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Forms of Participatory Modelling and its Potential for Widespread Adoption in the Water Sector

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ABSTRACT
This article serves as a support for those interested in learning more about participatory modelling and its potential for widespread adoption by resource managers. The first part introduces the reader to four basic forms of participatory modelling, identified by classifying nine example participatory modelling processes. The second part considers the potential widespread adoption of participatory modelling by resource managers in the water sector, concluding that this potential is low. It proposes recommendations as to how the potential for the adoption of participatory modelling by water managers can be increased. One of the most important recommendations is that policy-makers should focus on the promotion of forms of participatory modelling that support social learning and the development of conceptual models. These forms of participatory modelling are considered most likely to be adopted, especially if they can be promoted in terms of supporting learning cycles within an Adaptive Water Resources Management approach. Copyright © 2011 John Wiley & Sons, Ltd and ERP Environment.

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Introduction

PARTICIPATORY MODELLING DESCRIBES A DIVERSE RANGE OF MODELLING ACTIVITIES WHOSE COMMON ELEMENT IS THAT they involve stakeholders in one or more stages of the modelling process, from data collection through to model construction and use. Its popularity in natural resource management research is evidence, to some extent, of an acceptance of Haag and Kaupenjohann's (2001) call for greater recognition of the difference between modelling for scientific research purposes and for supporting policy- and decision-making, the latter requiring, they claim, stakeholder participation.

Its popularity is driven by a number of factors. First, participatory modelling is seen as a way of reducing the number of research-developed models remaining unused by managers (see Borowski and Hare, 2007). Secondly, Q2 some participatory modelling methods, such as group model building (Vennix, 1996), which facilitate a group to identify key system components and their relationships, and then to construct conceptual or system dynamics models, provide benefits which go beyond the production of the model itself. The discussions and negotiations between the group members during the model building, for example, improve the group's shared understanding of the management problem and its solutions. As such, participatory modelling can be a tool for supporting the type of social learning currently being promoted for water resources management (Ridder *et al.*, 2005).

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Another possible driving force behind its popularity is changing legislation requiring environmental managers and policy-makers to increase stakeholder participation in their work [e.g. Article 14 of the Water Framework Directive (see EU, 2002) and Article 18 of the European Marine Strategy Directive (see Fletcher, 2007)]. If one accepts Barreteau *et al.* (2010) statement that modelling is a major component of natural resources management, then participatory modelling becomes important.

Finally, the research sector is putting many resources and much enthusiasm into supporting researchers to propagate and examine different approaches to participatory modelling in natural resources management. The number of review articles in various journals (e.g. Bots and van Daalen, 2008; Ramanath and Gilbert, 2004; Hare *et al.*, 2003), as well as the number of European Union (EU) and EU member state-funded research projects investigating participatory modelling themes (e.g. FIRMA, HarmoniCOP, NeWater, AquaStress, PartizipA) are all evidence of this.

This article is intended to support researchers and policy-makers interested in learning more about participatory modelling and its potential. The first half of the article identifies four major forms of participatory modelling by categorizing nine examples according to an adaptation of Bots and van Daalen's (2008) categorical framework. The second half of the article discusses the potential for participatory modelling to progress from being a mainly research-driven activity in the water sector to one being adopted for widespread use by water managers. By widespread adoption I mean that participatory modelling becomes mainstream in the sector and that managers set up their own organizing teams, independent of researchers, to create their own participatory modelling processes. The article presents the arguments in favour of such a move and then considers the potential barriers, based on two basic conditions that need to be fulfilled if adoption is to take place: first, that sufficient resources are available for water managers to undertake the organization of participatory modelling processes, and secondly that there is a large demand from water managers for new models to directly support decision-making. Recommendations are then made as to how to increase the potential uptake of participatory modelling, should this be what water managers and policy-makers desire. With reference to the different forms of participatory modelling identified by use of the framework, the article concludes by suggesting which forms are most likely to experience widespread adoption.

Frameworks for Classifying Participatory Modelling Processes

Previous reviews have used different categorical frameworks for characterizing participatory modelling activities supporting natural resource management. Table 1 compares the criteria used in different frameworks with those **T1** adopted in the adapted framework described in this article. The framework used by Hare *et al.* (2003), for example, categorized participatory modelling case studies according to purpose and the participatory structure of the case study (i.e. the potential number of relevant stakeholders involved, the organizational levels at which they operate, the local political structure, and the actual stakeholders used in the model's co-design group). The purpose of the categorization was to analyse links between participatory structure and process implementation (see Table 1).

Barreteau *et al.* (2010) developed a framework for participatory research processes which, considering the importance they assign to the role of modelling in such processes, can be applied to participatory modelling as well. Their framework categorizes approaches in terms of: (1) stakeholder involvement in different stages of the modelling process (timing of events), (2) control of the flow of information between stakeholders and (3) whether the stakeholders are involved individually or in different types of groupings (participation mode). The purpose is to clearly represent to stakeholders their involvement in a process so that their expectations of it can remain realistic. It also supports process monitoring and evaluation.

Bots and van Daalen (2008) offer a similar framework to the one above (see Table 1). This too considers the timing of events and the participation mode, but also the type of model being produced and the purpose of the participatory modelling process. The framework is intended to support effective process design.

The adapted framework used in this article extends Bots and van Daalen's (2008) in order to support its intended use: to more clearly illustrate examples of participatory modelling and to better identify its general forms. It considers the following criteria (Table 1):

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Framework	Criteria used								Main purpose of framework
	Participatory modelling purpose	*Participatory structure*	*Control of flow of information between stakeholders*	*Timing of events*	*Participation mode*	*Model type*	*Participatory methods used*	*Actors involved (at each stage)*	*Support and skills needed*	
Hare *et al.* (2003)	X	X								**Analyse links between participatory structure and process implementation**
Barreteau *et al.* (2010)			X	X	X					**Provide clear description of process (manage expectations); monitoring and evaluation**
Bots and van Daalen (2008)	X			X	X	X	X			**Support process design**
Adapted framework used in this article	X			X	X	X	X	X	X	**Identify general forms of participatory modelling**

Table 1. Comparison of frameworks for categorizing participatory modelling processes. This table compares different frameworks (bold, first column) according to the categorical criteria they employ (columns in italics) and their purpose (bold, final column)

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- participatory modelling purposes,
- model type,
- stakeholders involved,
- timing of events,
- participatory methods used,
- participation mode,
- skills needed to organize and implement the participatory modelling.

The following subsections describe the criteria and their criterion (in italics) used to classify the participatory modelling nine process examples in Tables 2 and 3. **T2 T3**

Participatory Modelling Purpose

This refers to the purposes that the participatory modelling process is designed to achieve. Categories are:

- *direct decision-making* – a management decision will be made as a result of the process;
- *social learning* – see below;
- *model improvement*
  - *quality* – the model has a higher level of accuracy;
  - *acceptance* – the model will be better accepted for use by stakeholders;
  - *integration* – the model integrates cross-sectoral perspectives.

