European Water Management Online
Official Publication of the European Water Association (EWA)

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A flowchart for sustainable integrated water management following the EU Water Framework Directive

ABSTRACT

This paper proposes an operational flowchart for integrated water management in accordance with the EU Water Framework Directive (WFD), based on identified necessary components for efficiency, participation and legitimacy in environmental management decisions. The flowchart identifies general methodologies for answering these main questions and integrates thereby different types of water and environmental management tasks, including: 1) development of water management plans and action programs, as required by the WFD; 2) environmental evaluation of permit applications for various development projects; and 3) remediation decisions for contaminated land. For these tasks, the flowchart clarifies the same main questions that need to be answered, and the methodology to answer them by quantitative scientific analysis and negotiated agreements among stakeholders. The proposed flowchart also provides a general methodology for operational coordination and systematisation of scientific information and quantification needs and tools in sustainable integrated water management.

Keywords: Water management, Water Framework Directive, Environmental Information Systems, dynamic characterisation, economic optimisation.

INTRODUCTION

Water resources management, monitoring and regulation, as well as relevant research and education are traditionally fragmented between various functions and sectors of society. Agriculture, fishery, industry, transport, energy supply, households, water and sewage plants are examples of such different societal functions and sectors that in various ways influence or are influenced by the chemical, biological, ecological and quantitative water status, water and solute fluxes within and between water systems (such as soil- and groundwater, watercourses and lakes, wetlands, coastal and sea water). Responsibility for monitoring and regulation of these different water systems and actors is commonly divided among a wide range of authorities. It may also be so that none of these authorities has an overall responsibility for coordinating all these fragmented parts and aspects of water management with regard to the long-term sustainability of available water resources.

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The recently introduced EU Water Framework Directive (WFD) [1], further described by e.g. Chave [2], Griffiths [2] and Grimeaud [4-6] aims at reducing such fragmentation in European water management. For this purpose, it introduces and requires physical river basins, rather than any political division, to be the basic water management units within the EU in the future. In addition to the WFD itself, common water management methodologies and tools are presented and discussed within so-called Common Implementation Strategy guidance documents, being a mix of general conceptual frameworks, e.g., the planning process guidance document [7], or very specific technical guidelines, e.g. the GIS guidance document [8].

Already at the initial WFD implementation stage it has been questioned if and how the WFD and corresponding guidance documents will in practise be used and made useful considering the required extensive economic, administrative, regulatory, industrial and municipal resources for its implementation, in combination with an unclear public understanding of what the actual benefits may be from such resource spending [9]. Several recent studies (e.g. [4-6, 10]) also discuss the possible results of the mixed weak and strong legal requirements and ambiguous terminology in the WFD, which may considerably weaken the legal enforceability of the WFD. The fact that many EU countries failed to meet even the first deadline (December 2003) for implementation of the WFD into the national legislation indicates a generally limited commitment to install new authorities and develop and implement the methods and tools required by the WFD. One possible cause for such limited commitment may be a reluctance to spend considerable resources on WFD implementation while important parts of the requirements and benefits of this far reaching directive are unclear to the water management community and public and may even constitute open research fields (e.g., optimisation in environmental economics, large scale water system characterisation, the use of Environmental Information Technology for public participation). There is therefore a need to discuss, develop and apply appropriate methodologies and tools for the future water management cycle and its constituent parts in order to investigate the practical WFD applicability and its possible benefits and difficulties.

The paper proposes a conceptual flowchart for operational implementation of the WFD in order to achieve an efficient integrated water management while allowing for participation and legitimacy in the decision making. We identify and discuss a number of necessary components in such a flowchart and exemplify suitable scientific quantification tools for its implementation. The conceptual framework combines consideration to both ecological and socio-economic sustainability, with focus on water resources, clarifies and integrates a number of different main water management tasks, and formulates necessary main questions that need to be answered for solving these tasks, based on openly shared information, as a basis for negotiations and agreements among stakeholders. This paper presents the general methodological approach as implied by the proposed water management flowchart, without going further into details of specific water quality or quantity problems. Particular exemplification of how such a general flowchart can be applied to a specific water problem is given by the ERMITE Consortium [11] for the specific water quality problem of European mine water management, and by Destouni et al. [12] for specific Swedish water management conditions and problems.

