Draft 18/07/07

pCEA Synthesis: Sediment

S.T. Casper*, O. Jensen#

**Environment Agency, 10 Warwick Road, Solihull, West Midlands*
#ICF International Sardinia House, 52 Lincoln's Inn Fields, London.

4.8.1 Introduction

Sediment is a cross-cutting issue, interlinked with morphological, nutrients and chemicals pressures, and pressures from fisheries. The cross-cutting nature of sediment as a pressure is reflected in its coverage in this synthesis report. Measures relevant for sediment are discussed in the morphology, fisheries and alien species and nutrients chapters. Where possible, this chapter provides information on the likely impact on sediment from the implementation of these measures. Reference is made to information on the costs of these measures in this chapter but is not repeated. Instead, this chapter provides a discussion of the nature and extent of pressure from sediment, summarises the cross-cutting measures and highlights gaps in the existing regime for managing sediment.

One issue that is particularly problematic in terms of sediment management is its varying conceptualisation from potential contaminant to natural substrate to siltation nuisance amongst different stakeholders. This has in part led to the situation wherein there is no specific sediment legislative framework, and few specific requirements, with management tending to be explicitly or implicitly included in other regulatory contexts. Thus the existing approach to sediment management tends to be piecemeal according to the requirements of different sectors, and stakeholders, and is currently not well integrated across the UK or across the Member States of Europe.

Dredging is perhaps, at present one of the most well managed sectors for sediment pressures, partly due to the long-time need for management of dredged material. The disposal of dredged material, though, is handled under waste regulations, rather than any specific sediment regime. Similarly there are some provisions for management of sediment pressures in water, nature, marine and soil legislation, but sediment is not the primary focus of any of this legislation, so there tends to be a loss of coherency in

management. Initiatives such as catchment sensitive farming, salmon action plans, and sustainable drainage systems, can also have a role in managing the various sediment pressures on the environment, and can be very effective at the catchment scale.

Success in managing sediment pressures depends on having a clear characterisation of the pressure, and a framework in which to apply appropriate, possibly multiple, measures. The role and management of sediment as a supportive habitat, as a pollutant in itself, and as a carrier of associated contaminants (such as nutrients and other chemicals) is fundamental to the achievement of WFD chemical status and ecological objectives. However, our understanding of these roles, sediment linked ecological impacts, the effectiveness of measures to reduce these impacts, and timescales for recovery are all very limited.

An integrated approach to sediment will be needed in order to ensure that WFD objectives are met. This kind of approach might increase the efficacy of measures implemented for other pollutants and would reduce the risk that the effectiveness of measures would be less than expected because of a lack of consideration of sediment as a contributory factor. Sediment management will need to consider the economic removal and use or disposal of sediments, the in-situ influence of sediment on ecosystem health and functioning, and appropriate assessment and management of contaminated sediment in all types of waterbodies, and at different geographic scales.

4.8.2 Summary of Sediment Issues

Sediment pressures essentially comprise both quantity and quality issues, and it is essential that both are given consideration. Even uncontaminated sediment can cause pollution. Sediment quantity issues include for example the effects of siltation on fisheries and the need for maintenance dredging of waterways, but it must be recognised that consequences for ecological objectives may arise from insufficient sediment (for example erosion of salt marshes) as well as excess. Appropriate assessment will be essential for determining effective measures.

If pollutants are associated with the sediment, sediment management may be needed in order to deal with the pressure from the pollutant. Regular sediment management techniques such as dredging, may also result in the remobilisation of pollutants. With regard to sediment quality, the interpretation of the daughter directive on priority substances will have important ramifications for the ports and navigation sector in terms of the designation of dredged sediments as ‘clean’ or ‘contaminated’ (as a consequence of the daughter Directive EQS levels). This designation will determine whether dredged sediment can be disposed of by remobiliation or re-use within the aquatic system, can be beneficially re-used beyond the aquatic system, or must be disposed of as waste. This could have implications for the amount of sediment available for beneficial re-use measures, such as augmentation or development of salt marsh (for example as compensation habitat for capital developments), as well as considerable financial implications for sediment disposed of as waste.

Another important issue is the differentiation of sediment by urban and agricultural source environments, and the proportions of inorganic to organic sediment components. Sediment is a highly heterogeneous medium and the characteristics of the different components will behave differently and have different impacts. This will

influence for example the pollutants that are likely to be bound to the sediment, the fraction of sediment likely to be suspended or remobilised as a result of particle size, and the efficacy of measures. For example, in the urban environment there will be inorganic sediment from construction sites as well as organic sediment from sewage works. The specific nature of the pressure must therefore be determined in order to target measures appropriately.

Key uncertainties for sediment as a pressure, include:

- sediment apportionment in catchments by source and by sector;
- characteristics of sediment (in quantity and quality terms) that will provide good habitat for key biological indicators of good ecological status;
- the influence of sediment in linked pressures such as hydromorphological, and chemical pressures (including assessment of sediment for chemical status);
- the efficacy of measures to control sediment delivery and the impacts of associated pollutants; and
- the link between sediment quality and ecological response.