Bots and van Daalen's (2008) framework includes six categories of purpose such as 'clarify arguments', 'provide strategy advice', 'design/recommend' and 'democratize'. As the adapted framework used in this paper is not based on the assumption that directly influencing decision-making is a usual, implicit purpose of participatory modelling, 'direct decision making' is included explicitly as a purpose (subsuming the category 'provide strategy advice'), so that one can better judge what processes link directly to management decisions. Other purposes that can be unrelated to actual decision-making, such as model improvement and social learning, are consequently included as separate categories. In social learning (Ridder *et al.*, 2005), participants are facilitated in sharing perspectives with each other and are supported to develop collective problem-solving skills (cf. Barreteau *et al.*, 2010). In the right conditions, this can lead to the generation of new shared management ideas. This category therefore subsumes Bots and van Daalen's categories 'clarify arguments' and 'design and recommend'. However, successful social learning processes producing recommendations still may or may not directly influence decision-making (see **Squires and Renn** in this issue).

Model Type

This refers to the type of model to be built as a result of the participatory modelling process. The categories are:

- *simulation model* – a computational model of a system which allows the user to simulate system behaviour;
- *conceptual model* – a model that qualitatively explains a system 'on the basis of preconceived notions of how the system works' (Mulligan and Wainwright, 2005, p. 14). This might include paper- or computer-based representa- Q3 tions of a system's ontological model (i.e. key system components and their structural relationships). A common representation is a directed graph in which components are visualized by nodes and relationships by directed arrows between nodes (e.g. causal diagrams or influence diagrams).

Each type of model has a particular role (cf. Barreteau *et al.*, 2010):

- scientific – for research purposes;
- decision support system (DSS) – contributes to a DSS;
- discussion support – supports stakeholder deliberations and discussions;
- communication – explicitly communicates stakeholder perspectives to others.

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Example name	Purpose		Actors involved	Participatory modelling stage				
	Type of model	*Participatory purpose*		*Data*	*Definition*	*Construction*	*Verification/ Validation*	*Use*
FABE								
Grampian	Simulation model (scientific)	Improve model (quality)	Farmers, Farm business advisors	NOP	IND Interviews	NOP	IND Questionnaire – verification	NOP
			OT: Researchers	*M*	*KA/M*	*M (refinements)*	*KA*	*M*
Hase I	Simulation model (scientific; discussion support)	Improve model (quality, acceptance)	Farmers, local authorities, associations	IND Request for data	NOP	NOP	HET Show-and-tell verification	HET Use by demand
			OT: Researchers	*M*	*M (model already defined)*	*M (paramerization for scenarios)*	*F*	*M*
Wadden Sea	Conceptual models and simulation model (DSS)	Improve model (quality, acceptance, integration)	Policy-makers	NOP	IND Interviews (conceptual models)	NOP	NOP	IND Direct use (of resulting DSS)
			Domain experts	NOP	NOP	NOP	HOM Prototyping (conceptual models)	NOP
			OT: Researchers	*M*	*KA*	*M (conceptual models; simulation sub-model)*	*M/KA*	*M*

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Zürich	Conceptual model (discussion support)	Improve model (integration); social learning	Consumers, water utilities, housing associations	NOP	IND Cognitive mapping; card sorting	NOP	NOP	HET Gaming (role playing game). Simulation by hand (conceptual model)
			OT: Researchers	*M*	*KA*	*M (role-playing game; conceptual model)*	*M*	*F*
Nimes	Conceptual and simulation models (discussion support)	Improve model (quality); social learning	Extension workers	NOP	HOM ARDI (conceptual model)	NOP	NOP	NOP
			Mayors and government officers	NOP	NOP	NOP	NOP	HET Gaming
			OT: researcher; mayor and government officers		*F*	*M (simulation model)*	*M*	*F*

Table 2. Categorization table for the examples of FABE approaches to participatory modelling. A cell in the 'participatory modelling stage' can be interpreted in the following manner: where there is no stakeholder involvement, NOP is written. Where there is stakeholder involvement in the stage, the cell is grey and the participation mode (*IND* – stakeholders are involved individually; *HOM* – stakeholders with homogeneous interests are involved as a group; and *HET* – stakeholders with heterogeneous interests are involved as a group) is shown. Underneath, the method used at this stage for these stakeholder types is specified. Should there be two or more models being developed in the process, then the type of model to which the method was applied is shown in parentheses. *OT* refers to the composition of the organizing team. For organizing team involvement in different participatory modelling stages, the labels *F* – Facilitation, *M* – Modelling and *KA* – Knowledge Acquisition, represent the skills needed for the participatory methods for that stage. GMB = Group Model Building

Example name	Purpose		Actors involved	Participatory modelling stage				
	Type of model	*Participatory purpose*		*Data*	*Definition*	*Construction*	*Verification/ Validation*	*Use*
Co-construction								
Hase II	Conceptual model (Discussion support)	Improve model (integration); social learning	Farmers, local authorities, associations	NOP	IND Cognitive mapping	HET GMB	NOP	HET Simulation-by-hand
			OT: Researchers		*KA*	*F*		*F*
Iskar (Phase 1)	Conceptual model (Discussion support; Communication)	Improve model (integration); social learning	National policy-makers	NOP	IND Cognitive mapping	HET GMB	NOP	NOP
			Mayors	NOP	IND Cognitive mapping	HOM GMB	NOP	NOP
			Council workers	NOP	NOP	HOM GMB	NOP	NOP
			Citizens	IND Interviews	*NOP*	*NOP*	*NOP*	*NOP*
			OT: Researchers		*KA*	*F (GMB) M (Citizens' conceptual model)*	*M*	*KA (to analyse drivers)*
Front end								
Moorlands	Simulation model (Scientific)	Improve model (integration)	Gamekeepers, scientists	IND Request for data	IND Interviews	NOP	NOP	NOP
			OT: Researcher	*M*	*KA*	*M*	*M*	*M*
Back end								
Ebro	Simulation model (Discussion support)	Social learning	Main stakeholders	NOP	NOP	NOP	NOP	HET Gaming
			OT: Researchers	*M*	*M*	*M*	*M*	*F*

Table 3. Categorization table of co-construction, front-end and back-end approaches to participatory modelling. See caption to Figure 1 for explanation of table

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While Bots and van Daalen (2008) provide a detailed classification of natural resource management models, in this article a simpler approach is used to reflect the nature of the examples illustrated and to focus later discussions.

Stakeholders Involved

Many different types of stakeholder can be involved in a participatory modelling process. In this framework, the stakeholders involved are divided into:

- the organizing team – those organizing the participatory modelling process;
- the different stakeholder types (farmers, extension workers, mayors, etc.).

