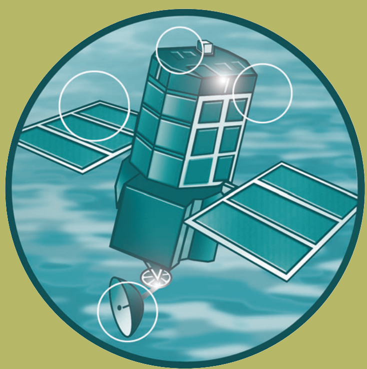
Joint Defra/EA Flood and Coastal Erosion
Risk Management R&D Programme

WFD Expert Assessment of Flood Management Impacts

R&D Technical Report FD2609/TR



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Management R&D Programme

WFD Expert Assessment of Flood Management Impacts

R&D Technical Report FD2609/TR

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Statement of use
This report can be used by surface water managers and practitioners to assist in defining a scope of works associated to WFD assessment or in undertaking the assessment itself. Look-up tables are provided as prompts to assist in defining FCRM engineering activities, hydromorphological response and the dependency of Biological Quality Elements on physical parameters. Accepted methods for assessing hydromorphology and ecology which may be used to support Expert Assessment are set out, indicating the required level of expertise.

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Executive summary

The Water Framework Directive (WFD) (2000/60/EC) is a substantial piece of EC water legislation which was made law in England and Wales in 2003 (Water Environment (Water Framework Directive) (England and Wales) Regulations 2003). The main purpose of the WFD is to establish a framework for the protection and sustainable use of the water environment. The Directive sets Environmental Objectives for all surface waters (rivers, transitional, lakes and coastal waters at the water body scale, the effective unit of management and monitoring defined under the WFD. The Objectives, set out in Article 4 of the Directive, include the prevention of deterioration of Ecological Status within the water body.

The objective of this project is to design a Framework for the assessment of the impacts of flood and coastal risk management (FCRM) activities on ecological status applicable to all surface water body types excluding lakes, where flood risk management activities were deemed to be limited. The types of FCRM activities considered are those relating to physical modification of water bodies as documented in Environment Agency operational guidance.

The project concluded that there is currently insufficient data on the hydromorphological conditions within each water body to develop a quantitative scoring mechanism to evaluate whether hydromorphological change results in deterioration between ecological status classes. The majority of surface water bodies have been modified in terms of river continuity and morphological structure and/or the hydrological, tidal and sediment regime, thus it is not possible to assume morphological response for a given surface water type. In addition, due to the gap in the science base in understanding the relationship between hydromorphological change and consequent impact on biology, it is not possible to define generic pressure impact relationships.

An Expert Assessment Framework has therefore been developed to provide a consistent process for selecting the proportionate level of assessment to determine the likely changes resulting from FCRM activities and potential ecological impacts. The Framework consists of three tiers: Preliminary, Level 1 and Level 2 assessment each with clear guidance on when each level of assessment should be undertaken. The assessments are based on professional judgement supported by accepted methods of geomorphological and ecological investigation and analysis. The expected outputs from each level of assessment and decision making process for when further assessment should be undertaken are contained within this guidance.

The outputs from the assessment will be used to document whether there is a potential for a deterioration in ecological status and the nature and magnitude of the hydromorphological changes causing adverse impact. This can be used as a record if there is later found to be deterioration in status in a water body where FCRM activities have been ongoing. The assessment could also be used as a basis for identifying better environmental options and practicable mitigation measures as part of project appraisal.

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1 Introduction

This report presents the outcomes from Defra project FD2609, Water Framework Directive (WFD) Expert Assessment of Flood Management Impacts. This project aims to develop a Framework for the expert assessment of the impacts of new or ongoing Flood and Coastal Erosion Risk Management (FCRM) infrastructure or activities.

The Framework uses existing tools to support expert assessment of hydromorphological change to identify potential impacts on water body Ecological Status or, for Heavily Modified water bodies[1], Ecological Potential. The purpose of the Expert Assessment Framework is to ensure that assessment of new FCRM infrastructure and activities is transparently documented and to promote the identification of solutions and mitigation measures as part of project appraisal which will minimise ecological impacts.

1.1 Context for using the Expert Assessment Framework

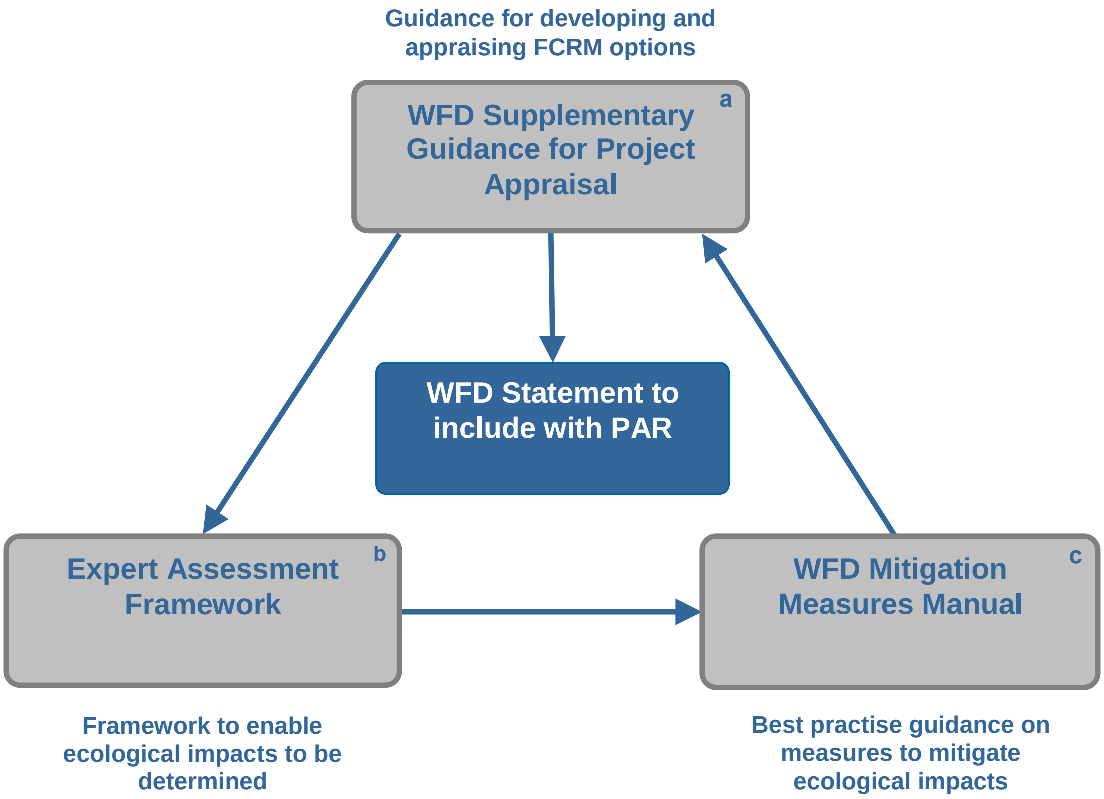
The background on the need to assess impacts of new and historic FCRM activities on ecological quality (set down in Article 4 of the WFD) is explained in the WFD Supplementary Guidance on Project Appraisal (Environment Agency, 2008). Figure 1.1 indicates where the Expert Assessment Framework can support project appraisal and link to other guidance on mitigation measures being developed to support FCRM in meeting WFD requirements.

The Expert Assessment Framework has been developed to provide guidance on the level of assessment required as part of project appraisal to ensure that the preferred FCRM options (FCRM infrastructure or activity) are compliant with requirements of the WFD. The Framework sets down different levels of assessment. Preliminary and Level 1 assessment would be undertaken during the project definition stage of project appraisal and Level 2 would be undertaken if it is required to support option development and comparison.

The Expert Assessment Framework should identify possible ecological impacts resulting from hydromorphological changes. These changes should then be mitigated where practicable through the design process. Further guidance on the selection and use of mitigation measures is being developed by the Environment Agency separate to this project (Water Framework Directive Mitigation Measures Manual for Flood and Coastal Risk Management and Land Drainage – under development).

[1] These water bodies, designated by the Environment Agency as a result of their use as either Heavily Modified or Artificial, will be set the alternative environmental objective of Ecological Potential rather than Good Ecological Status.

Figure 1.1 - Links with other WFD FCRM projects



a Water Framework Directive Supplementary Guidance on Project Appraisal, Environment Agency (2007)

b Water Framework Directive Expert Assessment Framework FD2609, Defra (2009)

c Water Framework Directive Mitigation Measures for Flood Risk Management and Land Drainage Activities, Environment Agency, Scottish Environmental Protection Agency and Environment Heritage Service (2009)

1.2 Definition of Ecological Status in the Water Framework Directive

"Ecological status is an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters, classified in accordance with Annex V". (The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003).

Annex V of the Directive sets out Biological Quality Elements (BQEs) which are used to classify ecological status using five classes from high to bad. In addition, ecological status is also classified on the basis of hydromorphological, chemical and physico-chemical elements that support the biological elements. Any change in ecological status could be the result of changes in one or more of the supporting elements which could impact on the biology. More details on the Biological Quality Elements are contained in Section 3 of this report.

The Expert Assessment Framework is set up to assess the impacts of FCRM activities which comprise modifications to surface waters resulting in alteration of hydromorphological quality elements. Hydromorphological elements cannot be measured in terms of their intrinsic quality in the same way as chemical elements, which can be measured against set standards. The functioning of surface waters and the relationships with biology within the waterbody are complex and will vary considerably dependent upon the prevailing legacy of both natural and anthropogenic changes. The methods available for consideration of hydromorphological change in relation to biology, therefore, need defining and that is the purpose of this Framework.

1.3 Current approaches to assessing ecological impact resulting from hydromorphological change

It should be recognised at this point that identifying the likely ecological impact of FCRM infrastructure or activity, based on the hydromorphological response to new infrastructure or activities, can be difficult. The primary reason for this is that there has, until very recently, been a lack of targeted scientific research to accurately define the relationship between ecology and hydromorphology. However, the WFD specifies that hydromorphology quality is a supporting element of 'Good Ecological Status' and it is widely accepted that hydromorphological integrity provides the foundation required to support ecological functioning. Moreover, there is a large body of literature which focuses either on the hydromorphological changes to a water body or the ecological impacts resulting from particular flood risk management activities. In many cases, the relationship between change in the physical environment and the response of the ecological environment has also been documented through empirically based studies of both hydromorphology and ecology. It is widely understood, as a result of these studies that the change of hydromorphology can lead to negative impacts for biology. Thus the premise for hydromorphology as a supporting element of Ecological Status or Potential is a reasonable one.

However, relatively few investigations have studied the interrelationships between the hydromorphology and ecology in a systematic manner. This gap in the knowledge base has been recognised by the scientific community (for example, Vaughan *et al*. 2009) and resulted in a call for further research to address the relationship between hydromorphological change and ecology. The current lack of scientific evidence of the complex relationships between hydromorphological response and ecological impact requires decision making using existing tools and expert judgement. This Framework will provide guidance on the use of expert judgement to compare the likely hydromorphological response/change (caused by an activity) to the physical conditions that are known to support the biological elements within the water body. This will provide a consistent approach to the assessment of ecological impacts (and possible deterioration in quality) in advance of on-going research. To be acceptable for application (operationally) the approach needs to use known and accepted methods and, where possible, empirical data. It is envisaged that, as other research methods become proven, they would be added to this Framework in the future.

1.4 Who should use the Expert Assessment Framework?

The Expert Assessment Framework is intended to be used by regulators, managers and practitioners either undertaking new FCRM strategies and schemes or commissioning assessment as part of project appraisal. The Framework is intended to be used to assess the impacts of mainstream FCRM activities (e.g. the construction and maintenance of a flood or erosion protection structure).

2 The Expert Assessment Framework overview

The Expert Assessment Framework (set out in Figure 2.1) has been developed as a tiered approach that involves working through a preliminary step to provide an initial assessment of the problem and then continuing through a process that builds up the assessment (through possibly two levels), to arrive at the final assessment for WFD purposes.

A Preliminary Assessment should first be undertaken to describe the planned project or historic modification, document and report the identified hydromorphological response and compare this to identified Biological Quality Elements (and their requirements).

If, as a result of this assessment, it can be concluded that particular biology are not present (and never will be, regardless of mitigation) or sufficient documentary evidence exists to eliminate the impact on the biology from hydromorphological change, then no additional insight will be gained from further assessment. In these circumstances a Level 1 assessment is not required. It is envisaged that in most (but not all) circumstances the process will need to proceed to a Level 1 assessment.

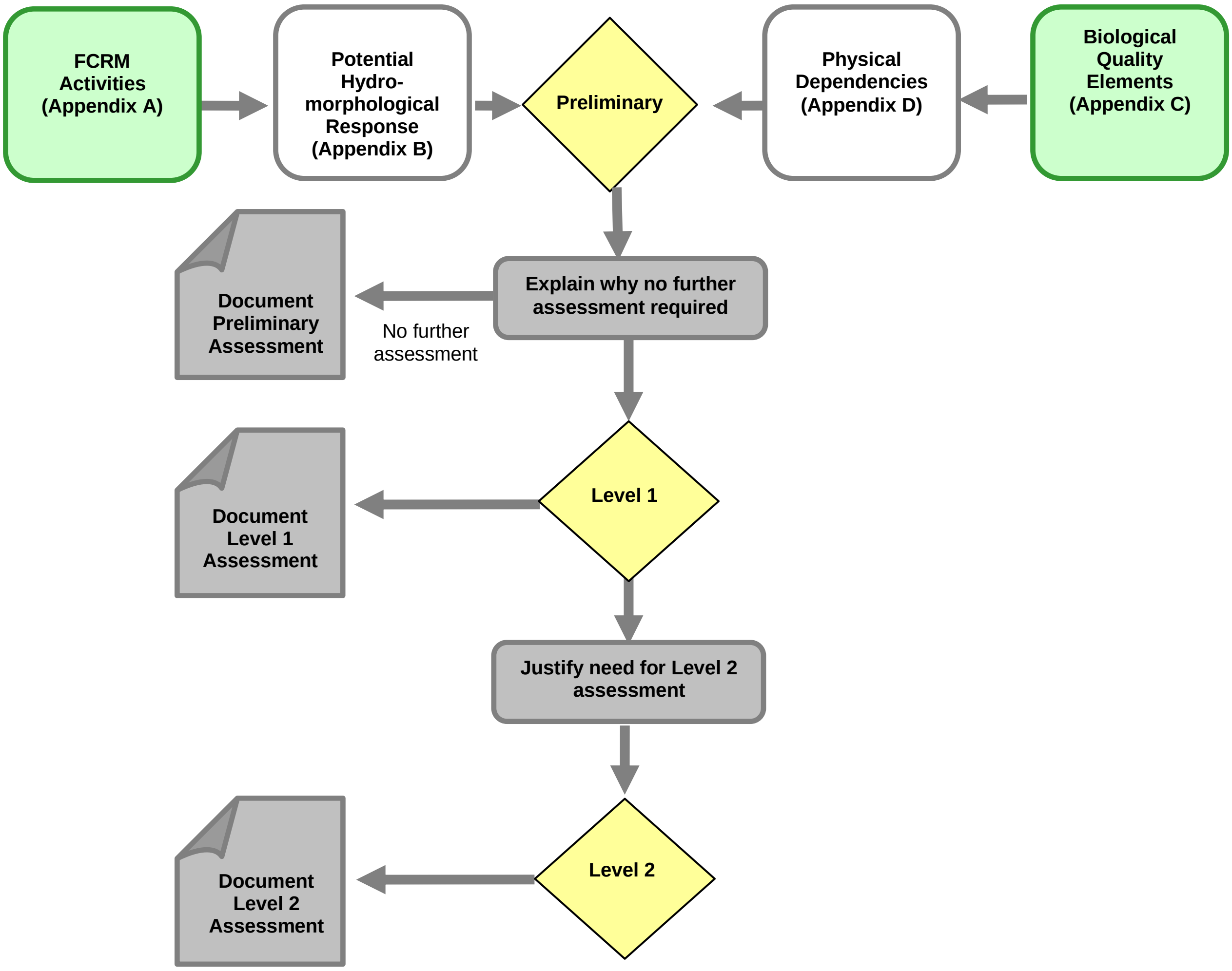
In Level 1, the Framework suggests appropriate tools to assess the likely changes to hydromorphology occurring as a result of an activity and the possible significance of changes for biology. It should be noted that more than one tool may need to be applied under Level 1. Desk-based and/or field techniques will be used to make an initial assessment of the function of the system, define and contextualise the problem(s) associated with the proposed FCRM infrastructure or activity, and identify the types of hydromorphological change that are likely to occur. The biological classification will also need to be established in relation to the reference condition and the impact of likely possible changes assessed. This approach will also consider and, where necessary, justify if there is any requirement for further detailed assessment of hydromorphological change and impact on biology at Level 2. In many cases a Level 1 assessment will provide as robust an answer (given the scientific limitations identified in Section 1.2 of this report) as at Level 2. Unless the requirement for a Level 2 assessment is clearly justified under Level 1, then Level 2 methods will provide no further insight and, hence, will not be required in terms of the WFD (although might be applied for other reasons, such as design).