These uncertainties will need to be addressed through further research, or more extensive use of the tools currently available, to increase confidence in the use of appropriate measures to improve ecological status of waterbodies impacted by sediment pressures. In addition, the current lack of sediment monitoring will need to be addressed in order to provide sufficient data to assess some of these issues in catchments.

The effect of sediment quantity on ecology is location specific, so further data collection and monitoring is needed to understand the nature of the pressure and the appropriate response. In this case understanding of the catchment-to-waterbody connectivity is essential in assessing sediment transport routes and delivery, and therefore for determining appropriate types and locations of measures. Measures such as changes in land use, improvements in land management, or interception, may need to be implemented at the catchment level in order to address local pressures. For example, extensive drainage of the upper parts of catchment will increase run-off rates and the erosive power of local streams, leading to increased sediment delivery, and greater loads carried downstream.

4.8.3 WFD Objectives

The WFD objectives for the water environment relevant to sediment are:

- to prevent deterioration in status of water bodies; and
- to aim to reach ‘good status’ in all water bodies by 2015.

For a surface water body to reach or maintain good status, the sediment conditions must be consistent with the achievement of the relevant biological, hydromorphological, and physico-chemical quality elements. An underlying issue is establishing the link between sediment quality/quantity problems and the achievement of good chemical/ecological status. Many of the measures considered in the pCEA aim to achieve specific standards, but for sediment there is still uncertainty about:

- what standards will be set or used beyond that currently available from the Freshwater Fish directive;
- whether there will be standards for bed sediment as well as suspended sediment;

- how the standards might be applied and assessed, for example at local or national scale; and
- the appropriateness of sediment standards.

Most importantly, it must be recognised that sediment conditions vary substantially both spatially and temporally in supporting different types of equally valuable habitat, and that a lack of sediment can be as problematic as an excess. Thus a single standard for sediment quantity applied with a pass/fail criteria is unlikely to be appropriate for all types of waterbodies. Compliance with the standards set for sediment quantity under the Freshwater Fish Directive also does not necessarily mean that ecological objectives will be achieved, because of the complex interrelationships between sediment condition and function and ecological response.

Compliance with chemical standards set for sediment quality should ensure achievement of good chemical status. But it may be very difficult to set single standards because of the tendency for associated pollutants to behave differently in sediment with different proportions of characteristic components such as particle size fractions, inorganic minerals, and organic matter. There is still some uncertainty regarding the potential for indirect knock-on effects of sediment (chemical) quality pressures to biological receptors.

The WFD replaces some existing Directives, and incorporates the objectives and requirements of others so that they are also WFD requirements. For sediment, relevant "protected area" requirements include:

- Freshwater Fish Protected Areas (Freshwater Fish Directive); this directive includes a standard for suspended sediment.
- Natura 2000 sites designated for the protection of habitats and species where the maintenance or improvement of the status of water is an important factor in their protection (Habitats Directive). (No specific standard for sediment).
- Drinking Water Protected Areas (Drinking Water Directive). (No specific standard for sediment).

4.8.4 Standards

Text recently agreed by the Environment Council on standards for priority substances does not include any sediment standards, and although derivation of such standards remains a priority, it is increasingly unlikely there will be any sediment standards for the first round of river basin planning. Waters with large sediment loads could however have the potential to compromise water column EQS standards for lipophillic pollutants where the concentration determined is directly proportional to the suspended particulate material present.

Standards for Suspended Solids (SS) have not, to date, been developed specifically for the WFD, partly because of concerns over the development and implementation of such a standard. Complications arise because of the high degree of spatial and temporal variation in the natural level of SS, and the need for any suspended sediment standard to take account of natural variations in flow, among other factors. The development of standards is also held back by the lack of data for SS, as they are not part of the routine river water analysis suite.

The **Freshwater Fish Directive** sets a Guideline Standard for Suspended Solids (rather than an Imperative Standard). It takes the form of an annual mean concentration of 25 mg/l. Generally it is the Imperative Standards that have attracted action. The type of standard set in the Freshwater Fish Directive, as an annual mean concentration, is almost meaningless for sediment management in the context of the achievement of ecological objectives for WFD because of the aforementioned spatial and temporal variability of sediment, and the need to identify issues of insufficient as well as excess sediment. It is also not the most appropriate for tackling sediment pollution problems such as those caused by occasional events; for example significant run-off from land during storm events. In these cases we may need an approach that is closer to incident management, such as a water quality standard for the 95-percentile. Monitoring might then be targeted at events likely to cause risks. There is therefore a dual need; for standards that tackle sediment as a diffuse pollution issue and define conditions for good sediment habitat supportive of ecological objectives, and a regime that can also manage specific risks.

The former English Nature (now Natural England) has conducted some preliminary work on sediment targets which confirms the inappropriateness of a single sediment standard. The research has shown that different river types need different sediment levels for effective ecological functioning.

A further issue with regard to standards is the distinction between suspended sediment and bed sediment. A sediment quantity standard is expected to apply to suspended sediment, though this will not necessarily directly correlate with bed siltation. It remains uncertain whether sediment quality standards would be applied to bed sediment, suspended sediment, or both.

4.8.5 Extent of Sediment Pressure

The WFD River Basin Characterisation (RBC) process mainly considers the specific sediment pressure in terms of delivery, that is, the siltation risk from sediment quantity in waterbodies. Chemical pressures are considered separately, and not specifically for sediment though it will be a contributing factor.

