The designs

There are four different categories for designing estuary edges:

Bioengineered designs – These designs rely entirely on plants for long-term protection from erosion. Bioengineering techniques can be appropriate in any situation as they mimic natural systems. However, the natural estuary state may have been changed by man to such an extent that bioengineering may be inappropriate.

The ecological value of such designs is generally the closest to that of a natural tidal bank.

Biotechnically engineered designs – plants contribute significantly to the design but harder engineering elements are also provided for stability in the long-term. The permanent man-made elements provide root anchorage for plants, which then raises the protection to an even higher level.

The ecological value of such designs can approach that of a natural bank.

Structurally engineered designs – the engineering provides the structure and any ecological elements are simply added on. These designs include structurally engineered elements that form terraces to hold silts and soils.

The ecological value of such designs varies widely, but can be high.

Hard engineering – these designs are used when there is too much water energy for anything to attach, other than seaweed and very exposure-tolerant invertebrates.

The ecological value of such designs is generally negligible.

Selecting a design

It is difficult to provide a simple set of rules for selecting a design as there are so many variables at any given site. Therefore it is important to create local trial sites to test the suitability of a design.

The table on the next page summarises the environmental variables described in this guidance and how they could influence the selection of a technique.

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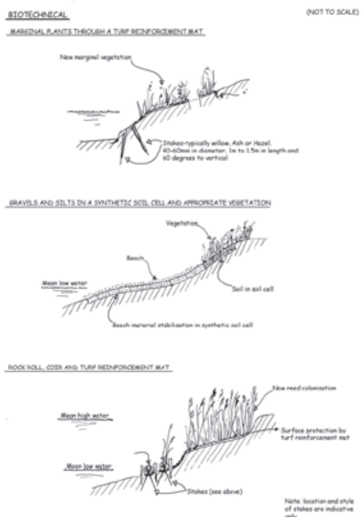
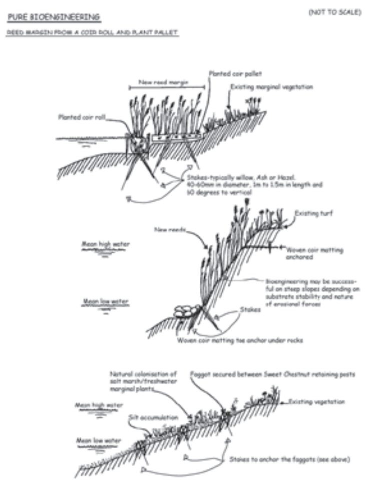
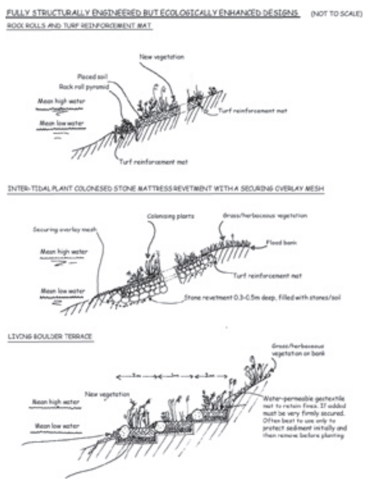
	Bioengineering	Biotechnical engineering	Fully structural engineering	Hard engineering
Techniques	• Reed margin from a Coir Roll or Coir Plant Pallet • Woven Coir Matting and Plug-Planting • Fascines or Brushwood Mattresses to trap silt • Natural colonisation promoted wherever possible	• Marginal plants growing through a Turf Reinforcement Mat • Gravels/ sands in a Synthetic Soil Cell plus appropriate plant regime • Rock rolls and Turf Reinforcement Mat	• Rock rolls or boulder packing and geotextile backing supports plant terrace • Stone Revetment promoting natural colonisation (may also be planted) • Hard engineered terraces to create beds for natural colonisation or planting • All revetments step BACK from existing intertidal not into it.)	• Sheet Piling • Concrete or Brick Walling • 'Block Stone' • Rip-Rap (1-tonne stones) • Concrete Block Systems
Illustrations				Not illustrated.

	Bioengineering	Biotechnical engineering	Fully structural engineering	Hard engineering
Land-based loadings and land values Loadings of substrate and features that put pressure on the tidal edge from the landward side. This is the factor considered first in combination with ground conditions to see if the tidal edge, at the proposed geometry, is 'intrinsically stable' (when protected from erosion).	Generally 'low' to 'medium' loadings (pedestrian to vehicle). In built-up areas these techniques may still be appropriate where other structures provide secondary line of flood defence.	Generally 'medium' to 'low' loadings (pedestrian to vehicle). In built-up areas these techniques may still be appropriate in a wide range of circumstances, where other structures provide secondary line of flood defence.	Generally 'high' loadings (buildings/heavy vehicles). The flood risk assessment often shows the land value to be high with little or no protection against flooding by secondary structures.	Generally 'high' loadings (buildings/ heavy vehicles). The flood risk assessment often shows the land value to be high with little or no protection against flooding by secondary structures.
Ground conditions (soil/geology) Ground conditions are considered at the outset along with land-based loadings and bank geometry to check for 'intrinsic stability'.	Ground conditions are critical to this technique. Roots of plants can undoubtedly contribute to bank stability and support loadings, but cannot be relied on due to the wide variability of the root penetration profile, root strength at different ages, etc. Accordingly, bioengineering is generally only selected when the erosion-protected estuary edge is 'inherently stable'. Plants can, however, be included to contribute to the resistance of the design. Soil must also be suitable to support the expected plant growth.	Ground conditions are critical to this technique. Biotechnical solutions are designed to prevent erosion rather than address problems of inherent stability in relation to ground-based loadings. Thus the erosion-protected edge must be 'inherently stable' at the geometry proposed. Soil must also be suitable to support the expected plant growth. The substrate will often be inherently weaker than where bioengineered solutions are proposed and plant rhizome/ root systems will often be slower to develop.	The substrate must be capable of being retained with stability. This technique should be used in preference to bioengineering or biotechnical systems only where the estuary edge is inherently unstable.	The substrate must be capable of being retained with stability. This technique should be used in preference to bioengineering or biotechnical systems only where the estuary edge is inherently unstable.