If the hydromorphological changes associated with the activity are, however, likely to result in impacts on biology, and can be further defined through additional assessment, then the methods from Level 2 will be required. In Level 2, more detailed assessment tools are used to examine the nature of the changes and impacts on biology. A variety of techniques are incorporated into Level 2 of the assessment, including a wide range of specialist techniques. As with Level 1, it may be necessary to apply more than one technique under Level 2. This could include additional desk-based assessment methods, (further) field-based assessment methods, and modelling techniques (conceptual, physical and numerical).

Through applying this Framework the most appropriate method for the assessment of hydromorphological changes will be identified and used. The approach will ensure that the methods necessary to meet the requirements of the WFD assessment are used and that this assessment is reported.

The Expert Assessment methodology is outlined in Figure 2.1 and explained in more detail in the following sections.

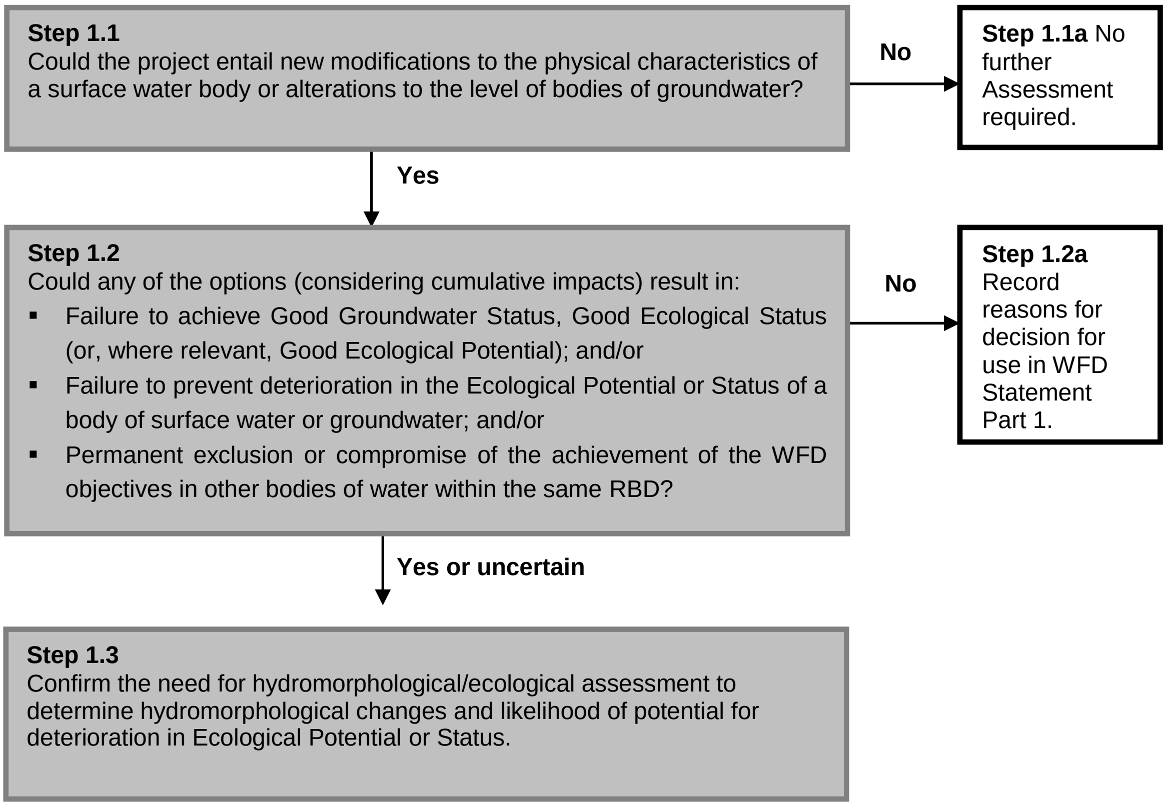
Figure 2.1 - Expert Assessment Framework Methodology



3 Preliminary Assessment

The Preliminary Assessment is the first step in the Framework and will be undertaken at the project definition stage of project appraisal. Figure 3.1 has been included within Supplementary Guidance for Project Appraisal to help determine whether an assessment is needed. The Preliminary Assessment will be used at Step 1.2 in the flow chart to help identify whether further assessment is needed.

Figure 3.1 - Flow Chart 1 from WFD Supplementary Guidance for Project Appraisal



3.1 FCRM infrastructure and activities and potential hydromorphological change

The type of FCRM infrastructure or activity in question is referenced in look-up table 1 (Appendix A). This provides basic information relating to the function of the structure, its likely footprint (i.e. the area it is likely to impact), and the materials from which it is likely to be constructed from; that is, the nature of the planned FCRM infrastructure or activity.

The possible hydromorphological response associated with the asset or activity is referenced in look-up table 2 (Appendix B). This also provides information relating to the likely response of the system to climate change. The Table is not intended to suggest that these changes are definitely going to occur. Instead, it is intended to present a preliminary, high-level assessment of changes that could happen in response to the introduction of FCRM infrastructure or activity into a water body system, and the likely consequences of the activity in light of predicted future climate change. Once relevant changes have been identified at this stage, expert advice will be required.

3.2 Identifying the Biological Quality Elements

The Biological Quality Elements (BQEs) that need to be assessed will be determined with reference to look-up table 3 (Appendix A). This Table has been adapted from the definitions of Good Ecological Status found in Annex V of the WFD, and provides an indication of the characteristics of each Quality Element in an undisturbed water body. A summary of the BQE definitions for Rivers, Transitional and Coastal waters is provided in Table 3.1.

Table 3.1 - Biological Quality Elements broad definitions

Biological quality elements (BQE)	Rivers	TRaC	Definition
Phytoplankton	✓[1]	✓	Unicellular algae and cyanobacteria, both solitary and colonial, that live, at least part of their lifecycle, in the water column of surface water bodies.
Macrophytes	✓		All aquatic higher plants, mosses and characean algae, but excluding single celled phytoplankton and diatoms.
Phytobenthos	✓		Vascular plants, heterotrophic organisms and photosynthetic algae (including cyanobacteria) living on or attached to substrate or other organisms in surface waters.
Macroalgae		✓	Multicellular algae such as seaweeds and filamentous algae.
Angiosperms		✓	The flowering plants. The group is specified in the Directive as a relevant biological element in transitional and coastal water. In these waters, angiosperms include sea grasses and the flowering plants found in salt marshes.
Benthic/macro invertebrate	✓	✓	Invertebrate animals living at least part of their lifecycles on or in the benthic substrates.
Fish	✓	✓	Indigenous fish species present within the water body.

Within the WFD, water bodies are classified according to ‘typology’, i.e. water bodies are grouped that share particular physical characteristics (e.g. altitude, morphology, hydrology). There are 18 river types, 6 transitional water types and 11 coastal water types identified for the United Kingdom. For each physical type, a biological 'reference' condition has been described, based on what would 'typically' be expected for that water body. For example, the expected macroinvertebrate and fish assemblage for a Type 7 river is shown in Box 1.

Box 1 Example of the expected fish and macroinvertebrate assemblage for a single river type

River Type 7:
Large catchment area (>1000 km2), mean catchment altitude- low (<200m), with a predominantly siliceous geology.

Morphology: This type occurs on mainly shallow slopes, with varying channel width. A wide range of substrates occur, with gravel and cobbles being the most common.

Hydrology: Siliceous catchments are likely to have a low baseflow index. The hydrological regime will exhibit a relatively rapid response to rainfall events, but the upstream area of large sized catchments moderates this response. This extends the hydrograph time-to-peak and slows the recession back to baseflow, compared with small and medium sized catchments of similar geological type. Catchments at low elevations will produce smaller discharges per unit catchment area.

Fish: The upstream sections of this type are likely to be dominated by salmonids whilst down stream sections more commonly support a mixture of coarse and salmonid species. Brown trout will occur in the upper reaches together with bullhead, minnow, brook lamprey, salmon and eel where there are no natural barriers to migration. In the middle reaches stone loach will also occur together with grayling and increased numbers of eel. Further downstream coarse fish such as chub, dace and bleak are likely to predominate together with gudgeon, roach, pike, perch, and ruffe. Eel, river and sea lamprey are also to be expected in the middle and lower reaches.

Macroinvertebrates: The fauna will be diverse with species of Ancylidae, Sphaeriidae, Oligochaeta, Erpobdellidae, Gammaridae, Baetidae, Ephemeridae, Hydrophilidae, Hydraenidae, Elmidae, Hydropsychidae, Sericostomatidae, Tipulidae, Chironomidae and Simuliidae occurring on a frequent basis.

This information will be useful in determining specific biological elements likely to be present and documenting the water body reference conditions as part of the Preliminary Assessment.

3.3 Identifying the physical parameters that the biology may be dependent upon

The 'reference' conditions do not explicitly link the hydromorphological and biological quality elements, thus raising the question if a hydromorphological change occurs within the water body as a result of engineering what physical changes are affecting which biology? A number of references and standards are available, but they neither consider all the BQEs nor attempt to explicitly demonstrate physical dependencies. To assist at the Preliminary Assessment stage and inform any further Level 1 assessment, the physical requirements of each BQE have been set out in look-up table 4 (Appendix D).

Look up Table 4 provides an indication of the type of water body in which the Quality Elements are present (i.e. rivers or transitional and/or coastal waters) and suggests the physical parameters of the water body on which the biological receptors are dependant. The list of physical parameters is only intended to be indicative, and does not necessarily list all parameters that may be important in individual situations, or suggest that all parameters listed are important in all cases. Furthermore, the relative importance of each physical parameter is likely to vary spatially and temporally at all scales. These issues need to be recognised when undertaking the Preliminary Assessment, using existing information where available as well as contextual information.

Useful guidelines are also available that focus on a either specific habitats or species and provide details of site suitability, including hydromorphological consideration, and can be applied if necessary either during the Preliminary or Level 1 assessment. These include:

- The Defra report 'Suitability Criteria for Habitat Creation' provides a useful resource for Transitional and Coastal (TraC) water bodies, demonstrating hydromorphological dependencies for transitional and coastal habitats, including saltmarsh and eelgrass beds.

- The Restoration of Vegetation on Saltmarshes: R&D Technical Report W208 (Environment Agency, 1999).

- Flow and Level Criteria for Coarse Fish and Conservation Species (Environment Agency, 2004).

- The Life in UK Rivers series of reports provides detailed habitat information for freshwater species and habitats of conservation concern (www.natural-england.org.uk).

3.4 Documenting the results

After the look-up tables have been consulted to give an indication of the likely hydromorphological response(s) and the physical parameters on which the key BQEs are dependant, the next stage is to identify whether hydromorphological change is likely to occur; determining the need for further assessment.

At this stage, judgement will be used to decide whether a proposed scheme warrants a Level 1 assessment, based on the potential hydromorphological responses and physical dependencies of the BQEs identified in the previous stages. This decision will need to be documented.

The criteria for recommending a Level 1 assessment are provided in the box below. Rather than justify why a Level 1 assessment should be undertaken, it is proposed that the reasons for not undertaking an assessment are identified and recorded. A Level 1 assessment will not be required if BQEs are not present and would not be expected to be found in the environment even if unmodified. A Level 1 assessment would also not be required if the hydromorphology will not be affected by proposed works (see Box 2). In all other cases, it is recommended that a Level 1 assessment is undertaken to ensure that all potential impacts on the biological quality of a water body are investigated.

Box 2 Why is a Level 1 assessment not being undertaken? (select from following)

1) The BQEs which may be affected are not present and will not be present in the future given the prevailing environmental conditions (this will seldom be the case). Note that this reason is not valid if the factor limiting presence of biology is artificial modification which could be later removed.

2) The BQEs which are present will not be affected by the hydromorphological response (this should only be accepted if there is already hydromorphological/ecological evidence which can be used to demonstrate that the hydromorphological response is likely to be spatially/temporally limited or the changes can be absorbed by the system, i.e. the system is resilient to change).

For all other schemes or where there is uncertainty, Level 1 should be applied to sufficiently explain and document hydromorphological changes and their impacts on biology under WFD.

4 Undertaking a Level 1 assessment

A Level 1 assessment is intended to provide information about the nature of the hydromorphological conditions of a water body and allow the likely hydromorphological responses to new FCRM infrastructure or activities to be investigated. This will, in turn, inform a more accurate assessment of whether BQEs are likely to be affected.

The Level 1 assessment should be undertaken by an experienced geomorphologist and ecologist. Specifically, it is intended that a Level 1 assessment will:

- Identify the hydromorphological changes that are likely to be attributable to the FCRM infrastructure or activity;
- Identify, where possible, any relationships between the hydromorphological changes and the biology that is supported;
- Provide an indication of the likelihood of deterioration in condition occurring;
- Identify the requirements for mitigation; and
- If needed, provide a justification for undertaking further assessments.

The assessment will be an expert judgement based on outcomes from existing techniques and methodologies; listed in Table 4.1.

A range of existing techniques are recommended for use in undertaking a Level 1 assessment (Table 4.1). These methods are intended to provide a high-level overview of the nature, behaviour and functionality of a water body.

Full details of each technique, including purpose, required experience, applicability, recommended methods, success criteria, and data and information requirements, are provided in Appendix E.