Siltation quantity pressures include:

- Siltation of spawning gravels
- Siltation and turbidity effects on nutrient cycling and dissolved oxygen leading to eutrophication and reduced oxygen capacity in overlying water
- Impacts on river morphology, which will have knock-on effects to ecology
- Increased flood risk due to obstruction of channels and increased sediment supply
- Adverse effects of insufficient sediment transport resulting in damage to downstream wetlands or increased riverbed erosion
- Changes in aquatic biodiversity and knock on effects to the higher foodchain
- Dredging and disposal of dredged materials

The environmental consequences of suspended sediment entering water bodies are siltation, reduction of light penetration (and hence biological productivity) and oxygen exchange, and smothering and clogging of spawning beds and freshwater habitats. Sediment also has a direct impact on fish by damaging the gills, and on their eggs by binding to the egg surface preventing oxygen diffusion. In addition, chemicals bound to sediments can lead to eutrophication (phosphates) and failures of

chemical standards. Research conducted to identify ecological impacts, such as unexplained fish kills, has identified sediment as a medium in which bioactive toxins accumulate (EA Science Project SC030159), indicating the necessity for full early consideration of the important role of sediments in this context. The increased turbidity associated with silt in the water column can also pose problems for drinking water abstraction in some parts of the country.

At present the evidence base for sediment impacts is patchy, with good evidence for some aspects (e.g. siltation effects on fish spawning gravels), but is very limited evidence for others. Significantly, the sediment evidence base for impacts of sediment on ecological objectives and function, and the effectiveness of measures is insufficient to support WFD, and clearly illustrates the need to develop sediment management tools and strategies. Recent Australian research has demonstrated that catchment-based sediment models can be used to predict zones of high sediment inputs into river systems, which have in turn been used to provide managers with predictive models demonstrating where riparian zone management will have the greatest impact on reducing sediment pressures to rivers. An equivalent approach needs to be developed for the UK.

The Environment Agency does not routinely measure sediment levels, and while levels of 'suspended solids' are quite widely, although not necessarily very frequently monitored, they are often designed to monitor discharges to the river, such as those from sewage works, rather than inputs from the land. This substantially limits our ability to quantify the extent of sediment pressures. Levels of suspended sediment will also not necessarily give a clear indication of the bed sediment condition or the amount of settling versus scouring, as this will depend on hydrological and morphological influences present in a particular location. Importantly, it must be remembered that the *quantity* of sediment by itself will not always indicate the level of adverse impact; it must be taken in the context of the requirements of the habitat or ecological objective, and the sensitivity of the waterbody. Preventing damage to important salmon spawning habitats, and protecting vulnerable saltmarshes will have very different requirements in terms of sediment quantity management.

The River Basin Characterisations and Strategic Assessment provide some indication of the level of risk from sediment impacts, though it has been recognised by both that the lack of sediment data available reduces our confidence in the results. The RBC I assessment used combinations of factors pertinent to sediment generation and transport (e.g. land use, slope, soil type, rainfall) to predict catchments likely to be at risk of impacts of sediment delivery to specific receptors. Although the logic of this process based approach is sound, it represents primarily the risk from land (usually agricultural) derived sediment, and does not consider other sediment sources. Additionally, the lack of understanding of the variation in these processes and their effects, coupled with a lack of data and availability of suitable models resulted in low confidence in the outputs, and the resultant risk map often did not agree with local observations of the importance and impact of sediment. The RBC II characterisation has not attempted to repeat or revise this process approach. Instead it has used the observations of local experts to assess sediment load and impact by a relative scoring system, and combined these into a risk assessment. This has resulted in approximately 30% of waterbodies classified as 'at risk' or 'probably at risk' of sediment impacts, with a further 15% classified as having insufficient data to make the assessment.

Of the 62 salmon rivers in England and Wales referred to in a 1998 Ministerial Direction, 29 are thought to be failing to comply with the Environment Agency's management objective for salmon mainly or partly because of channel structure and siltation issues. The management objective is for a river to meet or exceed its conservation limits for four years out of five. The assessment of failure is based on 2005 data and the assessment of channel structure and siltation as an issue was made by local technical specialists in 2004. Eight of these 29 failing rivers are designated under the Habitats Directive as Special Areas of Conservation (SACs) for salmon and one other is an SSSI for salmon.

Priority should be given to the 29 rivers failing conservation targets especially those failing Habitats Directive and SSSI requirements.

Trends

Changes in the agricultural sector would be expected to have an impact on sediment pressures, including:

- Fewer large herds.
- Reduction in farm numbers.

In addition, urban development, particularly in the South East, is expected to increase sediment pressures from non-agricultural diffuse sources including construction, transport and other urban diffuse sources.

Existing policies and measures will also affect the trend in sediments pressures. These include:

- Environmental stewardship programme.
- Catchment sensitive farming.
- Habitats review of consents: Of the 17 principal salmon rivers in England and Wales, 10 are failing their management objective. For 8 of those 10, channel structure and siltation (sediment quantity/location) are considered to be important issues. Where sediment quality is the issue, consents held by water companies and other industry will be reviewed.

