Department for Environment Food & Rural Affairs

Llywodraeth Cymru Welsh Government

Cyfoeth Naturiol Cymru Natural Resources Wales

Environment Agency

delivering benefits through evidence

Cost estimation for fluvial defences – summary of evidence

Report –SC080039/R2

Flood and Coastal Erosion Risk Management Research and Development Programme

We are the Environment Agency. We protect and improve the environment and make it a better place for people and wildlife.

We operate at the place where environmental change has its greatest impact on people's lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.

This report is the result of research commissioned by the Environment Agency's Evidence Directorate and funded by the joint Flood and Coastal Erosion Risk Management Research and Development Programme.

Published by:
Environment Agency, Horizon House, Deanery Road, Bristol, BS1 5AH

www.environment-agency.gov.uk

Email: fcerm.evidence@environment-agency.gov.uk.

Further copies of this report are available from our publications catalogue:
www.gov.uk/government/publications

or our National Customer Contact Centre:
T: 03708 506506

Email: enquiries@environment-agency.gov.uk

Author(s):
Kevin Keating, JBA Consulting
Angus Pettit, JBA Consulting
Andrew Wood, JBA Consulting

Dissemination Status:
Publicly available

Keywords:
Whole life costing, cost estimation, fluvial defences

Research Contractor:
JBA Consulting
South Barn, Broughton Hall, Skipton
North Yorkshire BD23 3AE
01756 799919

Environment Agency's Project Manager:
Adam Baylis, Evidence Directorate

Collaborator(s):
John Chatterton

Project Number:
SC080039/R2

Evidence at the Environment Agency

Evidence underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us, helps us to develop tools and techniques to monitor and manage our environment as efficiently and effectively as possible. It also helps us to understand how the environment is changing and to identify what the future pressures may be.

The work of the Environment Agency's Evidence Directorate is a key ingredient in the partnership between research, guidance and operations that enables the Environment Agency to protect and restore our environment.

This report was produced by the Scientific and Evidence Services team within Evidence. The team focuses on four main areas of activity:

- **Setting the agenda**, by providing the evidence for decisions;
- **Maintaining scientific credibility**, by ensuring that our programmes and projects are fit for purpose and executed according to international standards;
- **Carrying out research**, either by contracting it out to research organisations and consultancies or by doing it ourselves;
- **Delivering information, advice, tools and techniques**, by making appropriate products available.

Miranda Kavanagh

Director of Evidence

Executive summary

This detailed summary of evidence for fluvial flood defences provides indicative costs and guidance on two of the main structural elements used for flood risk management: flood walls and flood embankments.

Data for capital and maintenance works for fluvial flood defences are well understood without significant data gaps for high level or early stage cost estimation. The Environment Agency Unit Cost Database and Environment Agency Maintenance Standards provide a good basis for assessment.

Linear fluvial flood defences		
Key cost components	Key cost components will be the capital costs for walls and embankments. Maintenance costs may be an important consideration for embankments. Walls have a long design life and typically relatively low maintenance costs.	
Key asset types	• Walls • Embankments	
Data reviewed in specific guidance	Key reports and data sources include: • Environment Agency Unit Cost Database (capital costs) • Environment Agency Maintenance Standards (maintenance costs)	
Other relevant data	Local or proxy records such as data from Environment Agency SAMPs and local authority information	
Key cost components	Enabling costs	Variable cost. Early set-up costs can be high
	Capital costs	Variable costs depending on type of defence asset, length and size.
	Maintenance costs	Costs for walls are likely to be low unless poor condition and remedial works required. Embankments costs may be higher due to annual inspection, maintenance and repair costs. The receptors in the hinterland, age and original design of an embankment will be important considerations when determining a maintenance regime.
	Other cost considerations	Other costs may include environmental improvements and decommissioning costs.
Cost estimation methodology	Initial concept/ national appraisal	Approximate unit rates for the completed asset available. Operation and maintenance (O&M) rates also available.
	Strategic, regional, or conceptual design	Approximate unit rates for the completed asset available. O&M rates also available.

	Preliminary feasibility/design	No specific cost information provided. Guidance on data availability and procedures provided.
Quality of data	Data quality is good with approximate unit rates for the completed assets available for a range of wall and embankment types. Available data for unit costs are provided though cost curve information is not available. Cost curve information is available in the Environment Agency Unit Cost Database Estimating Guide and referred to in the guidance.	
Additional guidance	Checklist of factors likely to influence capital and maintenance costs, and key factors to consider for detailed costs estimation List of R&D and general design guidance Case studies of recent schemes	

Acknowledgements

The authors wish to thank the Project Board (Ian Meadowcroft, Linsay Hensman and Adam Baylis) and the Environment Agency, local authority and Internal Drainage Board representatives and operational staff who were consulted.