Experience required is split into three categories:

Expert - sufficient experience through applying methods, often in combination, across a wide range of environments and to a wide range of problems. Would review and direct work of experienced staff.

Experienced – good working understanding and knowledge of particular method(s) and its application through experience of application in a range of environments.

Intermediate – knowledge of the subject area and could use certain methods with training and/or under the direction of experienced or expert staff.

Table 4.1 - Level 1 Expert Assessment Techniques and Methodologies

Expert Assessment : Assessment by an experienced geomorphologist and ecologist of spatial and temporal changes in hydromorphology and consequent impact on ecology. Expert assessment can be supported by the outcomes of the following methods. Further guidance on the use and application of the methods is provided in Appendix E.	
Desk based review of existing reports/analyses	Collation and review of existing information, including consultation with local experts where useful.
Historical Trend Analysis (HTA)	Investigation of trends in geomorphological behaviour and ecological quality over time using available historic maps and datasets.
Field assessment	Visual assessment and interpretation of geomorphological forms and processes and/or ecological survey.
River Habitat Survey (RHS) and geoRHS repeat survey comparison	Standardised method which, where previous completed survey exists, could provide useful comparison if new survey were undertaken. Less useful if undertaken separately from field assessment.
Stream Power Assessment	A high level assessment of energy within the river system to determine likely response (deposition or erosion) or the river.
Tidal Prism Analysis	A method to identify the relationship of the form of an estuary to the function in relation to the exchange of tidal water.

Many schemes will already require a certain amount of environmental assessment, for example as part of the design process and Environmental Impact Assessment (EIA) of the preferred scheme options. However, these assessments may not provide the necessary data required to undertake an assessment of the likely impacts of the proposals on hydromorphological and biological quality under the WFD (since this is not specifically required as part of the EIA process). In such a case, it will be necessary to undertake further investigations to allow these impacts to be assessed in more detail to explicitly meet WFD needs. Equally, ongoing investigations as part of the design and / or EIA process may provide the opportunity to obtain the data required to undertake a Level 1 assessment. These investigations should therefore be identified at an early stage and, if necessary, adapted to ensure that relevant data are collected as apart of the scheme/project.

A Level 1 assessment is intended to provide an assessment of the nature of the hydromorphological changes that are likely to occur in response to a new or altered FCRM infrastructure or activity. This will provide a better indication as to whether or not biological quality will be affected by the hydromorphological changes. The desired outcomes from a Level 1 assessment are listed in Box 3. These outcomes should be documented in detail to provide a WFD assessment and, where relevant, provide justification for undertaking Level 2 investigations.

Box 3 A Level 1 assessment should:

- Document the likely scale (temporal and spatial) of the hydromorphological change, and identify any direct loss of BQEs.
- Document the likely nature (rate, direction and mechanism) of the hydromorphological change, to allow the indirect loss of BQEs to be evaluated.
- Identify the ability of the BQEs to recover from the changes that have been identified (eco-adaptability) and the timescale over which such recovery is likely.
- Identify whether any hydromorphological changes are likely to result in a deterioration in ecological status or ecological potential (taking into account spatial and temporal scales of change).
- Provide an indication of the level of confidence associated with the likely outcome (i.e. the degree of uncertainty in the assessment based on available information).
- Provide justification of why further Level 2 assessment is required to increase certainty about the likely change and impact.

If the Level 1 assessment delivers all of the desired outcomes listed above, the assessment should indicate, with some certainty, whether the likely changes in hydromorphology will lead to the loss or not of BQEs (either directly or indirectly) and whether that the changes will/will not lead to a deterioration in Ecological Status. It will, therefore, be possible to conclude that no further investigation is required and record the outcome for the WFD assessment. Documentation of the Level 1 assessment should be in accordance with Environment Agency requirements.

There are three circumstances where further investigation through a Level 2 assessment may be required (Box 4).

Box 4 A Level 2 assessment might be required:

- Where it is considered there is insufficient information from the Level 1 investigation to state whether there is likely to be a deterioration in status or not. In this case, it will be necessary to demonstrate that any further investigation will significantly reduce this uncertainty. If the outcome from further studies is unlikely to substantially reduce uncertainty, then expenditure will not be justified.
- Where the Level 1 expert categorically identifies the need to undertake a more detailed assessment because it will provide robust answers where Level 1 has not. This may result from uncertainty over the direction or magnitude of physical change that is likely to occur where this is critical to the BQEs involved.Identify whether any hydromorphological changes are likely to result in a deterioration in ecological status or ecological potential (taking into account spatial and temporal scales of change).
- Where it is concluded under Level 1 that there will be a deterioration in status and so mitigation is needed. Further information may be required to assist in designing mitigation measures (and hence subsequent reappraisal of whether there is still likely to be a deterioration in status after those mitigation measures).

If it is concluded that a Level 2 assessment is required, the purpose should be defined prior to selecting the method types to be adopted in the assessment. Box 4 indicates how a Level 2 assessment could be used.

Box 5 A Level 2 assessment is required to:

- Quantify the hydromorphological changes that are likely to occur in response to the FCRM infrastructure or activity.
- Improve understanding of the direction and nature of hydromorphological change.
- Inform the assessment of the ecology of the water body.
- Inform the assessment of direct and indirect losses of BQEs.
- Assist in the formulation of design options for the FCRM infrastructure or activity and / or the design of mitigation measures.

5 Undertaking a Level 2 Assessment

The scope for further Level 2 investigations should be determined at the end of the Level 1 assessment. A Level 2 assessment is intended to provide additional, targeted information regarding the nature of hydromorphological changes and the likely impact of these changes on biological quality and, as such, should build upon the existing information gathered as part of the Level 1 assessment.

Level 2 assessments may require different specialist input(s) and data and, in many cases, could already be identified as part of the EIA / design process. Even where the method has been identified for other purposes, this does not mean it will be sufficiently targeted to inform the assessment of hydromorphological and ecological impacts of the scheme. Where the Level 2 methods are already being applied, these investigations should be checked and adapted (where necessary) so that they are able to provide the information required by the WFD Expert Assessment process.

A range of existing methods are available for use in undertaking a Level 2 assessment (Table 5.1). This list covers widely accepted generic methods which can be undertaken under Level 2 and give a general overview of the purpose, applicability and requirements. Some key sources of applied guidance are referenced which provide more detailed overviews where necessary. The Expert applying the method will determine what specific tools or techqniues are best suited to the situation and demonstrate the benefits in terms of increasing certainty. The list is by no means exhaustive but covers or refers to those methods which are accepted and used by practitioners in FCRM.

Details of each technique, including purpose, required experience, applicability, recommended methods, success criteria, and data and information requirements are provided in Appendix F.

As with Level 1, experience required is split into three categories:

Expert - sufficient experience through applying methods, often in combination, across a wide range of environments and to a wide range of problems. Would review and direct work of experienced staff.

Experienced – good working understanding and knowledge of particular method(s) and its application through experience of application in a range of environments.

Intermediate – knowledge of the subject area and could use certain methods with training and/or under the direction of experienced or expert staff.

Table 5.1: Level 2 Expert Assessment Techniques and Methodologies

Level 2 Expert Assessment: Again, Level 2 assessment would be undertaken by an experienced geomorphologist and ecologist with knowledge of the particular tools and techniques, and experience in the interpretation of output from the methods. Further guidance on the use and application of the methods is provided in Appendix F.	
Fluvial audit	Establishment of baseline hydromorphological form and behaviour at a river reach in the context of conditions prevailing in the wider river network and catchment as a whole.
Physical biotope mapping	Detailed mapping of hydromorphological characteristics based on field observation to establish the key physical biotopes and hydromorphological features within the study area.
Particle tracking	Using the physical movement of a discrete and traceable group of particles to identify and quantify patterns of sediment erosion, transport and deposition in a water body.
Erosion monitoring	Identification of spatial and temporal patterns and rates erosion.
Accretion monitoring	Identification of spatial and temporal patterns and rates accretion.
Repeat survey	Identification of patterns of spatial and temporal morphological change, for example river bank erosion, point bar deposition and beach profile change.
Water level monitoring	Identification of spatial and temporal patterns of water level variation in a catchment or coastal cell, allowing the hydrological regime to be identified, flood risk to be evaluated, and likely morphological responses to changing conditions to be predicted.
Sediment survey	Determination of the physical and, in some cases, chemical characteristics of sediment in a water body.
Sediment budget analysis	Mapping and quantifying the sediment sources, transport patterns and sinks, to establish a budget of net gain and loss.
Physical niche modelling	Comparison of land elevations against tidal frame to determine suitability for plant colonisation.This can be applied to floodplain areas for assessment of potential habitat (under managed realignment) or existing intertidal areas linked to identified level changes.
Geodynamics assessment	Undertaking a detailed assessment of the physical characteristics, dominant processes and morphological dynamics of a river system.
Physical modelling	Creation of a scale model of a natural system to simulate responses to changing conditions (hydraulic and sediment) under controlled conditions.
Numerical and process modelling	Use of computer models to simulate physical processes over time and space.

Suitable methods should be selected based on the nature of the likely hydromorphological responses identified during the Level 1 assessment and the type of data that they require. In all cases, the simplest and least intensive method appropriate to the situation should be applied, in order to prevent unnecessary expenditure on investigations that will not provide any additional certainty. Many Level 2 assessment techniques are considerably more expensive (in terms of time and costs) than the more generic Level 1 techniques, so care should be taken to select the most appropriate method for the situation in question.

A Level 2 assessment is intended to provide a detailed indication of the nature of the hydromorphological changes that are likely to occur in response to new or altered FCRM infrastructure or activity, and demonstrate whether biological quality will be affected by these changes. The desired outcomes from a Level 2 assessment are listed in Box 5. On completion of the Level 2 assessment, the outcomes should be documented in detail to inform the decision making process.

Box 5 A Level 2 assessment should:

- Document the scale of the hydromorphological change that is likely to occur, to identify any direct loss of BQEs;
- Document the scale, direction and nature of the hydromorphological change, to allow the indirect loss of BQEs to be evaluated;
- Identify the ability of the BQEs to recover from the changes that have been identified (eco-adaptability);
- Identify the relevance of any hydromorphological changes which are likely to result in a deterioration in ecological status or ecological potential;
- Provide an indication of the level of confidence associated with the likely outcome (i.e. residual uncertainty in the assessment); and;
- Contribute directly to the design of mitigation measures.

As with Level 1 assessments, the outputs from the Level 1 assessment should be documented in accordance with Environment Agency requirements. Further information can be sought from the River Basin Management Planning Team within the Environment Agency.

6 References

Defra (2007) The Estuary Guide

Environment Agency (2008) Supplementary Flood and Coastal Defence Project Appraisal Guidance; Water Framework Directive.

Environment Agency (2008)The Restoration of Vegetation on Saltmarshes: R&D Technical Report W208

FRMRC (2006) Accounting for Sediment in Rivers; A tool box of sediment transport and transfer analysis methods and models to support hydromorphologically-sustainable flood risk management in the UK

http://www.english-nature.org.uk/LIFEinUKRivers/publications/publications.html

The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003).

The Water Framework Directive (2000/60/EC)

UKTAG (April 2008) UK Environmental Standards and Conditions (Phase 1) Final Report

Appendix A

Look-up table 1: FCRM assets and activities

FCRM assets and activities – (i) Rivers

Asset type	Asset	Function	Footprint	Materials
Channel / Watercourse	Watercourse	To increase conveyance in order to reduce water levels under a range of return periods to acceptable levels and/or function under low-flow conditions	Along the river = tens of kilometres; Cross river = metres to tens of metres	N.A. unless artificial, such as a canal (clay, concrete, rock)
	Bank protection	To prevent / reduce erosion of the channel banks	Along the river = metres to kilometres; Cross river = metres to tens of metres	Rock, Geotextile, Fascine, Concrete, Timber
	Bed protection	To prevent / reduce erosion of the channel bed	Along the river = metres to kilometres; Cross river = metres to tens of metres	Rock, Geotextile, Fascine, Concrete, Timber
Defence (linear flood defence)	Embankment	To prevent / reduce the inflow of river water to an area of low lying land	Along the river = kilometres to tens of kilometres; Cross river = metres	Soil (Clay, Sand)
	Revetment	To prevent / reduce embankment erosion	Along the river = metres to hundreds of metres; Cross river = metres	Rock, Concrete, Gabions, Timber
	Wall	To prevent / reduce the inflow of river water to an area of low lying land (often in combination with another main function such as traffic, building, navigation)	Along the river = kilometres to tens of kilometres; Cross river = decimetres to metres	Steel sheet pile, Concrete, Masonry, Timber
	Temporary / demountable defence, gate	To prevent / reduce the inflow of river water to an area of low lying land in flooding situations while allowing other functions in non-flooding situations	Along the river = metres to hundreds of metres; Cross river = decimetres to metres	Metal, Concrete, Timber, Glass/glass fibre, Polythene, Plastic
Point structure	Sluice, pipe, inlet, outlet, off-take	To enable controlled discharge of water through the flood defence (note could be to fresh or saline environment)	Along the river = metres to hundreds of metres; Cross river = decimetres to tens of metres	Concrete, Steel, Masonry

Asset type	Asset	Function	Footprint	Materials
Off-line structure	Lock	To enable shipping traffic through the flood defence, control water artificially down-slope (note could be to fresh or saline environment)	Along the river = metres to tens of metres; Cross river = metres	Concrete, Steel, Timber, Masonry
	Pumping station	To pump water from lower to higher sections of the drainage system (note could be to fresh or saline environment)	Along the river = metres to kilometres; Cross river = metres	Concrete, Steel
Structure (Point structure) On-line structure	Barrier	To prevent / reduce high water levels in flooding situations while allowing discharge and navigation in non-flooding situations	Along the river = metres to tens of metres; Cross river = metres to tens of metres	Concrete, Steel
	Culvert	To enable conveyance of water across other functions, e.g. transport infrastructure (note could be to fresh or saline environment)	Along the river = metres to hundreds of metres; Cross river = metres to ten metres	Concrete, Steel, Masonry
	Weir	To increase upstream water levels and/or detain discharge or address slope changes	Along the river = metres to tens of metres; Cross river = metres to tens of metres	Concrete, Masonry, Rock, Timber
	Barrage / dam (including components & installations)	To allow storage of water for flood defence, water supply, power generation (plus secondary functions)	Along the river = metres to tens of kilometres; Cross river = metres to tens of metres	Soil, Rock, Concrete, Steel, Timber
	Reservoir	To allow storage of water for flood defence, water supply, power generation (plus secondary functions)	Along the river = tens of metres to hundreds of metres; Cross river = tens of metres to hundreds of metres	Soil, Rock, Concrete, Steel
Maintenance activity	Re-pointing (blockwork structures)	To enhance or replace the cement bonding between different elements in a blockwork structure	Interstices between individual elements	Cement, Bitumen
	Void filling ('solid' structures)	To fill unwanted gaps that have opened in 'solid' structures	Voids between or within individual elements	Grout, Rock, Rubble, Cobbles

