Supporting the European Water Framework Directive: The HarmoniQuA Modelling Support Tool (MoST)

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EXTENDED ABSTRACT

The European Water Framework Directive (WFD) requires a holistic approach to water management, developing River Basin Management Plans to ensure good ecological status in water bodies. Modelling will form a vital component in defining ecological conditions and developing an appropriate programme of measures to attain good status. However, model credibility can be affected by various problems, including miscommunication within and between multi-disciplinary model teams and stakeholders, ambiguous terminology, poor documentation, inadequate model development/application procedures, and lack of easily available guidance. Given these concerns, the HarmoniQuA project has developed a software-based Modelling Support Tool (MoST) and Knowledge Base (KB) to provide generic guidance and harmonised Quality Assurance procedures across a range of selected scientific domains (groundwater, precipitation-runoff, hydrodynamics, flood-forecasting, water quality, biota, and socio-economics). The guidance helps to ensure a model is properly applied using consistent procedures (see Figure 1), a recording function allows decisions, methods and data use to be logged in a structured model journal, and a reporting function provides summary reports dedicated to specific users. MoST was developed by a broad based project team through consultation with a range of professionals. Feedback and critical evaluation from independent, internal and external reviewers has confirmed the potential of MoST to improve model credibility, but recognised that perceptions of the effort required by users and organisations will be critical to its adoption.

