is therefore known as probabilistic discounting.

3.30 The following caveats should be borne in mind:

- Probabilistic methods may give similar results to a deterministic approach, depending on the degree of variability; the skewness of the response and the spatial distribution of consequences (benefits); and the relationship between damage cost and flood severity. Such methods may be significantly more realistic if the benefits are dominated by a small number of high value assets.

- Probabilistic methods as outlined here produce expected values. These may be weighted to reproduce aversion to high consequence events. But in the final analysis, the decision criteria are generally based on single values of (expected) costs and benefits. In some cases, it may be more appropriate to examine alternatives to expected value criteria, such as multi-criteria methods, or to make several assumptions and discount each one separately.

- Probabilistic methods are best suited to processes that conform to random behaviour. The analysis is also used for other types of uncertainty, such as physical parameter and model uncertainty, but is not well suited to types such as 'incompleteness'. While experts are often employed to estimate probabilities, it should always be borne in mind that the results are to a degree artificial, reflecting strength of belief rather than a 'real world' probability.

<u>Recurrent flooding events</u>

3.31 Flooding is the most familiar type of event whose timing cannot be predicted precisely. The well-established approach of using a loss-probability curve (Chapter 5) is essentially a risk-based technique. This provides an estimate of the expected damage for the year in which the evaluation took place.

3.32 There may be a long-term change in the expected damage. For example, where a flood prevention scheme is being designed to alleviate fluvial/tidal flooding, the probability of damage behind the defences, due to overtopping, may increase due to expected sea level rises. In that situation, damages should be evaluated at several different points in the future, and these should be input into a discount table.

3.33 Under some circumstances, there will be a high degree of uncertainty associated with the predictions of expected damage. It will, therefore, be advisable to use a range of different estimates and discount each one separately. Probabilistic treatment of this uncertainty will seldom be justified.

SECTION 4

CHOOSING AND COMMUNICATING

Option selection

4.1 It is important to be clear about the reasons for a risk assessment, and what the assessment will be used for. It is of no value to identify and quantify a risk, and do nothing about it. Section 2 indicates how risks can be utilised in applying risk management. In project appraisal, risk assessment can be used to compare different solutions, and help define preferred options.

4.2 At each stage of a project, different options exist. Project appraisal is intended to assess those options and optimise decision-making. The 3 main factors influencing choice of any option are (i) technical viability and sustainability; (ii) environmental acceptability; and (iii) economic justification. In appraising options and making a choice, these factors have traditionally been considered in a relatively deterministic manner, without reference to the scale of the associated sensitivities or risks. Incorporation of risks into the assessment process enables a more informed choice.

4.3 The best option will be influenced by different factors, including the characteristics of the scheme, the acceptable level of individual risks, and their relative importance. It is not therefore possible to be prescriptive about the selection procedure. In some circumstances, the nature of the risk may override economic arguments. Flood defences are expected by the public to resist high water levels, wave activity, and river flows, with low probabilities of failure. In practice, the consequences of failure may influence the acceptable probability, and possibly the choice of option. Generally, a scheme with a failure mode that could have major consequences will be less acceptable than one involving a minor impact.

4.4 The relative risks between different options can be compared, using an option appraisal matrix, irrespective of how each risk is quantified. For example, some risks may be identified as High/Medium/Low, Serious/Not Serious, Likely/Unlikely, while others may have quantified probabilities. Application of this approach may be appropriate at all stages of appraisal and decision-making. As long as each risk is evaluated consistently for each option, direct comparison is possible. In addition, it can be advantageous to extend the matrix to rank the risks, both by severity or interest (those risks having the gravest consequences), and by scheme type. This can provide a clearer indication of the relative merits of different options and assist in selecting a preferred option.

4.5 An example of an option appraisal matrix and ranking of options is given in Example A. Example B discusses options for a flood prevention scheme.