Appendix A: Look up table 1: FCRM assets and activities

Asset type	Asset	Function	Footprint	Materials
Maintenance activity *continued*	Re-positioning (rock or rubble or blockwork structures)	To reposition dislodged elements of a structure	Individual elements	Rock, Blockwork, Rubble
	Replacing elements	To remove failed elements (e.g. due to cracking/weathering) and replace them with new elements	Individual elements	Rock, Blockwork, Rubble
	Re-facing / reinforcement	To build a protective layer over the surface of an existing structure to cover moderate defects and prevent them from becoming accentuated	Tens of metres to hundreds of metres	Concrete, Rock
	Skimming/covering	To place a protective layer over the surface of an existing structure to cover minor defects and prevent them from becoming accentuated	Tens of metres to hundreds of metres	Concrete, Asphalt
	Sediment management	Dredging or agitation of sediments to mobilise downstream/remove from channel to maintain competence	Tens of metres to hundreds of metres	N/A
	Vegetation management	Removal of in-stream vegetation as a result of growth to maintain system competence	Tens of metres to kilometres	N/A
	Blockage removal	Removal of accumulated debris from the system, particularly at culverts/screens etc to maintain through-flow in the system	Tens of metres to kilometres	N/A
	Vegetation clearance (Embankments)	To remove vegetation that could reduce strength of materials (or conceal or create structural faults)	Tens of metres to kilometres	N/A
	Vermin control (Embankments)	To eradicate vermin that can cause voids in structures		

FCRM assets and activities – (ii) TraC

Asset Type		Function	Footprint	Materials
Offshore structures	Breakwaters	To reduce erosion of the shoreline and to limit cross-shore sediment exchange	Shore parallel = tens of metres (individually) extending over tens of metres to kilometres; cross-shore = metres in width	Rock, Rubble, Concrete
Shoreline structures	Seawalls	To arrest the landward recession of the backing landforms by providing a physical barrier against marine processes and reflecting wave energy	Alongshore = tens of metres to kilometres; cross shore = metres in width	Concrete, Blockwork, Masonry
	Splash Wall	To limit overtopping and spray	Alongshore = tens of metres to kilometres; cross shore = metres in width	Concrete, Blockwork, Masonry
	Revetments	To arrest the landward recession of the backing landforms by providing a physical barrier against marine processes and breaking up wave energy at the structure's toe	Alongshore = tens of metres to kilometres; cross shore = metres in width	Rock, Stone, Asphalt
	Gabions	To slow the landward recession of the backing landforms by marine processes	Alongshore = tens of metres to kilometres; cross shore = metres in width	Steel cages filled with cobbles and/or shingle
	Aprons	To slow the landward recession of the backing landforms by marine processes	Alongshore = tens of metres to kilometres; cross shore = metres in width	Concrete, Rubble
	Breastwork	To slow the landward recession of the backing landforms by marine processes	Alongshore = tens of metres to kilometres; cross shore = metres in width	Timber
	Armour	To provide protection to the toe of an existing structure against undermining and to help reduce overtopping	Alongshore = tens of metres to kilometres; cross shore = metres in width	Rock, Stone, concrete

Asset Type		Function	Footprint	Materials
Shoreline structures *continued*	Piling	To provide additional support to the foundations of an existing structure (e.g. seawall or embankment)	Alongshore = tens of metres to kilometres; cross shore = metres in width	Steel
	Embankment	To prevent the inflow of tidal waters to an area of low lying land	Alongshore = tens of metres to kilometres; cross shore = metres in width	Clay, Soil, Asphalt
Cross shore structures	Groynes	To interrupt the alongshore transport of sediment and help build up a protective beach (on the updrift side)	Alongshore = metres (individually) over a cumulative length of often tens of metres to kilometres; Cross-shore = tens of metres	Rock, Timber, Concrete, Blockwork, Masonry
	Fishtail groynes	To interrupt the alongshore transport of sediment and help build up a protective beach	Alongshore = metres (individually) over a cumulative length of often tens of metres to kilometres; Cross-shore = tens of metres	Rock
	Hard points	To influence the re-alignment of the coastline towards a more sustainable form (by altering long-shore sediment transport)	Alongshore = tens of metres	Rock, Rubble
Beach management	Nourishment	To introduce as a one-off exercise a large volume of fresh sediment to the beach to restore volume, width and level	Alongshore = hundreds of metres to kilometres	Sand, Shingle, Clay
	Recycling	To move sediment from an area of deposition to an area of depletion to restore volume, width and level at a particular section	Alongshore = hundreds of metres	Sand, Shingle, Clay
	Recharge	To repeatedly introduce modest volumes of sediment on a regular and ongoing basis	Alongshore = hundreds of metres to kilometres	Sand, Shingle, Clay

Asset Type		Function	Footprint	Materials
Beach management *continued*	Reprofiling	To redistribute the sediment on a beach from the lower and mid beach to the upper beach to build a protective crest level and beach width	Alongshore = hundreds of metres	Sand, Shingle
Managed Retreat	Monitor and Manage	To allow the recession to continue, whilst monitoring its progress and locally managing any health and safety aspects		N/A
	Reduction of erosion rate	To manage the recession process by slowing, but not stopping, the rate through use of a structure or beach management activities	Alongshore = metres to hundreds of metres	Rock, Timber, Beach material
Unmanaged Retreat / realignment	Abandonment	To allow the recession of coastal features or flooding inland to continue unabated and unobserved	Tens to kilometres	N/A
Managed Realignment	Regulated or Unregulated Tidal Exchange	To allow the retention of existing defences whilst allowing tidal incursion to landward area	Alongshore – metres to tens of metres	Concrete, Steel
	Bank or Breach realignment	To create a gap in an existing defence for the exchange of tidal water to provide space for water, or resolve erosive pressures on defences	Alongshore = metres to hundreds of metres, cross shore metres to hundreds metres	N/A (unless secondary defence created to landward)
Flood Structure	Barrier	To hold back tidal waters in extreme events whilst allowing free flow of tidal (and fresh) water under other conditions.	Alongshore = metres to tens of metres; Cross shore = metres to hundreds of metres	Concrete, Steel

Asset Type		Function	Footprint	Materials
	Barrage (including components & installations)	To allow exclusion of tidal water for flood defence, water supply, power generation (plus secondary functions). May be set at level to allow overtopping in extreme events and also used for navigation in detaining water upstream.	Alongshore = metres to tens of kilometres; Cross shore = metres to tens of metres	Soil, Rock, Concrete, Steel
Cliff face stabilisation	Drainage	To improve coastal cliff stability by draining water, rather than allowing its movement through the cliff to trigger sliding	Tens to hundreds of metres	Clay, Plastic
	Geotextile	To improve coastal cliff stability by providing a covering membrane	Tens to hundreds of metres	Geotextile
	Soil nailing	To improve coastal cliff stability by nailing potentially loose sections of cliff into solid geology	Tens of metres	Steel
	Retaining wall	To improve coastal cliff stability by increasing the ability to withstand loading	Tens to hundreds of metres	Concrete
	Vegetation Planting	To improve coastal cliff stability by binding the soil surface using vegetation	Tens of metres	Vegetation
	Regrading	To improve coastal cliff stability by creating a more stable angle of repose	Tens to hundreds of metres	Natural cliff material
	Grouting/concrete protection	To improve coastal stability by filling voids and fissures	Tens of metres	Grout
	Netting	To prevent loose debris from falling to the ground by retaining it within netting	Tens of metres	Wire mesh

Asset Type		Function	Footprint	Materials
Dune stabilisation	Geotextile or vegetation planting	To stabilise dunes and encourage sediment trapping efficiency, thus protecting dunes (temporarily) from breaches/blow-outs due to wave/tide/wind action. Recognition of the natural sea defence function of dunes	Metres to hundreds of metres	Geotextile, Vegetation
Saltmarsh/mudflat stabilisation	Brushwood fencing or other wave breaks / sediment recharge	Protection of saltmarsh edge from wave erosion, stabilisation of sediment, enhancing sediment deposition and vegetation growth on cohesive sedimentary shores	Metres to hundreds of metres	Natural materials, Geotextile, Gabions, Clay/silt input
Maintenance activity	Re-pointing (blockwork structures)	To enhance or replace the cement bonding between different elements in a blockwork structure	Interstices between individual elements	Cement, Bitumen
	Void filling (‘solid’ structures)	To fill unwanted gaps that have opened in ‘solid’ structures	Voids between or within individual elements	Grout, Rock, Rubble, Cobbles
	Re-positioning (rock or rubble or blockwork structures)	To reposition dislodged elements of a structure	Individual elements	Rock, Blockwork, Rubble
	Replacing elements	To remove failed elements (e.g. due to cracking/weathering) and replace them with new elements	Individual elements	Rock, Blockwork, Rubble
	Re-facing / reinforcement	To build seaward a protective layer over the surface of an existing structure to cover moderate defects and prevent them from becoming accentuated	Tens of metres to hundreds of metres	Concrete, Rock

Asset Type		Function	Footprint	Materials
	Skimming/covering	To place a protective layer over the surface of an existing structure to cover minor defects and prevent them from becoming accentuated	Tens of metres to hundreds of metres	Concrete, Asphalt
	Recharge	See Beach Management		
	Reprofiling	See Beach Management		
	Recycling	See Beach Management	Tens of metres to kilometres	
	Vegetation clearance (Embankments)	To remove vegetation that could reduce strength of materials (or conceal or create structural faults)	Tens of metres to kilometres	
	Vermin control (Embankments)	To eradicate vermin that can cause voids in structures		

Appendix B

Look-up table 2: Hydromorphological Response

FCRM assets and activities – (i) Rivers

Asset type	Asset	Design Function	Potential Hydromorphological Consequences	Climate change responses
Channel / Watercourse	Watercourse alteration	To increase conveyance in order to reduce water levels under a range of return periods to acceptable levels and/or function under low-flow conditions	Reduced morphological diversity, natural headward migration, eomorpho, increased sediment supply downstream, eomorphologist of downstream bed and banks, siltation downstream, loss of shading associated to riparian zone.	Reduced morphological diversity, natural headward migration, eomorpho, increased sediment supply downstream, eomorphologist of downstream bed and banks, siltation downstream, loss of shading associated to riparian zone.
	Bank protection	To prevent / reduce erosion of the channel banks	Reduced morphological diversity, increased sediment supply downstream, eomorphologist of downstream bed and banks, siltation downstream, loss of shading associated to riparian zone.	Structures reduce ability of channel to adjust, loss of lower reaches to coastal drowning.
	Bed protection	To prevent / reduce erosion of the channel bed	Reduced morphological diversity, increased sediment supply downstream, eomorphologist of downstream bed and banks, siltation downstream.	Structures reduce ability of channel to adjust, loss of lower reaches to coastal drowning.

Asset type	Asset	Design Function	Potential Hydromorphological Consequences	Climate change responses
Defence (linear flood defence)	Embankment	To prevent / reduce the inflow of river water to an area of low lying land	Loss of floodplain ecology associated with connectivity, reduction/prevention of sediment input, reduction/prevention of channel in/outflow, increase in channel bank-full capacity, loss of shading from riparian zone.	Structures reduce ability of channel to adjust, loss of lower reaches to coastal drowning, reduced effectiveness with increased overtopping reducing consequences.
Defence (linear flood defence) ***continued***	Revetment	To prevent / reduce embankment erosion	Reduced morphological diversity, further loss of floodplain ecology associated with connectivity, further reduction/prevention of sediment input, further reduction/prevention of channel in/outflow, loss of shading associated to riparian zone.	Structures reduce ability of channel to adjust, loss of lower reaches to coastal drowning, reduced effectiveness with increased overtopping reducing consequences.
	Wall	To prevent / reduce the inflow of river water to an area of low lying land (often in combination with another main function such as traffic, building, navigation)	Loss of floodplain ecology associated with connectivity, reduction/prevention of sediment input, reduction/prevention of channel in/outflow, increase in channel bank-full capacity, loss of shading associated to riparian zone.	Structures reduce ability of channel to adjust, loss of lower reaches to coastal drowning, reduced effectiveness with increased overtopping reducing consequences.

Asset type	Asset	Design Function	Potential Hydromorphological Consequences	Climate change responses
	Temporary / demountable defence, gate	To prevent / reduce the inflow of river water to an area of low lying land in flooding situations while allowing other functions in non-flooding situations	During high flows: loss of floodplain ecology associated with connectivity, reduction/prevention of sediment input, reduction/prevention of channel in/outflow, increase in channel bank-full capacity, loss of shading associated to riparian zone.	Reduced effectiveness with increased overtopping reducing consequences.
Point structure	Sluice, pipe, inlet, outlet, off-take	To enable controlled discharge of water through the flood defence (note could be to fresh or saline environment)	Upstream flow impoundment, increased upstream siltation, reduced sediment supply downstream, eomorphologist of downstream bed and banks.	No effect.
Off-line structure	Lock	To enable shipping traffic through the flood defence, control water artificially down-slope (note could be to fresh or saline environment)	Upstream flow impoundment, increased upstream siltation, reduced sediment supply downstream, eomorphologist of downstream bed and banks.	Effects of closure occur more frequently, reduced effectiveness with increased overtopping reducing consequences.
	Pumping station	To pump water from lower to higher sections of the drainage system (note could be to fresh or saline environment)	Lower channel: increased sediment supply downstream, eomorphologist of downstream bed and banks, increased siltation downstream. Upper channel: downstream erosional scour, eomorphologist of downstream bed and banks.	Reduced effectiveness with increased flooding.
Structure (Point structure) On-line structure	Barrier	To prevent / reduce high water levels in flooding situations while allowing discharge and navigation in non-flooding situations	Reduction of flushing flows, higher probability of floodplain inundation associated with increased connectivity.	Reduced effectiveness with increased overtopping reducing consequences.

Asset type	Asset	Design Function	Potential Hydromorphological Consequences	Climate change responses
	Culvert	To enable conveyance of water across other functions, e.g. transport infrastructure (note could be to fresh or saline environment)	Removal of morphology, increased sediment supply downstream, destabilistion of downstream bed and banks, increased siltation downstream, (if structure is inappropriate for flow regime), upstream flow impoundment, increased upstream siltation, reduced sediment supply downstream.	Structures reduce ability of channel to adjust, loss of lower reaches to coastal drowning.
	Weir	To increase upstream water levels and/or detain discharge or address slope changes	Upstream flow impoundment, increased upstream siltation, reduced sediment supply downstream, eomorphologist of downstream bed and banks.	Reduced effectiveness with increased overtopping reducing consequences.
	Barrage / dam (including components & installations)	To allow storage of water for flood defence, water supply, power generation (plus secondary functions)	Upstream flow impoundment, increased upstream siltation, reduced sediment supply downstream, eomorphologist of downstream bed and banks.	No effect.
	Reservoir	To allow storage of water for flood defence, water supply, power generation (plus secondary functions)	Upstream flow impoundment, increased siltation, reduced sediment supply downstream, eomorphologist of downstream bed and banks, total loss of riparian zone, removal of natural floodplain, complete alteration of channel morphology.	No effect.