MAIN WATER MANAGEMENT TASKS AND FLOWCHART

Surface and subsurface water may be affected in various ways by past, on-going and planned activities within its catchment, on land or in the water system itself (Figure 1).

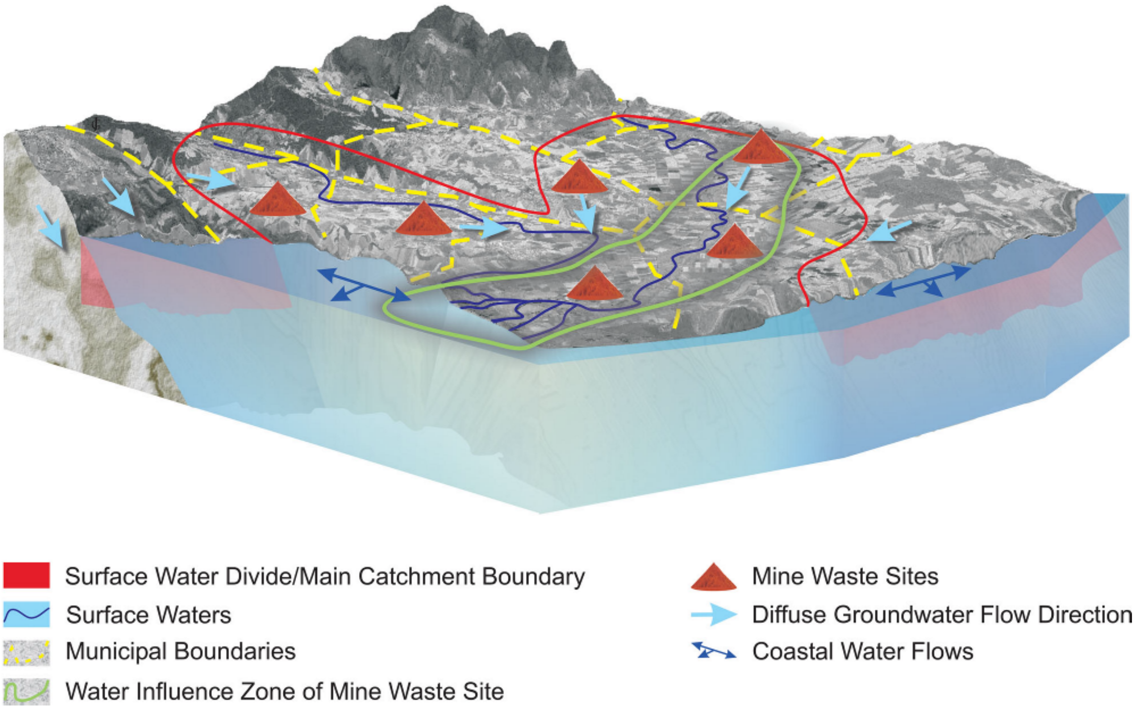

Figure 1. Identification of relevant water system boundaries. Surface and subsurface pathways for flow and dissolved substances originating from agriculture, atmospheric deposition, industrial activities (in this case symbolised as mine waste sites), contaminated urban runoff etc. transport naturally cross administrative boundaries. Dynamic interactions between surface water, groundwater and costal water must be quantified for relevant identification of water system boundaries. Reproduced by permission from ERMITE Consortium (2004).

Examples of present and past water affecting activities are agriculture, abandoned mine sites and waste heaps and industrially contaminated land etc. Planned activities and projects that may affect water resources in the future may for instance be new industrial and infrastructural projects, changed groundwater mining practices, major land use changes etc. All water being affected by such activities, presently or in the future, constitute an integral part of the hydrological cycle and should be managed and regulated based on consistent and coordinated criteria. An often highly fragmented responsibility for different water quantity and quality aspects, however, implies that various water management tasks may be treated separately and without coordination, even though they may have similar impact on downstream waters. Decisions on contaminated land remediation and environmental evaluation of permit applications for new industrial or waste management projects are examples of differently regulated and managed environmental tasks that may affect downstream water quality in similar ways, but may neither be recognised as essential water management problems, nor as problems of similar type. Efficient integrated water management, however, requires recognition and coordinated handling and regulation of all possible different sources that may impact water quality and quantity within a given catchment.

