Sediment Management at the River Basin Scale

Synthesis of the SedNet Work Package 2 Outcomes

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Introduction

For a long time, scientists have recognised that the movement of water and sediment are controlled to a large part by hydrological and geomorphological processes which themselves operate within the context of a river basin. The shape and characteristics of the river basin control the pathways and fluxes of water and sediment. From a management perspective, the river basin also represents a meaningful and convenient scale with which to address water and sediment management. Important issues associated with sediment management at the river basin scale were discussed by SedNet Work Package 2 at a series of workshops between 2002 and 2004. The minutes of these workshops can be found on the SedNet website: <http://www.sednet.org>. Some of the main outcomes are described below.

1 Conceptual Mapping of the River Basin

By considering the river basin as the prime unit of sediment management means that it is necessary to identify the various environments within a basin. Examples of these environments include:

- land (i.e. soils);
- river channels;
- lakes and reservoirs;
- floodplains;
- estuaries and harbours; and
- the coastal zone.

In this context, it is useful to recognise that typically >80% of the surface area of a river basin is *land*, and <20% is open surface water (e.g. rivers, lakes, reservoirs etc) and this obviously has important implications for the management of water and sediment.

To date, many of the environments within a river basin have been managed in relative isolation. However, these environments are interconnected, such that the alteration of one will have likely impacts on other environments. Thus to effectively manage sediment at the river basin scale it is necessary to identify the environments present and establish the interconnections between them in terms of water and sediment fluxes.

An important component of the conceptual mapping of a river basin for the purpose of sediment management is to identify the main sources of sediment and associated contaminants and the processes that control their transfers within the river basin.

Sediment and associated contaminant sources may take one of two general forms:

- point sources and
- non-point (or diffuse) sources

and each of these types poses specific problems regarding identification and management. Point sources of sediment and pollution are those sources originating from a single location, and as such are often readily identified. Furthermore, such sources are generally easily controlled and monitored. Non-point (diffuse) sources of sediment and contaminants are those originating from a wide area. As a result the identification, and in particular the control, of these sources presents much more of a challenge to sediment management. However, given the high level of success in controlling point sources of sediment and contaminants, these non-point sources are now recognised as requiring the most effort for identification and control.

Fig. 1 identifies the main pathways by which sediment and contaminants are delivered to rivers. **Table 1** lists some of the main types and sources of contaminants often associated with sediments.

Once we have identified the main environments within a river basin, the sources of sediment and contaminants, and the pathways and processes that control the movement of sediment and contaminants within the river basin, it is then possible to establish a conceptual river basin model.

In addition, most river basins in Europe are populated and thus there are many users and uses of sediment within a basin. Again, these different users and uses need to be iden-

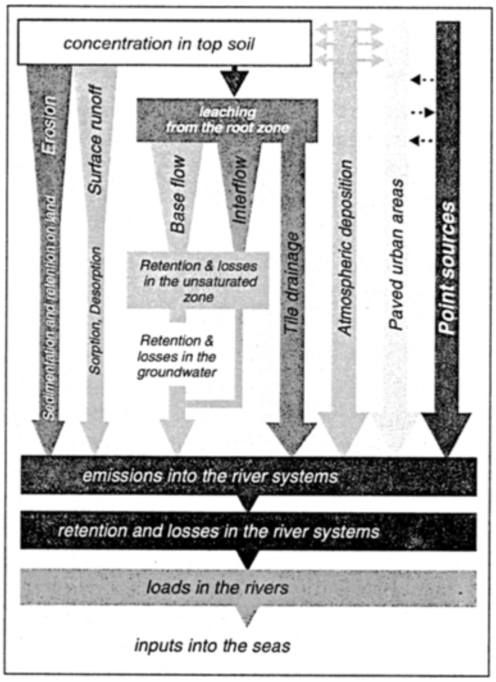

Fig. 1: Main point and diffuse sediment and contaminant pathways (from Behrendt et al. 2000, Vink 2002)

tified and conceptualised and **Fig. 2** provides a schematic representation of some of these. This also introduces the need to identify the relevant stakeholders within a river basin and to involve them in the decision-making process for managing sediment.

