Collaborative Modelling in Water Resources Management

Two approaches from the Netherlands

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Deltares Enabling Delta Life

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by

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Abstract

Water Resources Management (WRM) problems are now recognized for their complexity. Approaches for dealing with these problems must integrate a variety of interests, perspectives, values and knowledge into their potential solutions. They must also confront and manage problem uncertainties. The involvement of stakeholders in these approaches is critical. Collaborative Modelling (CM) offers a particularly promising set of approaches to involve stakeholders in computer-based modelling activities in WRM. This thesis analyses two of these approaches from the Netherlands: the development of the AZURE iMOD groundwater model using a Consortium Modelling approach, and the Model-Supported Collaborative Planning approach adopted during the Dutch Delta Programme Rivers (DPR). It identifies which characteristics, structures, and processes of collaboration were important in achieving approach objectives, in addition to establishing those the stakeholders involved most valued and appreciated.

Consortium Modelling is found to apply most in problem contexts where the scientific knowledge base is uncertain. The approach is premised upon cooperative stakeholder involvement at a high co-decision making level of participation. It is an intensive process of model co-construction, where specialists with sufficient technical knowledge collaborate in the development of a sophisticated groundwater model. In contrast, Model-Supported Collaborative Planning is more suited to problem contexts where different values and opinions proliferate and the scientific knowledge base is largely certain or uncontested. This approach directly supports policy-making, and relies upon highly structured involvement for large numbers of stakeholders at different levels of participation. It involves the development and use of a *Blokkendoos* model (or 'Planning Kit') to formulate an integrated flood protection strategy.

The thesis demonstrates which stakeholders to involve and when to involve them in these approaches depends upon the problem context and the specific purposes of the CM exercise. Higher levels of participation are generally preferred over lower levels for both approaches, and it is broadly beneficial if stakeholders are involved during the earliest agenda setting phases. Neutral expert advice and process management can also be of benefit, provided these experts enjoy the trust of the stakeholders involved. It is also essential to confront any uncertainties with stakeholders, and provide sufficient time for both collaborative *and* model-construction processes to occur. This notwithstanding, care must be taken in translating either of these approaches to cultural contexts significantly different to that existing in the Netherlands. The thesis confirms and reiterates many CM recommendations presented in previous research, however, several of these are found to also be dependent upon problem contexts and the specific purposes of the exercise.

Preface

Effective collaboration often takes longer than its practitioners expect. With the completion of this thesis, I also feel this sentiment could well be shared with research into collaborative methods! Over the past twelve months, I have had the privilege to engage deeply with these two examples of collaborative modelling practice from the Netherlands. I have had opportunities to work together and meet with many obliging and knowledgeable individuals, and consequently have been able to learn and gain much from the experience.

The completion a thesis such as this relies upon the support of many, and I would like to take this opportunity to briefly acknowledge the following individuals. First and foremost, I must make mention of my twin thesis supervisors Erik Mostert and Laura Basco Carrera. Without their constant assistance and guidance over the last year, I simply could never have fully formulated my ideas and arguments. To Laura in particular, the countless hours spent debating syntax and generalizable Collaborative Modelling approaches may have consumed a considerable amount of time, but it nevertheless proved invaluable. To the remainder of my graduation committee, Nick van de Giesen and Bert Enserink, I would also like to acknowledge their efforts and support during both the earliest and later stages of my research.

This thesis was completed in association with Deltares. To all in the Scenarios and Policy Analysis unit in Delft, I must extend my thanks for welcoming me so readily and providing a constant source of inspiration from the work that you do. In particular to Eelco van Beek, your gentle guidance over the course of my research provided me with a wealth of experience upon which to draw as it progressed.

To all those that I have formally met and interviewed in researching these case studies, I must acknowledge and thank you for your readiness to make time available in your busy schedules to speak with me. You are all to be commended for your roles in institutionalising collaborative WRM in the Netherlands, and I hope the findings from my research may assist you in any of your future Collaborative Modelling endeavours.

Finally, to my family, thank you for your endless and unconditional patience and support throughout this year. It took longer than we all expected, but it is finally complete. I hope to be able to return a similar favour to each of you soon.

A. Warren
Delft, May 2014

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Abbreviations

4B	Citizens/Interest Groups, Businesses, Officials and Decision Makers (Dutch: *Burgers/Belangenorganisaties, Bedrijven, Beambten en Bestuurders*)
ABG	Civil Advisory Group (Dutch: *Ambtelijke begeleidingsgroep*)
ACER	Adaptive Capacity to Extreme events in the Rhine basin
AZURE	Up-to-date Model for the Zuiderzee Region (Dutch: *Actueel Instrumentarium voor de Zuiderzee Regio*)
BE	Back-End
CM	Collaborative Modelling
COMDS	Collaborative Modelling for Decision Support
ComMod	Companion Modelling
CoopMod	Cooperative Modelling
DC	Delta Commissioner
DEM	Digital Elevation Model
DEMO	Participatory Catchment Modelling of Nutrient Transport for Sustainable Water Management
DiSS	Discussion Support System
DP	Delta Programme (Dutch: *Deltaprogramma*)
DPIJ	Delta Programme Lake IJssel (Dutch: *Deltaprogramma IJsselmeer*)
DPR	Delta Programme Rivers (Dutch: *Deltaprogramma Rivieren*)
DPRD	Delta Programme Rhine Estuary-Drechtsteden (Dutch: *Deltaprogramma Rijnmond Drechtsteden*)
DPRPB	Delta Programme Rivers Programme Bureau
DSS	Decision Support System
DWC	Drinking Water Company
EC	European Commission
EU	European Union
FABE	Front- and Back-End
FE	Front-End
FRM	Flood Risk Management
GIS	Geographical Information System
GMB	Group Model Building
GNMF	Gelderland Nature and Environmental Federation (Dutch: *Geldse Natuur Milieu Federatie*)
GUI	Graphical User Interface
GWP	Global Water Partnership
ICT	Information and Communications Technology
IM	Interactive Modelling
IR	Impulse-Response
IVM	Integrated Meuse Study 2 (Dutch: *Integrale verkenning Maas*)
IWRM	Integrated Water Resources Management
KBG	Sounding Board Group (Dutch: *Klankbordgroep*)
MER	Environmental Impact Assessment
MHW	Indicative Flood Level (Dutch: *Maatgeven Hoogwater*)
MIPWA	Methodology Development for Interactive Planning for Water Management (Dutch: *Methodiekontwikkeling voor Interactieve Planvorming ten behoeve van Waterbeheer*)
MM	Mediated Modelling

NESP	Networked Environments for Stakeholder Participation
NeWater	New Approaches to Adaptive Water Management under Uncertainty
NGO	Non-Governmental Organisation
NHI	National Hydrological Instrument
NIMBY	Not In My Backyard
OVIJ	Environmental Services Department for the Veluwe IJssel Region (Dutch: *Omgevingsdienst Veluwe IJssel*)
PKB	Key Planning Decision Room for the River (Dutch: *Planologische Kernbeslissing Ruimte voor de Rivier*)
PM	Participatory Modelling
PS	Participatory Simulation
PSM	Physical System Model
RA	Regional Advisor
RWS	National Ministerial Department for Public Works and Water Management (Dutch: *Rijkswaterstaat*)
SADM	Single Actor Decision Model
SAIM	Single Actor Impact Model
SPSM	Socio-Physical System Model
SSM	Social System Model
SVP	Shared Vision Planning
TMDL	Total Maximum Daily Load
TNO	Netherlands Organisation for Applied Scientific Research (Dutch: *Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek*)
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNESCO-IHE	UNESCO Institute for Water Education
USACE	United States Army Corps of Engineers
VKS	Preferred Strategy' (Dutch: *voorkeurstrategie*)
VNG	Association of Dutch Municipalities (Dutch: *Vereniging van Nederlandse Gemeenten*)
WFD	Water Framework Directive
WRM	Water Resources Management
WRMO	Water Resources Management Organisation
WS	Water Boards (Dutch: *Waterschappen*)
WWW	WaalWeelde West

1 Introduction

Water Resources Management (WRM) has long involved the use of computer-based models. Such modelling provides water planners and managers with an ability to predict the behaviour of a proposed WRM policy or system design before it is implemented (Loucks & van Beek, 2005). Computer-based models allow water managers to critically analyse and assess whether these proposed actions will have the desired effects, or will bring with them any unintended consequences. This is not to say that such modelling can yield definitive answers to all our water-related problems, but its application has undeniably improved our understanding of water system behaviour, and contributed to improved system design, management and operation across all domains. However, computer-based modelling processes in WRM are presently undergoing somewhat of a paradigm shift, reflecting our changing understanding of water-related problems today. Not only used for prediction, computer-based models are now also commonly used for communication, education and conflict mediation.

1.1 The Changing Nature of Water Resources Management Problems

Traditionally, modelling in WRM has been used to inform a broadly technocratic decision-making approach (Pahl-Wostl, 2002). Under such an approach, models are constructed and used by technical experts (i.e. engineers), who have been specifically assigned to apply their knowledge to determine the recommended course of action. In situations where problems are generally perceived as being certain and uncontested, a technocratic approach can be highly adept at overcoming many challenges. In the past, many WRM problems were so perceived (Pahl-Wostl, 2002). Rivers broke their banks and flooded homes, dry-spells led to water shortages, water was needed in agricultural areas to meet production demands, or public health was endangered by a lack of sanitary infrastructure. It was a relatively uncontroversial task for technical experts to formulate the necessary combinations of structural and non-structural measures to address these problems. The technocratic approach ensured that their potential solutions were quickly and efficiently identified, their effects modelled, and the recommended actions taken.

However, both the nature and our understanding of many of today's water-related problems have changed and so too now are our approaches for dealing with them. Climate change, growing populations, increasing global development and rapid urbanisation are all constantly increasing competition for water resources, exacerbating ecological damage, and aggravating disaster risks. We now recognise the integrated nature of water-related problems, and have begun to search for equally integrated approaches to solve them (e.g., IWRM; (GWP, 2000); the concept of Water Security (van Beek & Lincklaen Arriens, 2014); or the nexus approach to water, food and energy security; (Hoff, 2011)). Today's problems are still essentially concerned with finding ways of coping with too much water, too little water, or water of poor quality, but our understanding of the systems within which these problems manifest has started to recognise and confront their complexity. We now appreciate that these systems encompass not only technical, but also a variety of competing ecological, economic, and social dimensions (Pahl-Wostl, 2002; von Korff, Daniell, Moellenkamp, Bots, & Bijlsma, 2012).

Recognition of system complexity has also highlighted other issues. Many of today's water-related problems are now also recognised for their varying degrees of uncertainty and conflict. Described as being either 'wicked' (Conklin, 2005; Rittel & Webber, 1973) or 'messy' (Ackoff, 1974; Vennix, 1999), these problems can be ill- or undefined. Symptomatically we know they exist, but we may not know and/or cannot agree upon the precise reasons why they occur. Additionally, we may not agree upon the actions that should be implemented to tackle these problems. Lacking such shared perceptions can lead to either or both problem definitions and their proposed solutions becoming contested spaces amongst stakeholders, and potentially lead to conflict. Problems such as these therefore not only present complex interrelated webs of technical issues that demand cross-sector integration, but they are also embedded in complex social, cultural and political contexts involving multiple stakeholders, values and perspectives (Hommes, 2008).

Our evolving understanding of WRM problems has meant that our entire approach to conducting WRM has likewise needed to change. It is increasingly rare that purely technocratic approaches can be applied to complex WRM issues. No single 'optimal' solutions exist for these problems; hence, solving (or 'resolving'; Horn & Weber, 2007) them cannot exclusively rely on expert-driven processes. Rather, more collaborative approaches are needed that respect heterogeneity of values, knowledge and perspectives. Recognising this, methods of participatory and collaborative WRM and stakeholder involvement are becoming increasingly important (Mostert, 2003; Pahl-Wostl, 2007). For example, witness the specific requirements for participatory water governance present in recent global WRM frameworks (e.g. GWP, 2000; UN-Water, 2014), or its inclusion in binding legislative controls such as the EU Water Framework Directive (WFD; EC, 2000, Article 14).

1.2 The Emergence of Collaborative Modelling

A reflection of this changing approach has also started to emerge in relation to computer-based modelling in WRM. Participatory Modelling (PM) has been receiving increasing attention over the past twenty years, particularly within the research community (Hare, 2011). Essentially, this describes a diverse range of modelling approaches and activities, whose common element is the involvement of stakeholders in one or more stages of the computer-based modelling process. By extension, Collaborative Modelling (CM) describes those PM approaches and activities that are characterised by particularly high levels of stakeholder participation, influence and control. The emergence of CM recognises that experts cannot typically develop computer-based models and recommend solutions that adequately reflect and address complex WRM problems in isolation. No expert can be expected to understand sufficiently the multiple interdependent physical, ecological, social, cultural and political processes that govern the behaviour of water resources systems (Loucks & van Beek, 2005). Indeed, many of these processes, where identified, are completely unpredictable. Likewise, the notion that modelling is an 'objective' scientific activity has been challenged, in light of the many assumptions and judgements implicit within a given modelling process. Which processes and variables to model, which data to use, which alternative scenarios to examine, and which criteria and weighting to use to select a preferred policy action are all choices that render modelling a "value-laden part of the political process" (Smith Korfmacher, 2001). The inclusion of stakeholder perspectives is therefore vital in modelling processes to broaden system understanding as well as for model improvement, but also in order to democratise the process and open up the 'black-box' nature of many WRM models, planning and decision-making processes. Additionally, CM recognises that models and modelling processes can provide benefits that go beyond the production of the final model, the output predictions, or the resulting policy analysis. For some approaches (e.g. Group Model Building; Vennix, 1996), the discussions and negotiations that take place during the collaborative development of a conceptual model can establish a shared understanding of the WRM problem and its many dimensions, build consensus and cooperation, or even mediate conflicts. As such, CM has the potential to also be a tool for supporting the type of collaborative learning currently promoted in WRM (Hare, 2011; Pahl-Wostl, 2007).

The fulfilment of these potential benefits, however, is naturally dependent upon the CM approach selected and the specific collaborative processes it employs. Every approach includes different types and levels of collaboration. They can each serve different collaborative purposes and deliver any benefits of collaboration in different ways and to varying extents. For example, some approaches may be more effective at increasing model transparency or meeting collaborative learning objectives, whilst others may be more effective at improving the quality and credibility of model outputs. Other approaches may be more limited in their application of collaborative processes and their ability to deliver these benefits may be equally curtailed. Additionally, each approach may lend itself more to certain problem-types, situations or contexts. For the water manager, the selection of an appropriate CM approach therefore remains inextricably linked to the specific characteristics and objectives of each project.

1.3 Research Rationale

Many questions remain concerning the implementation of specific CM approaches. In particular, there is a significant gap in the literature assessing the problem contexts most suited to the application of each approach. Despite considerable research into developing and applying approaches and tools in specific instances, this shortcoming is rarely addressed in a structured fashion. Likewise, for many CM approaches little attention is given to analysing stakeholders participating at different participation levels. Rather, research cases often rely on involving all participants in the same modelling activities. The questions of which stakeholders to involve, and then when and how they should each be involved for a given approach often remains unclear, particularly in order to realise any of the specific purpose(s) of these exercises. What is most surprising is the absence of detailed stakeholder perspectives of these approaches in many CM exercise assessments. To encourage the wider adoption of these approaches, the research community must demonstrate that they are effective at achieving both their collaborative and model-based objectives. To accomplish this, it is imperative that the views of those specifically involved (or perhaps even not involved) in these approaches are taken into account.

The continued development of practical, effective and replicable CM approaches requires detailed analyses of current applications that address the above issues. Such analyses must be wide-ranging and contribute practical knowledge regarding when and how to implement the different approaches with different stakeholders. They must also be sensitive to stakeholder insights and perspectives. This thesis directly addresses this need, by analysing in detail recent implementations of two very different CM approaches in the Netherlands. The first case study examines the Consortium Modelling approach used to develop the AZURE groundwater model for the central Netherlands. This was an intensive, stakeholder-driven, collaborative model development process. Key national and regional government groundwater agencies, the relevant drinking water company, and technical experts came together to develop a consensus regional computational model to be used by stakeholders for all future groundwater management and planning. The second case study concerns the Model-Supported Collaborative Planning approach used in the Dutch Delta Programme Rivers. Here, many different stakeholders were involved in a variety of processes to develop an adaptive flood protection management strategy. In this case study, notionally accessible modelling activities were situated within a much wider planning programme of institutional collaboration and social participation. As in AZURE, national and regional government water agencies were the principal collaborators, however, local governments, businesses and special interest groups also had opportunities to contribute to the planning process through other participatory forums.

In studying these two cases, this thesis also addresses the relative paucity of 'real world' CM examples found in the literature. Despite much valuable work over the past two decades in developing the various CM approaches in various settings, CM remains firmly within the domain of the research community (Hare, 2011). Any peer-reviewed examples are typically the result of research projects, and the author could find few instances of CM where WRM organisations have acted as the key motivators and drivers for the implementation of a particular approach. Indeed, two identified constraints limiting the widespread uptake of CM by water managers are: (1) there is often insufficient project resources made available to water managers to support CM processes, and (2) there is insufficient demand from water managers for these approaches to support actual decision-making processes (Hare, 2011). In the two cases considered in this thesis, CM activities have been organised and implemented by the WRM organisations themselves. They have not been the result of an academic or institutional research project. Project and programme resources were made available and both Dutch decision-makers and water managers demanded that CM approaches were included in each instance. This in itself renders both these cases particularly salient examples for research.

1.4 Structure

The thesis is structured in the following manner. In the next chapter (Chapter 2), the specific research objectives and questions to be addressed by the research are outlined in detail. In Chapter 3, the themes and issues introduced above regarding the application of CM in WRM are explored further based upon the findings of the author's extensive literature review. The methodological approach including the detailed analytical framework and assessment methodology to be used for each of the case studies is then presented in Chapter 4. Chapters 5-8 present the results of the first case study, applying the analytical framework to the Consortium Modelling approach adopted in the AZURE case. The results from the author's research into stakeholder perspectives of the collaborative processes in this approach are also presented in these chapters. Similarly, the results and analysis of the Model-Supported Collaborative Planning approach utilised in the Delta Programme Rivers are presented in Chapters 9-12. In Chapter 13, the findings from both approaches are compared and discussed within a broader perspective, before the final chapter (Chapter 14) presents conclusions to the research questions and outlines the author's recommendations for future applications of these approaches in WRM practice.

2 Research Objectives

The overall objective of this MSc research is to critically evaluate two 'real world' implementations of CM in the Netherlands with specific regard to the local contexts, timing and manner in which they have been applied. Stakeholder perspectives are taken into account in the assessments of these aspects, in addition to establishing the degree to which stakeholders felt that each of the approaches delivered their potential participatory benefits. In doing so, this research identifies the enabling and disabling conditions that were important in each approach. It is hoped that these may assist water managers determine whether or not to use the two approaches in future situations and then also help them devise the nature of stakeholder involvement such exercises. As indicated in the introduction, the two approaches that have been selected for this research are the Consortium Modelling approach utilised in the development of the AZURE groundwater model and the Model-Supported Collaborative Planning approach used in the Dutch Delta Programme Rivers.

In meeting this overall objective, this research has focussed on the following two sub-objectives and associated research questions:

2.1 Research Sub-Objective 1

To analyse present implementations of two specific CM approaches in order to identify the contexts in which they have been applied, the computer-based models they have utilised, and the manner in which they have involved different stakeholders during the various modelling process stages.

Q1.1 To which situations and contexts have the two approaches been applied and which were important for them achieving their objectives?

It is hypothesised that each of the studied approaches may lend themselves to particular socio-political contexts, to specific technical problem types, or to specific CM purposes (e.g. for decision making, consensus-building, learning, model improvement, etc.). The purpose of answering this first question is not to suggest that these approaches can be applied exclusively in contexts similar to those studied, but rather to establish a set of circumstances – informed by stakeholder perspectives – in which they may or may not perform relatively robustly.

Q1.2 When and how were different stakeholders involved during the two studied approaches? Did they find this level of involvement appropriate to achieve the objectives of the modelling exercises?

Given the situations and contexts established above, this question focusses on the particular manner in which the different stakeholders were involved during each of the two CM processes. It is hypothesised that it may be appropriate to involve different stakeholders at different times, in different ways and at different participatory levels during a given exercise. Naturally, this will depend upon the objectives of the exercise. Stakeholder perspectives feature heavily in this analysis, in particular to assess their degree of satisfaction with their respective levels of involvement. In doing so, the analysis also reveals any differences between the desired and realised levels of participatory involvement for each stakeholder, as well as provides insight into how stakeholder interest was or was not maintained throughout the CM process.

Q1.3 What minimum technical, modelling, or other skills and resources (if any) were needed by the different stakeholders and organising teams for each of the two approaches?

Following on from the preceding analysis, this question assesses the specific skills and resources different stakeholders (including the organising team) needed to demonstrate and provide in order to contribute most effectively during the participatory processes. It is hypothesised that certain skills may preclude the involvement of some (particularly non-technical) stakeholders in some activities. For example, it is unlikely to be of benefit to have non-technical stakeholders complete the actual construction of a technical simulation model. Stakeholders' perspectives help assess the level to which they themselves felt theirs and others' skills enhanced or inhibited their involvement in the approaches. Key resources implications (time, money) for each of the approaches are also presented as part of this analysis.

2.2 Research Sub-Objective 2

To assess stakeholder perspectives of the overall effectiveness of the two studied approaches/tools in delivering any potential collaborative benefits.

Q2.1 What are the perspectives of the different stakeholders regarding the effectiveness (or otherwise) of the two studied approaches/tools in achieving any potential collaborative benefits?

Some of the reasons for collaborative WRM are to empower stakeholders, apply their knowledge and accommodate their perspectives in WRM problems. As such, assessing the extent to which stakeholders themselves believe the two modelling exercises have realised any of these, among other, collaborative benefits constitutes a key aspect to this study. For example, did CM activities result in increased transparency and democratic decision-making? Did they improve credibility by building ownership and consensus? Were innovative actions proposed that otherwise would not have been? Did stakeholders feel they gained additional learning via their involvement? Was conflict reduced as a result of the process? In assessing the degree to which stakeholders themselves feel these benefits of collaboration have or have not been realised, this study aims to formulate helpful suggestions as to how each of the two approaches could be improved for future applications.

Having outlined the research objectives and questions that are considered in this research, the next chapter presents the results of the author's review of existing literature exploring the many themes these objectives introduce.

3 Literature Review and Problem Analysis

In the first chapter, we introduced the notion that WRM problems are becoming increasingly recognised for their complexity. This has demanded our approaches for dealing with these challenges evolve, including those involving computer-based modelling. Typically, these new approaches call for better informed decision making via the increased collaboration of stakeholders in not only formulating our understanding of these problems, but also in developing acceptable, appropriate and sustainable solutions to address them. In this chapter, these themes and concepts are unpacked and expanded upon further according to the author's review of recent peer-reviewed literature. After commencing with a discussion of WRM, its complex problems, and a contextual typology for these, the chapter turns its attention to the why, who and how of stakeholder involvement in WRM, including a means to analyse and structure such collaboration. Following this, the review considers the specifics of using CM in WRM. Beginning with a discussion of the various purposes for these exercises, it then considers the means by which these processes can be analysed and categorised. A presentation of the variety of approaches and tools identified in the literature follows, along with a comparative review of the performance of previous CM exercises against the stated benefits and limitations of CM. The chapter concludes with a reflection of how the research community has attempted to formulate CM rules and guidelines to ensure that all the various aspects of CM approaches combine and enhance their abilities to meet their objectives and deliver any collaborative benefits.

3.1 Water Resources Management

The need to properly manage water resources has become increasingly important as states strive to improve their socio-economic situation. Water is a key condition for human health, generating livelihoods, growing food, producing energy, ensuring economic growth, and protecting the integrity of ecosystems and the services they provide. Increasing water demands and water pollution generally result from population growth and endeavours for socio-economic improvement, and lead to growing pressures on our water resources systems(UN-Water, 2006). Sustainably managing these demands and impacts is now recognised as an imperative for states. Integrated Water Resources Management (IWRM) has been globally accepted as the best way to improve WRM. According to the GWP (2000), IWRM is a process which can assist states in their endeavour to deal with water issues in a cost-effective and sustainable way. It "promotes the coordinated development and management of water, land and related resources to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP, 2000). One of its central aims is the coordination and integration of different policy sectors in water resources planning activities as a means to deliver more holistic WRM. Thus, successful IWRM rests upon three foundational pillars: an enabling environment, a solid institutional framework, and the availability of useful management instruments (GWP, 2000). In combination, these pillars permit states to strike a balance between the use of water resources as a basis for human livelihoods and the protection and conservation of the natural resource to sustain its functions and characteristics (GWP, 2000). Consequently, the integrated cross-sector approach also provides a solid foundation with which to confront and plan for complex WRM problems.

3.2 Complex Problems in Water Resources Management

Today's complex WRM problems comprise various competing contextual factors that all need to be considered during water resources planning activities. Such complex problems satisfy the following general contextual conditions: there is no single problem, but rather a tangled web of related problems; problem issues lie across or at the intersection of many disciplines (technical, ecological, economic, social, cultural and political), and involve many different stakeholders and interests; and the underlying processes interact at various spatial and temporal scales (van Asselt, 2000). Fleshing this idea out, Horn and Weber (2007) outline the many other characteristics of complex problems typically exhibit, including:

- No unique 'correct' view of the problem; different actors maintain different views and propose contradictory solutions
- Multiple ideological, political, economic, social and cultural value conflicts
- Considerable uncertainty or ambiguity predominates, with the necessary scientific data often uncertain or missing
- Problem consequences are difficult to imagine
- Numerous possible intervention points and measures exist
- A large resistance to change must be overcome
- Decision-makers and those analysing and formulating potential solutions to these problems are separated from them and the effects of their solutions.

Complex problems, therefore, consist of both normative and factual elements. They cannot simply be regarded as objective givens, but rather as highly subjective constructs dependent upon the perspectives of those determining the existence of the problem. From this foundation, Hommes (2008) presents a typology of problems that distinguishes between two main dimensions. The first dimension is the level of consensus regarding collective values and norms, and the second is the degree of collective certainty regarding the factual knowledge base. Problem complexity increases as either the degree of disagreement or uncertainty increases. Using these two dimensions, the following four types of problems can be identified (Figure 1):

1. **Structured problems:** these are problems for which both a certain knowledge base and consensus regarding values and norms exists. They are not complex, can be classified as 'routine', and can be readily solved by applying existing knowledge. Often they can be solved through optimisation, thus lending themselves to programmable solutions. These problems require minimal discussion, with solutions formed in a policy context that is largely expert-driven.
2. **Semi-structured problems (Uncertain):** these are problems where consensus over values and norms exists, but there is disagreement or uncertainty regarding the knowledge base to be used to solve them. For these problems, the degree of complexity increases, as negotiation is required to establish an agreed scientific knowledge base (which may include the generation of new knowledge via research). Knowledge is therefore used strategically in order to achieve the agreed consensus objectives.
3. **Semi-structured problems (Disagreement):** these are problems where the knowledge base is certain, but there is a lack of consensus regarding collective values and norms. For these problems, compromise solutions need to be reached, with knowledge use playing a supportive role.
4. **Unstructured problems:** these are problems distinguished by their high level of complexity. In these cases, there exists both a lack of consensus regarding values and norms, and an uncertain knowledge base. The only means to solve such problems is through consensus building via collective learning. Typically, solving these problems requires an iterative process where knowledge is used for enlightenment and generating ideas.

<table>
<tr><td colspan="2"></td><td colspan="2">Factual Knowledge Base</td></tr>
<tr><td colspan="2"></td><td>Certain</td><td>Uncertain</td></tr>
<tr><td rowspan="2">Values & Norms</td><td>Consensus</td><td>1. Structured
Knowledge use: Instrumental
Process: Routine</td><td>2. Semi-structured
Knowledge use: Strategic
Process: Negotiation</td></tr>
<tr><td>Disagreement</td><td>3. Semi-structured
Knowledge use: Supportive/Conceptual
Process: Compromise</td><td>4. Unstructured
Knowledge use: Enlightenment/Ideas
Process: Learning</td></tr>
</table>

Figure 1: Typology of problems (adapted from Hommes, 2008)

There are still some structured problems in WRM, where problem causes are viewed as being relatively certain and consensus solutions known or relatively uncontroversial to determine and implement. However, many of today's WRM problems arise within social and natural systems that are characterised by higher levels of complexity, uncertainty and disagreement. As such, they commonly exhibit characteristics of either semi-structured or unstructured problems. This growing uncertainty and the prevalence of divergent values and norms in WRM has made it increasingly obvious that stakeholder-driven strategies must also inform our planning and responses to these problems. 'Hard' technical methods of analysis and problem solving that reduce scientific uncertainties must be supported by 'soft' stakeholder-based policy-making and application, with the latter focussed on building consensus through negotiation (Pahl-Wostl, 2002). Decisions for semi-structured and unstructured problems will necessarily involve 'trade-offs' for those bearing their consequences. Hence, involving these stakeholders in problem solving, planning and decision-making processes is paramount (Bryson, 2004). It is now widely accepted that plans and decisions informed and driven by stakeholders will be more acceptable, appropriate and sustainable, and implemented with greater success and less conflict (Voinov & Bousquet, 2010).

3.3 Participation in Water Resources Management

3.3.1 Involving Stakeholders

The promotion of participatory methods in WRM is not new. The Dublin Statement (1992) first gave prominence to WRM decisions being "taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects" (UNESCO, 1992). This principle has since been echoed in the Hague Declaration (2000), is central to IWRM and other recent global WRM frameworks (GWP, 2000; UN-Water, 2014), and in other international conventions and regulations, such as the EU WFD (EC, 2000). Participation in WRM is promoted as it has the potential to achieve a number of beneficial objectives, some of which have been alluded to previously and are directly related to its ability to deal with complex water-related problems. These include (Hare, Letcher, & Jakeman, 2003; Mostert, 2003):

- Empowering stakeholders by making decision-making more transparent and democratic.
- Increasing the credibility and stakeholder support for management actions through building ownership and consensus.

- Giving rise to improved or creative management actions, by accounting for local knowledge that would otherwise have been overlooked.
- Promoting collaborative learning (shared or social learning) amongst stakeholders about the complexity of the water resources system, the perspectives of management agencies and various stakeholders, and the various means available to address any problems.
- Reducing conflict between competing stakeholders by opening channels of communication, generating mutual understanding and negotiating compromise solutions.

Mayer, van Daalen, and Bots (2004) frame the reasons behind stakeholder involvement in WRM slightly differently, in terms of its specific potential contributions to policy analysis, planning and decision-making. They suggest that stakeholder participation can be used to achieve six generic key purposes of policy analysis, namely to:

- **Clarify arguments and values:** to improve the quality of the WRM policy debate.
- **Research and analyse:** to better understand the complexity of the WRM system.
- **Design and recommend:** to gain insight into possible actions that can be taken to manage the water-related problem.
- **Provide strategic advice:** to gain insight into the political aspects of the complex system in order to assist a client to better protect its interests and achieve its goals via the decision-making process.
- **Mediate:** to mitigate or even resolve conflict between stakeholders.
- **Democratise:** to take into account the views and opinions of ordinary citizens and laypersons traditionally overlooked in the decision-making process.

Regardless of the manner in which its supporting reasons are framed, it must be recognised that simply conducting participatory activities will not automatically realise these benefits or achieve these purposes. Participation also has the ability to engender several potential problems if implemented poorly. As Mostert (2003) notes, decision-makers are often unwilling to listen to some stakeholders, particularly the public. This means that participation can be constrained, with little follow-up, resulting in disappointment and reduced acceptance. Likewise, poor participation can be limited and unrepresentative in its application, with unorganised interests not represented at all (Mostert, 2003). Or it may result in responses that are of a low quality, are ill-informed or short-sighted. In addition, participation can lead to inconsistent decision-making, or potentially complicate negotiations taking place at higher levels (Mostert, 2003). If mediation activities are handled poorly, conflicts can exacerbate as a result of participation. It must also be recognised that stakeholder participation can demand a great deal of time and money, which can mean that cheaper, less-participatory methods are often implemented instead.

Naturally, if participatory methods are employed in WRM, it is in order to harness their many advantages rather than their disadvantages. However, this leads to a number of questions, namely who should be considered as stakeholders to be involved in policy analysis and decision-making processes, and how they should be involved in order to efficiently achieve participatory benefits. Despite inclusions for participation in WRM in the many international institutions mentioned above, little indication is given within them regarding these questions. The WFD, for example, is unclear about who exactly should be included as a stakeholder and its wording covers a broad range of possible broad participatory methods – from simple information provision through to participatory planning – with no real direction given as to which should be used (Hare et al., 2003). In response, a guidance document on public participation and the WFD has since been prepared (EC, 2003), and there has been a proliferation of additional other research over the past two decades devoted to exploring various participatory alternatives (e.g. Creighton, 2005; HarmoniCOP, 2005; NeWater, 2012; van Asselt et al., 2001).

3.3.2 The Who of Stakeholder Involvement

Terms such as 'stakeholder' and 'actor' have become ubiquitous in WRM, with analyses of them constituting essential components to decision-making processes. Although several definitions for these concepts exist, generally both terms are used interchangeably and encompass any group or individual who is affected by or who has an ability to significantly influence (either directly or indirectly) an action or policy (Bryson, 2004). However, some definitions restrict the term 'actor' to a subset of stakeholders comprising exclusively those interested parties with the power and agency to affect action or policy outcomes (e.g. Enserink et al., 2010). Through this frame, the term 'stakeholder' includes all actors, but then also others who *only* have an interest in the water resources system. That is, possible stakeholders include groups and individuals who, regardless of their level of interest, have little ability or few means to influence system decision-making processes and outcomes. Such limited-influence 'stakeholders' can often include special interest or pressure groups, the public at large, or specific, unorganised parts of the public such as poorer households, certain age groups, and so forth.

Accepting the distinction between the two terms, this thesis considers that participation in WRM activities should (at least initially) consider the inclusion of as broad an array of affected people, groups or organisations as possible. This would appear more compatible with typical approaches to democracy and social justice, in which the interests of the nominally powerless must also be given weight (Bryson, 2004). Hence, the pool of potential stakeholders for any given WRM problem can be very large and include representatives from the following five broad categories (van Asselt et al., 2001):

- Government, including water governance organisations (typically the decision-makers)
- Citizens
- Interest groups, such as non-governmental organisations (NGOs)
- Business
- Scientific experts

Participatory methods typically seek to target citizens, interest groups and business representatives, as it is these stakeholders who have been traditionally marginalised by technocratic approaches. It is typically their influence that needs to be boosted via the inclusion of their values, preferences and non-scientific local knowledge. Government representatives and scientific experts, for whom involvement has normally been a given, remain central to planning processes due to their statutory authority and expert knowledge.

Obviously it is often not practicable to include every individual stakeholder directly in participatory activities, nor would every stakeholder necessarily wish to participate. Choices do sometimes have to be made about restricting the level of involvement of certain stakeholders or in determining the degree to which some stakeholder's values or requirements are satisfied within the process. It must be recognised, however, that these choices are inherently political and have ethical implications. A particularly thorough way to approach these choices is to involve the stakeholders themselves in making them via an iterative collaborative stakeholder identification and analysis process (e.g. see Bryson, 2004). However, as a minimum, organisers should ensure that stakeholder involvement is representative, with at least one spokesperson from each key interest having the opportunity to contribute to the principal participatory forums.

3.3.3 The How of Stakeholder Involvement

The question of how to involve stakeholders in WRM activities in order to achieve participatory benefits rests upon two fundamental considerations. The first relates to the level of participation that stakeholders experience, whilst the second concerns the organisational structure of that participation. Regarding the first consideration, various typologies have been developed that classify participation according to its degree of involvement or level of stakeholder commitment. Arnstein (1969) was one of the first to develop such a typology, with her original eight-rung 'Ladder of Citizen Participation', but this has since been adapted by various scholars. Mostert (2003), for example, identifies six main levels of stakeholder participation in WRM, which include (in increasing order of involvement intensity):

1. Information: Stakeholders simply receive information (one-way downward flow of information).
2. Consultation: Stakeholders provide information to policy advisors/makers (one-way upward flow of information).
3. Discussion: A two-way interactive relationship between stakeholders and policy advisors/makers.
4. Co-designing: The active public involvement of stakeholders in problem analysis and policy/project design.
5. Co-decision-making: The sharing of decision-making powers with stakeholders.
6. Independent decision-making: The independent performance of planning/management tasks by all stakeholders.

The appropriate level of participation for various stakeholders naturally depends upon the objectives of the participatory activity. If one considers the six policy analysis purposes outlined previously, one could hypothesise that lower levels of participation may be suitable when the purpose is to clarify arguments and values, research and analyse, or to provide strategic advice. For activities more related to designing and recommending actions, democratising the decision-making process or mediation, higher levels of participation will most likely be required.

Determining the appropriate level of participation is only one issue facing practitioners when involving stakeholders. Another concern relates to the manner in which to structure such participation, particularly in those instances when large numbers of stakeholders need to be engaged in participatory planning activities. A useful way of structuring participation to limit numbers but not the influence of specific stakeholders is provided by the 'Circles of Influence' model, developed by sociologist Robert Waldman and now used by the US Army Corps of Engineers' (USACE; Werick & Whipple, 1994). Under this model (Figure 2), trust is developed in concentric circles; planners and managers work to develop trust with leaders and organisations that other stakeholders already trust. That is, those most directly involved in policy analysis activities (i.e. planners, managers and modellers who do most of the actual work; Circle A) communicate with trusted leaders and major stakeholder representatives at the next level (Circle B). These stakeholders then in turn provide a trusted link to all other interested parties, who have less direct involvement (Circle C). Ideally, Circle B participants would be active in professional or issues-oriented organisations and provide links to others whose interests they represent. Hence, Circle C stakeholders should see their interests represented in Circle B, and have formal opportunities to shape the work of Circles A and B via these representatives. A fourth circle (Circle D) includes decision-makers such as agency heads and elected officials, who have been given the authority to accept or reject the recommendations of the policy analysis. Although possibly not directly involved in all problem solving and analysis activities, the latter should be clearly identified and engaged throughout the planning process with direction and information flows possible to and from all circles.

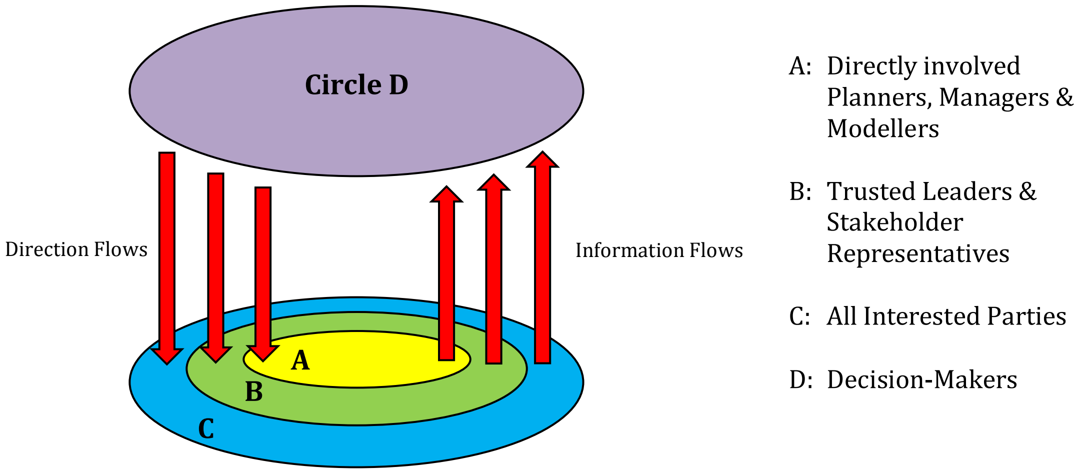

Figure 2: 'Circles of Influence' Model (adapted from Werick & Whipple, 1994)

The 'Circles of Influence' model structure allows and encourages open communication throughout a participatory engagement process. Its proponents hold that this openness then helps develop trust amongst the different parties and fosters respect for each other's interests and values (Cardwell, Langsdale, & Stephenson, 2009). Structuring participation in this way also lends itself to more easily define when and how each of the stakeholders situated within each circle is involved in specific participatory approaches. Combining the 'Circles of Influence' model with the typology of participatory levels, one could hypothesise that participation at lower levels (1-3) would be most appropriate for Circle C stakeholders, whilst middle levels of participation (3-4) would be better suited to Circle B stakeholders working in cooperation with those in Circle A. Co-decision-making (Level 5) would likely see Circle B stakeholders collaborate with those in both Circles A and D. The top independent decision-making level (Level 6) is somewhat of a special case, in that stakeholders operating at this level would assume the role of Circle D entirely.

Regardless of how it is structured, available methods for stakeholder participation are incredibly varied and can target any phase in a planning process. The list of possible methods include the passive provision of information to stakeholders via newsletters and press releases, to more consultative forms such as questionnaires, interviews and focus groups, to even more active forms of involvement such as citizen juries, scenario workshops and participatory planning.[1] Participatory Modelling is another active approach (or rather set of approaches), and is one that strikes at the heart of the technocratic process.

3.4 Participatory Modelling in Water Resources Management

As indicated in the first chapter, a central element of planning, designing and managing water resources systems today inevitably involves computer-based modelling. Models allow for the construction of a virtual representation of reality capable of assessing the future impacts of today's actions. Alternative futures based upon a variety of action scenarios can be tested, analysed and assessed, before their inclusion in a decision-making process. However, models can play different roles in WRM and policy development. Primarily (and traditionally), computer-based models are used for prediction and analysis activities. But they can also serve as 'eye-openers' or communication tools, by drawing attention to specific issues. They can create consensus, by accommodating alternative perspectives. Conversely, they can be used to support

[1] For a (non-exhaustive) list of other possible participation methods delineated according to participation level, see Mostert (2003), Table 2.

an either conformist or dissenting viewpoint by focussing on a particular perspective (van Daalen, Dresen, & Janssen, 2002).

Traditionally, modelling choices concerning any assumptions, variables, data, calibration, scenarios or alternatives to be included in modelling processes have remained firmly the domain of expert modellers. Although a valid approach for structured problems, for both semi-structured and unstructured complex problems these choices are informed by uncertain knowledge and/or subjective values. Often these choices conform to the perspectives of the principal client or organisation for which the modeller is working, or they can simply be influenced by the particular perspectives the modellers hold themselves. However, principals and modellers are sometimes more detached from actual impacts or final decision-making processes than the majority of stakeholders in the issue being decided upon (Bots & van Daalen, 2008). Participatory Modelling (PM) aims to directly mitigate this effect, by involving a greater breadth of stakeholders in one or more stages of the modelling process, from simple data collection and model definition through to model construction, verification and use (Hare, 2011). In doing so, many of the choices traditionally made by modellers are directly informed – or perhaps even made – by those stakeholders most concerned with the impacts of the modelling activity.

3.4.1 Participatory versus Collaborative Modelling

By involving stakeholders in modelling activities, PM has the potential to deliver many of the beneficial objectives of stakeholder involvement outlined previously. This is due to its theoretical allowance of high levels of participation. Specifically, PM has the ability to consistently reach Mostert's (2003) fourth 'Co-designing' level, and on occasion may be included within a broader 'Co-decision-making' process. More rarely, PM could even reach Mostert's top level; although that would entail the development and distribution of modelling tools stakeholders would be able to use independently, as well as an institutional arrangement authorising the performance of water resources planning and management tasks by non-government stakeholders. Then again, in other instances PM might limit stakeholders to 'Discussion' or perhaps even only 'Consultation' inputs. The ability of PM to deliver any participatory benefits in these instances would be similarly curtailed.

Consideration of participation levels within the context of PM leads to an important distinction the author would like to make with regards to PM: namely the difference between participatory and collaborative forms of stakeholder-based modelling activities. Often the terms 'Participatory Modelling' and 'Collaborative Modelling' are used interchangeably in the literature. However, the author would like to suggest that Collaborative Modelling (CM) specifically relies on a combination of high levels of participation and highly motivated stakeholders willing to both be involved in the modelling activities and to cooperate or negotiate with other stakeholders (Figure 3). If either of these conditions is not fulfilled, it is argued the nature of involvement will be necessarily more participatory in nature. At lower levels of participation, there is no requirement that stakeholder interests or policy recommendations will actually be taken into account by policy-makers, denying them the opportunity to truly collaborate in devising policy outcomes. Similarly, even at high levels of participation, if stakeholders are unmotivated or unwilling to cooperate or negotiate with others it is equally unlikely that truly collaborative outcomes will emerge. Yet it must be recognised that increasing stakeholders' influence in decision-making processes is much more likely to raise their willingness to cooperate in these activities than restricting their influence would.

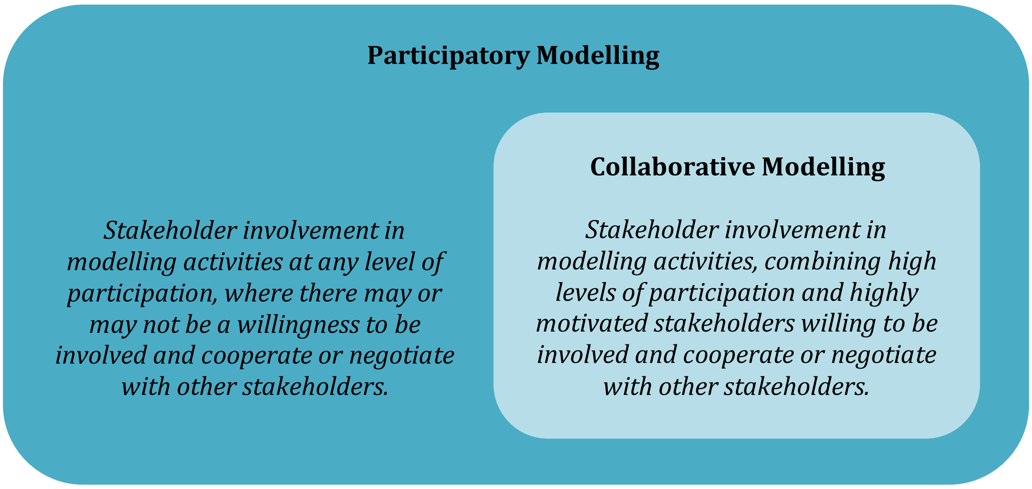

Figure 3: Participatory and Collaborative Modelling

According to this definition CM is both a subset and a much more intensive form of PM (Figure 3). It can only occur when stakeholder participation is conducted in cooperative contexts at co-designing levels and above (Levels 4-6). In this thesis, the author will refer to such instances of PM as CM. Note that this also applies when approaches combine a mix of collaborative involvement for some stakeholders with lower levels of participation for others (e.g. if participation is structured according to the 'Circles of Influence' model). Having now made this distinction, the following sections provide a review of existing PM literature. This review outlines the specifics behind its reasons for implementation, in addition to how the various PM approaches can too be analysed, structured and categorised. Here the more general PM term is used, as the information contained below applies to either participative or collaborative forms of stakeholder involvement in modelling.

3.4.2 Purposes of Participatory Modelling

In opening up the modelling process in this way, PM is able serve a number of specific purposes. Earlier in this chapter, the author presented Mayer's et al. (2004) classification of the six policy analysis purposes of stakeholder participation: to 'clarify arguments and values', to 'research and analyse', to 'design and recommend', to 'provide strategic advice', to 'mediate', or to 'democratise'. Bots and van Daalen (2008) apply this reasoning to PM, and argue that in designing potential PM approaches, water managers need to determine meeting which of these (or combination thereof) is most important given their particular complex problem. However, each of these purposes is directly related to informing policy or management-related decision-making processes. Categorising PM purposes in this way assumes that directly influencing decision-making is always an implicit purpose of PM (Hare, 2011). It obscures those other tasks of PM unrelated to actual decision-making, such as simply for model improvement or collaborative learning. Accordingly, Hare (2011) augments and reorganises these six purposes to three principal ones: direct decision-making, social learning and model improvement (Table 1).

Although the author finds this reorganisation useful, one can see from Table 1 that both 'provide strategic advice' and 'mediate' are unrepresented outside of 'direct decision-making' in the right hand formulation. Although this makes sense in the former case, it conceals the fact that a specific focus of PM can be simply to help mitigate conflict. That is, the objective of a PM exercise may be to help reduce conflict without leading to any specific decisions being taken. For example, having conflicting parties cooperate in a hypothetical role-playing simulation will not

Table 1: Comparison of two competing classifications of Participatory Modelling purposes

Bots and van Daalen (2008)	Hare (2011)	
Purpose	*Purpose*	*Corresponding Bots and van Daalen (2008) purpose(s)*
1. Clarify arguments and values	1. Direct decision-making	1, 2, 3, 4, 5, 6
2. Research and analyse	2. Social learning	1, 2, 3, 5
3. Design and recommend	3. Model improvement	
4. Provide strategic advice	a. Quality	2
5. Mediate	b. Acceptance	3, 6
6. Democratise	c. Integration	1, 2, 3, 6

necessarily be targeted towards generating a 'real world' decision, but rather could simply be intended to create space for genuine reflection (e.g., via collaborative learning). Recognising this, the author prefers Basco Carrera's (unpublished-b) formulation of PM purposes, which makes general use of Hare's approach with the addition of both 'Mediation' and 'Shared Learning' tasks; the latter included along with 'Social Learning' under an expanded 'Collaborative Learning' category.[2] However, what is important to remember within the context of the present discussion is that different PM approaches can be either selected or designed depending upon which of these – at times competing and conflicting – functions water managers (or the stakeholders themselves) perceive necessary or important to accomplish. Note that these context-specific choices may not be easy to make, as anticipating in advance all stakeholder learning, mediation and model improvement priorities will rarely present a straightforward task. For example, an unexpected conflict situation requiring mediation could emerge during an approach. If this were an approach ill-suited to mediating such conflict, then the approach would need to be modified to reflect the new situation. It is important for this reason that PM approaches therefore remain adaptable and flexible, and capable of serving additional functions to those originally intended by their initiators.

3.4.3 Participatory Modelling Frameworks and Forms

Having considered the specific functions that can be accomplished with PM, it is also necessary to take into account those other aspects of PM approaches that can impact on their ability to deliver these. Also, one simply needs a means to differentiate between the diverse approaches. To this end, several review articles published over the past decade all present different frameworks with which to categorise PM activities. Each framework serves a slightly different purpose and as such includes different criteria. Hare et al. (2003) categorise PM cases according to their purpose and their participatory structure, including the potential number of relevant stakeholders involved, the organizational levels at which they operate, the local political structure, and the actual stakeholders used during co-design exercises. This is in order to analyse the links between participatory structure and process implementation. Barreteau, Bots, and Daniell (2010), on the other hand, establish a framework to represent to stakeholders their involvement in these processes in order to more realistically manage their expectations. Theirs provides a clear description of the involved processes, focussing on the timing of stakeholder participation, the control of information flows between stakeholders, and whether stakeholders

[2] Social learning refers to learning that occurs only between collaborating participants, whilst shared learning refers learning that occurs between both collaborating participants and organising teams. A detailed description including this classification of CM purposes is provided in the following chapter.

will be involved individually or in group settings (participation mode). A third framework (Bots & van Daalen, 2008) includes elements of both the preceding two (e.g. PM purpose, participation timing and participation mode), but then also considers model type and the participatory methods used. Its intent is to support effective PM process design, and is thus not intended as a tool for ex post analysis. Finally, Hare's (2011) framework seeks to identify generalised PM forms by expanding upon Bots & van Daalen's (2008) with an analysis of the involvement of specific stakeholders and their required skills during each modelling stage.