In addition, climate change is also likely to exacerbate sediment pressures through increased numbers of storm events. This trend was identified by the Agriculture, Flood Risk Management, and Navigation and Ports pCEA working groups. Impacts identified included:

- Increases in sediment contamination pressures (siltation) from predicted increases in the intensity and frequency of winter rainfall.
- Increases in sediment pressures resulting in increasing impacts of sediment associated contaminants such as phosphorus.
- Increasing flood risk.
- Changes to dredging requirements, possibly increasing dredging needs.

In addition to these specific climate change related trends, it was noted that changes in policy, as well as emerging policies (e.g. ‘Making Space for Water’), may also alter activities in terms of the technologies or methods employed, and the specific locations that are prioritised for the application of measures.

The navigation group also noted that demand for dredging of inland waterways is increasing, but the amount undertaken is roughly stable due to budget constraints.

4.8.6 Apportionment across sectors

The main sources of sediment quantity pressures are agriculture, forestry and construction. Other sources include mining, aquaculture, diffuse urban pollution and point sources (STWs and combined sewer overflows). In addition, overstocking fish for angling can also cause turbidity by stirring up benthic sediments during feeding. Sediment management issues are relevant to the agriculture, navigation, ports, and flood management sectors.

The evidence may be grouped into that concerned with the sources, pathways and receptors respectively. There are environmental consequences at all three stages but the ecological indicators will concentrate on the receptor and pathways. In order to develop adequate measures that address the problem the sources and pathways need to be understood and data is required on these to provide a baseline from which to assess progress. Fish Farms and other consented discharges have some suspended solids (SS) data that can be fed into models to establish relative loads. Existing fisheries and environmental monitoring programmes review the impact of fisheries on the ecology. Excess siltation can cause flooding of new areas and increase the need for dredging.

4.8.7 Measures by Sector Groups

Sediment was identified as a pressure to be addressed by all of the pCEA sector working groups:

- Water Industry
- Industry
- Agriculture
- Non-agricultural diffuse pollution
- Flood management and Planning
- Navigation and Ports
- Fisheries & Biodiversity

In most cases, the sectors did not have data on the extent of their contribution to sediment pressures. They also could not cost measures precisely because of the lack of clarity on sediment standards. But, they did identify measures and cost information which are likely to be effective in reducing sediment, even if this is not their primary driver.

4.8.7.1 Summary of Relevant Measures

Measures relevant to sediment covered in the Chapter X on morphology include:

- Measures to be implemented by the ports and navigation sector (e.g. development of sediment management plans, changes to sediment management and dredging practices).
- Catchment restoration measures through community-led partnerships and/or catchment restoration funds.
- Measures to protect the riparian zone (including the use of anti-livestock fencing to allow the natural recovery of streams and lakes damaged by overgrazing).
- Removal of unnatural deposits of silt from selected shallow lakes.

- Blocking grips and drains to restore upland wetland source areas.
- Reducing over-stocking of fish.
- R&D to investigate the efficacy of these methods in delivering GES.

Measures relevant to sediment identified in other chapters but not costed include:

- Schemes to reduce sediment input to lakes from transport, such as diverting road drains and creating settlement ponds.
- Changes to land drainage consents.

Measures covered in Chapter X on nutrients are also likely to have a positive impact on reducing the pressure from sediment. These include:

- Measures to reduce nutrient discharges from agriculture (e.g. Water Protection Zones).
- Measures to reduce nutrient discharges from point sources (e.g. sewage treatment works).
- Measures to reduce a range of pollutants from urban diffuse sources (e.g. measures to deal with misconnections and misuse of sewers).

Fisheries/Aquaculture

The Fisheries and Biodiversity chapter suggests that reductions in fish stocking will reduce suspended sediment pressures in lakes. Otherwise, the chapter suggests that the fisheries and aquaculture sectors are already adequately regulated to meet WFD requirements. However, the chapter identifies the need for 'WFD-proofing' of existing fisheries controls. In the UK there are a number of legislative mechanisms to reduce the environmental impact of fish farming. Discharges are consented and the location of farms is regulated. These are detailed in Chapter X on fisheries and alien species.

4.8.7.2 Synthesis of Sediment as an Issue from Sector Groups

The sector groups contributing to the discussion of measures in relation to sediment include agriculture, flood defence, and navigation and ports. The water industry and industry groups did not have information on measures and costs in relation to sediment, though this should not necessarily be taken to mean that there are no relevant sediment pressure issues from these sectors. The non-agricultural diffuse water pollution (NADWP) report and recent Defra consultation on Hydromorphology also contain relevant information in relation to sediment pressures.

The groups did not specifically cost measures to reduce pressures from sediment. But many of the measures identified to reduce risks from other pressures would be likely also to reduce pressures from sediment. These are discussed in the following sections.

The **agricultural** pCEA working group have identified sediment as a pressure in terms of siltation caused by agricultural activities from all sectors of the agricultural industry (dairy/beef, sheep, pig & poultry, arable, and horticulture). This pressure has been assessed as affecting 76% of agriculture, although there is no individual apportionment across the sub sectors, and is anticipated to compromise the WFD good ecological status (GES) at a local level.