We identify here three, more or less, systematically reoccurring main environmental management tasks that need to be integrated and coordinated from a water perspective, in order to achieve an efficient and sustainable integrated water management:

1) Development of water management plans and action programs, as are now required by the WFD for river basins and their subsurface equivalents, hereafter referred to as catchments.
2) Environmental evaluation of permit applications for various development (such as infrastructural, industrial, agricultural, waste and waste water handling) projects that may impact water resources within a catchment.
3) Remediation decisions for contaminated land that may affect water within a given catchment.

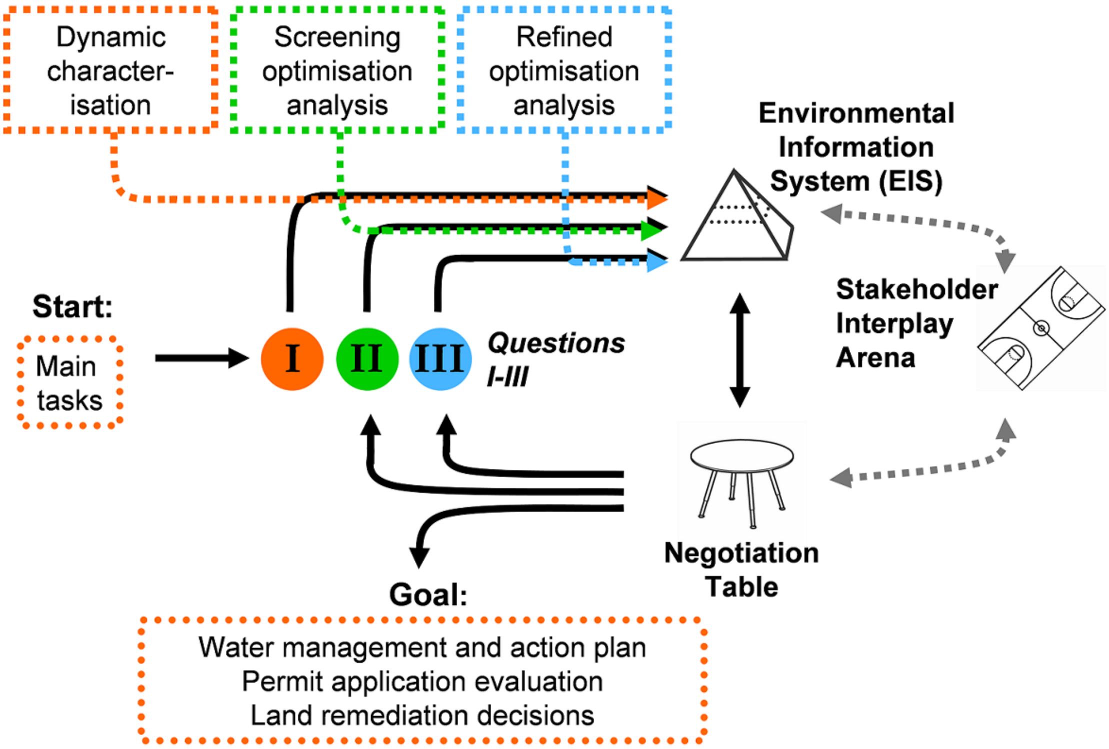

Figure 2. General flowchart for water management decisions involved in *Main Tasks;* 1) development of water management and action plans; 2) environmental evaluation of individual permit applications; and 3) remediation decisions for contaminated land. The three *Questions I-III* need to be answered by using the Negotiation Table (Figure 3), the dynamic characterisation and optimisation analysis (Figure 4), the Environmental Information System (Figure 5), and the Stakeholder Interplay Arena.

Figure 2 illustrates the main methodological flowchart that we propose to use for finding sustainable solutions to all these three main tasks within any considered catchment. The flowchart involves three successive questions; *Questions I, II and III*, which requires an answer for any given water environment within a considered catchment:

I. Does/will the given water environment comply with relevant water environment standards, e.g., in terms of ecological, chemical and/or hydrological status, now and in the future without need for further measures? If the answer is ***yes:*** no action is required for *Main Tasks 1* and *3* and the project application should be evaluated positively with regard to this particular water environment for *Main Task 2*. If the answer is ***no:*** the next step is to answer *Question II*.