Combining and augmenting many of the distinctions presented by these preceding frameworks, Basco Carrera (unpublished-b) has recently developed a single, expanded analytical framework with which to consider all PM approaches. In doing so, she has established a means to both undertake a complete ex post analysis of specific PM exercises and provide an ex ante tool to aid generalised approach selection. The ultimate objective of this expanded framework is to demonstrate the contexts in which each generalised approach could be applied, and then the broad manner in which to apply them. As it is proposed to use this framework in this study, a detailed description is provided in the next chapter; however, briefly it includes the following key criteria:

- **Problem Context and Application:** including problem type, scale, time horizon, decision type, domain, and decision-making context.
- **Specific Use:** including PM purpose and planning cycle phase.
- **Information Handling:** including model type, software platform, information type and delivery.
- **Stakeholder Involvement:** including the parties involved, model users, skills, participation mode, level, timing and form.
- **Organising Team:** including parties involved and skills.
- **Means:** including financial and timing.

As the above list demonstrates, there are many different criteria with which to classify a given PM exercise. Although none is necessarily more important than any other, it is useful to briefly focus on one of these – that of Hare's (2011) four dominant PM 'forms' – as it provides an easy-to-comprehend and effective means to broadly differentiate between the timing of stakeholder involvement promoted in different PM approaches. These four forms are:

- **Front- and Back-End (FABE) Modelling:** which concentrates the involvement of stakeholders in the early and later stages of a modelling exercise, excluding model construction as a minimum. Typically, participants can be involved in (variously) providing early inputs to data collection and model definition, before returning later to (either) give verification input to model validity, developing testing scenarios and alternatives, or assessing these.
- **Co-construction Modelling:** which involves stakeholders directly in model definition and construction, typically with stakeholders making the decision on final model structure. This form has been used almost exclusively in the construction of qualitative conceptual models, which are then used as the basis for system dynamics or Bayesian network simulation models, for example.
- **Front-end (FE) Modelling:** which is typically consultative, and is where stakeholder involvement is restricted to activities prior to model construction. This is generally only for data collection, but could also perhaps include consultations to improve model definition.
- **Back-end (BE) Modelling:** which is where stakeholders become involved only after the final model has been built. This can be in simulation exercises (such as role-playing games) or to allow stakeholder input into strategy development and assessment. Alternatively, BE modelling can also be used for stakeholder education purposes.

Having presented these dominant forms of PM, it now becomes possible to undertake a preliminary comparison of the various PM approaches that have been identified in the literature.

3.4.4 Participatory Modelling Approaches and Tools

A review of PM literature reveals a sometimes confusing catalogue of PM approaches, each employing its own particular nomenclature. This has the effect of somewhat obscuring both the similarities and differences between the approaches. In their review, Voinov and Bousquet (2010) provide an overview of many of the PM approaches that have been implemented to date and the range of software and analytical tools used in each of these. Building on this work, Basco Carrera (unpublished-a) has identified three additional approaches. Briefly, the identified PM approaches include, *inter alia*:

- **Group Model Building (GMB):** (Andersen, Richardson, & Vennix, 1997; Vennix, 1999) a specific process based upon the face-to-face development of conceptual causal loop diagrams for system dynamics models with stakeholders actively involved in a process of co-construction. Its main objectives are to foster shared learning and consensus building. Hence, GMB is a Co-constructed form of PM.
- **Mediated Modelling (MM):** (Antunes, Santos, & Videira, 2006; van den Belt, 2004) a trademarked co-construction process that uses system dynamics, but focuses primarily on environmental applications in situations of conflict.
- **Companion Modelling (ComMod):** (Becu, Neef, Schreinemachers, & Sangkapitux, 2008; Etienne, du Toit, & Pollard, 2011) another trademarked process that typically involves a stakeholder process involving a combination of building agent-based models and role-playing games. ComMod is again an example of Co-construction.
- **Participatory Simulation (PS):** (Castella, Trung, & Boissau, 2005) also based upon agent-based models and role-playing games, but where stakeholders only collaborate in simulations, and not model building. It is an example of the BE form of PM.
- **Collaborative Modelling for Decision Support (CMDS),** formerly **Shared Vision Panning (SVP):** (Cardwell et al., 2009; Langsdale et al., 2013; Langsdale et al., 2009) a trademarked approach of the US Army Corps of Engineers that is used in relation to the co-construction of integrated WRM Decision Support Tools. It combines traditional water resources planning, structured public participation, and integrated computer models. CMDS traditionally used system dynamics models but has more recently transitioned towards using more Excel-based models.
- **Cooperative Modelling (CoopMod):** (Cockerill, Passell, & Tidwell, 2006) an approach bearing similarities to GMB, where there is an express willingness on the part of stakeholders to cooperate in planning activities. It typically uses system dynamics, but other platforms may be supported. Stakeholders normally co-construct the model, but can only be involved during simulation and analysis phases (BE form). CoopMod has even been applied in settings where stakeholders have been spread over large distances with cooperation taking place via web interfaces (Cockerill, Tidwell, Daniel, & Sun, 2010).
- **Interactive Modelling (IM):** an approach that typically involves the development of a rapid visualisation model with which stakeholders can interact and which facilitates stakeholder understanding of complex physical processes. Typically used in groundwater management, flood management or land use applications, IM is an approach that can either involve stakeholders in simulation model development (FABE forms; e.g. Berendrecht, Snepvangers, Minnema, & Vermeulen, 2010), or simply in model use after its development (BE forms; e.g. Stock et al., 2008).

- **Networked Environments for Stakeholder Participation (NESP):** (Almoradie, 2014; Evers et al., 2012) a variant promoted by UNESCO-IHE that combines collaborative processes supported by a sociotechnical framework. Typically applied in Flood Risk Management (but also applicable to WRM), NESP is an intensive FABE form of PM that combines the development of robust rainfall-runoff simulation models with a focus on individual stakeholder collaborative learning to elevate flood risk awareness and planning activities. Communication tools feature heavily in this approach, with the entire process supported by a web-based collaborative platform.

In addition to the above, many case studies in the literature give no clear indication or particular nomenclature for the approaches they have applied, preferring simply to fall under the generic umbrella of 'PM' (or 'CM'). By way of example, these unspecified approaches can refer to stakeholder involvement in more traditional simulation modelling exercises (such as hydrological modelling: Gaddis, Falk, Ginger, & Voinov, 2010; Olsson, Jonsson, Andersson, & Arheimer, 2011), or in the construction of Bayesian Networks (Carmona, Varela-Ortega, & Bromley, 2013). Naturally, these additional approaches can accommodate a variety of modelling tools and all four PM forms: Co-construction, FABE, FE and BE.

As is no doubt evident, PM approaches can use a variety of modelling tools in their activities. Although there appears to be a dominance of system dynamics modelling in many of the approaches (GMB, MM, CMDS, CoopMod), PM tools can also range from simple Excel spreadsheet models, to more complex agent-based models, Bayesian network models, spatial GIS-based models, spatial vector-based models (e.g. hydrological models), or raster-based visualisation models that capture both temporal and spatial dynamics (Voinov & Bousquet, 2010; Voinov & Gaddis, 2008). These modelling tools can be used either independently, or as sub-model components to more complicated integrated assessment models and Decision Support Systems (DSS). Essentially, any existing modelling tool can be used in a participatory manner. However, the selection of a particular PM approach may dictate the specific tool to be used in many cases (e.g. for GMB, system dynamics models are required).

3.4.5 Beneficial Outcomes and Limitations of Participatory Modelling

By involving stakeholders in modelling activities, PM has the potential to deliver all of those benefits of stakeholder participation identified previously in this chapter (refer section 3.3.1). It can democratise model inputs and decisions that affect water system stakeholders. It can reduce the 'black box' nature of many models and illuminate how any recommendations were reached. It can build public trust in a model and its outputs, thereby increasing support and giving credibility to management decisions based upon those outputs and reducing conflict. It can result in improved model quality and decision-making by allowing for integrated perspectives and including for local knowledge. Also, it has the potential to dramatically increase collaborative learning amongst participants with regards to each other's perspectives, the modelled system's behaviour, and the potential effects of various action scenarios.

However, there are equally a number of limitations to PM, which can be categorised into either unintended consequences or difficult conditions to overcome. Expanding on the more general limitations of stakeholder participation previously outlined (refer section 3.3.1), four key potential unintended consequences of PM include (Smith Korfmacher, 2001):

- Risk of biased participant input, as it may be that only those participants who can either best understand the technical information and process, or alternatively are the most affected by the WRM decisions will prioritise their involvement in a lengthy (and potentially voluntary) PM exercise.

- Risk of reduced credibility, as involving laypersons in these technical exercises could easily lead to situations where the objectivity and scientific merit of the model results are cast into doubt by decision-makers and participants alike.
- Risk of over-legitimisation by water managers, should decision-makers judge that model results and recommendations are the technically and socially optimised 'solution', which may not be the case due to biased inputs or a poor understanding of the model by participants.
- Misrepresentation of consensus, as this may have been impossible to achieve. Hence, a single set of PM recommendations may not be adequately able to express the diversity in stakeholder values in the PM exercise. It could also be that the PM exercise itself actually results in reduced stakeholder consensus and increases conflict.

Further to these potential negative consequences, there are several conditions that may also need to be overcome in PM exercises, all of which have the propensity to similarly limit the effectiveness of these exercises. These include:

- Lack of technical expertise of the participants involved, for which the provision of sufficient training would be very time and resource intensive (Smith Korfmacher, 2001). Hence, participants may not be able to understand the material that is presented to them. Also, they may not be able to correctly interpret model results, which could put them at odds with expert opinion.
- Insufficient influence of participants on management decisions, which depends upon the use of model results (Smith Korfmacher, 2001). If participants feel that their extensive involvement in a PM exercise will yield little in the way of practical results, they will be disinclined to participate in the exercise. Hare et al. (2003) term this the degree of 'action mismatch'.
- Unwillingness of WRM organisations (WRMOs) and modelling experts to share discussion and decision-making powers and responsibility with non-legally responsible stakeholders, who may (rightly or wrongly) be considered to be non-experts (Hare, 2011). Water managers will likely remain accountable for any decisions taken, and permitting stakeholders to influence project planning may be viewed as highly risky for policy- and decision-makers.
- The time and resource-intensity of PM exercises, and how an iterative PM process may not be able to complete model development within a timeframe compatible with planning programmes (Hare, 2011). For example, in projects with penalties for late completion, project planning could race ahead of PM processes, thereby rendering the latter redundant. That being said, this perspective ignores the fact that reduced- or non-participatory planning may be plagued by conflict, and in some cases the additional time and money spent on PM may be a wise investment, helping to prevent long delays and increased costs in later phases (EC, 2003).

Naturally, it is of interest to establish the most appropriate means to incorporate stakeholder participation in project planning and computer-based modelling processes to maximise the potential benefits, minimise the negative consequences, and restrict or mitigate the impacts of any limiting conditions. It is only by doing so that the 'risks' of involving stakeholders in PM activities will become more acceptable to water managers, experts and decision-makers alike, and the demand for such approaches will increase. To do so, however, relies upon focussing attention upon the performance of PM exercises in achieving these aims.

3.4.6 Performance of Previous Participatory Modelling Exercises

The extent to which many PM exercises deliver these potential benefits or unintended consequences, or mitigate or fail to overcome any potential limitations is frequently unspecified.

A review of fourteen detailed case studies of various PM processes in the literature has revealed that relatively few studies have sought to systematically evaluate these aspects either qualitatively or quantitatively. In some studies, pre- and post-surveys and/or interviews of their respective PM participants were undertaken in order to assess some of these aspects, but no standardised evaluation framework exists. Moreover, in terms of giving a 'voice' to the stakeholders involved in each of these processes – that is, to give specific qualitative stakeholder insights into their opinions and perspectives of the processes and their delivery of any beneficial or more negative outcomes – only Gaddis et al. (2010), Olsson et al. (2011), and Cockerill et al. (2006) have done this to any great extent. The author found this somewhat surprising, for to improve our delivery of PM approaches, researchers and practitioners must be able to learn from the perspectives and experiences of the stakeholders participating in previous exercises. Quantitative surveys are certainly able to provide an indication of the level of satisfaction with a particular process, but they are less capable at determining the reasons that stakeholders hold these views. Nor do they provide stakeholders with an opportunity to suggest how they would have improved the PM process in any way, thereby limiting our ability to learn from their experiences. Somewhat more philosophically, a failure to ascertain and report detailed stakeholder perspectives of the processes also limits their agency in any future exercises that choose to employ a similar approach. To mitigate this, the author holds that any quantitative PM research should be systematically complemented by qualitative research.

Nevertheless, the reviewed case studies all confirm that PM approaches are successful to some degree in delivering the potential benefits of PM. Although it is not the author's intention to detail findings from each individual case, Table 2 outlines in which of these the fulfilment of each beneficial outcome is explicitly reported. In general, the assessment of each case is based upon any direct stakeholder feedback presented by researchers during the studies. However, in some instances it has been taken from the critically deduced findings of the researchers themselves. As Table 2 demonstrates, the greatest numbers of studies support the notions that PM leads to increased collaborative learning for their participants (13 cases); increases the perceived credibility of the model (11 cases); and heightens the sense of the model being unbiased, fair and inclusive of diverse perspectives (i.e. is more democratic; 9 cases). The ability for PM approaches to build consensus (5 cases), open up channels of communication (5 cases) and increase model transparency (4 cases) are also mentioned in several instances. Reducing conflict, incorporating local knowledge, increasing ownership and improving the quality of modelled outcomes are also all mentioned in at least one case, but do not seem to be a particular focus of many of these assessments. That is not to say that they play an insignificant or non-existent role in cases where they were not reported, but simply that either the stakeholders and/or researchers did not consider them relevant or important enough to explicitly assess or mention.

Review of these cases also suggests several potential PM-related findings. Firstly, three out of the four cases citing increased model transparency outcomes involved co-constructed forms of PM. Given that in these three instances participants developed conceptual models together, it is not surprising that they possessed and reported a strong understanding how the models worked. As one would expect, it is likely that co-construction processes improve model transparency more effectively than other forms. Secondly, in many instances building model credibility may be related to the involvement of trusted technical experts, as three of the cases explicitly mentioned the important role of expert involvement in aiding this outcome (Beall, Fiedler, Boll, & Cosens, 2011; Leys & Vanclay, 2011; Olsson et al., 2011). With respect to learning, Beall et al. (2011) found that participants with the least pre-existing technical knowledge learned the most during her SVP process in Idaho. However, Raadgever (2009) – in his specific research into whether collaboration leads to learning – speculates that the relation between collaboration and cognitive learning will be most obvious in cases in which more new research results are produced; expert knowledge is directly needed for decision-making; and

Table 2: Detailed Participatory Modelling case studies explicitly outlining the attainment of potential beneficial outcomes

Case	References	Approach	Approach Form	Increased Transparency	Increased Democracy[+]	Increased Credibility	Increased Ownership	Increased Consensus/ Negotiated Solutions	Improved Model Quality/ Creative Alternatives	Local Knowledge Incorporated	Increased Learning	Reduced Conflict	Opened Communication Channels
Kaggebo Bay Nutrient Management, Sweden (DEMO)	Olsson et al. (2011)	Not Specified	FABE		*	*	*				*		
Lake Champlain TMDL, St Albans, Vermont	Gaddis et al. (2010)	Not Specified	FABE		*			*		*	*	*	*
ACER/NeWater: Future flood management in the Lower Rhine basin, Germany & Netherlands	Raadgever (2009)	Not Specified	(FA)BE		*	*		*			*		*
Mae La Ngun, Thailand	Becu et al. (2008)	ComMod	(FA)BE	*							*		*
Groundwater management in Delft, Netherlands	Raadgever (2009)	Not Specified	(FA)BE			*					*		*
Sonora River Basin, Mexico	Robles-Morua, Halvorsen, Mayer, and Vivoni (2014)	Not Specified	BE			*					*		*
Guadiana River Basin, Spain	Carmona et al. (2013) Zorrilla et al. (2010): Upper Basin Carmona, Varela-Ortega, and Bromley (2011): Middle Basin	Not Specified	Co-construction	*	*						*	*	
Gila River Basin, New Mexico	Cockerill et al. (2010)	CoopMod	Co-construction		*	*				*			
Middle Rio Grande, New Mexico	Cockerill, Tidwell, and Passell (2004) Cockerill et al. (2006)	CoopMod	Co-construction		*	*					*		
Ria Formosa, Portugal	Antunes et al. (2006) with additional information in Kallis et al. (2006)	MM	Co-construction			*		*			*		
Plantation Forestry, Upper Clarence catchment, NSW	Leys and Vanclay (2011)	Not Specified	Co-construction		*	*		*		*	*		
Baixo Guadiana, Portugal	Videira, Antunes, and Santos (2009)	Not Specified (GMB/MM)	Co-construction	*	*	*	*	*	*		*		
Okanagan Basin, British Columbia, Canada	Langsdale et al. (2009)	Not Specified (GMB/SVP)	Co-construction			*					*	*	
Paluse Basin, Idaho	Beall et al. (2011)	Not Specified (SVP)	Co-construction	*	*	*					*		

[+] *Refers to the recognition of the inclusion of diverse views, or an unbiased process.*

Table 3: Detailed Participatory Modelling case studies explicitly outlining experience of potential unintended consequences or other limitations

Case	References	Approach	Approach Form	Biased Input	Reduced Credibility	Over-legitimisation	Misrepresent-ation of Consensus	Low Quality Outcomes / Inconsistent Decision-making	Exacerbated Conflict	Insufficient Participant Technical Knowledge	Insufficient Participant Influence / Action Mismatch	WRMOs/ Experts Unwilling to Cede Control	Too Time Intensive	Too Costly
Kaggebo Bay Nutrient Management, Sweden (DEMO)	Olsson et al. (2011)	Not Specified	FABE	*	*					*	*			*
Lake Champlain TMDL, St Albans, Vermont	Gaddis et al. (2010)	Not Specified	FABE							*	*			
ACER/NeWater: Future flood management in the Lower Rhine basin, Germany & Netherlands	Raadgever (2009)	Not Specified	(FA)BE	*							*		*	
Mae La Ngun, Thailand	Becu et al. (2008)	ComMod	(FA)BE				*			*				
Groundwater management in Delft, Netherlands	Raadgever (2009)	Not Specified	(FA)BE	*										
Sonora River Basin, Mexico	Robles-Morua et al. (2014)	Not Specified	BE		*									
Guadiana River Basin, Spain	Carmona et al. (2013) Zorrilla et al. (2010): Upper Basin Carmona et al. (2011): Middle Basin	Not Specified	Co-construction	*	*					*	*		*	
Gila River Basin, New Mexico	Cockerill et al. (2010)	CoopMod	Co-construction	*				*	*					
Middle Rio Grande, New Mexico	Cockerill et al. (2004) Cockerill et al. (2006)	CoopMod	Co-construction	*	*			*				(*) (Pre-survey)	*	*
Ria Formosa, Portugal	Antunes et al. (2006) with additional information in Kallis et al. (2006)	MM	Co-construction		*									
Plantation Forestry, Upper Clarence catchment, NSW	Leys and Vanclay (2011)	Not Specified	Co-construction										*	
Baixo Guadiana, Portugal	Videira et al. (2009)	Not Specified (GMB/MM)	Co-construction								*		*	
Okanagan Basin, British Columbia, Canada	Langsdale et al. (2009)	Not Specified (GMB/SVP)	Co-construction											
Paluse Basin, Idaho	Beall et al. (2011)	Not Specified (SVP)	Co-construction		*				*		*		*	

external influences on cognitive learning about the issue at stake are relatively small.[3] Of particular interest to other PM exercises, Raadgever also demonstrated that increased collaboration could facilitate significant learning in a direction that agrees with the technical modelling results.[4] Leys and Vanclay (2011) observed a similar learning shift towards modelling results in their Australian case, where community stakeholders' support for plantation forestry increased following the exercise, contrary to their initially held positions.

Repeating this exercise for any unintended consequences or limiting conditions in each of the cases likewise reveals that care must be exercised in all PM exercises (Table 3). The risks of biased or unrepresentative input, reduced model credibility, the degree of action mismatch and the required time for these exercises were the most cited PM limitations in all the cases (6 mentions). Interestingly, in many of the cases suggesting a degree of participant concern for biased inputs and model credibility were also cases that had also suggested that the majority of participants were all essentially satisfied with these aspects. Any concerns expressed were essentially only those of a vocal minority. Similarly, the fact that many cases reported a degree of action mismatch – not to mention the low number of cases reporting over-legitimisation or a potential misrepresentation of consensus (0 cases and 1 case respectively) – may be a reflection of the fact that very few of these research projects were situated within actual formal decision-making processes. The lack of any commitment from decision-makers or pressing planning processes in these exercises reduced participant motivation in some instances (e.g. ACER/NeWater: Raadgever, 2009; Videira et al., 2009). Time-related aspects of these processes are also evidently an issue, with many cases reporting declining participation as the processes progressed. Having said that, two cases suggested participants were generally content with the necessary time commitment, but had wished that meetings could have occurred more frequently in order to maintain interest and any learning gains (Langsdale et al., 2009; Olsson et al., 2011).

Insufficient participant technical knowledge was also a regular issue (4 mentions), and criticisms of lower quality outcomes and the general costliness of the exercises were also garnered (2 cases each). Interestingly, quality criticisms were restricted both to cases where participants were involved in co-construction conceptualisation processes, and one of these cases explicitly included stakeholder reference to the simplistic nature of the model (Cockerill et al., 2004). Two cases also referred to instances where conflict levels increased; however one of these then reported that this was effectively resolved during the ensuring processes (Cockerill et al., 2010). Similarly, two cases referred to participants actively not discussing sensitive issues and avoiding conflict, which could actually have the undesired effect of leading to future conflict (Cockerill et al., 2010; ACER/NeWater: Raadgever, 2009). No cases reported any instances of WRM organisations or experts unwilling to cede control of the process; however Cockerill et al. (2004) did conduct a telling pre-survey which revealed that its academic respondents were less likely to support the use of models as education tools for the general public given their assumed lack of technical knowledge. The involved technical experts in this case were also the most likely to question the quality of the developed system dynamics model in the post-modelling surveys.

3.5 Towards Structured Methodologies for Participatory Modelling

As may be evident from the preceding sections, the problem context and the selected PM approach hold implications for the ability of a PM exercise to achieve its stated objectives. The varied nature of stakeholder participation with respect to participatory structure; levels of

[3] Indeed, in one of his case studies (Groundwater management in Delft), Raadgever (2009) found that the lack of workshop participant learning was most influenced by external sources, preconceived notions, and strategic interests. However, given that these participants' involvement in the entire CM process was extremely limited, their general lack of learning was unsurprising.

[4] Refer case study: Groundwater management in Delft (Raadgever, 2009).

involvement; timing of any activities; the skills and knowledge of the participants; along with many other factors all likewise influence the ability of these exercises to deliver their many potential benefits and limit any unintended consequences. By way of example, Co-construction forms will typically involve the greatest level of stakeholder involvement, but may also lead to the greatest degree of collaborative learning for participants as they involve 'learning by doing'. However, and as the review of previous case studies supports, Co-construction can come at a cost, in terms of the time required for model building, the types of models that can be constructed, and for being perceived as less trustworthy or scientifically sound (Hare, 2011). FABE forms tend to be much more varied, in that they can range much more in their degrees of participation and stakeholder control, which impacts on the amount of time required for modelling activities, but then also on the participants' levels of social learning and sense of ownership over and involvement in the PM process. FE and BE forms are similarly variable, but typically involve much less stakeholder involvement than FABE or Co-construction forms. As such, these will both likely generate less in the way of participative benefits.

To aid researchers and practitioners designing and implementing these approaches maximise PM benefits and limit any undesired consequences, several sets of guidelines, lessons and best practices have emerged in the literature over the past ten or so years (Table 4). For example, Smith Korfmacher (2001) provided her foundational five "Guidelines for Good Practice", which have since been augmented by twelve "Lessons Learned" from modellers conducting PM exercises (Voinov & Gaddis, 2008) and echoed in Langsdale et al. (2013). Typically, these guidelines have set principled but vague objectives, (e.g., the modelling process should be transparent, stakeholders should participate continuously and have influence on modelling decisions) and suggest tactics (e.g., make modellers document and present their assumptions and the model's uncertainties and limitations, manage the expectations of stakeholders from the start). However, they do not make clear how these objectives can be attained or how these tactics can be implemented procedurally. Bots, Bijlsma, von Korff, van der Fluit, and Wolters (2011) have sought to rectify this tendency for vagueness with a set of procedural PM process 'rules of the game' targeting the constructive and participatory use of existing hydrologic models (i.e. for BE forms of PM). Hare (2011), on the other hand, has taken a somewhat harsher line towards PM, suggesting that its risks and limitations are too great for its direct inclusion in any formal decision-making processes. Rather, he sees an integral role for these models (and particularly co-constructed conceptual models) in a parallel social learning cycle that feeds into future decisions as part of an Adaptive Water Resources Management framework. Here the purpose of the PM exercise would be for social learning only, thereby removing many of the limitations of implementing PM for decision-making support. The benefits of this move for project planning cycles are evident, but it would mean that the legitimising and democratising potentials for stakeholder participation in decision-making via PM would be severely curtailed. The degree of action mismatch for participants would be considerable, such that motivating stakeholders to participate in these collaborative learning exercises could become an insurmountable challenge.

This review of the literature has revealed that there remains a need for a structured methodology to enable appropriate PM approach design and selection. Considerable uncertainty still exists as to when and how to efficiently utilise PM processes within WRM at a practical and procedural level. Although it is not within the scope of this study to generate such a wide-ranging methodology, the author recognises that it will necessarily need to be founded upon detailed case study analyses of PM exercises. Such studies need to identify what aspects of PM approaches have and have not worked in particular situations, and then identify the contextual reasons behind why this may have been the case. They also need to consider how both technical and non-technical stakeholders have been included in the modelling exercises, how the credibility of the constructed model has been maintained, and to what extent these approaches

Table 4: Guidelines, lessons and best practices for Participatory Modelling presented in the literature

Reference	Guidelines / Lessons / Best Practices for Participatory Modelling
Smith Korfmacher (2001)	1. Maintain a transparent modelling process. 2. Continuously involve stakeholders in as many of the modelling stages as possible. 3. Ensure appropriately representative involvement. 4. Maintain stakeholder influence on modelling decisions. 5. Establish the clear role of modelling in watershed management.
Voinov and Gaddis (2008)	1. Identify a clear problem and lead stakeholders. 2. Engage stakeholders as early and often as possible. 3. Create an appropriately representative working group. 4. Gain trust and establish neutrality as a scientist. 5. Know your stakeholders and acknowledge conflict. 6. Select appropriate modelling tools to answer questions that are clearly identified. 7. Incorporate all forms of stakeholder knowledge. 8. Gain acceptance of modelling methodology before presenting model results. 9. Engage stakeholders in discussions regarding uncertainty. 10. Develop scenarios that are both politically feasible and most effective. 11. Interpret results in conjunction with stakeholder group: facilitate development of new policy and management ideas, engage stakeholders in reporting results. 12. Treat the model as a process.
Langsdale et al. (2013)	1. Garner support of decision-makers. 2. Identify who to invite to the process. 3. Select software that is easy to learn and can be made available to all. 4. Approach the project with humility. 5. Design and execute a process where stakeholders are valued for their contributions. 6. Ensure the model and modeller can accommodate rapid modifications and new alternatives, and can simulate relatively quickly. 7. Frequently ask the team and all the participants throughout the process, "Who will use the model?" and "How will it be used?" 8. Build a simple model early in the process, and then improve it over time with input from stakeholders and experts. 9. Engage stakeholders in iterative model development and technical analysis to foster shared learning. 10. Choose modellers with collaborative skills and diverse modelling abilities, and choose facilitators with the ability to understand and appreciate what modelling can provide.

have contributed to stakeholder learning. To perform such analyses, it is clear that those perspectives from stakeholders, decision-makers and modellers that have been involved in these processes must play a central role. They must explore which participatory objectives of the PM exercises those involved have actually most valued, and which aspects of participation these stakeholders have perceived to be the most productive. Providing such detailed analyses of the two proposed Dutch case studies is the specific intention of this study.

4 Methodological Approach

This chapter presents the methodological approach used in this study. It includes both an overview of the assessment methodologies and strategies employed, as well as details on the specific analytical framework that has been applied to each of the studied cases.

4.1 Assessment Methodologies

The assessment methodologies employed in this study to establish answers to the research questions posed in Chapter 2 were those of literature review and qualitative case study research.

4.1.1 Literature Review

A comprehensive literature review was carried out of existing published theory and case studies to provide foundational and state-of-the art level understandings of current PM practice. Specifically, this included literature on: complex problems; participation in WRM; stakeholder analysis; collaborative learning; various PM approaches, forms and methods; existing PM analytical frameworks; previous PM case studies; along with any published stakeholder perspectives of these. Many of the outcomes from this work have been discussed in the preceding chapter. The method of a literature review was selected, as there exists a considerable body of work pertaining to these themes published over the course of the preceding two decades. As such, there was a substantial body of available knowledge from which to draw upon.

Literature was identified using a combination of Scopus and Google Scholar searches, with these supplemented by additional materials suggested by members of the graduation committee, colleagues at Deltares, and academics in the Water Management (Faculty of Civil Engineering and Geosciences) and Multi-Actor Systems departments (Faculty of Technology, Policy and Management) at TU Delft. As a result of this effort, an initial library of material was established, with this supplemented by additional relevant publications taken from citations included within the initial library.

4.1.2 Case Study Research

To improve specific understanding of the two CM approaches being researched, a qualitative case study approach has been employed to critically assess each of these against the research questions. By exploring each case in great detail, several generalizable conclusions and recommendations could then be drawn with respect to their implementation in other settings. As indicated in Chapter 1, the two selected CM case studies to be analysed in this research are as follows:

- **Consortium Modelling – AZURE Groundwater Model Development**:
  Utilising Deltares' iMOD groundwater modelling software package, this is the most recent in a series of stakeholder consortia to have undertaken the collaborative development of its highly technical groundwater model in the Netherlands.

- **Model-Supported Collaborative Planning – *Blokkendoos* Development and Use in the Delta Programme Rivers**:
  As part of the Dutch Delta Programme Rivers (DPR), this was the development and use of a 'planning kit' application designed to aid various stakeholders rapidly assess spatial measures for inclusion within adaptive flood protection management strategies.

These particular case studies were selected for a number of reasons, the first of which was in order to provide two very contrasting 'real world' examples of CM in the Netherlands. As was mentioned in Chapter 1, most of the cases of CM represented in the literature are a result of academic research projects, and have little connection with actual decision-making processes. Both these cases are not research projects, but a rather examples where WRM organisations themselves have initiated, organised and run these exercises themselves. As such, they offer insight into two different types of CM for which practical demand exists within WRM organisations. Secondly, the author's literature review revealed many PM cases in the literature rely on co-constructed forms of PM that involve collaborative conceptual model building for system dynamics or Bayesian network models. In these instances, modelling of physical processes is often not the primary goal of the exercise. In both the selected case studies, the focus is very much on physical system modelling, with the objective to as closely as possible reflect the physical realities within a system (subject to other project constraints). In both these cases, the technical and scientific credibility of the models were assumed to be of importance. Hence, examining the stakeholder processes that maintained this credibility (or not) is of particular interest. Finally, having both been completed in 2014, both cases offer recent examples with which to assess stakeholder perspectives. Naturally in carrying out an assessment of this kind, one would wish to census any participants whilst their recollections are still 'fresh' in their minds.

The qualitative case study methods adopted to complete these assessments consisted of document analysis, background meetings and stakeholder interviews.

4.1.2.1 Document Analysis

For each case study any relevant existing documentation (reports, papers, press releases) was analysed against the extended classification framework for PM approaches (presented in the next main chapter section, below). This was to formulate preliminary answers to the initial three research questions (Questions 1.1 – 1.3). Documents were analysed for both project context and stakeholder identification and involvement, the latter including levels, modes, timing and the skills necessary for that involvement. All documentation was obtained from Deltares and other case-specific stakeholder sources, wherever it was available. Information in both English and Dutch was collected, with the latter electronically translated into English and reviewed for any material of particular relevance. The author then carried out confirmatory, more detailed translations on any relevant material.

4.1.2.2 Background Meetings

In order to establish additional supporting and background information on each case study, a number of meetings with Deltares/TNO employees were carried out. For the AZURE case study, these included informal meetings with individuals that were involved in earlier groundwater model development consortia projects in the Netherlands, and included:

- Bennie Minnema (Deltares), former Project Leader for all other groundwater model development consortia, commencing with the MIPWA consortium (Northern Netherlands) in 2006-07.
- Mike Duijn (TNO), former Process Manager for the original MIPWA project.
- Jacco Hoogewoud (Deltares), current Project Leader for maintaining the original MIPWA groundwater model, and for the MIPWA redevelopment project commencing in 2014.

In the case of the *Blokkendoos*, meetings were undertaken with individuals who had been involved with earlier versions of such planning kits in the Netherlands, such for the Room for the River programme (in Dutch: *Planologische Kernbeslissing Ruimte voor de Rivier, PKB*; 2006). The individuals contacted in this regard included:

- André Hendriks (Deltares), former developer of the original *Blokkendoos* used for the PKB project (*PKB Blokkendoos*).
- Simone van Schijndel (Deltares), former liaison between WL|Delft Hydraulics and the PKB team in charge of stakeholder spatial planning workshops.

Notes of these meetings were kept, and any use of this material is indicated in later chapters.

4.1.2.3 Stakeholder Interviews

To answer the final research question as well as confirm and supplement the information provided by document analysis activities, ex post semi-structured interviews were conducted with stakeholders involved in each of the case studies. In doing so, the author was able to gain explicit information regarding their specific experiences and perspectives of the CM exercises.

The decision was taken to use interviews as these provide an undiluted focus on individual stakeholders and thereby give an opportunity to gain detailed information on their individual perspectives and issues well beyond any included in project documentation. Semi-structured interviews were conducted, as these provided both a consistent set of questions to be put to respondents as well as an opportunity for the author to probe beyond their constraints and explore each research question in greater depth. Interview questions included a mix of open and closed questions and were principally designed to assess stakeholder perspectives regarding the effectiveness of the CM exercises in delivering their potential benefits (Question 2.1). However, supporting questions were also asked, including those relating to the specific problem context, CM purpose(s), timing, level and mode of participation, and participant skills required (Questions 1.1 – 1.3). Stakeholder responses to these latter questions were used to directly inform the author's analysis of each CM approach against the classification framework (presented below). The interview schedule used in this research is provided as Appendix A.

Interviews were recorded with the approval of each participant, in order to facilitate later analysis and review. Detailed, paraphrased summaries of each interview were made, before these were sent to each respondent for checking to ensure no misinterpretation of the recorded audio by the author. Following this review, the approximately 180 pages of summaries were systematically analysed and coded (using text highlighting and labelling in PDF-reader software) against each of the key research questions and themes. Codes included more general labels like 'model development process', 'model use', 'stakeholder involvement', and 'participatory purpose', but also included those more specific to particular collaborative benefits or limitations, for example 'model improvement', 'learning', 'consensus', 'cooperation', 'conflict', 'credibility', 'transparency', 'influence and control', and 'time impacts'.

The respondents contacted and the means by which these were identified for each case study are as follows.

a) Consortium Modelling: AZURE case study

Consisting of a discreet list of members, identifying potential respondents from within the AZURE model development consortium was a relatively easy exercise. The client process manager provided the author with the consortium contact list, and then one member was selected from each stakeholder represented in the consortium. In all but two cases respondents from every stakeholder consented to be interviewed. These included:

- Wim de Lange (Deltares), the model development project leader
- Ab Veldhuizen (Alterra), who contributed specific unsaturated zone expert input to the modelling team
- Alex Hekman (Grontmij), the independent client process manager
- Geert Menting (Rijkswaterstaat, RWS), national ministerial department client representative
- Christoffel Klepper (Flevoland Province), provincial client representative
- Rob de Groot (Gelderland Province), provincial client representative
- Janco van Gelderen (Utrecht Province), provincial client representative
- Jan Hoogendoorn (Vitens), drinking water company client representative
- Almer Bolman (Water Board Vallei en Veluwe), water board client representative
- Jasper Jansen (RoyalHaskoningDHV), regional advisor for the Veluwe region
- André Blonk (Tauw), regional advisor for the Vallei en Eem region

In addition to consortium members, effort was made to interview additional AZURE model users who were not involved in the model development process. Only one other such stakeholder consented to be interviewed, with this stakeholder identified by both the process manager and a water board client representative.

- Hedwig Bisseling and Ingrid Riegman (*Omgevingsdienst Veluwe IJssel*, OVIJ), representatives from the environmental services organisation for the Veluwe IJssel region who had recently commissioned the use of AZURE for a current projects.

b) Model-Supported Collaborative Planning: DPR Blokkendoos case study

As there were many more individuals involved in the DPR who potentially might have come into contact with the *Blokkendoos*, the method of 'snowball sampling' (Tansey, 2007) was used to select the respondents in this case study. Initial interviews were conducted with Deltares and RWS representatives who were most involved with building the *Blokkendoos* model. After both of these interviews, both respondents were asked to give recommendations of other individuals from any stakeholders whom they were aware were involved in developing or using the *Blokkendoos* during the DPR. Based upon these discussions, it was decided to focus attention on a particular regional process area from within the DPR, namely the Waal-Merwedes region. This decision was taken as it would allow for the sampling of stakeholders at various levels of the DPR who had all been involved in the same consistent set of stakeholder processes in the same region. From the initial set of DPR programme bureau (DPRPB) members identified, these representatives were then also asked to provide additional recommendations of regional and sub-regional government and non-government stakeholders who were involved in the various DPR forums. The snowballing procedure was repeated until the author was able to gain interviews with at least one representative from all of the key DPR stakeholders who had had contact with the *Blokkendoos*; and when respondents could offer no additional suggestions for other potential respondents. The interviewed stakeholders from the DPRPB and Waal-Merwedes regional process included:

- Otto Levelt (Deltares), research institute member of the technical *Blokkendoos* development team situated in the DPRPB
- David Kroekenstoel (RWS), project manager for the *Blokkendoos* development process within the technical DPRPB team
- Bas Overmars (Gelderland Province), Team Leader of the Waal-Merwedes region liaison team in the DPRPB
- Evert Hazenoot (Water Board Rivierenland), key stakeholder liaison for the Waal region in the DPRPB
- Pim Neefjes (RWS), key stakeholder liaison for the Merwedes region in the DPRPB
- Sonja Seuren (Gelderland Province), Waal-Merwedes regional process provincial leader
- Erwin Klerkx (Gelderland Province), Waal-Merwedes regional process provincial project manager
- Myra Kremer (Water Board Rivierenland), Waal-Merwedes regional process water board member
- Hein van Middelaar (p2 projectmanagement), who represented and advised four municipalities (Zaltbommel, Massdriel, Neerijnen, Lingewaal) in the Waal-Merwedes regional process
- An additional anonymous municipal representative in the Waal-Merwedes regional process
- Bas van de Pas (Deltares), expert advisor to Gelderland Province during the Waal-Merwedes regional process

In addition to those most involved in the Waal-Merwedes regional process, interviews were also conducted with three members of other key DPR forums, who had only very limited contact with the *Blokkendoos* (e.g. via modelling results presented in DPR advice/reports).

- Henk de Hartog (Gelderland Province), DPR Rhine Steering Group Secretary and DPR Civil Advisory Group (*Ambtelijke begeleidingsgroep*, ABG) Chairperson.
- Jan Boelhouwer (Mayor of Gilze en Rijen), DPR Sounding Board Group (*Klankbordgroep*, KBG) Chairperson and DPR Steering Group Member.
- Roelof van Loenen Martinet (Gelderland Nature and Environmental Federation; Dutch: *Geldse Natuur Milieu Federatie*, GNMF), member of the DPR KBG.

4.2 Analytical Framework for Classifying Participatory Modelling Processes

As indicated in the previous chapter, this study adapts Basco Carrera's (unpublished-b) expanded analytical framework with which to consider PM approaches. Each of the two case studies is analysed against this framework in order to help determine the conditions that contributed to the successes and/or weaknesses of each approach. The reason for selecting such an expanded framework with which to analyse the case studies is that it permits the author to undertake a complete ex post analysis of these two CM cases that considers all the dimensions of the exercises relating to the research questions. In addition, it also allows for the broad identification of any applicable conditions, features and processes that would be of benefit to any future applications of each of the approaches.

Figure 4 provides an overview of the defining criteria utilised in this expanded framework, whilst the remainder of this section provides a detailed description for each of these.

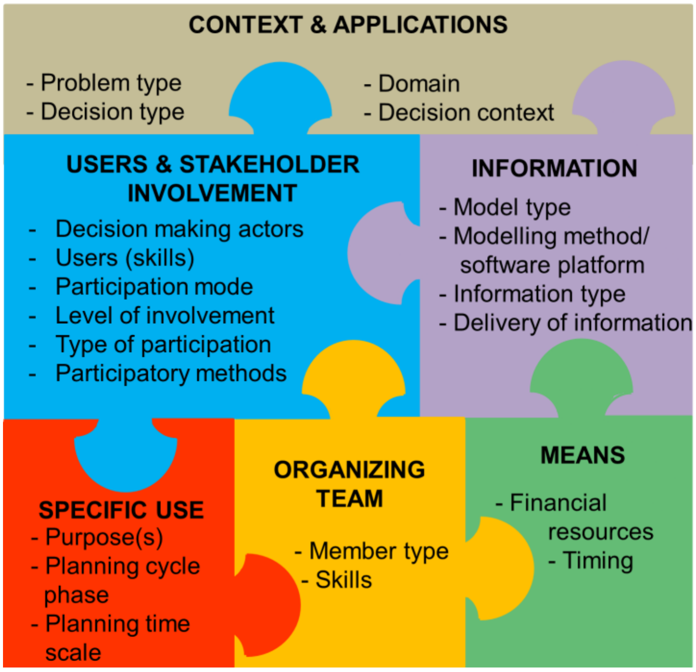

Figure 4: Criteria considered in the expanded analytical framework adopted in this study

4.2.1 Problem Context and Application

4.2.1.1 Problem Structure

As per the discussion presented in Chapter 3, the framework includes Hommes' (2008) typology of problem types according to their levels of consensus and certainty. The problems each model within the case studies seeks to overcome will be classified as being either:

- Structured
- Semi-structured (Uncertain)
- Semi-structured (Disagreement)
- Unstructured

With respects to PM, it is assumed that certain approaches and tools may be better suited to either semi-structured or unstructured situations.

4.2.1.2 Scale of Action

The scale of action for the problem and the size of its potential stakeholder community directly affect how many of these individuals may actually participate in various modelling stages. Whether the problem is situated at a local, regional, national or transnational scale will often determine whether those stakeholders with little influence can participate to the same extent that higher-level stakeholders can, or that they will perhaps need to delegate responsibility to a collective authority (e.g. industry representative, residential group, etc.). Hence, in this framework the problem scale used relates to the relevant scales of action (cf. Hare et al., 2003):

- **Local:** with the problem occurring at local levels and involving municipal populations.
- **Regional:** with the problem occurring at regional levels and involving provincial populations.

- **National:** with the problem occurring at national levels and involving national populations.
- **Transnational:** with the problem occurring at transnational levels and involving transnational populations.

4.2.1.3 Time Horizon

The time horizon of any mitigating actions can directly affect the level of interest and ability of certain stakeholders to participate effectively. When the impacts of any actions will not be experienced until far in the future, it may mean that it is no longer relevant or feasible to involve some stakeholders. For example, if there are some stakeholders for whom there is little likelihood that they will still constitute interested or affected parties at that future time, it may make little sense to include them within certain processes. Hence, the following key time horizons are considered in this framework:

- **Short:** where implemented actions are much more certain and will occur within 0-5 years.
- **Medium:** where implemented actions are relatively certain and will likely occur within 5-15 years.
- **Long:** where implemented actions are less certain and will possibly occur after a minimum 15 years' time.

4.2.1.4 Decision Level

The level at which WRM decisions are taken holds implications for the types of models that can be used, their specific purpose, and the degree of uncertainty that may be acceptable. Three levels have been identified in this framework (Basco Carrera, unpublished-b):

- **Operational Level:** the focus at this level is the short-term optimisation of resource utilisation tasks and activities. At this level fast-response, accurate and scientifically certain models are required, with actions undertaken by operators or perhaps even automated. These decisions do not typically involve stakeholder participation during the decision making process.
- **Management Level:** the focus at this level is the medium- to long-term management of design tasks, decisions, information, goals and rationale within a design process. At this level, alternatives are evaluated within an established policy context. Hence, relatively detailed models with reasonably high levels of scientific certainty are required, and generally include a valid representation of physical system processes. Stakeholder involvement could be used to improve model outputs and generate support for the management actions selected to meet the given policy context.
- **Planning/Policy Level:** at this level the focus is on long-term agenda setting and establishment of the policy context. Here, models can accommodate larger degrees of uncertainty and stakeholder involvement is crucial, as policies can be modified through stakeholders' inputs. Often integrated DSS models are used at this level, to facilitate the evaluation of a number of planning options.

4.2.1.5 Domain

Problem contexts can also be classified according to their management domain (Hare et al., 2003). Certain modelling approaches may lend themselves more to particular management domains, which include, *inter alia*:

- Integrated Water Resources Management
- Integrated Coastal Zone Management
- River Basin Management
- Urban Water Resources Management
- Rural Water Resources Management
- Flood Risk Management
- Drought Risk Management
- Groundwater Management
- Spatial Planning/Land Use Management

4.2.1.6 Decision-Making Context

Two decision-making contexts can also be distinguished and will impact directly upon the specific purpose of a PM exercise. These are determined by the comparative willingness or otherwise of the parties to the process to cooperate with each other (Basco Carrera, unpublished-b).

- **Cooperative Context:** here the various stakeholders agree to engage each other and work jointly towards finding solutions that are acceptable to all stakeholders. Typically data and information is shared, issues and ideas are discussed, and a common, agreed approach is formulated.
- **Competitive Context:** here the various stakeholders operate in more isolated fashion, pitting their respective points of view against each other. In these contexts, stakeholders will generally come up with their own individual preferred solutions, which can then be weighed up against each other and a compromise solution negotiated. These are adversarial contexts, which generate confrontation and discourage information sharing.

4.2.2 Specific Use

4.2.2.1 Collaborative Modelling Purpose

As introduced in the previous chapter, it is important to consider the specific purpose(s) served by the PM approach, as these can impact on whether or not the approach is relevant to a particular problem context. For this adapted framework, the specific purposes to be considered are:

- **Decision-Making:** where the result of the modelling process is that a planning/management decision is taken by the decision-making authority (Hare, 2011). This is not to say that any recommendations stemming from a PM exercise must be unquestioningly adopted, but that they serve as inputs to a subsequent decision-making process (as outlined by Borowski & Hare, 2006).
- **Collaborative Learning:** this is predicated on the idea that learning is a social act and that as participants communicate with each other, both group and individual learning occurs (Voinov & Bousquet, 2010). Via facilitation, stakeholders share their perspectives with each other, are supported to develop collective problem-solving skills, and generate shared management ideas (Hare, 2011). Two variants of collaborative learning have been identified:
    - **Social Learning:** refers to the process where participant knowledge and skills are enhanced via facilitated exchanges, dialogue or even conflict in social contexts (both face-to-face and virtual). Participants can gain an appreciation of system complexity, system feedbacks between physical processes and social dynamics, and of the perspectives of other stakeholders that may be different to their own (Evers et al., 2012; Hare, 2011; Voinov & Bousquet, 2010). In social

learning, there is no requirement that organising teams learn from their participating stakeholders, but rather that they simply facilitate learning outcomes for these participants.
  - **Shared Learning:** (also co-learning) reflects the notion that for learning to be truly collaborative, information flows must occur in all directions. That is, information flows must not only occur from the PM organising team to stakeholders and amongst stakeholders themselves, but also from stakeholders to the organising team (Voinov & Bousquet, 2010).
- **Mediation:** where a key purpose of the modelling process is to mitigate or even resolve disagreements or conflict between stakeholders (Bots & van Daalen, 2008).
- **Model Improvement:** where a key purpose of the modelling exercise is to improve the model according to the following three measures (Hare, 2011):
  - **Quality:** where understanding of how the system operates (i.e. facts and causalities), model accuracy and the reproducibility of outputs are improved.
  - **Acceptance:** where model credibility and its usefulness is recognised by stakeholders such that its outputs are then used.
  - **Integration:** where the model created is able to integrate and reflect cross-sector perspectives (including both social and technical aspects).

As Voinov and Bousquet (2010) note, in many PM exercises there is no single specific modelling purpose, but any combination of the above. Often these objectives are complementary, but they are not simply by-products of one another. Regardless, a dominant modelling purpose(s) should be present, and a particular distinction should be made between PM exercises more focused on collective analysis and learning, with those promoting a more solution-oriented process (i.e. between the first two listed purposes above).

4.2.2.2 Planning or Management Cycle Phase

Like other planning processes, water resources planning and management generally comprise several stages. These stages rarely form a simple sequence of steps to be followed, but more often involve cycles and feedbacks as potential solutions fail to meet criteria or new information comes to light. This framework considers three main phases in water resources planning and management: the inception, development and selection phases (Loucks & van Beek, 2005, p. 29, Figure 1.20).

- **Inception Phase:** here an *initial analysis* is carried out, which broadly identifies the stakeholders to be involved and the nature of their involvement, identifies the physical and socio-political contexts, identifies any initial problems, and sets the planning or management objectives and evaluation criteria. The result of the initial analysis is the general planning/management approach to be adopted.
- **Development Phase:** during this phase, this approach is then put into action, with *data collection* and *preliminary analysis* activities being undertaken. Here, the preliminary analysis will generally include a base case analysis that includes the establishment of agreed problem causes and effects, and an initial generation and screening of a suite of possible measures.
- **Selection Phase:** following the preliminary analysis, the selection phase commences with the *detailed analysis* of the most promising measures or strategies. These are assessed for their effects against the agreed evaluation criteria. This detailed analysis is then presented to the decision-makers for their selection.

In PM, stakeholder involvement can vary during each of these phases. For example, participatory activities related to some PM approaches will be carried out during the inception phase. Problem identification, goal and vision setting, stakeholder analysis, and the like can all feature as activities in various PM approaches. However, participatory data collection, model definition, construction and simulation will necessarily occur during the development and selection phases, with the planning cycle phase potentially impacting on the PM approach or tool to be selected, the specific participatory activities to be undertaken, and the level of scientific rigour and acceptable uncertainty required for the model.