In contrast to Barreteau et al. (2010), models are not treated as actors (active participants) in the activity. Also, researchers and policy-makers are subsumed, where appropriate, within the categories 'organizing team' and 'stakeholder types involved'.

Timing of Events

The modelling stages (cf. **Squires and Renn**) in which stakeholders in a participatory modelling process may be involved are:

- *data collection* – raw data are collected to support the definition of the model or later to parameterize it;
- *model definition* – suggestions as to design components of the model are elicited. Design components may include the modelled system's ontology, the model boundary and the user requirements;
- *model construction* – a technical activity in which final decisions on model ontology etc. are made and a working model is constructed;
- *model verification/validation* – model components or outputs are checked;
- *model use* – stakeholders use the model.

In Bots and van Daalen (2008), the participatory modelling process includes categories for 'model construction' (involving activities such as 'inform model construction' and 'make modelling decisions') and 'model use'. The main concern with their categories is that informing and making decisions are different in terms of the level and effort of participant involvement; a difference that is crucial to understanding participatory modelling approaches that are deliberately less stakeholder-intensive, such as Polhill *et al.* (2010), which will be described later in the paper. Therefore, 'inform model construction' has been included in the adapted framework as part of the model definition stage.

Participatory Methods Used

The following lists examples of different possible participatory methods (in italics) that can be used at each modelling stage:

Data collection – Methods include *participatory monitoring and surveys* that return data for modelling purposes. Stakeholders can also be *requested to contribute data*.

Model definition – Model definition can be supported by individual stakeholders through the use of knowledge acquisition methods to identify an individual's views about the management system, such as *structured or unstructured interviews*, *card sorting* (Rugg and McGeorge, 2005) and *cognitive mapping*, which produces qualitative conceptual models [e.g. the causal loop diagrams in Vennix's (1996) interview approach to diagramming (p. 119)]. Design suggestions can also be elicited from groups of stakeholders by applying the ARD stages of the *ARDI* method (Etienne *et al.*, 2008a), in which a facilitator elicits suggestions in terms of important actors, resources and dynamics, by use of a specially coded, text-based representation. Other techniques (see Ramanath and Gilbert, 2004) include *requirements analysis*, *joint application design workshops*, *prototyping* (in which mock-ups, or latest versions of the model are created and shown to stakeholders for feedback) and *user panels*.

Model construction – Stakeholder involvement in model construction is typically through some form of group modelling exercise. These forms include *group model building* (Vennix, 1996), which supports stakeholder groups

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to produce either causal loop diagrams or systems dynamics models, as well as the *ARDI* co-construction method (Etienne *et al.*, 2008a) and the group version of *hexagon modelling* (Hodgson, 1992) which facilitate groups to produce influence diagrams.

Model verification and validation – Methods include *show and tell verification* (the model contents are presented to stakeholders for their feedback); *show and tell validation* (results are presented to stakeholders for their judgement about their validity); *focus groups* (see **Squires and Renn**); document-based *questionnaires or workbooks* [model results are documented and stakeholders complete a questionnaire to assess their views on the validity or verification of the model (Vennix, 1996)].

Model use – Stakeholders can use a simulation model directly, independent of the organizing team (*direct use*), or with the support of the organizing team (*mediated use*). They can request the organizing team to run specific simulations, e.g. as part of a scenario-testing phase (*use-by-demand*) or they can use a model as part of a role-playing game (*gaming*[I]). If a causal conceptual diagram has been built, the stakeholders can also use the model to identify measures and simulate their effects by hand (*simulation-by-hand*).

Participation Mode

This specifies (Bots and van Daalen, 2008) whether the stakeholders are involved as individuals (IND) or as part of a group, with homogeneous interests (HOM) or with heterogeneous interests (HET).

Skills Needed

This specifies the skills the organizing team need, to carry out different stages of the participatory modelling process:

- modelling skills (*M*),
- facilitation skills (*F*) and
- knowledge acquisition skills (*KA*).

Examples of Participatory Modelling Processes and their Classification

Nine examples of participatory modelling processes were selected for classification to illustrate the extent to which such processes vary. Most examples are from the water sector, reflecting the background of the author, but examples from other sectors are also examined. The examples are labelled according to the geographical area of application. Examples such as Zürich and Hase II have already been reviewed and categorized in Hare *et al.* (2003) and Bots and van Daalen (2008), respectively. The entire Iskar process, of which Iskar (Phase I) is a part, has been categorized by Barreteau *et al.* (2010). All are included in this review to provide alternative analytical perspectives. The full list of examples in order of their appearance in Tables 2 and 3 are:

(1) Grampian (Polhill *et al.*, 2010);
(2) Hase I (Newig *et al.*, 2008);
(3) Wadden Sea (Engelen, 2004);
(4) Zürich (Pahl-Wostl and Hare, 2004);
(5) Nîmes (Etienne *et al.*, 2008b);
(6) Hase II (Newig *et al.*, 2008);
(7) Iskar (Phase I) (Daniell, 2008);
(8) Moorlands (Hare, 1999);
(9) Ebro (Valkering *et al.*, 2009);

[I]A category of model use also identified by Bots and van Daalen (2008).

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The following sections describe and classify the nine process examples according to the four general forms of participatory modelling that are identifiable from the categorizations in Tables 2 and 3, using the adapted framework in Table 1. These categorizations are according to the author's own interpretation of the processes.

Form I: Front- and Back-end (FABE) Participatory Modelling

This form of participatory modelling concentrates involvement on the early and later stages of the modelling. It tends to be consultative in nature, asking for input on definition and validity, but without extensive work between stakeholders and/or with the organizing team on model construction. The following subsections classify five examples.

Example 1: Grampian (Polhill *et al.*, 2010). This process sought to incrementally improve a pre-existing land-use simulation model (called FEARLUS) for scientific purposes by using heterogeneous groups of stakeholders to 'suggest and check' the model. It is a good example of deliberately trying to implement a less stakeholder-intensive participatory modelling process in terms of stakeholder time and effort. Farmers and farm business advisors were interviewed to get suggestions on decision-making and change processes, and to inform revisions in model ontology and definition. Once the modified model version had been developed, participants were sent a questionnaire describing the new model's structure for comment. These comments then fed back into a new round of model re-development.

Example 2: Hase I (Newig *et al.*, 2008). Hase I and Hase II were subprocesses of a larger process in the Hase sub-basin in Germany which Bots and van Daalen (2008) in their review refer to as an example of participatory modelling embedded in a decision-making process. However, during the project implementation it became clear that a direct link to a decision-making process was not feasible and, instead, the purpose focused, as reported in Newig *et al.* (2008), on supporting stakeholders to improve their knowledge of the EU Water Framework Directive and collectively investigate measures for groundwater protection in the sub-basin.