II. Are there any (for *Main Task 2*: additional to the ones proposed in the permit application) technologically and/or socio-economically feasible and sustainable measures that can be taken for achieving environmental compliance in the considered water environment? If the answer is ***yes:*** the next step is to answer *Question III*. If the answer is ***no:*** the considered water environment should be classified as heavily modified in *Main Task 1and 3* and the next step is to choose relevant non-deterioration measures by continuing to *Question III;* the permit application should be negatively evaluated with regard to this water environment for *Main Task 2*. If the answer is ***yes***, the next step is to answer *Question III.*

III. Which particular, among possibly several feasible measure allocations or methods identified with regard to *Question II,* should be chosen for compliance with environmental standards, or at least for non-deterioration of the water environment?

Figure 2 illustrates that both a series of quantitative analyses ("Dynamic characterisation", "Screening optimisation analysis" and "Refined optimisation analysis") and an Environmental Information System (EIS) that support these analyses are needed for answering Questions I-III. These types of analyses and their information and quantification tool requirement are described and discussed further in the following section 3. Figure 2 also illustrates that different stakeholders need to meet, discuss and reach sustainable water management agreements on the actual answers to *Questions I-III*. These interactions and negotiations are carried out both at the informal symbolic *Stakeholder Interplay Arena*, standing for all stakeholders actions, interactions and interpretations affecting the water management process outside the formal decision pathways at the symbolic *Negotiation Table* (described further in Figure 3), which stands for the formal forum for discussions and negotiations that must underlie decisions on *Question I-III* in accordance with WFD participatory requirements. Political will, legislation, local and regional economical and other interests and stakeholder interpretations of the EIS and quantitative analyses set the limits for stakeholder discussions, actions and interactions, both at the formal *Negotiation Table* and in the informal *Stakeholder Interplay Arena.*

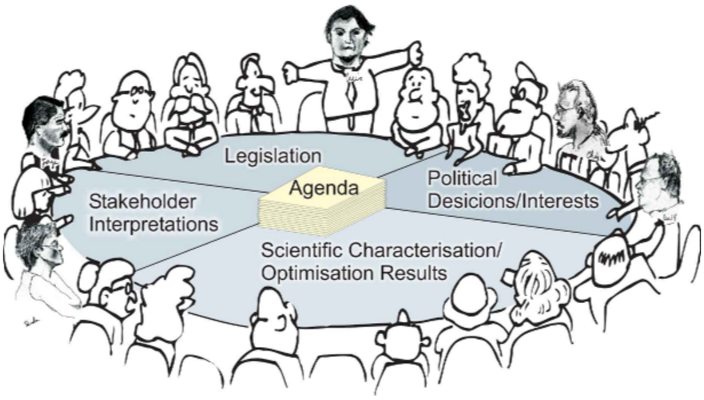

Figure 3. Components of the symbolic negotiation table. It is the formal meeting forum for all stakeholders and public, relevant authorities, politicians and experts and the place for evaluation, discussion and decision on *Questions I-III*. Reproduced by permission from ERMITE Consortium (2004).

REQUIREMENTS FOR ANSWERING QUESTIONS I-III

Water system identification and characterisation

Relevant identification of both the surface and subsurface catchments of any considered water environment (Figure 1) is of vital importance for answering *Questions I-III*. Both the surface and subsurface catchments may include important water-pollutant pathways and sources of negative water impacts with water influence zones that may persist over large spatial and temporal scales. The scientific literature includes several recent findings that particularly emphasize the environmental importance of groundwater interactions with surface water [13-17]. Such scientific results also emphasise the importance of dynamic water system characterisation for identification of relevant influence boundaries in both space and time and must be taken seriously in water management. The meaning of dynamic characterisation is illustrated in Figure 4 and includes, besides investigation of the current status of a water environment, also quantitative assessment of the main cause-effect relationships that govern the development from historic, via the current, to future water status, that is dynamically updated as current status information in the EIS changes.