Example A: Option selection

Option appraisal matrix

Identified Risk (Hazard and Consequences)	**Option**				
	A	**B**	**C**	**D**	**E**
Risk 1	0.006	0.002	0.007	0.001	0.003
Risk 2	Low	High	High	Medium	High
Risk 3	Unlikely	Likely	Uncertain	Unlikely	Likely
Risk 4	0.001	0.020	0.015	0.050	0.008
Risk 5	High	High	Low	Medium	Low
Risk 6	£1.4m	£1.6m	£0.8m	£2.0m	£1.8m

Ranking of risks

<table>
<tr><th rowspan="2">Severity</th><th rowspan="2">Identified risk</th><th colspan="6">Risk</th></tr>
<tr><th colspan="6">Lowest → Highest</th></tr>
<tr><td>Paramount</td><td>Risk 4</td><td>A</td><td>E</td><td>C</td><td>B</td><td></td><td>D</td></tr>
<tr><td>Very important</td><td>Risk 6</td><td>C</td><td>—</td><td>A</td><td>B</td><td>E</td><td>D</td></tr>
<tr><td>Important</td><td>Risk 3</td><td colspan="2">A, D</td><td colspan="2">C</td><td colspan="2">B, E</td></tr>
<tr><td>Influential</td><td>Risk 2</td><td colspan="2">A</td><td colspan="2">D</td><td colspan="2">B, C, E</td></tr>
<tr><td>Minor</td><td>Risk 5</td><td colspan="2">C, E</td><td colspan="2">D</td><td colspan="2">A, B</td></tr>
<tr><td>Minor</td><td>Risk 1</td><td>D</td><td>B</td><td>E</td><td>—</td><td>A</td><td>C</td></tr>
</table>

The top section of the matrix shows how each option A to E performs in terms of risks 1 to 6, in either quantitative (where available) or qualitative terms. In the bottom section, the risks are ranked in decreasing order of priority and the options are ranked according to how they address each risk. For example, from the upper section, option D is the lowest risk solution in relation to Risk 1, whereas option C is the highest, followed closely by option A. This is reflected in the lower section, where it can also be seen that Risk 1 is classified as minor. Similarly, for Risk 4, which is described as paramount, option A scores the lowest risk, whereas option D has the highest. Overall, an initial qualitative review would appear to show that option A offers the lowest risk solution.

Example B: Option selection within a flood prevention scheme

Following severe flooding from a stream running through the centre of a small town, an improved level of protection was considered. The realistic options were (i) enlarge the existing channel, (ii) provide temporary flood storage upstream, or (iii) provide a tunnel diversion for flood flows. Initial economic assessment suggested that all 3 options could have similar benefit-cost ratios, depending on the results of further studies.

Environmental assessment did not favour more than a limited increase in channel capacity through the town. A channel that would have provided a significant increase in capacity would have resulted in a ‘concrete canyon’ dividing the town.

From a risk viewpoint, a preliminary assessment of ground conditions, in the area where flood storage would need to be provided, suggested that the construction of any raised structure might be difficult. It was considered that costs could well rise through the design and construction phases. There were also risks associated with the provision of flood storage immediately upstream of an inhabited area.

The tunnel was expected to be driven for most of its length through competent sedimentary shales. However, it was acknowledged that tunnels always carry a risk of encountering adverse ground conditions, with a consequent increase in construction costs. With limited channel improvements through the town, there would be significant residual damages, and potential loss of life, when the design capacity was exceeded. However, design and construction costs could be estimated with reasonable accuracy.

It was decided that the risks of high residual damages, plus the environmental disbenefits of the channel, and the increased cost risks of the flood storage option, outweighed the tunnelling risks. In the event the tunnel option was chosen, but adverse ground conditions were encountered and costs increased significantly.

This does not mean that the decision was wrong, though with hindsight it might have been worth carrying out further site investigation to assess the tunnelling risks more fully, and possibly to investigate other tunnel routes.

Presentation of results

4.6 Risk-based approaches can provide more information than a deterministic analysis. This should enable a fuller and better informed assessment of the risks and the robustness of the decision. However, there is a limit to the information processing capabilities of any individual or organisation. Therefore, when communicating results, the emphasis should be on conciseness and clarity. To ensure that the results are accessible to the non-specialist, a summary report may be required, supported by technical annexes.