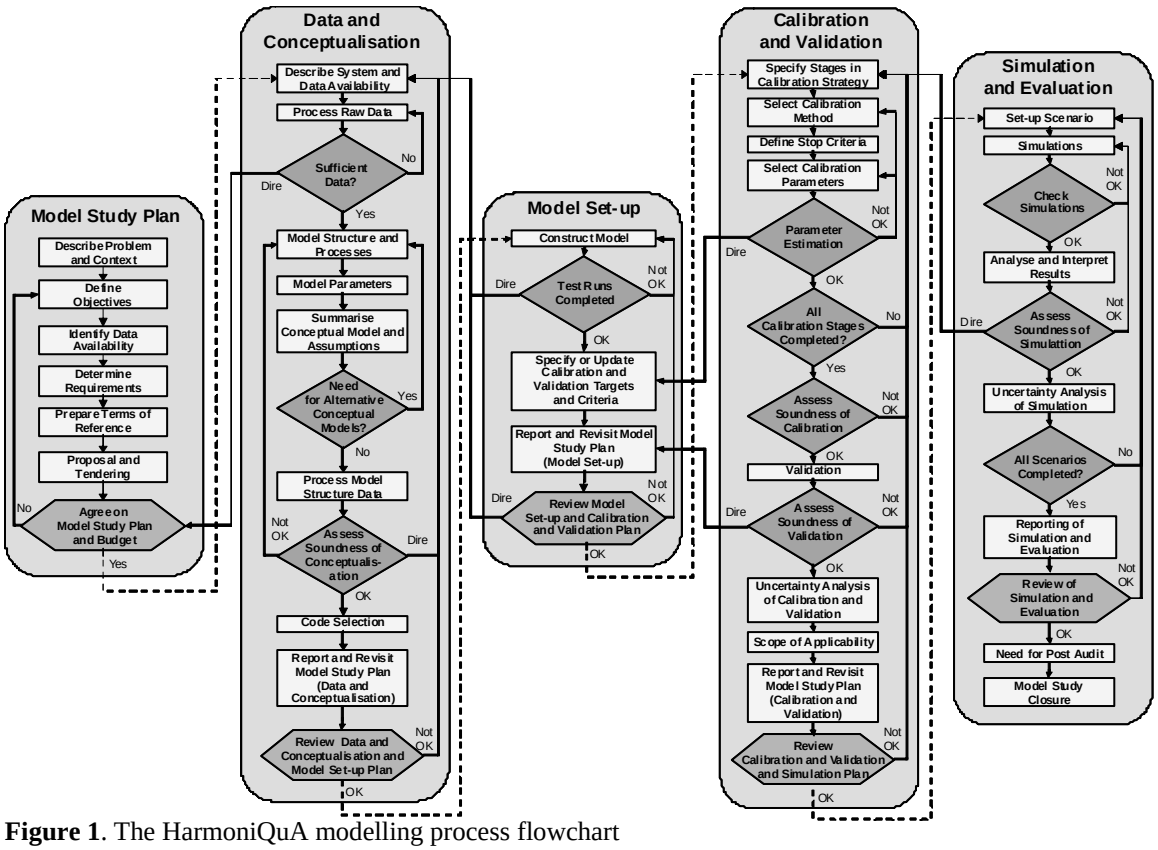

Figure 1. The HarmoniQuA modelling process flowchart

1. INTRODUCTION

European Community (EC) water legislation began in 1975 and subsequent EC Directives have had a major influence on community water law and regulation. These directives tackled specific issues (e.g. water quality objectives for waters with specific uses, or control of dangerous substances). However, they were fragmented in nature and there was a lack of progress with regard to their implementation (Woods, 2004).

Recognising the need to safeguard the water environment, in December 2000, the European Commission published a proposal for the Water Framework Directive (WFD) (European Commission, 2000). It is the most important piece of water legislation produced by the EC, embracing the principles of sustainable development, replacing many earlier directives and strongly influencing water policy in all member countries. The overall objective of the WFD is achieving good status for all water bodies by 2015.

Mathematical modelling plays a major role in modern day water management and it is likely to support the WFD. It is often referred to as an art. This illustrates the subjective nature of modelling which largely reflects the many choices that the modeller experiences, the complexity of the problem and the often incomplete body of theoretical knowledge. These factors result in uncertainty in the model and its results (Scholten *et al*., 2001). However, uncertainty is widely acknowledged by scientists engaged in modelling and several initiatives have been developed to improve the quality of modelling. An international multi-disciplinary literature review and expert consultation was undertaken to identify existing quality assurance procedures followed in the water industry, the requirements for new procedures and to define a generic flowchart of the modelling process (Refsgaard, 2002). Various guidelines on the modelling process have been produced but they are mostly national or discipline specific. For example, the Dutch Good Modelling Practice Handbook (Van Waveren *et al*., 1999) was produced to stimulate the proper use of models in The Netherlands and the Groundwater Flow Modelling Guideline (Middlemis, 2000) was written to promote best practice in Australian groundwater modelling. Although these guidelines are liked by the modelling community the associated paper based record keeping procedures are rarely used. In response, the HarmoniQuA project has developed a computer based Knowledge Base (KB) and Modelling Support Tool (MoST). The HarmoniQuA KB and MoST support modelling in several domains and have been produced by a team of experts from 10 European countries.

This paper aims to illustrate how the HarmoniQuA modelling Support Tool (MoST) supports modelling for the WFD. More specifically the objectives are to:

- Present an overview of the European Water Framework Directive;
- Identify where computer models are likely to be used;
- Outline the HarmoniQuA Modelling Support Tool (MoST) and illustrate how it can support the WFD; and
- Present a critical evaluation and discussion of MoST.

2. THE EU WATER FRAMEWORK DIRECTIVE (WFD)

The WFD adopts a holistic approach to water management that aims to achieve good water status in all water bodies by 2015. In this paper only a brief summary of the directive is given as more comprehensive descriptions have been published elsewhere (Foster *et al*., 2000 and Woods, 2004).

The WFD applies to all inland surface waters, ground waters, transitional waters (estuaries and lagoons) and coasts (to one nautical mile from the coast). It is important to note that ecological quality is the primary criterion by which the status of surface waters will be evaluated. Limited exceptions exist to achieving these objectives. These include artificial or heavily modified water bodies and where exceptional circumstances (droughts or floods) prevail. Protected Areas may also be designated and protected with higher standards.

The necessary improvements in water status should be achieved through a process of analysis and planning at the river basin scale, called River Basin Management Planning (RBMP).