Contents

1	**Flood mitigation measure – fluvial raised defences**	**1**
1.1	Data requirements for fluvial defence whole life costs	1
1.2	High level cost estimates	1
1.3	Detailed cost estimation	8
1.4	Capital costs	8
1.5	Operation and maintenance costs	9
1.6	Environment Agency operation and maintenance costs	10
1.7	Other cost estimate requirements	12
1.8	Cost estimation methodology	14
1.9	Case studies	15
1.10	Checklist	15
1.11	R&D and general design guidance	16
1.12	References	17

Table 1.1	Environment Agency Unit Cost Database wall raising and wall construction mean costs per m length	2
Table 1.2	Environment Agency Unit Cost Database wall mean costs per metre length	3
Table 1.3	Factors influencing capital costs for walls	3
Table 1.4	Environment Agency Unit Cost Database mean unit costs for embankments	4
Table 1.5	Environment Agency Unit Cost Database mean, upper and lower bound unit costs for embankments	5
Table 1.6	Factors influencing capital costs for embankments	5
Table 1.7	Environment Agency Unit Cost Database mean unit costs for sheet piling	7
Table 1.8	Environment Agency Unit Cost Database mean and upper and lower bound unit costs for sheet piling	7
Table 1.9	Factors influencing capital costs for sheet piling	7
Table 1.10	Embankment unit costs (£/km/year)	11
Table 1.11	Concrete wall unit costs (£/km/year)	11
Table 1.12	Steel wall unit costs (£/km/year)	11
Table 1.13	Brick wall unit costs (£/km/year)	11
Table 1.14	Weighing of factors influencing embankment maintenance costs	12
Table 1.15	Weighing of factors influencing wall maintenance costs	12
Table 1.16	Gabion wall	13
Table 1.17	Brick/masonry/concrete wall	13
Table 1.18	Sheet piles	13
Table 1.19	Narrow turf embankment	13
Table 1.20	Wide turf embankment	14

Figure 1.1	Flow diagram for fluvial defence whole life costs	14

1 Flood mitigation measure – fluvial raised defences

This evidence summary provides indicative whole life costs and guidance on two of the main structural elements used for flood risk management:

- floodwalls
- flood embankments

1.1 Data requirements for fluvial defence whole life costs

A number of cost elements are required for fluvial raised defences barriers. These include:

- design and inception costs
- capital costs
- operational costs (inspection)
- maintenance costs (annual frequent and intermittent repair costs)
- refurbishment or decommissioning costs

In addition an indication of design life and deterioration rates is useful to determine requirements for asset replacement.

1.2 High level cost estimates

1.2.1 Capital costs

Capital costs suitable for high level analysis, early stage assessments or national level appraisals may be available from a number of sources such as local authorities, the Environment Agency and Internal Drainage Boards (IDBs).

Estimated capital costs for walls and embankments are available within the Environment Agency's Flood Risk Management Estimating Guide (Environment Agency 2010a) – also known as the Unit Cost Database. The costs available are based on out-turn costs from a large number of projects to install new walls and embankments for the purposes of flood risk management in England and Wales. The costs include all associated works, temporary works and any contractor variations, compensation events/delay costs.

In the Unit Cost Database costs are broken down into the most important asset types including walls, embankments and sheet piling as summarised in the sections below.

Walls

The costs of flood defence wall will depend on a number of factors such as the wall type, wall length and wall height. Walls may include a number of sub types such as:

- retaining walls with foundation, but no piling – may be reinforced concrete or brick construction
- retaining walls with sheet-piled cut-off wall beneath or adjacent to wall
- retaining wall and piling
- raising of existing walls

Table 1.1 provides unit costs from the Unit Cost Database for both wall raising and generic costs for new walls.

Table 1.1 Environment Agency Unit Cost Database wall raising and wall construction mean costs per m length

Height band	Wall raising (£/m)	All wall types (£/m)
<1.2m	1,029	1,419
1.2–2.1m	2,177	2,905
2.1–5.3m	–	3,577
>5.3m	–	11,168
All heights	1,526	2,984

Note. The average plan length of wall in the Unit Cost Database is 180 m.

The length of wall is a critical variable in terms of costs, with cost per metre (m) for shorter lengths significantly higher. Cost saving and efficiency gains are available for longer wall lengths. Costs per metre for three different height bands are provided in the Unit Cost Database to allow practitioners to determine indicative costs for different wall lengths (up to approximately 400 m).