4.2.3 Information Handling

4.2.3.1 Model Type

Bots and van Daalen (2008) argue that all WRM systems consist of three major components to be modelled: the physical system, the social system, and actors (stakeholders). From this generalised starting point, any number of these components can form the basis for a WRM model. Hence, 5 model subtypes can be identified for inclusion in this framework (Bots & van Daalen, 2008):

- **Physical System Models (PSM):** used in instances when it is only of interest to model physical system processes to assess the impacts of changes to that system (e.g. the hydrological and ecological consequences of building a dam in a river).
- **Single Actor Decision Models (SADM):** used when it is of interest to model how stakeholders might respond to policy outcomes. Policies are typically represented as external influences, and the models predict stakeholder reactions (but not the consequences of these reactions). A willingness-to-pay model is an example of a SADM.
- **Single Actor Impact Models (SAIM):** used when a combined representation of individual actor behaviour and the physical system is required. Such a model could represent how individual actors influence the physical system and vice versa through their decisions and actions, the latter represented by a series of logical rules, for example. These models disregard the social interactions and mechanisms amongst actors.
- **Social System Models (SSM):** used when the structure and dynamics of the social space or 'policy arena' where stakeholders interact must be represented. Stakeholder goals and preferences are inputs to these models, which then model social behaviour (e.g. using game theory).
- **Socio-Physical System Models (SPSM):** used when a completely integrated model of the entire WRM system is required to represent the physical mechanisms of the resource, the actors involved in its utilisation, and the social mechanisms that determine actor behaviour. Models such as these tend to consist of a series of integrated sub-models and are generally more complicated to construct.

Building upon the above distinctions, models can be further categorised as either being simulation models or conceptual models (Hare, 2011).

- **Simulation models:** are typically quantitative computational models of the system being represented and allow the user to quantifiably simulate system behaviour according to different scenarios.
- **Conceptual models:** are models that can qualitatively describe the system on the basis of the preconceived notions of how the system works. That is, conceptual models typically illustrate the key system components and their structural relationships (e.g. causal diagrams or influence diagrams). In many PM exercises, a conceptual model can be initially prepared in order to facilitate the development of a quantitative simulation model. Frequently, conceptual models are only relevant and applicable for the stakeholders who have been involved in their definition and construction, and for the particular time they were developed.

Although these are both included as part of the analytical framework, both the selected case studies in this research involve physical system simulation models (i.e. 'PSM' and 'Simulation models'). Indeed, these were two reasons for having selected these two particular case studies for this research.

4.2.3.2 Modelling Tool / Software Platform

Somewhat related to model type is the specific modelling tool or software platform selected for the PM exercise. PM modelling tools can range from simple Excel spreadsheet models, to agent-based models, Bayesian network models, system dynamics models (e.g. Stella) spatial GIS-based models, hydraulic/hydrological models (e.g. SOBEK or RIBASYM), or raster-based visualisation models that allow the ability to capture both temporal and spatial dynamics (e.g. iMOD, 3Di) (Voinov & Bousquet, 2010; Voinov & Gaddis, 2008). Different models may require different skillsets in order to facilitate model development and use.

4.2.3.3 Information Type

The type of information that the model provides users may also impact on stakeholder involvement (Basco Carrera, unpublished-b). Here, distinction is made between two major types of information:

- **Complex Processes:** the model focuses on representing particular individual system and sub-system processes at specific scales.
- **System Interactions:** the model takes a broader view and focuses on the more general interactions between the various elements or sub-systems, and is not so concerned with any particular system processes operating at specific scales.

4.2.3.4 Delivery Medium

Finally, the medium in which any PM information is delivered to stakeholders will directly impact on the effectiveness of stakeholder collaboration, particularly in dispersed geographic settings. In this framework two modes of delivery are defined (Heller, 2010):

- **Face-to-face:** in this mode collaborating participants are required to interact with each other and modelling information in face-to-face sessions with the organising/modelling team. Face-to-face sessions facilitate the transfer of tacit or experiential knowledge, where quick and immediate feedback is obtained and rapid adjustments can be made.
- **Virtual Platform:** in this mode, the Internet is used to either provide model access or to deliver/receive modelling information directly to/from collaborating stakeholders. Model use and information receipt/provision typically occurs independently in this mode. This has several advantages, principal among which are the increase in the accessibility of information to and from stakeholders and the potential for customisation and personalisation of content. However, although web delivery offers the potential for online collaboration, it can be difficult to synchronise such collaboration if it is to occur in real time (due to competing schedules). Likewise, depending on the interface web delivery may require training to facilitate proper use of the information/technology/ model.

4.2.4 Stakeholder Involvement

4.2.4.1 General Classification

This framework distinguishes stakeholder involvement in modelling activities according to the two broad categories presented in the previous chapter; namely those that are more participatory and those that are more collaborative. Both can achieve the specific purposes of stakeholder modelling exercises, and both perceive the involvement of stakeholders as critical in the development and/or use of computer-based models. Their differences lie in a combination of stakeholder willingness to cooperate, and their level of participation. In summary:

- **Participatory** types: where stakeholders may not necessarily be motivated to either become involved or cooperate with other stakeholders. Participation occurs at low-middle levels of participation.
- **Collaborative** types: where stakeholders demonstrate high levels of motivation and willingness to be involved in the collaborative activities and to negotiate/cooperate with other stakeholders. Stakeholder involvement occurs at high levels of participation.

4.2.4.2 Stakeholders Involved

Many different stakeholders can be involved in a PM process, including individuals, organisations, or unorganised groups with a declared or conceivable interest in the problem being considered. In this framework, stakeholders will be identified by organisation (or unorganised grouping) together with their minimal skills and backgrounds required to develop and/or use the developed model/tool.

Skills and knowledge that the different stakeholders may need to participate in the various modelling stages include:

- General skills and knowledge (e.g. local knowledge)
- Technical skills and knowledge specific to the problem at hand (e.g. specific knowledge of physical or social system processes)

4.2.4.3 Model Users

Although model users are also involved stakeholders, distinction is also made here between those stakeholders specifically targeted to be direct or indirect users of the model (Hare, 2011).

- **Direct users:** are those who will directly manipulate and provide inputs to the developed models.
- **Indirect users:** are those who will indirectly manipulate and provide inputs, for example, via an expert modeller.

Naturally the computer skills required to be direct model users may differ to those of indirect users, and include:

- General computer skills
- Specific (higher-level) computer skills
- No computer skills

4.2.4.4 Participation Mode

This delineates whether stakeholder involvement during the various modelling stages is as individuals or as part of group (Bots & van Daalen, 2008):

- **Individuals**: where individual stakeholders are involved separately.
- **Homogenous Groups**: where groups of stakeholders with similar interests and perceptions of the problem participate together.
- **Heterogeneous Groups**: where groups of stakeholders with divergent interests and problem perceptions participate together.
- **No Participation**: where no participation is possible or takes place.

4.2.4.5 Level of Involvement

As indicated in Chapter 3, the level of involvement for different stakeholders and the roles they are allowed to take can vary. Various participation level typologies exist (e.g. Arnstein, 1969; Mostert, 2003), however, for the purposes of this framework Deltares' seven-level typology has been adapted (Meijer, Marchand, Franssen, Ottow, & Roeleveld, 2013). This typology is by-and-large the same as that presented in the previous chapter, but includes for two additional lower levels of involvement and excludes the highest Independent Decision-Making level where the public performs public tasks independently (cf. Mostert, 2003). Thus, it reflects the fact that some stakeholders may be entirely excluded from the PM process, and that independent public decision-making is rarely (if ever) carried out in most public policy and planning contexts. Hence, the framework includes the following levels:

- **Ignorance:** where a stakeholder is not aware that anything is happening.
- **Awareness:** where a stakeholder is aware that something is happening.
- **Information:** where a stakeholder has been specifically provided with information and is left to decide what to do with it. The emphasis here is on the one-way provision of information, with no formal option for the stakeholder to provide feedback, negotiate or participate in the decision-making process.
- **Consultation:** where a stakeholder is asked to provide information inputs to the decision-making/modelling process. Here information flows are likewise one-way, but in the opposite direction. That is, information is extracted from stakeholders although no commitment is given to use it.
- **Discussion:** at this level stakeholders are fully participating and are asked to give advice and recommendations. Here information flows in both directions between stakeholders operating with different interests and levels of influence, and also between these stakeholders and the organising team. Since two-way interactions occur, there is room for alternative ideas/solutions/strategies to emerge.
- **Co-Designing:** at this level stakeholders are actively involved in problem analysis and problem design, which fosters ownership, but where final decision-making powers reside with the governing agencies.
- **Co-Decision-Making:** here decision making powers are shared with those participating stakeholders, leading to their empowerment with respects to the policy/planning decision taken. Typically decisions in these contexts would emerge from a process of stakeholder negotiation.

The first five levels above could be thought of as exclusively 'top-down' approaches towards participation, where stakeholders have little control over the decision-making process. The final two levels may also be initiated in a 'top-down' fashion, but they also lend themselves to more 'bottom-up' approaches to participation where stakeholders exert much more control over and are much more active in the decision-making process.

4.2.4.6 Timing of Participation

The modelling stages in which stakeholder may be involved during a PM exercise are (adapted after Hare, 2011):

- **Data Collection:** where stakeholders participate in the collection of data to support model definition or later parameterisation. Typically this could include *participatory monitoring and surveys*, or merely a *request to contribute data*.
- **Model Definition:** where stakeholders provide input to decisions regarding components of the model to be included, model assumptions, scenario variables, or user requirements. Stakeholder knowledge can be elucidated via *interviews*, *card sorting*, *cognitive mapping*, *design workshops*, etc.
- **Model Construction:** where stakeholders actively participate in the technical activities to determine the ontology of the model, and a working model is constructed. Here distinction can be made between:
    - **Initial model building** (e.g. *GMB*)
    - **Model refinement** towards its final form (i.e. stakeholders are initially presented with a draft model built by the organising team to edit and refine).
- **Model Verification/Validation:** where either model components (verification) or outputs (validation) are checked to ensure that model is operating as intended. Methods include *show and tell workshops*, *focus group discussions*, *questionnaires*, etc.
- **Model Use:** where stakeholders use the model (either directly or indirectly, refer above). Here distinction can be made between:
    - Use that involves **providing model inputs** (e.g. scenarios/policy contexts)
    - **Actual use of the model**, where its outputs are analysed and discussed
    - The special case where stakeholders become part of the model through **acting in gaming simulations** (Bots & van Daalen, 2008).
- **Alternatives/Strategies Development:** where stakeholders are actively involved in the formulation of alternative strategies or measures to deal with the problem being modelled. Again, *focus group discussions* and *workshops* could be used.

Based upon the above timing of stakeholder involvement, each of the PM approaches will also then be classified into one of the four generalised forms that were presented in Chapter 3 (Hare, 2011):

- **Front- and Back-End (FABE)** form: where stakeholders are involved in at least one modelling stage both before and after (but not including) 'Model Construction' activities.
- **Co-construction** form: where stakeholders participate in the 'Model Construction' stage.
- **Front-end (FE)** form: where stakeholders participate in any number of modelling stages prior to 'Model Construction'.
- **Back-end (BE)** form: where stakeholders participate in any number of modelling stages following 'Model Construction'.

4.2.5 Organising Team

The organising team is responsible for the design and guidance of the PM process, including model construction. As such, an organising team will typically include at least one member who is a modelling expert with comprehensive knowledge of the modelling tool being used (e.g. Stella, RIBASYM, etc.).

As with the other stakeholders involved in the PM process, the organising team requires specific skills in order to carry out the different stages of the PM process (Hare, 2011). These include:

- Modelling skills
- Facilitation skills
- Knowledge acquisition skills
- Process management skills

4.2.6 Means

Finally, PM approaches can be analysed according to the degree time commitment and financial resources required (if this information is made available) to deliver the process to the stakeholders.

4.3 Concluding Remarks

Having presented the principal assessment methodologies and analytical framework for this study, the following two main thesis sections present the results and the author's analysis of these assessments to each of the case studies in turn.

Case Study 1

Developing the AZURE Groundwater Model Using a Consortium Modelling Approach

5 Introducing AZURE

5.1 Introduction to the Case Study

Like many other areas of WRM, groundwater management frequently makes use of models. Since one cannot see what is happening beneath the surface, groundwater modelling is somewhat of an essential task in this regard. Computer-based modelling allows us to visualise the physical geohydrological processes taking place beneath the surface, and provides us with an ability to assess the impacts of any actions on these subsurface processes. Much of what is modelled is unseen, and relies on the data provided by a network of groundwater monitoring wells and geotechnical data detailing groundwater levels, types and thicknesses of soil layers, hydraulic conductivities, and the like. Since processes are unseen, there is also a large degree of uncertainty with regards to many of these and other physical subsurface phenomena. Considerable doubt and disagreement can exist amongst scientists as to what is the best manner and means to use to model them.

One method of dealing with this uncertainty is provided by the CM approach developed by Deltares in the Netherlands, termed 'Consortium Modelling' by this author. Originally referred to as 'Interactive Modelling' within Deltares, its current iteration is typified by a high degree of collaboration between organisations financing the joint development of a scalable regional groundwater model. These key actors, along with an array of other supporting stakeholders join together in a consortium and collaborate intensively in all model development activities ranging from model conceptualisation and definition, through to construction, and model verification and validation. The Consortium Modelling approach is characterised by its high degree of client control over the process and is principally designed to build joint consensus, acceptance and trust for the developed groundwater model amongst both its financing parties and other involved stakeholders. The most recent implementation of the Consortium Modelling approach is that of the AZURE model in central Netherlands. Having concluded its initial development phase in 2014, the AZURE consortium is presently transitioning towards its next focus; that of using the developed model in its client members' (and others') groundwater management projects in order to further improve and refine its performance. This chapter analyses AZURE's implementation of the Consortium Modelling approach in great detail, in order to illuminate its key features, benefits and limitations.

The case study is broadly structured into four chapters. This initial chapter outlines the necessary contextual and background details regarding the AZURE case study, including the problem needing to be addressed, the key stakeholders involved, the specific objectives of employing a CM approach and the modelling tool utilised. The second chapter (Chapter 6) then turns to a consideration and analysis of the Consortium Modelling approach used in the case study, including its organisational structure of participation; the collaborative model development processes followed; the necessary skills and knowledge requirements for those involved; and the time and financial resources consumed in delivering its outcomes. The third chapter (Chapter 7) presents key stakeholder perspectives on the ability of the approach to deliver or limit any potential collaborative benefits. The final chapter (Chapter 8) concludes with a consideration of the key successes of the approach in combination with author recommendations for potential improvements that could be made to enhance it.

5.1.1 A Note on Nomenclature

Before commencing with the specifics of this case study, the author wishes to first briefly make a point with regard to nomenclature, and his reasons for proposing a name change to this CM approach. The 'Interactive Modelling' approach as it was originally conceived placed a much stronger emphasis on interactive features embedded within the computer-based modelling software to enhance both the model development process and the subsequent use of the model (Berendrecht et al., 2010). That is, these features were specifically designed to enable stakeholders to interact more closely with both the model and each other, using the software interface to support these interactions. Somewhat regrettably, these features are no longer used within the approach and it makes little sense to the author to continue referring to it as being 'Interactive' in this sense. Terming it as such conjures up a mental image of model interaction that simply is not present. Although it is not proposed to consider these aspects in any great detail here (they are mentioned in a later section); suffice it to say that the current iteration of the approach no longer utilises these features. For this reason, the author proposes to refer to the approach in this thesis by what he considers to be its most distinguishing feature, that of the formation of the joint development consortium. It is important to keep in mind that this is not to suggest that the approach is in any less way collaborative or that collaboration between stakeholders has been significantly impeded. The proposed rebranding is rather to simply ensure that readers form a more accurate first impression of the approach and what it involves from the outset. Having made this distinction, let us return to the specific focus of the case study.

5.2 Background and Context

5.2.1 Institutional Context

Responsibilities for groundwater management in the Netherlands are divided over several government institutions including provinces, water boards, drinking water companies and the ministerial WRM department. Prior to the development of the AZURE model, many different geohydrological models were being built and used by each of these institutions in the AZURE coverage area. Many of these were detailed smaller-scale models, which were generally concerned with stakeholder-specific, localised issues (Hekman, van Manen, & de Lange, 2014). Other, separate models addressed larger regional issues, and the National Hydrological Instrument (NHI) was available for even larger (national) scale questions. Thus, the primary objective of the Consortium Modelling approach was to develop a single, scalable regional model, which could replace all the individual local models and was capable of linking both with its surrounding regional consortia iMOD models and the NHI (Deltares, 2014). Essentially, the ultimate intention was for all consortium stakeholders to be able to use the model to technically analyse and determine solutions to any geohydrological problem that may arise. In addition, other stakeholders external to the consortium were also to be able to make use of AZURE if they needed to carry out any groundwater modelling activities. AZURE's development was therefore a generalised technical model development process, and not one focussed on a specific policy problem or management issue. The consortium developed an instrument to be applied in both planning- and management-level decision-making contexts and across any temporal and spatial scales within the modelling area.

Building upon the earlier experiences of several other Dutch groundwater modelling consortia[5], the fourteen key regional groundwater management organisations (detailed in section 5.4 below) joined together in a three-year Consortium Modelling process in 2011. All of these

[5] Previous consortia have included: MIPWA (Northern Netherlands), IBRAHYM (Limburg and de Peel), REGGE EN DINKEL (Eastern Overijssel), AMIGO (Eastern Gelderland), MORIA (Rivierenland), and HYDROMEDAH (Stichtse Rijnlanden).

stakeholders were willing members to the consortium, and all were committed to building the single consensus model acceptable to every other party involved. In order to achieve this common goal, client stakeholders agreed to both focus their energies and pool their financial resources. It was generally felt that a much better result could be achieved for the same total investment than if separate models continued to be developed by each party individually as per earlier practice (Hoogendoorn, 2014). Indeed, this extremely cooperative context was in many ways critical to the consortium achieving its aims. Had the development taken place in a less cooperative or more competitive context, it is most likely that additional negotiation and perhaps conflict resolution processes would have needed to be included within the CM approach.

5.2.2 Geographical Region

Including parts of the Provinces of Flevoland, Gelderland and Utrecht, the AZURE model area covers a large part of central Netherlands (Figure 5). It takes in the IJsselmeer and Markermeer, the polder areas of Flevoland, and extends beyond the pushed moraine ridge of the Veluwe region to the Rivers IJssel, Nederrijn and Lek. Its land boundaries generally follow those of its included water board areas (i.e. major surface water catchment boundaries), and the model area has been divided into three sub-regions according to the boundaries of the three original water boards (Zuiderzeeland, Veluwe, and Vallei en Eem).[6]

Figure 5: AZURE model boundary (pink) and area of interest (yellow/blue) (Deltares, 2014)

5.3 Problem to be Addressed

As noted, the overarching objective of the AZURE model development process was to provide consortium (and other) parties with a single, unifying, high quality modelling instrument with which to support integrated groundwater management. The issue with the prior proliferation of separate groundwater models by the various WRM organisations was that these models were not built according to a consistent set of assumptions, scheduling or parameter values (Hekman et al., 2014). Rather, they had been developed according to different schematisations, and had had their parameters calibrated to meet project- and problem-specific conditions. That the

[6] The two water boards Vallei en Eem and Veluwe were amalgamated into a single entity (Vallei en Veluwe) during the course of the AZURE development.

models in each of these instances employed different conceptualisations rendered it difficult to translate and compare model results between the various models whenever this was required. Unsurprisingly, many groundwater issues in the Netherlands do not respect the boundaries of the individual groundwater management organisations (de Lange, 2014; Hoogendoorn, 2014). In those instances where cross-institutional projects needed to generate and view results across different spatial scales or conflicting model areas, it became increasingly challenging to cooperate and reach agreement over which models to use or which results were more 'correct'. The emergence of the single consensus instrument was meant to bring an end to these challenges, as well as cease the practice of developing new groundwater models as every new specific groundwater problem arose (Hekman, 2014).

The problem structure that prompted the development of AZURE could therefore best be described as being either semi-structured and uncertain or completely unstructured. Putting aside the potential disagreements the various stakeholders may or may not have over future specific groundwater policy or management questions, the driving motivation of the Consortium Modelling approach was the reduction of technical knowledge uncertainties in these future problem contexts. The development of AZURE, as with all the other regional Dutch groundwater models, was intended to directly address this issue, by generating a common modelling consensus for all the key institutional stakeholders. Consequently, the developed model could then be applied both in those instances where stakeholders broadly agreed with each other over any necessary policy or management actions, or alternatively where key differences and disagreements persisted. In that latter case, the consensus 'knowledge' produced by the model would be considered 'neutral' by stakeholders, and thereby contribute to increasing the level of structure for the specific problem context.

5.4 Key Stakeholders Involved

The AZURE model development consortium includes members from the principal water governance institutions in the project area: the provinces, water boards (Dutch: *waterschappen,* WS), drinking water company Vitens (DWC), and the ministerial WRM department (*Rijkswaterstaat*, RWS). These were the principal financing actors, or client members. Yet the development consortium is also considered to include those members of what could be best termed the 'organising team'. These include those members of the physical model building team (Deltares and Alterra), three regional advisors from independent commercial entities each responsible for a particular model sub-region, and an independent process manager (Table 5). Generally, clients were represented by dual members in the consortium, whilst organising team members were typically restricted to one member per entity. Deltares, as the principal modelling organisation, was the exception to this rule, with three members. In addition to client and organising team members, indirect stakeholders in the Consortium Modelling approach included those potential external model users who were not members of the development consortium. Largely these consisted of the relevant municipalities and any special interest organisations active in the model area.

5.4.1 Consortium Clients

Client actors were largely determined by the overlapping and geographical proximity of their various jurisdictions. Naturally, the regional model (and hence, the consortium) could have been made even larger still with the additional involvement of further institutional actors situated along its boundaries. Although these additional parties were invited to join in AZURE, for many they had either already been involved in other regional model consortia, or perhaps felt that the

Table 5: AZURE Consortium members

Client Group	Modelling Team	Regional Advisors	Process Manager
Rijkswaterstaat (RWS) Flevoland Province Gelderland Province Utrecht Province DWC (Vitens) WS Zuiderzeeland WS Vallei en Veluwe Waternet[7]	Deltares Alterra	Acacia (Zuiderzeeland) Royal HaskoningDHV (Vallei en Veluwe: Veluwe) Tauw (Vallei en Veluwe: Vallei en Eem)	Grontmij

timing was not right for them to become involved (Hekman, 2014). The parties that did eventually become involved were therefore those that ultimately wanted the joint regional model and were willing to co-finance its development (de Lange, 2014; Menting, 2014). Client actors in the consortium are detailed in the sections below.

5.4.1.1 Rijkswaterstaat

Part of the Ministry of Infrastructure and the Environment, RWS (the national Department of Public Works and Water Management) is the national agency responsible for *inter alia* formulating national policies regarding WRM in the Netherlands and the management and maintenance of the main Dutch waterways and water resources systems. In practical terms the latter includes the management of the major Dutch rivers, the coast, the IJsselmeer region, the Wadden Sea, the Southwest Delta and the North Sea (RWS, 2014).

Until AZURE, RWS had not been involved in any previous regional groundwater modelling consortia (de Lange, 2014). However, its specific interests in the AZURE model were raised given its management responsibility for the IJsselmeer region. When one considers groundwater problems in the vicinity of Flevoland Province, one must also consider the large surface area located below the IJsselmeer and Markermeer as seepage through this soil also effects the neighbouring polders (de Lange, 2014).[8] RWS thus had a need for a model that was capable of modelling these interactions at higher resolutions than were possible with the NHI (Menting, 2014). Essentially, RWS was extremely keen to have a single model developed for the area that it would be able to use to answer its larger-scale regional questions at both coarse and detailed resolutions.

Given its involvement in AZURE, RWS was appointed as the principal client within the consortium; however, this was more to facilitate organisation rather than to establish any sort of hierarchy within the client group (Menting, 2014). That being said, as the principal formulator of national policy, RWS nevertheless sits atop the Dutch groundwater management institutional hierarchy (Figure 6).

[7] Waternet has become a recent new consortium partner in its delegated capacity undertaking the water management activities of the WS Amstel, Gooi en Vecht.

[8] A particular RWS concern prior to the development of AZURE was its approaching Delta Programme investigation into the increased seepage effects from possibly raising the water level of the Markermeer.

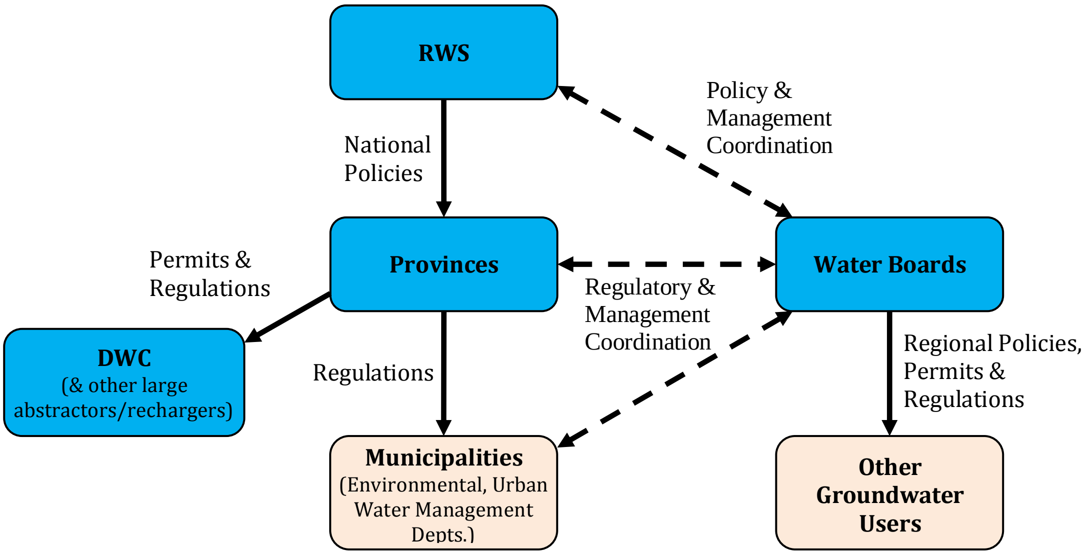

Figure 6: Client member (blue) dependencies in groundwatrer management (non-exhaustive). Solid arrows indicate a hierarchical relationship, dashed arrows indicate formal cooperation.

5.4.1.2 Provinces

The provinces constitute the regional level of government in the Netherlands. They take the water resources policies formulated by RWS and convert these into provincial level orders and plans (Vewin, 2014) (Figure 6). In terms of groundwater management, the provinces are responsible for the issuance of any groundwater extraction licences to the DWCs, large industrial abstractors (>150,000 m^3/year), and geothermal energy storage rechargers ("Water Act," Section 6.4). They also coordinate closely with the water boards in the management of smaller scale hydrology issues (Klepper, 2014).

Provincial interests in groundwater management relate to their needing to be able to monitor and verify the effects of any large extraction or storage wells requested and permitted under their jurisdiction. For this they rely on groundwater models. In particular, they are concerned with the influences these may have on nature, agricultural and urban areas. Key provincial-scale groundwater concerns include the potential for the soil to ‘dry out’, nature protections as required under the WFD, the protection of designated Natura2000 areas, and the management of diffuse groundwater pollution (de Groot, 2014).

In relation to each province’s specific motivations for becoming involved in AZURE, Flevoland Province needed an instrument that was capable of modelling groundwater issues on scales much wider than its provincial boundaries and existing provincial models (Klepper, 2014). Gelderland Province was primarily interested in developing a new and better model for the Veluwe region. Given the known groundwater interactions between the Veluwe and its adjacent polder areas, it also made sense to Gelderland to work together with Flevoland. More fundamentally, Gelderland was also keen to ensure that AZURE was built in a manner consistent with its other two regional models (de Groot, 2014). Utrecht supported Gelderland’s need for a new and improved model for the Veluwe, but was also keen to see any developed model extend its coverage to include the entire province of Utrecht (van Gelderen, 2014).

5.4.1.3 Drinking Water Company (Vitens)

As the largest DWC in the Netherlands, Vitens is responsible for the supply of clean drinking water to 5.4 million customers in the provinces of Friesland, Overijssel, Flevoland, Gelderland and Utrecht (Vitens, 2014). All its water is extracted from groundwater extraction fields across this area, for which it receives abstraction permits from the relevant provincial authority (Figure 6). In former times, each of its 110 well fields had its own separate model with which to determine all extraction-related groundwater effects. Having now played an instrumental role in five regional groundwater model consortia, Vitens can service its entire area of operation with only five models of which AZURE is the latest.

The DWC specifically needs these groundwater models to predict and monitor the effects on nature and crop production caused by its wells from vertical seepage and infiltration fluxes (Hoogendoorn, 2014). Close monitoring of these effects is required as groundwater abstractors are liable for any damages that their abstractions cause ("Water Act," Section 7.18). The DWC also needs the models to calculate groundwater flow patterns for water quality monitoring, and to establish recharge areas and 25-year source protection zones (Hoogendoorn, 2014). As such, the interests of the DWC are best served by having a series of larger, consistent, scalable models. This is because they offer a means to undertake more integrated analyses across a wider area, including for the effects of any groundwater interactions between well fields.

5.4.1.4 Water Boards

Dutch water boards are decentralised public authorities with their own legal personality and financial resources, based on the Dutch Constitution. They act independently of other governmental bodies and are responsible for the quality and quantity management of regional water within their specific geographical areas. Since 2010, with the entry into force of the new Water Act (2009), water boards have become responsible for licensing groundwater abstractions. This is with the exception of any exempted small abstractions and those largest abstractions remaining as provincial responsibilities (refer above). With this development, the water boards now effectively manage all water systems and flood protection structures. Practically, this means that they set and implement regional policy in cooperation with RWS; monitor and manage all physical water levels within their regions; control the quality of surface water; treat all urban wastewater; and physically maintain almost all dykes, waterways and canals (Vewin, 2014) (Figure 6).

Given the influence of surface water levels on surrounding groundwater levels, the water boards need detailed groundwater models to predict and optimise water levels in ditches and canals for agricultural activities and the stability of urban structures. Furthermore, they use these models to calculate the groundwater quantity and quality effects of land uses practices, and establish the most appropriate land use types in their respective regions. They similarly need detailed models to monitor those abstractions for which they have now become responsible. Finally, any groundwater interactions with large RWS-controlled water bodies also must to be taken into consideration and managed (Bolman, 2014). Although the water boards had existing groundwater models with which to work prior to AZURE, in some instances these had been found to either be outdated (e.g. Veluwe region), contain faults (e.g. Vallei en Eem region), or operate at too restrictive a spatial scale (e.g. Zuiderzeeland region). It was for these principal reasons that each of the water boards was interested in developing AZURE.

5.4.2 Organising Team Members

5.4.2.1 Modelling Team

a) Deltares

Deltares is an independent Dutch institute for applied research, with considerable expertise in the field of groundwater modelling. Its experts have been involved in the development of every regional consortium groundwater model in the Netherlands since the original MIPWA development. It is also heavily involved in the development and maintenance of the NHI. Indeed, it was Deltares experts who developed the iMOD software used in these modelling consortia. Furthermore, Deltares experts (at that time as TNO) were the primary agents to initiate and build support amongst the various water governance organisations to become involved in the earlier consortia.

As the primary contracted model builder, Deltares was responsible for managing all the technical modelling activities, including data management, programming and ensuring the model behaved as would be expected in reality (de Lange, 2014). Consequently, Deltares' stake in the AZURE project was considerable. Simply put, it had been contracted by the client group to deliver on its prior reputation and physically build a high quality functioning model.

b) Alterra

Like Deltares, Alterra is an independent Dutch research institute, but rather focuses on the green living environment, climate change, soil, water and food security (WageningenUR, 2014). Similar to Deltares, its experts have been involved in every regional groundwater model development consortia. In each of these it has been subcontracted by Deltares, and has been responsible for ensuring a very specific part of the model works: namely the behaviour and interactions between the vegetation, soils and groundwater in the top-most soil layers (i.e. the unsaturated-saturated transition zone) (Veldhuizen, 2014). As the modelling concepts between each of the consortia models have not changed significantly over the past 10 years, Alterra's role in AZURE was considerably smaller than it had been in earlier consortia. Deltares was able to complete much of this work itself, and Alterra believes its involvement was mainly to lend additional credibility to the science behind the delivered product (Veldhuizen, 2014).

5.4.2.2 Regional Advisors

The involvement of the regional advisors (RA) was a new development in the AZURE process. No other previous Dutch regional groundwater model consortium had included these parties as members. Also subcontracted by Deltares, the RAs were selected from a pool of local technical experts in each of the model sub-regions, with the final selection based upon client-defined key selection criteria and the competitive tenders of the experts' 'parent' organisations (i.e. engineering consultancies) (de Lange, 2014). The RAs were included for two main reasons: first, to introduce into the consortium groundwater modelling expertise in each of their specific regions, and second, to provide a bridge between the pure modelling expertise of the modelling team and the more localised expertise of the clients (Hekman et al., 2014). Hence, they represented their clients' interests in the development of model content and interpreted any modelling concepts and jargon in ways that their clients could more easily understand. They would similarly translate client demands and needs in such a way that the modelling team could understand them more easily (Blonk, 2014; Jansen, 2014).

In terms of the specific regions assigned to each RA, Acacia was selected to advise the Zuiderzeeland region, and as such worked most closely with WS Zuiderzeeland, Flevoland Province, RWS and the DWC. Royal HaskoningDHV (RHDHV) sat in the Veluwe region, working most closely with WS Vallei en Veluwe, Gelderland Province and the DWC. Finally Tauw advised the western region parties, including WS Vallei en Veluwe, Utrecht Province, Gelderland Province and the DWC.

5.4.2.3 Independent Process Manager

Another new development in the AZURE process, the independent process manager was contracted separately by the client group to manage stakeholder processes within this group and the consortium as a whole. Given the different interests of each of the clients, they had identified a need for an independent representative to help them determine and communicate their collective needs to the modelling team (de Lange, 2014). This meant that the process manager aided in all client negotiation, consensus-building and decision-making processes, and also acted as the clients' focal point and intermediary between themselves and the modelling team. Grontmij was the party selected to provide process management services in AZURE.

5.4.3 External Model Users

The list of involved client stakeholders only includes the key regional WRM agencies. In addition these stakeholders, there remain other parties not involved in the consortium who may nevertheless need to make use of AZURE. These users include the municipalities, but then could also include special interest groups such as environmental groups and farming groups. The municipalities could require modelling to assist in environmental or urban water management regulatory control (Figure 6). For example, they may need to assess any issues arising in built-up areas from groundwater that is too low or too high, and the associated effects that this may have on urban structures and urban flooding. Similarly, groundwater flooding or drying out could lead to agricultural, nature and environmental impacts, and would concern special interest groups as well. Groundwater pollution and contaminant transport may similarly present an issue for many of these organisations.

In the particular case of municipal stakeholders, it is interesting to note that these had been included in some previous groundwater modelling consortia in the Netherlands (e.g. MIPWA). The non-involvement of municipalities in AZURE (as well as other excluded stakeholders) was a conscious decision on the part of the consortium for four principal reasons. First, it was generally assumed that municipal representatives would not have possessed the necessary technical knowledge to have been able to effectively participate in consortium discussions (de Lange, 2014; Hekman, 2014). Second, it was assumed their interest in model performance would have been only at very local scales, and often at odds with the initial overriding objective to develop an operational regional model (Veldhuizen, 2014). Third, it was assumed they would not wish to be involved in an abstract and generalised model development process (de Lange, 2014; Klepper, 2014). Finally, it was felt that the consortium group would have simply become too large to manage effectively with the inclusion of these stakeholders (de Lange, 2014; Hoogendoorn, 2014). The general feeling in the consortium was that the municipalities and any other non-financing stakeholders would become more involved with AZURE after the initial development process had concluded, and once the model begun to be used in specific policy and management decision-making processes (de Lange, 2014; Klepper, 2014).[9] The municipal environmental department interviewed in this study validated these sentiments, and expressed no desire to have been involved in the model development process (Bisseling & Riegman, 2014).

[9] Note that in MIPWA, such a specific policy analysis component was included In addition to its model building processes, to assess changes to the prevailing groundwater management regime (Duijn, 2014). Hence, it had made more sense to include the municipalities within this consortium. This was not the case with AZURE, which was simply concerned with the development of the technical model.

5.4.3.1 Omgevingsdienst Veluwe IJssel

Despite not being involved heavily in the Consortium Modelling approach, one external AZURE user made itself available to the author for the purposes of this study: *Omgevingsdienst Veluwe IJssel* (OVIJ, a regional environmental services department). OVIJ was one of the first external uses of AZURE. OVIJ performs all environmental work for two Veluwe region municipalities (Apeldoorn and Epe), in addition to some environmental functions for two additional municipalities (Voorst and Brummen) (Bisseling & Riegman, 2014). It commenced using AZURE to help assess the groundwater transport pathways beneath the city of Apeldoorn. This modelling was to help it design monitoring and containment systems to mitigate the effects of historical pollution related to Apeldoorn's former paper and chemical laundry industries, which was threatening to contaminate residential areas (Bisseling & Riegman, 2014). Note that OVIJ did not carry out its groundwater modelling analysis independently itself, but rather hired expert consultants to undertake this work.

5.5 Objectives of using a Collaborative Modelling approach

The primary function of employing a CM approach to develop AZURE was to deliver model improvement outcomes; that is, building stakeholder consensus and acceptance for modelling results derived during subsequent project work. An additional stated purpose of the CM approach was to enable the development of the best quality model for the resources that had been made available (Hekman, 2014). The understanding was that stakeholders would contribute and pool all their available data, knowledge and information, so that it could be collected and stored in a central database for use in the model (de Lange, 2014; Hekman, 2014). In this way, all stakeholders could benefit from this diverse range of knowledge and would no longer have to repeatedly request data from other agencies for every new modelling project (Menting, 2014).

Collaborative learning, although not a frequently stated purpose for the exercise, can also be seen to have served an implicit function of the exercise. The inclusion of the RA (and to a lesser extent the process manager) was intentionally designed to facilitate shared learning exchanges between the modelling team and client group. Their role to effectively act as 'translators' between the two groups was meant to help each to understand the other's perspectives, but then also to assist in the communication of their respective requirements.

Finally, one must remember that the principal outcome of the CM process was the technical instrument itself. Hence, a related but nevertheless important purpose of the Consortium Modelling exercise is the ability of the AZURE model to inform any subsequent policy and management decision-making processes within which it is applied.

5.6 Collaborative Modelling Tool: iMOD

The AZURE model was built using Deltares' iMOD software package (Vermeulen, 2006). iMOD offers a fast groundwater modelling environment that has been specifically developed to allow the construction of large, high resolution groundwater flow models. It combines a Graphical User Interface (GUI) with an accelerated version of MODFLOW, widely considered the standard finite difference modelling source code (Deltares, 2015). As such, iMOD allows for complex modelling of the physical subsurface system and all its associated geohydrological processes.

5.6.1 iMOD Functionality

A major advantage of using iMOD is that it allows for the necessary gathered subsurface information to be stored at the finest available resolution in the model database (Figure 7). Key parameter input data does not need to be pre-processed into a predefined common model grid resolution (Deltares, 2015). Similarly, resolution distributions for any individual parameters may also vary across the model area, and the spatial extents of input parameters need not be the same. The software will automatically perform the necessary parameter up- and down-scaling (Vermeulen, 2006) whenever the desired simulation resolution is lower or higher than that of the available data, with data values either interpolated or down-sampled respectively (Minnema et al., undated). This core functionality means that the existing input data set may be continually edited and updated as new information becomes available (e.g. at higher resolutions). It also means that models can be operated at whatever spatial and temporal resolution the user wishes, within the constraints of computer processing times. Consequently, for preliminary policy-making studies, users are able to define coarser model resolutions and longer time steps to cut down on model run times and facilitate quick assessments of alternative policy outcomes (de Lange, 2014). Conversely, for later planning phases where greater levels of detail might be required, models with higher resolutions and shorter time steps can also be created.

In addition to the 'scalability' of its models, iMOD permits users to 'cut out' and generate detailed localised sub-domain models from within the global regional model as per their specific needs (Minnema et al., undated). The global model can then be used at coarser resolutions to provide the necessary boundary conditions to these local models (Figure 8). Thus, sub-domain models remain consistent with the larger regional model. To further maintain model consistency, the regional model database can be updated with any information added locally to sub-domain models (Deltares, 2015). The ability to create sub-domain models within the global regional model leads to another advantage. Often it would not be possible to run the large regional model at high resolutions given current computer hardware processing limitations (and time). To address this, iMOD facilitates the user to generate and run a number of partly overlapping higher resolution sub-models which are then later reassembled to generate the whole picture (Deltares, 2015). Running a number of small models instead of running one large model requires less computational power and takes much less computation time. It also permits the utilisation of parallel computing. Thus, modelling workflows are very flexible and no longer limited by hardware constraints when utilizing iMOD (Deltares, 2015).

iMOD further enables groundwater model development and use by permitting the rapid visualisation of model inputs and outputs (Deltares, 2015). Visualisations are both two- and three- dimensional, and support integrated viewing of stationary geologic/hydrostratigraphic outputs as well as dynamic model outputs (Deltares (2015); Figure 9). These visualisations – as well as model outputs in general – are made available much more quickly than in some other groundwater modelling software packages due to several timesaving software techniques. These include the generation of MODFLOW inputs directly in computer memory rather than the more standard and time-consuming process of producing MODFLOW input files prior to model runs (Deltares, 2015). Such efficiencies are particularly useful during the model-building phase when checking newly processed or imported data.

In sum, the purpose of the iMOD software package is to provide expert modellers with a groundwater modelling tool that has the flexibility to generate high resolution model grids everywhere when needed, the flexibility to use or commence with a coarser model grid, reasonable computing runtimes, and conceptual consistency for the entire model area (Deltares, 2015).

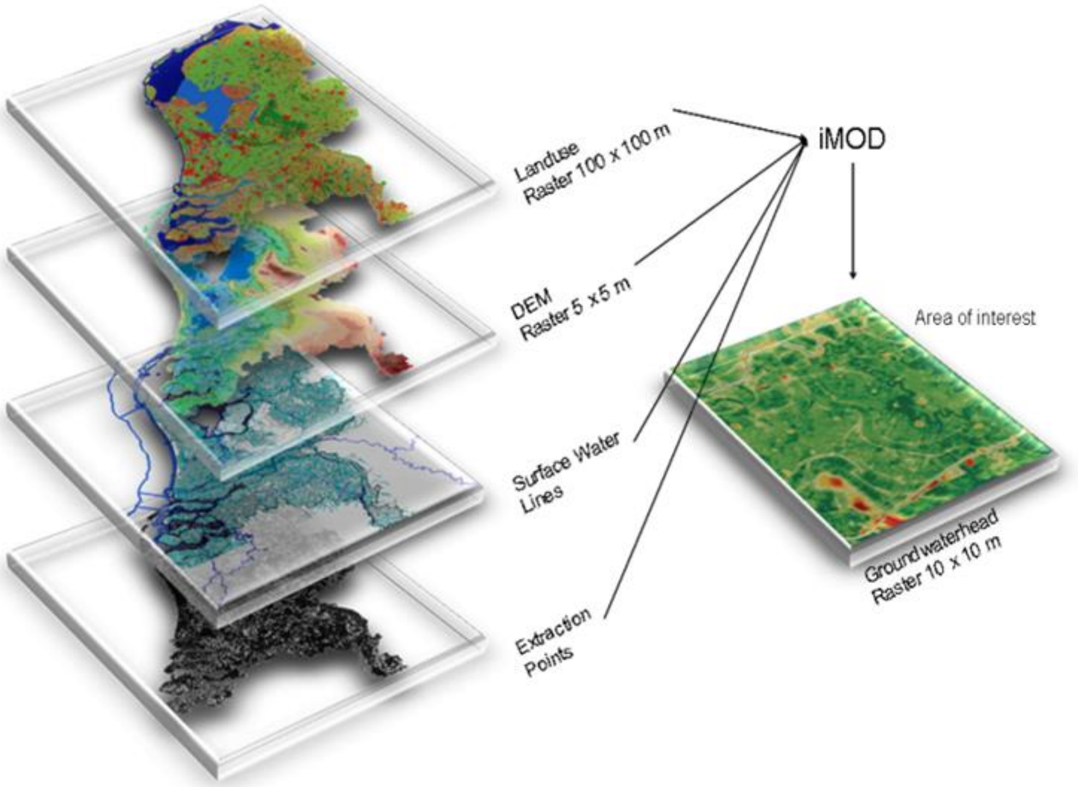

Figure 7: The iMOD approach - an expandable data set covering all possible future areas of interest (Deltares, 2015)

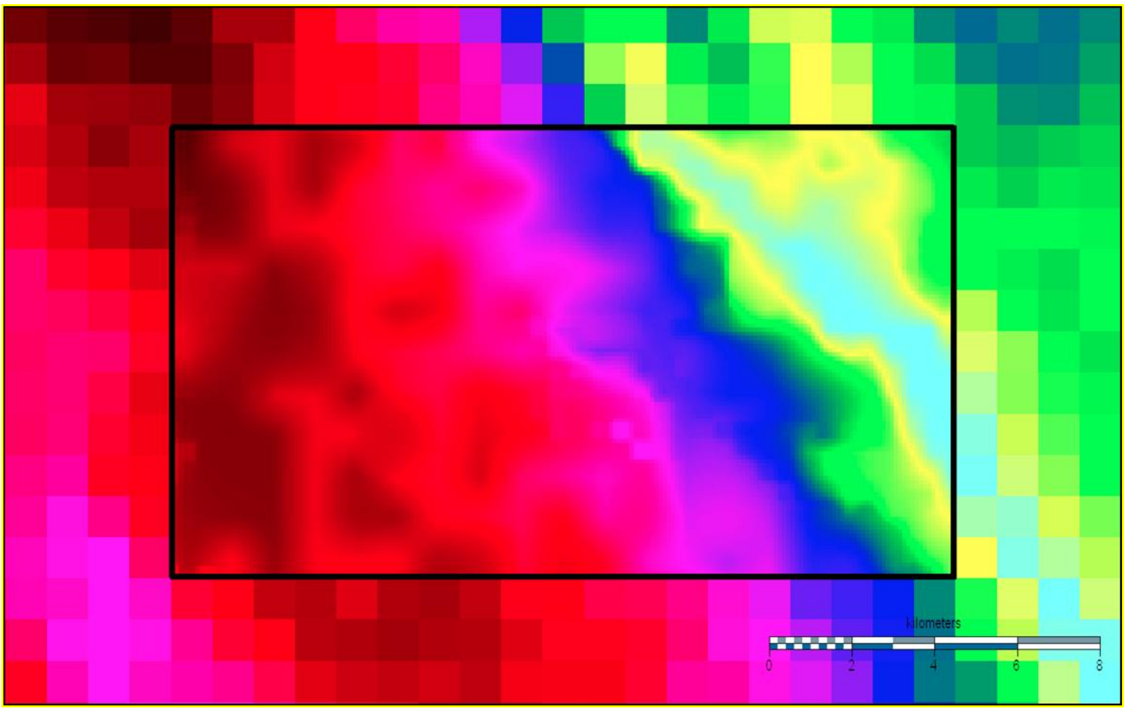

Figure 8: Groundwater flow model nesting.
A sub-domain model (rectangle) is embedded in a coarser regional model. Both models are based on the same data set, the only difference is the assigned grid-extent and resolution (Deltares, 2015).

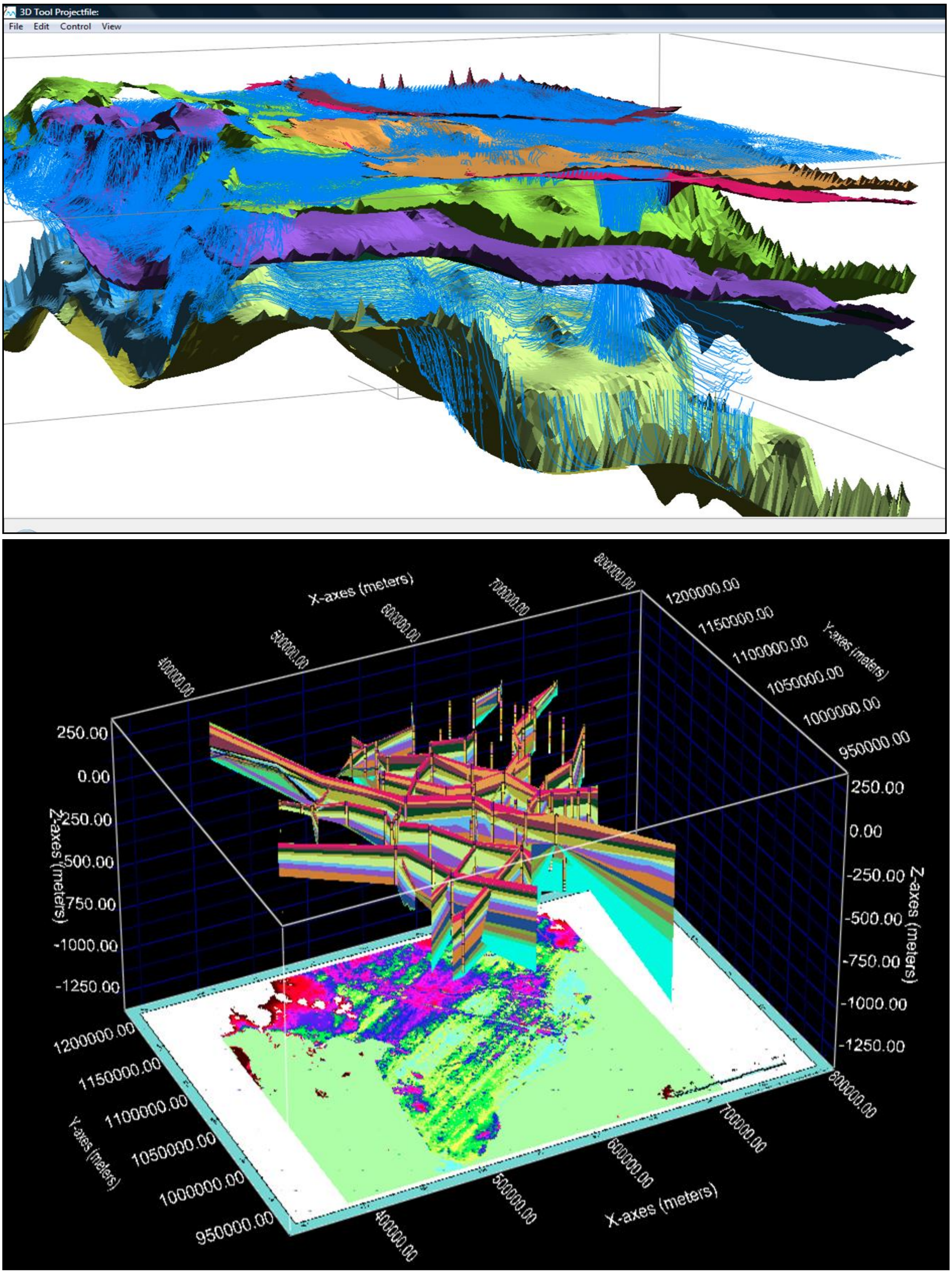

**Figure 9: Examples of 3D-visualisation capabilities of iMOD.
The lower figure demonstrates how users can use visualisations to interactively edit subsurface input data (Deltares, 2015).**

5.6.2 AZURE

The AZURE model has been developed in keeping with the key iMOD functionalities outlined above. In relation to the resolution of its input data, the current model version relies on subsurface data that is often only available up to resolutions of approximately 100m x 100m or less (de Lange, 2014; Veldhuizen, 2014). For other inputs, such as the location of surface water bodies and the Digital Elevation Model (DEM), resolutions are often much higher (e.g. 25 x 25m). Thus, the current model version relies considerably on interpolated sub-surface parameter values to generate any higher resolution local sub-models, leading to increased uncertainties at these scales. Reducing these uncertainties and improving the accuracy and performance of AZURE at these scales necessarily requires that the resolution of the available subsurface data increases (through additional physical subsurface investigations, for example). It may be that some of this information exists in the problem-specific local models developed prior to AZURE, however, as one modeller noted, it would have been almost impossible to include all such information from every separate local model in the first version of AZURE (Veldhuizen, 2014). The initial model was simply too large to permit this given time and budget constraints. Moreover, the intention is that AZURE's continued use and development in the immediate future will gradually improve the resolution of the subsurface database. For the initial version, the focus for the consortium was very much on getting the wider, regional model functioning consistently and correctly at coarser resolutions, rather than developing its detailed local scale capabilities (Veldhuizen, 2014).