3. RIVER BASIN MANAGEMENT PLANNING FOR THE WFD

Member states must firstly assign water bodies to River Basin Districts (RBDs) which are based on hydrological catchments. The Competent Authority (CA) will then be responsible for RBMP (e.g. DEFRA, 2005). As described by Woods (2004) the RBMP process should include the following components:

- Evaluation of current status of river basin districts: including characterisation of water bodies, impact of human activity and economic analysis of water use;
- Specifying reference conditions, environmental objectives and classifying water bodies;
- Establishment of monitoring programmes;
- Analysing the difference between the current status of a water body and that required under the WFD;
- Designing programmes of measures to preserve or restore a water bodies' good status; and
- Production of a draft (for public consultation) and final RBMP (for approval by ministers).

It is important that interested parties are actively involved in the RBMP process. A period of six months is allowed for written comments. The RBMP is then submitted to the European Commission. The first programme of measures for each RBD must be in place by December 2009, operational by December 2012 and updated by December 2015 and every 6 years thereafter. The 6 yearly cycle of updating the RBMP allows recognition of changing pressures on water bodies, and refinements to monitoring programmes and programmes of measures.

4. MODELLING NEEDS

It is widely accepted that mathematical models will play an important role in implementing the WFD (e.g. Irvine *et al*, 2004, Wasson *et al*., 2003).

In the Directive modelling is explicitly mentioned in Article 5 – Characterising the surface water bodies. It is stated that modelling may be used to:

- establish type specific reference conditions and
- assess the likelihood that surface water bodies will fail to meet environmental quality objectives.

In the first instance several types of model are available with the potential to support the determination of reference conditions. Global, regional and functional response models are likely to be appropriate (Wasson *et al*., 2003). In the second instance models may be used that contribute to understanding the risk to ecological systems of catchment pressures. Modelling may be needed to understand the extent of pressures, particularly where diffuse pollution is an issue (e.g. Environment Agency, 2004). Pressure state models may be used to understand diffuse movement of nutrients.

Although no other explicit reference to model use occurs in the directive it is likely that they will be instrumental in cost-effective implementation of the WFD. Sælthun *et al*. (2000) outline other areas where models are likely to be used in the WFD:

Article 8: Monitoring surface water status, groundwater status and protected areas. Modelling may be used to design optimal monitoring programmes and to interpolate monitored data. ***Article 9: Recovery of costs for water services.*** Socio-economic models may be used to investigate the effect of water pricing on consumption. ***Article 10: The combined approach for point and diffuse sources.*** Models may be used to assess the effects in water bodies of emission control. ***Article 11: Programme of measures.*** Impact assessment models may be important in selecting cost effective measures. ***Article 13: River Basin Management Plans.*** Impact assessment models may be important in producing management plans. Furthermore, operational planning and forecasting models are likely to be important in the operational phase.

4.1 Specific requirements of modelling for the WFD

Although the requirements of modelling for the WFD will include the usual requirements of best practice, there will be greater emphasis on the following three specific areas:

- Multi disciplinary catchment scale problems;
- Active stakeholder participation; and
- Six-yearly updating of the RBMP.

It should also be recognised that although the primary WFD criterion is to achieve good ecological status, ecological modelling is relatively undeveloped in comparison with other domains.

5. THE HARMONIQUA MODELLING SUPPORT TOOL (MoST) AND ITS KNOWLEDGE BASE (KB)

HarmoniQuA MoST, and its associated KB, has been developed to provide a user friendly guidance and quality assurance framework that will contribute towards enhancing the credibility of river basin modelling. It prompts users with the appropriate 'next step' in the modelling process

and provides an audit trail to check previous decisions. It is a stand alone Java implementation that runs on individual computers, under a range of operating systems (including Windows). For a comprehensive description of MoST and its KB see Scholten *et al*. (2005).

MoST and its KB provide harmonised support for modelling across seven domains (groundwater, precipitation-runoff, river hydrodynamics, flood forecasting, water quality, ecology and socio-economics). The tool has been designed to support modellers, water managers, auditors, stakeholders and the public. It has the functionality to help guide, record and report the actions of the project team throughout the modelling process. The KB, consisting of a flowchart of the modelling process and associated guidance, is central to MoST. The current version of the full MoST flowchart is presented in Figure 1. It comprises five main steps, each incorporating a number of separate tasks followed by a review by the model team, water manager and (if appropriate) other stakeholders. The KB contains 1.2 Mb of guidance text relating to the activities within each task show in Figure 1.