Asset type	Asset	Design Function	Potential Hydromorphological Consequences	Climate change responses
Maintenance activity	Re-pointing (blockwork structures)	To enhance or replace the cement bonding between different elements in a blockwork structure	No consequence	No consequence
	Void filling ('solid' structures)	To fill unwanted gaps that have opened in 'solid' structures	No consequence	No consequence
	Re-positioning (rock or rubble or blockwork structures)	To reposition dislodged elements of a structure	Increased sediment supply downstream (that may have built up behind dislodged element)	No consequence
	Replacing elements	To remove failed elements (e.g. due to cracking/weathering) and replace them with new elements	May reduce flow dynamics.	No consequence
	Re-facing / reinforcement	To build a protective layer over the surface of an existing structure to cover moderate defects and prevent them from becoming accentuated	May reduce flow dynamics and associated hydromorphological responses.	No consequence
Maintenance activity *continued*	Skimming/covering	To place a protective layer over the surface of an existing structure to cover minor defects and prevent them from becoming accentuated	May reduce flow dynamics and associated hydromorphological responses.	No consequence
	Sediment management	Dredging or agitation of sediments to eomorph downstream/remove from channel to maintain competence	Reduction of upstream impoundment, reduced upstream siltation, increased sediment supply downstream, eomorphologist of downstream bed and banks.	No consequence

Asset type	Asset	Design Function	Potential Hydromorphological Consequences	Climate change responses
	Vegetation management	Removal of in-stream vegetation as a result of growth to maintain system competence	Reduction of upstream impoundment, reduced upstream siltation, increased sediment supply downstream, eomorphologist of downstream bed and banks.	No consequence
	Blockage removal	Removal of accumulated debris from the system, particularly at culverts/screens etc to maintain through-flow in the system	Reduction of upstream impoundment, reduced upstream siltation, increased sediment supply downstream, eomorphologist of downstream bed and banks.	No consequence
	Vegetation clearance (Embankments)	To remove vegetation that could reduce strength of materials (or conceal or create structural faults)	Reduction in loss of floodplain ecology associated with connectivity, lowered reduction/prevention of sediment input, lowered reduction/prevention of channel in/outflow, loss of increased channel bank-full capacity.	No consequence
	Vermin control (Embankments)	To eradicate vermin that can cause voids in structures	No consequence	No consequence

FCRM assets and activities – (ii) TraC

Asset Type	Asset	Function	Potential Hydromorphological consequences	Climate Change Adaptation
Offshore structures	Breakwaters	To reduce erosion of the shoreline and to limit cross-shore sediment exchange	Build up of sediment in lee, scour around structure, acceleration of flows around structure, interception of longshore drift, downdrift erosion, wave focusing between structures.	May become less surface piercing hence increasing wave energy passing over and around the structure leading to lowering of accumulated sediments.
Shoreline structures	Seawalls	To arrest the landward recession of the backing landforms by providing a physical barrier against marine processes and reflecting wave energy	Reflect wave energy leading to clapotis and scour, beach lowering, movement of sediment offshore or alongshire.	Coastal squeeze. Structures preventing migration landward. Foreshore lowering on positive feedback.
	Splash Wall	To limit overtopping and spray	Small increase in wave reflection and backwash, increasing reflected energy impacts (enhance beach lowering and movement of sediment offshore).	Reduced effectiveness with increased overtopping reducing consequences.
	Revetments	To arrest the landward recession of the backing landforms by providing a physical barrier against marine processes and breaking up wave energy at the structure's toe	Reduction in wave energy allowing sediments to remain in-situ	Coastal squeeze. Structures preventing migration landward. Foreshore lowering on positive feedback.
	Gabions	To slow the landward recession of the backing landforms by marine processes	Some wave reflection leading to foreshore lowering but may be countered by absorption of wave and tidal energy alongshire.	Coastal squeeze. Structures preventing migration landward. Foreshore lowering on positive feedback. Short term underming and failure.

Asset Type	Asset	Function	Potential Hydromorphological consequences	Climate Change Adaptation
	Aprons	To slow the landward recession of the backing landforms by marine processes	Reduction in reflected wave energy allowing sediments to remain in-situ	Coastal squeeze. Structures preventing migration landward. Foreshore lowering on positive feedback.
Shoreline structures *continued*	Breastwork	To slow the landward recession of the backing landforms by marine processes	Reduction of sediment input into marine environment, possible consequences of sediment starvation, breakdown of wave eomor and longshore currents to allow sediments to remain in-situ.	Increased wave action leading to less reduction of sediment input (increased sediment supply).
	Armour	To provide protection to the toe of an existing structure against undermining and to help reduce overtopping	Reduction in reflected wave energy allowing sediments to remain in-situ,	Coastal squeeze. Structures preventing migration landward. Foreshore lowering on positive feedback.
	Piling	To provide additional support to the foundations of an existing structure (e.g. seawall or embankment)	Highly reflective of wave energy leading to clapotis and scour, beach lowering, movement of sediment offshore or alongshire.	Coastal squeeze. Structures preventing migration landward. Foreshore lowering on positive feedback.
	Embankment	To prevent the inflow of tidal waters to an area of low lying land	Reflect wave energy and deflect tidal energy leading to foreshore lowering, movement of sediment into suspension.	Coastal squeeze. Structures preventing migration landward. Foreshore lowering on positive feedback.
Cross shore structures	Groynes	To interrupt the alongshore transport of sediment and help build up a protective beach (on the updrift side)	Interception of longshore drift, short term reduction of sediment supply alongshore, acceleration of longshore flow and sediment transport seaward of structures, changing the system from drift to swash aligned.	Increased energy leading to movement of sediments offshore, potential misorientation.

Asset Type	Asset	Function	Potential Hydromorphological consequences	Climate Change Adaptation
	Fishtail groynes	To interrupt the alongshore transport of sediment and help build up a protective beach	Interception of longshore drift, medium term reduction of sediment supply alongshore, acceleration of longshore flow and sediment transport around ends of structures, changing the system from drift to embayment form.	Increased energy leading to movement of sediments offshore, bay deepening.
Cross shore structures *continued*	Hard points	To influence the re-alignment of the coastline towards a more sustainable form	Reduction of long-shore sediment transport, reorientation of coastlines, creation of sediment divide point.	Division of shoreline, embayment, accentuation of drift divide.
Beach management	Nourishment	To introduce as a one-off exercise a large volume of fresh sediment to the beach to restore volume, width and level	Feed longshore drift and absorb wave energy.	Effects shorter lived.
	Recycling (can be maintenance)	To move sediment from an area of deposition to an area of depletion to restore volume, width and level at a particular section	Intercepts longshore drift, can lead to sorting or sediment size, aborption of wave energy.	Effects shorter lived.
	Recharge (can be maintenance)	To repeatedly introduce modest volumes of sediment on a regular and ongoing basis	Feed longshore drift and absorb wave energy.	Effects shorter lived.
	Reprofiling (can be maintenance).	To redistribute the sediment on a beach from the lower and mid beach to the upper beach to build a protective crest level and beach width	Fix position of the beach, oversteepen upper profile, remove sediment source for natural sediment movement.	Becomes leptokurtic and more liable to catastrophic failure, removal of material offshore.

Asset Type	Asset	Function	Potential Hydromorphological consequences	Climate Change Adaptation
Managed Retreat	Monitor and Manage	To allow the recession to continue, whilst monitoring its progress and locally managing any health and safety aspects	Largely allows natural processes to function.	Largely allows natural response to function.
	Reduction of erosion rate	To manage the recession process by slowing, but not stopping, the rate through use of a structure or beach management activities	Reduction in sediment supply	Rate of erosion will increase, increase of sediment supply.
Unmanaged Retreat / realignment	Abandonment	To allow the recession of coastal features or flooding inland to continue unabated and unobserved	Allows natural processes to function.	Allows natural response to function.
Managed Realignment	Regulated or Unregulated Tidal Exchange	To allow the retention of existing defences whilst allowing tidal incursion to landward area	Accretion of sediments on floodplain, jetting, eomorpho scour, increase in tidal prism (leading to alteration of creeks and channels)	No effect.
	Bank or Breach realignment	To create a gap in an existing defence for the exchange of tidal water to provide space for water, or resolve erosive pressures on defences	Accretion of sediments on floodplain, eomorpho flow increase, eomorpho erosion, increase in tidal prism, alteration of creeks and channels, reduction in reflected wave energy, reduction in water level	Largely allows natural response to function.
Flood Structure	Barrier	To hold back tidal waters in extreme events whilst allowing free flow of tidal (and fresh) water under other conditions.	Localised scour and change in flow patterns around structure, increase in water levels to seaward when operated leading to more frequent inundation of intertidal areas	Effects of closure occur more frequently

Asset Type	Asset	Function	Potential Hydromorphological consequences	Climate Change Adaptation
	Barrage (including components & installations)	To allow exclusion of tidal water for flood defence, water supply, power generation (plus secondary functions). May be set at level to allow overtopping in extreme events and also used for navigation in detaining water upstream.	Reduces tidal prism, alteration to creeks and channels, reduction of sediment supply from landward.	More overtopping allowing increase in tidal prism leading to changes in creek and channels.
Cliff face stabilisation	Drainage	To improve coastal cliff stability by draining water, rather than allowing its movement through the cliff to trigger sliding	Reduction/prevention of sediment input, eomorpho scour at discharge points.	More persistent discharge leading to more scour.
	Geotextile	To improve coastal cliff stability by providing a covering membrane	Reduction/prevention of sediment input.	No effect.
	Soil nailing	To improve coastal cliff stability by nailing potentially loose sections of cliff into solid geology	Reduction/prevention of sediment input.	No effect.
	Retaining wall	To improve coastal cliff stability by increasing the ability to withstand loading	Reduction/prevention of sediment input.	No effect.
	Vegetation Planting	To improve coastal cliff stability by binding the soil surface using vegetation	Reduction/prevention of sediment input.	No effect.
	Regrading	To improve coastal cliff stability by creating a more stable angle of repose	Reduction/prevention of sediment input.	No effect.
	Grouting/concrete protection	To improve coastal stability by filling voids and fissures	Reduction/prevention of sediment input.	No effect.

Asset Type	Asset	Function	Potential Hydromorphological consequences	Climate Change Adaptation
	Netting	To prevent loose debris from falling to the ground by retaining it within netting	Reduction/prevention of sediment input.	More debris
Dune stabilisation	Geotextile or vegetation planting	To eomorpho dunes and encourage sediment trapping efficiency, thus protecting dunes (temporarily) from breaches/blow-outs due to wave/tide/wind action.	Reduce landward eomorp sediment supply, prevention of roll-over, disruption of sediment supply in storm events.	Prevention of rollover leading to coastal squeeze or catastrophic dune failure.
Saltmarsh/mudflat stabilisation	Brushwood fencing or other wave breaks / sediment recharge	Protection of saltmarsh edge from wave erosion, eomorphologi of sediment, enhancing sediment deposition and vegetation growth on cohesive sedimentary shores	Sediment accretion on inter-tidal, modification of creeks and channels, better absorption of wave energy, reductions in flows locally.	Prevention of rollover leading to coastal squeeze.
Maintenance activity	Re-pointing (blockwork structures)	To enhance or replace the cement bonding between different elements in a blockwork structure	No consequence	
Maintenance activity *continued*	Void filling ('solid' structures)	To fill unwanted gaps that have opened in 'solid' structures	No consequence	
	Re-positioning (rock or rubble or blockwork structures)	To reposition dislodged elements of a structure	No consequence	
	Replacing elements	To remove failed elements (e.g. due to cracking/weathering) and replace them with new elements	No consequence	

Asset Type	Asset	Function	Potential Hydromorphological consequences	Climate Change Adaptation
	Re-facing / reinforcement	To build seaward a protective layer over the surface of an existing structure to cover moderate defects and prevent them from becoming accentuated	No consequence	
	Skimming/covering	To place a protective layer over the surface of an existing structure to cover minor defects and prevent them from becoming accentuated	No consequence	
	Vegetation clearance (Embankments)	To remove vegetation that could reduce strength of materials (or conceal or create structural faults)	No consequence	
	Vermin control (Embankments)	To eradicate vermin that can cause voids in structures	No consequence	

Appendix C

Look-up table 3: Biological Quality Elements

RIVERS

BIOLOGICAL QUALITY ELEMENTS
Phytoplankton Taxonomic composition of phytoplankton Average phytoplankton abundance Frequency and intensity of planktonic blooms
Macrophytes and phytobenthos The taxonomic composition Average macrophyte and phytobenthic abundance
Benthic invertebrate fauna Taxonomic composition and abundance Ratio of disturbance sensitive taxa to insensitive taxa Level of diversity of invertebrate taxa
Fish fauna Species composition and abundance. Presence of type specific disturbance sensitive species. Age structure of fish communities
HYDROMORPHOLOGICAL QUALITY ELEMENTS
Hydrological regime Quantity and dynamics of flow Connection to groundwaters
River continuity Continuity providing for migration of aquatic organisms and sediment transport
Morphological conditions Channel patterns Width, depth variation Flow velocities Substrate conditions Structure and condition of riparian zone
PHYSICO-CHEMICAL GENERAL
Salinity Nutrient concentrations pH Oxygen balance Acid neutralising capacity Temperature

TRANSITIONAL WATERS

BIOLOGICAL
Phytoplankton Composition and abundance of the phytoplanktonic taxa Average phytoplankton biomass consistency with type specific physico-chemical conditions Degree of alteration of the type-specific transparency conditions Frequency and intensity of Planktonic blooms
Macroalgae Composition of macroalgal taxa Macroalgal cover
Angiosperms Taxonomic composition Angiosperm abundance
Benthic Invertebrate Fauna Level of diversity and abundance Presence of disturbance-sensitive taxa
Fish Fauna Species composition and abundance is consistent with undisturbed conditions
HYDROMORPHOLOGICAL QUALITY ELEMENTS
Hydrological regime Flow regime
Morphological conditions Depth variation Substrate conditions Structure and condition of intertidal zone
PHYSICO-CHEMICAL GENERAL
Temperature Oxygen balance Transparency

COASTAL

BIOLOGICAL
Phytoplankton Composition and abundance of phytoplanktonic taxa Average phytoplankton biomass consistency with type-specific physico-chemical conditions Degree of alteration of the type-specific transparency conditions Frequency and intensity of Planktonic blooms
Macroalgae and angiosperms All disturbance-sensitive macroalgal and angiosperm taxa associated with undisturbed conditions are present. The levels of macroalgal cover and angiosperm abundance are consistent with undisturbed conditions.
Benthic invertebrate fauna The level of diversity and abundance of invertebrate taxa is within the range normally associated with undisturbed conditions All the disturbance-sensitive taxa associated with undisturbed conditions are present
HYDROMORPHOLOGICAL QUALITY ELEMENTS
Hydrological regime Flow regime
Morphological conditions Depth variation Substrate conditions Structure and condition of intertidal zone
PHYSICO-CHEMICAL GENERAL
Temperature Oxygen balance Transparency