The Hase I sub-process (see Table 2) refers to the participatory parameterization and use of an existing nutrient model (STOFFBILANZ) for the purposes of developing scenarios to support the group discussion of measures. The sub-process sought to gain stakeholder acceptance of the model by involving them in the provision of data and in model validation. Stakeholder use of the model was by demand, with requests to the organizing team to run specific scenarios. Due to multiple factors, including the failure to obtain stakeholder verification of the model parameters (Newig *et al.*, 2008) and stakeholders' doubts as to the validity of the model (Berkhoff, 2008), the model results were not used in the rest of the process.

Example 3: Wadden Sea (Engelen, 2004). This process illustrates a participatory method for developing scientific-based models used in a decision support system for the management of the Wadden Sea in the Netherlands. The purpose was to improve model quality, integration and acceptance. Policy-makers were envisioned as the end users and were interviewed to define model boundaries and requirements. The organizing team then created conceptual models of the system using these as well as literature reviews. Experts were brought together in small groups and supported in using a graphical modelling tool to verify and redefine these conceptual models. The quantified versions of these conceptual models were then constructed by the organizing team, and verified and refined by subject experts. The organizing team used these to develop simulation sub-models for use in the decision support system.

Example 4: Zürich (Pahl-Wostl and Hare, 2004). This process illustrates an example of a FABE process involving the generation of conceptual models without stakeholder involvement at the model construction stage. The process sought to support social learning between urban water management stakeholders to improve discussion and the sharing of perspectives, as well as to reinforce their collective problem-solving capacities, the results of which might eventually support decision-making at some point in the future. Cognitive mapping (using a hexagon modelling approach applied to individual stakeholders) and card sorting were used to elicit individuals' perspectives and suggestions regarding the behaviour of the management system, as part of model definition. The organizing team then filtered these suggestions and made decisions as to which parts of them should be integrated to compose a single conceptual model. As such, the stakeholders could not be deemed to have been involved in model construction, as they had no control over the final form of the model or choice of its components. The heterogeneous stakeholder group was then facilitated to use the influence model to identify measures and impacts using simulation-by-hand techniques. In addition, the group used the role-playing game to further test their management ideas and system understanding.

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Example 5: Nîmes (Etienne *et al.*, 2008b). This process sought to support social learning and develop collective management ideas for urban fire prevention, whilst developing conceptual and simulation models. It is an uncommon example in which decision-makers (mayor and government officers) were made part of the organizing team. Extension workers used an ARDI-based group modelling exercise to develop a conceptual model which provided system knowledge for the organizing team to build their intended simulation model. The latter provided the platform for a role-playing game which was used by the organizing team and additional mayors to explore how to improve fire prevention in Nîmes. Table 2 describes just the ARDI and role-playing phases of what was a longer participatory process.

Form II: Co-construction[2] participatory modelling

This form, co-construction, involves stakeholders directly in model construction (see Table 3), with final decisions on model structure being made by the stakeholders. It is used almost exclusively for the construction of conceptual models. Two examples are highlighted.

Example 6: Hase II (Newig *et al.*, 2008). The second sub-process within the Hase case study (see Hase I above) developed an integrated conceptual model of the environmental, social and economical aspects of water quality management within the sub-basin. Building on the work of Pahl-Wostl and Hare (2004), cognitive mapping was used to elicit individual stakeholder perspectives regarding the existing management system. If one considers the model output of Hase II to have been the integrated conceptual model, then, in contradiction of Bots and van Daalen (2008), the model construction stage was not carried out using cognitive mapping, but involved the stakeholders doing group model building, using the cognitive maps created as model definition inputs, to create an integrated conceptual model. The stakeholders then used this to discuss and evaluate measures. This difference in analysis is important as it correctly establishes the focal point of social learning as being in the group activity.

Example 7: Iskar (Phase I) (Daniell, 2008; Daniell *et al.*, 2010). This example illustrates the early phase of a larger multi-level stakeholder process. The process aimed to support flood and drought management for the Iskar river basin (Bulgaria) through improvement of stakeholder communication, the development of common visions and a common evaluation of management strategies. The process categorized in Table 3 refers to Phase I (up to Workshops 1 and 2), in which stakeholder views regarding drivers and barriers to effective flood and drought management were elicited. The participatory modelling approach depended on the stakeholders involved. National policy-makers and mayors followed the approach used in Hase II: cognitive mapping on individuals used as input for the group model building of a conceptual model of the management system. Council workers directly carried out group model building to build their conceptual model, without the cognitive mapping phase. Citizens, due in part to their large numbers, were interviewed and the organizing team developed the citizens' group conceptual model. All models were used to communicate the stakeholders' views between different organizational levels of stakeholder, and to allow the organizing team to analyse important perspectives on drivers and barriers within the management system.

Form III: Front-End Participatory Modelling

This form includes very limited participation, focused exclusively on the early stages of the modelling process.

Example 8: Moorlands (Hare, 1999). This modelling activity sought to develop competing models of red grouse population dynamics and management, within a simulation laboratory, for scientific purposes, i.e. assessing model structural uncertainties. Requests for data were made and non-structured interviews used to gather conflicting knowledge about grouse dynamics, which, along with data and knowledge from the literature, was then analysed by the researcher to construct alternative models for assessment.

Form IV: Back-End Participatory Modelling

This form brings in stakeholders exclusively to use the model, after it has been developed by the organizing team.

[2]For more background on the term co-construction see, for example, Etienne *et al.* (2008a) and Daniell (2008).

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Example 9: Ebro (Valkering *et al.*, 2009). This process sought to support exploration and social learning in river basin management. The model was designed and built by the organizing team, with stakeholders using it as part of a role-playing game. Valkering *et al.* describe this approach as participatory simulation.

Implications of Process Design Choices

The implications of method choice

As these examples illustrate, there is a multitude of possible approaches to participatory modelling, even when the purposes or form are similar. In terms of participation mode (see above), there are processes with similar participatory modelling forms in which stakeholders always work together in groups and others in which the organizing team work with stakeholders individually. The examples demonstrate, however, that despite the emphasis Bots and van Daalen (2010) place on the importance of participation mode in determining the process, the impact of the participation mode is itself determined by the choice of participatory method used. For example, whilst both a show-and-tell validation activity and group model building are group activities (i.e. their participation mode involves heterogeneous or homogeneous groups), a group model building method will have a better chance of achieving the participatory purpose of social learning.