Costs for walls in the Unit Cost Database are split between each of the three main retaining wall types and provided on a per metre length and per m^2 basis. The costs are summarised in Table 1.2 based on a per metre length basis. It is recommended that practitioners review the Unit Cost Database and any updates to the database from the Environment Agency.

Table 1.2 Environment Agency Unit Cost Database wall mean costs per metre length

Height band (m)	Data	Retaining wall (£/m)	Retaining + cut off (£/m)	Retaining + piled foundations (£/m)
<1.2	20th percentile cost	576	N/A	1,597
	Average cost	1,917	1,122	1,910
	80th percentile cost	2,599	N/A	2,166
1.2–2.1	20th percentile cost	1,055	1,982	1,898
	Average cost	2,097	2,696	4,300
	80th percentile cost	2,633	3,384	5,169
2.1–5.3	20th percentile cost	2,010	2,633	3,385
	Average cost	2,800	3,712	7,960
	80th percentile cost	3,684	4,976	13,831
>5.3	20th percentile cost	N/A	N/A	3,567
	Average cost	N/A	N/A	11,168
	80th percentile cost	N/A	N/A	13,105

Note. The average plan length of wall in the Unit Cost Database is 180 m.

These costs should be considered to be indicative and useful for early stages of design. In addition to the wall types, height and length, capital costs will also depend on other factors as presented in Table 1.3. These factors should be considered in any cost estimate where the above indicative costs are used. Identification of any significant risk factors at an early stage in the scheme appraisal should help practitioners to identify cases when the upper or lower cost percentiles may be more appropriate.

Table 1.3 Factors influencing capital costs for walls

Factor influencing capital costs	Impact on cost estimation
Access constraints	Urban/rural locations, distance to site, confined working conditions, ease of movement along site, need for temporary access
Type, condition and stability of any existing foundations	Important for wall raising Careful investigation will be required if walls are to be upgraded or refurbished.
Economies of scale	Shorter or isolated walls or embankments will increase costs.
Construction weather	Winter working will influence productivity and on-site works duration.

Factor influencing capital costs	Impact on cost estimation
Ground conditions or contaminated land	Presence of poor ground conditions or contaminated land will increase costs.
Materials	The quality and availability of materials will influence costs.
	The use of cladding to improve visual acceptability on walls will influence costs, particularly if decorative finishes are required.
Disposal of waste	Important consideration in the case of replacement. Disposal costs will depend on landfill costs and distance to landfill.
Presence of historic wall elements	Driving of new sheet piles can be very difficult and increase costs.
Access through the defence	The requirement to retain access to the river for continuation of business and leisure activities on the river frontage.
Wall loadings	Traffic loading on the landward side and mooring/boat impact on river side.

Embankments

Flood embankments are earthfill structures designed to contain high river levels. They are commonly grass-covered, but may require additional protection against channel erosion or overtopping. Embankment costs will be heavily influenced by the size, cross-sectional shape and length, fill material, and as the requirements for cut-offs and bank protection measures.

Table 1.4 provides unit costs from the Unit Cost Database for embankments. Costs have been presented by average costs per m^3 and per metre length, based on the assumptions of an average embankment volume of 18 m^3 per m (as defined in the Unit Cost Database).

Table 1.4 Environment Agency Unit Cost Database mean unit costs for embankments

Volume band	Mean cost per m^3 fill volume (£)	Mean cost per m length (£)	Number of projects
<500 m^3	188	£3,384	9
500–5,000 m^3	94	£1,692	28
5,000–15,000 m^3	64	£1,152	11
>15,000 m^3	33	£594	18

Notes: The dataset has an average volume of 18 m^3 per metre unit length of embankment. Therefore the costs per unit metre would be £64 × 18 = £1,152.

The Unit Cost Database also breaks down the costs for upper and lower uncertainty bands based on the number of example projects included within the database. These are provided in Table 1.5.

Table 1.5 Environment Agency Unit Cost Database mean and upper and lower bound unit costs for embankments

Volume band	20th percentile cost per m^3 fill volume	Mean cost per m^3 fill volume	80th percentile cost per m^3 fill volume
<500 m^3	118	188	238
500–5,000 m^3	39	94	122
5,000–15,000 m^3	55	64	71
>15,000 m^3	19	33	50

Notes: The dataset has an average volume of 18 m^3 per metre unit length of embankment. Therefore the costs per unit metre would be £64 × 18 = £1,152.