4.7 Many risk-based methods will provide graphical results in the form of probability distributions that give an immediate and concise impression of variability. Particular care should be taken to give the axes appropriate labels and scales.

4.8 As with any scientific or engineering analysis it is important to state the assumptions and sources of information. Results should be accompanied by a commentary on:

- the approach adopted;
- particular sources of uncertainty in the models used;
- the scope and results of any sensitivity testing
- residual risks;
- the potential impacts of phenomena which are not well understood, or are not represented by the models used, particularly where this may influence the choice of preferred option;
- which input parameters have been modelled as probability distributions, and which have been given deterministic values; and
- how dependency between input parameters has been dealt with and, in particular, where independence has been assumed and why.

4.9 Where there has been a significant input of expert judgment this should be stated, and a commentary provided on:

- the evidence that the expert judgment was based upon;
- the use, if any, made of peer review; and
- sensitivity to variability in expert judgment (including the expert's own estimates of potential variability).

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Annotated key references

Flood risk

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The report identified more than 300 references relating to risk and uncertainty in flood defence and related fields. It emphasised the links between different levels of the flood and coastal defence system, discussed benefits and barriers of risk-based methods, and proposed a programme of R & D to encourage improved decision-making taking better account of risk and uncertainty.

2. US Army Corps of Engineers: *Risk Based Analysis for Flood Damage Reduction Studies*, EM 1110-201619, 1996.

The report contains procedures for estimation of expected benefits of proposed flood damage reduction plans using risk and uncertainty analysis.

3. TAW (Technical Advisory Committee on Water Defences): *Safety of Flood Defences - A New Perspective from the TAW Marsroute Research Programme.*
Brochure published by the Department for Transport, Public Works and Water Management, Directorate-General of Public Works and Water Management, Road and Hydraulic Engineering Division, Delft, Netherlands, 1997.

This research programme is intended to develop a comprehensive methodology for appraisal of flood defences based on the probability and impact of flooding rather than the probability of extreme water levels as at present. The research has included extensive investigation of the use of probabilistic reliability analysis to estimate the probability of failure of individual dyke sections, and the connection between failure of various sections that make up a complete dyke ring.

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4. Godfrey, P S: *Control of Risk - A Guide to the Systematic Management of Risk from Construction*, Construction Industry Research and Information Association (CIRIA) Special Publication 125, CIRIA, 1996.

This is a guide for the systematic management of risk from construction.

5. Simon, P S, Hillson, D and Newland, K (eds): *Project Risk Analysis and Management (PRAM) Guide*, The Association for Project Management, Norwich, 1997.

This report, published by the Association for Project Management, is 'a formalisation of the common sense which project managers normally apply to their projects'. It describes a systematic and disciplined approach to controlling risks to help improve the success of projects.

6. Institution of Civil Engineers and the Faculty and Institute of Actuaries: *Risk Analysis and Management of Projects (RAMP)*, Thomas Telford, 1998.

This report, published by the ICE, covers similar ground, but with more emphasis on the financial return of projects.

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This report is more comprehensive and covers a very wide range of tools and techniques likely to be of most interest for particularly large or complex projects.

8. Environment Agency: *Risk Assessment and Management - Guidance for Assessment and Management of Risks in Project Management for Engineering Works - Risk 2*, Environment Agency Engineering Project Management Group, 1997.

This Environment Agency guide is used on all Agency projects as part of the project management system. It is based on CIRIA125, using risk registers and analysis and management of generic, specific and residual risks. It is designed to be practical and applied at an appropriate level of detail.

9. Simm, J D and Cruikshank, I (eds): *Construction Risk in Coastal Engineering*, Thomas Telford, 1998.

This is a comprehensive review of risk analysis methods, sources of risk, and risk mitigation measures specifically aimed at coastal construction projects. It includes physical hazards such as storms, and process risks such as supply of materials.

Environmental and health risk assessment

10. Department of the Environment: *A guide to Risk Assessment and Risk Management for Environmental Protection*, HMSO, 1995.

The guidelines aim to highlight basic concepts and point to more detailed information and other resources where relevant, rather than providing detailed prescriptive guidance.