What is also apparent from the examples is that decisions about the participatory methods used at different stages will alter the balance of the share of work between the organizing team and stakeholders. Interviews, for example, will require less effort for stakeholders than taking part in group model building. Cognitive mapping at the model definition stage, although a little more work-intensive for the stakeholder, produces a complete system model ontology for the organizing team. This in turn eliminates the need for the qualitative analysis otherwise required of the organizing team when analysing interview protocols during the model construction stage of processes such as Grampian. The type of skills needed by the stakeholders and organizing team when participating in different stages also depends on method choice. In Iskar (Phase I), for example, the national policy-makers were asked to be system analysts and modellers, to the extent that they needed to understand the specific modelling syntax and semantics required to build qualitative conceptual models. Likewise, the organizing team not only had to have modelling skills but also knowledge acquisition and facilitation skills, as cognitive mapping and group model building methods were used.

What Type of Model: Simulation or Conceptual?

Decisions on model type developed through participatory modelling have serious implications, for example, on the durability and applicability of the models produced. Whilst simulation models for research should be reflections of how a system might work, conceptual models developed through participatory processes and based on stakeholder perspectives will not necessarily be. This means that although the research model has an applicability stretching to a point in time in which it is proven to be no longer valid, the participatory conceptual model will generally only have applicability for the stakeholders concerned, at the time in which it was developed, unless the knowledge they bring to the model, and the way it is integrated, happens to be scientifically sound.

There are other issues to bear in mind when choosing to develop participatory conceptual models, such as causal diagrams (see also Daniell, 2008). The meaning of such models may be difficult to interpret by those outside the process, as it is sometimes difficult for stakeholders to reach and maintain a high level of terminological clarity, even when there is a moderator to assist them. Also, individual members of the group might not necessarily feel that the final group model, even when co-constructed, represents their views adequately; their views might no longer be clearly represented in it. This problem is exacerbated when, as reported in Daniell (2008), such models are further processed by the organizing team to tidy up and homogenize terms used within different stakeholder groups.

The decision as to which type of model to develop is also important as it appears from the examples that social learning purposes are most readily supported through the participatory modelling of qualitative conceptual models within co-construction, or some front-and-back-end processes. The important thing for social learning is that the

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stakeholders work together on tasks, preferably in a heterogeneous grouping (Ridder *et al.*, 2005). Such tasks may be sharing perspectives on model definition (e.g. Iskar), using a model for strategy identification and testing (e.g. Zürich) or constructing a conceptual model (e.g. Hase II). **Squires and Renn's** analysis in this issue suggests that choice of model developed in the process might sometimes matter if social learning is to be supported effectively. The development of the technical, bio-economic model in their case study supported social learning to a limited extent.

Supporting Decision-Making or Supporting Social Learning for Future Decision-Making?

When Bots and van Daalen (2008) write that 'the [participatory] modelling exercise is expected to have some impact on the decision-making process it is part of . . .' it may appear to the reader that there is an assumption that such processes have this purpose per definition. What is clear from the examples is that none of the cited articles describing them claim to have directly led to a specific water management or planning decision (although the complete Iskar process got as far as generating recommended technical planning project proposals for which funding was to be sought). This is true too of the process described in **Squires and Renn**. In an earlier review of processes, Hare *et al.* (2003) came to the same conclusion and treated this as a cause for concern. Consideration of these examples, however, leads to the conclusion that this concern may not be so important if one considers the equally valid purpose of social learning, i.e. increasing stakeholders' capacity for taking collective decisions or for supporting decision-making processes at some point in the future. How participatory modelling processes leading to social learning might be a latent asset for future decision-making in this way is discussed at the end of this article.

Should a process designer want to support decision-making directly then, among other things, the scale of mismatch problem (Hare *et al.*, 2003) will need to be solved by including many different organizational levels of stakeholders in different activities (for good examples, see Daniell, 2008; Barreteau *et al.*, 2010).

The Potential for the Widespread Adoption of Participatory Modelling in the Water Management Sector

Based upon experiences from European research and consultancy, as well as international development, this article now considers whether participatory modelling can move from being a research-driven activity to being one that is widely adopted by water managers.[3] I argue that the widespread adoption of participatory modelling by water managers is important for a number of reasons. First, if adopted, participatory modelling could become a valuable tool in the participatory toolbox of water managers and so provide them with effective ways of meeting, or even going beyond, legislative requirements for participation in water management. They would also gain the benefits the approach offers in terms of model improvement (e.g. better stakeholder acceptance and improved quality due to the cross-sectoral integration of knowledge). Widespread adoption and the mainstreaming of participatory modelling within the water management sector would also mean that the water managers no longer have to rely on the research community to run their processes. This is crucial as the research community does not have the capacity to act as the organizing team for that many participatory modelling processes. Also, research objectives and management objectives are not always compatible. Daniell (2008, p. 224) suggests that some research approaches have a 'reliance on results or model validation . . . at the expense of the participants'. In this case, either the objectives of the research or the management sector have to take precedence. Daniell *et al.* (2010) call for managers to lead processes if operational management is the priority.

Given the above benefits, I propose that for widespread adoption to occur, at least two conditions need to be met:

(1) there need to be sufficient resources available to water managers to support participatory modelling processes; and
(2) there is a large demand for new models to support actual water management decisions.

The next sub-sections will discuss whether these conditions are currently being met.

[3]Water managers, with operational decision-making responsibilities, are referred to here rather than policy-makers, as it is they who are most likely to directly use models for their work.

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Are There Sufficient Resources Available for Water Managers to Support Participatory Modelling Processes?

To answer this question, it is worth considering the experience that researchers and consultants have had in trying to promote participatory processes in general in some parts of the water management sector. For example, recent participatory work involving the construction of water retention areas, with local government authorities from north-west Europe as part of the TRUST project (Krywkow *et al.*, 2007), highlights the barriers to the uptake of more intensive forms of participation by water managers and planners. One of the foremost resource constraints is the human capacity within the water management organization to organize participation. The skills and personnel needed to plan and facilitate intensive participatory processes are often lacking.

Even when the organization has generous human and financial resources, it may be that participatory processes which shift power and responsibility in decision-making are not seen as a priority for the organization. For example, some water management organizations are seen by themselves and others as *the* competent authorities, and their managers may be legally responsible for their management decisions. There is therefore an understandable reluctance to change what apparently works and to share discussion and decision-making with non-legally responsible stakeholders who may rightly or wrongly be considered non-experts. Without making clear the costs and benefits of implementing participatory processes, changes in established practice are not likely to occur.

Additionally, although the existence of legislation prescribing participation in water management can encourage the adoption of approaches such as participatory modelling, it can also act as a barrier, depending on what level of participation[4] is prescribed and on the level of risk that the water manager is willing to accept (e.g. planning schedule slippage). For example, in the case study of Moellenkamp *et al.* (2010) the competent authority for planning the implementation of the Water Framework Directive (WFD) was reluctant to accept the risk of carrying out a higher level of participation and divert its resources in this direction when the EU WFD only specifies information provision and consultation as obligatory (active involvement of stakeholders is merely encouraged). As participatory modelling is a tool that can be considered as supporting a high level of participation, corresponding to Mostert's fourth level, namely co-designing (Mostert, 2006), its adoption might therefore be hindered if legally binding participatory obligations continue to be set at low levels. This fear is further reinforced by Videira *et al.*'s (2006) review of public stakeholder participation in various European water management projects, which suggests that conforming to regulatory requirements can mean there is 'no room for active involvement' (p. 19). Promotion of participatory modelling and other higher levels of participation are also unlikely in cases where the directive is unclear on how to involve stakeholders, as for example in the Marine Strategy Directive (Fletcher, 2007).