Table 1.5 provides indicative costs for high level assessments and for use in early scheme appraisal studies. For new embankments where the embankment sizing is known but detailed costs are not required, it is recommended that the embankment costs are based on the calculated embankment value, together with the average unit cost in the relevant volume band provided by the Unit Cost Database. An example is provided below.

Example of embankment cost per linear metre with estimated embankment sizing

Assuming an embankment with 1 in 3 side slopes, a crest width of 3 m and a height of 2 m and no cut-off, the cross-sectional area is 12 m^2. Assuming an embankment length of 100 m, the total volume of fill per metre is therefore 1,200 m^3. Based on the average cost per m^3 from the Unit Cost Database of £94/m^3, the total cost would be approximately £113,000.

In addition to the embankment sizing, fill volume and length, capital costs will depend on other factors as presented in Table 1.6. These factors should be considered and estimated costs based on the indicative costs given in Table 1.5 should make allowance for any known impact. Identification of any significant risk factors at an early stage in the scheme appraisal should help practitioners to identify cases when the upper or lower cost percentile costs given in Table 1.5 may be more appropriate.

Table 1.6 Factors influencing capital costs for embankments

Factor influencing capital costs	Impact on cost estimation
Embankment shape	Steep narrow embankments will have smaller footprint and lower earthfill requirement than wider embankments with gentle slopes.
Access constraints	Urban/rural locations, distance to site, confined working conditions, ease of movement along site, need for temporary access

Factor influencing capital costs	Impact on cost estimation
Type, condition and stability of any existing foundations	Important for embankment raising Careful investigation will be required if embankments are to be upgraded or refurbished.
Economies of scale	Shorter, embankments will increase unit costs.
Materials	Higher clay content fill material may be required for steeper embankments or where clay cut-offs are required. The use of alternative materials in embankment design may increase costs.
Ground conditions	Ground conditions will influence the cost of the works and design and engineering requirements.
Construction weather	Winter working will influence productivity and duration of on-site works.
Requirements for protection against erosion	Requirements for bed protection to protect against scour and erosion will increase costs. Requirements to protect or provide for extreme overtopping scenarios and additional hard crest/bank protection will increase costs.
Access through or over the defence	The requirement to retain access to the river for continuation of business and leisure activities on the river frontage. The provision of gates or ramps over the embankment will increase costs. Stock-proof fencing, gates or stiles may also be required to maintain or prevent access.
Wall loadings	Traffic loading on the landward side and mooring/boat impact on river side
Landscaping	Degree of additional landscaping and landforming may impact on costs where these are required for aesthetic reasons.

Sheet piling

Sheet piles are typically used to provide retaining structures such as on river frontage, wharfs or quays. They may also be used to form cut-offs within embankment structures. The Unit Cost Database reviewed the costs associated with 56 projects where sheet piles were used. The analysis does not provide sufficiently reliable information to provide cost curves for the unit cost per metre length. However, the Unit Cost Database suggests that there is correlation between the cost of piling and access (urban and rural locations). The costs are also presented for urban reaches of less than and greater than 100 m in length.

Table 1.7 summarises unit costs from the Unit Cost Database for sheet piles. It is recommended that practitioners review the Unit Cost Database and any updates to the database by the Environment Agency.

Table 1.7 Environment Agency Unit Cost Database mean unit costs for sheet piling

Reach type	Average (£/m^2)	Average (£/m length)	Number of projects
Urban reach <100 m	1,287	9,148	8
Urban reach >100 m	484	2,476	19
Rural reach	212	1,843	29

Notes: The average piling depth in the above projects was 7 m and the average length of piling was 240 m.

The Unit Cost Database also breaks down the costs for upper and lower uncertainty bands based on the number of example projects included within the database. These are provided in Table 1.8.

Table 1.8 Environment Agency Unit Cost Database mean and upper and lower bound unit costs for sheet piling

Volume band	20th percentile cost per m (£)	Average cost per m (£)	80th percentile cost per m (£)
Urban reach <100 m	4,168	9,148	15,565
Urban reach >100 m	1,309	2,476	3,563
Rural reach	370	1,843	2,811

These costs should be considered as indicative. In addition to the sheet piling length, depth and access restrictions, the costs will also depend on other factors as presented in Table 1.9.

Table 1.9 Factors influencing capital costs for sheet piling

Factor influencing capital costs	Impact on cost estimation
Access constraints	Urban/rural locations, distance to site, confined working conditions, ease of movement along site, need for temporary access.
	There is a high cost associated with piling rig mobilisation.
Type, condition and stability of any existing foundations	Careful investigation will be required if sheet piles are to be upgraded or refurbished.
	Driving of new sheet piles in the presence of historic wall elements can be very difficult and increase costs.
Economies of scale	Shorter or isolated walls or embankments will increase costs.
Type of piling and ground conditions	More expensive silent or low impact piling rigs are more likely to be required in urban areas.
	Dense gravels or obstructions may require a heavier duty pile.