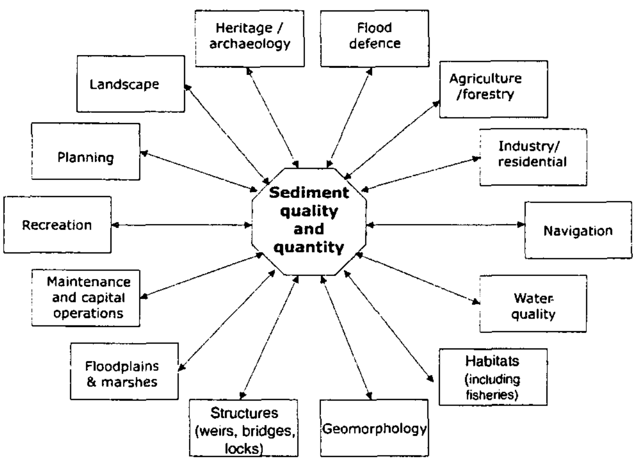

Fig. 2: Some of the many uses and users of sediment in a river basin

2 The Use of Tools to Provide Data and Inform Decision-Making

In establishing a conceptual river basin model which also identifies the uses and users of sediment within a river basin there is a need to assemble the necessary information in order to inform the decision-making process. There are a variety of tools available for scientists and managers to use for sediment management. These tools can be divided into several groups:

- measurement and monitoring tools for assembling information on sediment-contaminant processes and dynamics;
- physical and mathematical models;
- decision support systems (DSS);
- risk assessment; and
- (societal) cost-benefit analysis.

The information obtained from each of these types of tools is different and complementary, and each type can be considered part of a sequential process of decision-making.

The first group (measurement and monitoring tools) primarily provide information and data on how the sediment-contaminant system behaves. Such information is needed because:

- It tells us the source of the sediment and contaminants;
- It tells us how much is being transferred (fluxes);
- It provides us with an understanding of how the sediment-contaminant system behaves and functions at a variety of scales from particle interactions up to the river-basin scale;
- It provides baseline values and temporal trends in system behaviour and response; and
- It informs decision-making for sediment managers and assists with policy-making.

An additional need is that such information and data are required by models and DSS.

There are a large number of measurement and monitoring techniques and tools. Some of these are listed in **Table 2**. Each of these has strengths and limitations. It can be argued that there is probably a sufficient 'toolbox' to be able to provide most of the information and data needed to make informed management and policy decisions. It is likely, however, that these tools and techniques are not being used in the most appropriate and cost-effective way. In addition, there is a lack of integration between scientists and sediment managers, which means that appropriate state-of-the-art tools are not being used by managers, and also that scientists may not be collecting the right type of information for sediment managers.

Models represent one of the most useful types of tool available to scientists and managers as they can provide represen-

Table 1: Examples of sources of sediment and associated contaminants to river basins

Material	Sources
Sediment (organic and inorganic)	Erosion from rural, agricultural and forested land, channel banks, urban road dust, STW solids, atmospheric deposition, inputs from tidal areas and coastal zone (during flood and ebb tidal cycle)
Metals (Ag, Cd, Cu, Co, Cr, Hg, Ni, Pb, Sb, Sn, Zn, As)	Geology, mining, industry, acid rock drainage, sewage treatment, urban runoff
Nutrients (P, N)	Agricultural and urban runoff, wastewater and sewage treatment
Organic compounds (pesticides, herbicides, hydrocarbons)	Agriculture, industry, sewage, landfill, urban runoff
Xenobiotica and antibiotics	Sewage treatment works, industry, agriculture
Radionuclides (^{137}Cs, ^{129}I, ^{239}Pu, ^{230}Th, ^{99}Tc).	Nuclear power industry, military, geology, agriculture (secondary source)

Table 2: Measurement and monitoring techniques and tools used to identify and quantify sediment and contaminant sources and transfers in river basins

Direct	In-direct
River gauging	Remote sensing including digital photogrammetry
Sediment/turbidity monitors	Historical data and surveys
Chemical monitoring	Biological assessment
Sediment sampling • automatic river water samplers • sedimentation tube sampler • Helley-Smith sampler • net and basket samplers • buckets and pit traps • vortex bedload sampler • conveyor belt bedload sampler and sediment analysis	Tracers and fingerprinting techniques including: • colour; • magnetic tracers; • radionuclide tracers; • geochemical tracers; • organic tracers; and • N and C isotopes.
Bank erosion pins/stakes/PEEPs	Sediment in depositional environments (reservoirs, lakes, floodplains, river dead zones)
Temporal assessment of landscape changes	

tations of sediment fluxes and transfers in rivers systems. As such, they enable managers to evaluate different scenarios, including changes in the role of point and diffuse inputs to rivers, and the response of river basins to changes in policy, land use, land management and climate. There are a variety of models currently available, or under development, which include: physically based models, conceptual models, statistical models and regression models, and **Table 3** lists some examples.