A final barrier is when the infrastructure planning department is separated organizationally from participation and modelling activities within a water management organization (see, for example, Krywkow *et al.*, 2007). If so, then problems of incompatible time-schedules may occur unless there is a strong capacity for interdepartmental coordination, as planning goals will tend to take precedence if there is the risk of severe penalties for late completion. Thus, planning will tend to race ahead of both modelling and participatory activities, with the risk that the latter two become redundant (see also Bots and van Daalen, 2008). Given these conditions, activities such as participatory modelling, when tried, would ultimately be seen as ineffective within the organization and resources moved elsewhere.

To conclude, resources, in terms of human, technical, institutional and financial capacities, may not always be sufficient to allow participatory modelling processes to be adopted successfully by water managers.

Is There a Large Demand for New Models to Support Water Management Decisions?

Given recent research (e.g. Borowski and Hare, 2007; Mysiak *et al.*, 2008; **Webler *et al.***), it is questionable whether the modelling community is often producing the type of models or decision support systems (DSS) that decision-makers in the water sector can or desire to use. In other words, although the potential role of models in decision-making is high, there may not be a large demand for the types of models the decision-makers are currently being offered.

[4]See Mostert (2006) for a description of such levels.

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Research on the uptake of research sector models and DSS in the EU by Borowksi and Hare (2007) and Mysiak *et al.* (2008) report the problem of such tools being left unused on the shelves of users' organizations after limited initial use. Msyiak *et al.* report that half of the potential users they surveyed who had been involved in requirements analysis for a DSS never ultimately used it. Although one can query the validity of surveys as measures of true demand, different research activities in the water sector have identified similar barriers to the use of models that may explain their comparatively low uptake.

For example, the findings of Borowski and Hare (2007) concur with those of **Webler *et al.*** in the present special issue in indicating that the modelling community is not always communicating well with the user side, and thus not providing the type of models for which there is a demand [e.g. models that are maintained and well documented (Borowski and Hare, 2007)]. Further corroboration comes from the work by van Overveld *et al.* (2010) concerning the use of technical knowledge and scientific information. They too cite a lack of sensitivity to the demands and needs of policy-makers as a possible reason for such knowledge not being made use of in water policy decisions.

A worrying example of potential mismatch in demand and supply is the current trend within the research community towards producing ever more complex integrated simulation models. According to Borowski and Hare (2007), despite this trend, there is greater demand by managers for simple, data-rich models. Indeed, **Webler *et al.*** report that modellers and outreach professionals think that such an increase in complexity is a 'handicap for policy models'. This trend leads to an increase in the difficulty of obtaining sufficient data to enable such complex models to be transferred easily for use in new management locations, a problem which the latter two cited articles both highlight. The trend also increases the amount of model uncertainty that has to be dealt with. Again, both those articles report great differences in opinion as to the degree to which decision-makers or other users want to deal explicitly with uncertainty in models and what type of support modellers should provide to users for dealing with it. This in turn has an impact on model trust.

Ultimately, trust in their information sources is an important issue for all managers. Water managers need to be able to trust in the validity of the models they are using, especially as the manager often has a legal responsibility for the decisions made and has to clearly justify the reasons for their decisions to their superiors or to the public (cf. Borowski and Hare, 2007; **Webler *et al.***). With this in mind, it has to be remembered that information from models is just one of many sources that are used by a decision-maker to make decisions (van Overveld *et al.*, 2010). Models are in competition with other sources of influence, such as trusted expert opinion, personal hunches and rules of thumb, expediency and power politics. Thus if trust in the model is lacking, due to high levels of model uncertainty, models can be easily ignored as decision-making support tools, and replaced by other sources. Similar issues related to trust and uncertainty can also be read in van Overveld *et al.* (2010), confirming the ferocity of the competition taking place to influence decision-making in the water sector.

The picture does not improve considerably when one considers the demand for models at the international level in the area of water-related cooperation and development work. Recent UN reports on less-developed countries' water sector capacity development requirements (UN-HABITAT/UNW-DPC, 2009; UNW-DPC, 2009) cite many requirements, including better monitoring systems, more data and support in organizing participatory processes, but few requirements pertain to new models. When the latter are mentioned, single-issue models are requested, e.g. supply network models.

In conclusion, it is easy to overestimate the demand for new models within the water management sector, especially for those models developed by the research sector. The demand appears to be mainly for simple, data-rich, trustworthy models, to be used as one of many sources of information to support decision-making.

Supporting Widespread Adoption

As discussed in the previous section, neither the two proposed conditions for the adoption of participatory modelling by resource managers can be assumed to be generally met in the water sector. This section sets out recommendations for ways of overcoming these barriers to adoption.

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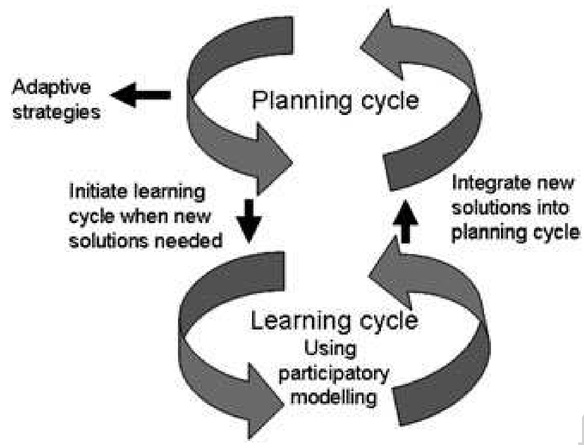

Figure 1. The link between planning and learning cycles in Adaptive Water Resources Management and the potential role of participatory modelling. (Adapted from Mysiak *et al.*, 2010, figure 12.1.)

Improving the Resources Available for Implementing Participatory Modelling

All forms of participatory modelling, as with participation in general, will be hard to adopt if there is a lack of human and institutional capacity within water management organizations to properly organize and coordinate participatory modelling processes within planning activities. If EU environmental policy-makers believe widespread adoption of participatory modelling within water management organizations is important, then they should consider the following recommendations.

Awareness-raising – The research sector should be supported to provide water management organizations with the costs and benefit estimates of participatory modelling. It should also advocate the link between different types of participatory modelling and the water manager's ability to meet (and go beyond) current legislative prescriptions for participatory management.