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Bank geometry including maximum slope Bank geometry is considered at the outset along with land-based loadings and ground conditions to check for ‘intrinsic stability’. Steeper slopes are possible with more robust ground conditions and lower land-based loadings.	The slope depends completely on the inherent stability of the bank. This is typically ‹1:7 at freshwater salinities and ‹1:2 at brackish salinities; but such techniques have been used on inherently stable banks at slopes of up to 1:1 (see case studies on the River Severn).	Depends completely on the inherent stability of the bank. Bioengineered erosion protection has been used on inherently stable banks at slopes of up to 1:1, to increase the opportunities for vegetation in the river edge.	Generally slope ›1:7 and in most cases the only option at slopes ›1:1. These techniques can create the framework for plants to survive on the exterior surface.	Any slope.
Duration and return interval Estimated duration of the peak dynamic force is considered to help define the ‘peak dynamic event’. The acceptable duration and return interval are based on a risk assessment that involves considering monitoring and maintenance options and commitments, and the plants’ ability to recover from damage.	Whilst these factors are undoubtedly crucial to the survival of bioengineered erosion protection, there are no reliable data testing the effects of these variables on unprotected vegetation. Accordingly, local decision is based on context and precedent. This type of vegetation is used to being tidally inundated.	Published test data are used to assist in the choice of design to withstand the predicted peak dynamic events. This will vary enormously between sites and can not be defined here.	The range of species that will survive on the engineered edge will vary inversely with increasing duration of event and return frequency of peak dynamic forces.	Not relevant.

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Frequency of inundation Frequency of inundation is considered in relation to the ability of different plant species to survive on the river edge at a given tidal level.	Tidal levels below Mean High Water Neap tide level are typically unlikely to support vegetation. At low salinities however (below c. 10% seawater), planting can survive more often below this tidal level.	As for bioengineering.	As for bioengineering.	Not relevant.
Water chemistry The consideration of water chemistry involves an assessment of the ability of different species to tolerate mainly different salinities but also sediment loads and in some cases pollution.	Most examples of bioengineered tidal solutions are in brackish water. Bioengineering solutions are quite feasible at full marine salinities (see www.intertidalmanagement.co.uk). As the fully marine environment is typically high-energy, bioengineered solutions in such situations involve saltmarsh restoration techniques and shallow slopes (see *The Saltmarsh Creation Handbook* – full details are given in the 'More information and advice' section of this guidance).	Definitely viable at brackish salinities and probably at seawater salinities.	Definitely viable at brackish salinities and probably at seawater salinities.	Not relevant.

	Bioengineering	Biotechnical engineering	Fully structural engineering	Hard engineering
Strength and durability of individual components The selection of man-made materials is based on the ability of the materials to withstand the regime. The abilities of different plant species to consolidate surface sediments are also considered.	Strength and durability of components are not typically measured for plant components but are in relation to biodegradable components that help the plants to become established and then survive on site.	A very wide range of options is available. There are published performance characteristics on the man-made components. Data are also available on the additional erosion resistance that the vegetation gives and the speed of loss of the latter with increasing duration of a peak event.	A very wide range of options is available to suit any conditions.	A very wide range of options is available to suit any conditions.
Required design life The design life is set by the joint consideration of the strength and stability of the individual components and the monitoring and maintenance regime.	If appropriately chosen and properly applied, the design life is indefinite unless there are significant biophysical condition changes.	As for bioengineering.	Such designs are typically installed for a design life of at least 50 years, but this may vary depending on planning constraints and lifetime risk assessment.	Such designs are typically installed for a design life of at least 50 years, but this may vary depending on planning constraints and lifetime risk assessment.
Monitoring and maintenance	Monitoring is an important part of any scheme, especially shortly after construction. This will help identify benefits and areas for improvement. Ecological monitoring may need to be undertaken for several growing seasons . These designs can be self-sustaining, or require much more regular maintenance.	As for bioengineering.	A long interval between maintenance inspections is acceptable (though these are critical). Some areas must be left un-vegetated to allow full inspection of the structural integrity of walls.	Generally a much longer interval between maintenance inspections is acceptable (though these are critical).