Within MoST the guidance functionality helps ensure that, throughout the entire modelling process, there is appropriate: ***communication*** (within and beyond the modelling team), ***consideration of each stage***, ***integration of domains***, ***selection of methods*** and ***awareness of pitfalls***. It does not provide guidance relating to specific modelling software or scenarios but on quality assurance for the modelling process. The recording functionality allows ***a log of decisions***, ***methods and data*** to be held in a structured model journal. The reporting functionality creates reports from the model journal that can be dedicated to specific users and their particular needs. The model journals, archived by MoST, also allow the user to consult previous studies for guidance. The screenshot shown in Figure 2 is intended to give a brief introduction to how MoST works. It shows the typical three panel layout under the **Project** tab for guiding and recording work on a specific **Task** within the modelling flowchart. The left-hand panel shows the sequence of **Tasks** completed or skipped, and highlights the current **Task 2.4: Model Structure and Processes** (which forms part of **Step 2: Data and Conceptualisation**). Note that **Task 1.6: Proposal and Tendering** has been skipped as the work is being done 'in-house". The upper right-hand panel shows the (currently blank) model journal for an **Activity: Spatial resolution** selected from the drop down menu of **Activities** currently open under the **Task**. The user can enter details of the actions and outcomes relating to this **Activity**, or can attach files or enter references relevant to the **Activity**. The lower-right panel shows part of the guidance text on what the **Activity** should address**,** with hyperlinks to glossary terms. Each panel has a scroll bar and each can be resized. Interested readers can find more about working with MoST, including the guideline and reporting functions by accessing training movies on the project website at www.HarmoniQuA.org.

6. THE ROLE OF MoST IN SUPPORTING THE WFD

Consultations with auditors, stakeholders and experienced modellers have highlighted several problems that may undermine the credibility of modelling for the WFD. HarmoniQuA MoST and its KB support the WFD by helping to resolve a number of these problems, listed below.

Miscommunication in multi disciplinary projects often occur both within the modelling team and between the team and the water manager. Within the modelling team it is often due to members having very different backgrounds and using different terminology. MoST encourages the use of standard terminology by the inclusion of a glossary of terms. Furthermore, the guidance functionality of MoST ensures that appropriate communication occurs throughout the modelling process. This is particularly important when specifying management objectives (Irvine *et al*., 2004) and delivering model results.

Difficult to audit model studies. The recording and reporting functionality of MoST will facilitate this process.

Public and Stakeholders are frequently left out. The levels of public participation of importance in implementing the WFD are described in the guidance document produced by the Common Implementation Strategy (EC, 2003). The competent authority (water manager in HarmoniQuA) is obligated to inform and consult the public and stakeholders; they are likely to have good local knowledge and they will be directly affected by management decisions. HarmoniQuA supports this obligation by including, in the first step of the modelling process, the development of a Stakeholder Involvement Plan. Stakeholders and the general public are normally invited to comment on the requirements of the modelling study (see Model Study Plan) and, in particular, participate in the end of step reviews. Furthermore, the recording and reporting functionality of MoST ensures that the modelling process is transparent. Public participation in HarmoniQuA and potential