11. Parliamentary Office for Science and Technology: *Safety in Numbers? Risk Assessment in Environmental Protection*, 1996.

This report, published by the Parliamentary Office of Science and Technology in 1996, identified many of the key issues in dealing with risks. The report recognised the need for a consistent framework across risks of very different natures such as flooding, physical, chemical and radiological risks, and stressed the importance of taking account of both the natural and social scientific dimensions of risk.

12. ILGRA: *Use of Risk Assessment within Government Departments*, Report prepared by the Interdepartmental Liaison Group on Risk Assessment, Health and Safety Executive, London, 1996.

This report reviewed and compared the use of risk assessment, and found that the use of risk underpins many of the functions undertaken by government. But the use of risk assessment has not been developed systematically within government. The report concluded with suggested areas where greater coherence and consistency are desirable, including a common methodology and

terminology, links between risk assessment and benefit-cost analysis, risk ranking and risk communication.

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GLOSSARY OF TERMS

Consequence An outcome or impact such as economic, social or environmental impact. May be expressed quantitatively (eg monetary value), by category (eg High, Medium, Low), or descriptively.

Decision/Event/Fault tree Ways of describing a system and the linkages between different parts. Useful for identifying causes, tracing possible sequences of events, and investigating the effects of decisions.

Deterministic method Method in which precise, single values are used for all variables and input values, giving a single value as the output.

Hazard A situation with the *potential* to result in harm. A hazard does not necessarily lead to harm.

Monte Carlo modelling A numerical technique for assessing the probability of different outcomes from two or more variables.

Probability The probability of an outcome is the relative proportion or frequency of events leading to that outcome, out of all possible events.

Probabilistic method Method in which the variability of input values, and the sensitivity of the result, are taken into account to give results in the form of a range of probabilities for different outcomes.

Probabilistic discounting Use of probabilities and probability distributions in order to account for uncertainty when estimating present values of streams of cost, or benefit, over a period of time.

Probability distributions Used to describe the likelihood of different values across the whole range of the variables, eg flood damage, extreme loads, particular storm conditions, etc.

Qualitative methods Approaches which use descriptive rather than numerical values for assessment and decision-making.

Residual life of defences The remaining time until a defence is likely to fail or no longer achieve minimum acceptable performance criteria in terms of serviceability or structural strength. (Criteria for failure need to be carefully considered.)

Return period	The average length of time separating extreme events (eg a flood) of a similar magnitude.
Residual risk	The risk which remains after risk management and mitigation. May include, for example, risk due to very severe (above design standard) storms, or risks from unforeseen hazards.
Risk assessment	Consideration of risks inherent in a project.
Risk management	The activity of mitigating and monitoring risks, which predominately occurs after the project appraisal stage.
Risk register	An auditable record of the project risks, their consequences and significance, and proposed mitigation and management measures.
Sensitivity testing	Method in which the impact on the output of an analysis is assessed by systematically changing the input values.

ANNEX A

IDENTIFICATION OF RISKS

A.1 Risk categories and areas

Fundamental to both risk assessment and risk management is the identification of existing risks. This need not be an onerous task but it does require a careful and considered approach. It should be carried out for any project regardless of size or simplicity. It is not appropriate to adopt the risk identification from a previous project since each will have its own unique risks. This section provides some examples of the main risk areas to be considered at the project appraisal stage. The extent to which each area needs to be considered will vary from stage to stage and project to project.

For convenience in this Annex, risks are considered in the following way:

- Risks are divided between a number of categories as listed below.

- Within each category there are a number of areas for consideration. These are intended to provide a general indication of areas where risk issues may need to be addressed, though the lists should not be regarded as comprehensive, and several areas will be irrelevant to many projects.

- Specific risks within each area should be determined as part of the assessment procedure. They are not listed in this document as there are potentially a huge number of risks, many of which are project specific.

	Category
Non-project specific (A2)	1. Funding
	2. Statutory framework
	3. Socio-economic framework
Project development (A3)	1. Management of project development
	2. Strategic risks
	3. Impact of natural processes
	4. Performance of existing works
	5. Ecology, heritage and amenity
	6. Human intervention
	7. Design parameters
	8. Knowledge of principles/methods
	9. Scheme performance and response
Project implementation (A4)	1. Procurement and construction
	2. Operation and maintenance

Risks associated with each category are discussed in the sections below.