For **flood risk management**, the main sediment pressures of concern relate to dredging activities, and dredge spoil disposal. This sector is also involved in several

activities with morphological consequences, such as shoreline reinforcement, and habitat manipulation (restoration/improvement). These can have knock-on effects for sediment management that must be considered, especially as there is no individual standard for morphology as a supporting element. The main WFD objectives likely to be impacted are GES, GEP (good ecological potential), and no deterioration as a result of new developments. Other directives may also have an impact, for example the requirement for the protection of designated sites or replacement of habitat lost through coastal squeeze for the Habitats and Birds Directive.

The main interests of the **navigation and ports** group for sediment management are dredging activities and the disposal of dredgings. But they do recognise other pressures such as abstraction/water supply may have physico-chemical impacts on suspended sediment. Some efficiencies are assumed to take place from resulting synergies with particularly the agricultural and flood risk management sectors. This group thought that WFD implementation should help to reduce inputs of sediment to navigable water bodies, but that there was still a need to deal with the legacy of sediment run-off.

4.8.7.3 Measures by Sector

Agriculture

The measures considered and costed for the agriculture sector are based on combinations of measures drawn from the Catchment Sensitive Farming User Manual. The measures in this manual are shown in Box 1. Some of these are particularly relevant for sediment. In a Defra conducted review of the first year of the CFS programme there was only limited evidence on the take-up of these measures by farmers that could be analysed. It remains necessary to see whether farmers are taking up the sediment-relevant options and whether an additional regulatory approach (such as Water Protection Zones) might be needed to ensure that sediment standards are met in addition to nutrients standards.

Many of the CSF User manual measures given in Box 1 are likely to have an impact on sediment. Those considered most relevant for sediment management include measures 1-16 in the land use, soil management, and livestock management categories, and measures 39-44 in the connectivity management category. It is difficult to say which of these might have the biggest impact for sediment, or which are the most cost effective without further research in some of these areas, particularly where measures may represent significant change, such as the conversion of arable to grassland. More relevant perhaps is the analysis of measures taken up to reduce other pressures, which may have benefits for sediment at no additional cost, and targeting uptake of other sediment measures to reduce the impact of specific issues. Measures in the connectivity management category are likely to be good candidates for reducing sediment pressures by virtue of breaking the source-pathway–receptor pollutant linkage for both sediment and associated contaminants.

Box 1: Catchment Sensitive Farming User Manual Measures

Land use

1 Convert arable land to extensive grassland

Soil management

2 Establish cover crops in the autumn
3 Cultivate land for crop establishment in spring rather than autumn
4 Adopt minimal cultivation systems
5 Cultivate compacted tillage soils
6 Cultivate and drill across the slope
7 Leave autumn seedbeds rough
8 Avoid tramlines over winter
9 Establish in-field grass buffer strips
10 Loosen compacted soil layers in grassland fields
11 Maintain and enhance soil organic matter levels
12 Allow field drainage systems to deteriorate

Livestock management

13 Reduce overall stocking rates on livestock farms
14 Reduce the length of the grazing day or grazing season
15 Reduce field stocking rates when soils are wet
16 Move feed and water troughs at regular intervals
17 Reduce dietary N and P intakes
18 Adopt phase feeding of livestock

Fertiliser Management

19 Use a fertiliser recommendation system
20 Integrate fertiliser and manure nutrient supply
21 Reduce fertiliser application rates
22 Do not apply phosphorus fertilisers to high phosphorus index soils
23 Do not apply fertiliser to high-risk areas
24 Avoid spreading fertiliser to fields at high-risk times

Manure Management

25 Increase the capacity of farm manure stores
26 Minimise the volume of dirty water produced
27 Adopt batch storage of slurry
28 Adopt batch storage of solid manure
29 Compost solid manure
30 Change from slurry to a solid manure handling system
31 Site solid manure heaps away from watercourses and field drains
32 Site solid manure heaps on concrete and collect the effluent
33 Do not apply manure to high-risk areas
34 Do not spread farmyard manure to fields at high-risk times
35 Do not spread slurry or poultry manure to fields at high-risk times
36 Incorporate manure into the soil
37 Transport manure to neighbouring farms
38 Incinerate poultry litter

Connectivity Management

39 Fence off rivers and streams from livestock
40 Construct bridges for livestock crossing rivers and streams
41 Re-site gateways away from high-risk areas
42 Establish new hedges
43 Establish riparian buffer strips
44 Establish and maintain artificial (constructed) wetlands

Defra Interim review of Entry Level Stewardship (April 2006)[1] found that the most popular options among those entering ELS were hedge, ditch or hedge and ditch management, protection of infield trees in grassland, field corner management on arable land, permanent grassland with low or very low inputs, and all four management plans. The options with low uptake (less than 5% of agreements) included stone-faced hedgebank management, most options to protect archaeological features, buffer strips on intensive grassland and around ponds, wild bird seed mix or pollen and nectar mix on setaside, beetle banks, skylark plots, conservation headlands

[1] http://www2.defra.gov.uk/research/Project_Data/More.asp?I=MA01028&M=CFO&V=CSL

and uncropped cultivated margins on arable land, all options to encourage a range of crop types, options to protect soils, and most grassland options.