Despite this data limitation, AZURE model users are still able to analyse a wide variety of groundwater management problems. In particular, in its current version the model is adept at answering many quantitative groundwater management questions; for example, those related to drinking water production wells or injection wells. It is currently less capable of handling water quality issues satisfactorily (e.g. those relating to the saltwater-freshwater interface and saltwater ingress), although it is intended to gradually add these functionalities to later model versions (de Lange, 2014). Typical model run times are in the order of hours-days and are dependent upon the specific requirements of the questions to be addressed (de Lange, 2014). As noted, coarser model resolutions can complete their calculations more quickly than those with finer resolutions. This is similarly the case for models operating at different spatial and temporal scales.

The AZURE model resides on Deltares' servers, and is accessible to users via login to a web portal.[10] Access to the model is provided (and indeed promoted) to both consortium and external parties free of charge. Users can either choose to run the model remotely via the Internet from the server, or alternatively download local copies of the model to a computer system of their choice. Given its typical run times, it is important to note that AZURE is not a model that lends itself to interactive and collaborative face-to-face use in modelling workshops with stakeholders. Rather, it is more oriented towards individual modeller use within stakeholder organisations or by their contracted advisors.

Having now outlined the broad context within which the Consortium Modelling approach manifested, including those stakeholders involved and the modelling tool utilised, the following chapter turns its attention to the specifics of the Consortium Modelling approach.

[10] See www.azuremodel.nl

6 Consortium Modelling Approach

The preceding chapter provided the necessary background and contextual information for this case study. Having done so, this chapter focuses on the specific stakeholder structures and processes of the Consortium Modelling approach as it was conceived during the development of AZURE, and includes the author's analysis of these.

6.1 Consortium Modelling in AZURE

6.1.1 Structure of Participation

To facilitate effective collaboration within the consortium, the stakeholders involved were divided up amongst five sub-groups. As per the whole consortium, these were all heterogeneous entities with each sub-group having a particular set of collaborative functions and responsibilities. Representatives from the various client members were present in all sub-groups and 'organising team' members were similarly spread across these. The five collaborative consortium sub-groups included:

- Core Management Group
- 3 Regional Groups
- Expert Group

A sixth sub-group, the Modelling Team has been introduced in the previous chapter, but did not feature as a forum for client member collaboration.

6.1.1.1 Core Management Group

A central core group was responsible for the day-to-day management decisions regarding the development of the project. This group included the modelling team project leader, the process manager and a member from each client 'type' (RWS, the DWC, one water board representative, one provincial representative), whilst also ensuring representation from each of the three regional groups. It never made any technical decisions, but was responsible for making the final 'Go/No-Go' assessment once it understood that all consortium requirements had been met.

6.1.1.2 Regional Groups

As the AZURE model covers such a wide area, the client group was divided into three sub-regional areas that conformed to the boundaries of the original three water boards. These sub-regional groups each consisted of a representative from RWS, the DWC, its relevant provincial representatives, water board representatives, and RA. Each regional group was specifically responsible for providing and closely examining input data and model performance as it related to its area, checking that it met with all client needs. Regional groups were also tasked with defining the subsurface schematisation requirements (e.g. number of soil layers) for their respective areas.

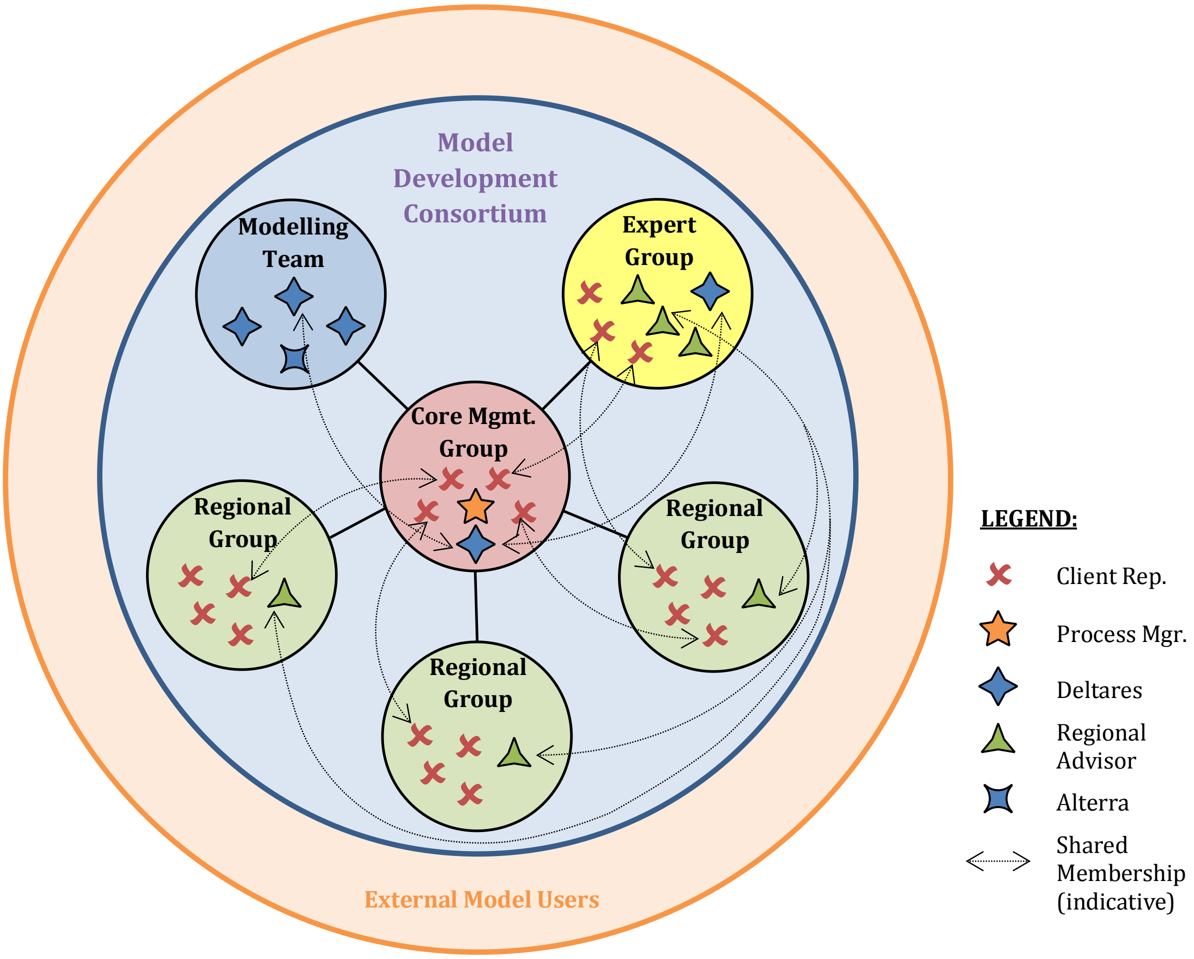

Figure 10: Consortium Structure

6.1.1.3 Expert Group

A sub-group of modelling experts involved within the consortium was responsible for developing the conceptual basis for the regional model (e.g. the included soil layers, how to deal with discontinuous layers, non-stationary behaviour, salt intrusion, etc.). The composition of this group included experts from Deltares, the three RAs, the DWC, RWS and provincial experts, among others. These were individuals who had a deep understanding of modelling approaches and had a specific interest in how the model looked and functioned on a detailed level (de Lange, 2014). An equal representation of stakeholders was not required for this group; but rather membership was determined solely on the level of the expertise of the specific individuals involved.

Despite being sub-divided in this way, all major decision-making powers rested with the whole consortium. Sub-groups would prepare advice or proposals to be presented to the complete consortium, where all stakeholders would formulate consensus decisions. Figure 10 helps visualise the structure of the consortium, including indicative shared sub-group memberships. Similarly, the specific responsibilities of both the whole consortium and each of the collaborative sub-groups are outlined in greater detail in Table 6, including each group's decision-making powers (if any) and their frequency of contact.

Table 6: Key collaborative sub-group responsibilities and frequency of contact (de Lange, 2014)

Collaborative Forums	Responsibilities	Meeting frequency (approx.)
Entire Consortium	*MANAGEMENT* – Decision-making: Major budgeting and programme decisions (based on advice from core group) *TECHNICAL* – Decision-making: Model concepts/schematisation according to expert and regional group proposals – Decision-making: Model improvements to be incorporated – Decision-making: Stipulation of Go/No-Go requirements prior to each calibration/optimisation process (based on advice from regional groups)	Bimonthly
Sub-Groups		
Core Group	*MANAGEMENT* – Decision-making: Day-to-day budgeting and programme decisions (based on advice from regional groups) – Advice preparation: Major budgeting and programme decisions (based on advice from regional groups) *TECHNICAL* – Decision-making: Final Go/No-Go decision when agreed consortium requirements have been met	Bimonthly, with weekly email correspondence in between.
Regional Group	*TECHNICAL* – Advice preparation: Sub-regional model concepts/schematisation proposals (e.g. number of layers) – Raw data collation and validation – Model input data validation – Interim model results validation/verification – Advice preparation: Technical model improvements for Consortium Group – Advice preparation: Propose technical Go/No-Go requirements for Consortium Group	Monthly
Expert Group	*TECHNICAL* – Advice preparation: Area-wide model concepts/schematisation proposals – Area-wide model concepts/schematisation validation/verification – Advice preparation: regarding proposed model improvements from regional groups (if required)	As required (3-4 over course of development process)

6.1.2 Collaborative Processes

Consortium members were heavily involved in all phases of the model development process. This was an iterative process, with six calibration or optimisation cycles (Deltares, 2014). Extensive collaboration between modelling experts and other consortium members conceptualised how the model would be schematised at both regional and sub-regional levels. Data collection, improvement and validation were carried out in each of the sub-regional groups with the support of the RA. Once all these inputs were validated and any recommendations incorporated into the model, a 'Go/No-Go' decision would then determine whether the consortium as a whole accepted the model and agreed to the calibration run proceeding. A 'Go' decision was a significant mechanism within the development cycle, with serious implications (de Lange, 2014). Once a 'Go' decision had been awarded, there was no longer an opportunity to revisit any performance issues addressed during that particular project phase in a later phase (i.e. during a subsequent calibration cycle). The award of a 'No-Go' decision simply meant that any identified lingering deficiencies were promptly rectified. Once this had occurred, a 'Go' decision could then eventually be awarded and the calibration run proceed. Following this model run, interim results were examined in great detail in the regional groups and any new potential issues and solutions identified. These recommendations would go on to inform the consortium-determined conditions for the next 'Go/No-Go' decision. A visual representation of the complete collaborative model development process is provided in Figure 11.

This process notwithstanding, a further core feature of the Consortium Modelling approach is that the initially developed model version is subjected to continuing processes of model improvement and refinement throughout its use. That is, as AZURE is used in specific client and external stakeholder projects, additional data from improved sources or from those with a higher resolution will be collected and included in these project-specific models. All these individual project improvements are to be collected centrally by the consortium. Every two years the consortium will then consider all of the individual improvements to the model in a formal version update process, and determine which of these it agrees to incorporate into the next model version (Menting, 2014). Naturally, obtaining model improvements made by the client actors themselves presents a relatively uncomplicated exercise. However, receiving model improvements from external model users (e.g. consultancies, municipalities, interest groups, etc.) could prove a little more problematic. To mitigate such issues, an important condition permitting the use of the model by these other stakeholders is that any locally-generated improvements or new data must be forwarded to the consortium group as they become available (Hekman, 2014).

Given the high level of stakeholder input, the Consortium Modelling approach is best described as an intensive co-construction form of CM. Client stakeholders were involved in all data collection, model definition, conceptual modelling, and model testing and verification activities during the development process. Indeed, the only modelling activity in which client members did not collaborate was the formal programming and coding of the model. The intensive nature of the approach guaranteed the highest degree of participation for all the client members. They held equal co-decision-making powers and were thus empowered to exert considerable control over the development process. The additional support that client members were able to receive from their advising RA only strengthened their abilities to challenge the modelling team, set the development agenda and exert even greater control over the final structure and performance of the model. Similarly, the involvement of the independent process manager helped enable the clients reach collective positions regarding 'Go/No-Go' decisions. External users were only ever informed about the development of the model.[11] However, this is not to say that external stakeholders will not reach higher levels of involvement in any subsequent specific collaborative groundwater planning activities using AZURE.

If one considers the 'Circles of Influence' model presented in Chapter 3, it may seem at first difficult to apply this model to AZURE's Consortium Modelling structure. This is because the approach to date has been entirely focussed on the development of the operational model, and rather not on any specific policy-making, planning or management outcomes. Given this constraint, it is perhaps most useful to view the entire consortium structure as a combined 'Circle A'. The consortium consisted of those organisations – and even the specific individuals – who are the central planners, managers and modellers who will drive and perform the majority

[11] For example, a workshop was conducted with potential external user organisations towards the end of the development phase in order to encourage and incentivise them to use AZURE and contribute to its continual improvement (de Lange, 2014).

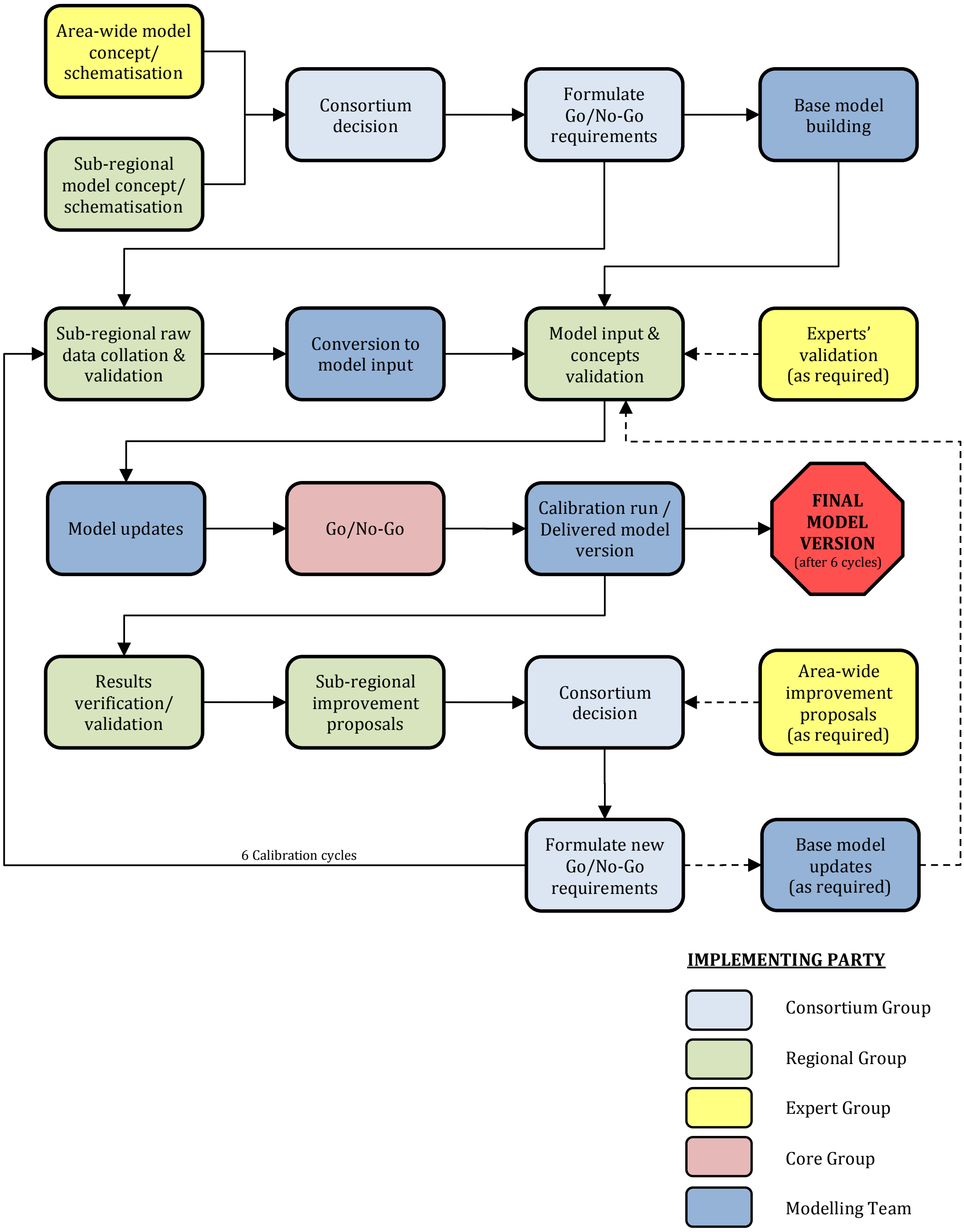

Figure 11: Collaborative model development process followed for AZURE

of future groundwater management tasks using the model. External model users more correctly comprise 'Circle B' (Figure 10). Similarly, any other external parties who perhaps should be engaged in any specific policy-making or management projects using the model would also sit in 'Circle B' and provide linkages to other less-involved stakeholders in 'Circle C'. As the present analysis only considers the specifics of the development process, the author will not consider these latter participants any further.

6.1.3 Skills and Knowledge Needed in the Approach

6.1.3.1 Stakeholder Skills

All stakeholder representatives in the consortium had either hydrological, geological or groundwater modelling backgrounds. Although not all expert modellers, each consortium member had sufficient technical knowledge and understanding of groundwater management issues and modelling concepts. Most had experience using groundwater modelling software to some extent in their current or previous positions. Even the process manager – who served in a largely non-technical capacity – had an educational background in geohydrology. Indeed, this is one of the key elements of the Consortium Modelling approach. One of the reasons it is effective is because it brings together 'like-minded' technical representatives from groundwater management organisations in the model areas (Minnema, 2014). This assists both in the predominantly technical discussions and with cooperation, as a common basic level of technical knowledge exists within the group and they can communicate with each other using the same vocabulary.

In addition to common technical knowledge, it was also advantageous if consortium members had competent social and communication skills needed to effectively interact with other members. In particular, there was a need for all members to be open-minded to working with the other partners and willing to share their information and data, rather than being more closed and simply keeping their own counsel (de Lange, 2014). It was generally felt that all in the consortium group demonstrated these skills, however, one must not forget that the process manager was always on hand to be able to assist those who may have struggled in this area (de Lange, 2014). He was there to specifically facilitate the communication between the various parties and to ensure that the consortium remained focussed on its core goals, which demanded effective cooperation.

6.1.3.2 Model User Skills

Directly operating iMOD relies upon user abilities to compose, edit and run the necessary model run files (in FORTRAN). Alternatively, users can make use of iMOD's built in GUI to perform many of the most essential tasks. Users less comfortable with scripting run files would typically rely on the GUI to select from its predefined scenarios and strategies. In whichever form it is used, the model demands specialist modelling skills. All 'non-expert' modellers in the consortium testified to this fact, and one stakeholder suggested that provinces would typically hire expert advisers to use AZURE for them (de Groot, 2014). Another summed up the skill demands of the model nicely,

> "[AZURE] is no more difficult than any other groundwater model…Having said that, AZURE is a highly technical tool and one needs a high level of geohydrological knowledge to operate it correctly and to interpret and reflect on the results. High level computer skills are another necessary requirement" (Menting, 2014).

It is important to recognise that the AZURE model is not one that can be competently operated directly by individuals with only general computer skills. It is also relevant to highlight that the majority of indirect model users were nevertheless directly involved in the consortium, and possessed the necessary technical knowledge base to comprehend and interpret any presented modelling results.

6.1.3.3 Organising Team Skills

Naturally the modelling team and RAs relied upon their expert modelling skills to build and assist the client group in the development of the physical groundwater model. However, the RAs also had to demonstrate competent communication, facilitation and knowledge acquisition skills in the regional teams. They were the facilitator of technical discussions within their regional groups and similarly provided technical 'translation' services to communicate any demands between their clients', the modelling team and vice versa. They were specifically included to acquire the necessary knowledge to ensure clients' interests were correctly represented in the final model version's run files, inputs and outputs.

Correspondingly, the modelling team (and principally the Deltares team leader) needed to demonstrate similar skills in the other consortium forums. Particularly in the expert group, Deltares both facilitated all discussions and synthesised inputs from any expert members and the RA. Likewise, during the whole-of-consortium meetings, Deltares needed to acquire and digest the technical needs of the entire client group (Menting, 2014). However, in this instance it was assisted by the presence of the RA. Furthermore, facilitation responsibilities during both whole-of-consortium as well as core group meetings could be shared with the process manager, contracted to enable and smooth communication pathways between the clients and modelling team.

Finally, effective process management skills needed to be demonstrated by both Deltares and the process manager. In the case of Deltares, this related to its abilities to maintain an overview of the collaborative model development process and ensure that the model was behaving technically as would be expected in reality (de Lange, 2014). More prosaically, this also relied on Deltares being able to ensure that the modelling team met key deliverable deadlines and that sufficient quality control measures were in place. Model building of this kind is not a straightforward task, and can very easily encounter hiccoughs, fall behind schedule and go over-budget. Such situations demand sound project management skills to be able to deal with them. For example, explanations need to be provided as to the reasons why the project may fall behind schedule, or why additional expenditure may be required, and negotiations then need to take place to set new realistic target milestones (Veldhuizen, 2014). Deltares needed to regularly demonstrate these skills in both the core and consortium group forums. For the independent process manager, he was the responsible party within the client group for managing and controlling similar processes and discussions, for example in coordinating negotiations to formulate or update its common objectives and positions as new information came to hand.

6.1.4 Means

There is little doubt that the AZURE model development process involved intensive time and financial commitments for all its members. As indicated in Table 6, the regional groups were meeting on average monthly and the core and consortium groups bimonthly. This was in addition to considerable interim communication and individual technical effort from all members with regards to data collection, validation and model building activities. Not to mention the additional time commitment for any expert group meetings that were needed during the process. With a total development period of three years and a total budget of EUR 1.2 million, the AZURE development was not an insignificant undertaking for the funding members of the consortium. Of this figure, it is estimated that approximately EUR 400,000 went towards stakeholder processes and involvement (i.e. approximately 33% of total costs) (de Lange, 2014; Hekman, 2014).

6.2 Generalised Consortium Modelling Approach

A complete summary of the Consortium Modelling approach as it was applied for AZURE – synthesising the information detailed in the preceding sections – is tabulated in the following pages according to the analytical framework (Table 7). To further assist others in decisions whether to apply a similar approach in other situations, the Consortium Modelling approach can be summarised as follows:

Consortium Modelling should be applied in unstructured and semi-structured problem contexts where a key objective is to reduce knowledge uncertainties through building consensus. The defining focus of this CM approach is on achieving model improvement (quality, acceptance, integration) outcomes in the construction of a detailed, sophisticated, computer-based physical system simulation model. The approach relies upon key institutional client stakeholders and expert modellers collaborating closely together; in which case it should also help deliver any shared learning outcomes. Also central to the application of the approach is a broadly cooperative institutional and decision-making context. Institutional stakeholders and modellers must not only be willing participants, but must also demonstrate a willingness to be open to others' needs and interests, share their data and knowledge, and commit to generating consensus. Given these contextual realities, the Consortium Modelling approach is exemplified by its intensive, co-decision-making level of participation for its collaborating institutional stakeholders. These are divided amongst a number of heterogeneous sub-consortium groups, and are enabled by the inclusion of independent expert modelling advisors (i.e. the RAs) to engage fully with the co-construction of the sophisticated simulation model. Stakeholders collaborate in all data collection, model definition, conceptual model building, and model testing and verification activities. Model use in the approach is typically restricted to any modelling experts and conducted independently of collaborative forums, and the model is either accessed locally or via the internet. An independent process manager supports the entire process. He or she is responsible for managing the relationships between institutional stakeholders and modellers, and for facilitating all consortium decision-making processes.

Given the complex, detailed and sophisticated nature of the developed simulation model, a Consortium Modelling approach will likely restrict consortium participation to institutional stakeholder representatives with sufficient technical knowledge to effectively contribute to model construction discussions. Even with the inclusion of independent expert modelling advisors, baseline technical skills and knowledge will likely remain a precondition to stakeholder involvement in the approach. As per most other CM approaches, the modellers and process managers comprising the organising team must demonstrate the requisite facilitation, knowledge acquisition, modelling, and process management skills to bring about the broad success of the approach. Furthermore, the approach is predicated upon considerable financial and time resources being made available by its institutional client stakeholders.

Having broadly defined the Consortium Modelling approach, the next chapter reflects upon stakeholders' experiences of the approach as it was applied in AZURE. In particular, these consider the abilities of the approach to meet the objectives of the exercise as well as achieve any of the collaborative benefits of CM.

Table 7: Summarised analysis of the Consortium Modelling approach according to the analytical framework

	CONTEXT AND APPLICATION					
	Problem Type					Domain
	Structure			Scale of Action	Time Horizon	
	Structured	Semi-structured	Unstructured		# years	
AZURE (General)		Semi-structured (Uncertain). Proliferation of different GW models generating conflicting results. Need for consensus.	Unstructured. Some values and norms also remain contested.	Local - Regional. Entire model can be used for regional problems, whilst smaller local models can be cut for local scale problems. Model up- & down-scaling automatic.	Short-Medium: 0-15 years typically, but could also be used for longer time horizons.	Groundwater Management
National Water Agency						
Drinking Water Company						
Provinces						
Water Boards						
Regional Advisors						
Model Building Team						
Process Manager						
External Model Users						

Table 7: Summarised analysis of the Consortium Modelling approach according to the analytical framework (continued)

	CONTEXT AND APPLICATION				
	Decision level			Decision-making context	
	Operational	Management	Planning & policy	Cooperative	Competitive
AZURE (General)		Management tool for testing different interventions within given policy context.	Planning tool for testing effects of both different local-regional scale policies.	Cooperative. All stakeholders willing to work together in model development process.	
National Water Agency				x	
Drinking Water Company				x	
Provinces				x	
Water Boards				x	
Regional Advisors					
Model Building Team					
Process Manager					
External Model Users					

Table 7: Summarised analysis of the Consortium Modelling approach according to the analytical framework (continued)

	SPECIFIC USE					
	Participatory modelling purpose					Planning or Managmeent Cycle Phase
	Decision-making	Collaborative Learning		Mediate	Model Improvement (quality, acceptace, integration)	
		Social learning	Shared learning			
AZURE (General)	Model will be later used to support decision making processess.		Some shared learning regarding how to model some phenomena. RA role key to communication of client needs to Modelling Team and vice-versa.		Main objective to build a quality consensus model to which all SHs agree.	Inception & Development Phases. However, developed model will be applied both in future Development and Selection phases. i.e. all potential project phases that require modelling. AZURE development not for a particular project, but to meet a recognised general need for a new model.
National Water Agency						
Drinking Water Company						
Provinces						
Water Boards						
Regional Advisors						
Model Building Team						
Process Manager						
External Model Users						

Table 7: Summarised analysis of the Consortium Modelling approach according to the analytical framework (continued)

	INFORMATION HANDLING						
	Model type		Modelling tool / Software platform	Information type	Deltvery Medium		Simulation Time
	Model System Focus	Simulation / Conceptual			Virtual / Web	Face-to-face	
AZURE (General)	PSM	Simulation	iMOD	Complex processes	Model can be accessed and run on Deltares Server. Alternatively, user can download a local copy to their own machine.		Hours-Days
National Water Agency							
Drinking Water Company							
Provinces							
Water Boards							
Regional Advisors							
Model Building Team							
Process Manager							
External Model Users							

Table 7: Summarised analysis of the Consortium Modelling approach according to the analytical framework (continued)

	STAKEHOLDER INVOLVEMENT						
	General Classification		Stakeholders Involved			Model Users	
	Participatory	Collaborative	Stakeholder	Minimal knowledge & skills	Background	Direct / Indirect (i.e. mediated)	Mimimum Skills
AZURE (General)		All stakeholders participating at high levels and with high willingness to cooperate. Ability to control and determine their own involvement.	Refer Below	Refer Below	Refer Below	Refer Below	CS Use can either be via iMOD GUI interface or through runfile manipulation. The GUI offers less functionality, but requires fewer skills to operate.
National Water Agency			RWS	KT/KR	GW Hydrology & Management	Direct	CS Specialist Modelling Skills
Drinking Water Company			Vitens	KT/KL	GW Hydrology & Management	Direct	CS Modelling Skills
Provinces			Flevoland Gelderland Utrecht	KT/KL	GW Hydrology & Management	Direct / Indirect	CS Modelling Skills
Water Boards			Zuiderzeeland Vallei en Veluwe (Waternet)	KT/KL	GW Hydrology & Management	Direct / Indirect	CS Modelling Skills
Regional Advisors			Acacia RHDHV TAUW	KE/KL	GW Hydrology & Modelling	Direct	CS Specialist Modelling Skills
Model Building Team			Deltares Alterra	KE	GW Hydrology & Modelling	Direct	CS Specialist Modelling Skills
Process Manager			Grontmij	KT (of benefit)	Process Management (GW Hydrology of benefit)	N/a	N/a
External Model Users			Municipalities Others	KL	Various: Environmental science, GW management, etc.	Indirect (via consultancy)	N/a

KE: Expert Knowledge & Skills
KT: Technical Knowledge & Skills
KR: Regional Knowledge & Skills
KL: Local Knowledge & Skills

CS: Specialist Computer Skill
CG: General Computer Skills
NOC: No Computer Skills

Table 7: Summarised analysis of the Consortium Modelling approach according to the analytical framework (continued)

	STAKEHOLDER INVOLVEMENT			
	Participation mode			
	Only modellers (NOP)	Individuals (IND)	Group	
			Homogeneous interests (HOM)	Heterogeneous interests (HET)
AZURE (General)	Any construction programming or model use primarily by modelling experts only.	Engagement of other SHs in application activities project specific.	Engagement of other SHs in application activities project specific.	Model development activity groups all HET entities. Engagement of other SHs in application activities project specific.
National Water Agency	Model Use in projects			Core Group Expert Group Regional Groups Consortium Group
Drinking Water Company	May engage consultancy for Model Use in projects			Core Group Expert Group Regional Groups Consortium Group
Provinces	Typically would engage consultancy for Model Use in projects			Core Group Expert Group Regional Groups Consortium Group
Water Boards	May engage consultancy for Model Use in projects			Core Group Expert Group Regional Groups Consortium Group
Regional Advisors	Model testing, verification & refinement (Programming). May be engaged to use model in projects for clients			Expert Group Regional Groups Consortium Group
Model Building Team	Model building (Programming)			Core Group Expert Group Regional Groups Consortium Group
Process Manager				Core Group Consortium Group
External Model Users	Typically would engage consultancy to do modelling work	Project specific	Project specific	Project specific

Table 7: Summarised analysis of the Consortium Modelling approach according to the analytical framework (continued)

	STAKEHOLDER INVOLVEMENT						
	Level of Involvement						
	Ignorance	Awareness	Information	Consultation (feedback)	Discussion (advice/ recommendations)	Co-Designing (ownership)	Co-Decision-Making (empowerment)
AZURE (General)	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below
National Water Agency							x
Drinking Water Company							x
Provinces							x
Water Boards							x
Regional Advisors					x	(x)	
Model Building Team						x	(x)
Process Manager					x		
External Model Users			x				

Table 7: Summarised analysis of the Consortium Modelling approach according to the analytical framework (continued)

	STAKEHOLDER INVOLVEMENT									
	Timing of Participation									
	Data collection	Model definition		Model construction		Model testing and verification	Model use		Development of strategies	Dominant Form
		Model assumptions	Scenarios development	Model building	Model refinement		Provide inputs for model use	Use computer model		
AZURE (General)	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Co-construction
National Water Agency	x	x	Project specific		Via use	x	x	x	Project specific	
Drinking Water Company	x	x	Project specific		Via use	x	x	x	Project specific	
Provinces	x	x	Project specific		Via use	x	x	(x)	Project specific	
Water Boards	x	x	Project specific		Via use	x	x	x	Project specific	
Regional Advisors		x Sub-regional Schematisation	Project specific		(x)	x	x	x	Project specific	
Model Building Team		x	Project specific	x	x			x	Project specific	
Process Manager										
External Model Users	(x) Local Data for specific projects		Project specific		Via use		x		Project specific	

Table 7: Summarised analysis of the Consortium Modelling approach according to the analytical framework (continued)

	MODELLING / ORGANIZING TEAM					MEANS	
		Skills					
	Team	Modelling skills	Facilitation skills	Knowledge adquisition skills	Process management skills	Timing	Financial resources
AZURE (General)	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	3 years Meeting freq.: Monthly-Bimonthly	Total Costs: € 1.2 million Stakeholder Processes: € 400.000
National Water Agency							
Drinking Water Company							
Provinces							
Water Boards							
Regional Advisors	x	x	x in Regional Groups	x			
Model Building Team	x	x	x in Expert Group	(x) Assisted by RA 'translation'	x Technical process management		
Process Manager	x		x Consortium & Core Groups		x Stakeholder process management		
External Model Users							

7 Stakeholder Perspectives on Approach Outcomes

It is clear from the analysis in the preceding chapter that the Consortium Modelling approach is an intensive collaborative groundwater model building process for all the consortium stakeholders involved. It demands high levels of involvement, cooperation, technical knowledge and skills. It also relies upon considerable time and financial resources. Having analysed AZURE's Consortium Modelling approach against the analytical framework, it is now instructive to consider the perspectives of the stakeholders who were most involved in these processes. It is only by doing so that one will be able to gain and learn from their experiences of the approach, and take the necessary steps to improve and develop it further.

In general, one can say that the stakeholders all view the AZURE process as having been a qualified success. Most found the process useful and almost all suggested they would become involved in a similar process again. That being said, certain elements of the project generated considerable frustration amongst the parties. To analyse these in greater detail, stakeholder perspectives have been assessed against both the intended project outcomes and the purported collaborative benefits and limitations identified earlier in Chapter 3. At the request of several respondents, specific stakeholder comments and opinions have typically not been attributed to specific individuals within this chapter.

Before exploring these perspectives in detail, it is perhaps first useful to illustrate them more generally. Delineated according to clients, organising team members and external users, Figure 12 illustrates the number of respondents that indicated whether each beneficial outcome was achieved during the approach. Figure 13 provides a similar illustration for the identified negative consequences or limiting conditions. Note that these graphs do not indicate the specific magnitudes or levels of stakeholder satisfaction or dissatisfaction with the outcomes, consequences or conditions. Stakeholder perspectives were counted if an outcome was simply mentioned in passing, or qualified further with additional comment. As such, both figures are intended to simply provide an initial general impression. As both figures illustrate, positive outcomes tend to dominate more so than negative outcomes, and one can also recognise that the final two limiting conditions (i.e. poor technical process management and poor contractual arrangements) have little to do with the Consortium Modelling approach itself, but rather with the manner in which it was implemented. It is not intended to examine these figures in any greater detail here, but it may be useful to keep them in mind as the reader considers the specific stakeholder perspectives that have informed these graphs outlined in each of the remaining sections of this chapter.

7.1 Model Quality and Acceptance

As noted in Chapter 5, the primary reason for employing the Consortium Modelling approach was model improvement. Hence, it is important to gauge stakeholder perspectives on the ability of the approach to deliver this outcome, both in terms of the technical quality of the model and stakeholder acceptance of the delivered version. It is encouraging that every stakeholder interviewed in this study judged the Consortium Modelling process to be generally successful in meeting these objectives.

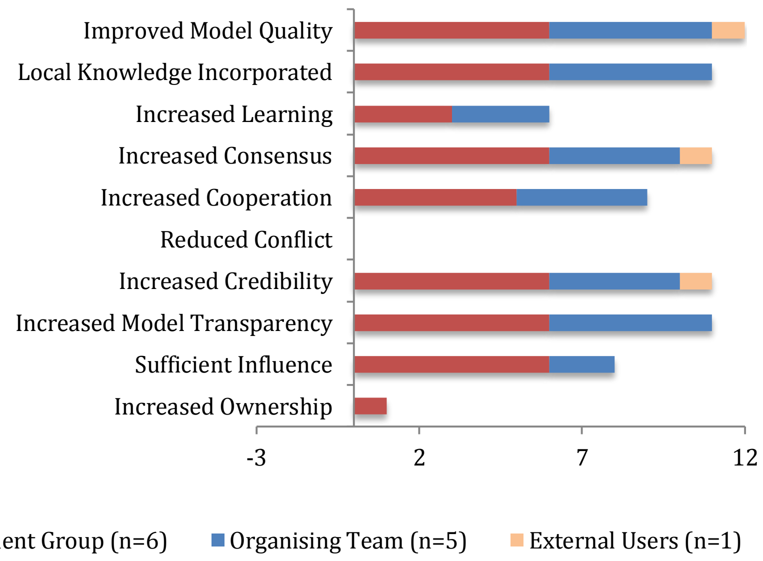

Figure 12: Positive outcomes of the AZURE consortium modelling approach as identified by stakeholders

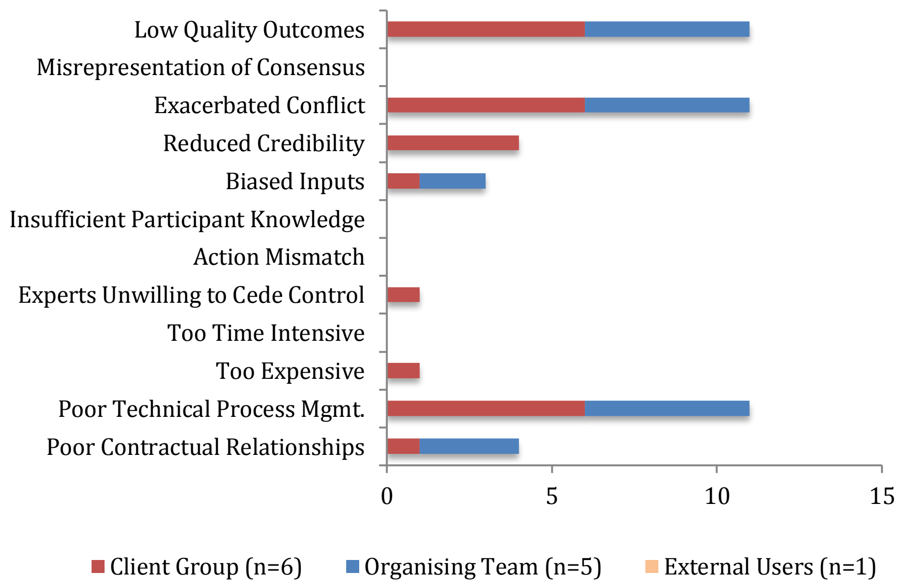

Figure 13: Negative outcomes or limiting conditions of the AZURE Consortium Modelling approach as identified by stakeholders

All client stakeholders explicitly commented on the fact that the quality of the model was directly improved as a result of the collaboration between the parties. Simply put, they felt that combining the knowledge of many experts had helped to generate the best possible conceptual schematisation for the model. Similarly, the considerable effort that the RA and other stakeholders invested in checking the validity of results was viewed as having greatly enhanced the model's general reliability and performance. Various stakeholders also pointed to the ability of the Consortium Modelling approach to incorporate diverse and locally-specific technical knowledge. This was seen not only to contribute to capturing system complexity, but also enabled the consortium to incorporate experiences gained in other regions. Groundwater influences at regional scales were thus integrated in ways that otherwise would not have been possible. Similarly, clients appreciated the calibration and spatial consistency in the model such that the impacts of any actions in one area could be assessed on much wider scales. They also judged that combining knowledge had yielded improvements related to modelling specific hydrological phenomena. Importantly, stakeholders generally considered that collective investment had meant that comparatively more could be achieved for the same amount of money. As one client remarked, "a regional system demands regional investment, and pooled project resources were focussed most on any problem areas."

The modelling team likewise all assessed the Consortium Modelling process to have delivered a much higher quality result. In Deltares' opinion, AZURE is more hydrologically advanced than many other models. The inclusion of the RA within the consortium structure meant that Deltares felt it could more easily promote and introduce additional knowledge and techniques into the process without overwhelming clients, since the RA could easily explain these improvements to clients and validate their worth. In previous consortia, Deltares had had to play the role of both promoter and interpreter for any proposed technical enhancements. In those contexts, building acceptance and trust for its proposals was more difficult as clients felt that the modellers were at times simply pursuing additional project funding.

Although the model's quality has benefitted from the employed Consortium Modelling approach, some stakeholders nevertheless also indicated a level of dissatisfaction with the performance of the model at detailed scales. These perspectives seemed in part the result of unmet expectations formed at the beginning of the project. Some stakeholders broadly understood that the final model version would include all information to a resolution of 25 x 25m, and that the model would function as well at detailed local scales as it would at regional scales. As this was not possible within the constraints of the available time and money, there was a lingering perception for some stakeholders that the model did not met with its original specification. That being said, other clients were unsurprised by this eventuality. They merely viewed AZURE as being at a stage that organisations acting at detailed local scales (typically the water boards) can begin to decide which areas of the model to earmark for further improvement and investment (e.g. via more detailed data, modelling of locally-specific phenomena, etc.). Other model performance-related aspects contributing to stakeholder dissatisfaction were the persistence of errors in the model, as well as a lingering perception that it was not as error-free as it possibly could be (addressed further in a later section). However, in general stakeholders were equally prepared to point out that in a model of this size and with so many parameters, it would have been difficult to remove all errors. Hence, most viewed the initial version as a sound basis from which to work, improve and build upon in later versions.

Despite its imperfections, stakeholder acceptance for the delivered model version was high. Since all stakeholders were heavily involved in every negotiation and decision regarding each development choice, inclusion and omission, this meant that they could understand why the model performed to its developed standard, and that they accepted the model for what it was. Furthermore, all parties were committed to using it in their future groundwater management projects. Similarly, they were committed to promoting it use amongst other agencies, such as OVIJ or other municipal authorities.

7.2 Collaborative Learning

When stakeholders were asked to consider any shared learning outcomes of the Consortium Modelling approach, responses typically gravitated to one of three main areas: learning about the perspectives and interests of other stakeholders; technical learning regarding the functioning of the physical groundwater system; and learning related to the structure and organisation of the CM exercise.

One of the key areas of shared learning that both client and organising team members mentioned related to finding common interests with other parties. By sharing types of problems each client wished to solve with the model, all parties came to learn of each other's needs, and the development process could be targeted towards delivering these functionalities. Parties could also ascertain that their groundwater modelling issues were common to others. For example, one province pointed to the example of another's desire to improve the model's replication of the behaviour of clay cracks and cleavages encountered in its region. Although this was an element of the model that other representatives had not considered important, he came to realise that improving the top-most model layers would likewise lead to improved performance in his region. Similarly, several modelling team members stated they too had been able to improve their understanding of stakeholder perspectives and interests. For one RA, learning about these qualities was somewhat new for him, as he had never had to consider these aspects before in his primary role as a modeller. A particularly important piece of knowledge he gained was the extent to which the clients really wanted to be able to see that the data or information they had supplied to the developers had actually made its way into the model. In contrast, a number of consortium members indicated they learned relatively little in this regard, as much of this information was already known to them from previous experience, or because they felt the various actor interests were largely similar.

Technical learning about the groundwater system and how to model it occurred as a direct result of knowledge sharing between both experts and clients. As two consortium members noted, every party had their own particular knowledge about their certain field or area. Through collaboration, this knowledge was shared and everyone could learn and benefit from its inclusion in the model. Local knowledge was also shared and applied in other locations. Stakeholders recognised they were able to gain a deeper appreciation for their place in the larger groundwater system, and how this system impacted and interacted with their more localised systems. Additionally, the collaborative development process was viewed as having illuminated and highlighted to all the areas of the AZURE region about which little knowledge existed, and where further investment would be required.

Finally, in terms of organisation and process management, several stakeholders indicated that they had also learned much from how the Consortium Modelling processes had been organised and structured. In particular, one client pointed to gaining an explicit appreciation for the inclusion of both the RA and the process manager within the consortium, and also for the structuring of the consortium into sub-groups. These are all experiences and knowledge that he appreciated being able to take with him to apply in future collaborative projects. Similarly, a RA indicated that he felt that the client stakeholders gained increased awareness with regards to the effort involved in building a complex groundwater model and the problems that can emerge as a result. Somewhat related to this last point (albeit negatively), one client indicated that he had learned that, for modelling projects of this size, stakeholders should satisfy themselves with smaller, more achievable goals, as mistakes will inevitably be made and expectations can remain unmet.

7.3 Degree of Consensus

The clearest indication that the Consortium Modelling approach was successful in achieving consensus was the development AZURE model, unanimously accepted by the various stakeholders. As one provincial representative explicitly indicated, the most valuable outcome to come out of the process was the consensus it yielded, particularly between the provinces and the DWC. Simply put, there is now a single model to which stakeholders can use and encourage to others to use. Also, despite some recognition that the final model version may not have been 'perfect', stakeholders still viewed the process as having been extremely useful in generating a technical consensus. The countless productive hydrological discussions conducted at both regional and sub-regional scales were seen to have directly contributed to establishing a common understanding with respect to the model.

A related characteristic that also contributed to building stakeholder consensus was the manner in which decisions were made during the project. Stakeholders recounted appreciating that all model development decisions were taken collectively and only after unanimous positions had been negotiated and reached by all parties. No single party felt another could exert overriding decision-making powers. One stakeholder even suggested the decision-making process were analogous to '*polderen*' (a Dutch colloquialism), referring to a process where different parties continue to discuss an issue until everyone has been heard and a consensus reached.[12] The fact that client stakeholders felt equally empowered to make all major project decisions was viewed as a critical factor in building their support and acceptance for the final model.

7.4 Level of Cooperation

Naturally, it is difficult to achieve consensus without effective cooperation. It should therefore be unsurprising that stakeholders generally indicated they had little difficulty in cooperating effectively together. The general assessment was that stakeholders were all very willing to get involved and put effort into the development of the model. One client found this particularly impressive, especially given the fact that the project required more time and effort than the participants had initially thought. Modellers appreciated that clients were ready to contribute their best available data they had access to, and were prepared to approach the modelling of their own areas differently to ensure no negative interferences on neighbouring areas. That is, although there were competing interests within the consortium, these did not play out in the sense that each party was trying to advance their own interests over those of others. Rather, when it came to determining which areas of the model would receive special or additional attention, client actors were all able to effectively negotiate and target those areas that would benefit the model as a whole.

It is also generally held by all actors that relationships between consortium members have been enhanced as a result of the development process. Although the client organisations were already used to collaborating and working with each other, many indicated that they nevertheless felt these relationships had been strengthened and communication enhanced. As one stakeholder remarked,

> "Parties were able to gain a better understanding of each other's perspectives and interests as a result of the process. Consequently, there now exists a much better platform to discuss and share experiences. There are also now much closer working relationships between the parties that have developed via regular meetings and formed friendships. There is openness now that perhaps was not there before. Workshop discussions now progress in such a way that discussions are much freer; and ideas are being put forward that otherwise would not have been."

The process manager also noted that both the modelling team and RAs appeared to appreciate the opportunity to work together in the open environment with other top Dutch geohydrologists. He also felt that Deltares very much enjoyed the interaction with the RAs. This could provide valuable external feedback with regards to its working methods and how it approached modelling projects, as well as prompting it to think more about user perspectives. One RA expressed his similar satisfaction with having had the opportunity to gain insight into

[12] Fortunately – as another stakeholder remarked – the process manager was present during these discussions to ensure that decisions were taken in a timely fashion, and that discussions did not continue endlessly! This had apparently been an issue in other groundwater modelling consortia.

Deltares' working processes and its pursuit of innovation, and of working together with talented modellers from other organisations.

However, several consortium members also indicated that the level of cooperation and goodwill was not constant throughout the process. They recounted that there was quite a lot of enthusiasm for building the model together at the beginning of the project, with everyone keen to discuss the various modelling techniques to try and the like. The inability of the project to maintain its schedule meant that cooperation became less effective as frustrations between the clients and the modellers emerged (outlined further below). Similarly, as the end of the project approached and budget constraints came to bear, the collegial atmosphere was viewed as having diminished somewhat and discussions transitioned more towards what was or was not included in project contracts.

7.5 Conflict Mitigation/Exacerbation

As noted previously, the AZURE development process was not characterised by high levels of pre-existing conflict between the various stakeholders involved. This in part explains why no stakeholders suggested that conflict had been reduced as a result of the process; it was not the purpose of the approach. However, that is not to say that disagreements did not occur regarding the model, nor tensions increase at any stage during the development process. Principal amongst these were those that emerged between Deltares and the clients as project delays were incurred and the delivered results did not meet with expectations. Several clients indicated that their trust in Deltares was weakened as a result of interim model results that were delivered with too little time to allow for checking and that contained errors. Some reported instances when large numbers of results would be delivered the day before the consortium was to meet to discuss their validity. Others referred to instances where the results that had been delivered were recalled as the modelling team had discovered errors; only then to have the replacement results recalled again as even further errors were encountered. There was a perception within the client group that Deltares had perhaps tried to achieve too much for the money that was available, and had not put in place the necessary organisational and quality controls to always ensure the delivery of a high quality product. There was also perception that Deltares spent too little time on data analysis and relied too much on the regional groups to provide this. Given the considerable geohydrological expertise contained within the research institute, one stakeholder felt this was a missed opportunity and contributed to frustrations within the group. A final source of dissatisfaction and tension occurred as it became increasingly evident that the local-scale performance of the model would not meet with the expectations of some clients (as discussed previously).

On the other hand, other client members had more circumspect attitudes towards the proceedings, recognising that there is always a tension that exists between receiving deliverables on time and with sufficient technical depth. Following this line of reasoning, they argued tensions were simply the result of misunderstandings or misplaced expectations of one sort or another. Indeed, the modelling team leader felt that often these expectations had somehow extended beyond what had been initially proposed and included for under the contract. Similarly, other modelling experts suggested that some client expectations regarding what constituted the reasonable validation of results were unrealistic. One expressed that he sometimes felt that clients thought that every single input and output should have been checked and rechecked, without realising the additional time and money that this would have involved. Likewise, another was keen to point out,

> "Modelling is such a difficult job, and often this is not understood by non-modellers. It is a challenge to communicate how difficult the task is, how easy it is to make mistakes, [and] how difficult it is then to find these mistakes."

Significantly, several stakeholders expressed the sentiment that any tensions that emerged were not necessarily a bad thing, but rather simply a necessary part of the discussion process to clarify the situation and reach a decision. They were also keen to stress that the inclusion of both the process manager and RA also ensured that any tensions were kept firmly under control and never escalated into anything more serious. On those occasions where client frustrations regarding unmet expectations came to a head – for example during Go/No-Go meetings – the process manager was always there to intervene and remind stakeholders about what had or had not actually been agreed to the contract and any previous meetings. In this way, stakeholder expectations could be realigned, and any tensions somewhat curtailed. Similarly, the RA viewed themselves as being able to provide clients with an expert modeller's perspective on what their demands would mean in terms of time and investment. This was seen to enhance levels of understanding between the two groups, and one RA suggested that these had improved considerably by project's end.