Factor influencing capital costs	Impact on cost estimation
Construction weather	Winter working will influence productivity and duration of on-site works.
Wall restraints	The need for tie rods or ground anchors to restrain the wall against overturning will increase design and engineering costs.
Materials	The quality and availability of materials will especially influence costs.
	The use of cladding to provide visual acceptability on walls will influence costs, particularly if decorative finishes are required.
Access through the defence	The requirement to retain access to the river for continuation of business and leisure activities on the river frontage.
Wall loadings	Traffic loading on the landward side and mooring/boat impact on river side.

1.3 Detailed cost estimation

1.3.1 Enabling costs

As with any scheme there will be initial procurement and capital costs that cover the initial stages of the project. These will include the costs associated with:

- professional fees – initial appraisal and design costs
- consultation including planning, management and agreements
- licences and consents (planning permission, land drainage consent and others)

These costs should only be considered at very early stages in a project as they will be considered to be sunk costs once they have been incurred and the appraisal process has moved on to detailed design stages.

Typical enabling costs vary from 8% to 32% of the total scheme cost for flood defence projects, but vary depending on the size of the project and the operating authority carrying out the works. No specific costs are available for fluvial defence works. Indicative values for these enabling works are provided in the generic guidance for use where more detailed estimates are not available.

1.4 Capital costs

Detailed costs estimation will require costs to be broken down into categories that may include:

- materials – including supply, delivery, unloading, storage
- contractor costs – labour, plant, site establishment, temporary works

- supervision and professional fees
- waste disposal
- land purchase/compensation

Costs based on the high level analysis can be used to obtain indicative costs in the first instance of a long-term cost estimate. Additional local or proxy records may also be available from the Environment Agency (for example, information from System Asset Management Plans (SAMPs)) or local authorities.

More detailed analysis will require costs to be determined from price estimating books such as SPONS (Davis Langdon 2010) and CESMM (ICE 2012), previous experience or tender returns at the design stage of an analysis.

For contractors working under the Environment Agency's Water and Environmental Management (WEM) Framework, costs for specific principal work items that cover typical Environment Agency schemes have been provided and agreed for use in project appraisal report (PAR) construction cost estimates and for the benchmarking of prices.

1.5 Operation and maintenance costs

Ongoing operation of fluvial flood defences and maintenance of embankments incurs costs. Failure to address maintenance requirements as part of the design can lead to:

- the risk of asset failure
- higher long-term costs associated with expensive asset management remediation/repairs

The whole life cost process needs to identify and define all necessary inspection, monitoring and maintenance requirements.

1.5.1 Walls and embankments

Operation and maintenance (O&M) costs for walls and embankments will depend on:

- the frequency of regular inspections
- annual maintenance activities
- long-term intermittent maintenance activities

Types of wall and embankment maintenance activities will include:

- defence repairs (concrete repairs, sealant replacement, replacement of damaged bricks and steel pile painting)
- localised embankment raising due to settlement
- vegetation cutting/clearance
- invasive weed control
- vermin control
- tree work

- graffiti removal

1.5.2 Sheet walls and retaining walls

In general the frequency and number of maintenance activities will be significantly smaller for sheet piled and retaining wall defences than embankments due to the design, materials used and slower deterioration of assets. Obviously this may not be the case for existing assets that have not been maintained and are seriously deteriorated to the point that either mayor refurbishment or repairs are required.

In addition, these defence asset classes will require a range of inspections including:

- visual asset conditional surveys
- public safety inspections
- operational inspections
- pre/post storm inspections for high risk assets

1.6 Environment Agency operation and maintenance costs

Combined annual O&M costs are available in Environment Agency's Maintenance Standards (Environment Agency 2010b): for:

- embankments
- concrete walls
- steel walls
- brick walls

Costs are provided for three target condition grades based on the Environment Agency Condition Assessment Manual (Environment Agency 2006). These costs have been derived from experience, contract rates and estimating rates for a range of activities. They represent indicative costs and provide a broad range of annual costs per watercourse length depending on the type of maintenance works required for each asset class and method of vegetation clearance.

The range of costs associated with each linear defence asset type are summarised in Table 1.10, Table 1.11, Table 1.12 and Table 1.13 for embankments, concrete walls, steel walls and brick walls respectively. Costs for three condition grades are provided based on the grades used in the Environment Agency Condition Assessment Manual.