One of the main requirements of these models is data, both for running the models and for model validation. Examples of the type of detailed data that many of the models listed in Table 3 require, but are currently lacking, include:

- estimates of soil erosion and sediment delivery from land to waters;
- sediment (suspended sediment and bedload) and contaminant fluxes;
- sediment-contaminant interactions;
- geochemical and biological processes and interactions;
- sedimentation dynamics in rivers (including floodplains), reservoirs and harbours; and
- the amount of gravel abstracted from channel beds and banks.

For most of these, detailed spatial and temporal data are needed. In addition, there is clearly a need for a harmonised sediment measurement and monitoring network throughout Europe to provide the data needed for models and other tools.

Another group of tools that offer great potential for sediment management are Decision Support Systems (DSS). These are computer-based information systems developed to assist decision-makers to address semi-structured tasks in a decision domain. Typically there are three main components within a DSS:

- A user interface enabling easy interaction between the user and the system;
- A database containing the raw and processed data of the domain and the study area; and
- A toolbase (or toolbox) with the methods, techniques and software instruments required to work in an effective manner with the domain models and the data.

The tools discussed above deal with obtaining the necessary information and data needed to characterize the state of the river basin and to evaluate how the river basin may respond to changes, such as those due to changes in policy, land use, climate, or due to interventions of the sediment system through management actions, such as dredging. As such this information is part of the conceptual river basin model and helps to personalise it to a particular river basin. In terms of tools for making decisions and identifying where and when management strategies are to be implemented, risk assessment and cost-benefit analysis are being increasingly used for sediment management decision-making. The former is considered more within WP5, although is clearly important for sediment management at the river basin scale (**Fig. 3**).

Cost-benefit analysis represents a useful tool with which to assess, and ultimately rank, different management options by evaluating the gains and losses for each potential management option. Importantly for sediment management is the need to include socio-economic and environmental (such as ecological) factors and considerations. Central here is the identification and subsequent involvement of stakeholders in this process. (Societal) cost-benefit analysis has mainly been used to a limited extent for sediment management, but has been used extensively for water management (**Fig. 4**).

Table 3: Examples of models used to estimate water, sediment and contaminant fluxes and transfers in river basins

Material	Models
Water	SWAT, TOPMODEL, SHE
Soil erosion/sediment delivery	USLE, EUROSEM, SWAT, WEPP, ANSWERS, Morgan-Morgan-Finney, Sedimentgraph
Sediment (and associated contaminants) transport and deposition	Sedimentgraph, SOBEK, COSMOS, HEC.RAS, HEC6, MIKE 21C DEFT, TELEMAC
Metals	MONERIS
Phosphorus	PIT, PSYCHIC, INCA-P, MONERIS
Pesticides	EXAMS, GLEAMS, AGNPS, MIKE-SHE, POPPIE, SWATCATCH, GWAT

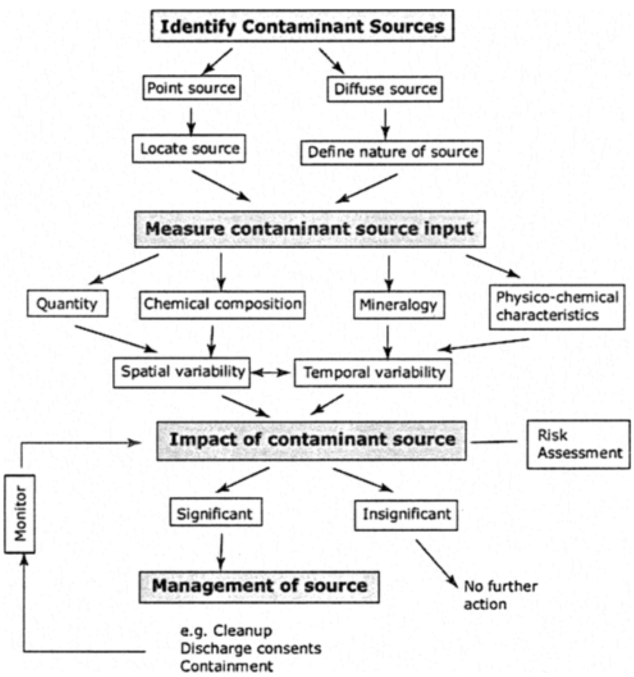

Fig. 3: Suggested steps for the management of contaminant sources to river basin sediments