Measures to achieve sediment targets are currently likely to be taken through the application of other policy measures, particularly those employed to tackle phosphorus causing eutrophication in freshwaters. This will result in benefits for sediment at no extra cost, generating savings and efficiencies through this dual approach, but risks not addressing all relevant sediment issues. These additional benefits for sediment from the implementation of phosphorus reduction policy options are estimated to be in the region of £56.3m-£59.6m for the lower band and £75.0m-£97.4m for the upper band depending on the exact nature of the policy option (WPZ48, WPZ48 + ECSFDI scheme, or WPZ48 + ECSFDI scheme + advice).

The measures considered included economic, supportive/voluntary and regulatory, but it was felt that the regulatory option was likely to give the most certainty in closing the gap in achieving WFD targets. Tradeable permits were thought likely to be ineffective because of the spatial variation of sediment problems as well as not being cost-effective, and the supportive/voluntary options (English Catchment Sensitive Farming Delivery Initiative (ECSFDI) and Environmental Stewardship) raised concerns in terms of the take-up of options likely to bring benefits for sediment. The regulatory mechanism considered was the use of Water Protection Zones (WPZs), allowing specific problem areas to be designated, so that the required standards can be achieved.

Specific mechanisms for phosphorus with benefit for sediment include:

- Implementation of water protection zones.
- Increased number of water protection measures under the environmental stewardship scheme.
- Extension of the ECSFDI across the entire country.

Clearly measures which reduce initial phosphorus loading to land, or strategies which reduce specifically the likelihood of phosphorus run-off to water courses (such as varying application times) may not necessarily reduce sediment runoff to rivers at critical times of the year, or the annual sediment loading to waterbodies.

Flood Risk Management & Coastal Defence

Most of the measures considered by the group are not specifically for sediment management, but a number are related including:

- Use of natural processes and monitoring (e.g. use of natural attenuation, and monitoring impacts of pressures).
- Modifying/removing/building structures (e.g. removal, softer engineering, channel modification).
- Restoration/remediation/re-creation (e.g. creating habitat, re-instating features).

The main consideration in application of these measures is an understanding of their probable effectiveness, and appropriate strategic location in the catchment for maximum ecological benefit, neither of which is currently well understood. Expensive measures with little of no evidence of their effectiveness could result in wasted money and conflict with wider flood risk and conservation objectives.

Navigation & Ports

There is already a substantial amount of regulation relating to dredging activities and the disposal of dredged material. More recently this has included an increasing emphasis on retaining sediment within the natural system through, for example, the Habitats regulations, maintenance dredging protocol, and FEPA consent requirements, and an increased impact of waste disposal legislation on the disposal of dredged material. The proposed Marine Bill will also extend regulation to all forms of dredging while the UK marine SACs project has highlighted voluntary good practice measures, and some ports are developing EMS schemes.

Appropriate sediment related measures for this sector include:

- Reducing the need to dredge by
  i) Modifying navigation management
  ii) Source control (tackling sources of diffuse supply, bank rehabilitation, and point sources)
  iii) Sediment trap and flow control structures for sediment transport
  iv) Timing of operations
- Developing and implementing a dredging and disposal strategy (or modifying existing strategies)
- Use of appropriate techniques to reduce the impacts of dredging, for example,
  i) dredging methods (e.g. suction dredging to reduce turbidity),
  ii) habitat creation (strategic placement),
  iii) choice of location for dumped dredgings

  i.e. Constrain or modify dredging or disposal techniques and consider beneficial re-use of dredged sediment.
- For existing reclamation, structures, measures considered to be potentially effective and widely applicable for sediment management include:
  i) sediment bypass,
  ii) beneficial placement and
  iii) other habitat enhancement.

Urban Diffuse Pollution

Relevant measures considered by the NADWP group which could have an impact on reducing pressures from sediment:

- Misconnections (range of measures form awareness raising to regulatory measures e.g. ban on households doing their own plumbing and the institutional changes to improve awareness and provide incentives for local authorities to use their powers to address misconnections).
- Misuse of sewers and drainage (range of measures ranging from awareness raising, voluntary codes of good practice, General Binding Rules (GBRs) for wet trades, heating firms and registration of wet trades operators).
- Sustainable Drainage Systems (SUDS).
- Commercial, institutional and industrial site management (Range of measures from awareness raising and voluntary initiatives to GBRs).
- Construction site management (Range of measures from awareness raising and voluntary initiatives to GBRs).

No specific measures were considered for the transport sector, for which the SUDS approach would be relevant.

The group developed indicative costs for these measures but given the innovative nature of the measures and poor understanding of apportionment and pathways of pollutants in the urban environment, the group was not able to assess the effectiveness of the measures in terms of reduction in pressures.

Table 1: Summary of costs for selected measures:

Misconnections	EAV (England + Wales)
Awareness raising/training	£1.75mn
More monitoring in current regime	£235mn
Institutional change	Cost neutral
Misuse of sewers	
Awareness raising/award schemes	£490,000
GBR for heating firms and wet trades	£3mn
Registration	£49.5mn
Construction site management	
Surface water management plan	£46mn
GBR	£34mn
Awareness raising	£2.5mn
Pollution prevention work	£6.2mn

SUDS would be expected to be an effective measure in reducing urban sediment run-off. The following estimates were made in the NADWP report for urban roof run-off only. Like the other NADWP measures, SUDS is a measure that would reduce a range of pressures, including sediment. When considering the costs of SUDS, we should therefore take into account their likely effectiveness in reducing a variety of pressures.