A.2 Non-project specific risks

Awareness of a range of non-specific project risks is important in the project appraisal process, though it will rarely be appropriate to consider many of these in great detail. Some will, however, be particularly relevant to large-scale planning or the development of major strategic plans.

A.2.1 Funding

The availability of funding for a project presents a risk which can be non-project specific. This can arise through changes in funding policy, particularly rules for grant aiding of schemes, and can apply at local or national level.

Areas which may be considered include:

- availability of funds;
- changes in funding rules; and
- financial year constraints.

A.2.2 Statutory framework

Risks related to the statutory framework involve possible future changes which might affect the scheme. Such changes might include new legislation, changes in planning procedures and institutional changes. For example, changes in legislation regarding environmental designations could result in previously agreed policies being rejected.

Areas which may be considered include:

- change in policy or legislation;
- change in regulation;
- changes to structure, local and other management plans;
- approvals/permissions/authorisations;
- planning;
- statutory consultees; and
- legal challenge.

A.2.3 Socio–economic framework

Socio-economic risks are those which relate to people, communities, national and regional assets affected by, or having an interest in, the scheme. For example, a change in local government could result in the withdrawal of local authority support for the scheme. The scheme may not be accepted for amenity, visual or other reasons. There may be future changes in local conditions or attitudes which make the scheme less acceptable, for example, the development of tourism, or the development of major new infrastructure.

Areas which may be considered include:

- public perception/expectation;
- public acceptability;
- socio-economic change;
- recreation, amenity, tourism;
- demography; and
- changes in economic base values (eg through market change).

A.3 Project development risks

A.3.1 Management of project development

The management of the project development process is a crucial element in effective appraisal and decision-making. Risks associated with unsatisfactory management include inadequate use of information, lack of communication, and poor quality of assessment, appraisal and decision-making.

Areas to be considered include:

- staff skills and resources;
- management of the analysis and appraisal process;
- approaches to consultation;
- relations between stakeholders; and
- knowledge and understanding of processes.

A.3.2 Strategic risks

Some risks will apply particularly at the strategic level. For example, inappropriate phasing of works within a strategy may have an adverse impact elsewhere, whilst the full effects of a planned strategy may be different from expectations. This may result in a need for mitigation and amendment to schemes elsewhere.

Areas which may need to be considered include:

- interaction between schemes;
- timing and phasing of schemes;
- other resources eg appropriately skilled labour;
- multiple failures;

- large-scale impacts on natural processes;
- interaction with urban drainage systems;
- relationship with land use planning; and
- implications of non-implementation.

A.3.3 Impact of natural processes

Knowledge of river processes is fundamental to scheme design and appraisal but is often limited, particularly in the case of extremes. Events that cause flooding are extremes with a low probability of occurrence. There is, therefore, a risk that the combination of circumstances that cause extreme events may not be predicted by conventional techniques.

For example, the great flood of 1993 on the River Tay was caused by a combination of rainfall and snowmelt. This condition would not necessarily have been predicted using conventional hydrological techniques.

There is also considerable uncertainty regarding the behaviour of sediment under extreme conditions. For example, sediment movement in a river flood may significantly change the river cross section. This will in turn affect flood levels. These examples point to the need to consider an appropriately wide range of conditions when determining likely extremes.

The natural processes that affect flood defence may change during the life of a project as a result of climate or other changes. The aim of risk assessment in relation to such changes should be to determine the robustness of current decisions to a reasonable range of external changes. For localised changes, such as those due to future development, a specific assessment of likely future scenarios may be required. For larger scale impacts, such as those due to global climate change, it will not normally be appropriate to carry out an assessment of variability for each individual project.

Long-term changes in river morphology, whether natural or human induced, may also lead to changes in the risk profile over time.

For each project it is important to determine which impacts are most crucial to the decision-making. They can then be given appropriate priority in the analysis.