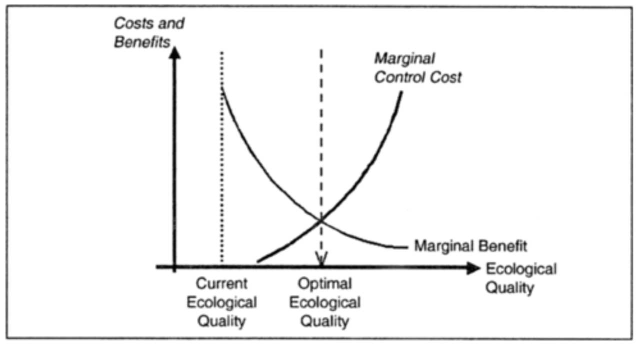

Fig. 4: Cost-benefit analysis theory relating to the comparison of the opportunity costs of improving the ecological quality of the river basin, and the expected increase in the services provided by the water system to the economy

3 Drivers, Policy and Legislation that Relate to Sediment Management

With the recognition that the river basin is likely to represent the best unit for sediment management in most situations, it is important to identify and evaluate the various drivers as to why sediment has to be managed and the scales at which these drivers apply. Such information is an essential requirement if sediment is to be managed effectively at the scale of the river basin.

Historically, sediment has been managed at the local level and the main driver has been a specific local issue such as dredging for navigation, and sediment management in specific reservoirs. Associated with this local level of management are specific existing policy, legislation and guidance requirements. Existing sediment management guidelines, for example, include:

- Conventions for the protection of the marine environment;
- Conventions for the trans-boundary movement of hazardous waste;
- Recommendations for the management of dredged material.

At the national and regional level (such as the EU), then EU policy and legislation is a main driver for environmental management. Although sediment does not have dedicated legislation, it does, however, interface with many other legislative fields (implemented or under construction), particularly EU directives that relate to waste, water and soil (such as the Habitats Directive, Fisheries Directive, Bathing Waters Directive, etc.). With a change in the focus of water policy towards the river basin scale, mainly through the introduction of the Water Framework Directive, there is now a need to recognise and consider not only the WFD (as a driver for management) but also a much broader range of policy and legislative drivers that relate to the different parts of a river basin (land, rivers, coasts etc, also see below).

There is also EU-level policy that relates to soils that is presently under development and consideration within the Soil Thematic Strategy. This is likely to influence sediment management in the future through EU-level policy and legislation which in turn will be converted into national policy. The UK, for example, is already developing policy for soils which recognises sediment as part of the soil–water system, particular in terms of the interface between land and rivers.

The identification and evaluation of the drivers for sediment management at different spatial scales, from local to river basin to EU, and the recognition of the importance and role played by drivers at the global scale, such as global market forces and global climate change, are an important requirement for sediment management.

4 Conclusion

The previous sections have identified some of the important considerations and requirements for sediment management at the river basin scale. In particular, it is necessary to identify and evaluate the:

- relevant stakeholders within a river basin;
- various uses and users that interact with sediment in a river basin;
- various environments within a river basin;
- pathways and fluxes of sediment and water between these environments;
- tools that can be used for assembling the data and information for sediment management;
- options for management so as to select the optimum solution; and
- various drivers (especially legislation and policy) for sediment management.

Scientists have long recognised that the most meaningful unit for understanding water and sediment fluxes within the landscape is the river basin. It is, therefore, promising that water policy in the EU has moved towards this scale for water management. What is perhaps lacking, however, is the recognition of the role of sediment within river basins (especially in terms of its effects on water quality, aquatic ecosystems and human health) and that sediment should also be managed at the river basin scale.

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