Dynamic characterization comprises the identification of all sources that impact or may impact the considered water environment by past present or future operations and is a basic necessary requirement for answering *Question I*. Various quantitative modelling approaches for such dynamic impact characterisation are currently discussed in the scientific literature, for instance for water pollution spreading and fate along main pathways from source to water recipient, in term of more generally adoptable models to different types of reactive pollutant transport problems, see e.g. [18-21], or pollutant specific transport models, for instance, for nutrients [22-23]. The resulting answer to Question I is obtained by the use of such models for interpreting the present and modelling the future impacts on a considered water environment under a no-action scenario (see Figure 4).

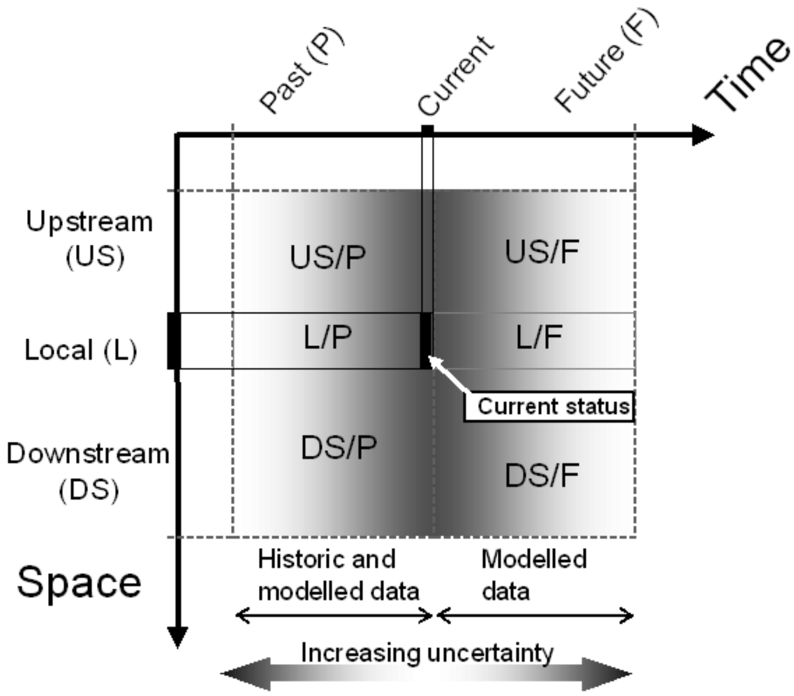

Figure 4. Schematic illustration of dynamic water system characterisation. The dynamic characterisation is updated by, and updates, the EIS for different possible action and development scenarios as recent monitoring and interpretation of relevant cause-effect relations changes (EIS, further detailed in Figure 5).

In order to answer *Questions II-III*, dynamic characterisation is, in addition, used for modelling possible water impacts under different action and development scenarios, i.e. for different possible measures taken to mitigate water impacts, water responses to such measurement and relevant site and development assumptions. For such purposes one must then use pressure-impact models, such as those exemplified above for water pollution problems in combination with catchment-scale economic optimisation models (for the example of quality standards/targets, see, e.g., [14,24-26]) that can identify optimal measure allocation for achieving compliance with different types of water environment standards and targets. There is a need for such catchment-scale economic optimisation within the surface and subsurface catchments of any considered water recipient because:

a) not all possible water impact sources cause actual environmental damage to this water;

b) different possible impact sources may affect the same water in similar ways;

c) not all possible sources should be subjected to actions for mitigating water impacts, because whether or not a particular water impact source should be subject to mitigation actions depends on both its individual mitigation cost and its individual impact on the considered water recipient.

By definition there exists only one optimal allocation of impact mitigation measures for given site conditions and a given impact mitigation target. However, different stakeholders may have quite different interpretations of both impact mitigation targets and site conditions, the investigation of which will commonly result in a range of optimisation solutions for all the different possible conditions and target interpretations. The whole set of different possible optimisation solutions constitutes a quantitative decision support for achieving agreement on the relevant answer to *Question II* at the *Negotiation Table*, along with the complementary set of qualitative information and preferences of different stakeholders.

The answer to *Question III*, is which, out of several possible mitigation measure allocations, that is finally chosen, based on produced quantitative and qualitative information. This answer must take into account not only ecological, but also socio-economic sustainability considerations for various development scenarios and stakeholders preferences. Examples of decision support models that may be relevant in this context are currently discussed in the scientific literature, e.g., in Collentine et al. [27] and Lahdelma et al. [28].