Human, organizational and institutional capacity development – The research sector should be funded to support the transfer of the necessary skills and tools in participatory modelling, knowledge acquisition and facilitation to the water management sector, so the latter can implement independently. Similarly, the research sector should support institutional and organizational strengthening of inter-departmental coordination, and social learning, within water management organizations.

Infrastructure project funding – To avoid participatory approaches such as participatory modelling becoming redundant during planning projects, EU funds (e.g. INTERREG) should not support projects in which participation is a separate work package from infrastructure development. There should be financial penalties for not implementing participation in coordination with the planning, as there can be for failure to implement infrastructure plans on time.

Legislation – Legislation regarding stakeholder participation in water management should clearly prescribe levels of involvement higher than information and consultation, preferably active involvement.

Improving the Demand for Participatory Models

The recommendations here depend on the purpose of the participatory modelling desired and the types of models to be built.

If participatory modelling is to be adopted as a technique for developing simulation models for supporting decision-making, then severe barriers need to be overcome. As previously mentioned, these include a lack of trust in the involvement of non-expert, non-legally responsible stakeholders, as well as a lack of trust by water managers in the use of models that are not data-rich. Great care therefore needs to be taken in trying to deliver the right type of models that might be produced via such processes. The recommendations of Borowski and

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Hare (2007) for improving the adoption of models can be usefully adapted for such participatory modelling purposes:

- use only expert stakeholders or those who have the trust of the water manager;
- resist the temptation to develop data-hungry, complex, integrated models;
- develop simple models, based on rich data sources;
- write funding proposals that allow for professional levels of model documentation and maintenance;
- include water managers in the organizing team, as in Etienne *et al.* (2008b);
- implement less stakeholder-intensive FABE forms of participatory modelling, such as the one proposed by Polhill *et al.* (2010), given the reported lack of time for participation that practitioners may have for such activities (Borowski and Hare, 2007).

On the other hand, if one accepts that water managers' demand for stakeholder-derived simulation models for supporting decision-making will remain low, then forms of participatory modelling that generate them are unlikely to be adopted. Policy-makers should instead seek to encourage and resource the adoption of forms of participatory modelling that generate conceptual models for social learning purposes. The benefits of these approaches have been well documented (e.g. Daniell *et al.*, 2010), but an additional benefit would be that the fears that some water managers may have about model validity, data availability and of active non-expert involvement in decision-making can be side-stepped by these approaches, as the development of a valid simulation model for directly supporting decision-making is not their purpose. In the terms used by van Daalen *et al.* (2002) to describe the different roles of models in the environmental policy life cycle, the models participatorily developed in this way would not be for management directly, but used as consensus creators, 'arguments in dissent' and 'eye openers'.

As illustrated in the examples Hase II and Iskar, the co-construction of conceptual models can be useful as a basis to support the integration and representation of multi-stakeholder views on the management system and to support stakeholders in developing strategy recommendations that might eventually indirectly influence future decision-making processes. FABE approaches to the development of conceptual models would also be appropriate for social learning if, as illustrated by the Zürich and Nîmes examples, heterogeneous group-based activities can be included in them (such as sharing of perspectives via cognitive maps, simulation-by-hand or gaming).

What might it mean for participatory modelling to be used to support social learning as a latent asset for future decision-making, whilst at the same time minimizing the risks and associated fears for the water management community? Adaptive Water Resources Management (Mysiak *et al.*, 2010) provides a framework for answering this question. An important aspect is that it links formal, integrated planning cycles with learning cycles whose purpose is to feed new knowledge, ideas and alternative strategies into the planning cycle whenever the latter needs extra support to adapt to new situations or to policy failures. The learning cycles operate in a niche adjacent to the formal planning cycle (see Figure 1). **F1**

As the participatory process case study of Moellenkamp *et al.* (2010) shows, water managers and implementing authorities are more willing to accept higher levels of stakeholder involvement when it can take place in such niches so that the planning cycle is insulated from the risks of failure in participation. Eventually, if the niche functions well, the results coming from the learning cycles may also impact on the decision-making in the planning cycle, as happened in Moellenkamp *et al.* (2010). Similarly, forms of participatory modelling that support the development of conceptual models for social learning purposes could effectively be adopted by water managers, alongside other participatory methods, for widespread use in supporting these learning cycles,[5] in order to aid future decision-making in the formal planning cycle as and when support is needed by the water managers.

Conclusions

Using a framework adapted from Bots and van Daalen (2008) and Barreteau *et al.* (2010), this article classified nine participatory modelling process examples. As a result, four general forms of participatory modelling (FABE, front-end,

[5]See **Stefanska *et al.*** (this issue) for another example of the activities of such a niche in the form of shadow network.

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co-construction and back-end) were identified, each requiring different combinations of skills, methods and participation modes to implement them. The categorized examples also show that assumptions that the usual purpose of participatory modelling is to directly support decision-making are not valid.

The potential for the widespread adoption of participatory modelling amongst water managers was then considered and adjudged to be currently low. Further research should be carried out to judge to what degree the demand for participatory modelling matches the necessary research investment. With this information, the policy-makers at the EU level can better judge whether and how to promote its adoption.

Should promotion be considered necessary, both the EU at the policy level and the research sector have a major role to play in supporting the widespread adoption of participatory modelling. Recommendations for these actors include raising awareness about the link between participatory modelling and meeting legislative requirements for participatory water management in the EU; improving human, organizational and institutional capacities of water management organizations to carry out participation; and changing the funding structures of infrastructure planning projects. One of the most important recommendations is for policy-makers to focus on promoting co-construction and FABE forms of participatory modelling that support social learning, rather than forms that develop simulation models to directly support decision-making. The key to achieving widespread adoption of participatory modelling in the water management sector might ultimately be to propose the use of participatory modelling as a means for supporting learning cycle niches, adjacent to formal planning cycles, as part of an Adaptive Water Resources Management approach.

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References

Barreteau O, Bots PWG, Daniell KA. 2010. A framework for clarifying 'participation' in participatory research to prevent its rejection for the wrong reasons. *Ecology and Society* **15**: 1. http://www.ecologyandsociety.org/vol15/iss2/art1/.

Berkhoff K. 2008. Spatially explicit groundwater vulnerability assessment to support the implementation of the Water Framework Directive – a practical approach with stakeholders. *Hydrology and Earth System Sciences* **12**: 111–122.

Borowski I, Hare MP. 2007. Exploring the gap between water managers and researchers: difficulties of model-based tools to support practical water management. *Water Resources Management* **21**: 1049–1074.

Bots PWG, van Daalen CE. 2008. Participatory model construction and model use in natural resource management: a framework for reflection. *Syst Pract Action Res* **21**: 389–407. Q4

Daniell KA. 2008. Co-engineering participatory modelling processes for water planning and management. Doctoral Thesis, Agro Paris Tech. and the Australian National University.