Year	**TSS 000's tonnes**			
	England		**Wales**	
	To Water	**Removed by SUDS Low – Medium - High**	**To Water**	**Removed by SUDS Low – Medium - High**
2005	2800 / 81000 / 166000	890 / 48600 / 137800	180 / 5100 / 10600	60 / 3050 / 8800
2015	2900 / 83900 / 172000	930 / 50300 / 142800	185 / 5400 / 11000	60 / 3250 / 9100
2021	3100 / 89700 / 184000	990 / 53800 / 152700	200 / 5700 / 11800	65 / 3400 / 9800
2027	3200 / 95600 / 189000	1020 / 57400 / 156900	210 / 6100 / 12100	65 / 3650 / 10050

The NADWP report developed the following costs for SUDS:

Table 0-1 Costs of SUDS, exemplary (expected life time 50 years)

Element	**Description**	**Effectiveness****	**Investment**	**Investment costs**	**Maintenance**	**Maintenance costs** (£ per year)
Permeable surface	200x500m, high maintenance required, economies of scale factor: 0.75		Infrastructure	£3,543,839	Annual high-level maintenance	£ 645
			Planning/design	15% of Infrastructure cost	Intermittent maintenance cost (every 25yrs)	£ 2,967,000
			Construction overhead	15% of Infrastructure cost		
Filter strips and swales	Mentioned in DTI/CIRIA (2001), no cost information found in UK WIR	70-90%	No economies of scale	£ 15k to £ 40k*)		£ 350*
Infiltration devices	7,500m x 0,75m wide x 0,85m depth; economies of scale factor: 0.75	80-90% except Cu	Infrastructure	£ 234,174	Annual high-level maintenance	£ 1,060
			Planning/design	15% of Infrastructure cost	Sediment removal (1x per 10yrs)	£ 3,840
			Construction overhead	15% of Infrastructure cost		
			Land purchase	£ 1,125,000		

Element	Description	Effectiveness**	Investment	Investment costs	Maintenance	Maintenance costs (£ per year)
Basins and ponds	27,000 m^3 attenuation volume, 26,000 m^3 water quality volume; economies of scale factor: 0.75	60-90% except Cu and Pb	Infrastructure	£ 394,495	Annual high-level maintenance	£ 3,990
			Planning/design	15% of Infrastructure cost	Intermittent maintenance cost (every 4 yrs)	£ 22,000
			Construction overhead	15% of Infrastructure cost	Sediment removal (per 10 yr)	£ 4,160
			Land purchase	£ 5,777,740	Vegetation replacement (per 25 yr)	£ 12,000
					Construction sediment removal	£ 3000
Reference information traditional systems						
Gully/Pipe/Kerb systems		10-30%	Construction	£ 180-220k	Annual or 6-montly cleaning	£ 1,000

Sources: UKWIR, chapter 8, and *) Department of trade and industry & CIRIA (2001), Sustainable urban drainage systems, best practice manual for England, Scotland, Wales and Northern Ireland
* Source: Groundwater in the Urban Environment, by John Chilton et al., 1997, p. 135
** Source: DPI SUDS monitoring project, by Tom Wilde, SEPA, 2001, p. 4

Construction was one of the sectors highlighted in the apportionment section as contributing to sediment pressure. The NADWP group considered a range of measures to improve construction site management.

Sediment Quality

Sediment quality issues from priority and priority hazardous substances are a potentially serious risk to chemical status, and thus overall good status. The extent to which it will be necessary to address sediment quality issues directly will depend on the interpretation of the daughter directive. Costs associated in reducing pressures from these chemicals are covered in Chapter X.

4.8.8 Areas of Uncertainty

Key areas of uncertainty with regard to sediment pressures are detailed in this section.

- For sediment/siltation effects, it is understood that under the WFD there will not be a national standard for sediment, but rather that local assessments will be made. This will make it very difficult to estimate any gaps under the low reference case for achieving WFD objectives. Further investment is needed for research on water quality to look at the effects of water connectivity in the catchment, the impacts of sediment stores, and the effectiveness of mitigation measures.

- There is currently insufficient progression of the relevant science to determine when mitigation methods are likely to result in environmental outcomes; that is, there is a lack of certainty relating to cause and effect. Although measures might be in place to achieve the WFD standards, these may not actually be achieved until potentially some years later. For example, the main uncertainty surrounding the cost effectiveness of measures to reduce phosphorus is in the time taken for changes in farmer behaviour to translate into environmental benefits and reduce loads in rivers. Thus, there is a need for research targeted at improving understanding of pressure-response, and the effectiveness of measures, and investment in pilot and monitoring schemes to fill this gap.

In many cases, because the scientific evidence base is weak regarding the effectiveness of measures, this uncertainty is likely to rule out costly measures for at least the first round of River Basin Planning (RBP 1).

- Uncertainties on the effectiveness of measures also includes site specific characteristics, the effect of climate change on implications for sustainability, implications of new regulations such as the Marine Bill, and the level of benefit delivered by other mechanisms, e.g. through the Habitats Directive.