Environmental Information Systems

A critical component in both the Dynamic Characterization (Figure 4) and the overall Main Flowchart (Figure 2) is the so called Environmental Information System (EIS; see detailed illustration in Figure 5) including a technical and institutional solution for storage, dissemination and up-dating of all available information, data and modelling results that may be of relevance for identifying and characterising dynamically the water environment. Currently, all such relevant information and data may not commonly be coordinated between different authorities and other organisations and may often be difficult to find, access and understand. Regardless of how well or badly coordinated and organised they may be, we refer here to the total existing set of such data and information of relevance for dynamic water system characterisation as the available data and information base of the EIS (Figure 5). In addition to such a base, the EIS should comprise information tailor-made for experts and non-experts via a systems solution building upon, and being updated by, the data and information base.

Several recent studies point out public participation [29-31] and communication of expert knowledge with transparent and generally accessible information systems [32-34] as important cornerstones for sustainable integrated water management. These participatory and information accessibility principles are formalised in European law by the Directive on public access to environmental information (2003/4/EC) and the Directive on public participation in respect of drawing up certain plans and programmes relating to the environment (2003/35/EC) which are both part of the transposition into European law of the Århus Convention [35]. The recently amended Directive on re-use of public sector information, (2003/98/EC), points also in the same participatory and information accessibility direction.

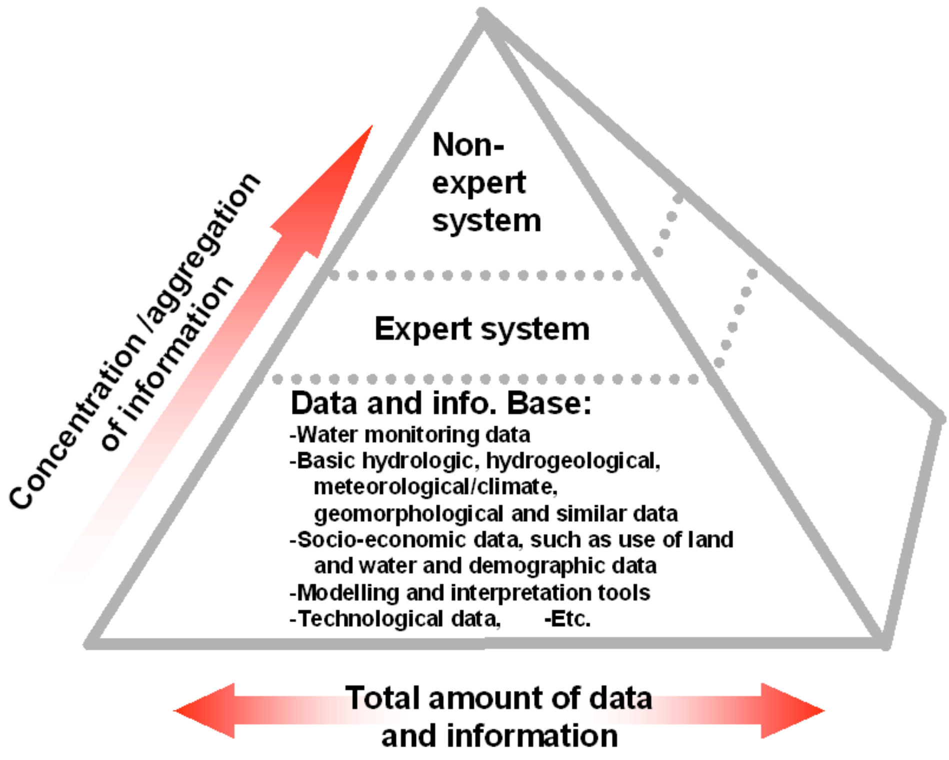

Figure 5. Schematic illustration of the generally accessible Environmental Information system (EIS) including a data and information base that contains core data, an expert system for users with necessary knowledge, and a highly aggregated and easily understandable non-expert system.