Appendix D

Look-up table 4: Physical parameters on which biology are dependent

Biological quality elements (BQE)	Rivers	TraC	Physical parameter
Phytoplankton	✓	✓	Residence time Water depth Thermal regime Turbidity
Macrophytes	✓		Slope Longitudinal position Shoreline complexity or heterogeneity Light quality and quantity (for macro algae and bryophytes) Episodicity of flows and inundation Turbidity Baseflow (in chalk streams) Riparian shade and structure Substrate conditions (stability, particle size distribution and variability)
Phytobenthos (diatoms only)	✓		No hydromorphological elements determined.
Macroalgae		✓	Episodicity (at the low end of velocity spectrum) Salinity Abrasion (associated to velocity)
Angiosperms		✓	Inundations (tidal regime) Sediment loading Land elevation Salinity Abrasion (associated to velocity)
Benthic/macro invertebrate	✓	✓	Beach water table (TraC) Rainfall patterns Light Groundwater connectivity Availability of leaf litter/organic debris Connectivity with riparian zone
Fish	✓	✓	Heterogeneity of habitat (substrate, provision of shelter) Continuity for migration routes Substrate conditions Presence of macrophytes Accessibility to nursery areas (elevation of saltmarsh, connectivity with shoreline/riparian zone)

Appendix E

Level 1 Assessment Methods

Expert Assessment: Level 1	
Method Description	
Purpose	To use expert knowledge to assess the functionality of a morphological system and relationship to ecological quality
Experience	Expert
Time	Dependent upon scale of water body and other assessments complete.
Applicability	• Applicable to all water bodies. • Applicable at range of scales from small scale reach or sub-cell to catchment or coastal cell • Undertaken prior to further targeted investigations.
Method	*Typical Activities:* • Interpretation and assessment of data and information from a range of desk based sources and field sources, usually including a visit by those undertaking expert assessment. • Where appropriate development of a conceptual model for use in the assessment of geomorphological processes and trends. • Analysis of change under different circumstances through application of theory to particular system or • Application of suitable assessment methods for further targeted investigations. *Outputs/Deliverable for Level 1 should:* • Document the scale of the hydromorphological change that is likely to occur, to identify any direct loss of Biological Quality Elements. • Document the scale, direction and nature of the hydromorphological change, to allow the indirect loss of BQEs to be evaluated; • Identify the ability of the BQEs to recover from the changes that have been identified (eco-adaptability); • Identify whether any hydromorphological changes are likely to result in a deterioration in ecological status or ecological potential; and • Provide an indication of the level of confidence associated with the likely outcome (i.e. how uncertain the assessment is). • Where Level 2 assessment is recommended, provide justification of why further assessment will provide a better assessment for WFD purposes.
Success criteria	• **Recommended minimum:** A high-level assessment of system functionality based on the previous expert knowledge of the practitioner.
Data and Information (* essential)	
Data requirements will vary according to the nature of the infrastructure and/or activity and the nature of the environment to be assessed. Essential requirements are likely to include a description (including site) of the features to be assessed etc.	

Desk based review of existing reports/analyses	
Method Description	
Purpose	Desk based review of hydromorphological or ecological character, behaviour and sensitivity to change(s).
Experience	Experienced supported by intermediate.
Time	Up to 3 days for 10-100km
Applicability	• Applicable to all types of water body. • Applicable at the local, strategic and catchment/coastal management cell-scale. • Undertaken on a "one-off" basis although may be updated if new information comes to light. • Ideally undertaken prior to field-based assessment to inform on-site observations.
Method	This method can be tailored to suit the data and information available. The form of deliverables should be agreed prior to the review to ensure that the elements of the scheme and biology at the site are addressed in a focussed way rather than becoming tangential or academic in their nature. This thus requires understanding of pragmatism of the proposal(s) on the part of the reviewer linked with the knowledge of the physical system functioning. *Typical Activities:* • Consultation with key stakeholders to identify relevant data sources and gain insight to local understanding. • Collation and review of existing hard copy and electronic reports to extract relevant data and information. • Online data search and review of relevant information (including online empirical datasets, online GIS sources, and e-journals). *Typical Outputs /Deliverables:* • Reference list documenting from where data was obtained. • Record of consultation with key stakeholders. • Presentation of key information to form part of expert assessment
Success criteria	• Clear understanding of the purpose of the desk-based review by the reviewer • **Recommended minimum**: Sufficient interpretation and synthesis of information to enable assessment of site hydromorphological functioning and how this may be affected by the proposed activities, identification of level of sensitivity within the system to change and indications (qualification) of the level of certainty in the assessment and value of any further assessment.
Data and Information *(* essential)*	
Ordnance Survey Mapping*	
Web-based Mapping/Satellite Imagery/Aerial Photography*	
Strategic Plans (such as CFMP, LEAP, CAMS, SMP, EMP, SEA etc,)	
Details of designated international, national, and local sites (Natural England, Local Authorities)	
Geomorphological overviews* (e.g. Fluvial Audits, Future coast, JNCC Coastal Directories Series, JNCC Geological Conservation Review Series, bespoke assessments, Monitoring data, photographic records)	
Ecological surveys* (covering all biological quality elements)	
Waterbody designation and classification information*	

Historical Trend Analysis (HTA)	
Method Description	
Purpose	To establish morphological and landscape changes that are likely to have influenced the hydraulic and sediment regime and ecological response over time at the site in question.
Experience	Experienced, directing intermediate
Time	3-5 hours per kilometre
Applicability	• Applicable to all types of water body. • Applicable at the local, strategic and catchment/coastal management cell scale. • Undertaken on a "one-off" basis although may be updated if new information comes to light. • Can be undertaken prior to field-based assessment to inform on-site observations, or post field assessment to check any observations – usually a combination of both.
Method	Time-series data (remotely sensed data, maps, measured depth/bathymetric data and historical charts and reports, bank or shoreline position lines, strategic monitoring data) are used to identify plan form and (potentially) volumetric trends and rates of morphological change, over varying time steps. *Typical Activities:* • Visual comparison of time series of historical maps and documentation of observed changes in morphological form (e.g. cut off meanders, spit formation), styles of change, rates of change followed by quantification of change where discernable. • Analysis of aerial photographs to identify palaeo-features and measure changes in features (note accuracy will vary on rectified or non-rectified images, if accuracy required for assessment rectification may be required). • Assessment of changes in long-term hydrological records such as water levels or wave records • Literature review of existing reports and online resources to extract evidence and analysis of physical change over time. • Assessment of anthropogenic induced changes that may have modified the physical system. • Likely that a field visit will be beneficial in interpretation of observed changes. *Typical Outputs /Deliverables:* • Text documenting hydromorphological change over time and the probable causes/linkages of this. • Digital mapping of changes. • Timeline of change / events with commentary.
Success criteria	• Scope of assessment needs to be tailored to historical information available and proportionate to the investigation. • **Recommended minimum**: Comparison of online historic mapping and current OS mapping, together with online analysis of aerial photographs.
Data and Information *(* essential)*	
Historical mapping*, preferably a time series	
Aerial photographs*, preferably a time series.	
Long-term water level gauging station records (rivers and transitional water bodies)	
Cross sections, long profile time series, water quality records	
Records of historical events	
Wave / Wind Records (transitional and coastal water bodies)	
Range of existing reports and local information depending on the site.	

<table>
<tr><th colspan="2">Field Assessment</th></tr>
<tr><th colspan="2">Method Description</th></tr>
<tr><td>Purpose</td><td>Field based assessment of hydromorphological and/ or ecological character and behaviour</td></tr>
<tr><td>Experience</td><td>Experienced or Expert, ideally the expert assessor.</td></tr>
<tr><td>Time</td><td>1 day for up to 8km</td></tr>
<tr><td>Applicability</td><td>• Applicable to all water body types.
• Well suited to where an initial assessment of key issues is required or field check of any particular matters needed.
• Flexibility within this method enables the scope to be adapted to the site in question.
• Timing of field visit will depend on the conditions of interest and health and safety considerations (e.g. low tide to assess inter-tidal habitats, summer to assess low flow conditions in rivers).
• May require repeat surveys in order to assess hydromorphological character and processes under varied conditions (each field visit only provides a “snapshot” in time although interpretation of morphological features can provide a broader view of changes)</td></tr>
<tr><td>Method</td><td>This method can be tailored to suit proposals in question and timed accordingly. The methods to be used and form of deliverables should be agreed prior to the survey to ensure that they meet the needs of the project in question.

Typical Activities:
• Desk-based preparation – this may be the minimal required to locate the site or may comprise other techniques, e.g. HTA, desk-based review etc.
• Annotated field mapping using Ordnance Survey base maps.
• Field notes and sketches to document hydromorphological features and potential behaviours/processes. Use of existing methods for field recording may include use of Stream Reconnaisance Sheets for bank erosion processes.
• Photography of typical characteristics and key features (most useful if georeferenced)
• Selected measurements or sampling where appropriate (e.g. gravel sizing, dipping etc.)

Typical Outputs /Deliverables:
• Field survey report documenting methods undertaken and the findings of the survey in terms of the hydromorphological form and behaviour observed, based on professional judgement.
• May be supported by annotated mapping and photographs.</td></tr>
<tr><td>Success criteria</td><td>• Clear understanding of the purpose of the field assessment by the surveyor and agreement of the required outputs.
• Recommended minimum: Study of the OS mapping prior to field assessment, completion of the field assessment, production of brief report or memo / field notes documenting the key findings of the assessment.</td></tr>
<tr><th colspan="2">Data and Information (* essential)</th></tr>
<tr><td colspan="2">Ordnance Survey Mapping*</td></tr>
<tr><td colspan="2">Historic mappping</td></tr>
<tr><td colspan="2">Aerial photographs</td></tr>
</table>

River Habitat Survey (RHS) and geoRHS repeat survey comparison

<table>
<tr><th colspan="2">Method Description</th></tr>
<tr><td>Purpose</td><td>Assessment of physical habitat change changes over a 500m reach of river. Geo-RHS extends the survey method to include the associated floodplain.</td></tr>
<tr><td>Experience</td><td>Undertaken by an accredited RHS surveyor.</td></tr>
<tr><td>Time</td><td>3 hours per 500m reach</td></tr>
<tr><td>Applicability</td><td>Applicable currently only applicable to riverine water bodies
Limited to 500m reaches (boundaries not defined by hydromorphological character).
Guidance indicates that typically May and June are optimal months for survey (excepting high flow events).
Although suited to monitoring change, has limitations in determining hydromorphological function.
Requires a minimum of two surveys, one to establish baseline and one to assess change.</td></tr>
<tr><td>Method</td><td>River Habitat Survey (RHS) and geo-RHS are standard techniques routinely used by the Environment Agency, for which there is detailed guidance on the standard approach that should be adopted.

Typical Activities:
Initial desk-based assessment analysis of current OS mapping
GeoRHS Remote Sensing / Desk Study.
Field survey by accredited surveyor using standard proforma.
Analysis of data to provide a broad assessment of habitat quality and naturalness through the use of established scoring indices.
Typical Outputs /Deliverables:
Completed standard pro-forma that can be submitted to the Environment Agency (if surveyor accredited).
Photographs to show typical reach characteristics and key structures.
Indices of Habitat Modification and Habitat Quality that can be set in the context of the national dataset.</td></tr>
<tr><td>Success criteria</td><td>Adherence to standard guidance.
Recommended minimum: Adherence to standard guidance.</td></tr>
<tr><th colspan="2">Data and Information (* essential)</th></tr>
<tr><td colspan="2">OS Mapping*</td></tr>
<tr><td colspan="2">geoRHS GIS tool (ArcGIS extension) (*if undertaking geoRHS)</td></tr>
<tr><td colspan="2">RHS / geoRHS site details – grid reference / H&S notes (required for repeat survey).</td></tr>
</table>

Stream Power Assessment	
Method Description	
Purpose	A high-level assessment that uses stream power to predict whether a river is likely to be a sediment source or sink (i.e. whether erosion or deposition is likely to occur).
Experience	Experienced
Time	1 day per reach
Applicability	• Applicable to rivers only. • The most reliable results are obtained in alluvial river channels.
Method	Stream power is estimated using the physical characteristics of the river channel, including bankfull discharge and slope. *Typical Activities:* • Unit stream power (in Wm^{-1}) can be calculated using the formula $\Omega = \rho g Q S$, where ρ is the specific weight of water, *g* is the acceleration due to gravity, *Q* is the discharge and *S* is the slope. • As an alternative, stream power can be expressed relative to a unit of stream bed area. This measurement, unit stream power, can be calculated using the formula $\omega = \Omega / w$, where Ω is the unit stream power and *w* is the channel width. • Data can be gathered from archive sources and used to calculate stream power for the reach of interest. • Existing tools are available from Flood Risk Management Research Consortium outputs (River Energy Audit Scheme – REAS; Stream Power Screening Tool) [*] *Typical Outputs / Deliverables:* • Values for unit and/or specific stream power for a river reach. These can be used to determine whether erosion or deposition is likely to take place. Typically, deposition is likely to occur if stream power is less than 15 – 25 Wm^{-1} and erosion is likely to occur if stream power exceeds 25 – 35 WM^{-1}. However, further site-specific investigations may be required to characterise conditions more accurately and this tool should only be used. • Stream power values can also be compared to values recorded in other river systems to characterise the sedimentary characteristics of the reach.
Success criteria	• The outcome provides an indication of the likelihood of sediment erosion or deposition occurring in a river reach. It should only be used as part of expert judgement to allow an understanding of the localised variability and other influences on sediment regime, including the impact of sediment supply • **Recommended minimum:** Stream power should be calculated for the reach of interest, plus neighbouring reaches that could also be affected (e.g. those immediately downstream). Discharge can be estimated from nearby EA gauging records or previous studies, if available.
Data and Information *(* essential)*	
Bankfull discharge measurements (*Q*)*	
Channel slope measurements (*S*)*	
Channel width measurements (*w*)	
Stream power measurements from other river reaches / catchments	
Surface particle analysis for D50, D16, D84	

[*] FRMRC (2006) Accounting for Sediment in Rivers; A tool box of sediment transport and transfer analysis methods and models to support hydromorphologically-sustainable flood risk management in the UK

Tidal Prism Analysis

Method Description	
Purpose	To identify the relationship of the form of an estuary to the function in relation to the exchange of tidal water.
Experience	Experienced with Expert Review
Time	2-3 days per estuary
Applicability	• Applicable in estuaries, tidal rivers, and enclosed tidal areas. • Applicable to estuary or sub-estuary scale. • Generally undertaken to understand longer term evolution of estuaries or to determine the degree to which a system is at or close to its regime shape, this provides indication of the amount of adjustment left within the system which may be outwith any project or proposals. • Usually linked with other methods to provide a better understanding of system functioning.
Method	Use of cross sectional/bathymetric data coupled with topographic data to provide a surface against which water levels and hence volumes are compared with the inclusion of time to uinderstand exchange properties. Various analytical methods exist to compare to the state of Regime or Equilibrium including theoretical and empirical relationships. Can also be used linked to inlet stability analysis to determine the likelihood of stability or opening or closure of an inlet mouth. *Typical Activities:* • Generation of a bed/intertidal surface through use of available data and use of measured water levels for volumetric assessment. Establish baseline (existing) condition. • Consideration of change to either/both bed surface and tidal level through either historic change or imposed proposed project. • Comparison of results to field observation, local knowledge, or existing reports to aid system understanding. • Consideration of geological controls on form and how these may affect responses. *Typical Outputs / Deliverables:* • Assessment of degree to which the system is in regime or equilibrium. • These data can be presented numerically, as a written report, and as a series of maps.
Success criteria	• A thorough and detailed understanding of how near a system is to a stable form and how this may change with environmental or imposed factors. • Ability to project change that is outwith the project impacts. • **Recommended minimum:** Calculation of tidal prism at two cross sections.