Daniell KA, White I, Ferrand N, Ribarova IS, Coad P, Rougier J-E, Hare MP, Jones NA, Popova A, Rollin D, Perez P, Burn S. 2010. Co-engineering participatory water management processes: theory and insights from Australian and Bulgarian interventions. *Ecology and Society* **15**: 11. http://www.ecologyandsociety.org/vol15/iss4/art11/.

Engelen G. 2004. Models in policy formulation and assessment: the WadBOS decision-support-system. In Environmental Modelling: Finding Simplicity in Complexity, Wainwright J, Mulligan M (eds). Wiley: Chichester; 000– 000. Q5

Etienne M, Du Toit D, Pollard S. 2008a. ARDI: a co-construction method for participatory modelling in natural resources management. In Proceedings of the Fourth Biennial Conference of the International Environmental Modelling and Software Society (iEMSs), Sànchez-Marrè M, Béjar J, Comas J, Rizzoli A, Guariso G (eds). Barcelona. Q6

Etienne M, Bourgeois M, Souchère V. 2008b. Participatory modelling of fire prevention and urbanisation in southern France: from co-constructing to playing with the model. In Proceedings of the Fourth Biennial Conference of the International Environmental Modelling and Software Society (iEMSs), Sànchez-Marrè M, Béjar J, Comas J, Rizzoli A, Guariso G (eds). Barcelona.

EU. 2002. Guidance on public participation in relation to the Water Framework Directive. Prepared in the framework of the Common Implementation Strategy of the European Commission and the EU Member States. http://forum.europa.eu.int/public/irc/env/wfd/library.

Fletcher S. 2007. Converting science to policy through stakeholder involvement: an analysis of the European Marine Strategy Directive. *Marine Pollution Bulletin* **54**: 1881–1886.

Haag D, Kaupenjohann M. 2001. Parameters, prediction, post-normal science and the precautionary principle – a roadmap for modelling decision-making. *Ecological Modelling* **144**: 45–60.
Hare MP. 1999. Weaver: A hybrid artificial intelligence laboratory for modelling complex, knowledge- and data-poor domains. PhD Thesis, Department of Computing Science, Aberdeen University.
Hare MP, Pahl-Wostl C. 2002. Stakeholder categorisation in processes of participatory integrated assessment. *Integrated Assessment* **3**: 50–62. Q7 Q8
Hare MP, Letcher RA, Jakeman AJ. 2003. Participatory modelling in natural resource management: a comparison of four case studies. *Integrated Assessment* **2**: 62–72.
Hodgson AM. 1992. Hexagons for systems thinking. *European Journal of Operational Research* **59**: 220–230.
Krywkow J, Rasche K, Moss E, Mitchell T, Vancleemput K, van der Kroef R, Hotting R, Rodenbach A, Noordanus C. 2007. Public and stakeholder participation. Theme Group III Final Report of the TRUST Project, TRUST: Rotterdam.
Mulligan M, Wainwright J. 2004. Modelling and model building. In Environmental Modelling: Finding Simplicity in Complexity, Wainwright J, Mulligan M (eds). Wiley: Chichester; 000–000. Q9 Q10 Q11
Moellenkamp S, Lamers M, Huesmann C, Rotter S, Pahl-Wostl C, Speil K, Pohl W. 2010. Informal participatory platforms for adaptive management – insights into niche finding, collaborative design and outcomes from a participatory process in the Rhine. *Ecology and Society* **15**: 41. http://www.ecologyandsociety.org/vol15/iss4/art41/.
Mostert E. 2006. Participation for sustainable water management. In Sustainable Management of Water Resources: An Integrated Approach, Giupponi C, Jakeman AJ, Karssenberg D, Hare M (eds.). Edward Elgar: Chichester; 153–176.
Mysiak J, Giupponi C, Depietri Y, Colombini G. 2008. A note on attitudes towards and expectation from the Decision Support Systems. In *Proceedings of the Fourth Biennial Conference of the International Environmental Modelling and Software Society (iEMSs)*, Sànchez-Marrè M, Béjar J, Comas J, Rizzoli A, Guariso G (eds). Barcelona.
Mysiak J, Henrikson H-J, Sullivan C, Bromley J, Pahl-Wostl C. 2010. The Adaptive Water Resource Management Handbook. Earthscan: London.
Newig J, Gaube V, Berkhoff K, Kaldrack K, Kastens B, Lutz J, Schlußmeier B, Adensam H, Haberl H. 2008. The role of formalisation, participation and context in the success of public involvement mechanisms in resource management. *Systemic Practice Action Research* **21**: 423–441.
Pahl-Wostl C, Hare MP. 2004. Processes of social learning in integrated resources management. *Journal of Community and Applied Social Psychology* **14**: 193–206.
Polhill JG, Sutherland L-A, Gotts NM. 2010. Using qualitative evidence to enhance an agent-based modelling system for studying land use change. *Journal of Artificial Societies and Social Simulation* **13**: 10.
Ramanath AM, Gilbert N. 2004. The design of participatory agent-based social simulations. *Journal of Artificial Societies and Social Simulation* **7**(4): 1. http://jasss.soc.surrey.ac.uk/7/4/1.html.
Ridder D, Mostert A, Wolters H. 2005. Learning Together to Manage Together. Improving Participation in Water Management. HarmoniCOP Handbook on Social Learning. University of Osnabrück, Institute of Environmental Systems Research: Osnabrück.
Rugg G, McGeorge P. 2005. The sorting techniques: a tutorial paper on card sorts, picture sorts and item sorts. *Expert Systems*, **22**: 94–107.
UNW-DPC. 2009. Institutional Capacity Development: Working Together to Support Policy and Legal Reforms for Equitable Water Allocation. UNW-DPC Publication Series: Knowledge #3. UNW-DPC: Bonn.
UN-HABITAT/UNW-DPC. 2009. Proceedings of the International Workshop on Drinking Water Loss Reduction: Developing Capacity for Applying Solutions. UNW-DPC Publication Series: Proceedings #1. UNW-DPC: Bonn.
Valkering P, Tabara JD, Wallman P. 2009. Modelling cultural and behavioural change in water management: an integrated, agent based, gaming approach. *The Integrated Assessment Journal* **9**: 19–46.
van Daalen CE, Dresen L, Janssen MA. 2002. The role of computers in the environmental policy life cycle. *Environmental Science and Policy* **5**: 221–231.
van Overveld PJM, Hermans LM, Verliefde ARD. 2010. The use of technical knowledge in European water policy-making. *Environmental Policy and Governance* **20**: 322–335.
Vennix JAM. 1996. Group Model Building. Wiley: Chichester.
Videira N, Antunes P, Santos R, Lobo G. 2006. Public and stakeholder participation in European water policy: a critical review of project evaluation processes. *Environmental Policy and Governance* **16**: 19–31.

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