- For flood risk management, there is additional uncertainty in cost effectiveness in that ongoing and minor capital costs are difficult to estimate, and can be highly site specific while increased costs associated with different methods of delivering an activity e.g. dredging are rarely captured.

Measures to reduce uncertainty:
As for many of the other pressures covered in this report, some of the measures likely to be most cost effective are those that seek to reduce uncertainty, such as research and pilot projects.

Research is needed in the following areas:

- Improving identification of sediment pressures in the catchment.
  - Developing approaches to characterise source apportionment of sediment pressures.
  - Better evidence of the sediment pressures, for example for urban sediments, such as a current baseline.
  - Understanding of the connectivity of waterbodies in the catchment, from headwaters to the coast, and the impacts of change in one waterbody/river stretch on those connected to it (e.g. downstream reaches).
  - Developing tools for diagnosing sediment issues and impacts in catchments – for example in terms of indicator species, and genomics.
  - Developing and implementing appropriate sediment standards and/or ecological indicators of good sediment habitat/supportive functioning.
  - Influences of climate change on sediment transport in catchments and appropriate management for different hydrological/climatic regimes. Tools to determine probable changes in rainfall frequency, duration, intensity etc, and associated changes in antecedent soil conditions (e.g. more friable soils etc).

- Reducing uncertainty through improved data collection and use.
  - Development of cost effective methods for monitoring sediment quantitatively.
  - Identification of the needs for sediment monitoring and modelling in relation to the development of catchment management strategies. For example, where, and how often we need to monitor for different catchment types, and how to deal with temporal effects in monitoring to ensure realistic representation of catchment dynamics.
  - National scale assessment of sediment quality conditions in waterbodies, and development of risk assessment/vulnerability tools.

- Developing better evidence for the effectiveness of measures.
  - Understanding the links between morphological, hydrological and sediment processes and pressures, and consequent impacts on receptor ecology, including invertebrates, vertebrates and plant species (from both sediment quantity and quality perspectives).
  - Understanding of the spatial and temporal complexity of sediment issues and recovery timescales.
  - Understanding the relative impacts of both coarse and fine sediment in key sediment processes in the catchment.

- Developing integrated catchment management strategies.
  - Developing approaches to manage multiple sector pressures.
  - Understanding the catchment scale influences of sediment transport (e.g. downstream impacts), and ways in which land management and sediment management must be linked for effective catchment management.
  - Understanding the influence of land management of organic carbon on soil physical stability and sediment processes and impacts – how crop management will influence in-stream effects.

Testing and monitoring in the following areas would allow further measures to be targeted effectively:

- Establishment of a multi-organisation integrated sediment management group to co-ordinate information collection and analysis.
- Monitoring of the effectiveness of catchment sensitive farming programme implementation on reducing pressures from sediment.
- Monitoring of the effectiveness of NADWP measures in reducing sediment discharges in urban areas.
- Monitoring of the effectiveness of improved sediment management measures by the navigation sectors on pressures from sediment in TRAC areas.

Measures to reduce uncertainty identified in the morphology chapter of relevance here are:

- Further testing and monitoring the effects of livestock fencing, grip blocking, tree planting.
- Learning from the strategic documents produced under the 'maintenance dredging protocol' by navigation authorities.
- Piloting and researching river restoration techniques that do not at present have demonstrable impact on the relevant WFD quality parameters.

Establishment of an integrated sediment management regime will be important to overcome the existing lack of coordination in this area and to ensure that the pressure is tackled effectively.

4.8.9 Conclusion

Probably the biggest challenge facing management of sediment pressures is the lack of available data and robust scientific evidence base. This limits our ability to assess risk to the achievement of good status for the WFD, reduces confidence in the effectiveness of measures and therefore our ability to influence the uptake of such measures, and compromises our ability to effectively manage sediment pressures (quantity and quality) in catchments.

There are considerable cost-benefit gains to be made for sediment pressures through the use of measures to manage other pressures such as nutrients, chemicals, and morphology. However, it is unlikely that these will be sufficient in themselves to manage the range and level of existing sediment issues. An integrated cross-sectorial approach to sediment management is also needed in order to avoid the problem of addressing a pressure in one location, only to create another somewhere else, for example through downstream impacts.

Recommendations:

1) The lack of evidence probably rules out the introduction of costly measures for RBP1. The effectiveness of current measures for sediment, their level of uptake, and the benefit to sediment from other measures should be closely monitored and assessed during the RBP1 process.
   Targeted influencing for increased voluntary uptake of sediment measures in priority areas should be considered.

2) Improvements in achieving targets in the RBP2 process will depend on **immediate support** for the development of better data and evidence, particularly in the areas of:
   - improving identification of sediment pressures in the catchment;
   - reducing uncertainty through improved data collection and use;
   - developing better evidence for the effectiveness of measures; and
   - developing integrated catchment management strategies.

   (For additional detail relevant to these broad areas for research and development, see section 4.8.8).

3) Further specific measures for sediment, and powers for implementation should be considered for RBP2.

Acknowledgement.
Thanks go to all those who have contributed to, or commented on, this chapter.