This notwithstanding, one stakeholder suggested that he did not consider the consortium a synergetic whole by the end of the project. Development processes had led to a degree of tension emerging, and several relationships had suffered as a result. Relationships came to be characterised more by their 'pragmatism', and there was broad recognition that the consortium simply needed to close the initial development chapter and move on.

7.6 Model Credibility

In general, all client stakeholders agreed that the model is reasonably trustworthy and accurate, and they were committed to using it in their future groundwater management projects. One client went so far as to state that AZURE is "likely the best of the regional models that have been developed to date." Similarly, external model users indicated that they too trusted the model completely, largely due to the involvement of Deltares as well as the relevant Dutch WRM agencies in its development.

However, there are a number of model deficiencies that impact on stakeholder perceptions of its credibility in certain application contexts. The most frequently mentioned of these was, of course, the reduced performance of the model at local scales. RWS, the provinces and the DWC viewed the current version of AZURE as being of most use to them, since they operate and wish to examine impacts at the larger scales at which the model performs satisfactorily. The water boards most frequently need the model to operate at more detailed scales. However, despite several stakeholders indicating that the water boards would be the least satisfied with model performance, the interviewed water board representative expressed his general satisfaction. He simply explained that the reduced local scale performance met with his expectations and would now form the focus of the next phase of model development. Other discrediting deficiencies specifically mentioned by stakeholders included the persistence of errors in the model, its inability to examine groundwater-surface water processes and interactions sufficiently, and its lack of saltwater-freshwater interface modelling capabilities. Nevertheless, stakeholders recognised that these features can all be rectified or developed and included in later versions of the model.

The existence of other pre-existing groundwater models naturally poses somewhat of a threat to the uptake of AZURE. A few clients indicated that they would continue using other models for certain problems. In one instance this related to the fact that it was felt that some other models performed better in particular geographic areas (e.g. in modelling anisotropy in the Veluwe), whilst for others the reasons for using other models were to address questions that AZURE could not yet answer (such as those related to the latter two deficiencies mentioned above).

From the perspective of the expert modellers, all were at pains to point out the model was not one hundred per cent accurate at all scales and at all locations, but also that the first version was not ever meant to be. That is, they viewed the current model as providing a credible basis for most groundwater questions, but not every question. Otherwise, one RA indicated that he is less willing to use the model within the iMOD interface due to his dislike for the software's poor scenario and workflow management capabilities when changing parameters. Unless clients were to specify the use of iMOD, he outlined that he preferred to import AZURE into an alternative MODFLOW interface to undertake any refinements or analysis activities.

7.7 Model Transparency

The high technical degree to which consortium stakeholders were all able to discuss the developed model provided the clearest indication of their sound understanding of AZURE and how it works. All agreed they understood the basic principles, concepts and schematisations lying behind the model's run files, and generally knew which data had been included and which had been omitted. They also understood the limitations of the model and knew that it would require further investment and development on their part for certain questions, particularly at local scales. That being said, one non-expert modeller indicated that with approximately 23 parameters (all of which can be changed), he found the model too complicated. He often found it difficult to determine which parameter most significantly affected results. Similarly, another client indicated that the calibration techniques employed remain a 'black box' to many in the consortium.

Given the established technical knowledge of all within the consortium, it is to be expected that this group would have a sound knowledge regarding the model's make-up and functions. Thus, when discussing model transparency, one should theoretically compare the consortium against a higher degree of understanding than for less technically minded groups. In this regard, AZURE is perhaps not as transparent as it could be. Even amongst its modelling experts, there was some frustration that one could not easily determine which specific data had been used or edited within the model. Likewise, a consistent modelling data system was not set up for all model components and parameters, which similarly reduced transparency. As one RA commented,

> "…it is not very clear as to how many parts of the model have been constructed and are connected to the raw input data sets. It is disappointing that this has not been done right, and really constitutes a missed opportunity; particularly given the fact that it was something the regional advisors had emphasised as being important to make the model more user-friendly."

Similarly, clients expressed concerns that it was at times difficult to track and discern what had been included or excluded; or whether improvements from earlier interim versions were included in the latest version or had otherwise been forgotten. These are certainly all aspects of the modelling process that could benefit from additional attention in future Consortium Modelling projects.

7.8 Influence, Control and Ownership

All client stakeholders expressed opinions that they had been able to exert a satisfactory degree of influence and control during the model development process. Most clients felt that each party's interests were represented, as all shared decision-making powers and all equally shared the financial costs of the model. Although only one client explicitly mentioned feeling a degree of ownership over the model, one might assume that other clients did not make mention of this due to their actual financial ownership of the model. Again, the central role the process manager was able to play in supporting these outcomes was frequently recognised.

That being said, a few stakeholders suggested that the influence of RWS and the DWC might have been a little stronger than for other clients. This is somewhat supported by the fact that the model works at larger regional scales than it does at more local scales, and that it is consistent with the national-scale models. But it could also be a reflection of the technical challenges of modelling some areas, as was suggested by one modeller.

Despite adequate influence, a number of stakeholders also indicated that potential restrictions nevertheless existed to the level of control stakeholders could respectively exert during the development process. The process manager assessed that at times certain individuals were perhaps more prominent in discussions than others, and that many discussions ended up taking place between only a few people. Naturally, this could have resulted in slightly biased outcomes. Similarly, a client remarked that he found it took much more effort to exert influence over the development process in the multi-client context rather than in a single-client context. This meant that he found he did not always make sufficient effort to influence outcomes, again leading to bias. A final perceived source of restriction was the relative influence of Deltares. One client pointed to certain misgivings he had related to the attention given to promoting Deltares' preferences for the conceptual modelling framework, rather than listening to and accepting how the end-users saw it conceptually.

> "At times it became confusing as to whether the modelling effort was following the will of the funding parties or Deltares…control went a little too far in Deltares' direction."

Somewhat related to this, the difficulty clients had in being able to track whether Deltares had implemented those decisions taken during the group workshops and regional meetings also meant that they felt their control and oversight was impeded to a certain extent. Stakeholders viewed these as both being important areas of technical process management that could be improved upon in future modelling exercises.

In relation to the relatively limited influence that external stakeholders were able to exert over the model development process, the perspectives of the only external stakeholder interviewed suggest that it was little concerned in becoming involved during these early modelling activities. This stakeholder explicitly stated that it felt the most appropriate parties were involved in the consortium and that it would not have wished for its representatives or any others to be involved in model development activities.

7.9 Existence of other Limiting Conditions

With regard to any other conditions that limited the effectiveness of the consortium approach, these did exist, but did not necessarily conform to those that were earlier identified in the literature. Given the skills, knowledge and background of the consortium members, insufficient participant technical knowledge was never really a factor during model development activities. Likewise, 'action mismatch' was not a factor, as the organisations involved all have legislated responsibilities for groundwater management, and also because the Consortium Modelling activities largely took place within the innermost 'Circle of Influence' (i.e. Circle A). Some expert resistance to ceding modelling control was perceived by one stakeholder (as indicated above), and the time and cost requirements were by and large taken as given, and had been agreed to by the parties prior to project commencement. There was broad recognition within the consortium that building consensus takes time. Similarly, any time extensions, additional work packages and their associated cost variances were collectively agreed to whenever required. Thus, the stakeholders remained in control of the process, even as it fell behind schedule. That being said, one client did express doubt as to whether or not the AZURE process had delivered value for money, and suggested that he believed a similar result could have been obtained for fewer costs.

Two other aspects of the AZURE implementation had more far-reaching effects. The first of these relates to quality and technical process management within Deltares. All stakeholders, including those in modelling team, recognised that these areas were possibly the major weaknesses during the approach. As the Deltares team leader admitted, "things that Deltares should have done well were not done well." Individual model components were not built according to a coherent structure and utilised different software versions. When it came time to stitching these components together in AZURE, the model would crash for reasons of inter-component incompatibility or other such details. Other errors also found their way into the model, and were not picked up systematically by a rigorous quality screening process. Thus, faulty results were issued to the clients and the regional groups. Similarly, several clients indicated that they felt Deltares spent too much time focussing on seeking technical innovations (e.g. in terms of new data screening and organisation ICT processes, new modelling techniques, etc.) rather than on assessing model outputs and delivering a working model according to the allocated budget and time. The ultimate consequences of Deltares' poor quality and technical management were modelling delays and the untimely delivery of (erroneous) interim results, which of course delayed the project as a whole and generated considerable frustration. Several stakeholders commented on the fact these deficiencies directly led to a loss of confidence and trust in Deltares' abilities as a model services provider.

That being said, the above issues were recognised and openly discussed during the course of the project. Also, measures were put in place to try and combat them. The process manager's role was expanded, and he took a greater role in the direct project management of the modelling team. Deltares introduced the 'HydroConnect' model management tool, an internal device designed to maintain quality standards. Specifically, this is meant to ensure every modeller models in a consistent fashion; track model updates and provide version control; and document the workflow for each modelling component and parameter to improve model transparency (de Lange, 2014). However, as indicated by one RA, the system was only introduced during AZURE, and a complete workflow was only documented for a single model parameter (top layer resistance). Implementing the system was a time-intensive exercise, and no budget had been allocated to do this for the other parameters. Consequently, many quality and transparency issues were seen to remain with the current AZURE version.

A second key aspect that was seen to constrain the ability of the approach in meeting its outcomes was the contractual relationships between Deltares and the RAs. As indicated in Chapter 5, the RAs were sub-contracted to Deltares and not directly contracted by the clients (as in the case of the process manager). Their payment depended on Deltares, whilst their role demanding they act in the best interests of their clients necessarily resulted in finding fault with Deltares' work. Thus, there was a small organisational contradiction in the consortium. Additionally, the contractual relationships created tension between what the RAs were being asked to do by clients – or felt they should do for their clients to ensure quality – and what they would be paid to do by Deltares. One modeller remarked that on a number of occasions, it emerged that RA had completed work for clients that fell outside of the scope of what had been agreed with Deltares. However, this is again an issue that has already been recognised by the parties involved. It is intended that in all future Consortium Modelling projects RAs will no longer be subcontracted to Deltares, but will be contracted by the client parties directly. This has been a key learning experience that has come out of the AZURE process, and was not something any stakeholders had anticipated when the original contractual relationships were established.

8 Key Successes and Potential Improvements

As is hopefully evident from the preceding chapter, the Consortium Modelling approach employed in the AZURE project was by and large successful in meeting both the specific outcomes of the project and achieving many additional beneficial collaborative outcomes. Consortium modelling delivered to clients a groundwater model that all stakeholders accepted and generally regarded as being fit for purpose. Of course, further improvements to the model can still be made, and all clients are committed to continuing this work during the next phase of model use and refinement. Levels of cooperation during the approach were both high and constructive, and the process only ever proceeded according to the consensus of all parties. Most clients expressed a general satisfaction for the high levels of participation, and in particular for the ability it gave them to effectively influence the direction of the developed model. Furthermore, collaborative learning did appear to take place, and may be credited for improving future collaboration between the various parties.

Principal among the reasons for the approach's success were the introduction of both the process manager and RA into the consortium structure. Every stakeholder expressed a high degree of satisfaction for their inclusion within the Consortium Modelling approach. The process manager was able to effectively guide and manage the involvement of all the stakeholders, ensuring that negotiated consensus positions were reached, and diffusing any conflict. He ensured that clients felt their concerns were being heard and their interests taken into account. His independency was also critical in his being able to fulfil this role. As one client remarked, this independency resulted in more formal relationships between all the parties to the consortium, and ensured there was never a perception he was preferencing the interests of any party over another. If the process manager had been drawn from either the modelling team or a particular client, then this would have been much harder to achieve. Equally, the RA could empower the clients with additional knowledge, helping them understand the more complicated aspects of the model construction process and equipping them to engage with the modelling team on a more equal footing. Likewise, the considerable effort that these individuals invested in checking all model inputs and outputs was one of the key reasons for the quality of the model reaching the standard it did.

Given these successes, it is fairly simple to draw the conclusion that both the process manager and RA should remain as key features of the Consortium Modelling approach. This is not to suggest that there should be no aspects to their involvement that should change. As indicated in the preceding chapter, the contractual relationships between the RA and Deltares need to be revised, with the RA to be directly engaged by the client group in the future. However, putting the successes of these key process innovations aside, there are also a number of other aspects to the approach that could also be modified.

8.1 Ensure Sound Technical Process Management

As indicated in the previous chapter, at times stakeholders in the consortium questioned whether Deltares was able to maintain its focus on delivering a working model according to the defined programme and budget. Instead, they felt that it would often focus more on the technical content of the model, looking for new modelling innovations and exploring new modelling techniques. This is not to say that there is no place for innovation within the Consortium Modelling approach. Rather it is only to suggest that additional attention needed to be placed on technical process management within the modelling team. To this end, a suggestion of one stakeholder was that future model development projects could consider engaging a specific project manager focussed on the technical model construction process. This could be as simple as having a non-expert modeller from within Deltares manage the modelling team's activities. Alternatively – and as eventually occurred in AZURE – it could involve increasing the responsibilities of the independent process manager to include the management of these aspects. However, the author recognises that this may not be a realistic option in many instances, as it would involve considerable devolution of power and responsibility from Deltares to an external organisation, which may present too great a concession.

Improving the technical process management in whichever way would hopefully yield significant benefits in terms of reduced frustration for consortium parties and improved project delivery. Similarly, it may also help to improve the influence of client stakeholders even further. It is interesting to note that in the original Dutch groundwater modelling consortium, MIPWA, an individual within the Deltares-equivalent expert organisation (i.e. TNO) did fulfil this role. A policy specialist, he essentially provided the TNO project leader (a modelling expert) with the necessary advice and support to both manage and conduct all stakeholder participation processes, whilst also ensuring that the technical process management was effectively controlled and deliverables submitted as per the predetermined schedule (Duijn, 2014). Given the MIPWA development was widely hailed as a success – so much so that it spawned the subsequent consortia emerging – the value of a non-expert modeller guiding the processes from within the expert organisation is self-evident.

8.2 Implement Sound Quality Management Processes

Related to the above, and as has been earlier referred to, improved internal quality management and control procedures need to be implemented within Deltares. Nothing erodes confidence, enthusiasm and trust more than the delivery of error-ridden results to clients expecting the highest quality outputs. Naturally the current move towards implementing HydroConnect in Deltares' modelling projects is a welcome development that will hopefully address the quality issues discussed earlier in this case study. However, what is important is that to be truly effective, such a system must be implemented across an entire model, and not just simply for piecemeal sections. Naturally this will increase model development costs, but its implementation should be one that is promoted to clients, budgeted for, and implemented as a matter of course. Such a quality management protocol is fundamental in increasing both model transparency and credibility, not to mention reducing a significant source of frustration and conflict.

8.3 Consider Reinstating Alternative Information Delivery Mechanisms

Having now dealt with those improvements specifically addressing the key limitations of the AZURE process, the author would like to consider two aspects related to the delivery of information within the Consortium Modelling approach. Neither of these aspects was identified by any of the AZURE stakeholders as being potential areas for improvement; however, they relate more to a consideration of the approach against both the findings of the analytical framework and the original MIPWA process. The two aspects include making validation and verification more interactive for stakeholders, and reintroducing certain capabilities back into iMOD to enable more interactive use of the model with stakeholders.

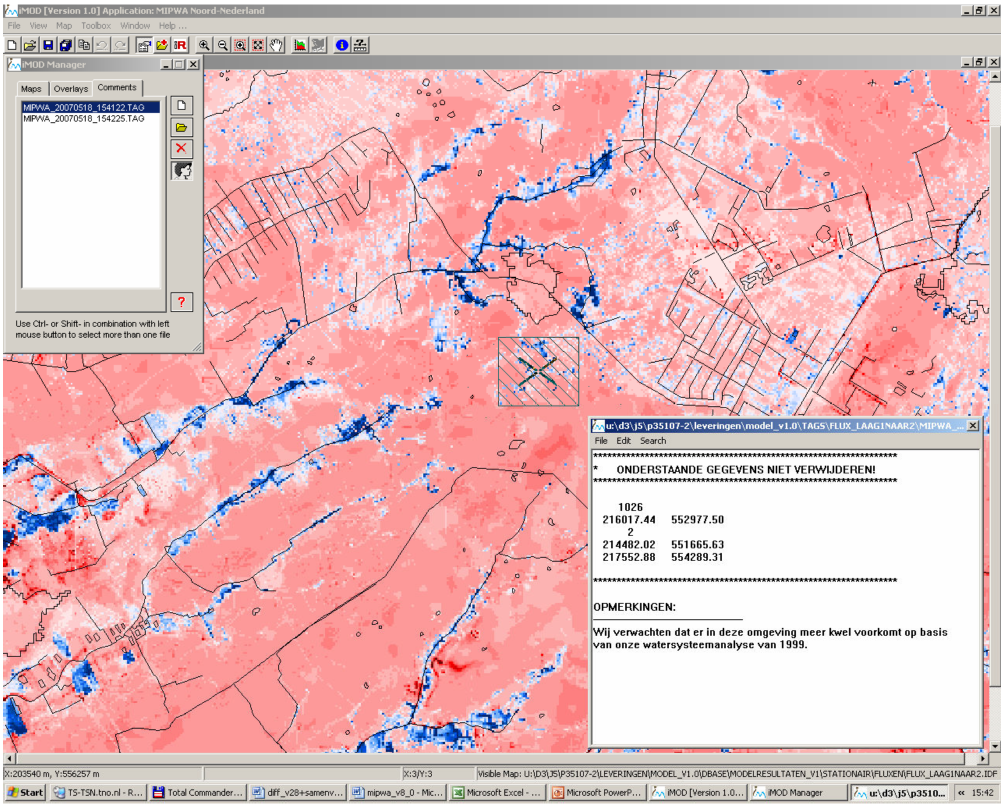

Figure 14: Example of digital commenting functionality in iMOD (TNO, 2007)

8.3.1 Make Validation and Verification Activities more Interactive

In AZURE, model data and results validation and verification activities largely took place within the regional groups. Deltares issued the results to these groups before their members (and in particular the RA) would check these carefully. However, the presentation of these results remained firmly within the control of Deltares. In contrast, during the MIPWA project, use was made of a currently dormant iMOD feature, that of its ability to function as an online communication tool (Deltares, 2014). When running a version of the model remotely off the TNO server, stakeholders were able to explore the complete model and any interim results they wished independently. It was not left up to Deltares to determine which results were most relevant for stakeholders to consider, or which of iMOD's visualisation capabilities to use to view these. Not only could stakeholders individually control which results they wished to examine, but they could also leave digital comments on these inputs (Figure 14). These notes would then reside on the server for the modelling team to review. As such, they provided an effective avenue for stakeholders to more closely interact with the modelling team and vice versa (Berendrecht et al., 2010).

Promoting and reinstating this feature within iMOD would not only further increase client control over the Consortium Modelling process, but also potentially speed up review processes. Instead of following a trail of paper results and reviews, comments could be directly inserted within the model and immediately addressed by the modelling team. Similarly, it is an activity that could be carried out both independently by individual stakeholders (providing they could sufficiently navigate the iMOD interface) or in regional or consortium group settings with the RA 'driving' the model. In the latter cases, the results could be projected onto a screen, and the stakeholders could then collectively discuss these, commenting on them as they went. Furthermore, as was noted by a Deltares modelling expert, this feature could come to play an important role within quality management procedures such as HydroConnect (Hoogewoud, 2014). The comments included within the model could be logged and tracked by both Deltares and other stakeholders alike, assisting each to ensure that every comment was dealt with satisfactorily.

8.3.2 Reintroducing iMOD Capabilities to Facilitate Use of the Model in Interactive Settings

The manner in which AZURE is applied to projects is generally expected to follow a very traditional trajectory. Modelling experts will use the model to generate and analyse results to specific questions, before writing up advisory reports of these findings to be provided to key project stakeholders for their deliberation. However, in former times, the iMOD software package was designed to more explicitly provide participatory policy-level support via the inclusion of an impulse-response (IR) database. Given the otherwise lengthy time taken to complete conventional model runs, the IR database was developed to introduce rapid assessment functionality to iMOD models. Much like the *Blokkendoos* to be presented in the next chapter, the basic idea behind the IR database was that a number of predefined groundwater interventions were calculated *a priori* for every model cell, with these calculated effects all stored in a database (Berendrecht et al., 2010). These (originally 27) interventions ranged from *inter alia* changing the water levels in any surface water bodies by a range of predefined amounts, to decoupling urban areas, shifting extraction or even shifting cities (TNO, 2007). Interventions carried out over multi-cellular scales would then have these effects simply superimposed within the affected grid cells. During policy assessment, the IR database could then facilitate an initial rapid analysis and assessment of the effects of many alternatives and scenarios quickly and easily (Berendrecht et al., 2010). Since it was rapid (i.e. simulation times in the order of seconds), policy assessments could take place in interactive settings with stakeholders. Again, the model could be projected onto a screen and the various scenarios, and policy interventions given an initial collaborative assessment.

Despite being incorporated into the original MIPWA model and having conducted a practical workshop with MIPWA stakeholders to promote this functionality, the IR database seemingly received little follow-up and was eventually dropped in later model versions. It appears that there was little demand for this feature from MIPWA consortium stakeholders. This may have also been a function of the fact that relevant policy processes did not present themselves after the model was developed; and by the time they did, stakeholders may have already forgotten about the feature. Or it may simply have been the result of the fact that all groundwater modelling work was typically left to experts who were less inclined to become involved in participatory stakeholder processes and preferred to model independently.

Regardless of the reason for its demise, reinstating to consortium models functionality similar to the IR database remains a valid objective for stakeholder planning processes in groundwater management. Having stakeholders be given the opportunity to further deepen their collaboration by using the model in interactive workshops would likely engender additional collaborative benefits. Most significantly, it could increase the participation and access to the model for those stakeholders not engaged in these modelling consortia; that is, for Circle B (or perhaps even Circle C) stakeholders.

8.4 Concluding Remarks on this Case Study

As one hopes is evident from these four chapters, Consortium Modelling is a valid CM approach to apply in the development of groundwater models where the scientific knowledge base is uncertain. It relies upon the highest levels of participation (co-decision-making) and cooperation between its participating stakeholders, both of which render it truly collaborative. Although demanding intensive involvement throughout all model development activities, the Consortium Modelling approach demonstrates that stakeholders are prepared to invest the required amount of effort in order to achieve project objectives. This is most likely due to the fact the principal stakeholders are also its financing clients, and as such have a very real interest in ensuring the development process achieves its aims. But it could also be due to the common technical background the consortium members shared, along with the fact that the subject matter constituted a familiar area of expertise. Notwithstanding these aspects, it can be concluded that the organisational structures behind the Consortium Modelling approach were essentially sound. The inclusion of the process manager and RA in the consortium, along with the division of the consortium into various regional and other sub-groups have all been beneficial and valued additions to the approach. Locally specific knowledge and expertise has been incorporated and client stakeholders have been able to exert a generally high degree of influence and control over the development process through robust technical and decision-making procedures. This has meant that consensus has been achieved, the model is viewed as largely credible, and its transparency has to a certain extent been enhanced.

However, we can also recognise within the AZURE experience the propensity for CM exercises to run awry. Poor quality and technical process management led to increased conflict within the consortium, and impacted on the abilities of all parties to cooperate effectively. Model credibility suffered, as did the trust client organisations had placed in Deltares, and at times clients felt to some extent they were losing their control over the process. Similarly, the somewhat contradictory contractual arrangements between Deltares and the RA at times impacted on the abilities of the latter to effectively perform their functions; also heightening tensions within the group. Yet none of these issues truly impacts on the efficacy of the Consortium Modelling approach in and of itself. Rather, they are ancillary aspects to the approach to which water managers need to pay particular attention when implementing it to ensure that it can meet its objectives to the highest possible degree.

This is not to say that the approach cannot be further improved or enhanced. It was noted at the beginning of this chapter that the author felt it was inappropriate to refer to the Consortium Modelling approach as being ‘interactive’. Indeed, reinstating those interactive elements of the original approach to enhance model validation and verification activities and enable the collaborative use of the model in interactive stakeholder settings offer two potential approach improvements. By making use of the nascent digital commenting feature in iMOD, validation and verification activities perhaps could be made more efficient, process and quality management improved, and it would be likely that transparency outcomes would also benefit. Likewise, reinstating an analogous feature to the former IR database within these consortia models would return the approach into the domain of model use and not just of model development. It could help improve stakeholder access to these instruments, and perhaps facilitate their collaborative use with external stakeholders. Any learning outcomes would then be more widely shared, and improved policy and management strategies developed. That being said, both these improvements would only be further enhancing an already strong collaborative approach.

Case Study 2

Developing and Using the* Blokkendoos *Using a Model-Supported Collaborative Planning Approach During the Delta Programme Rivers

9 Introducing the Delta Programme Rivers and the *Blokkendoos*

9.1 Introduction to the Case Study

The Netherlands is a low-lying country, vulnerable to flooding. Indeed, Flood Risk Management (FRM) has become somewhat entwined with the national identity, and its comprehensive network of dykes, dunes and storm surge barriers form an integral part of the Dutch landscape. For centuries, Dutch riverine FRM consisted of simply strengthening and raising the level of dykes located along its rivers. After every dyke breach disaster, the dyke system was simply repaired, raised and reinforced. However, Dutch attitudes towards FRM have evolved over the last two decades. The traditional approach has come to be replaced with a preference for spatial solutions that give more 'room' back to the rivers. This was a response to the realisation that its rivers had become increasingly clamped between higher and higher dykes, and that any future breaches might be more likely to result in catastrophic disaster. Providing 'room for the river' was recognised as a means to be able to reduce the need to continually keep raising and reinforcing the dykes, by allowing for the accommodation of larger flood waves within a given dyke height.

Like other areas of WRM, FRM has long relied on models to assist in the planning and design of infrastructure needs. For example, in recent decades hydrodynamic flow modelling has been frequently used to model river behaviour under statistically determined design peak weather events. In doing so, peak water levels and hence, design dyke levels have been determined according to the necessary safety standards. With the shift towards a preference for spatial 'room for the river' measures, the task in planning FRM infrastructure has taken on an added degree of complexity. No longer is it simply a case of approaching increasing peak flows in a highly structured, engineering fashion – running the models and raising the dykes where needed. Rather, many more options now need to be modelled and considered, and their comparative water level reducing effects assessed in combination with the competing social, environmental, economic or political impacts associated with each option. To assist in these newer tasks, additional model types have also since been developed, an example of which is the Dutch *Blokkendoos* (Planning Kit).

The latest Dutch FRM planning assignment to confront the above issues has been the Delta Programme Rivers (Dutch: *Deltaprogramma Rivieren*, DPR). Given the increased spatial planning dimension to the infrastructure planning problem – with the multitude of differing views and opinions such spatial planning inevitably entails – stakeholder involvement was considered an essential component to the programme. Thus, a Model-Supported Collaborative Planning approach was adopted. This functioned on a number of levels and considered a wide range competing interests from so-called '4B' stakeholders: citizens and interest groups, businesses, officials, and decision-makers (Dutch: *burgers/belangenorganisaties, bedrijven, beambten en bestuurders*). The approach sought to combine more collaborative planning activities for its higher-level institutional stakeholders with more participatory activities for others situated at lower levels. Moreover, modelling activities within the approach served a supporting function to the broader collaborative planning processes. That is, although modelling was an important element to the approach, it was not its only input. The development and use of the *DPR Blokkendoos* simply served to provide stakeholders with the necessary technical information to inform broader planning discussions regarding the infrastructure options under consideration for the proposed FRM strategy. The approach is an example of a FABE form of CM, although it must be recognised that stakeholders played a relatively minimal role in the development of the model, aside from their important involvement in developing the specific measures to be included within it. Rather, CM and planning efforts in the approach were much more focussed on the 'back-end' activities of strategy formulation and evaluation. This chapter analyses the implementation of the Model-Supported Collaborative Planning approach in the DPR's Waal-Merwedes region in great detail, in order to help illuminate its key elements, features, benefits and limitations.

The case study is structured in a similar manner to the previous one. This chapter outlines the necessary contextual and background details regarding the DPR, including the problems needing to be addressed, the key stakeholders involved, the specific objectives of employing a CM approach and the modelling tool utilised. The second chapter (Chapter 10) then turns to a consideration and analysis of the Model-Supported Collaborative Planning approach used in the case study, including its organisational structure of participation; the collaborative processes employed; the use of the model during the approach; the necessary skills and knowledge requirements for those involved; and the time and financial resources consumed in delivering its outcomes. The third chapter (Chapter 11) presents key stakeholder perspectives on the ability of the approach to deliver or limit its potential benefits. The final chapter (Chapter 12) concludes with a consideration of the key successes of the approach in combination with author recommendations for potential improvements that could be made to enhance it.

9.2 Background and Context

9.2.1 Delta Programme

Launched in 2010, the Delta Programme (DP) is a collaborative national planning programme in which the overarching objectives are "to protect the Netherlands from flooding and to secure a sufficient supply of freshwater for the generations ahead" (DP, 2014). Led by a national Delta Commissioner (DC), the DP asks the central government, provinces, municipal councils and water boards to cooperate and work together, whilst both social organisations and the business community also have opportunities to provide input. The programme is specifically focussed towards anticipating and dealing with the challenges relating to climate change such as increased rainfall, rising sea levels and higher temperatures. In particular, the programme concentrates its attention on the following three aspects (DC, 2015b):

- Developing new risk-based flood protection standards
- Rendering more predictable the availability of freshwater for agriculture, industry and nature, and
- Making spatial planning more climate-proof and water-robust.

A specific emphasis of the DP is on adaptive delta management. The DP seeks to ensure the Netherlands is prepared for various future scenarios to problems that, in part, occur in the long term (up until 2100) (DP, 2012). By looking into the future and examining the potential issues the Netherlands may face during this time, its intention is to aid the Dutch government to better plan for and take appropriate and affordable mitigation at appropriate times (DC, 2015a). An important element of this task is to permit the flexibility to respond to any new circumstances, opportunities and insights that may emerge in the interim. Herein lies the 'adaptability' of the approach. Ensuring that any potential responses remain flexible to future changes is intended to help avoid 'lock-in', a phenomenon whereby only a single strategy can be followed as a result of prior actions. Instead, multiple strategies (or adaptation pathways[13]) are considered and can be modified as the situation changes or new information comes to hand. In the short term, only 'no

[13] For additional information on adaptation pathways, refer Haasnoot (2013)

regrets' measures should be taken; that is, those that are worthwhile in every long-term scenario (DP, 2012). Another intention of adaptive delta management is to enable investments in FRM and freshwater supply measures to more easily integrate with other investments; for example, with those related to spatial planning and the natural environment (DP, 2012).

The DP was divided into nine sub-programmes in order to provide focus and aid delivery. The DPR was one such sub-programme. It focussed its attention most on establishing a strategy for the current and future infrastructure requirements for Dutch riverine areas, to ensure their long-term safety and protection from flooding. As such, its areas of focus were those parts of the Netherlands adjacent to the Dutch sections of the Rhine and Meuse deltas. As these riverine areas still constitute a relatively large proportion of the Netherlands, the DPR was further sub-divided into a further six regions, organised according the major Dutch river branches and (where possible) provincial boundaries (Figure 15):

- Meuse Valley (Limburg Province)
- Dyked Meuse (North Brabant Province)
- Waal-Merwedes (Gelderland Province)
- Lower Rhine-Lek (Utrecht/ South Holland Provinces)
- IJssel Valley South (Gelderland Province)
- IJssel Valley North (Overijssel Province)

Each DPR region came under the leadership of a different province (indicated by the first named province in the above list) responsible for the specific collaborative processes adopted in their respective regions. Each so-called 'regional process' in the DPR was therefore conducted in a slightly different manner. In the Waal-Merwedes region, officials at Gelderland Province coordinated these processes.

9.2.2 Waal-Merwedes Region

The DPR's Waal-Merwedes region covers a major branch of the river Rhine from the Dutch border with Germany to Hollands Diep in the west (Figure 18). For a large proportion of this area, the DPR regional process was the third in a line of recent stakeholder-based water safety planning processes to be implemented. Preceding it had been the original national Key Planning Decision – Room for the River (Dutch: *Planologische kernbeslissing – Ruimte voor de Rivieren*; or PKB) programme in the early 2000s and the still-running provincial *WaalWeelde* (Wealthy Waal) programme launched in 2006. A consequence of this close succession of planning programmes is that several representatives from key DPR stakeholders have participated in all three of these programmes, and several were even participating concurrently in both the DPR and *WaalWeelde*. More importantly for the present study, some *WaalWeelde* outputs were used to directly inform the DPR process in the Waal-Merwedes region. So the two programmes were somewhat linked, and any consideration of DPR processes must also take into consideration the associated or informing *WaalWeelde* processes. For this reason, it is useful to provide a brief explanation of the latter programme and its precise linkages to the DPR.

WaalWeelde was originally an initiative of the Radboud University of Nijmegen and has since been adopted by Gelderland Province (Fliervoet, Van den Born, Smits, & Knippenberg, 2013). Its coverage area differs slightly from the DPR Waal-Merwedes region, in that it only covers the reach of the Waal from the German border to its transition to the Merwedes near Gorinchem. It does not include the Merwedes as these lie outside of Gelderland in the provinces of North Brabant and South Holland. It only covers the fifteen neighbouring *Gelderse* riparian municipalities situated along the banks of the Waal, and divides these into three clusters (*West*, *Midden*, and *Oost*; i.e. West, Central and East) of 4-7 municipalities (Figure 16).

Figure 15: Major Dutch Rhine and Meuse river branches considered in the DPR (adapted from van Schijndel, 2006)

The programme aims to join public, private and civil entities in making the riparian areas along the Waal safer, more natural and economically stronger (Fliervoet et al., 2013). It largely developed as a regional response to the national PKB programme. In spite of efforts to integrate stakeholder interests and use an overall landscape quality approach to water safety, the PKB programme predominantly ended up emphasising strictly technical spatial measures falling under the traditional institutional domain of WRM organisations (Scholten, 2009). In the case of the river Waal, many of the eventually adopted 'room for the river' measures were located solely within the riverbed and typically comprised a mixture of groyne lowering and channel deepening. Few measures focussed on achieving broader spatial quality objectives for the floodplains or areas behind the dykes. Many regional and local Waal actors came to view the programme as having missed its opportunity to truly integrate a variety of interests and connect increasing river safety with improvements to the surrounding landscape (Vreugdenhill, Slinger, Smits, & Kater, 2008). Accordingly, *WaalWeelde* was launched and brought its wide array of stakeholders together to collaborate in the development of an integrated future vision for the entire Waal region (WaalWeelde, 2009). As part of this vision, stakeholders specifically allowed for the consideration of integrated development actions in floodplain areas and those located along or behind dykes.

Having developed this general vision, *WaalWeelde* has since entered its next phase. Here, stakeholders collaborate to formulate a detailed Structural Vision (or Spatial Development Plan; Dutch: *structuurvisie*) for their respective local areas, by determining the specific integrated

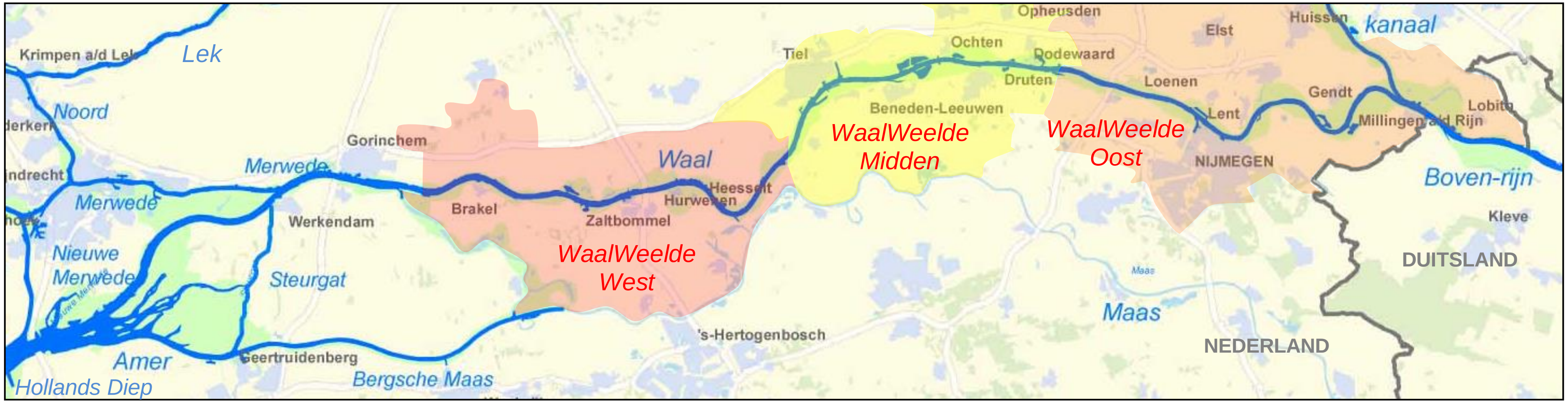

Figure 16: River Waal and the Merwedes (adapted from Topografische Dienst Emmen, 2005; WaalWeelde, 2014a)

measures to be implemented at each river location. Since 2010, the *WaalWeelde West*[14] stakeholder cluster has been the first to commence formulation of its Structural Vision (WaalWeelde, 2014b). As these processes commenced prior to those of the DPR, Gelderland Province was able to use the interim outputs from *WaalWeelde West* as direct inputs to the DPR regional process. That is, the specific integrated spatial development alternatives being discussed at local levels in *WaalWeelde West* came to be the water safety alternatives that were discussed for those areas during the DPR regional process (de Hartog, 2014). Furthermore, the province could use the information contained in the broader *WaalWeelde* vision as a basis for discussions on safety measures for the rest of the Waal region. This was not the case for those areas not covered by *WaalWeelde* (i.e. the Merwedes), where discussions were either based on any new suggestions that emerged directly from DPR processes, or alternatively on any measures that had originally been catalogued during the earliest PKB programme.

9.3 Problems to Be Addressed

The overarching objective of the DPR was for stakeholders to collaboratively formulate a strategy to continue protecting Dutch riverine areas from flooding until 2100 (DPR, 2010). This objective moreover provided the water safety basis to the broader *WaalWeelde West* spatial development assignment. Essentially, two main physical problems were posed by the water safety assignment. The first relates to the ability of the existing network of dykes to cope with the effects of climate change, whilst the second relates to the actual structural strength and integrity of these dykes. The following two sub-sections consider each of these in turn.

9.3.1 Climate Change Considerations

The DP has predicted that climate change will lead to increases in peak river discharges and sea levels in the Netherlands (DPR, 2014a). In the case of the river Rhine, predicted peak discharges with a return period of 1250 years are expected to gradually increase from the current 16,000 m^3/s to 18,000 m^3/s by 2100, with the majority of these flows to be conveyed down the Waal-Merwedes (Table 8). At the same time, sea levels are expected to increase in the order of 85cm by 2100 (DPR, 2014b). Such increases mean that – with no action – river levels during future extreme weather events will more likely surpass current dyke levels and lead to potentially catastrophic flooding.

Such water level increases can be mitigated in essentially three different ways. The first is by looking for spatial measures in the existing beds and floodplains of the rivers (e.g. floodplain excavation, dyke relocation, side channels, etc.), all of which increase discharge capacity by providing additional 'room for the river' (Figure 17). The second possibility also provides 'room for the river', but rather via upstream retention to temporarily store floodwaters for later gradual release after the peak discharge has passed. The third is to increase the height of any existing riverbanks and dykes to accommodate the increased water levels. As introduced earlier, providing 'room for the river' has been a particular focus of Dutch FRM since the late 1990s, increasingly recognised as being more effective at reducing catastrophic risks (RvdR, 2012). This focus continued in the DPR, and the general technical approach of the programme was to consider, where possible, spatial measures to accommodate additional flows rather than simply raising the dykes (Hazenoot, 2014).

[14] *WaalWeelde West* consists of the four municipalities of Lingewaal, Maasdriel, Neerijnen and Zaltbommel.

Table 8: Anticipated increases in peak river discharge due to climate change effects (Kroekenstoel, 2011)

River Branch	Peak Discharges (m^3/s)		
	2015	2050	2100
Rhine	16,000	17,000	18,000
Waal-Merwedes	*10,165*	*10,970*	*11,758*
Lower Rhine-Lek	*3,376*	*3,376*	*3,376*
IJssel	*2,459*	*2,654*	*2,866*
Meuse	3,800	4,200	4,600

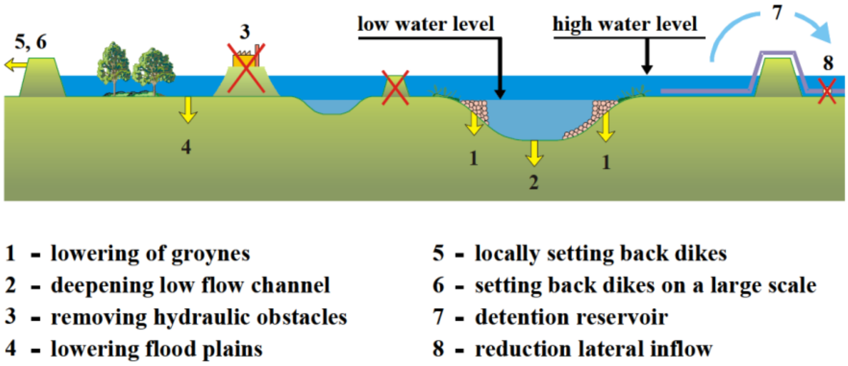

Figure 17: Eight examples of 'room for the river' measures (Silva, Klijn, & Dijkman, 2001)

9.3.2 Piping Considerations

In addition to climate change effects, an additional problem posed during the DPR related to recent revelations that many existing Dutch dykes were not as strong as previously thought, and were susceptible to 'piping'. This is a phenomenon in which water flows underneath the dyke, transporting sand particles to form an under-dyke canal (i.e. a 'pipe') (Schielen & van den Aarsen, 2014). If this mechanism is not stopped, the 'pipe' can become so big that a dyke can lose its integrity and fail. Reinforcing dykes with additional berms is at present the only means to solve piping problems (Schielen & van den Aarsen, 2014). Complicating matters, piping risks are not concentrated at any particular focal points in the Dutch river network. Rather, they occur along entire river stretches, and their precise locations are both difficult to determine and dependent on soil properties (Schielen & van den Aarsen, 2014). Consequently, hundreds of kilometres of existing dykes will need to be strengthened with berms in the immediate future (i.e. in the short term).

9.3.3 Preferred Flood Protection Strategy

Taking both these issues into consideration, stakeholders in the DPR were set the assignment to formulate a so-called 'preferred strategy' (Dutch: *voorkeurstrategie*, or VKS) for flood protection (DPR, 2014b). This was to outline a recommended combination of measures and provide an indicative timing for their implementation against three time horizons: 2030, 2050 or 2100. Stakeholders were essentially tasked with negotiating and selecting their preferred locations to implement any spatial measures, dyke reinforcement berms, or raised dykes. As may be evident, piping risks complicated this task considerably. Given their widespread nature, they occur at many locations where spatial measures could also be considered. Particularly for any locations where dyke relocations were a realistic possibility, DPR stakeholders faced three choices:

1. To reinforce weakened dykes in the immediate future before implementing the spatial measure later as required; running the risk that at some locations reinforced dykes would then need to be later relocated to make way for the spatial measure.
2. To reinforce weakened dykes in the immediate future at the same time as implementing the proposed dyke relocations.
3. To reinforce the weakened dykes in the immediate future in combination with raising their crest levels to accommodate future peak flows.

The option to delay dyke reinforcements in any areas until their dyke relocations were also needed was never a realistic option. This would have left these areas with potentially weakened dykes for an extended period of time, at significant risk to the communities situated behind them. Of the three other options, the first would have allowed for the most adaptable and flexible strategy but would have provided a potentially poor return on investment for some of the reinforced dykes. The second, if it were to be applied in all instances, would have been too cost-prohibitive to the Dutch government given the immense upfront investment costs to implement all these measures. It also would have potentially seen the implementation of some spatial measures that may have later proved unnecessary, given the inherent uncertainty of climate change predictions. The third option presented the most cost-effective solution. However, if it were implemented in all instances, it would have flown in the face of Dutch preferences for spatial measures, as well as removed all adaptability and flexibility from the safety strategy. Any future need for spatial measures would have been effectively eliminated, and a permanent strategy of raising the reinforced dyke levels higher and higher would have been 'locked in'.

Given the competing social, economic, environmental and institutional dimensions implicit to these choices – let alone those relating to establishing any locations where spatial measures could be considered in the first place – problem structure in the DPR is best described as being semi-structured and characterised by disagreement. Many water safety measures involve land use changes, which are inherently political. Citizens may be forced to move, farming land can be lost, or businesses disrupted. The various DPR stakeholders differed in their interests, values and perspectives regarding the development and selection of specific measures, which could then lead to broader disagreement regarding the composition of the VKS as a whole. That being said, DPR problem structure could also at times veer into completely unstructured territories. With some degree of uncertainty inherent to climate change predictions, the potential also existed for stakeholders to challenge the scientific basis of the DPR assignment. For example, some could challenge the rationale to accommodate an 18,000 m^3/s discharge in 2100 instead of, say, 17,000m^3/s (Neefjes, 2014).

Given this dominant problem structure, it was determined that stakeholder involvement in the DPR would be necessary to build consensus for the VKS. Led by the relevant provincial authority, key stakeholders in each DPR region undertook the task to collaboratively develop its regional VKS, before these were all combined to form the final overall DPR VKS. Before turning to the specifics of the model-supported collaborative planning approach adopted in the Waal-Merwedes region, it is first necessary to introduce the various key stakeholders who were involved in the DPR (and any informing *WaalWeelde*) processes.

9.4 Key Stakeholders Involved

The competing social, economic, environmental and political dimensions of the problem assignment yielded a large number of stakeholders with an interest in DPR outcomes. Stakeholder involvement was a key feature of both the DPR and *WaalWeelde*, and both programmes have sought to provide collaborative and participatory avenues for all '4B' stakeholders, including citizens and interest groups, businesses, officials, and decision-makers. That being said, DPR activities were dominated by government institutions in a more top-down fashion, whilst the informing *WaalWeelde* programme has focussed more on bottom-up involvement for its more locally based stakeholders. The following subsections outline the key stakeholders that have been involved in both processes, and focus most on those stakeholders with direct influence on or contact with the *Blokkendoos* model.

9.4.1 Rijkswaterstaat

As indicated in the previous case study, RWS is the national agency responsible for formulating national policies regarding WRM in the Netherlands and the management and maintenance of the main Dutch waterways and water systems. Given the policy-making focus of the DPR and the broader DP in general for these major systems, RWS had the statutory authority and responsibility to adopt its leading role in the programme. RWS's key interests and motivations for their involvement was to ensure that the DPR assignment was undertaken satisfactorily as a whole, and that acceptable, technically feasible strategies to mitigate the predicted increased flood risks were found. That is, their focus was very much upon the core safety aspects of the DPR problem assignment, and less on any ancillary integrated development objectives. RWS provided many key personnel to staff the central organising DPR Programme Bureau (DPRPB), in addition to other programme forums. For the DPRPB, individuals with the relevant technical skills (e.g. experts in hydraulics, modelling and flood risk management) were assigned to the DPRPB to help develop the methodological approaches and tools (e.g. the *Blokkendoos*) to be used to support the regional processes (Kroekenstoel, 2014b). Similarly, other regional RWS officials were assigned to support and collaborate in the regional stakeholder processes directly.

9.4.2 Gelderland Province

As also indicated in the previous case study, a provincial responsibility is to convert national policies into regional-specific plans. Additionally, two specific provincial-level tasks are those relating to regional area management and spatial development (GotN, 2015). Given VKS outcomes explicitly impact regional spatial development policy, provincial authorities also had considerable statutory interests in the DPR. Specifically, they were responsible for the design and leadership of the six regional processes, and thus coordinated and collaborated heavily in all its regional groups. However, provincial officials were also assigned to the DPRPB (among other DPR forums), typically filling roles supporting the delivery of the regional processes.

In the Waal-Merwedes region, Gelderland Province took the decision to link DPR processes to the already running *WaalWeelde* (and specifically *WaalWeelde West*) planning processes – for which it also served as the coordinating body. As a general rule, its provincial representatives were more eager than others to integrate broader provincial spatial development objectives (environmental, spatial quality, etc.) into the formulated VKS. Put another way, these representatives were more enthusiastic about possibilities to integrate spatial measures into the planned strategies than some other stakeholders.

9.4.3 Water Board Rivierenland

A primary function of Dutch water boards is to manage and maintain most flood protection structures in the Netherlands. It is therefore the statutory responsibility of the water boards to ensure that the dykes are kept in good condition and capable of withstanding peak design discharges. Given these responsibilities, they too played significant roles in many DPR forums. Water boards contributed technical advice and assistance, primarily via their representation within the regional groups (Kremer, 2014). Here, the water boards' detailed knowledge of the existing dyke conditions was an incredibly important input to VKS deliberations. Water board staff were also assigned to the DPRPB, in order to both share their technical knowledge and provide their input and support to the regional processes.

In the Waal-Merwedes region, the primary responsible water board was Rivierenland, which was likewise collaborating in the concurrent *WaalWeelde* process. Given its responsibilities for dyke safety, the recent piping revelations took on a greater degree of seriousness and urgency for the water board than for many other stakeholders in the DPR and increased its stake in the process considerably. Within the context of VKS formulation and decision-making, Rivierenland's representatives were much more focussed on including the necessary dike reinforcement measures into the proposed strategy than perhaps other stakeholders.

9.4.4 Municipalities

Municipalities provide the local level of government in the Netherlands. They execute national and provincial policies at local levels, but can also develop their own policies as long as these do not conflict with those at national or provincial levels. In general, municipal statutory responsibilities include those relating to local land management (specifically local zoning laws), local transport and infrastructure, and the local environment (VNG, 2008). Municipal interests in the DPR were somewhat similar to those of the province (i.e. spatial quality, integrated development planning), but on a much more localised scale. Moreover, an individual municipality's interest in the DPR increased the more likely it was to be affected by any of the proposed measures in the VKS. Their involvement was primarily via the municipal forums in the regional process, with some municipalities participating more in these than others. In theory, municipalities were free to determine the extent to which they would (or would not) be involved in the DPR (Hazenoot, 2014). This was not only determined by a municipality's individual interest in the DPR, but also often by its capacity to participate (available staff, budget) in these processes (de Hartog, 2014; Hazenoot, 2014; Kroekenstoel, 2014b). Sometimes several municipalities would be represented by a single individual in DPR processes (Neefjes, 2014). Indeed, this was how the four *WaalWeelde West* municipalities chose to approach their involvement in the programme (van Middelaar, 2014). By way of contrast, in *WaalWeelde West* these four municipalities were much more involved in the coordination of its collaborative stakeholder processes; given that programme's greater focus on municipal rather than regional levels. Essentially, these municipal authorities played a somewhat similar role in *WaalWeelde West* to that which Gelderland province played in the DPR.

9.4.5 Special Interest Groups

The spatial development dimension to the DPR problem assignment also meant that various special interest groups had their own particular stake in DPR outcomes. For example, Dutch water companies often have extraction wells located along the banks of Dutch rivers. Riverside businesses and industries are also situated in these areas, as are agricultural farms, shipping docks and any inland harbours. Organised representatives of these interests, along with any landowner organisations, all naturally had their own particular opinions and values regarding land-use changes stemming from the implementation of spatial or dyke measures. Moreover, providing 'room for the river' is often combined with improving environmental objectives; which thereby also attracts the interest of nature, environment and other impacted stakeholders (e.g., tourism, sports or recreational organisations).