However, environmental information according to the Århus Convention is commonly understood to be aggregated information, such as Environmental Impact Assessments or final management and action plans. In this paper, we emphasize the need to go one step further than this common interpretation and include also underlying information and data in a generally accessible EIS (see Figure 5). The transformation of such underlying data and information to aggregated resulting environmental impact assessments or water management plans, is by no means a straightforward and standardised procedure and can not be expected to yield the same answers regardless of how it is done. Such transformation through dynamic characterisation and pressure-impact analysis, is for many water management problems still an open research field, as explained in the discussion and example literature of dynamic characterisation and optimisation studies in the previous sub-section (3.1). Different research groups, companies or authorities analysing the same problem may therefore come up with different quantifications and solutions to the same problem. A comprehensive coordinated and generally accessible EIS including data, analysis tools and results and derived information therefore allows for independent quality control of such transformation and interpretations of underlying data in water management. In contrast, the currently prevailing, uncoordinated and access-limited EIS, with differing accessibility for different stakeholders, may lead to considerably differing water system identification and characterisation results, and thereby to different answers to the main *Questions I-III*. Limited public and stakeholder accessibility to the EIS may thus be a major source of conflict between different stakeholders and actors and thereby lead to general water management inefficiency.

For a sustainable implementation of the EU WFD general EIS accessibility may not least be important for relevant and consistent water system identification and characterisation in the many transboundary river basins of Europe. A recent study shows that 66% (area-wise) of the future River Basin Districts in Europe are expected to be international [10]. Appropriate and generally accessible information support to international river basin commissions, or similar, via a common EIS is essential for confidence building among different national representatives and thus necessary for sustainable management of international water bodies.

DISCUSSION AND CONCLUSIONS

We have presented and described a basic methodological concept for integrated water resources management in accordance with the WFD, in the form of an operational flowchart that: a) is generally applicable to and thereby integrates different types of water management tasks, including water management plans and action programs, individual permit evaluation for development projects, and remediation decisions for contaminated lands; b) combines different types of quantification tools (dynamic characterisation, economic optimisation and Environmental Information System) and clarifies why and how these tools can be used by responsible authorities and other actors; and c) integrates quantitative water management analysis with qualitative stakeholder interactions, and clarifies relevant steps and requirements for efficient stakeholder discussions and negotiations.

In this flowchart, dynamic characterisation is identified as a core component. Dynamic characterisation differs from current common characterisation practices by addressing short- and long-term pressure-impact relations over a range of spatial scales for different possible action and development scenarios, rather than providing only a static picture of present water status. Some WFD guidance documents [7,36] also stress the importance of scenario-based pressure-impact assessment. The present flowchart, however, combines several WFD guidance components into a single logical framework, which also integrates these components with other environmental management and remediation practices (*Main Tasks 2* and *3*).

Relevant dynamic water environment characterisation requires and combines different types of base data, such as land use, meteorological, soil, elevation, water flow and substance concentration, demographic, technological and sector-specific data. These must all be combined in order to derive and interpret pressure-impact relations, fluctuations, and long-term trends under different action and development scenarios on different catchment scales. Such analyses are far from trivial and their results and water management implications may seriously affect stakeholders and the general public. There is therefore a need for transparency and quality control of data, information and used interpretation and extrapolation models. Transparency can be secured by an open EIS, embracing not only the technology needed for broad dissemination of environmental information but also the institutional structure needed to handle the information process. The EIS should be continuously updated with new data and interpretation information produced by responsible authorities, permit applicants, associated experts and independent actors. Technological methodology for such EIS is presented and discussed in the scientific literature, e.g. in [32, 37-38]. An organisational problem that needs to be solved for such an EIS is how costs for data and information from public authorities should be handled. Many European authorities have a cost-recovery principle forcing them to charge for EIS data. Not only the transparency problem, but also the cost-efficiency of this cost-recovery principle is currently debated and compared to the system in the U.S., e.g., in [39-40].

Even though final water management decisions may be taken primarily based on socio-economic and qualitative aspects, the quantitative scientific analyses involved in the herein proposed decision flowchart are needed for independent quantification and clarification of the environmental and economical implications of such decisions. An efficient WFD implementation also requires systematic information management and the flowchart may aid as a general methodology for operational coordination and systematisation of scientific information and quantification needs and tools in sustainable integrated water management.

ACKNOWLEDGEMENTS

We would like to thank the Centre for Environmental Science at KTH, Royal Institute of Technology, Stockholm, and the Swedish Research Council, for making this research possible through their financial support.

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