Data and Information *(* essential)*
Topographic data (e.g. generated from contour data or LiDAR)*
Bathymetric data (e.g. generated from hydrographic charts or high-resolution scanning)*
Tidal elevations (e.g. from Admiralty tide tables)
Tide gauge records*

Appendix F

Level 2 Assessment Methods

Expert Geomorphological Assessment: Level 2

Method Description	
Purpose	To use expert knowledge to assess the functionality of a morphological system.
Experience required	Undertaken by an experienced hydromorphologist.
Applicability	• Applicable to all water bodies. • Applicable at the micro, meso and macro scales. • Undertaken prior to further targeted investigations.
Method	*Typical Activities:* • Use the outcomes from Level 1 assessments to direct further detailed investigations, analyses or survey to answer targeted questions regarding the nature and extent of hydromorphological change on which biology is dependent. • Specialist interpretation of outcomes from further work including assessment of certainty of outcomes. *Outputs/Deliverable of a Level 2 assessment should:* • Document the scale of the hydromorphological change that is likely to occur, to identify any direct loss of Biological Quality Elements; • Document the scale, direction and nature of the hydromorphological change, to allow the indirect loss of BQEs to be evaluated; • Identify the ability of the BQEs to recover from the changes that have been identified (eco-adaptability); • Identify the relevance of any hydromorphological changes which are likely to result in a deterioration in ecological status or ecological potential; • Provide an indication of the level of confidence associated with the likely outcome (i.e. residual uncertainty in the assessment);and; • Contribute directly to the design of mitigation measures.
Success criteria	• An understanding of the likely behaviour of a system. • **Recommended minimum:** A high-level assessment of system functionality based on the previous expert knowledge of the practitioner.
Data and Information (* essential)	
Data requirements will vary according to the and the nature of the environment to be assessed. Essential requirements are likely to include a description (including site) of the features to be assessed, high-level map data, etc.	

Fluvial Audit	
Method Description	
Purpose	Establishment of baseline hydromorphological form and behaviour at a river reach in the context of conditions prevailing in the wider river network and catchment as a whole. Frequently focussed on addressing sediment related management issues, and can be tailored to address particular issues, e.g. siltation in relation to physical dependence of biological quality elements.
Experience	Experienced directed and reviewed by Expert
Time	3 days per kilometre
Applicability	• Applicable to rivers and transitional waters. • Applicable at the reach and catchment-scale. • Traditionally undertaken on a "one-off" basis to inform future management although may be repeated for monitoring purposes.
Method	The method is intended to establish an understanding of the reach-scale sediment budget, the hydromorphological processes operating and the causes of instability or other hydromorphological problems. Setting the context and identifying influencing factors includes a historical dimension, as the impacts of past as well as contemporary events and catchment changes may influence current hydromorphology. *Typical Activities:* • Desk-based review (see Tier 1). • Historical trend analysis (see Tier 1). • Continuous field survey using approved survey proforma. • Investigations of sediment sources, transport processes and sinks. • Spatial analysis of field data in GIS to develop an understanding of baseline hydromorphological conditions and influencing factors. • Development of conceptual model of sediment and geomorphological system over long, medium and short time scales. • Analysis can be targeted towards addressing particular issues, e.g. where hydromorphology may be limiting achievement of biological objectives. *Typical Outputs /Deliverables (in addition to Desk-based review and HTA outputs – see Tier 1* • Technical report describing the hydromorphological character and behaviour of the site according to findings of the Fluvial Audit. Typically divided into sections and supported by mapping of available data. Should • Database and GIS shapefiles containing field data collected. • Geo-referenced photographic record. **See Defra (2003) Applied Guidebook of Fluvial Geomorphology**
Success criteria	• Sequencing of tasks so that field survey is informed by desk-based assessment. • Capturing of expert judgement during the field survey through free response alongside standardised data. • Clear interpretation of findings to make the outputs accessible to a wider audience. • Fieldwork should ideally be undertaken between May and October (not in spate flows). • **Recommended minimum**: Minimum desk-based review and HTA, followed by targeted fluvial audit along selected reaches (selection dependant on end use of the fluvial audit).
Data and Information *(* essential)*	
See Desk-based review and Historical Trend Analysis (Tier 1) for data sources required for these tasks.	
OS Mapping (1:10,000, 1:50,000)*	
River network (Scale of at least 1:50,000)*	

Physical biotope mapping

Method Description	
Purpose	Detailed mapping of hydromorphological characteristics based on field observation to establish the key physical biotopes and hydromorphological features within the study area.
Experience	Experienced
Time	2 days per kilometre
Applicability	• Applicable to all types of water body • Most applicable at the local scale. Potentially applicable at the strategic scale. • Most useful when undertaken pre and post- intervention to identify changes. • May require repeat surveys in order to assess hydromorphological character and processes under varied conditions (each field visit only provides a "snapshot" in time). • Can be readily used alongside other mapping techniques • Fieldwork should ideally undertaken between May and October (not in spate flows).
Method	Geomorphological / physical biotope mapping is a detailed approach to continuous spatial recording of hydromorphological characteristics. There is currently no standard procedure for undertaking this method for rivers . *Typical Activities:* • Annotation of base mapping in the field according to a defined key to document physical biotopes, bank and bank substrate and other geomorphological features. • Digitisation of the annotated maps to produce GIS layers. • Repeat of the survey post intervention to assess hydromorphological change. *Typical Outputs /Deliverables* • Map(s) illustrating physical biotopes and hydromorphological character (a scale of 1:2,500 is appropriate) • Technical report documenting method used and interpretation of observations / comparison between surveys. • GIS shapefiles containing mapping data.
Success criteria	• Clear view of the channel bed is required to accurately map channel forms and substrate. • Key should be clear and consistent to avoid ambiguity, preferably following existing symbology. • Most useful when used in combination with other mapping techniques and set within the catchment context. • **Recommended minimum**: One off mapping exercise with preliminary interpretative report.

Data and Information *(* essential)*
See Desk-based review and Historical Trend Analysis (Tier 1) for data sources required for these tasks.
OS Mapping* (1:10,000, 1:50,000)*
OS MasterMap / Land-Line mapping*
River network (Scale of at least 1:50,000)*

Particle Tracking

Method Description	
Purpose	Using the physical movement of a discrete and traceable group of particles to identify and quantify patterns of sediment erosion, transport and deposition in a water body.
Experience	Undertaken by experienced sediment tracking staff or those trained in use of particular methods.
Time	1 day to seed, 2 days to collect tracers. Analysis will be dependent upon size of investigation.
Applicability	• Applicable to all types of water body. • Applicable to the local and catchment/coastal cell scales. • Can be undertaken as part of a single study, or can be repeated to identify temporal patterns.
Method	The physical movement of particles is estimated using the physical or chemical properties of a particular group of particles to track patterns of sediment movement in a water body. This can include dyed sediment tracing, magnetism, geological composition, or electronic approaches such as smart pebbles. *Typical Activities:* • Seeding particles of known properties into the natural environment. • These particles frequently have easily traceable physical properties (e.g. density, mineralogy, magnetism), have been painted or dyed (e.g. pebbles or sand), or have been fitted with electronic tracking equipment (e.g. Smart Pebbles). • Using mixing models to determine the proportion of sediment in a sample that has been derived from particular sources. These techniques usually rely on the natural physical, magnetic and/or geochemical properties of sediment, which are measured in both the sample to be traced and the source samples. These techniques are commonly referred to as “composite fingerprinting” techniques. • Recovery of sediment by sediment capture, surface dab samples, retrieval of pebbles etc and analysis of recovered sediment through counts, weights, uv light levels, signature etc and scaling to represent the process. *Typical Outputs / Deliverables:* • Quantitative model calculations of sediment erosion, deposition and transport rates and patterns. • Spatial analysis of sediment transport patterns and potential transport volumes.
Success criteria	*Seeding:* • At least one property of sediment being introduced into a system should be unique to that sediment, and not otherwise found naturally in the environment under investigation. • Quantities of seeded sediment must be sufficient for the environment in question (i.e. not too large or too small). • Sediment tracers must be representative of the natural sediment load of the water body (e.g. particle properties). • Particles must be left in system for a sufficient length of time for processes of interest to operate, could be interaction on short or longer timescales. • Ultimate success dependant on retrieving seeded sediment. • Ensure no conflict in introducing sediment or foreign bodies to the location, consider use of indigenous sediment. **Recommended minimum:** Seeding and tracing of suitable particles into water body of interest. *Fingerprinting:* • Source group properties must be adequately characterised for tracing to be successful. • Source groups should be representative of types of material being eroded. • **Recommended minimum:** Statistically valid sample within a methodological framework valid for the types of study.

Data and Information *(* essential)*
Physical and chemical properties of ‘natural’ particles: e.g. size distribution, density; mineralogy, magnetic properties

Erosion Monitoring

Method Description	
Purpose	To identify spatial and temporal patterns and rates erosion.
Experience	Survey network and set up should be overseen by experienced geomorphologists, field assessment can be undertaken by intermediate level with training.
Time	1 day to install equipment; monitoring for period of interest; 1 day to undertake measurements or retrieve data loggers
Applicability	• Applicable to all water bodies (particularly to erosive environments such as rivers and coastal waters). • Can be used at a small scale to determine micro-scale variations in erosion patterns, e.g. spatial patterns on a river bank. • Also applicable at a larger scale, e.g. river reach, catchment or coastal cell.
Method	Bank erosion rates are monitored over a range of timescales using manual measurement techniques or automated measuring devices. Visual and field assessment should be combined to assess processes and controls on erosion. *Typical Activities:* • Repeated surveys of bank/shoreline and comparison with historical rates and patterns (see Survey sheet for further discussion). • Installation of erosion pins into a river bank or coastline, and regular repeated measurements to determine rates of retreat. • Installation of photo-electric erosion pins (PEEPs) for automated monitoring of erosion. These devices, which are connected to a data logger, automatically record the timing and amount of erosion that occurs on a river bank or coastline. • Remote sensing comparison (see HTA approaches). • Field assessment and mapping of controls on and processes of erosion combined with other forms of analysis where useful. *Typical Outputs / Deliverables:* • Quantitative data detailing spatial and temporal patterns of erosion. • Spatial representation of erosion patterns over time.
Success criteria	• Scope of assessment needs to be tailored to the environment under investigation. • Measurement techniques must be sufficiently accurate to detect changes in erosion over the temporal scale applied. Where possible use the most accurate measurement technique • **Recommended minimum:** Emplacement of suitable monitoring equipment to cover the area of interest in sufficient detail for patterns to become apparent.

Data and Information ***(* essential)***
Records of river bank / coastline position: OS mapping.
Records of river bank / coastline position: historical mapping.
Records of river bank / coastline position: aerial photography.
Records of landform surface position, e.g. survey data, LiDAR, etc.
Existing records and information on spatial and temporal erosion patterns.

Accretion Monitoring	
Method Description	
Purpose	To identify spatial and temporal patterns and rates accretion.
Experience	Experienced supported by intermediate for field survey.
Time	1 day to install equipment; monitoring for period of interest; 1 day to undertake measurements or retrieve data loggers
Applicability	• Applicable to all water bodies. • Can be used at a micro, meso or macro scale, depending on the nature of the depositional environment (e.g. river floodplain, saltmarsh).
Method	Bank erosion rates are monitored over a range of timescales using manual measurement techniques or automated measuring devices. *Typical Activities:* • Repeated surveys of bank/shoreline and comparison with historical rates and patterns (see Survey sheet for further discussion). • Direct physical measurements using techniques such as expanded plates and floodplain sediment traps, which collect sediment on their surface. • Reconstructive techniques using sediment core samples and short-term dating techniques such as ^{137}Cs and ^{210}Pb. • Remote sensing comparison (see HTA approaches) *Typical Outputs / Deliverables:* • Quantitative data detailing spatial and temporal patterns of accretion. • Spatial representation of erosion patterns over time.
Success criteria	• Scope of assessment needs to be tailored to the environment under investigation. • Measurement techniques must be sufficiently accurate to detect changes in erosion over the temporal scale applied. Where possible use the most accurate measurement technique. • **Recommended minimum:** Emplacement of suitable monitoring equipment to cover the area of interest in sufficient detail for patterns to become apparent.
Data and Information *(* essential)*	
Records of river bank / coastline position: OS mapping.	
Records of river bank / coastline position: historical mapping.	
Records of river bank / coastline position: aerial photography.	
Records of landform surface position, e.g. survey data, LiDAR, etc.	
Existing records and information on spatial and temporal erosion patterns.	

Repeat Survey	
Method Description	
Purpose	To identify patterns of spatial and temporal morphological change, for example river bank erosion, point bar deposition and beach profile change.
Experience	Intermediate trained in field survey
Time	3 days for up to 5km
Applicability	• Applicable to all types of water body. • Applicable at the micro, meso and macro spatial scales, depending on the resolution of the techniques used. • Applicable at a variety of temporal scales, depending on the availability of historical data and the frequency of repeated surveys. • Applied after baseline Historical Trend Analysis has been undertaken.
Method	A large number of ground-based and remote sensing techniques are available for use in the identification of directional trends and morphological change over a variety of spatial and temporal scales. *Typical Activities:* • Ground based techniques such as levelling, total station survey, Differential GPS survey and ground-based laser scanning can be used to physically survey a feature of interest. • Bathymetric survey using techniques such as digital echo-sounding, multi-beam sonar etc. These techniques are particularly useful when complete land and underwater profiles of the system of interest are required. • Remote sensing techniques such as aerial photography, LiDAR and SAR can be used to remotely survey a feature of interest. • Additional direct measurement techniques can be used to monitor erosion (see Erosion Monitoring) and accretion (see Accretion Monitoring). • Surveys can be repeated at intervals suitable for the environment of interest, in order to provide an indication of temporal as well as spatial patterns of change. These could be regular pre-defined intervals (e.g. monthly), seasonal, or after events that are likely to lead to morphological change (e.g. floods or severe storms). • Survey data can be compared to spatial data from other time periods in order to determine rates and spatial patterns of change, e.g. previous surveys, historical mapping, and aerial photography. ken. *Typical Outputs / Deliverables:* • Quantitative data detailing spatial patterns of morphological change over time. • These data can be presented in GIS format or a series of hard copy maps. • Full three-dimensional analysis can be undertaken if data are converted into Triangular Irregular Networks (TINs) or Digital Elevation Models (DEMs).
Success criteria	• Choice of method is dependant on scale of area to be surveyed and type of technology available. • Will provide an understanding of spatial and temporal patterns of morphological change, on timescales shorter than those detected using Historical Trend Analysis. • **Recommended minimum:** At least two surveys should be undertaken to determine short-term trends of morphological development. These can be placed into context through comparison with archive sources.
Data and Information *(* essential)*	
Ordnance Survey mapping (preferably in GIS-compatible format).	
Historical mapping (preferably in GIS-compatible format) end existing records of spatial and temporal patterns of change.	
Aerial photography (preferably in GIS-compatible format).	
LiDAR (resolution dependant on scale of area of interest – use highest feasible resolution).	