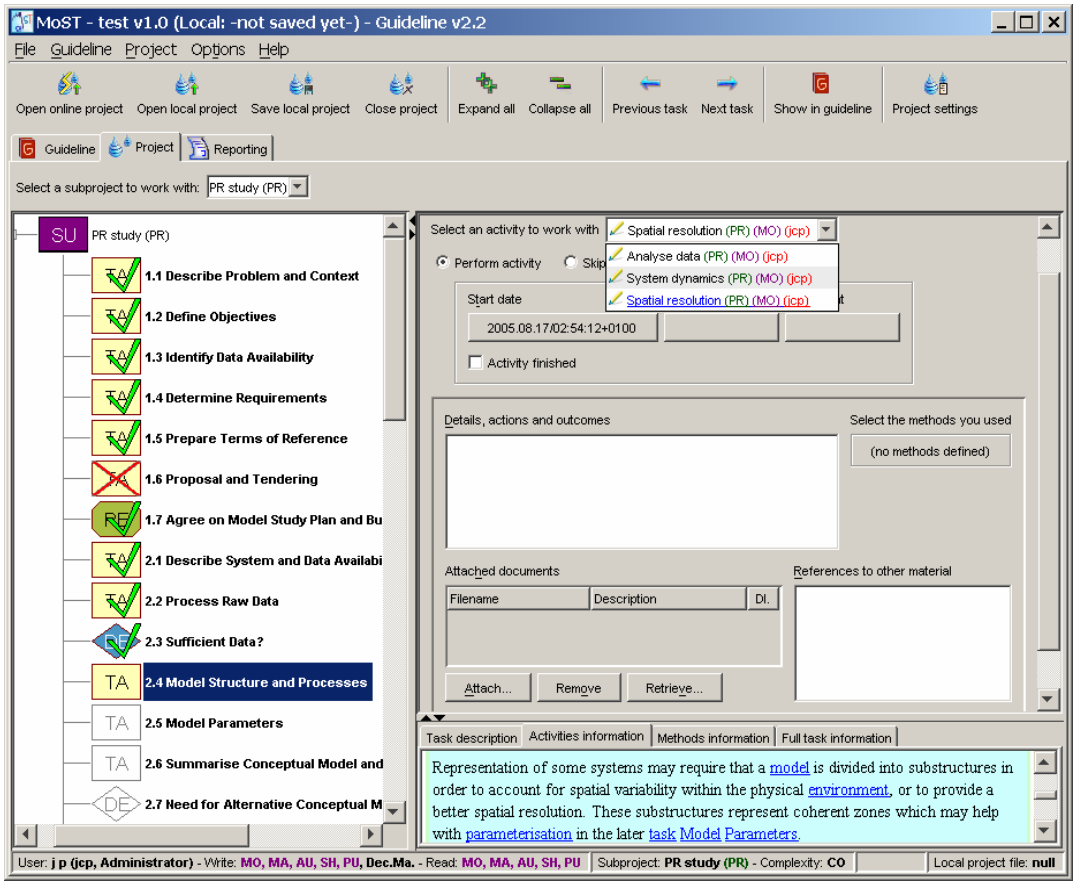

Figure 2. The HarmoniQuA Modelling Support Tool (MoST)

for its enhancement are discussed in full by Henriksen *et al.* (2005, submitted).

Inadequate support for multi disciplinary modelling. Water management for the WFD often involves multi disciplinary studies. MoST provides specific guidance for coupled multi disciplinary studies and for multi disciplinary studies involving several sub projects. The former are supported by guidance requiring explicit descriptions of couplings between domains and checks that these are fulfilled. MoST supports the latter by facilitating working in multi disciplinary teams. Members of a modelling team may work on different sub projects, in different locations and access a common model journal held on a central server. All members of a modelling team may be granted read access to the complete model journal.

Modelling guidance is not readily available or is nationally based. MoST provides guidance that has been developed by experts from 10 European partner countries. Although guidance is currently in English MoST and its associated knowledge base can be easily translated. Guidance is usually domain specific. MoST provides single domain, multi-domain and generic guidance. Furthermore, guidance dedicated to new domains can be relatively easily added to the knowledge base. Guidance is also often paper based. MoST is a computer based system that makes it easily accessible to most members of a modelling team.

The WFD enforces shared objectives across Europe despite a diversity in modelling expertise (within and between countries). By guiding modelling teams through an agreed modelling process MoST should contribute towards standardising the approach to modelling and, therefore, enhancing its quality. In particular, MoST should reduce the likelihood of key stages in the process being missed either intentionally or unintentionally.

7. CRITICAL EVALUATION AND DISCUSSION OF MOST

Within the HarmoniQuA project two rounds of testing were carried out by an extended team. External persons were also invited (formally and informally) to comment on MoST and its KB. The comments relate to MoST version 1.1.4-1.1.8 and

KB guidelines version 2.2. Work is currently progressing towards producing a final project version of MoST and the guidelines. It is noted where criticisms are currently being addressed.

Comments clearly demonstrate that HarmoniQuA MoST and its KB represent significant advances in assuring the quality of modelling studies. However, despite support for the HarmoniQuA approach acceptance of new software by large organisations (i.e. Competent Authorities) is likely to take several years.