Such special interest groups along the Waal-Merwedes were all able to participate in the DPR via the Sounding Board Group (Dutch: *Klankbordgroep*, KBG). This was a higher-level forum, external to the regional process, and sub-divided according to the two major river basins (Rhine and Meuse). Waal-Merwedes groups shared 'their' forum with organisations from the rivers IJssel and Lower Rhine-Lek. In addition to the KBG, some Waal-based special interest groups were also members of the *WaalWeelde West* 'Mirror Group' (Dutch: *spiegelgroep*). This acts as the sounding board for *WaalWeelde West*, albeit one that is much more integrated into that programme's planning and decision-making processes than the DPR's KBG (detailed later in this case study). As such, the relationship between *WaalWeelde West* and the DPR has meant that *spiegelgroep* organisations have had another, albeit indirect, avenue to influence DPR processes outside of the KBG.

9.4.6 Citizens

Obviously, individual residents and citizens also have an important stake in the spatial development of their communities. Should land-use zones change or a spatial measure impact on their property, this can have a serious effect on its value or continued existence in a particular location. Despite this, the formal active involvement of individual citizens in DPR activities was not facilitated (van der Hoeven, 2014). This was largely due to the DPR's focus upon 'early-phase' planning for a longer-term strategy that was deemed to be of less relevance to present-day citizens. Hence, citizen access to the programme was largely restricted to any publicly available information via websites, news reports, and the like (van der Hoeven, 2014). It is anticipated that once the strategies and plans for any measures have become more certain and concrete, participatory citizen input will be sought at that time.

That being said, when one also considers the relationship between the DPR and *WaalWeelde West* – the latter including much higher levels of public participation – the Waal-Merwedes regional process was able to indirectly consider and include for the views of these citizens during VKS formulation and decision-making.

9.5 Objectives of using a Collaborative Modelling approach

The primary objective of employing CM in the DPR was to determine the VKS. That is, the principal function of the approach was to feed into formal DPR (and by extension DP) decision-making processes. Involving stakeholders in the formulation of the VKS was intended to build sufficient acceptance and support for the final adopted strategy, and thereby minimise the propensity for any later opposition (Boelhouwer, 2014; de Hartog, 2014; Kroekenstoel, 2014b; Overmars, 2014). An important secondary aspect of the approach was to enable the planning process to generate more integrated spatial solutions to the water safety assignment: those that would both fulfil safety objectives and reflect other cross-sector interests of key stakeholders. The *Blokkendoos* model used to support the approach was an important element in this regard. Its use was intended to provide actors with a quick and effective means to visually analyse and assess the technical effects of any spatial measures to be considered in a potential strategy. This is not to suggest that the model would automatically determine the optimal strategy for their region. Rather, it comprised one of the inputs used to inform the ensuing discussions and negotiations concerning the available set of measures.

Foundations for building strategy support and integration were laid during design and development processes for the potential spatial measures (detailed in a later section). The intention of involving stakeholders directly in measures development was to yield potential measures that acceptable to all key actors (Kroekenstoel, 2014b; Seuren & Klerkx, 2014). Additionally, local knowledge could be incorporated into the measures' design and any compatible regional and local objectives could be integrated (Hazenoot, 2014). There was recognition local actors would be best placed to consider how to accommodate spatial measures into their areas, and ensure that wider benefits could flow from any investments in water safety (Overmars, 2014). Measures could be developed that concurrently fulfilled other management targets, such as transport, navigation or WFD objectives (de Hartog, 2014).

By integrating development objectives into the potential measures, a few respondents in this study suggested that an additional intended consequence of the approach was to lay the future foundations for measures cost sharing between government agencies (Hazenoot, 2014; Kroekenstoel, 2014b). That is, in those instances where other objectives were successfully integrated into selected measures (e.g. construction of a new road along a relocated dyke crest), then those agencies responsible for the 'integrated' components could help finance these measures rather than having them solely paid for out of the national water safety budget. Likewise, via the increased involvement of industries and businesses in *WaalWeelde West*, it was hoped that stakeholder integration would yield opportunities to reduce the net investment costs for some measures. This had been something that some stakeholders recognised was lacking in the earlier PKB programme (de Hartog, 2014). For example, those measures involving significant earthworks could be made more cost effective by creating linkages to local sand mining operators who could perhaps purchase the excavated material.

Involving stakeholders in measures development was likewise meant to improve the credibility, quality and integrated nature of the developed *Blokkendoos* model. Integral components to the model are the measures contained therein, so collaborative measures development would correspondingly increase the credibility of the tool as a discussion aid. Stakeholders could view measures within the model that they themselves had helped devise (Levelt, 2014). Similarly, any improvements in the levels of quality and integration for each developed measure could be directly translated to improvements in the quality and integrated nature of the model. In addition to the above, model improvement was the motivation behind consultations the model developers carried out with prior users of earlier Dutch planning kits (detailed further below). This was performed explicitly to help determine ways to improve the functionality and quality of the model. It was also intended to ensure the relevancy of the redeveloped tool to its intended users (Kroekenstoel, 2014b; Levelt, 2014).

A final, ancillary objective of the CM approach was stakeholder learning. An intention was to remind and reinforce to stakeholders the importance of water safety within the Dutch context (Hazenoot, 2014; Kremer, 2014). It was additionally anticipated that shared and social learning would occur regarding stakeholder interests and perspectives, identifying those areas of stakeholder commonality and difference. More specifically, it was also hoped that stakeholders would gain an improved technical appreciation for the different hydraulic effects the alternative measures would generate, along with the response of the river to flood conditions.

9.6 Collaborative Modelling Tool: DPR *Blokkendoos*

Inspired by and maintaining the core functionality of several earlier planning kits developed and used previously in the Netherlands (most notably the *PKB Blokkendoos* and *IVM Blokkendoos*[15]), the *DPR Blokkendoos* was a tool to indicate to stakeholders how to address the portion of the DPR assignment related to increased peak river discharges.[16] It was an internet-based model that allowed its users to quickly create and compare combinations (or packages) of spatial 'room for the river' measures against increased river discharges, to ascertain the ability of both these and existing flood protection structures to withstand such increases. Should spatial measures be shown to not reduce water levels sufficiently, the *DPR Blokkendoos* (hereafter *Blokkendoos*) also provided an indication of the locations at which raising the levels of existing dykes would become necessary.

Dutch planning kits are typically classified as Discussion Support Systems (DiSS) and are characterised by three main factors: their rapid response, an emphasis on the visualisation of results rather than their computation, and access to background information on the scenarios and strategies used in the system (Hendriks, 2007).[17] The latter can include information on each of the proposed measures, for example: situation sketches, aerial photographs, cost estimates, ecological effects, soil types and excavation volumes. By providing users quick and easy access to complex calculation outputs (calculated with other models) as well as all this background material via a single model interface, all information relevant to the decision-making process can be immediately accessed and taken into consideration during the design of spatial flood protection strategies (Hendriks, 2007).

These planning kits can be used in a variety of ways. Experts can use the application independently, to devise 'optimised' strategy proposals for later discussion with colleagues or other stakeholders. Non-experts can likewise make use of the model to devise their own strategies or to review those that have been suggested by others. Alternatively, planning kits may also be applied directly in face-to-face meetings of stakeholder groups, thereby operating as a more interactive DiSS (Hendriks, 2007). In the case of the DPR, the explicit purpose of the *Blokkendoos* was to operate as an analytical and communicative tool to be used both by, and

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[15] The *PKB Blokkendoos* was the original planning kit developed to assist in the decision-making processes for the Key Planning Decision (Dutch: *Planologische kernbeslissing*, *PKB*) Room for the River programme in the early 2000s. This was a project in which key Rhine stakeholders suggested over 700 individual spatial measures that could contribute to providing additional space for the river. Similarly, the *IVM Blokkendoos* was a planning kit that was used during planning exercises to repeat the PKB assignment for the river Meuse under the Integrated Meuse Study 2 project (Dutch: *Integrale verkenning Maas*, *IVM*). For further information on these earlier planning kits, see for example van Schijndel (2006), Kroekenstoel (2006), Kors (2004).

[16] The *DPR Blokkendoos* was not a tool that could be used for the analysis of dyke measures to combat piping, nor to analytically compare the relative advantages and disadvantages of spatial measures to dyke measures. It provides indicative comparison of the efficacy of the various spatial measures only. To support dyke reinforcement analysis, a separate tool was developed – the *Dijkentool* (Dykes Tool) – which calculated the costs and impacts of dyke reinforcement measures (i.e. broadening), including indicative house removal costs. Outputs from both tools, in addition to other inputs, were then considered together by stakeholders in the final formulation of the VKS.

[17] DiSS differ from more traditional Decision Support Systems (DSS) for several key reasons (Hendriks, 2007). Their rapid response and reliance on relatively simple calculations can lead to the accuracy of results being insufficient to base final decisions on and often the most promising strategies will have to be recomputed using more elaborate models. Also, the incorporation of background information within the model to support stakeholder reflection and stimulate discussion would typically be absent in a DSS. DiSS also generally have a reduced reliance on sound case management procedures since simple computations convert large and complex inputs into these rapid outputs. In a DSS, it is more common that simple inputs are converted via complex computations into more complex outputs.

with, stakeholders (Levelt, Udo, & de Jong, 2010). From the outset, it was recognised that the primary users of the tool would most likely be the members of the DPRPB; RWS; other officials from the Ministry of Infrastructure and Environment; and any provincial, water board and municipal representatives participating in the DPR regional process. That is, it was expected that a wider audience than simply engineers would use the model. Previous experience with the earlier planning kits supported this expectation and suggested that the potential users of the *Blokkendoos* could include (Levelt et al., 2010):

- Policy makers
- Hydraulic specialists, spatial planners, nature specialists, ecologists, economists, cultural historians, landscape architects, etc.
- Elected officials, and
- Interested laypeople.

Although the core functionality of the *Blokkendoos* remained unchanged to the earlier planning kits, several changes were made to its model interface to improve its ease-of-use and communicative capacity in the DPR. These included (Kroekenstoel, 2014b):

- Making the tool available via the internet, thereby broadening its access and guaranteeing version control.[18]
- A greater emphasis placed upon the spatial aspects of measures by improving and increasing its GIS capabilities.
- Simplifying its operation and functionality, to increase its access to non-experts.
- Improving its visual design and appeal.
- Simplifying and reducing the large number of aspects that could be considered for each measure, which stakeholders had often found overwhelming (Hendriks, 2014; Kroekenstoel, 2014b).

Given the model's intended relevance and accessibility to such a wide range of stakeholders, the reader may find it useful to better understand the functionality of the *Blokkendoos* in greater detail.

9.6.1 Model Functionality

The *Blokkendoos* sits within the DP's Delta Portal[19] and is accessed via a login and password obtained from the DPR Programme Bureau. Users define the scenario to be modelled by selecting the river branch and time horizon (2050 or 2100) of interest, along with a corresponding preferred strategy from either the Rhine Estuary-Drechtsteden (DPRD) or IJsselmeer (DPIJ) sub-programmes.[20] A single climate change scenario is considered in all cases within the model (that of 'rapid climate change')[21], which corresponds to the maximum predicted river discharge increases as outlined in Table 8 and sea level rises of 0.35m (in 2050) and 0.85m (in 2100).

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[18] Both the *PKB Blokkendoos* and *IVM Blokkendoos* had been made available on CD-ROM only.

[19] See www.deltaportal.nl

[20] Each of these strategies directly influences water levels in the Rhine and Meuse branches.

[21] Climate change effects are contained within the four so-called Delta Scenarios. These are Busy, Rest, Steam and Warm. These define alternative futures according to two varying factors: socio-economic growth and climate change. Rapid climate change relates to both the Steam and Warm scenarios, as varying levels of socioeconomic growth have no effect on river levels. For further information refer (DP, 2011, Figure 4)

The central element of the user interface is the water level graph located at the top of the screen (Figure 18 and Figure 19). This illustrates the simulated peak flood water levels along the selected river branch in an upstream-downstream direction (from left to right). Key location names for each river branch are indicated along the x-axis of the graph, and any predicted water level changes are plotted against the y-axis. With this graph, users can quickly identify water level increases resulting from the selected model scenario (assuming no measures are taken) with the grey water level line. This presents the 'Indicative flood level assignment' for the user (Dutch: *MHW-opgave*). The blue line presents the target value (Dutch: *Doelwaarde*), and corresponds to a 0 cm increase in water levels from current norms (2015 flows). The dark red line represents the predicted effects that any user-selected spatial measures will have on river levels (Dutch: *Effect maatregelen*) and changes as the user selects each spatial measure in the model.

Measures are selected in the measures chart located directly below the graph (Figure 18). Measure selection icons change when selected and become 'greyed-out' when other measures preclude their simultaneous selection in a strategy. Potential measures are arranged within the measures chart according to the different types of measures, indicated in the right-hand legend (Dutch: *Maatregel types*; e.g. dyke relocation, green river, secondary channels, etc.). Hovering over a measures selection icon displays a brief summary 'popup' with the name, origin and type of the measure (Figure 18).

Essentially, the task for the user is to select a number of long-term spatial measures such that as many climate change effects are neutralised as possible. That is, so that the dark red line more or less follows or remains below the blue line. By defining the task in this way, the *Blokkendoos* simplifies the many complex hydrological and hydraulic processes generated by the model scenario down to a single water level parameter, communicating this visually via the graph.

A GIS map sits below the measures selection chart (Figure 18). With this the user can zoom into their location of interest and view the areal extents of any potential or selected measures. These are indicated by the shaded green areas adjacent to the river courses. Selected measures change to a darker shade of green, and can be selected directly from within the map. Rivers illustrate any critical water level increases by means of a colour scale and river kilometre markers are included to aid in orientating the map to the water level graph above. Users can also choose to have this information displayed over a simple map base of Dutch rivers, one with basic elevation contours and urban area extents, or a more complete map base drawn from OpenStreetMap[22] (as is shown in Figure 18).

As an alternative to displaying the GIS map, the user may choose to view and select measures listed in a table (Figure 19). This summarises all the available data regarding each measure, including the following details:

- Name
- Reference Code
- Type
- Location kilometres
- River reach and section
- Maximum water level savings (in cm)

[22] OpenStreetMap is an open source internet-based mapping service built by a community of mappers. See www.openstreetmap.org

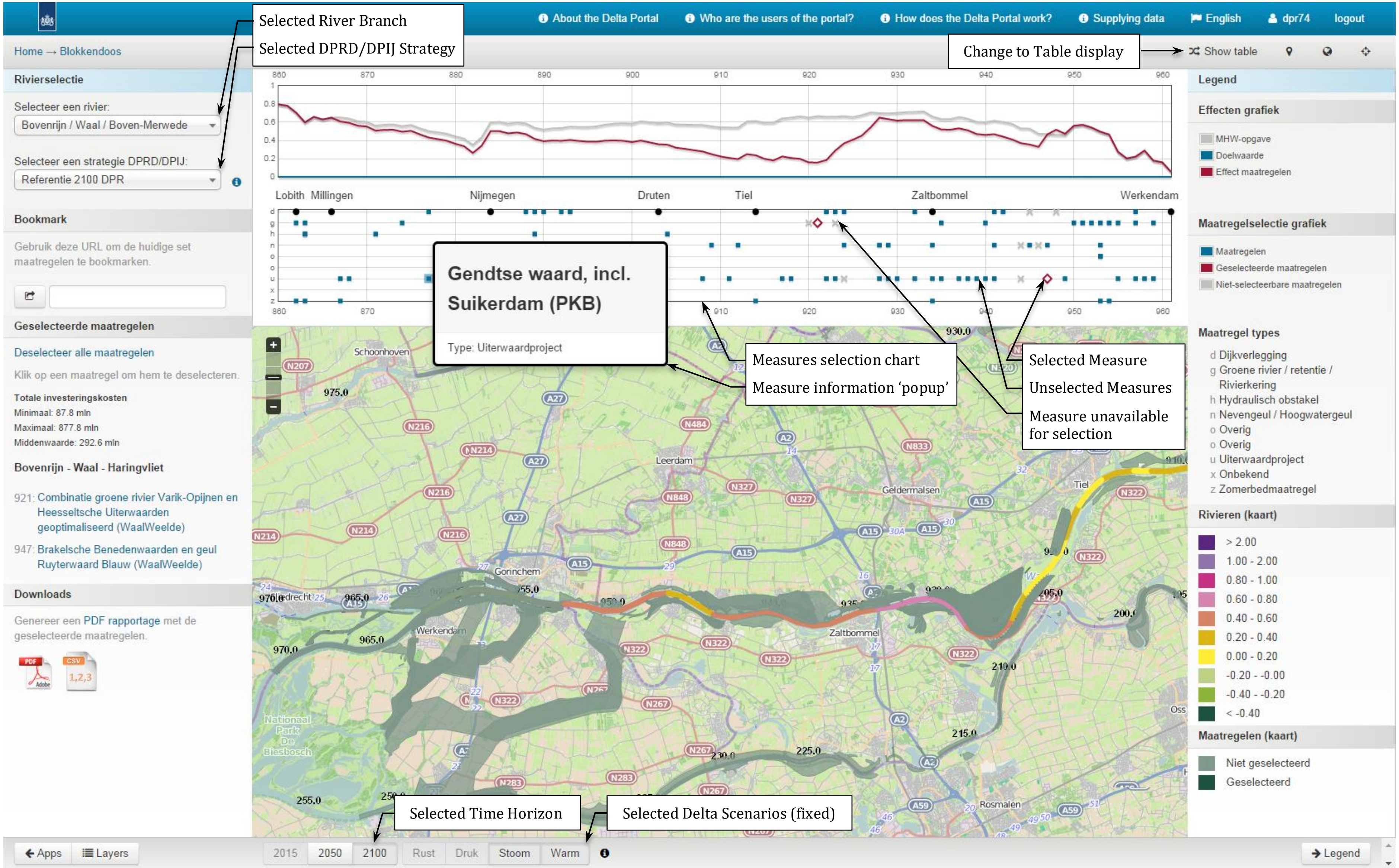

Figure 18: ***Blokkendoos*** **user interface with the GIS map displayed**

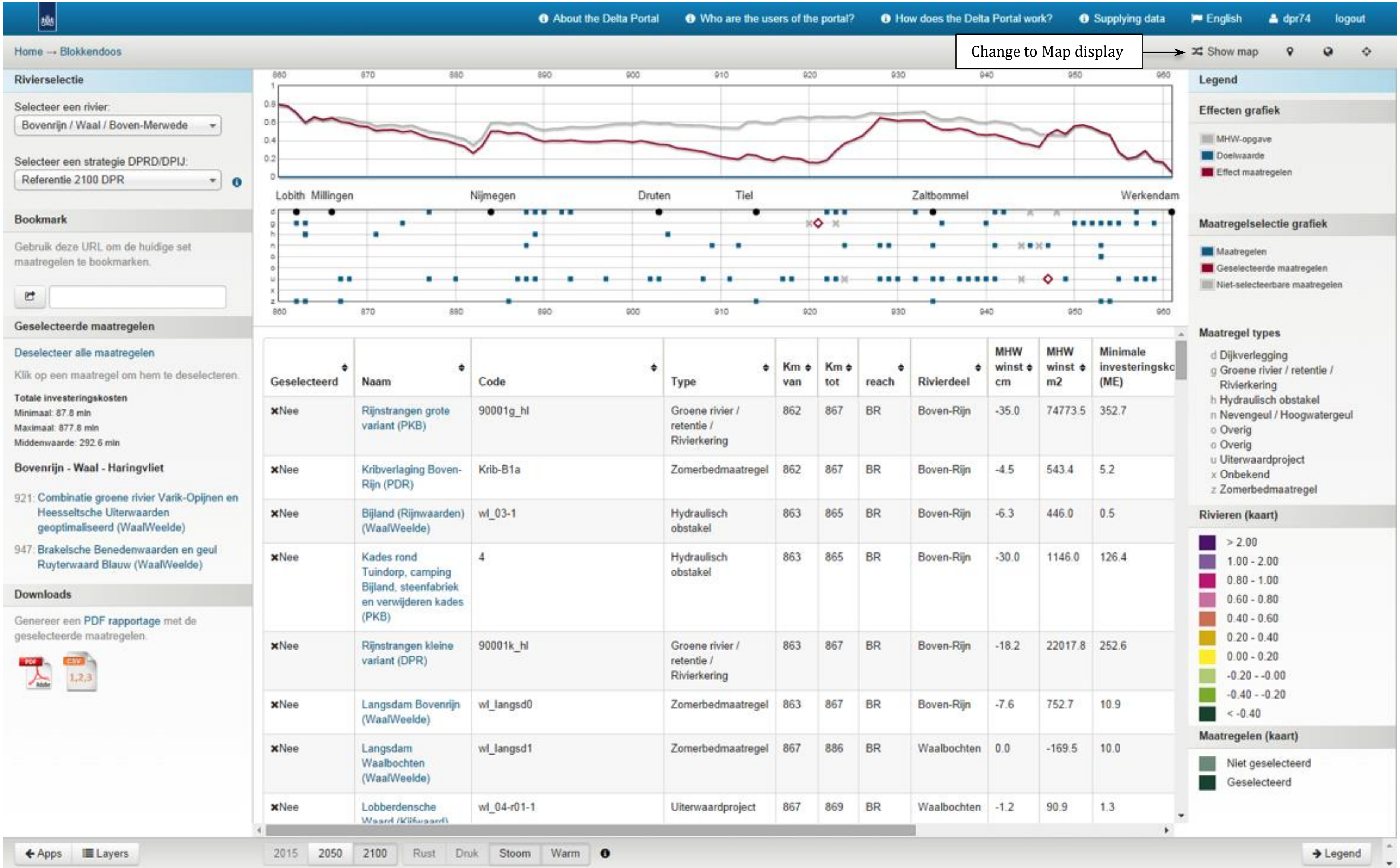

Figure 19: *Blokkendoos* user interface with the table displayed

- Spatial requirements (in m^2)
- Minimum, expected and maximum investment costs
- Cost effectiveness (in m^2/EUR)
- Provisions for nature areas (in ha), and
- Excavation requirements (in m^3).[23]

Users can download factsheets from this table for each measure in the *Blokkendoos*. All the additional background qualitative information for the measures (situation sketches, aerial photographs, cost estimates, ecological effects, etc.) is contained in these (subject to availability).

Once users have devised a proposed measures package, the package can be exported as a summary report document. Alternatively, users can download the tabulated information and calculated package effects as an Excel spread sheet, for use in further external analysis. Users can also generate a package URL that can be either bookmarked or shared with other users for review.

9.6.2 Pre-Calculation Database

The core of the *Blokkendoos* is formed by a database containing all the information and effects of each of the spatial measures to be considered in any potential mitigation strategies. To give an idea of scale, nearly 400 potential long-term measures were included within the *Blokkendoos* throughout the course of the DPR (Kroekenstoel, 2014a). This database includes all the information presented within the table display of the user interface (including the factsheets). However, more importantly, it also contains the data for all existing dyke levels along each river branch, along with the pre-calculated water level effects for each individual measure along its river branch at every river kilometre. Similarly, it includes the pre-calculated water levels for each river branch according to the reference scenario (2015) and for every combination of model scenario options (time horizons, DPRD/DPIJ strategies). All these calculations have in the main been performed using generally consistent and sophisticated 2D hydrodynamic models for each river branch before having their individual results inputted into the *Blokkendoos*. (Kroekenstoel, 2014a).

Since all the hydraulic water level effects for each individual measure are pre-calculated, the *Blokkendoos* essentially works as a simple counting model, applying the principle of superposition. As each additional measure is selected, the pre-calculated water level effects for every river kilometre are simply added together to generate the total effect illustrated in the water level graph.[24] This makes the model extremely quick in returning an output for a given package of measures, as all the time-consuming hydrodynamic equations have already been performed. It is precisely this speed of results delivery that renders the *Blokkendoos* as a viable interactive discussion aid.

[23] At time of writing, data for the final three aspects in the list above was not yet included in the *Blokkendoos*. However, the intention is that this information will be inserted into the model for later planning phases as the preferred measures become more certain and the information becomes available.

[24] The non-linear nature of hydrodynamic behaviour would normally preclude the principle of superposition from being applied in this way. However, studies comparing calculations of complete measures packages undertaken with earlier planning kits and 2D hydrodynamic models revealed that this approach is quite acceptable (within ±5cm) for most types of spatial measures (excluding detention measures); particularly as the number of measures included in the package increases. Refer van Schijndel (2006).

9.6.3 A note on model versions

As indicated earlier, the *Blokkendoos* is the latest in a series of several Dutch planning kits developed over the past fifteen years. Within the combined context of the DPR and *WaalWeelde West*, it is important to stress that different versions of the model may have been used at different points in the programme. As *WaalWeelde West* processes initially preceded those of the DPR, the *DPR Blokkendoos* was not ready to be used for strategy development activities during the municipal programme. Rather, a purpose-built *WaalWeelde West* planning kit was developed, which by-and-large adopted the earlier interface of the *PKB Blokkendoos*. Similarly, some stakeholders reported relying upon the earlier *PKB* model during earliest DPR planning phases, for the same reason that the DPR tool had not yet been issued for use. Although the calculations in this earlier model were for a reduced peak river discharge, stakeholders could still use it to gain an idea of orders of magnitude for measures effects and background information. As the core functionality of all these planning kits is essentially the same, stakeholder experiences of any of these models during the DPR and *WaalWeelde* have been included within the analysis of this case study.

Having now outlined the broad context within which the DPR's CM approach manifested, including those stakeholders involved and the modelling tool utilised, the following chapter turns its attention to the specifics of the Model-Supported Collaborative Planning approach.

10 Model-Supported Collaborative Planning Approach

The preceding chapter provided the necessary background and contextual information for this case study. Having done so, the following section turns its attention to the specific stakeholder structures and processes of the CM approach used during the DPR, including the author's analysis of these. Where relevant, any of the DPR's informing *WaalWeelde West* processes have also been detailed. In reading this section, it is important for the reader to keep in mind that the focus of the approach is not on the modelling *per se*, but rather the planning and strategy formulation activities that the modelling activities support.

10.1 Model-Supported Collaborative Planning in the DPR

10.1.1 Structure of Participation

With its large numbers of potential '4B' stakeholders (citizens and interest groups, businesses, officials, and decision-makers, introduced in the preceding chapter), structuring participation in DPR processes was an important requirement within the approach. Passing mention has already been made of several forums that operated within the DPR, such as the DPR Programme Bureau (DPRPB), the regional groups and the Sounding Board Group. In addition to these, other heterogeneous bodies were also organised, and all are briefly detailed in the below sub-sections. The individual stakeholders and stakeholder types involved in each forum are outlined in Table 9. Essentially, the participatory structure broadly followed the 'Circles of Influence' model presented in Chapter 3, with the levels of participation and influence of each stakeholder body radiating out from a central core (Figure 20).

10.1.1.1 DPR Programme Bureau (Organising Team)

As indicated earlier, the DPRPB principally comprised members from RWS, the provinces and water boards (with a couple of municipal members). It formed the central collaborative core (or organising team; Circle A, Figure 20) for the DPR, and was responsible for developing the approaches and technical tools to be used in the programme. It was also responsible for overall process management in the DPR, and thereby supported each of the provinces in their coordination of the respective regional stakeholder processes. The structure of the DPRPB largely followed these two core functions. It consisted of a number of teams, including *inter alia* a technical team and regional river teams (DPR, 2013). The technical team (Strategy and Knowledge) was responsible for determining the overarching processes to be followed during the DPR, and included the technical development of the *Blokkendoos*. RWS river experts with the necessary modelling, GIS and FRM knowledge and skills largely populated this team (Kroekenstoel, 2014b).[25] In contrast, the three river teams (Waal and Rhine Estuary; IJssel, Lower Rhine and Lek; and Meuse) were responsible for the development of the six regional VKS in coordination with the respective regional groups. These were typically populated by members from the provinces and water boards (and municipalities) – along with some additional RWS members – who possessed the necessary regional FRM knowledge and skills (Kroekenstoel, 2014b).

[25] Support and linkages to specialist knowledge and advice was also provided to this group in the form of two representatives from Deltares, an independent Dutch institute for applied research in delta management.

Table 9: Stakeholder membership to each of the principal DPR forums

DPR Forum	Circle of Influence	Stakeholders Involved	'4B' Category
DPRPB (Organising Team)	A	RWS Provinces Water boards Several municipal representatives Expert research institute (Deltares) representatives	Officials (*Beambten*)
Regional Process Working Groups	B1	RWS Provinces Water boards	Officials (*Beambten*)
Wider Regional Process Groups (*WaalWeelde West '4B' Working Groups and 'Mirror Group', or spiegelgroep*)	B2	Circle B1 stakeholder representatives Municipalities Special Interest Groups (*WaalWeelde West* only)	Officials (*Beambten*) Interest Groups (*Belangenorganisaties*) and Businesses (*Bedrijven*)
Information and Feedback Groups (Sounding Board Group, or *Klankbordgroep*) (*WaalWeelde West citizen forums*)	C	Drinking Water Companies Businesses and Industry NGOs Tourism Operators Sports and Recreation Organisations Citizens (*WaalWeelde West* only)	Interest Groups (*Belangenorganisaties*), and Businesses (*Bedrijven*) Citizens (*Burgers*)
Decision Makers (Steering Groups)	D	Ministry Officials RWS Regional Directors Provincial Deputies Water Board Chairs Mayors Aldermen Water Safety Programme Directors	Elected Officials (*Bestuurders*) (or their delegated representatives)
Administrative Advisory Group	(Supporting D)	Ministry Officials RWS Provinces Water boards Municipalities	Officials (*Beambten*)

Stakeholder involvement in the DPRPB was essentially dependent upon whether one's parent organisation was willing or could afford (i.e. had budgeted) to second them to the bureau, as the DPRPB did not pay salaries (Kroekenstoel, 2014b). For this reason, it was somewhat easier to source bureau staff from RWS. RWS had been allocated national government funding to staff the DPRPB, whereas other governmental organisations had to allocate any staff from their existing budgets (Kroekenstoel, 2014b). Despite these arrangements, it is important to stress that any individuals seconded to the DPRPB were to work in the interests of the bureau (i.e. successful

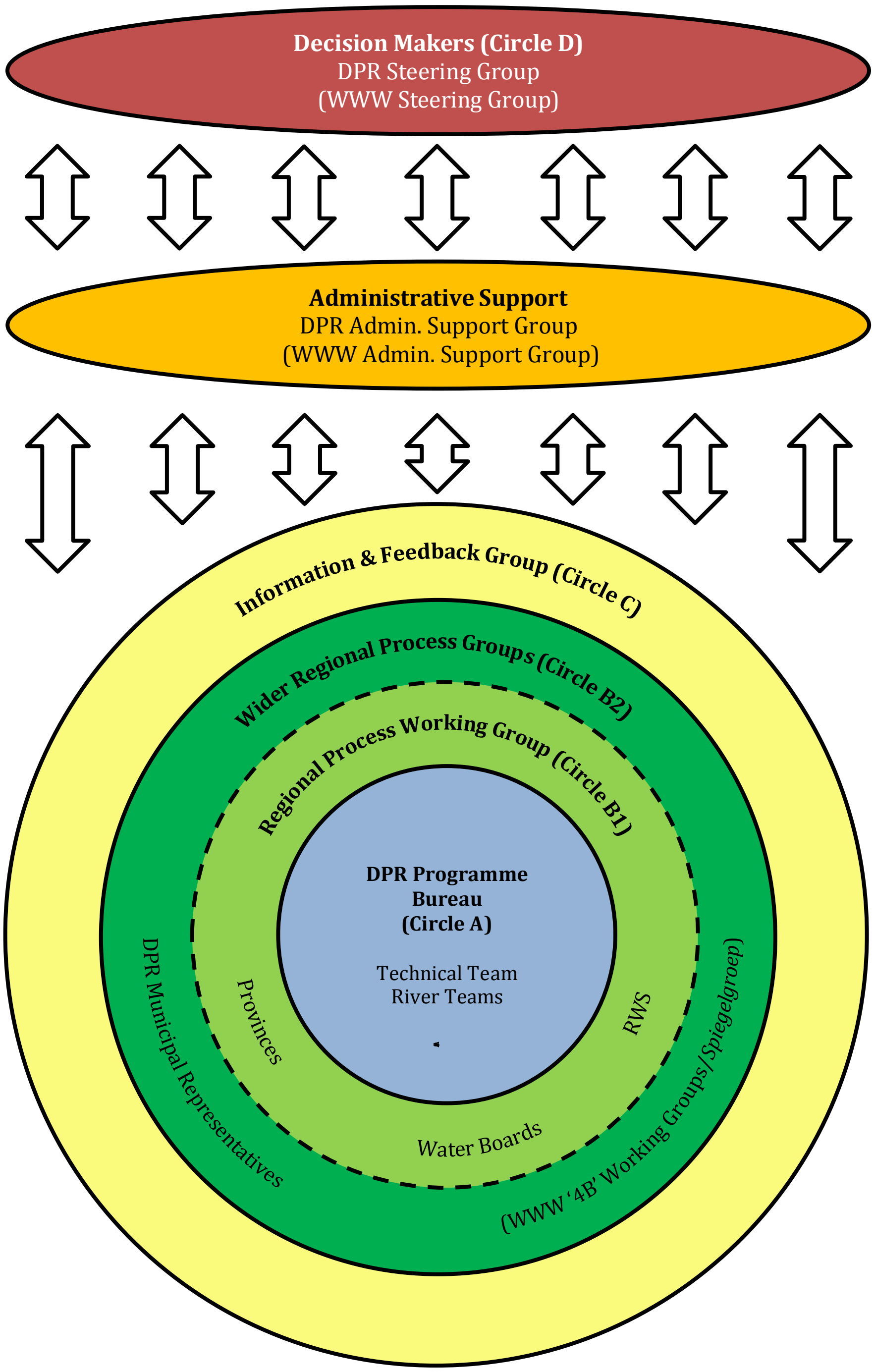

Figure 20: Structured participation and Circles of Influence in the DPR (and *WaalWeelde West)*

delivery of the completed VKS), and not of their individual parent organisations (Kroekenstoel, 2014b). This is not to say that the bureau could not make use of its members' particular regional or organisational perspectives and knowledge; this was the very reason they were asked to join the bureau. But they were not there to pursue the policies of their parent organisations.

10.1.1.2 Regional Process Working Group

The regional process working group was a sub-grouping of key actors collaborating in the Waal-Merwedes regional process. It comprised members of the coordinating provincial agency (Gelderland), the water board (Rivierenland) and regional RWS officials. Participants' backgrounds in this group were mixed; spatial planners participated from the province, and both the water board and RWS contributed policy makers and flood risk managers. In addition to these members, direct technical support was provided to the group by Gelderland's independently contracted specialist advisors. Process management support came from members of the DPRPB's Waal and Rhine Estuary river team.

The working group formed somewhat of an inner circle (Circle B1, Figure 20) within the wider group of stakeholders directly participating in the Waal-Merwedes regional process. It was responsible for developing the initial draft strategy proposals to be put to the wider regional group, and then for finalising the preferred proposals to be presented to the programme steering group. In effect, the province determined the membership of the group. Included stakeholders could exert considerable influence over the entire modelling and VKS formulation process, corresponding to a 'co-designing' level of participation.

10.1.1.3 Wider Regional Process Groups

If one considers the DPR in isolation, the wider regional process groups included all working group members plus representatives from the riverine municipalities (Circle B2, Figure 20). Municipal representatives in these groups typically comprised municipal land and water managers or occasionally external advisors (as in the case for the four *WaalWeelde West* municipalities). Under the coordination of the provincial regional process lead, the wider regional group were invited to suggest any new measures to be considered in the programme, and then for reviewing the working group's draft strategy proposals and providing their feedback. Consequently, their level of participation was effectively restricted to an advisory role (i.e. one of 'Discussion').

However, if one also considers the DPR-informing pilot *WaalWeelde West* processes, the members of its '4B' working groups/'Mirror Group' (Dutch: *spiegelgroep*) as being included within this circle of influence. In this project, the collaborating municipalities, businesses and interest groups have played an increased role in measures design and strategy formulation. Within the context of formulating the *WaalWeelde West* Structural Vision, these stakeholders shared responsibilities for both measures development and determining their preferred strategic plan. As such, collaborating stakeholders in *WaalWeelde West* have frequently reached 'Ownership' or 'Co-designing' levels of participation. That being said, it is not the author's intention to imply that a higher level of municipal and other '4B' participation in *WaalWeelde West* directly translated to a higher level of participation in the DPR. This is not strictly the case, as any recommendations from *WaalWeelde West* still needed to be formally accepted and included within the finalised VKS by the regional working group. Furthermore, one cannot forget that *WaalWeelde West* only included four riverine municipalities along the Waal. For other municipalities, participation was largely restricted to the wider DPR regional group as described in the previous paragraph.

10.1.1.4 Information and Feedback Group

The DPR's outer circle of influence was populated by the special interest groups in the Sounding Board Group (Dutch: *Klankbordgroep*, KBG) and those interested members of the public participating in broader *WaalWeelde West* processes (Circle C, Figure 20). In the case of the KBG, its potential members were essentially self-selected and free to participate as little or as much as they wished. Consequently, participation from these organisations has varied, with some organisations having taken the opportunity to be more involved in KBG activities than others (van Loenen Martinet, 2014). Given its role to review and provide feedback on each regionally developed VKS proposal prior to decision makers in the relevant DPR Steering Group, its involvement was also one of 'Discussion', but to a much reduced level to that of the participating DPR municipalities. This was similarly the case for the interested public in *WaalWeelde West*.

Here, the '4B' working groups/*spiegelgroep* took public preferences for individual measure alternatives into consideration in formulating the preferred plan for the Structural Vision.

10.1.1.5 Decision Makers

The DPR Rhine Delta Steering Group took the decisions regarding which measures were included within the final Waal-Merwedes VKS (in addition to its other branches).[26] Its decisions were then passed up to higher-level decision-makers in the broader DP. The majority of members to this group were elected officials, and included all collaborating provincial deputies (members of the provincial executive, Dutch: *Gedeputeerde Staten*) and water board chairs (comparable to a mayor, Dutch: *Dijkgraaf*), as well as several riverine mayors and aldermen (DPR, 2013). The chair of the KBG (himself a municipal mayor) also sat on the Steering Group, as did other appointed officials representing higher-level decision makers, for example: ministerial delegates, regional RWS directors, and DPR and Room for the River programme directors (DPR, 2013). Municipal representation in the Steering Group was determined by the Dutch Association of River Municipalities (Dutch: *Nederlandse Vereniging Riviergemeenten*), with each of the three Rhine river branches (Waal-Merwedes, Lower Rhine-Lek, IJssel) assigned 2-3 representatives (de Hartog, 2014).

WaalWeelde West also had its own Steering Group, comprised of elected officials for the four collaborating municipalities and chaired by the Gelderland Provincial Deputy for Spatial Development. This was responsible for making decisions regarding the proposed Structural Vision. Notably, its chair also served as the chair for the DPR Rhine Delta Steering Group and thus provided a link between decisions made in the two programmes (de Hartog, 2014).

10.1.1.6 Administrative Advisory Groups

Assisting decision makers in both the DPR and *WaalWeelde West* were Administrative Advisory Groups (Dutch: *Ambtelijke begeleidingsgroep*, ABG). They prepared the advisory documentation for their respective Steering Groups, and the chair of the DPR Rhine Delta ABG served as the secretary for the DPR Rhine Delta Steering Group (de Hartog, 2014). Any relevant findings and information that came out of the regional process was essentially distilled into an executive-summary for steering group members (de Hartog, 2014). Often, members of the ABG (or their close colleagues) also participated in other DPR regional process groups and had assisted in developing the strategies (Kroekenstoel, 2014b).

10.1.2 Collaborative Processes

The stakeholder-inclusive processes employed in the preparation of the Waal-Merwedes VKS can essentially be divided into two distinct types: the more top-down processes of the DPR, which were contrasted with the more bottom-up informing processes of *WaalWeelde West* (at least for the four municipalities it covered). The following sub-sections detail each of these in turn.

10.1.2.1 Top-down Processes (DPR)

When considering the role of CM in formal DPR processes, again two distinct processes must be considered. The first concerns the development and continued refinement of the model, whilst the second concerns the *Blokkendoos*-supported activities of strategy formulation.

[26] There was similarly a DPR Meuse Delta Steering Group, which took decisions related to the river Meuse.

a) Model Development

The development of the *Blokkendoos* was an iterative process lasting the duration of the DPR (Figure 21). The process was carried out in large part by the DPRPB technical team (and its external consultants). This team took all decisions regarding the model interface (how it functioned, its capabilities, etc.); however, participation from potential and active model users was actively sought throughout the development process. Initially, potential user input was gathered during the preparation of the model's functional design (Levelt et al., 2010). This included interviewing seven representatives from selected different government agencies (e.g. ministerial departments, provincial offices), all of who had previous experience with the earlier *PKB* and *IVM* planning kits. They were asked to outline any improvements they felt could be made to the interface and functionality, with many of these incorporated into the final model design along with other DPRPB-generated requirements (Levelt et al., 2010).

Following this initial consultation, external ICT developers took care of constructing the updated model interface. At the same time, the DPRPB technical team built the initial model database from remaining *PKB* and *IVM* measures, all of which needed to be recalculated according to the stipulated DP climate scenario horizons (Levelt, 2014). After the functioning model was issued for use in the regional process, the development process transitioned to one dominated by stakeholder-driven revision to the model database. As new measures were defined or refined in the regional process, these would be communicated back to the DPRPB technical team via their river team colleagues (Kroekenstoel, 2014b). The necessary technical calculations and information factsheets for these new measures could then be produced (or updated) for inclusion in the database. Similarly, model interface or database information errors could be established via this feedback loop, as it was often only during regional use of the model that these would be identified (Kroekenstoel, 2014b).

b) Measures Development and Strategy Formulation

The development of measures comprised an integral part of the model development process. However, measures development sat within the much wider collaborative process of strategy formulation driven by the regional working group (Figure 22). Essentially, the DPR was divided into three phases (Schielen & van den Aarsen, 2014):

1. The initial development of all possible spatial measures, in combination with the scheduling of necessary sites for dyke reinforcements to combat piping.
2. The distillation, packaging and refinement of these measures into the most likely maximum spatial strategy, in combination with the generation of a maximum dyke reinforcement / dyke raising strategy.
3. The final processes of negotiation to determine the preferred measures and strategy (the VKS) drawing from the two likely strategies (i.e. spatial and dyke improvements).

Updates to the *Blokkendoos* database occurred during all three phases; however the redeveloped model was only used during the final phase, when the likely measures were whittled down to the preferred measures (Neefjes, 2014). That being said, prior to the issue of the redeveloped tool, some actors chose to refer to older planning kits to ascertain orders of magnitude for any potential water level savings from the older measures that were still deemed possible (Neefjes, 2014).

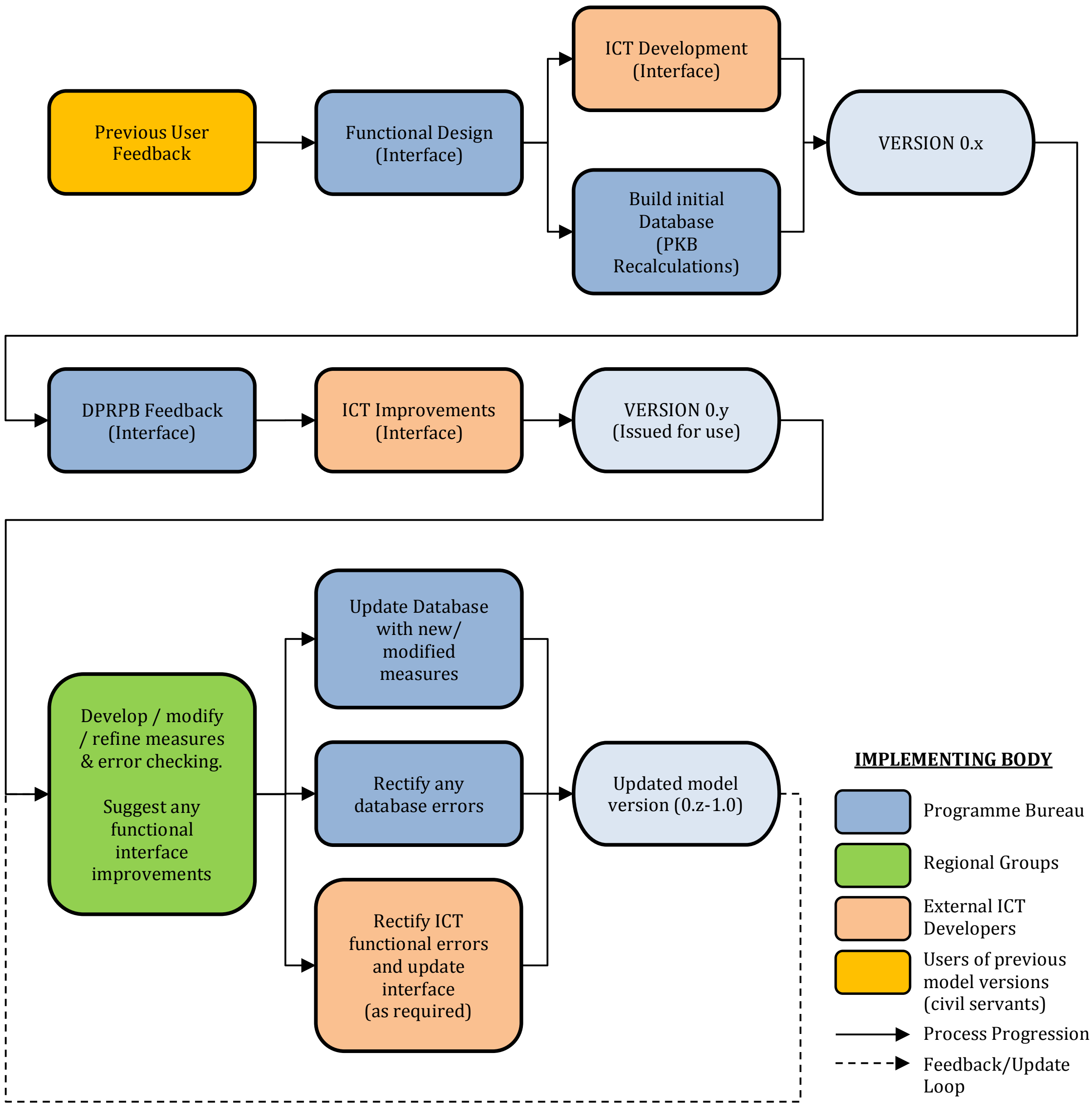

Figure 21: *Blokkendoos* Development Process

In developing the initial list of possible spatial measures for the Waal-Merwedes regional process, remaining *PKB* measures were vetted according to their water level savings efficiencies by the DPRPB technical team and for their 'acceptability' by the wider regional group.[27] In the latter case, municipalities were consulted regarding whether any of these measures would fail to generate the necessary public support, or whether any of them conflicted with other planned developments, vital infrastructure, homes, or sites of cultural heritage (Hazenoot, 2014). At the same time, both the regional working group and municipalities were asked to brainstorm any new measures that had not yet been considered. These were then mapped and assessed for their likely water level effects by either preliminary modelling or expert judgement (provided by Gelderland's hired consultants or the DPRPB technical team). The more promising measures were then fully modelled by the DPRPB technical team and their results inputted into the

[27] Note that the original *PKB* measures had been previously devised by RWS, the provinces and the water borads, with expert assistance from Deltares (van Middelaar, 2014).

Blokkendoos. On occasion, some members of the regional working group also made use of an additional interactive design tool to assist in new measures design and refinement: the MapTable (Hazenoot, 2014).[28]

From the catalogue of possible spatial measures, it then became the task of the regional working group to determine (again with wider municipal feedback) the measures to be included in the maximum likely spatial strategy. The province wanted to commence discussions by focussing on a few key large measures; those that would lower water levels significantly at key river bottlenecks (van de Pas, 2014). This was a very different way of thinking to what had occurred during the *PKB* programme. Given the DPR strategy was considering a much longer-term time horizon, the province felt this provided an opportunity to consider more controversial measures with larger physical impacts on their surrounding areas. Under the *PKB* programme – which focussed much more on shorter-term planning (i.e. to 2015) – there had been little provincial appetite for contraversial measures as it was felt that the necessary community support would have been too difficult to garner (van de Pas, 2014).[29] Consequently, the 'backbone' principle was born, providing a focus for the formulation of the likely spatial strategy. The six key measures that comprised this potential strategy 'backbone' included (Provincie Gelderland, 2014):

- Providing retention behind the dykes at Rijnstrangen (~20cm water level decrease)
- Increasing the width between the dykes at Ooijpolder (~20cm water level decrease)
- Creating a secondary 'green river' flood channel across the large river bend at Varik-Heesselt (~45-52cm water level decrease)
- Increasing the width between dykes at Brakel in combination with a secondary channel in the Ruyterwaard (~18cm water level decrease)
- Increasing the width between dykes at Werkendam (~45cm water level decrease)
- Reconnecting the Steenenhoek Canal to the Merwedes (including dyking) in combination with a new Sliedrechtse Biesbosch channel across to the New Merwede (~14cm water level decrease)

To these 'backbone' measures, other measures that induced additional (albeit reduced) water level savings were inserted into the likely spatial strategy.

Having determined the two maximum likely strategies (dyke improvements and spatial measures), the task for the regional working group turned to one of consensus building and negotiation in the formulation of the final VKS. In general terms, the province was the principal proponent for the spatial strategy, and the water board for the dyke strategy. Wider municipal feedback on working group proposals was again sought, and it was also during this phase that the KBG could also review strategy proposals and provide its feedback directly to the DPR Rhine Delta Steering Group. The steering group then cast its decision on the preferred strategy, with these determinations informing higher-level DP decisions taken in the Hague (de Hartog, 2014) (Figure 22).

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[28] The MapTable is a large interactive touch screen device that can be used to design land use changes for riverine environments. It combines an existing GIS map base with underlying hydrodynamic models. It is expressly designed for stakeholder use, as stakeholders can sit together around the table, collaboratively propose, discuss and design possible riverine land use changes (e.g. relocating a dyke, installing a new bypass or green river, etc.) and then have the water level effects of these changes calculated within 10-15 minutes. Land use changes are physically 'drawn' into the model with styli, and users can change input dimensions and key parameters for these (e.g. dyke levels, channel and floodplain resistances, etc.). Naturally it is a tool with the potential to accelerate measures development activities considerably. See http://www.maptable.nl/maptable.html.

[29] This was the main reason most of the measures selected under the *PKB* programme were of a technical nature and focussed in the summer bed.