For all four asset types, vegetation clearance can be performed manually using small handheld tools and mechanical methods where small machines such as excavators are used. Maintenance activities include vegetation clearance (grass cutting and tree work) and vermin control.

Table 1.10 Embankment unit costs (£/km/year)

Target grade	Manual clearance	Mechanical clearance
2	2,770–17,225	80–5,430
3	1,385–17,225	20–5,430
4	250–2,615	10–725

Table 1.11 Concrete wall unit costs (£/km/year)

Target grade	Manual clearance	Mechanical clearance
2	270–855	210–710
3	125–565	85–420
4	0–200	0–140

Table 1.12 Steel wall unit costs (£/km/year)

Target grade	Manual clearance	Mechanical clearance
2	160–530	105–390
3	105–400	65–260
4	0–165	0–105

Table 1.13 Brick wall unit costs (£/km/year)

Target grade	Manual clearance	Mechanical clearance
2	355–1,020	300–875
3	135–695	100–550
4	0–215	0–155

As the range of costs for watercourse maintenance is very wide, the Environment Agency recommends use of a weighting and scoring methodology to determine an appropriate point within the range based on the key factors that influence operation and maintenance costs. The suggested weighting system is shown in Table 1.14 and Table 1.15 for embankments and walls respectively. A score between 0 and 2 is given to each factor. Scores are multiplied by the weight to give a score between 0 and 8. A value of 0 corresponds to the lower end of the cost range and a value of 8 corresponds to the higher end of the unit cost range.

Table 1.14 Weighing of factors influencing embankment maintenance costs

Factor that influences maintenance costs	Weight
Difficult access (distance to work-site, protected sites/species, overhead power cables)	2
Invasive weeds	1
Protected species which may require a more sensitive environmental option	1

Table 1.15 Weighing of factors influencing wall maintenance costs

Factor that influences maintenance costs for walls (all types)	Weight
Difficult access (distance to work-site, protected sites/species, overhead power cables)	2
Wall is prone to vandalism	2
Wall is located in an aggressive environment (for example, coastal, high velocity reach)	1
Wall is higher than 1 m	1

1.7 Other cost estimate requirements

In addition to the above cost estimates, the following parameters are required to ensure whole life costs are correctly defined so as to incorporate these into an appraisal. The design life and discount rates are used to convert future costs over a scheme life to 'present values' so that they can be compared against the benefits.

1.7.1 Appraisal period/design life

The design life is typically defined as the minimum length of time a scheme is required to perform its intended function. The design life for appraisals is typically taken to be 100 years, although alternative periods can be used. The design life is also an important consideration in whole life costing as component assets of a design may have a shorter service life and not be last as long as the design life. This has implications for cost estimates to ensure that a whole life cost estimate correctly identifies all long-term maintenance and asset replacement costs over the intended appraisal period.

If no maintenance or intervention is performed, linear defences will deteriorate over time. This deterioration has been determined from the Environment Agency's Asset Deterioration project (Environment Agency 2009). This provides the asset deterioration under both maintained and non-maintained scenarios for a range of embankments and vertical walls – gabion wall (Table 1.16), brick/masonry/concrete wall (Table 1.17), sheet piles (Table 1.18), narrow turf embankment (Table 1.19) and wide turf embankment (Table 1.20). The information on asset deterioration summarised in these tables provides an indication of the likely deterioration rates from a new (Grade 1) culvert to gradually poorer asset conditions. Only turf embankments are included here. Users should refer to the generic guidance document for other fluvial embankments (rigid, rip-rap and flexible).

Table 1.16 Gabion wall

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Best estimate	0	5	10	22	28
Fast estimate	0	4	8	15	20
Slow estimate	0	5	10	25	30

Notes: There is no difference between deterioration rates for with and without maintenance scenarios.

Table 1.17 Brick/masonry/concrete wall

		Grade				
		1	2	3	4	5
Without maintenance	Best estimate	0	20	50	70	90
	Fast estimate	0	10	30	45	55
	Slow estimate	0	20	60	85	100
With maintenance	Best estimate	0	20	50	100	120
	Fast estimate	0	10	30	60	75
	Slow estimate	0	20	60	120	150

Table 1.18 Sheet piles

	Grade				
	1	2	3	4	5
Best estimate	0	20	80	120	140
Fast estimate	0	10	30	60	75
Slow estimate	0	20	100	140	160

Notes: There is no difference between deterioration rates for with and without maintenance scenarios.