Water Level Monitoring

Method Description	
Purpose	To identify spatial and temporal patterns of water level variation in a catchment or coastal cell, allowing the hydrological regime to be identified, flood risk to be evaluated, and likely morphological responses to changing conditions to be predicted.
Experience	Experienced, knowledgeable of that type of environment to ensure correct equipment selection.
Time	1 day to install monitoring equipment; monitoring period dependant on nature of interest; frequency of measurement dependant on type of equipment used
Applicability	• Applicable to all types of water body. • Applicable at the local and catchment scales. • Applicable at a variety of temporal scales, depending on the duration of the event of interest (e.g. hourly for a single river flood event, and daily or monthly for longer-term trends).
Method	Water levels can be monitored using permanent fixed monitoring equipment, or temporary, portable equipment. Note temporary gauges require consents. *Typical Activities:* • Water levels can be monitored using the existing Environment Agency gauging station network or (in saltwater) Class A gauges or other classes with verification. • In rivers, these stations are located throughout the national river network, and measure water levels and/or discharge against in a channel of known cross section (e.g. a flume, weir or rated natural river channel). These stations often record measurements every 15 minutes, and automatically relay readings to a regional monitoring centre • Tide gauges are used to monitor sea water levels at a number of sites around the UK. . In saltwater environment gauges may be telemetred and require record retrieval, be in private ownership, or data processed to provide standard water level measurements/ • Mobile flow monitoring equipment can also be installed on a temporary or semi-permanent basis to monitor water levels in areas where no fixed gauge is present. This equipment automatically records flow depth and/or discharge at a timescale that can be pre-defined by the user. The same is true of saltwater environments as fixed point measurement or through other techniques that can provide other information such as ADCP where suspended sediment concentrations can also be derived. • Water levels can also be recorded manually, using video recognition or visual records. *Typical Outputs / Deliverables:* • Quantitative data that provides details of temporal variations in water levels at a fixed point. • Outputs from several monitoring points can be used to identify spatial variations in water levels and propagation of changes in water levels over time and space. • These data can be compared to other indicators (e.g. rainfall data, land use data, storm conditions) to identify how a water body responds to variations in hydrological conditions.
Success criteria	• A detailed understanding of the response of water levels to hydrological conditions and relation of this to physical morphology. • Monitoring data can be compared to long-term records to identify trends over a longer temporal scale including lunar cycles or sea level rise. • **Recommended minimum:** Use of existing water level monitoring equipment (e.g. an EA gauging station) to determine the hydrological regime of the water body in question.

Data and Information *(* essential)*
Verified gauging station records (water levels /discharge, retained on an hourly, daily or monthly basis, potentially higher resolution available; water level gauges at major ports and estuaries and through strategic monitoring programmes).
Rainfall and weather data through EA or Meteorological Office

Sediment Survey

Method Description	
Purpose	To identify the physical and, in some cases, chemical characteristics of sediment in a water body.
Experience	Experienced (sedimentologist or geomorphologist).
Time	2 days per 5km for sample collection; 3 days for laboratory analysis of physical characteristics; 5 days for laboratory analysis of chemical characteristics.
Applicability	• Applicable to all types of water body. • A sediment survey can be undertaken at the micro, meso and macro scales. • Can be undertaken on a one-off basis, or repeated as part of a wider investigation of morphological dynamics.
Method	There are a large number of techniques that are suitable for use in surveying the quantity, quality and general characteristics of sediment in a water body. *Typical Activities:* • Sediment surveys typically involve the physical collection of samples of active (i.e. being transported) or passive (i.e. not actively transported) sediment from a water body. Active sediments can be collected from suspension, or the bed of the water body using appropriate samplers. Passive sediments can be collected *in situ* using a variety of standard sampling techniques. • The physical characteristics of sediment can be determined using particle size analysis. Here, individual grain size fractions are separated, using manual techniques for large particles (i.e. cobbles and larger) and dry or wet sieving techniques for smaller particles (i.e. gravels, sands, silts and clays). The proportions of material derived from each size fraction can then be calculated. This can provide information on the likely source of material, and how it is likely to behave when subjected to changing hydrological conditions. • Other physical tests include the measurement of the texture, density, porosity, permeability and strength of a body of sediment. These characteristics are frequently measured under laboratory conditions, and can be used to provide information about the conditions under which the sediment was formed. • Sediment characteristics can also be surveyed *in situ*, using a variety of manual techniques (e.g. manual measurements of clast size and sediment fabric) and new automated methods (e.g. use of digital photography and specialist software to measure sediment size, shape and orientation). • The chemical characteristics of sediment can be determined using a variety of techniques. Standard geochemical analysis methods can be used to measure concentrations of elements of interest (e.g. toxic metals and other inorganic contaminants, and organic compounds such as pesticides and PAHs). These techniques typically involve the collection of sediment samples in the field and subsequent laboratory analysis (e.g. dissolution and measurement using AAS or ICP-MS). Emerging techniques such as hand-held XRF-spectrometry can also be used to measure certain chemical characteristics of sediments *in situ*. *Typical Outputs / Deliverables:* • A detailed understanding of the quantity and quality of sediment in a water body. • Numerical data can be presented in report format, and can also be used to demonstrate spatial trends as part of a GIS.
Success criteria	• The success of a sediment survey is dependant on the type of data that is required. • Accurate sampling and laboratory analysis is required in order to provide high-quality data. • **Recommended minimum:** A sediment survey should cover the area of interest at a minimum. The characteristics to be surveyed are dependant on the desired outcomes of the investigation.

Data and Information *(* essential)*
Existing records and information on sediment characteristics.

Sediment Budget Analysis

Method Description

Purpose	To identify sediment sources, transport patterns and sinks, and establish system dynamics over longer timescales.
Experience	Experienced (geomorphologist or sediment transport modeller).
Time	1 day per 10km to calculate a detailed sediment budget based on archive data, plus additional timing for field measurements if necessary
Applicability	• Applicable to all types of water body. • Applicable at the meso and macro scales (river reaches, catchments, estuaries and coastal cells). • Can be undertaken on a one-off basis, but can be more effective if undertaken as part of a wider investigation of morphological dynamics.
Method	A variety of techniques can be used to determine the quantities of sediment that are being stored, eroded and transported, and thus determine a sediment budget for a water body. *Typical Activities:* • The quantities of sediment being transported and deposited can be physically measured in the field using a variety of sampling techniques (e.g. suspended sediment and bedload samplers, and sediment traps to record deposition). • Physical survey techniques can also be used to measure the amount of sediment that is eroded from bed and banks/beach and accreted in sinks, for example using a combination of topographic survey, cross section, or bathymetry. • Remotely sensed data such as aerial photography and LiDAR can also be used to quantify amounts of sediment erosion and deposition above water; may be limited in areas of intertidal flats. • Measured quantities of sediment erosion, deposition and transport can be used to calculate a detailed sediment budget for a water body. Comparisons with historical data can be used to identify temporal changes in sediment dynamics. • GIS-based analysis using high-resolution DEMs can be used to rapidly quantify erosion or deposition rates and produce a sediment budget with considerable accuracy. • Physical or hydrodynamic modelling (see below). *Typical Outputs / Deliverables:* • A quantitative assessment of the amount of sediment that is being eroded, transported and deposited in a system. May be linked to analysis of the (dynamic) equilibrium form. • These data can be presented numerically, or mapped.
Success criteria	• A detailed understanding of sediment dynamics within a system. • The viability of a sediment budget is dependant on the accurate quantification of the amount of sediment that is being eroded, transported and deposited in a system. • **Recommended minimum:** A sediment budget based on the desk-based assessment of erosion and deposition between two different time periods.

Data and Information *(* essential)*

Ordnance Survey mapping (preferably in GIS-compatible format).
Historical mapping (preferably in GIS-compatible format).
Aerial photography (preferably in GIS-compatible format).
LiDAR (resolution dependant on scale of area of interest – use highest feasible resolution).
Existing records and information on spatial and temporal patterns of morphological development.

Saltmarsh (Physical) Niche Modelling

Method Description	
Purpose	To identify the likelihood of land elevation (compared to tidal levels) being suitable for plant colonisation or not. This can be applied to floodplain areas for assessment of potential habitat (under managed realignment) or existing intertidal areas linked to identified level changes.
Experience	Experienced geomorphologist with Expert direction
Time	2-8 days
Applicability	• Applicable to estuary or sub-estuary scale or to managed realignment sites. • Generally undertaken to identify which areas may be vegetated or not dependant on an action. • Usually linked with other methods to provide a better understanding of system functioning.
Method	Use of cross sectional/topographic data coupled with water level parameters to drive equation based calculations (empirically derived) for different key species of saltmarsh vegetation. *Typical Activities:* • Generation of a bed/intertidal surface through use of available data and use or generation of water level parameters. • Calculation of niche levels and projection of these onto the surface; areal extents can then be calculated. • Comparison of results to field observation, or survey records for cross checking. • Re-running the process following projected changes (such as sea level rise), or imposed changes through alteration of the system. *Typical Outputs / Deliverables:* • Assessment of potential for vegetation establishment or survival. • Area extents of saltmarsh versus mud/sand flats. • Maps of potential niche habitat development.
Success criteria	• A report of the potential for saltmarsh plant survival based on level changes in the surface. • Ability to project change that is caused by a project or outwith the project impacts. • **Recommended minimum:** Application to *Spartina* as the broadest elevation range niche species if it is present, application to a mix of species otherwise.

Data and Information Data and Information *(* essential)*
Topographic data (e.g. generated from contour data or LiDAR)*
Tidal elevations (e.g. from Admiralty tide tables)*
Ecological assemblages (e.g. distribution of *Spartina* colonies)*
Information on tidal currents and/or regimes
Salinity data

Geomorphic Dynamics Assessment	
Method Description	
Purpose	To undertake a detailed assessment of the physical characteristics, dominant processes and morphological dynamics of a river system. This approach uses a variety of field-based techniques to gain a detailed understanding of the functionality of the river system.
Experience	Experienced, supported by intermediate
Time	5 days for 1kilometer
Applicability	• Applicable to rivers. • Applicable at the reach scale. • Generally undertaken at selected study sites that are representative of a larger catchment. • Geomorphic Dynamics Assessment should only be undertaken once baseline investigations such as fluvial audit have been completed.
Method	Geomorphic Dynamics Assessment involves a detailed evaluation of fluvial processes, morphological adjustment mechanisms and channel dynamics in a river reach. The assessment builds upon the findings of previous investigations such as catchment baseline studies and fluvial audits. *Typical Activities:* • Direct field-based observation and quantitative measurement of fluvial forms, including high-resolution mapping of channel planform and bed topography. • Measurement of water surface conditions, flow types and velocity profiles in 1, 2 or 3 dimensions. • Measurement of suspended sediment loads and bedload. • Measurement of erosion and deposition rates and processes. • Investigations of bank conditions, hydrology and structural mechanics. *Typical Outputs / Deliverables:* • Fully quantitative data on as many fluvial forms and processes as possible. • These data can be presented numerically, as a written report, and as a series of GIS layers.
Success criteria	• A thorough and detailed understanding of fluvial forms and processes in a river reach. • Ability to extrapolate reach-scale observations to wider stretches of the river system. • **Recommended minimum:** A Geomorphic Dynamics Assessment is a highly detailed investigation that should encompass all feasible forms and processes (see above). There are therefore no recommended minimum requirements. **See Defra (2003) Applied Guidebook of Fluvial Geomorphology**
Data and Information *(* essential)*	
Ordnance Survey mapping (preferably in GIS-compatible format)*	
Historical mapping (preferably in GIS-compatible format)*	
Aerial photography (preferably in GIS-compatible format)*	
LiDAR (resolution dependant on scale of area of interest – use highest feasible resolution)	
Hydrological data – flow type, discharge, rainfall	
Substrate conditions – sediment type, particle size distribution	
Existing records and information on river forms and processes in the river catchment*	

<table>
<tr><th colspan="2">Physical Modelling</th></tr>
<tr><th colspan="2">Method Description</th></tr>
<tr><td>Purpose</td><td>To create a scale model of a natural system to simulate responses to changing conditions under controlled conditions.</td></tr>
<tr><td>Experience</td><td>Expert modellers with appropriate scale of facility ranging from flumes to large tanks, usually within universities or applied research institutions.</td></tr>
<tr><td>Time</td><td>Timing dependant on the complexity of simulations and the number required. Should allow at least 1 day for each simulation if reasonably complex</td></tr>
<tr><td>Applicability</td><td>Applicable to all types of water body.
Applicable on the micro, meso and macro scales.
Techniques rely on creating scaled simulations of forms and processes. This may not be applicable for all situations or provide sufficient quantification of magnitudes of morphological change.</td></tr>
<tr><td>Method</td><td>Creation of a scale version of the system under consideration using scaled flows, waves and sediments to provide a facsimile of the natural environment.

Typical Activities:
Flume or tank based experiments which simulate the likely responses of sediment and/or landforms to changes in hydrological conditions (e.g. wave magnitude and frequency, and river flow velocity, turbulence and volume).
Flume or tank based experiments that are used to identify the likely response of a system to the addition of a new structure.
Flume or tank based experiments that are used to simulate sediment movement and flow patterns, for example using coloured sediments or liquid dyes.
Typical Outputs / Deliverables:
Semi-quantitative data that highlights the likely response of a system to changing baseline conditions.
These data can be used to demonstrate relationships that are difficult to measure under natural conditions.
Visual observation (direct by client as well as experts) or video record of process changes</td></tr>
<tr><td>Success criteria</td><td>An understanding of the likely response of a water body to changing hydrological or physical conditions.
Where possible, results should be validated against observed conditions in the field.
Recommended minimum: At least two physical simulations, which represent baseline and changed conditions, respectively.</td></tr>
<tr><th colspan="2">Data and Information (* essential)</th></tr>
<tr><td colspan="2">Topographic data</td></tr>
<tr><td colspan="2">Hydrological data – flow type, discharge, rainfall</td></tr>
<tr><td colspan="2">Substrate conditions – sediment type, particle size distribution</td></tr>
</table>

Numerical and Process Based Modelling for Geomorphology	
Method Description	
Purpose	Use of computer models to simulate physical processes over time and space
Experience	Experienced; level of experience is dependent upon the complexity of the model
Time	Dependent upon complexity of model and required outcome.
Applicability	• Dependent upon desired outcome. • Applicable to all types of water body as a general impression of change but limited where strong cross flows/currents. • Applicable at the meso and macro spatial scales. • Applicable over a wide range of temporal scales (from single flood events or tidal cycles to longer time periods).
Method	A wide range of numerical and process based models are available for use to meet different requirements. Geomorphological models are increasingly used and available. Reviews of these may be found in references: FRMRC (2006) Accounting for Sediment in Rivers; A tool box of sediment transport and transfer analysis methods and models to support hydromorphologically-sustainable flood risk management in the UK Defra (2007) The Estuary Guide
Success criteria	**Required minimum**: An understanding of the likely response of a water body to changing hydrological or physical conditions that is set within documented review of model development and limitations, for example outline in full assumptions made, constraints associated to data quality, boundary conditions. Results should be validated against observed conditions in the field.

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