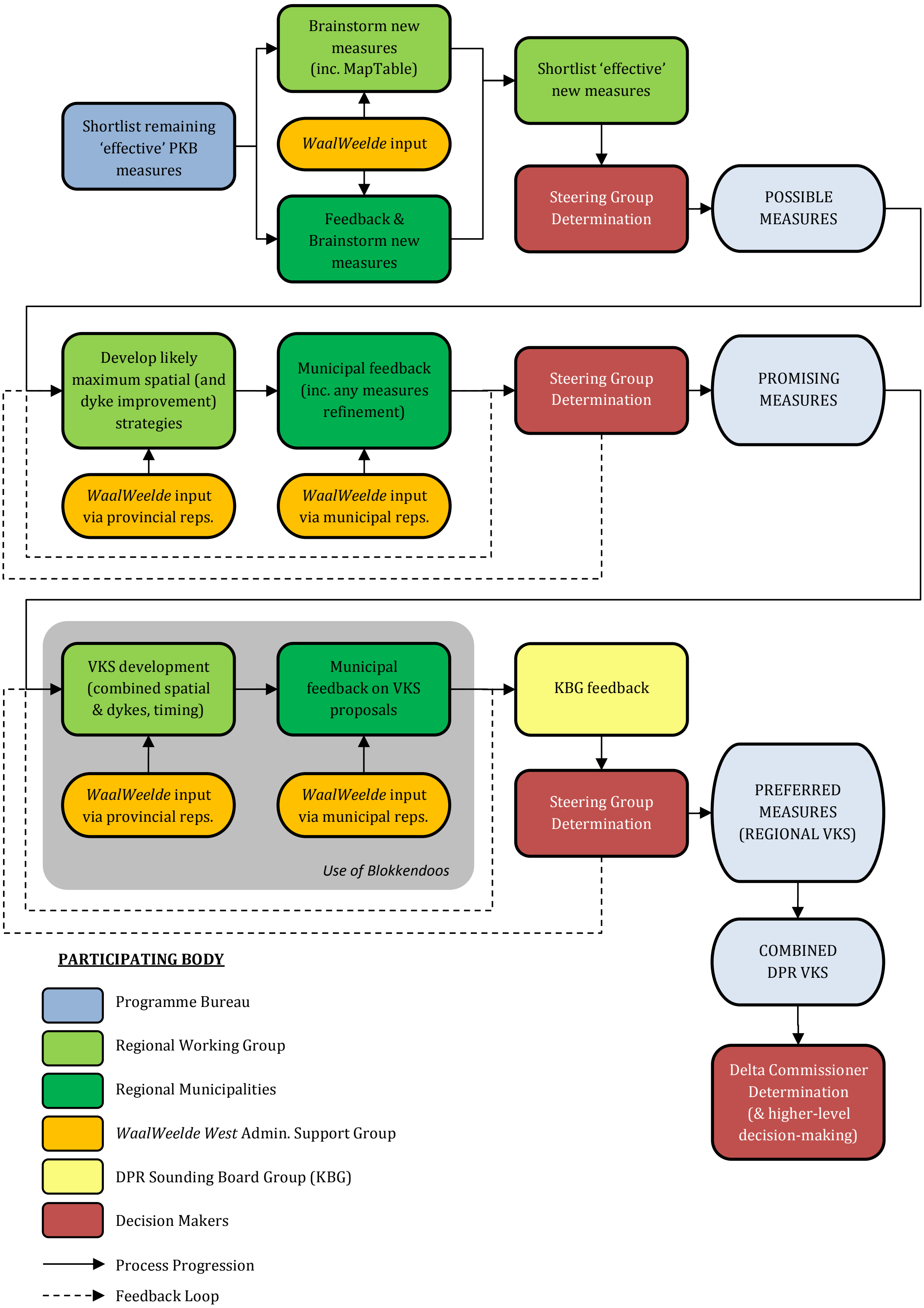


Figure 22: Measures development and strategy formulation in the DPR

10.1.2.2 Bottom-up Processes (WaalWeelde West)

a) Measures Development and Strategy Formulation

As indicated in Figure 22, opportunities existed throughout the DPR strategy development process for input from the concurrent *WaalWeelde West* processes. *WaalWeelde West* input largely occurred within the regional working group via provincial representatives and in the wider regional group via a municipal representative involved in both processes. However, the informing *WaalWeelde West* processes (Figure 23) were much more inclusive than their DPR equivalents, in that they involved the willing collaboration of a much wider array of stakeholders at higher levels of participation.

The key to understanding measures development in *WaalWeelde West* is to comprehend that spatial measures alternatives could be classified as being either ‘Blue’, ‘Green’ or ‘Red’ (van Middelaar, 2014). ‘Blue’ alternatives were simply those that were most efficient in reducing water levels. That is, they were solely focussed on the water safety objective and formed the basis for their ‘Green’ and ‘Red’ alternatives. ‘Green’ alternatives were those that took the base ‘Blue’ measure and modified it towards more nature and environmental outcomes. ‘Red’ alternatives took the ‘Blue’ alternative and modified it towards more residential development, industrial or recreational outcomes. ‘Red’ and ‘Green’ alternatives would typically lead to less water level reductions as compared to their pure ‘Blue’ counterparts, but had the added advantage of meeting additional community-driven non-safety related requirements.

‘Blue’ measures were largely drawn from the leftover PKB ‘catalogue’ or had been developed by provincial officials in consultation with expert advisors.[30] From these measures, the expert advisors then developed a preliminary optimised ‘Blue’ strategy for the *WaalWeelde West* section of the river. Members of the ‘4B’ Working Groups/*spiegelgroep* then collaborated in workshops to develop ‘Red’ and ‘Green’ alternatives to the favoured ‘Blue’ measures. In these workshops, the interest groups and other stakeholders most concerned with each ‘colour’ would collaborate in the development of those alternatives (van Middelaar, 2014). Nature and environmental groups were involved in the development of the ‘Green’ alternatives, whilst local businesses, industries and recreational organisations were involved in developing ‘Red’ alternatives.

Following these developments, open informal public consultation meetings were held for interested community members to attend (van Middelaar, 2014). At these workshops, members of the public could find out key information about each of the measure alternatives directly from the various ‘4B’ sectoral ‘specialists’ who had helped design them. The key to these sessions was to not simply present a proposed plan, but to rather engage the public in a series of two-way discussions with individuals and small groups about each alternative. The public participants in these meetings were then asked to cast a vote for their preferred alternative for each floodplain measure, be it ‘Blue’, ‘Green’ or ‘Red’. Thus, the sessions were not simply an opportunity for the public to obtain information about the proposed alternatives, but also an occasion for the *spiegelgroep* and project team to gather vital information on the community’s own concerns and development preferences (van Middelaar, 2014). These preferences, along with those of the *spiegelgroep*, would then be presented to the *WaalWeelde West* Steering Group to assist in the selection of the preferred alternatives for the Draft Preliminary Structural Vision.

[30] Note that Gelderland Province engaged the same expert advisors for both the DPR and *WaalWeelde West*.

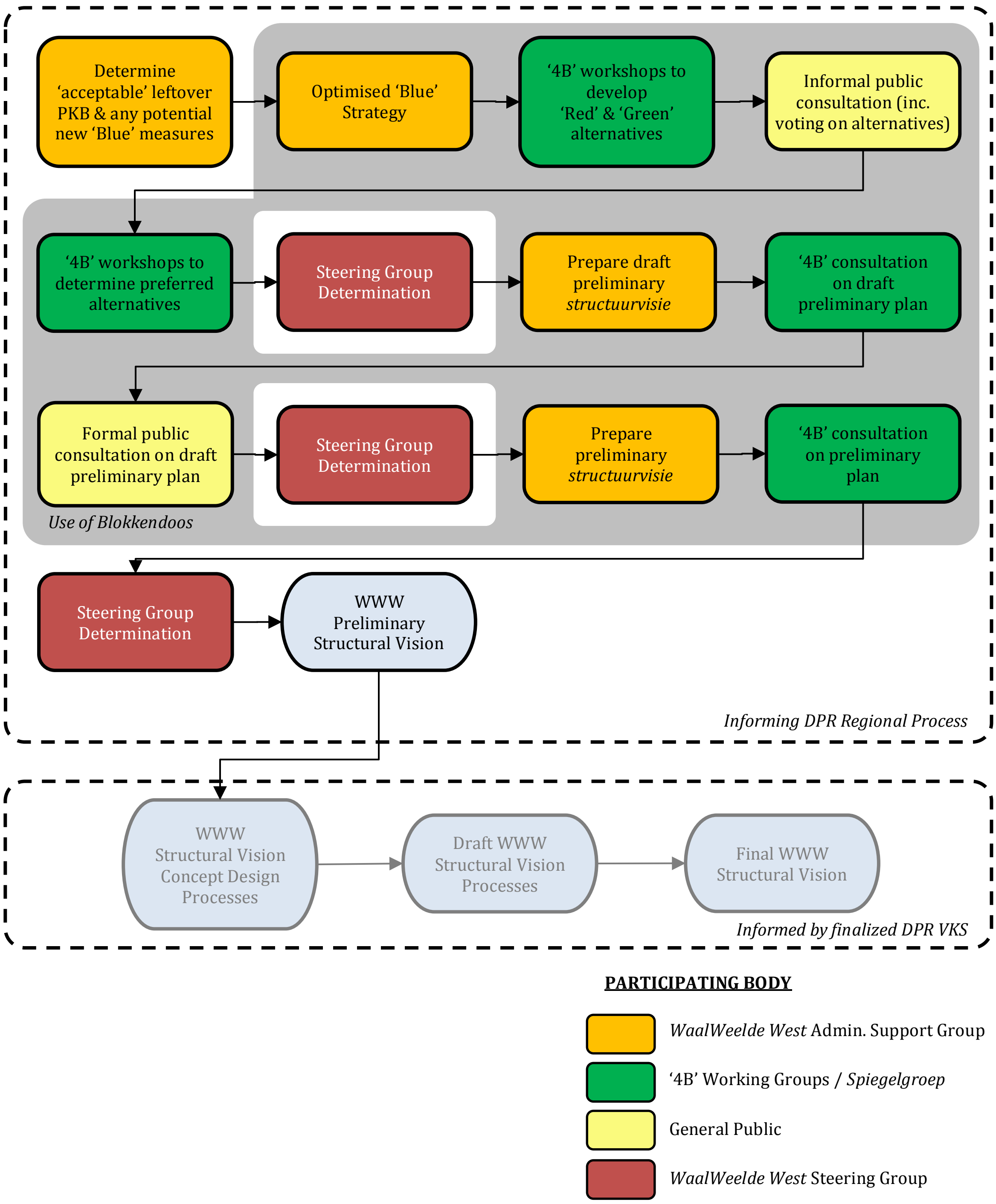
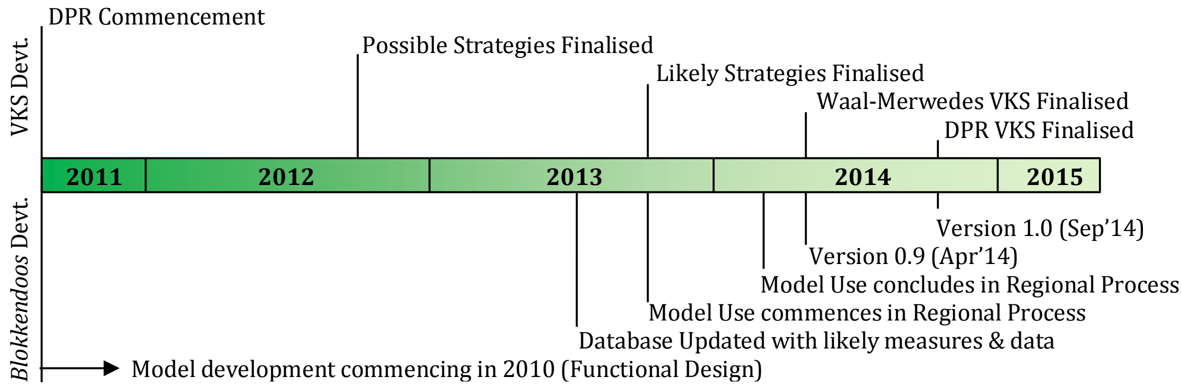


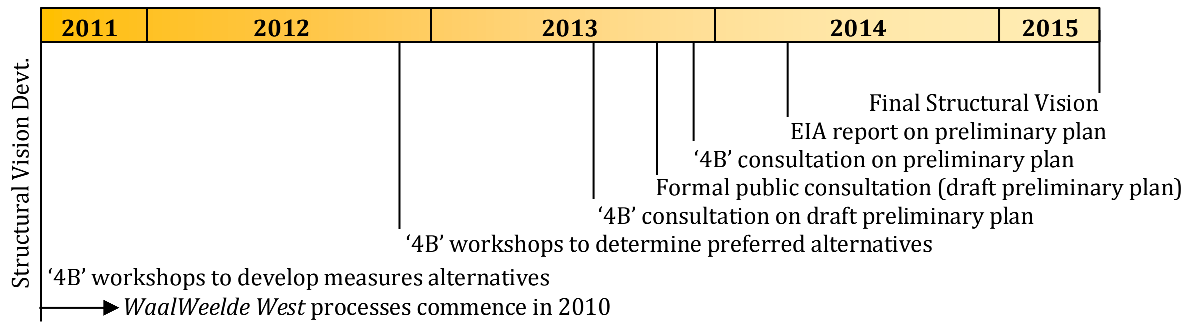
Figure 23: Structural Vision formulation in *WaalWeelde West*

Several rounds of public and '4B' consultation followed for each of the Draft Preliminary and Preliminary Structural Visions, which were in turn to be followed by further consultative processes to refine the vision into its final form, including the necessary Environmental Impact Assessments (WaalWeelde, 2015; WaalWeelde West, 2013).

In terms of the integration of *WaalWeelde West* planning processes into the DPR, it logically would have been best if the Structural Vision could have been finalised prior to the completion of the Waal-Merwedes VKS, and its final outputs directly incorporated. Unfortunately, neither



(a) DPR



(b) *WaalWeelde West*

Figure 24: Indicative programme timelines for (a) the DPR, and (b) *WaalWeelde West*

the timing nor the more top-down DPR planning approach permitted this. This resulted in VKS formulation processes overtaking those of *WaalWeelde West* (van Middelaar, 2014), which occurred following the preparation of the Preliminary Structural Vision (Figure 23). To help illustrate this, Figure 24 provides an indicative timeline for each of the DPR and *WaalWeelde West* processes considered in the preceding sections.

10.1.3 Model Use in the Approach

Use of planning kits in each of the DPR and *WaalWeelde West* differed somewhat. As previously indicated, the redeveloped *Blokkendoos* was principally used in the DPR during its final phase to determine the preferred measures for inclusion in the finalised VKS. Although the tool had been specifically developed with stakeholder use in mind, it transpired that the key stakeholders involved in the regional processes were largely content to leave its direct use to their contracted expert advisors. These advisors would then undertake the majority of *Blokkendoos*-supported analytical work 'behind the scenes', before using the instrument to present their findings to the regional working group for discussion. This is not to say that provincial, water board, municipal and other stakeholders were not exposed to the *Blokkendoos*, but rather that its use during any collaborative workshop sessions was mediated by experts and used primarily as a communication aid to test and justify strategy choices. Moreover, such mediated use predominantly occurred with the regional working group, and not with the wider group of municipal representatives. The latter would simply be presented with model outputs from the latest working group proposals. Outside of these regional workshops, some stakeholders (including the two municipal respondents) did report using the model infrequently to check proposed strategy effects. But they never used the *Blokkendoos* to develop their own independent strategies (Seuren & Klerkx, 2014). Members of the DPRPB Waal and Rhine Estuary river team similarly made use of the model in this way (Hazenoot, 2014; Neefjes, 2014; Overmars, 2014). KBG and Steering Group members were never directly exposed to the model. Rather, they were simply presented with its distilled results and graphical outputs in summary-style reports prepared by the ABG in advance of their meetings (Boelhouwer, 2014; de Hartog, 2014).

In *WaalWeelde West*, the redeveloped version of the *Blokkendoos* was little used due to its not yet having been developed. Instead, the province's expert advisors developed a smaller standalone model version (the *WWW Blokkendoos*) more in the vein of the earlier *PKB* model (van de Pas, 2014). As in the DPR, all direct model use was by expert advisors, either the provincial advisors or those engaged by the municipalities (van Middelaar, 2014). However, the exposure of other stakeholders to its indirect use was much wider than in the DPR. For example, it was always present and projected during the '4B' design workshops. Participants would refer to the model if they wanted to know the effects of turning off a particular 'Blue' measure (van Middelaar, 2014). Similarly, the model was used during the informal public consultation sessions, where again it would be projected on a screen for interested members of the public to interrogate the hydraulic effects of the various alternatives (van Middelaar, 2014). Provincial respondents also reported having used the *WWW Blokkendoos* as a communication tool in other consultative *spiegelgroep* meetings to provide members with expert-assisted explanations of river behaviour and responses to various spatial measures (Seuren & Klerkx, 2014). However, as with their counterparts in the DPR, *WaalWeelde West* Steering Group members were never exposed to the model, aside from any summarised presentations of its results in received advice.

Four primary reasons were cited as to why expert advisors predominantly mediated model use in both programmes, and why non-expert DPR stakeholders did not make greater use of the modelling tool explicitly redesigned for their direct use. First, provincial representatives were keen to point out the proposed strategies constituted official advice, and they had to be sure that these strategies were founded upon a sound technical basis. Relying on experts therefore safeguarded provincial stakeholders against any issues emerging relating to the inclusion of individual measures. Several stakeholders were keen to point out that to formulate a robust spatial river strategy, direct model users required a fundamental technical understanding of how the river behaved as a whole; what exactly was meant by each different type of spatial measure; and how each of these functioned to reduce water levels. For example, the expert regional advisor indicated that some municipal proposed changes to his initial strategy – although resulting in an analogous water level effect – would have resulted in a less effective strategy in terms of its ability to combat seepage. Hence, even though stakeholders acknowledged the model was able to simplify many complex system processes into a single water level line, they nevertheless recognised that sufficient technical knowledge regarding these complex processes was necessary for robust strategy design.

The second factor stakeholders attributed to minimal direct stakeholder use of the model related to the time pressures of the DPR. As one pointed out, although the earlier *PKB* programme had allowed approximately 2.5 years for stakeholder-based strategy planning processes, the DPR demanded stakeholders develop a comparable strategy within a single year. This naturally meant that strategy-formulation processes needed to be sped up, which resulted in an increased need to engage expert advisors who could complete the technical analysis more quickly. Related to this point, the redevelopment of the *Blokkendoos* also took somewhat longer than had been initially planned, further limiting the available time remaining to stakeholders to explore and model potential strategies.

Third, several stakeholders questioned the user-friendliness of the model interface for non-technical users. Despite only needing basic computer skills to navigate around the model, stakeholders reported difficulties with the model related to the fact that one needed to be very precise when clicking on the measures squares in the selection chart and that it was reasonably easy to select/deselect unintended measures. Similarly, with so many measures included in the model (as well as different alternatives for each measure, in the case of *WaalWeelde West*), users needed to have a solid knowledge of which precise measure was the most up-to-date version, or which was the correct alternative to select. Naming conventions and measure reference codes often did not help in this regard, as some were simply given an additional number or a letter suffix to the base measure. The orientation of the water level graph in relation to the GIS map below was yet another cause for criticism, with several stakeholders suggesting that it would be better if the graph could have been orientated with the downstream direction on the left; that is, flowing in the direction of the GIS map below. Stakeholders found it a little confusing having the two images back-to-front. A DPRPB member also suggested that less-technical stakeholders could not easily understand the technical terms and abbreviations used in the interface.

Finally, one respondent suggested that the simple reason the model was little used by stakeholders directly related to the fact that one needed to access it using valid login credentials obtained from the DPRPB. Even though any stakeholder could request a login in theory, the simple addition of this step was perhaps enough to discourage many from independently engaging with the model.

10.1.4 Skills and Knowledge Needed in the Approach

10.1.4.1 Stakeholder Skills and Knowledge

The preceding section touched on the technical knowledge respondents felt was necessary to use the *Blokkendoos* independently. As the majority of model use the in the DPR was mediated, stakeholders did not need to possess this knowledge; the engaged experts could provide the necessary explanations. Nevertheless, other stakeholder skills and knowledge were required for participation in DPR forums.

The advantage and simplicity of the water level graph made it extremely easy for stakeholders to understand technical *Blokkendoos* outputs (van de Pas, 2014). Yet stakeholders still needed to be able to understand and recall a couple of conceptual principles to effectively contribute to discussions. These were that the hydraulic effects of most measures would be experienced upstream, and that the further downstream a measure was located, the more its effects would be experienced in the Netherlands (Hazenoot, 2014; Neefjes, 2014; Overmars, 2014; Seuren & Klerkx, 2014; van Middelaar, 2014). A water board representative was also keen to point out the usefulness of stakeholders remembering that piping reinforcements could not be delayed for many dykes (Kremer, 2014). In general, regional group representatives from RWS and the water board retained this type of technical knowledge as a matter of course, but this was not necessarily the case for the spatial planners from the province and the municipalities. Likewise, other less-involved, non-technical stakeholders found it difficult to grasp some of this information (e.g. members of the KBG, *WaalWeelde West spiegelgroep*, citizens, and even members of the steering groups).

Aside from an ability to grasp technical concepts, participating stakeholders in the regional groups needed to possess the necessary local knowledge regarding their region, communities and floodplain areas. It was also important that stakeholders could effectively communicate their perspectives in DPR forums (Overmars, 2014). Participating actors likewise benefitted from displaying openness, tolerance and flexibility in relation to accommodating others' perspectives and thinking beyond the scope of their own interests. It was particularly important for the more technically-minded actors involved to understand that water safety measures were not just about water (Seuren & Klerkx, 2014). Others also indicated that an understanding of DPR and government decision-making processes at all levels was of particular benefit (Hazenoot, 2014).

10.1.4.2 Organising Team Skills

The members of the DPRPB technical team obviously needed to possess the necessary technical skills to redevelop and maintain the *Blokkendoos*. Hence, components to their collective skillset included database management and GIS skills, as well as the necessary knowledge of hydrodynamic modelling to populate the model database. Given the decision to survey previous model users for feedback on functional improvements, knowledge acquisition and the ability to synthesize and translate this information into meaningful interface enhancements were additional skills required.

The DPRPB river teams more relied on process management, communication and facilitation skills to assist the regional process. This was particularly the case within the regional working group, where most negotiations between the various key stakeholders occurred. In addition to these skills, river team members needed to possess technical knowledge and social skills analogous to the collaborating and participating stakeholders outlined above. Most importantly, they also needed to demonstrate a capacity to be sensitive to the local concerns of the various municipalities, and needed to be well equipped to help resolve potential conflicts that could emerge in opposition to contentious measures.

10.1.5 Means

As the DPR formed part of a much wider programme, it is difficult to establish the precise resources required to undertake the formulation of the VKS. Needless to say, considerable time and financial resources were demanded of all of the key actors involved. As previously illustrated in Figure 24, the DPR ran over a period of 4 years. An initial 1-2 years consisted of preparatory DPRPB tasks including process strategy design/task setting and model development. In 2012, the regional processes also commenced, which allowed approximately 2 years for the cataloguing of possible measures and the subsequent shortlisting of likely measures and strategies. This was followed by an additional year of collaboration and negotiation to formulate the preferred strategy (Schielen & van den Aarsen, 2014). During this time, the DPRPB was staffed with a mixture of full- and part-time staff, and the regional processes included approximately 40 people from all institutional stakeholders distributed across the six DPR regions (Beurskens, 2015). Programme costs were in the order of EUR 3 million/year, with one third of these being attributed to finance the DPRPB. Total direct costs for the development and maintenance of the *Blokkendoos* were in the order of EUR 700,000 (Kroekenstoel, 2015).

By way of comparison, programme timing in *WaalWeelde West* commenced at the end of 2010 with its first integrated '4B' workshop, and it took approximately 3.5 years for the preparation of the preliminary Structural Vision (WaalWeelde West, 2013). Finalisation of this was expected to take an additional 1-1.5 years in the wake of the finalised DPR VKS (WaalWeelde, 2015) (Figure 24). The costs for this programme are not known to the author.

10.2 Generalised Model-Supported Collaborative Planning Approach

A complete summary of the CM approach as it was applied in the DPR – synthesising the information detailed in the preceding sections – is tabulated in the following pages according to the analytical framework (Table 10). To further assist others in decisions whether to apply a similar approach in other situations, the approach can be summarised as follows:

A Model-Supported Collaborative Planning approach can be applied in both unstructured and semi-structured contexts where significant disagreements over values and norms are in existence. Increasing technical knowledge certainty is not a principal concern of the approach; in which case its applicability to completely unstructured settings may require additional processes to generate knowledge consensus. The approach is very much focussed towards the preliminary phases of a planning process, when many competing strategies and alternatives are being considered for their inclusion in later planning phases. It relies upon key institutional stakeholders collaborating in planning workshops, however, avenues for the participation (and preferably collaboration) of non-institutional stakeholders to inform and influence their decision-making is an additional feature. Stakeholder interactions in these forums are intended to facilitate collaborative learning and help generate compromise strategies. A broadly cooperative institutional and decision-making context is thus also central to applications of the approach. Institutional stakeholders in particular must not only be willing participants, but must also demonstrate a willingness to be open to other stakeholders' needs and interests, and be committed to formulating compromise solutions.

Given such conditions, the Model-Supported Collaborative Planning approach is exemplified by its multi-level participation for a wide variety of stakeholders with different backgrounds, skills and knowledge. These participate in a series of heterogeneous groups, broadly structured according to the 'Circles of Influence' model. Key institutional stakeholders collaborate most in co-designing workshops, whilst less-involved stakeholders are restricted to discussing prepared strategy proposals. That being said, the author would encourage raising the level of participation for these latter stakeholders also to co-designing levels (to be argued further in the following chapters). Decision-making powers rest with elected officials serving at all institutional levels. Although a FABE form of CM, the timing of any stakeholder involvement in modelling activities is focussed most towards the 'Back-End'. That is, stakeholders mainly take a pre-prepared model and use it to simulate various policy strategies. However, stakeholder acceptance for the included measures in the model is a critical consideration in the approach. For this reason, stakeholders are also involved in prior activities to develop and refine these measures.

The approach is well served by simulation models that are DiSSs; that is, primarily targeted at supporting discussions that inform later decision-making. It may be these models comprise only one of many inputs informing decisions. Reflecting this, the models used within a Model-Supported Collaborative Planning approach may be less focussed on the absolute accuracy of their simulated system processes. Rather, they should be targeted towards their abilities to stimulate stakeholder discussion and learning about measures effects, generating their outputs quickly. Stakeholders are the intended direct users of the model, however its use can also be mediated or restricted to experts if these stakeholders should prefer. Such use of the model can occur either during interactive group workshops or independently. To enable direct stakeholder use, model interfaces should be kept as simple as possible, and require no more than basic computer skills to operate.

As per other CM approaches, the organising team must demonstrate the requisite facilitation, knowledge acquisition, modelling, and process management skills to bring about the broad success of the approach. Finally, the approach is predicated upon sufficient availability of stakeholder resources (largely time, but also financial) to participate continuously in its potentially extensive planning activities.

Having broadly defined the Model-Supported Collaborative Planning approach, the next chapter reflects upon stakeholders' experiences of the approach as it was applied during the DPR. In particular, these consider the abilities of the approach to meet its objectives as well as achieve any of the collaborative benefits of CM.

Table 10: Summarised analysis of the Model-Supported Collaborative Planning approach according to the analytical framework

	CONTEXT AND APPLICATION					
	Problem Type					Domain
	Structure			Scale of Action	Time Horizon	
	Structured	Semi-structured	Unstructured		# years	
DPR (General)		Semi-structured (Disagreement) Scientific knowledge is largely uncontested, but stakeholders disagree about the types of measures to implement	Unstructured (on occasion) Stakeholders contesting the scientific basis for the DPR assignment (e.g. size of predicted discharge increase)	Local - National. (Actions determined at scale of a river reach) Smaller local scales possible (e.g. WaalWeelde West), as well as larger regional scales (e.g. Waal-Merwedes)	Medium - Long: 15-85 years	Flood Risk Management, Spatial Planning, Adaptive Delta Management
Circle A: Organising Team (DPRPB)						
Circle B1: Regional Working Group						
Circle B2: Wider Regional Group						
Circle C: Information & Feedback Group						
Circle D: Decision Makers						

Table 10: Summarised analysis of the Model-Supported Collaborative Planning approach according to the analytical framework (continued)

	CONTEXT AND APPLICATION				
	Decision level			Decision-making context	
	Operational	Management	Planning & policy	Cooperative	Competitive
DPR (General)			Planning approach focussed on strategy formulation, utilising a rapid assessment tool to compare effects of large numbers of potential spatial river measures.	Cooperative (i.e. especially for those most heavily invoved in the processes). Stakeholders cooperating to develop a joint river strategy.	
Circle A: Organising Team (DPRPB)				x	
Circle B1: Regional Working Group				x	
Circle B2: Wider Regional Group				(x) (WaalWeelde)	
Circle C: Information & Feedback Group				(x) (WaalWeelde)	
Circle D: Decision Makers				x	

Table 10: Summarised analysis of the Model-Supported Collaborative Planning approach according to the analytical framework (continued)

	SPECIFIC USE					
	Participatory modelling purpose					Planning or Managmeent Cycle Phase
	Decision-making	Collaborative Learning		Mediate	Model Improvement (quality, acceptace, integration)	
		Social learning	Shared learning			
DPR (General)	*Blokkendoos* is a Techncial Discussion Support Tool designed to aid in strategy decision-making processes.	Social Learning for Lower Participation Levels. KBG learning about areas of common interests, etc. Potential to be *Blokkendoos* -supported	Shared Learning for Higher Participation Levels. Organising Team also learn from regional stakeholders about acceptable measures. Stakeholoder Participants learn about acceptable measures and comparative effects of measures.		Building acceptance for proposed measures. Inclusion of Stakeholder-developed measures also allows for integration of cross-sector perspectives	Development Phase: Preliminary analysis of hydraulic effects. Initial analysis already carried out, and final detailed analysis of strategies to be subsequently modelled in full modelling packages. VKS was adaptable and flexible and subject to change in future. Included analysis simply to prove the strategy was possible.
Circle A: Organising Team (DPRPB)	x		x			
Circle B1: Regional Working Group	x		x		x	
Circle B2: Wider Regional Group	x		x		x	
Circle C: Information & Feedback Group	(WaalWeelde)	x	(WaalWeelde)		(WaalWeelde)	
Circle D: Decision Makers						

Table 10: Summarised analysis of the Model-Supported Collaborative Planning approach according to the analytical framework (continued)

	INFORMATION HANDLING						
	Model type		Modelling tool / Software platform	Information type	Deltvery Medium		Simulation Time
	Model System Focus	Simulation / Conceptual			Virtual / Web	Face-to-face	
DPR (General)	PSM	Simulation	*Blokkendoos*. Database tool for cumulative calculation of combined measures effects. Founded on Spreadsheet and GIS capabilities. Also information provision capabilities (factsheets).	Complex Processes	x *Blokkendoos* made available to users over the internet for use in own time.	x Although not used much in this way during the DPR, high potential for collaborative use in interactive workshops.	Seconds
Circle A: Organising Team (DPRPB)							
Circle B1: Regional Working Group							
Circle B2: Wider Regional Group							
Circle C: Information & Feedback Group							
Circle D: Decision Makers							

Table 10: Summarised analysis of the Model-Supported Collaborative Planning approach according to the analytical framework (continued)

	STAKEHOLDER INVOLVEMENT						
	General Classification		Stakeholders Involved			Model Users	
	Participatory	Collaborative	Stakeholder	Minimal knowledge & skills	Background	Direct / Indirect (i.e. mediated)	Mimimum Skills
DPR (General)	Most lower-level participants in DPR forums invited in a top-down fashion to participate at middle levels of participation. Lower levels of willingness to become involved.	National & regional water governance organisations involved at high levels of participation. Willingness to cooperate amongst this group. Autonomy to determine how other stakeholders participated.	Refer Below	Refer Below	Refer Below	Refer Below	CG However some technical knowledge required to understand model inputs and outputs
Circle A: Organising Team (DPRPB)		x	DPRPB Tech Team DPRPB River Team	KT	River/GIS Experts, Spatial Planning, Dyke/Water/River Management, Policy Makers	Direct	CS CG
Circle B1: Regional Working Group		x	Province WB RWS	KR / (KT)	Spatial Planning, Dyke/Water/River Management, Policy Makers	Indirect / Direct (minimal) (Predominantly advisor use) High potential for indirect use	CG Refer comment above NOC
Circle B2: Wider Regional Group	x	(WaalWeelde)	Municipalities (WaalWeelde spiegelgroep)	KL	Spatial Planning Water/River Management, Policy Makers (WaalWeelde: Various - environmental, business, recreation)	Direct (minimal) Potential for more direct use High potential for indirect use	CG Refer comment above NOC
Circle C: Information & Feedback Group	x (WaalWeelde)		DPR Klankbordgroep (WaalWeelde Residents)	KR/KL	Various -environmental, business, recreation (WaalWeelde: Citizens)	Potential for direct use High potential for indirect use	CG Refer comment above NOC
Circle D: Decision Makers	N/A	N/A	DPR Steering Group (WaalWeelde Steering Group)	KR/KL	Politicians	Potential for indirect use	NOC

KE: Expert Knowledge & Skills
KT: Technical Knowledge & Skills
KR: Regional Knowledge & Skills
KL: Local Knowledge & Skills

CS: Specialist Computer Skill
CG: General Computer Skills
NOC: No Computer Skills

Table 10: Summarised analysis of the Model-Supported Collaborative Planning approach according to the analytical framework (continued)

	STAKEHOLDER INVOLVEMENT			
	Participation mode			
	Only modellers (NOP)	Individuals (IND)	Group	
			Homogeneous interests (HOM)	Heterogeneous interests (HET)
DPR (General)	Refer Below	Refer Below	Refer Below	Refer Below
Circle A: Organising Team (DPRPB)	x All model construction work except measures development	(x) Occasional individual model use		x Dominant mode of DPR activities
Circle B1: Regional Working Group	x Expert Advisor conducting much of the modelling and analysis work	(x) Occasional individual model use	x Individual stakeholder group measures development and strategy formulation activities	x Dominant mode of DPR activities
Circle B2: Wider Regional Group		(x) Occasional individual model use	x Individual stakeholder group measures development and strategy formulation activities	x Dominant mode of DPR activities
Circle C: Information & Feedback Group			x Individual stakeholder group strategy review activities	x Dominant mode of DPR activities
Circle D: Decision Makers				x Dominant mode of DPR activities

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Table 10: Summarised analysis of the Model-Supported Collaborative Planning approach according to the analytical framework (continued)

	STAKEHOLDER INVOLVEMENT						
	Level of involvement						
	Ignorance	Awareness	Information	Consultation (feedback)	Discussion (advice/ recommendations)	Co-Designing (ownership)	Co-Decision-Making (empowerment)
DPR (General)	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below
Circle A: Organising Team (DPRPB)					x Strategy formulation (River Team)		x Model Functionality, Interface & Hydrodynamic Modelling (Tech Team)
Circle B1: Regional Working Group						x Measures and Strategy (with expert assistance)	
Circle B2: Wider Regional Group					x Strategy formulation	(x) Measures design (WaalWeelde measures & strategy)	
Circle C: Information & Feedback Group	(x)	(x)	(x)	(x)	x Strategy formulation (WaalWeelde strategy)		
Circle D: Decision Makers							x Strategy (WaalWeelde strategy)

Table 10: Summarised analysis of the Model-Supported Collaborative Planning approach according to the analytical framework (continued)

	STAKEHOLDER INVOLVEMENT									
	Timing of Participation									
	Data collection	Model definition		Model construction		Model testing and verification	Model use		Development of strategies	Dominant Form
		Model assumptions	Scenarios development	Model building	Model refinement		Provide inputs for model use	Use computer model		
DPR (General)	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	(FA)BE Measures development critical to model functionality.
Circle A: Organising Team (DPRPB)	x	x	x	x	x	x				
Circle B1: Regional Working Group					x Measures development & refinement	x via Model Use	x (Advisor-led)	(x) (Advisor-led)	x (Advisor-led)	
Circle B2: Wider Regional Group					x Measures development & refinement (WaalWeelde measures)		(x) Occasional Use (Advisor-led)	(x) Occasional Use (Advisor-led)	(x) (WaalWeelde)	
Circle C: Information & Feedback Group									(WaalWeelde)	
Circle D: Decision Makers										

Table 10: Summarised analysis of the Model-Supported Collaborative Planning approach according to the analytical framework (continued)

	MODELLING / ORGANIZING TEAM					MEANS	
		Skills					
	Team	Modelling skills	Facilitation skills	Knowledge adquisition skills	Process management skills	Timing	Financial resources
DPR (General)	Refer Below	Refer Below	Refer Below	Refer Below	Refer Below	4 years (Approx. 2,5 years for measures development & strategy formulation)	€ 3 million/yr (approx.) with 1/3 relating to DPRPB and modelling costs and the remaining 2/3 to regional process implementation
Circle A: Organising Team (DPRPB)	DPRPB Tech Team DPRPB River Team	x	x	x	x	Full Time for 4 years	<u>Blokkendoos</u> Software: € 100.000 Modelling Data: € 400.000 Management: € 200.000 <u>General DPRPB Costs (inc. staffing):</u> € 825.000/yr (approx.) All except staffing costs born by the DPR directly. Staffing costs born by contributing stakeholders individually
Circle B1: Regional Working Group			(Province)	(Province)	(Province)	Estimated monthly meetings with considerable background work required	<u>For all 6 DPR Regions:</u> € 2 million/yr (approx.) Costs born by collaborating/ participating stakeholders individually
Circle B2: Wider Regional Group						Estimated bi-monthly meetings with considerable background work required	
Circle C: Information & Feedback Group						1 year KBG met on 4-5 Occasions	Costs born by participating stakeholders individually
Circle D: Decision Makers						2 years DPR Steering Group met on 4-5 occasions	Costs born by each involved institution individually

11 Stakeholder Perspectives on Approach Outcomes

The previous chapter analysed the DPR's Model-Supported Collaborative Planning approach against the analytical framework. This chapter presents a detailed, stakeholder-based assessment of the ability of the approach to achieve its intended objectives, as well as any of the more general outcomes of CM exercises identified in Chapter 3. It is instructive to consider the perspectives of the stakeholders most involved in these processes as it is only by doing so that one can gain and learn from their experiences, and take the necessary steps to improve and develop the approach further. As in the preceding case study, stakeholder comments and opinions have not typically been attributed to specific individuals within the chapter, at the request of several respondents.

In general, one can say that stakeholders were largely positive about the role that the *Blokkendoos* could play in the approach. Most stakeholders considered it a high quality, credible and useful tool, and were particularly enthusiastic about its abilities to enhance measures effects and river system understanding. Stakeholders who came into contact with the model also typically judged it to have sufficiently incorporated local knowledge, leading to improved DPR decision-making. For the most involved stakeholders, they also judged the approach to have generated consensus through effective cooperation and the provision of sufficient opportunities to influence outcomes. However, some lower-level stakeholders were less enthusiastic about the planning approach applied, particularly regarding their levels of influence in the programme. These stakeholders generally felt that a true consensus strategy was never reached, and held that the strategy formulation processes were subjected to biased inputs. Typically, such criticisms followed the 'Circles of Influence' structure of the DPR, with those located further from the centre expressing greater frustration with DPR processes than those more involved. The pressures of the strict time constraints applied to the programme were also widely identified has having significantly limited some outcomes in the programme.

Figure 25 and Figure 26 illustrate the above broad trends in stakeholder perspectives, delineated according to each main circle of influence. As in the previous case study, these graphs neither indicate the comparative extent of any specific stakeholder satisfaction levels for each outcome or condition. Stakeholder perspectives were counted if an outcome was either simply mentioned in passing or qualified further with additional information. The intention of these figures is to simply provide an initial impression of stakeholder perspectives and confirm the broad generalisations presented above. It is not intended to examine these figures in any greater detail immediately here, but the reader may find them useful to refer back to whilst considering the detailed perspectives relating to each outcome, consequence or condition contained in each of the remaining sections of this chapter.

11.1 Improved Decision-Making

All DPRPB and regional working group respondents were enthusiastic about the role the *Blokkendoos* played in stimulating stakeholder discussions and assisting their collaborative selection of spatial measures to include in the VKS. As one respondent noted,

> "The *Blokkendoos* is very helpful in combining all the possible different measures for a river into one compact model. Having all the measures contained within a single model means that you can undertake a good assessment of the river as whole as you switch the

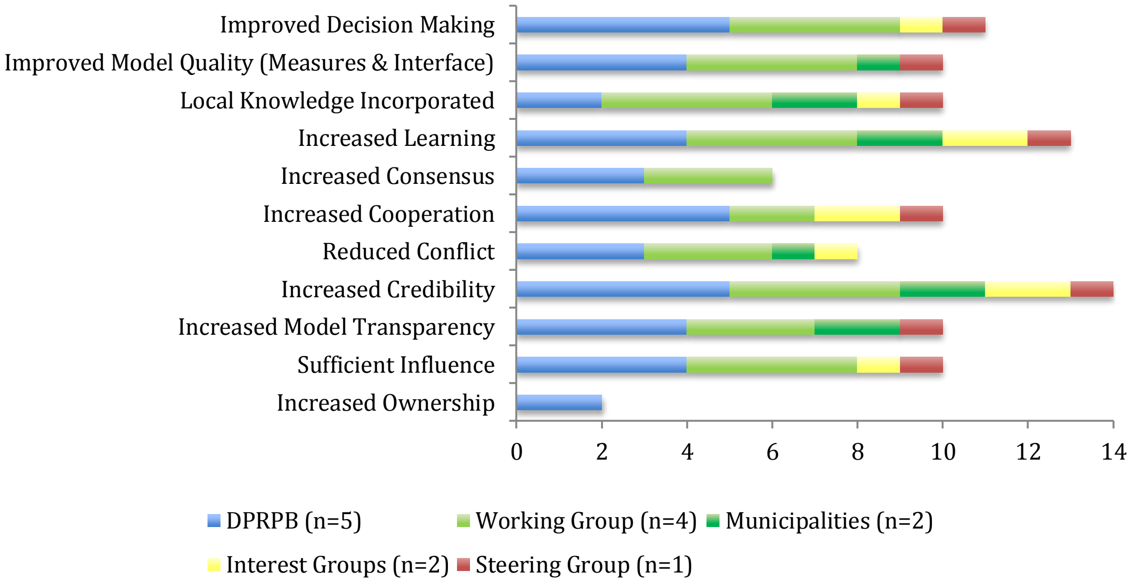

Figure 25: Positive outcomes of the Model-Supported Collaborative Planning Approach in the DPR

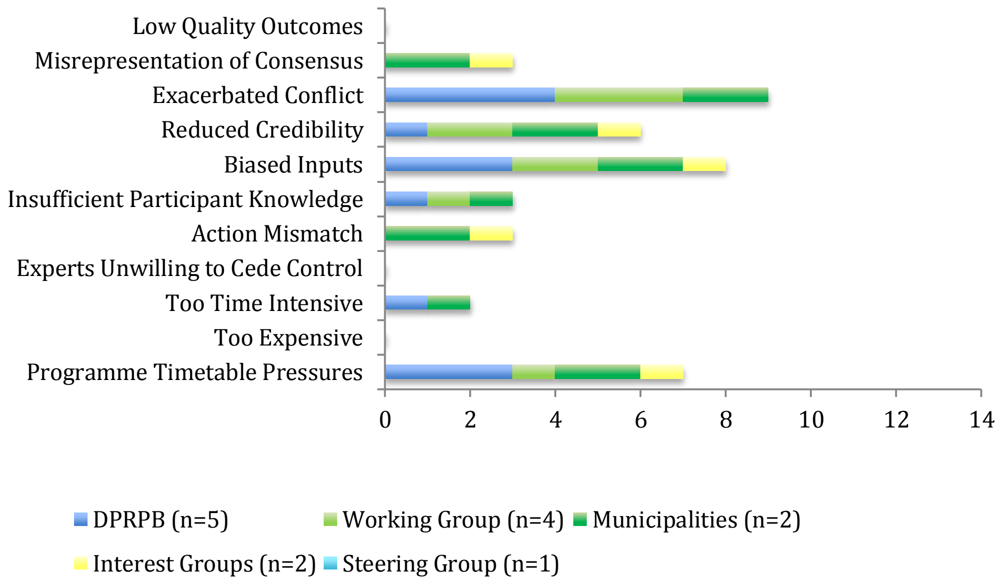

Figure 26: Negative outcomes or limiting conditions of the Model-Supported Collaborative Planning Approach in the DPR

> measures on or off. In doing so, one can better see what happens to the water level in the river when each measure is selected."

The ability of the model to simplify the complicated scientific modelling of physical processes into something easy for non-technical people to understand (i.e. the single water level line) was an aspect of the tool that policy makers particularly appreciated. It allowed these stakeholders to more easily incorporate and factor the necessary scientific information into their deliberations. Another respondent was particularly impressed with the ability to be able to use the tool to plan infrastructure needs against different time horizons. Despite its advantages, a couple of respondents, were keen to stress that the *Blokkendoos* was simply one source of information being considered during VKS formulation, and that its role in the process should not be overstated.

Municipal respondents were less enthusiastic about the virtues of the *Blokkendoos* in assisting decision-making. However, this is likely a reflection of their reduced contact with the model and extra degree of removal from direct VKS measures selection processes. Nevertheless, those municipal stakeholders who used the model generally agreed that it allowed them to gain a better idea about what each measure comprised (via the fact sheets), the effects that it would have on river water levels, and also to establish which measures were the most efficient in terms of costs per lowered centimetre. Any feedback these stakeholders provided to the working group regarding its proposed strategies was therefore better informed by the information contained therein, indirectly assisting decision-making in the working group. Likewise, the mediated provincial/municipal use of the model to communicate any proposed strategies and obtain community feedback during public or special interest group forums (e.g. in *WaalWeelde West*) yielded similar indirect benefits.

11.2 Model Quality and Acceptance

As its primary function was to directly support DPR policy-making processes, the quality of the *Blokkendoos* was of importance to the CM approach. If stakeholders did not believe the instrument provided outputs of sufficient quality for use in strategy formulation, they simply would not have used it (or allowed their advisors use it). Two aspects of the model need to be considered in the analysis of its quality: the quality of the model interface, and the quality of the individual measures comprising its database.

In terms of the model interface, no stakeholders reported experiencing significant issues with it. One advantage the *Blokkendoos* had in terms of its development was that it was building upon an already existing interface many stakeholders were familiar with from earlier programmes. The DPRPB modelling team were essentially working from an already successful template. Many stakeholders were familiar with its outputs and the process of assessing spatial measures according to their comparative water level effects. However, it is important to keep in mind stakeholders made little direct use of the model, so it also makes sense they had few issues with the interface. Even so, respondents still had suggestions as to how the model could be improved. Many of these related to its ease-of-use (covered previously on p.128), and could be implemented if direct stakeholder use of the model were to increase in the future (e.g. the orientation of the water level graph, improved numbering conventions, explanations for any technical jargon used). One respondent also suggested a positive addition to the model would be the incorporation of a comparative risk graph in the *Blokkendoos*. This could illustrate risk impacts for the selected measures package against the existing situation (no measures) and a reference strategy of dyke raising. However, it is important to stress these are all minor criticisms of the model, with stakeholders typically impressed with the latest version of the instrument.

Given their primary use of the model, it is the criticisms from its expert users that perhaps hold greatest currency. The dominant feedback received by the model developers from these users was that experts missed some of the more ‘expert features’ that had been available in previous planning kits but removed from this version. For example, some missed the ability to vary river discharges across a broader range of values than were contained in the two time horizons of the preselected climate change scenario. Similarly, others missed all the additional information that had been contained in the *PKB* and *IVM* model databases (recall, however, that stakeholder model users in these programmes had found this amount of information overwhelming). The expert advisor interviewed in this study also suggested that one feature he had always felt was lacking from all Dutch planning kits was a better spatial interface for measures selection. The redeveloped *Blokkendoos* went some way to rectify this with its increased incorporation of improved mapping and GIS functions; however, this advisor still found that it remained simpler to build a strategy using only the database table. But again, these remained largely minor criticisms of the tool, and the quality of the interface was little questioned or never accepted during the DPR.

For the quality of the developed measures in the model database, most respondents believed the collaborative processes yielded improved and more acceptable measures. This is no more evident than the modellers' testimony that the majority (if not all) measures that made it in to the final VKS were those that had been developed or modified in some way by the stakeholders themselves during the regional process. Respondents outlined that improvements in measures quality were essentially for one of two reasons: that the regional process allowed for the inclusion of local knowledge in measures design, as well as the integration of water safety objectives with broader development objectives. By incorporating local knowledge and perspectives, the proposed measures became more realistic and acceptable to local stakeholders as they influenced what the final measures looked like. Similarly, through stakeholder discussion, measures became more integrated into their surrounding environments. *WaalWeelde West* processes that took the base 'Blue' measures and modified them to correspondingly deliver either 'Red' or 'Green' objectives were often cited as clear examples of this. That being said, one respondent did point out that the acceptability (and hence quality) of all the measures in the model depended upon one's level of participation, with some stakeholders (i.e. working group members, municipalities and *WaalWeelde West* special interest groups) having greater input than others.

11.3 Collaborative Learning

Capacity exists to achieve collaborative learning objectives in the approach, and respondents tended to focus on two distinct types of learning stakeholders could gain. First and foremost, many respondents were quick to point out the ability of *Blokkendoos*-aided processes to communicate to stakeholders the necessary technical information about the river system and the proposed strategies. That is, which sections of the river needed action to be taken, the likely time horizon in which these actions would need to be taken, the various alternative measures that could constitute these actions, as well as their comparative water level reducing effects. As a member of the DPRPB noted, many of the stakeholders involved in the DPR were not river engineers, but rather spatial planners and policy makers. Consequently, a means of translating these technical elements of the DPR assignment was needed, and the Blokkendoos provided such means. By improving stakeholder understanding of the technical dimensions to the problems, another respondent experienced that stakeholder communication about these issues became much easier. Stakeholder exposure to the model had raised their levels of understanding regarding the river and its behaviour.

That being said, two respondents were also keen to point out that in some ways the *Blokkendoos* simplifies the technical dimensions of the problem too much. By reducing analysis and information to the consideration of a single parameter, this can lead to some confusion or errors in understanding. For example, one respondent found that some stakeholders erroneously assumed that by providing room for the river and lowering water levels, river flow velocities would increase, leading to other downstream problems. The *Blokkendoos* did not provide a level of information sufficient to counter these assumptions. Both these respondents identified that to enable increased stakeholder uptake of technical information, a more realistic three-dimensional model would be of better use, where one can visualise the reality of flood flows and the up- and downstream effects of river widening measures.

Aside from any technical learning stakeholders could achieve from exposure to the *Blokkendoos*, many respondents also indicated that stakeholders participating in DPR forums were able to gain a better understanding of each other's perspectives. As one noted,

> "Just by sitting around the same table and talking about these strategies and measures, you get an exchange of thoughts and perspectives, which is useful to facilitate one's own learning about these."

Specifically, a water board respondent indicated that she was able to gain important understandings of the choices municipal stakeholders were being confronted with in the DPR given their particular local situations. Conversely, a municipal stakeholder suggested that he had welcomed the opportunity to gain useful insight into the internal views and operations of other government organisations, such as the province and water board. Also, despite not being exposed the *Blokkendoos* itself during the DPR, a KBG member nevertheless indicated that his many discussions with other KBG members allowed him to learn about each organisation's competing issues and helped determine areas of common interest.

This KBG respondent, however, was also eager to point out that he felt the potential for such social or shared learning was much reduced in the DPR as compared to earlier spatial river planning processes (e.g. during the *PKB* programme). This related most to the essentially minimal role KBG members played in any collaborative planning activities with the institutional stakeholders in the DPR. They were excluded from the regional process where all measures development and measures selection occurred. In addition, other respondents indicated that knowledge of the collaborating institutional organisations perspectives and interests was relatively well known to stakeholders already and that opportunities for social or shared learning were minimal. One was keen to point out that the political ramifications for many of the measures were also known from prior PKB or *WaalWeelde* processes, and community responses could therefore be easily predicted. Similarly, other respondents indicated that often the more local stakeholders were less concerned with the interests and perspectives of others, but simply concerned with the implications of any specific measures for them. That is, a NIMBY mind-set predominated.