Table 1.19 Narrow turf embankment

		Grade				
		1	2	3	4	5
Without maintenance	Best estimate	0	3	6	25	30
	Fast estimate	0	1	3	5	7
	Slow estimate	0	5	10	40	80
With maintenance	Best estimate	0	15	30	130	150
	Fast estimate	0	2	5	7	10
	Slow estimate	0	20	40	140	160

Table 1.20 Wide turf embankment

		Grade				
		1	**2**	**3**	**4**	**5**
Without maintenance	Best estimate	0	3	6	25	40
	Fast estimate	0	2	6	10	14
	Slow estimate	0	5	10	40	60
With maintenance	Best estimate	0	15	30	130	150
	Fast estimate	0	4	10	14	20
	Slow estimate	0	20	40	140	160

It can be seen that a new and maintained turf embankment would need replacement at year 100, although site specifics or the type of culvert constructed could vary this from Year 35 to Year 120. Further guidance and examples are provided in the Asset Deterioration guidance (Environment Agency 2009).

1.8 Cost estimation methodology

The flow diagram in Figure 1.1 summarises the key aspects required to generate a whole life cost for a fluvial defence to include all relevant capital costs and O&M costs.

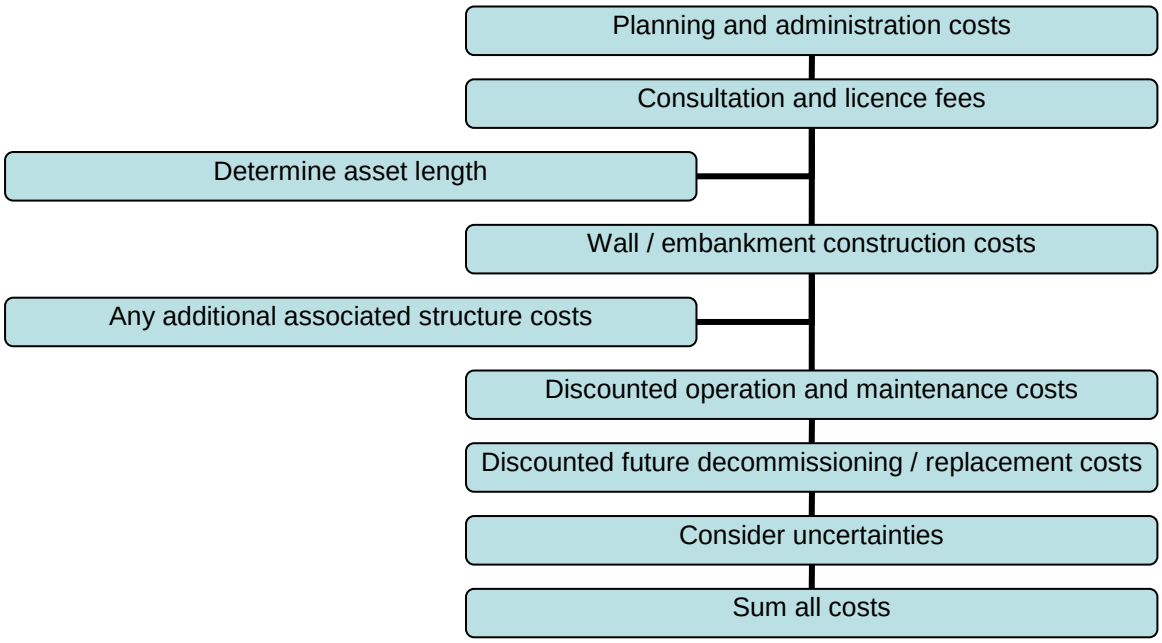

Figure 1.1 Flow diagram for fluvial defence whole life costs

1.9 Case studies

The following case studies may help those producing cost estimates for fluvial defences.

- General embankment and wall case studies and examples. Environment Agency's Fluvial Design Guide Available from: http://evidence.environment-agency.gov.uk/FCERM/en/FluvialDesignGuide/ [Accessed 27 January 2014].
- Sustainable re-use of tyres in port, coastal and river engineering. HR Wallingford project for Environment Agency and DTI.
  - R&D Technical Summary W5-002/E/TS available from: http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/SCHO0304BJHM-E-E_pdf.sflb.ashx [Accessed 27 January 2014];
  - full technical report available from: http://www.aircrafttyres.com/images/Hergebruik%20banden.pdf [Accessed 27 January 2014].