Areas to be considered include uncertainty in:

- tidal flows and levels;
- storm frequency, intensity and duration;
- storm surge;
- waves (height, direction, period, transformation);
- wind setup;

- precipitation type, intensity and distribution in space and time;
- runoff, river flow and levels;
- temperature/snowmelt;
- correlation between river flow, tides, surges and waves;
- morphology of rivers;
- extent, depth and duration of flooding;
- speed of propagation of flood waves;
- flood routes and flow velocities; and
- interaction with structures.

A.3.4 Performance of existing works

Schemes often depend on the performance of existing defences and other engineering works, yet there is uncertainty over the way in which existing flood defence structures and other works will perform in the future. Further, the condition of a structure is likely to deteriorate with time, resulting in an increase in risk.

Areas to be considered include:

- condition and performance of existing structures (eg residual life);
- probability of failure and changes with time;
- inter-relationships between structures; and
- hidden weaknesses.

A.3.5 Ecology, heritage and amenity

Many risks associated with natural habitats, archaeology, recreation and amenity need to be considered. Often the actual impact on the environment of a scheme may differ from that predicted. In addition, measures that are intended to enhance the environment may not behave as intended.

There is also a risk that new information may become available at any stage of project development and implementation. For example, a new protected species may be discovered or project excavation may reveal previously unknown archaeological evidence. These can cause delay and can result in the need for radical alterations to a scheme, or even abandonment. Areas to be considered include:

- ecology;

- habitats;
- fisheries;
- landscape;
- implications of enhancements;
- Sites of Special Scientific Interest, etc;
- archaeology; and
- potential for discovery of unknown features.

A.3.6 Human intervention

In addition to natural processes, the scheme may be affected by human activity. The development of other schemes may affect conditions, for example, the construction of a storage reservoir in a river catchment will increase the response time and, therefore, the characteristics of the critical flood. Other developments and land use changes in a river catchment may also affect runoff, and hence, the downstream flow regime. Areas to be considered include:

- dredging;
- barriers and barrages;
- flood protection schemes;
- loss of floodplain storage/conveyance due to development; and
- runoff from new development.

A.3.7 Design parameters

Hydraulic conditions are one of the key parameters in design of flood prevention schemes, with design conditions usually defined as extreme values extrapolated from shorter term data sets. Depending upon the length of the data record and methods employed, there will be differing degrees of accuracy in the predicted values. Risks to be considered include the sensitivity of scheme response, and subsequent consequences to variations in these values. Other risks include over-estimation of conditions if the joint likelihood of combined events is not considered, although the potential for greater inaccuracy in predictions is currently inherent in the methods available to perform this analysis. Because knowledge of hydraulic conditions is fundamental to all that is subsequently designed and constructed, a significant risk exists if insufficient attention is given to providing appropriate accuracy.

The use and analysis of field data is also essential for understanding defence problems and developing appropriate solutions. Appreciation of site conditions in a mobile environment is particularly important.

Areas to be considered may include:

- adequacy of site investigation;
- sensitivity to uncertainty in input parameters and design assumptions;
- joint probability of different loads (eg waves and water levels);
- site conditions (eg ground conditions);
- choice of design conditions;
- accuracy of extrapolation or derivation; and
- data quality and length of record.

A.3.8 Knowledge of principles/methods

The risk of inadequate design exists, particularly with new techniques and approaches. There are areas where knowledge and the ability to produce quantified results continue to be limited without extensive work (for example, overtopping rates for different construction forms).

Areas to be considered include:

- new techniques and approaches;
- limited knowledge (data or understanding); and
- experience of designer.

A.3.9 Scheme performance and response

There are considerable uncertainties over the way in which new flood prevention schemes will respond in the future. Hazards to be considered include seepage, breaching and overtopping of a structure (including that from events which exceed the design standard). The condition of a structure is also likely to deteriorate with time, resulting in an increase in risk during its lifetime.

Scheme response must also be considered in combination with changes to natural processes. If, for example, river flood conditions worsen with time, the risk of structure overtopping or failure will also increase.