MoST was found to be user friendly but complex. Project initiation and customisation was found to be particularly complex and confusing. The project team are currently producing a Help System, a series of job type templates and are improving the start-up text.

The guidance in MoST was found to be too general. MoST cannot give guidance on every model and its pitfalls. It is not intended to replace specific model manuals. The guidance is meant to be generic, covering basic concepts for relatively inexperienced users or those working with teams from unfamiliar domains. Experienced users can minimise the guidance window, or more detailed guidance could be developed for specific applications or models (future project).

Use of MoST was found to be too onerous, particularly for basic modelling jobs. Initialisation is currently being streamlined and templates are being developed for common types of projects. Recording at the Task level will become the default as opposed to for each individual activity (this is likely to be favoured by many experienced modellers with their own ways of working at the activity level). However, the Activity list in each Task does give a useful 'aide memoire' of the things to be done. Many of the early project tasks leading to the Terms of Reference may already have been done by the Water Manager, and relevant documents can be attached to the model journal. Modeller inputs need not be onerous if treated as daily logs of work done, attaching summary documents of results when appropriate. However, MoST is best suited to large multi disciplinary modelling studies conducted by teams.

Estimates of the time saving potential of MoST have been requested. This is difficult to answer as quality assurance in modelling is not currently quantified. As MoST automates existing quality assurance procedures it has potential to save time. The time invested in using MoST will depend on how comprehensively activities are recorded.

Senior managers must be convinced of the benefits of MoST. Existing quality assurance in river basin modelling is usually accomplished by project specifications, reporting requirements and review meetings. MoST reproduces these basic structures, but also incorporates guidance, key facts, and score sheets for managers and modellers on what is important in the modelling process. MoST gives modellers a user-friendly means of maintaining the records that water managers need to audit models and ensure repeatability. The thoroughness of recording should however be agreed between the modeller and water manager. At review stages, the content of the end of step reports will demonstrate (to the auditor) whether information has been recorded with sufficient accuracy and detail.

Translation of MoST and the KB is needed in some partner countries. The likely need for translation of MoST was recognised at the outset but is for a future project. Multiple versions of MoST, in terms of language, may be beneficial but would involve considerable maintenance effort. Local versions could also conflict with the original aim of harmonising the approach to quality assurance in modelling between scientific domains and countries.

Several users would like information to be automatically placed in MoST whilst working in a modelling package. Ways of implementing this have been considered and software developers are interested but it has been deferred for a future project.

8. CONCLUSION

The European Water Framework Directive is a major piece of legislation that will strongly influence the management of water in all member states. The value of mathematical modelling has been demonstrated in supporting the WFD. Indeed, modelling support is likely to increase in the future as (1) more truly integrated models become available; and (2) our ability to model ecology is developed. The computer based HarmoniQuA Modelling Support Tool (MoST) and its associated Knowledge Base (KB) were described and shown to support modelling for the WFD in the following ways:

- ensuring appropriate communications occur throughout the modelling process;
- facilitating model audit;
- supporting obligatory public and stakeholder participation;

- supporting multi disciplinary modelling in teams; and
- making modelling guidance easily accessible.

A critical evaluation of MoST and its KB, based on comments from independent internal and external reviewers, was also presented. Overall it was clear that MoST and its KB have made significant advances in contributing to quality assurance in modelling. However, the following criticisms were raised:

- customisation and initiation of projects is complex;
- guidance is too general;
- MoST is too onerous;
- senior managers need convincing of benefits;
- MoST and its KB needs translation ; and
- MoST needs to be integrated with model applications.

These criticisms were discussed in the paper and have been carefully considered by the project team. Whilst some are being addressed and will be available in the final project version of MoST and its KB, others were either beyond the scope of the current project or in conflict with the objectives of the HarmoniQuA project. Overall MoST and its KB has the potential to contribute to establishing a harmonised approach to quality assurance in modelling throughout Europe and possibly further a field. However, its introduction to large organisations is likely to be a long process involving customisation. A programme of workshops is currently underway to demonstrate the functionalities of MoST and its KB and encourage its adoption.

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