1.10 Checklist

Use the checklist to:

- identify the key cost elements required for watercourses
- ensure all relevant whole life costs are incorporated into the cost estimate

Whole life cost estimate checklist for fluvial defences

Item	Description	Cost frequency	Comment
Planning costs			
Professional fees	Initial appraisal and design costs	One-off	May be sunk costs depending on the stage of assessment
Consultation	Including planning, management and agreements	One-off	
Licences and consents	Planning permission, consents and so on	One-off	
Capital			
Construction costs	Linear defence asset costs and applicable bank reinforcement costs	One-off	
Change cost	Asset raising due to external pressures such as climate	One-off or recurring	Only required if anticipated but not designed

Item	Description	Cost frequency	Comment
	change or land use change		for.
Decommissioning/replacement costs	Future discounted replacement or decommissioning costs if design life is less than appraisal period	One-off	May not be required unless environmental
Inspections			
Visual asset inspection	Condition assessment inspections	Recurring	
Operational inspection	General inspection and minor maintenance aspects	Recurring	
Public Safety inspection	Safety inspections in urban areas or high risk locations.	Recurring	
Post storm inspections	Pre or post storm inspections if asset or receptor risk is considered high Gate closures prior to flood events.	Recurring	May not be required.
Maintenance			
Annual maintenance	General vegetation management to embankments	Recurring	May not be required for walls.
Intermittent maintenance activities	Embankment and wall repairs	Recurring	

1.11 R&D and general design guidance

- ArcelorMittal, 2008. *Piling Handbook,* 8th edition. Available from: http://sheetpiling.arcelormittal.com/page/index/name/arcelor-piling-handbook [Accessed 27 January 2014].
- Davis Langdon, 2011. *Spon's Civil Engineering and Highway Works Price Book*, 25th edition. Spon Press
- Defra and Environment Agency, 2004. *Operations and Maintenance Concerted Action Report.* Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. R&D Technical Report W5A-059/3/TR.
- Defra and Environment Agency, 2004. *Engineering Materials in Flood and Coastal Defence – Review of Current Knowledge*. Joint Defra/Environment

Agency Flood and Coastal Erosion Risk Management R&D Programme. Technical Report W5A-069/TR/1.

- Defra and Environment Agency, 2007. *Management of Flood Embankments: A Good Practice Review.* Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. R&D Technical Report FD2411/TR1.
- Environment Agency, 2007. *Landscape and Environmental Design Guidance*.
- Environment Agency, 2009. *Guidance on Determining Asset Deterioration and the Use of Condition Grade Deterioration Curves*. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Science Report SC060078/SR1
- Environment Agency, 2009. *Assessment and Measurement of Asset Deterioration including Whole Life Costing*. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Science Report: SC060078/SR2.
- Environment Agency, 2010. *Fluvial Design Guide*, Chapter 9, Section 9.7. Available from: http://evidence.environment-agency.gov.uk/FCERM/en/FluvialDesignGuide/Chapter9.aspx?pagenum=7 [Accessed 27 January 2014].
- Institution of Civil Engineers, 2012. Civil Engineering Standard Method of Measurement (CESMM), 4th edition. ICE Publishing
- Kirby, A.M and Ash, J.R., 2000. *Fluvial Freeboard Guidance Note*, R&D Technical Report W187. Environment Agency.
- Morris, M., Bramley, M. and Smith, P., 2004. *Good practice in design and management of flood embankments*. Proceedings of the 39th Defra Flood & Coastal Management Conference, 2004.

1.12 References

DAVIS LANGDON, 2011. *Spon's Civil Engineering and Highway Works Price Book*, 25th edition. London: Spon Press.

ENVIRONMENT AGENCY, 2006. *Managing Flood Risk. Condition Assessment Manual.* Document Reference 166_03_SD01. Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2009. *Guidance on Determining Asset Deterioration and the Use of Condition Grade Deterioration Curves*. Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management R&D Programme. Science Report SC060078/SR1. Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2010a. *Flood Risk Estimating Guide – Update 2010*. Bristol: Environment Agency.

ENVIRONMENT AGENCY, 2010b. *FCRM Asset Management, Maintenance Standards, Version 2, March 2010.* Bristol: Environment Agency.

ICE, 2012. *Civil Engineering Standard Method of Measurement (CESMM)*, 4th edition]. London: ICE Publishing.

Would you like to find out more about us or about your environment?

Then call us on

03708 506 506 (Monday to Friday, 8am to 6pm)

email

enquiries@environment-agency.gov.uk

or visit our website

www.gov.uk/environment-agency

incident hotline **0800 807060** (24 hours)

floodline **0345 988 1188 / 0845 988 1188** (24 hours)

Find out about call charges (www.gov.uk/call-charges)

Environment first: Are you viewing this on screen? Please consider the environment and only print if absolutely necessary. If you are reading a paper copy, please don't forget to reuse and recycle if possible.