The nature of failure of any structure or scheme influences the risks that exist. Different failure modes may exist for the same scheme depending upon the circumstances that induce failure. Depending upon the nature of the scheme, and these circumstances, such failure may be either instantaneous or progressive. This has potentially different consequences.

A distinction should also be made between functional failure and structural failure, which again have potentially different consequences. For example, flooding arising from overflow of an embankment when design levels are exceeded may be very different from structural failure, which may be potentially catastrophic, leading to breaching and more severe consequences.

Areas to be considered include:

- performance of new structures and schemes;
- impact of events larger than the design event;
- flood defence structure response (eg overflow, overtopping, seepage, or breaching);
- degree or extent of failure;
- nature of failure (instantaneous or progressive);
- change in probability of failure over time;
- factors of safety and freeboard allowances; and
- interaction with other structures.

A.4 Project implementation risks

Dealing with risks at the project implementation stage is largely a matter for risk management. There are many standard texts that deal with all aspects of construction risk management, which is outside the scope of this guidance. Nevertheless, a number of issues which arise in the implementation phase should be considered during project appraisal.

A.4.1 Procurement and construction

To allow the identified risks to be assessed by the contractors at procurement stage, they must be communicated in a clear manner, facilitating appreciation and understanding.

The contract provides for the allocation of risk between the various parties. The contract form adopted should therefore be appropriate to the nature of the risks associated with the scheme. In principle, responsibility for each of the risks should be allocated to the party best able to manage them.

'Buildability' issues should be addressed during scheme development and design. They should not be left to the contractor, though the opportunity should be given to develop alternative proposals. While it is the contractor's responsibility to design and mitigate risks of temporary works and working methods these should be adequately considered in the design stage. Similarly, the possibility of adverse weather or storm occurrence during construction deserves appropriate attention.

In many cases, river defences will be constructed on recently deposited alluviums or other weak strata. It is important to ensure that their strength characteristics are taken into account when considering feasible approaches to construction of the works and access to the site.

Environmental sensitivities will be identified in scheme development and appraisal. These must be adequately communicated to the contractor and site managers if appropriate measures are to be adopted during construction. Practical methods of dealing with any restrictions identified in the environmental assessment should be considered carefully.

Areas to be considered include:

- risk communication and documentation;
- contract terms and conditions;
- funding and financial budgets;
- contractor experience and resources;
- health and safety issues;
- buildability;
- flooding or storm conditions during construction;
- ground conditions;
- access;
- accommodating environmental requirements; and
- potential environmental impacts of construction.

A.4.2 Operation and maintenance

Assumptions about the philosophy and approach to long-term project operations and maintenance will often have to be made at the appraisal stage. These will have to be communicated effectively to those responsible for the operation and management of the scheme, to ensure it is managed appropriately in accordance with the design.

The different risks associated with different structure types will influence the monitoring regime that is adopted, and the intervention thresholds that need to be set for maintenance or repair. For example, for some defences the failure mode may be sudden and complete, whereas others may deteriorate in a more gradual and progressive manner.

The available maintenance resources will affect the operation and management practices that are likely to be implemented. Limited access, resources and material availability may mean that a slow speed of response must be assumed with consequent risks. Alternatively, it could be decided that fast response systems are essential for some specific risk areas, which will have cost implications for the management regime required. For defences with mechanical components, or other high maintenance elements that are potentially subject to failure, duplication or back-up systems may need to be considered.

Flood warning may be a valid response strategy for some residual risks. However, there are many risks associated with any flood warning system such as the communication of the warnings, public response and the ability of people to respond. These need to be considered in the development of emergency response plans. In making assumptions about operation and management procedures it is important that the risks associated with any flood warning system are taken into account.

Areas to be considered include:

- risk communication;
- characteristics of structure response;
- risk appreciation and understanding;
- frequency and nature of monitoring;
- intervention thresholds;
- failure mechanisms and consequences;
- maintenance regime; and
- flood warning systems and their effectiveness.

CHAPTER SEVEN

Environmental Appraisal/Impacts

CHAPTER EIGHT

Social Appraisal

CHAPTER NINE

Project Prioritisation Methodology

CHAPTER TEN

Post-Project Evaluation

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