11.4 Degree of Consensus

Somewhat echoing respondents' perspectives of the abilities of the model-supported approach to improve decision-making, a clear division emerged in stakeholder responses regarding its abilities to help gain and achieve consensus. Stakeholders involved in the regional working group, all reported that consensus recommendations successfully emerged from their discussions. Indeed, as one of these respondents highlighted, the VKS bears the names of these stakeholders, which they would have disallowed if they did not broadly agree with the strategy. These stakeholders were keen to point out that although working group members may not completely agree with every individual measure included in the VKS, they nevertheless understand the technical, social and political justifications for their inclusion and recognise the selected measures are all reasonable choices. The extensive discussions and negotiations that took place between working group stakeholders were essential in building this consensus, and the *Blokkendoos* was a key technical input to these discussions.

However, for those stakeholders located outside of the regional working group, the ability of the approach to achieve VKS consensus has been much more mixed. Indeed, one could suggest there is a certain misrepresentation of consensus for these stakeholders, particularly for the municipalities whose involvement in measures development and providing strategy feedback was greater. For example, despite local and municipal opposition to several of the large 'backbone' measures, the working group nevertheless included them within the final VKS. One municipal respondent suggested that the VKS decision-making processes were not particularly clear, and that it was often very difficult to track what became of municipal feedback as the 'consensus' position emerged. Even within *WaalWeelde West* communities, which had much greater input than many, municipalities reported losing their sense of influence over the final VKS. Here, a lot of effort had been invested into establishing consensus positions for '4B' stakeholders regarding the Preliminary Structural Vision. Although many of these (typically smaller) measures were then adopted in the VKS, the fact that DPR processes overtook those of *WaalWeelde West* did mean that municipalities felt somewhat forced into accepting the larger, less popular 'backbone' measures regardless of their current established levels of community support.

For the even less-involved KBG, it was suggested that it was simply too difficult for the VKS to attain the consensus of the special interest groups involved given their limited participation in measures selection. They were a limited advisory body only, and as such could only exert a very minor influence over the developed plans. This was in stark contrast to the involvement of the interest groups in *WaalWeelde West*, where the generation of an inclusive bottom-up consensus had been a guiding principle for all '4B' stakeholders.

11.5 Levels of Cooperation

11.5.1 Programme Bureau

All DPRPB respondents generally agreed that levels of cooperation within the DPR were both constructive and enabling to the regional processes. DPRPB members were eager to point out that cooperation within their collaborative bureau particularly improved over the duration of the DPR, as each of its members from the contributing stakeholder organisations got to know each other better. As one highlighted:

> "When you get to know people and their backgrounds better, you gain a better understanding of their actions and reactions, how they think, and what their interests are."

The DPRPB actively sought to encourage cooperation within the bureau through conducting monthly meetings for all bureau staff, in order to provide its members with information regarding the current status in each of the regions, and any technical information that needed to be shared. The explicit aim of these meetings was to improve group knowledge and inter-team interaction and coordination, as this could then filter down to the regional stakeholder representatives. Consequently, another DPRPB member suggested that future inter-agency cooperation and communication between DPRPB members (having returned to their respective 'normal' positions) will now be much more likely to occur.

11.5.2 Regional Groups

Within the regional process, working group stakeholders similarly related that they too believed the stakeholders involved now communicated more than they used to. However, responses from both these and municipal stakeholders suggested that cooperation in these forums could have been better. One municipal respondent related that he noticed that each governance agency tended to "keep to its own island." That is, that they found it difficult to set aside their organisation-specific interests and open up to genuine cooperation. He found this to particularly be the case when discussions tended towards any issues most closely related to the respective responsibilities for each stakeholder. A review of provincial and water board responses illuminates this tendency, in terms of their competing preferences for spatial and dyke improvement measures and a perceived lack of willingness to compromise. For example, a water board respondent suggested:

> "[The water board] felt at times the province was little bit stubborn, and wanted to bring forward ʻtheir' spatial measures in the proposed timing…*WaalWeelde* measures kept being promoted, even though there was not yet sufficient funds allocated to complete them by any level of government."

Whilst a representative of provincial interests outlined:

> "[The water board] was typically always pushing its agenda of improving the dykes… [there was] never much cause to discuss spatial measures with them. They brought their Flood Protection Programme to the table and constantly repeated that the dykes needed to be worked on anyway, and that these works could easily accommodate the new safety standards. In their opinion, providing room for the river was not necessary. This made the relationships between the province and water board a little difficult at times."

Further to the above, *WaalWeelde West* municipalities also suggested that the DPR regional process had a destructive effect on the previously high and effective levels of cooperation that existed between the provinces, water board and municipalities during the earliest phases of *WaalWeelde West*. As this respondent noted, once the DPR came along and started imposing its time pressures, planning constraints and measures selections on these municipalities, it led to their reduced desire to cooperate with the other DPR stakeholders.

11.5.3 Sounding Board Group (*Klankbordgroep*)

KBG members suggested that levels of cooperation within this forum were high and constructive. One member noted a specific example where his organisation was able to actively seek and develop a mutually beneficial common position with Rhine shipping and navigation organisations. Nevertheless, this member was also keen to point out that there was much less collaboration and cooperation in the DPR amongst NGO partners and between these groups and institutional actors than there had been in other programs such as PKB; due simply to the lack of opportunity.

11.6 Conflict Mitigation/Exacerbation

There was capacity for the CM approach to both exacerbate and mitigate instances of stakeholder conflict during the DPR. As most stakeholder respondents noted, the issues under discussion were inherently political. The section above made mention of the competing interests and perspectives of the province and water board. Such fundamental differences of opinion at times led to frustrations emerging in the regional working group. That being said, working group respondents were eager to point out that an advantage of the regional process was that it allowed each of these stakeholders to confront these differences and resolve them through robust discussion. As one noted:

> "It is normal for different organisations to have different interests and to try to advantage these when the opportunity arises. But it is also part of professional conduct to talk and be open about these and then to discuss any competing interests until a consensus is reached."

Perhaps the greatest potential for conflict, however, was between the regional working group and the municipalities – along with their associated local communities – participating in the wider regional process (and especially *WaalWeelde West* processes). Unsurprisingly, local opposition was greatest in those municipalities where each of the large 'backbone' measures was located. These large measures all involved significant riverside land use changes, including dyke relocations (Ooijpolder, Brakel, Werkendam) or the construction of secondary flood bypasses (Varik-Heesselt). These are areas in which people currently live and have built houses and livelihoods, and the implementation of these measures would result in loss of these. A degree of community opposition to these measures was inevitable. Therefore, on the one hand, the participatory approach adopted in the DPR (and *WaalWeelde West*) exacerbated the situation; the local communities came to learn of these proposals and conflict emerged. However, by engaging these communities in the process as early as they did, respondents also noted that the key regional stakeholders were able to maximise opportunities to facilitate community understanding for the technical justifications for these measures, and also to incorporate some community concerns in the final VKS. Indeed, in two of these instances (Brakel and Varik-Heesselt, both *WaalWeelde West* communities), separate additional stakeholder processes (external to the DPR) were even launched, each with its own sounding board group. As one respondent noted, these have resulted in (for example) the Varik-Heesselt bypass remaining a recommended spatial measure in the VKS, but with the proviso that it is implemented as soon as possible so as to provide planning certainty to landowners. In other instances, a respondent recounted that concessions granted for the inclusion of these large measures in the VKS have meant that the final document explicitly stipulates that they remain only 'options', and that they stay subject to further discussion and additional studies to find alternatives.

11.7 Model Credibility

In general, all stakeholders viewed the *Blokkendoos* as a credible and fit for purpose model to aid in DPR planning processes. In terms of its level of accuracy, most realised that it does not return values accurate to the exact centimetre, but more likely within a range of ±5 cm of a 'properly' simulated result. However, one respondent did suggest that in returning results that are notionally accurate to the 0.1 cm, the model perhaps gives an illusion of being far more accurate that it actually is. Nevertheless, all recognised the model was accurate enough to support decision-making at the level at which it was being employed (i.e. during the earliest planning phases). That is, all reported a generally high level of trust in the model and its outputs.

Stakeholders offered essentially two reasons for placing their trust in the model. The first was the role of Deltares and RWS in its development. The second related to the inclusion of the measures that had been developed or modified by the stakeholders themselves. For example, despite a desire to maintain the quality and consistency of the pre-calculation database by completing all hydrodynamic calculations themselves, limited time constraints saw the DPRPB model building team accept some stakeholder-generated modelling results. This therefore allowed for the inclusion of some regional measures alternatives stakeholders wished to evaluate for the VKS that otherwise would not have been present in the model. As noted by a couple of respondents, it was important to be able to demonstrate to other stakeholders that all alternative options had been considered and taken into account during strategy formulation, including any potentially unpopular measures.

That being said, model developers did report that regional stakeholders might have purposefully excluded some more controversial measures from the model database.[31] This related to the fact that some government stakeholders felt that there were some measures that were simply too controversial to be included and that would derail the VKS-formulation process should lower-level stakeholders know they were being considered. In a similar vein, a municipal respondent

[31] Note that these respondents suggested this related more to spatial measures located in the Meuse delta than along the Rhine.

also related his experiences of devising possible measures that were later not included in the *Blokkendoos*. Justification for their exclusion apart from that of 'expert judgement' were never provided to the municipality, such it never really understood why its measures could not be considered during strategy formulation. The regional expert advisor similarly related that he was not always able to get all the various *WaalWeelde West* 'colour' alternatives migrated across to the *Blokkendoos*, as this would have meant that it became too large and unwieldy. The potential implications of such restrictions for stakeholder perceptions of model credibility are clear.

In addition to the above, other smaller issues also had the potential to erode stakeholder confidence in the *Blokkendoos*. Errors in the model database that came to the notice of stakeholders during model use were not conducive to building trust in the credibility of the model (e.g. the selection of a measure returning obviously erroneous water level 'humps'). Equally, a municipal respondent recounted his interactions with DPRPB members who warned him about the accuracy of the model and the fact that it included out-dated measures. To some extent, this eroded his confidence in the validity of the model for the programme. Finally, and on a more fundamental level, a few respondents suggested that the model's credibility – along with that of the developed VKS more generally – could be called into question by opposition stakeholders due to a key underlying DPR assumption: that of the predicted 18,000 m^3/s Rhine discharge in 2100. There is considerable uncertainty regarding the validity of this assumption, both amongst river experts in the Netherlands and those in neighbouring Germany, who do not consider these future flows possible. Even though most stakeholders did not report it as a significant issue at this stage of the process, its potential impacts on any later VKS implementation activities (e.g. in terms of mobilising opposition to the strategy) could yet prove significant.

11.8 Model Transparency

Almost all respondents who had contact with the *Blokkendoos* during the DPR generally found it an easy and transparent tool to understand. Several respondents remarked upon the fact that it is essentially a simple counting model, with one of the model's strengths being its ability to convey and clarify complex river hydraulic knowledge to non-technical laypeople. Others remarked that since stakeholders had developed most of the measures contained within the model, this likewise had the effect of increasing the model's transparency.

However, in terms of actual model construction, all non-expert respondents reported having little understanding of the hydrodynamic modelling undertaken to populate the pre-calculation database. Similarly, one pointed out that stakeholders essentially had to accept 'at face value' the simulation results generated by the *Blokkendoos*, and that it was very difficult to ascertain if there were errors in the pre-calculation database (unless these happened to be glaringly obvious). As there was little way to track model inputs to outputs, model transparency was certainly impacted. Even so, no respondent indicated that they considered this a major issue, or that they would have preferred being more involved in the technical modelling activities to populate the database.

11.9 Influence, Control and Ownership

Stakeholders reported that influence levels in DPR processes essentially reflected the 'Circles of Influence' structure presented earlier in this chapter (Figure 20). That is, all interviewed respondents generally agreed that the DPRPB and regional working group stakeholders exerted the most influence over DPR processes, followed by the municipalities and then the special interest groups and any other stakeholders.

With respects to the DPRPB, stakeholders agreed that its technical team members were able to exert the most influence over the *Blokkendoos*, in so far as it largely determined the functionality of the model and its interface. Furthermore, this team also essentially controlled stakeholder access to the model via the issuance of valid login credentials. Even though access to the model for key government stakeholders was intended to be open, placing it behind a login screen was suggested to have discouraged some stakeholders from accessing the instrument. It also prevented non-government stakeholders from using the model. Provincial representatives were a little disappointed at this as granting these stakeholders access:

> "…would have allowed everyday citizens and other organisations to come up with their own measures package proposals…[Perhaps] the DPRPB did not want all measures options to be up for discussion with all people."

Moreover, community demand for model access apparently did exist. Whenever the *Blokkendoos* was presented in any formal *WaalWeelde West* or 'backbone' measures public forums, some community members would inquire as to how to access the model outside of the forums to explore their own questions regarding the proposed strategy. Model functionality and access aside, most respondents also recognised that stakeholders in the regional groups could significantly influence the content of the *Blokkendoos* database. But again, this reflected the 'Circles of Influence' structure, with the regional working group exerting greater influence than municipalities or other *WaalWeelde West* stakeholders in the wider regional group.

This situation repeated itself with respects to the measures that were selected for inclusion in the VKS. All DPRPB and working group respondents were generally satisfied with the outcomes of the regional process. Indeed, neither of the two main working group protagonists (the province and the water board) assessed that either actor had been able to significantly influence its final outcomes more than the other. That the finalised VKS includes a comprehensive combination of both dyke improvements and spatial measures unquestionably validates these reflections. However, dissatisfaction with DPR outcomes and their level of influence and control emerged in interviews with municipal stakeholder representatives. Indeed, according to one municipal respondent, the municipalities never really had much influence in the DPR at all. He noted that:

> "DPR staff…had already formed a pretty good idea as to the processes and steps to take and the breadth of the questions and problems to put to the municipalities to review. So the municipalities had influence, but not very much. The issue to be addressed was water safety, with discussions not being allowed to venture beyond this boundary… When the process to follow was already laid out, along with the degree to which one could move within this firm boundary, then the room to manoeuvre [and exert influence] was not very large."

WaalWeelde West municipalities could notionally exert greater influence than others given the linkages between their processes and those of the DPR. However, they similarly questioned their power in the DPR, thereby revealing the tensions inherent to the competing top-down and bottom-up approaches of the two programmes. The simple fact that any decisions made in relation to the *WaalWeelde West* Structural Vision could be effectively trumped by those of the DPR led its aldermen to question both the value and validity of their lower-level decision-making as well as whether their communities would hold them responsible for the decisions that were ultimately being taken in the Hague.

Within these municipal reflections, the province was generally identified as the branch of government able to exert the greatest influence over VKS outcomes. However, this may be more a reflection of the greater shared interest between the municipalities and provinces for spatial development as compared to the water board. One factor that municipal respondents did report as having affected their comparative influence in the DPR was whether they held a seat on the

DPR Delta Rhine Steering Group. Only three municipal members represented the Waal-Merwedes region (Tiel, Gorinchem, Werkendam). Neither of these was drawn from any of the *WaalWeelde West* communities, whilst two of them were drawn from locations along the Merwedes. *WaalWeelde West* decision-making processes notwithstanding, when it came to deciding the measures to be included in the final VKS, *WaalWeelde West* municipalities could play no part in this decision. Hence, the Varik-Heesselt and Brakel 'backbone' measures were included in the VKS despite these municipalities not yet having finalised their attitudes towards them. These municipalities had to rely upon the provincial Deputy (the chair of both the DPR and *WaalWeelde West* steering groups) to represent their interests in this regard, yet he would have been most concerned with representing the overarching provincial interests. In contrast, the existence of a Werkendam alderman on the DPR Steering Group enabled this community's strident opposition to its 'backbone' measure play a much more decisive role in the final VKS wording, and the relegation of this measure to a much more 'provisional' status in the VKS.

Exerting even less influence over DPR decisions and processes were members of the KBG. As was pointed out by the respondents from this forum, they never had any role to play in measures design workshops or the selection of any specific measures to be included in the VKS. Rather, their input and influence was restricted to advising on ancillary whole-of-strategy issues such as how best to achieve any overall navigation or nature objectives. Their focus was not so much on the potential impacts of individual measures, and this function effectively served to limit any influence the KBG had over the decision-making process in and of itself. Further eroding its influence, the Dutch parliament had determined that national DPR funds would only be directed towards meeting the water safety objectives of the program. Any costs to meet other more integrated development objectives would have to be paid for by the provinces, municipalities or other organisations themselves. This made it much more difficult for special interest groups (along with the municipalities, for that matter) to integrate their recommendations into the strategies, as they were generally striving for objectives that went beyond the basic safety requirement and whose financing was thus all the more uncertain. A possible reflection of the KBG's perceived lack of influence amongst special interest groups was the relatively little interest such organisations had in becoming involved in the KBG. As noted by one KBG member, active participation in the KBG was limited to 4-5 organisations, a far cry from the more than fifty organisations that had been initially invited to join the forum.[32]

11.10 Existence of other Limiting Conditions

Stakeholders identified four additional conditions that also contributed to limiting the effectiveness of the Model-Supported Collaborative Planning approach. Three of these were in accordance with those outlined in the earlier literature review, but did not generate a significant response from most respondents. First, three respondents suggested that their lack of influence led to an 'action mismatch' with regards to their participation in the programme. Unsurprisingly, these views echoed the concerns and perspectives presented in the preceding section, and were only mentioned by representatives from municipalities or special interest groups. Second, three respondents suggested that limited participant technical knowledge also caused minor issues in some instances. Mainly these related to the technical capacity of spatial planning participants to adequately comprehend the more technical dimensions of the water safety assignment. A DPRPB respondent also suggested that relationships between the bureau's technical and river teams could become strained due to the lack of modelling experience within the latter, who had difficulties understanding the amount of work required to populate the *Blokkendoos* with each new measure. Third, two respondents felt the need to mention that some stakeholders had found the time commitment of the DPR too great. One municipal representative suggested that this commitment was generally beyond the means of smaller municipalities, and a DPRPB

[32] For a complete review of social participation in the DPR KBG, see van der Hoeven (2014).

representative suggested that this might also explain the limited participation of special interest groups in the KBG. Positively, no interviewed stakeholders mentioned that they thought expert modellers were able to exert undue influence over DPR processes, and neither did they volunteer that the programme had cost too much money to implement. A possible explanation for this last point may be related to the fact that the most involved stakeholders were government agencies with statutory responsibilities (and budgets) to collaborate in the programme.

The fourth limiting condition, mentioned by half the respondents, related to the imposed strict timetable of the DPR. Many stakeholders felt that these time pressures, in addition to impacting on some of the specific approach outcomes above, significantly limited the performance of the DPR overall. As a DPRPB respondent noted,

> "[Time constraints were] more important than the technical content [of the programme]…one may have wanted to do more research to produce a better result, but then there was no time to be able to do it. Hence, some ideas were abandoned (or left to 'future investigations') and the process went on…the timetable was everything, and the Programme Director, the Steering Committee and the other stakeholders had been tasked by the Delta Commissioner to maintain this at all costs."

In specific relation to the *Blokkendoos*, DPR time constraints meant that the information contained in the model database was often out-of-date almost as soon as it was issued. By the time the DPRPB had been able to update it with the latest information to emerge from the regional processes, often even newer information had already emerged and was waiting to be incorporated. Naturally, this could lead to frustrations emerging between the DPRPB and the regional groups, but also between the DPRPB river and technical teams. Furthermore, model users (i.e. expert advisors) often had to contend with missing measures during strategy formulation activities. Consequently, advisors had to employ other 'workaround' technical approaches to assist in proper and timely strategy analysis.[33] In this case, it was perhaps fortunate that regional stakeholders were not directly using the model more themselves. Had these non-expert stakeholders actually been formulating their own strategies with the model, it is likely that finding these alternative approaches would have been beyond many of their abilities.

For the DPR more generally, time pressures were considered to have impacted on the quality of the programme and its outcomes. For example, even though the regions may have preferred more time to carry out their regional processes – perhaps to wait for *WaalWeelde West* processes to conclude or to increase other opportunities for community participation and influence – this simply was not permitted under the DPR. In the case of *WaalWeelde West*, the overtaking of its processes by those of the DPR also provoked and exacerbated tensions between its municipalities and other regional stakeholders from the 'necessarily imposed' 'backbone' measures. There is a lingering perception amongst DPR stakeholders that the developed regional strategies may not have necessarily been the best possible, the most affordable, or the most acceptable, but that they were the best given the available time. Indeed, several of the six regional VKS (including that of the Waal-Merwedes) will require considerable further study, planning and consultation in ensuing years.

[33] For example, a 'workaround' approach could involve selecting another measure already in the model that – via expert judgement – was predicted to have a similar effect to the absent measure.

12 Key Successes and Potential Improvements

As is hopefully evident from the preceding chapter, there were both successful and less successful aspects to the Model-Supported Collaborative Planning approach implemented in the DPR. These both related to the use of the *Blokkendoos* as the principal modelling tool in the approach, as well as the broader approach more generally.

12.1 The model

A key success of the approach was the *Blokkendoos* model. Its collaborative development and refinement of the pre-calculated measures contained therein delivered a generally high quality, accepted, relatively transparent instrument that enjoyed a high degree of trust amongst those stakeholders that came into contact with it. However, this is not to say that the quality and credibility of the model could not have been further enhanced. Reflecting upon the stakeholder feedback presented in the previous chapter, there are essentially four aspects to the model that could have been improved. First, all possible stakeholder-generated measures suggestions should have been calculated and inserted into the database. Second, enough time and resources should have been allocated within the process to ensure the model was kept up-to-date at all times. Third, consideration should have been given to allowing stakeholders participate in decisions to formulate and select key modelling (and assignment) assumptions. Finally, the model's accessibility for non-technical users could have been improved. The following sub-sections confront each of these in turn.

12.1.1 Include all 'possible' measures in the model

Stakeholder feedback suggested that some respondents would have found it useful and more credible had the model – and subsequent strategy formulation activities – included *all* the possible measures that stakeholders devised during the process, rather than leaving the inclusion of some to the vagaries of 'expert judgement'. It may be that these measures were ineffective at reducing water levels, but it nevertheless would have been beneficial for stakeholders to be able to assess this for themselves. Interestingly, such stakeholder reflections confirm the intent or philosophy behind the earliest *PKB Blokkendoos*. During the development of that tool, the attitude taken was that no measure should be excluded from this model, regardless of the magnitude of its effects (Hendriks, 2014; van Schijndel, 2014). It was considered far more important that stakeholders were able to see all of 'their' measures during strategy formulation – to specifically ensure that no lingering stakeholder doubts regarding their efficacy remained. Under the more restrictive DPR approach, such doubts may persist in the minds of some stakeholders regarding both the credibility and transparency of the preferred strategy, as well as the model used to develop it.

To counter the argument that the above recommendation would render the database too large and unwieldy for strategy formulation activities, a simple feature could be added to the model allowing the user to hide (or unhide) each measure from appearing in the table, selection chart or GIS map. During strategy formulation, only measures that were considered most likely could be displayed, but if stakeholders then wished to refer back to a previously determined non-likely measure to check its effects, this could easily be permitted.

12.1.2 Allocate enough time and/or resources for updates to model content to be made within the process

The preceding suggestion would have increased the workload of the DPRPB modelling team, as they would have needed to model and insert into the database an even greater number of measures. Within the strict time constraints of the DPR, this would likely have presented a considerable challenge. As it was, the DPRPB struggled to keep up with developments in the regional processes, as well as ensuring that model version updates were issued with the necessary up-to-date information. Despite being a key limiting condition of the DPR, the only way to improve these elements of the approach would have been to allocate sufficient time and/or resources to them. Had this been provided, out-of-date model versions would not have had to be used and experts would not have had to devise 'workaround' solutions during strategy formulation activities. It would likely have improved both stakeholder perceptions of the model's credibility and perhaps facilitated stakeholder use (either indirect or direct) of the model in interactive strategy design sessions.

12.1.3 Consider involving stakeholders in decisions to set assignment/modelling assumptions

The overall credibility of the *Blokkendoos* (as well as the DPR assignment more generally) would have been further enhanced had stakeholders been more involved in earlier processes to set assignment and modelling assumptions, such as the target peak 2100 Rhine discharge of 18,000 m^3/s. It must be recognised, however, that the potential collaborative benefits of involving stakeholders in these activities for what was an already large and protracted national program must be weighed against the additional time and resources needed to accommodate this involvement.

Even without such involvement, all stakeholders must regardless have the key assumptions and lingering uncertainties underpinning the model and scenarios explicitly justified during the approach. This could occur via the provided model documentation for model users, or preferably be supplied directly by the members of the organising team, contracted expert advisors, or regional process coordinators. Doing so would improve transparency outcomes for the modelling outputs used in planning, communication and decision-making, and help increase the credibility of the planning process overall.

12.1.4 Consider increasing the model's accessibility for non-technical stakeholders

One of the key stakeholder-identified benefits of the use of the *Blokkendoos* during the DPR was its ability to support both regional working group discussions and broader stakeholder interactions. Many respondents pointed to the ability of the model to help improve understanding of the comparative water level effects of the measures being proposed. However, broader understanding of measures and river system behaviour was harder to derive. In addition, the direct use of the model by stakeholders was much less than was originally envisaged by model developers.

Several potential reasons for this were detailed previously in section 10.1.3, including those relating to its ease-of-use (e.g. orientation of the water level graph, numbering conventions for included measures, technical jargon used, etc.) and restrictive login access. If non-technical stakeholders remain the intended direct users of *Blokkendoos* models, developers would do well to incorporate many of these stakeholder suggestions to make its use more intuitive and less confusing for these stakeholders. In addition, instead of having stakeholders need to request login credentials, these could be automatically issued to them as a matter of course.

That being said, given apparent stakeholder preferences for official strategy analysis being carried out by expert advisors, it is likely that the existing functionality and more technical interface of the model could remain unchanged (or perhaps even modified to reincorporate some more expert features). In this case, model developers could then perhaps consider developing an alternative model version; one more explicitly focussed on stakeholder use and its abilities to communicate more of the physical realities of individual measures and their resulting strategy effects. Such a model could be designed specifically with stakeholder-use in mind, and could perhaps incorporate more three-dimensional map-based visualisations of the proposed strategies and their predicted effects on peak flood waves. As one respondent suggested, the current *Blokkendoos* cannot very clearly or effectively illustrate to stakeholders the real spatial differences between various measures alternatives at the same location (van de Pas, 2014). Developing a model that incorporated three-dimensional visualisations would certainly rectify this and also enhance the capacity of the model to assist in any activities to communicate and justify measures and strategy selections to a wider range of stakeholders.

12.2 The model-supported approach

A key success of the Model-Supported Collaborative Planning approach was its intention to involve such a large number of diverse stakeholders in its planning processes. Although a 'Circles of Influence' participatory structure was largely appropriate to apply to the specific problem context, this case study has revealed some weaknesses in the manner in which it was applied.

Stakeholder reflections have demonstrated that the approach was relatively successful in delivering collaborative benefits to those stakeholders most involved in its processes. That is, for stakeholders involved in the two innermost 'Circles of Influence': the DPRPB and the regional working group (RWS, the province and the water board). Within these two circles, stakeholders reported general satisfaction with the levels of cooperation the approach permitted; the levels of consensus the recommended VKS achieved; the collaborative learning that occurred; and the ability of the approach to deliver improved decision-making in general.

However, aspects to the participatory structure and methods that could benefit from further attention, relate to the fact that stakeholders situated in outer 'Circles of Influence' felt that they could exert insufficient or meaningful power within the planning process. Both municipalities and special interest groups felt as though the developed VKS somewhat misrepresented their interests, and that their involvement demonstrated elements of 'action mismatch'. This was even the case for more highly involved *WaalWeelde West* municipalities, for whom the inclusion of 'backbone' measures felt imposed rather than self-determined. Levels of cooperation between the innermost and outermost circles were also poorer than they could have been, and the reduced influence of the latter helped promote tension and frustration between stakeholders populating the different circles. Essentially three improvements to the DPR's approach could help rectify the perceived loss of outer circle influence. The first involves simply raising their influence by increasing opportunities for these stakeholders to participate in strategy co-design. The second involves strengthening the linkages between the various circles of influence. The third relates back to allocating sufficient time to allow for these improved processes to take place.

12.2.1 Increase the influence of stakeholders situated in outer 'Circles of Influence'

Increasing opportunities for the less involved stakeholders to actively participate in VKS co-design provides the most direct way to improve these stakeholders' influence in the DPR. This does not necessarily mean that these stakeholders all needed to become members of the regional working group, but simply that their level of engagement within their 'outer circles' be increased from a 'discussion' level of involvement to one of 'co-design'. Fortunately, the experiences of municipal and special interest group stakeholders within *WaalWeelde West* offer a ready example of the type of collaboration that could be envisaged if it were to be scaled up to the entire DPR region. Measures alternatives that fulfilled various municipal, special interest or business needs could be more collaboratively developed, thereby increasing opportunities for improved integration in any development proposals. Municipalities could participate directly in negotiations to determine the necessary 'backbone' measure locations. This would result in these stakeholders being carried along in the selection of these for VKS inclusion, building greater acceptance and support for the strategy. Such negotiations would also offer opportunities to develop potential trade-offs to these municipalities from upstream 'beneficiary' municipalities where 'backbone' measures are not a technical possibility. Refinement of the proposed strategy could then be iteratively performed with the active involvement of special interest groups. Naturally the *Blokkendoos* (or an improved redeveloped alternative) could play an important role in these processes, via increased interactive use in collaborative strategy negotiations or design workshops involving all '4B' stakeholders.

12.2.2 Improve linkages between the 'Circles of Influence'

It is posited that increasing municipal and special interest group levels of participation in the above manner would have helped increase these stakeholders' influence over DPR processes. However, one could argue that this essentially is what occurred for the *WaalWeelde West* municipalities, with the increased involvement of its municipalities and special interest groups via that programme. These municipalities nevertheless considered their influence in the DPR to be constrained. It is the author's contention that this more relates to the relatively 'informal' linkages between the two programmes rather than a failure of increased stakeholder collaboration in *WaalWeelde West*. One cannot forget that these were two separate programmes, operating according to separate objectives and timetables, and with different organisational structures. In an improved manifestation of the two programmes, the DPR programme would have better incorporated *WaalWeelde West* processes into its own. These would have waited for *WaalWeelde West* processes to conclude and been more respectful towards its outputs. Likewise, *WaalWeelde West* officials would have had stronger linkages to the DPR regional working group, and a representative *WaalWeelke West* alderman would have been represented in the DPR steering group.

Putting the specifics of *WaalWeelde West* to one side, a similar model could have been followed for the other municipalities in the Waal-Merwedes region under the singular auspices of the DPR. The riverine municipalities could have been divided into collectives, with each collective having a representative in branch-specific working groups and steering groups. As a minimum, such representation should have been extended to any potential 'backbone' municipalities located in each collective, as it is these municipalities that were most affected by the potential developments under the DPR.

For stakeholders in the KBG, there were similarly no effective linkages between themselves and the stakeholders in the regional groups. They sat outside the regional process and were only briefly consulted about the proposed plans before any Steering Group determinations. Hence their minimal influence over strategy formulation. Bringing special interest groups into the regional process in a manner more akin to that in *WaalWeelde West* or as described in the previous section would naturally improve these linkages and hence the influence of special interest groups in VKS formulation.

12.2.3 Allocate sufficient time for collaborative processes to occur within the process

As is no doubt evident from the above two suggestions, setting up such collaborative structures and processes would have required considerably more time, resources and patience on the part of its participants. Even though the time was not available within the context of the DPR, stakeholder reflections nevertheless generally suggest that additional time should have been allocated to complete the collaborative regional processes. The results of the actual DPR process support this contention. As it currently stands, considerable further research is still required into several of the larger included VKS spatial measures, and the VKS has registered community opposition to the plans and recognises the need to alleviate this during the next DPR phase. Had an appropriate amount of time (possibly in the order of 4-5 years) been allocated in the regional process, a more readily acceptable VKS may have emerged; and requirements for further public consultation and research could perhaps have been avoided.

12.2.4 Dealing with a counterpoint to the above recommendations

The preceding recommendations somewhat ignore the fact that the specific nature of the DPR assignment may have placed hurdles in the way of achieving more representative and meaningful participation from those 'less-involved' stakeholders. Principal among these was the largely abstract nature of the problem being considered, and the difficulties that municipalities and special interest groups found in relating to these issues. Although water safety is an issue with the potential to affect many current and future stakeholders in the Netherlands, discussions surrounding this largely regional issue were apparently at times too conceptual and technical for many of the more local stakeholders. That is, the fact that the purpose of the DPR was to develop a *flexible* strategy served to restrict their effective collaboration. DPRPB and working group stakeholders were eager to stipulate that the VKS was 'only a strategy': one intended to demonstrate the feasibility of pursuing a climate-dependent adaptable and flexible long-term policy of combined spatial and dyke improvement measures. That is, it was not the intention of the programme to define the concrete set of measures that were certain to be implemented over the ensuing 85 years. Rather, the VKS was intended to validate the conceptual thinking forming the basis for the DPR assignment. As one municipal respondent indicated, such a style of high-level abstract thinking was often difficult to relate to specific local issues and concerns. Thus, it was often challenging to obtain local feedback regarding measures that may or may not need to be implemented, or that could be later replaced with other measures.

> "It is difficult to explain to local communities that discussions are only about 'options'. If you put a line on a map, it is difficult to get communities to understand that it is not a design, that it is not a new dyke route. Local residents simply consider the immediate impacts to their house and community."

The relevancy of these discussions to local stakeholders was similarly impacted by the specific time horizons being considered in the VKS (2030, 2050 and 2100). Communities and interest groups were typically most concerned with actions that were likely to occur in the short-term (e.g. the next 15 years), and not with those that might (or might not) take place in the distant future. Consequently, most local and special interest stakeholders were concerned most with the more certain of the proposed measures; that is, those scheduled to be implemented before 2030.

Alternatively, they were interested in rendering some of the less certain measures more certain, for instance by having them promoted earlier in the proposed implementation schedule.

Taking these factors into consideration, one could very well argue that it would have benefitted the DPR little to have sought to increase the involvement and influence of lower-level stakeholders in the regional process. Indeed, one could go so far as to say that collaboration and strategy formulation could have even remained solely the domain of the national and regional policy makers in the province, water board and RWS. Such a view, however, ignores many of the potential benefits of involving lower-level stakeholders in planning exercises, none the least being that it restricts the formation of effective early foundations for strategy acceptance, along with the emergence of alternative and innovative ideas founded on detailed local knowledge and experience.

It is the author's contention that the participatory structures and processes adopted in the Waal-Merwedes region actually helped exacerbate the effects of the more abstract problem assignment for these stakeholders. By restricting lower-level stakeholders' abilities to effectively exert influence over the process or its outcomes, it became somewhat of a self-fulfilling prophecy that these stakeholders would view the assignment as being too abstract. By limiting VKS co-designing activities to the regional working group, this ensured that municipal and special interest stakeholders approached the VKS proposals in an entirely reactive manner. Rather than stimulating a proactive assessment of its more conceptual objectives through collective strategy formulation, these stakeholders were simply being asked to react to the suggested alternatives by basing their assessments on existing conditions and short-term plans. It remains the author's position that providing sufficient additional opportunities and adequate time for all stakeholders to have collaborated in co-designing the VKS would have significantly benefited DPR outcomes.

12.3 Concluding remarks

The Model-Supported Collaborative Planning approach adopted in the Waal-Merwedes region of the DPR clearly demonstrates many of the comparative advantages and disadvantages of planning programmes seeking to involve large numbers of stakeholders at different levels of participation. In those processes where the approach tended towards higher levels of participation, it was largely successful in delivering beneficial outcomes for the stakeholders involved. Decision-making processes were considered to improve, levels of cooperation and consensus were considered to be high, conflicts and disagreements were largely resolved, and modelling outputs and strategy selections were clearly understood and rarely questioned. Most significantly, in these instances collaborating stakeholders felt they were able to exert sufficient influence and control over the decision-making process and its outcomes. Where the approach tended towards lower levels of participation for stakeholders, positive outcomes were more difficult to realise. Decision-making processes were questioned and doubts were cast over their transparency, stakeholder cooperation was considered to have been less effective and true consensus regarding the developed VKS was not achieved, rather replaced with a 'resigned' consensus. Thus, conflicts and frustrations tended to more easily emerge and remained unresolved, and a sense of 'action mismatch' prevailed.

It is no doubt apparent to the reader that processes for higher levels of participation occurred for stakeholders in the two innermost 'Circles of Influence': RWS, the province and the water board. One would also consider the *WaalWeelde West* Structural Vision development processes as being equally collaborative for its included '4B' stakeholders. However, problems were encountered for this latter group of stakeholders in translating some Structural Vision aspirations into the VKS, largely due to the more top-down implementation of the DPR's approach. *WaalWeelde West* municipalities and interest groups thus experienced a comparable loss of influence to their counterparts situated in the DPR's two outermost 'Circles of Influence', for whom the only avenues for DPR involvement were via advisory discussion forums.

Based on these findings, it is the author's recommendation that involvement for the outermost 'circles' would have benefited considerably from being increased to more collaborative 'co-designing' levels similar to the inner circles. Stakeholders in the outer circles expressed a clear desire for such increases. In combination with broader structural changes to improve linkages between the circles, raising these levels of participation would have increased the influence of all stakeholders to meaningful levels and minimised any propensities for 'action mismatch'. It is unquestionable that additional time and/or resources would have needed to be allocated within the approach to accommodate these improvements. But allocating sufficient time for collaborative consensus-building processes to run their course is one of the most important enabling conditions to keep in mind when undertaking planning approaches in semi-structured problem contexts defined by their high levels of stakeholder disagreement.

As for the *Blokkendoos* model, a strong case can be made that little needed to be improved in relation to its role in the approach. By and large those stakeholders who came into contact with it were complimentary regarding its interface, functionality and abilities to support the collaborative and participatory processes. This is not to say that improvements to the model and modelling processes cannot be made. Indeed its credibility, along with that of the decision-making process more generally, could have been further enhanced had it followed the guidelines of its predecessor and incorporated all possible measures into its database, rather than simply the likely ones. Allocating sufficient time and resources within the approach to both allow for this and ensure that any issued model versions were kept up-to-date and relevant to the current stage of the planning process would also have improved its usefulness and enhanced its credibility for some users. Furthermore, consideration could be given to involving lower-order stakeholders more in those decisions determining modelling assumptions, or at the very least confronting any uncertainties with these stakeholders. This would strengthen the semi-structured nature of the problem assignment and help to ensure consensus regarding the scientific knowledge base. Finally, the model's accessibility to non-technical stakeholders and its abilities to convey even more spatial information regarding the measures and strategy are also two areas that would lend themselves to further consideration.

13 Discussion

The preceding two large thesis sections presented detailed analyses of the two Dutch case studies. They included extensive presentations of the perspectives of the stakeholders involved in each of these Collaborative Modelling (CM) exercises, along with some case-specific suggestions as to how each of the approaches could have been improved. Despite considerable differences between the two approaches, the purpose of this chapter is to comparatively reflect on them more generally by considering the broader enabling characteristics of CM exercises. Specifically, consideration is given to issues surrounding which types of stakeholders should have been involved in each of the exercises, as well as the importance of involving stakeholders in their earliest development phases. The contributing role that expert knowledge institutes play in building model credibility in each case is also considered, along with the importance of adequately addressing with stakeholders any scientific uncertainties present in these models. Somewhat similarly, the role of process manager neutrality within the context of these approaches is also contemplated. Additional time-related implications are then discussed, as are necessary reflections of the cultural context in which the two approaches were implemented. Following this comparative discussion, a reflection on the various suggested 'guidelines', 'lessons learned' and 'best practices' for CM from the literature is presented. The chapter concludes with a discussion of the study's limitations and opportunities for future research.

13.1 Who to Involve?

In Chapter 3, the author introduced some of the themes and issues regarding which stakeholders to involve in collaborative and participatory exercises, along with potential approaches to differentiate and structure that involvement. Naturally these strategies should be founded upon comprehensive and sound stakeholder analyses. Revisiting these issues in light of the case studies, one can identify that, somewhat significantly, Dutch institutional representatives and scientific experts dominated the central stakeholder forums in both instances. Both cases therefore conformed to more traditional and technocratic notions of stakeholder involvement in planning programmes. Naturally this raises the question whether it was appropriate for other stakeholders to have been more actively involved in either case.

In the AZURE model development project, stakeholder involvement was restricted to national and regional government, water board, DWC and expert actors. AZURE involved the development of a highly complex and technical mathematical model, and consortium members felt that other lower-level and non-government parties would have lacked the necessary technical knowledge to effectively participate in consortium discussions. One might suggest that this demonstrates unwillingness on the part of these actors to open up the Consortium Modelling approach to non-technical stakeholders, as well as the preferencing of expert over more local forms of knowledge. However, one must also remember that the purpose of the project was to develop and build a scientifically sound expert regional model generalizable to a wide variety of problem contexts. Improving the scientific certainty and validity of groundwater modelling outputs were the primary project objectives, not considerations of competing stakeholder values or attitudes regarding how to best manage or protect groundwater resources.

Given these objectives, it was entirely appropriate that only key national and regional institutional actors were involved in the model's development. These organisations employ individuals with the necessary hydrological expertise to understand and effectively contribute to consortium discussions. They are also the public and private institutions in which lower-level Dutch stakeholders have broadly placed their trust to develop such scientifically sound and accurate models. Consortium discussions focussed upon the behaviour of specific geohydrological phenomena, subsurface processes, and the minutiae of generalised parameterisations. It is unlikely that more local, less-technical actors would have been interested or felt capable of contributing to such discussions, even with the additional support of the RAs. Indeed, taking part may have only served as a cause of frustration for non-technical stakeholders, contributing only to viewing their involvement in these activities as a waste of time.

One area of the model development process that could perhaps have incorporated more lower-level stakeholder involvement was determining the types of geohydrological problems the model could handle. Municipalities and interests groups could have been consulted during the earliest model development phases to enquire about the types of questions they would need a groundwater model to answer, in order to ensure that the developed model was able to deliver such functionality. That being said, one could equally argue that such consultations would have been too locally focussed for the initial development of a functioning *regional* model. In which case, the current phase of continual model improvement via its use in specific consortium/non-consortium actor projects is again the appropriate juncture for such inputs to improve the functionality and local-scale performance of AZURE to be made.

In the DPR case study, the question of who should have been involved in model development and strategy formulation is more complicated. One has to admit that increasing stakeholder involvement in the design of the user interface for the *Blokkendoos* may have led to increased direct stakeholder use of the model (as per the programme's original intention). But this is only one aspect to the model in the approach; one must also consider its core functionality and the population of its pre-calculation database with the necessary geohydrological data. As was the case in AZURE, DPRPB actors again enjoyed broad public trust to independently undertake these technical tasks and thereby develop a sufficiently accurate and functional *Blokkendoos*. In the DPR, stakeholders were not so concerned with the absolute certainty of the scientific knowledge being used to inform their planning discussions. As such, the model was viewed as a credible instrument to use and modelling outputs were rarely questioned during the programme. The reduced involvement of lower-level stakeholders in these modelling activities can therefore also be considered to have been appropriate.

By contrast, stakeholder involvement was imperative to all approach activities relating to measures development and strategy formulation. Almost all disagreements between stakeholders in the programme centred most on their competing values, views and opinions regarding the future protection and development of riverine areas. Every stakeholder – including those at lower levels – had their own opinions regarding the proposed development agenda. Naturally, these would never always be in agreement with those of the limited number of regional working group officials assigned to formulate policy. Indeed, this is the very foundation of the philosophy behind stakeholder engagement and participation in planning activities. If government officials were able to independently reflect everyone's interests, advocacy and involvement of special interests and civil society in these processes would hardly be required. Since officials can do this only imperfectly, the question thus becomes one of balancing policy-making efficiency with the provision of adequate opportunities for lower-level collaboration or participation.

It is commendable that avenues for stakeholder involvement were provided in the DPR. A broad range of stakeholders including government organisations, businesses and special interest groups were all approached to participate in its various forums and present their views. This was appropriate and was one of the key successes of the approach. However, as indicated in

Chapter 12, it is the author's position that it would have been even more beneficial had opportunities been pursued for 'outer circle' stakeholders to collaborate in VKS formulation at higher levels of participation. The suggestion was made that municipalities could have collaborated in interactive strategy formulation activities to negotiate and recommend 'backbone' measure locations as well as any locations for smaller spatial measures and dyke strengthening. This could have occurred in the wake of collaborative integrated measures development and ranking workshops throughout the region with special interests, businesses and citizens in a manner akin to that applied in *WaalWeelde West*. Indeed, multiple 'backbone' strategy options could have even been developed at the municipal level before being put to these 'outer circle' stakeholders to help determine final preferred policy recommendations. Granted, such an approach would have required a greater number of strategy iterations and hence, time and resources. Nevertheless, it is undeniable that the proposed water safety measures have the potential to considerably affect many lives. It is appropriate for such proposals – even if they are to remain adaptable and flexible – to be determined by the broadest range of stakeholders as possible. The alternative, in which the relatively small number of officials essentially made policy informed by feedback from lower-level stakeholders, was not able to completely reap the benefits of involving stakeholders in planning. Although relatively efficient in terms of time, it tended to exacerbate some of the potential negative consequences of participation.

Stakeholder perspectives from both cases suggest that the question of who to involve depends most upon the particular problem context and structure, as well as the specific objectives of the exercise. Following Mayer, van Daalen, and Bots' (2004) classification of policy analysis objectives presented in Chapter 3, if the purpose of the CM exercise is to simply research and analyse the complexity of the water resources system, a collaborative technocratic approach may be valid. However, when the purpose is more focussed upon designing and recommending potential management actions, or democratising the policy making exercise, a technocratic institutional approach is much less appropriate. In these cases, collaborative processes should be opened up to the widest group of potential stakeholders identified through comprehensive stakeholder analysis. Furthermore, participation should be structured in such a way that stakeholders can exert real influence over any decision-making processes. This means committing to increase the participation of even lower-level stakeholders to higher levels wherever possible.

13.2 When to Involve?

Whom it was appropriate to involve in each approach is only part of the issue. Another key question to consider is the timing of such involvement. In AZURE, consortium stakeholders began collaborating together at the very outset of the Consortium Modelling approach, jointly establishing the objectives of the process along with any constraints. From this starting point, the key stakeholders were all engaged in the collaborative co-construction process, defining all modelling assumptions and schematisations, verifying interim modelling outputs, and the like. Client actors were empowered decision-makers during the entire development process. This was uncontroversial; indeed, such control is typically maintained in most client-advisor relationships. Nevertheless, given this control, stakeholder perceptions of a lack of influence or any 'action mismatches' were negligible.

Turning attention to the DPR a different picture emerges. The DPR involved a process and stakeholder structure that extended well beyond the principal sponsors of the programme. Thus, questions of control and influence and how these relate to the timing of its collaborative or participatory activities are all the more pertinent. In the DPR, only those involved in the DPRPB (and particularly the technical team) had any opportunity to influence the earliest phases of the planning process. This was when most of the exercise's objectives and modelling assumptions were set. Particularly in the case of the national water authority (RWS), their dominant role in initial agenda setting, development and resourcing for the DPRPB arguably led to the DPR's focus being firmly set on water safety at the expense of more integrated outcomes. Naturally, RWS's hands were somewhat tied by the Dutch Parliament's limiting of DP financing to safety and drought issues, as well as the imposed time constraints for the programme. Nevertheless, the outcome was that the DPR was much less concerned with the other integrated aspects of the planning process, meaning that the inclusion of these in the VKS was always going to be a result of whatever other stakeholders could manage to incorporate into the largely pre-defined problem assignment.

An alternative to the above would have been for the national government to have provided the necessary space to the DPR to further open its planning processes up via earlier lower-level stakeholder involvement to jointly develop and define the objectives of the DPR. That is, to have increased avenues for more 'Front-End' stakeholder collaboration within the approach. Even if this had only occurred amongst a wider range of government stakeholders (including municipalities), it could have meant that a broader, more integrated development agenda was truly countenanced under the auspices of the DPR. Financial and time constraints could have been renegotiated to enable this, in addition to better incorporating *WaalWeelde West*-type processes into the DPR. Consequently, municipal frustrations regarding their minimal room to manoeuvre within the constraints of the DPR assignment may have been avoided.

It is somewhat of a truism that whichever stakeholders have the power to set agendas and objectives in collaborative exercises will be most able to exert the most influence over their eventual format and outcomes. If problem contexts lend themselves to stakeholder collaboration, then it makes sense that a wide range of stakeholders should be involved in the earliest agenda setting phases of these exercises. Only then can it be ensured that all stakeholder interests are served by the exercise. As a comparison of stakeholder experiences in both AZURE the DPR illustrates, not doing so only serves to sow the seeds for later dissatisfaction, disagreement and 'action mismatch'.

13.3 Building Credibility

Which stakeholders to involve and when to involve them in CM approaches are not the only important issues raised in these case studies. For those stakeholders who are to be involved, both the implemented CM processes and the developed models need to be judged to be credible, trustworthy and broadly acceptable. Both these cases illustrated three important contributors in this regard, namely: the role that expert knowledge institutes played in these approaches; the importance of addressing any uncertainties with stakeholders; and the impartiality of any process management during these approaches.

13.3.1 Role of Expert Knowledge Institutes

Mention has already been made of the broad public trust enjoyed by Dutch water governance agencies to develop the necessary models in each of the case studies. Recall that in both cases, all stakeholders largely accepted the developed models and their overarching quality was rarely questioned (lingering consortium concerns regarding the ability of the AZURE model to perform at local scales aside). Both AZURE and the *Blokkendoos* were generally considered to constitute credible, trusted instruments with which to apply to real-life problem contexts. A key factor contributing to this trust that received minimal attention in the preceding two chapters was the role of Dutch expert knowledge institutions in the development of both models. As noted in earlier studies, model acceptance and the placement of trust in their results are dependent upon stakeholders' confidence in the institutions that build these models (Cockerill et al., 2004; Olsson & Andersson, 2007; Yearley, 1999). Such trust is affected by earlier positive or negative stakeholder experiences of these institutions. For those that do not command the trust of stakeholders, using models that they develop in decision-making processes might not be as successful as in situations where there is high trust.

In both AZURE and the DPR, the involvement of Deltares (also Alterra in AZURE) was seen to have directly enhanced the credibility of the developed models and their outputs. In the case of AZURE, such an assessment was most clearly demonstrated in the perspectives of the two external model users interviewed who placed their complete confidence in the model's outputs. They explicitly stated that this was the direct result of the involvement of technical specialists from Deltares and Alterra. These were both institutions that these stakeholders trusted to construct high quality, fit-for-purpose, geohydrological models. Thus, these stakeholders saw little benefit in questioning the model's validity, or in expressing a desire to have been more involved in its development. Even amongst consortium members – for whom frustrations with Deltares over its quality and technical process management undeniably existed – there was nevertheless recognition that Deltares was the only institution in the Netherlands with sufficient technical capacity to build the large regional groundwater model. Its expert geohydrological and modelling skills were never questioned. Likewise, the accuracy of *Blokkendoos* results was never questioned in the DPR; again, in large part due to the involvement of Deltares in developing the model and populating its database. "Deltares is an institute that people trust to get the hydraulic modelling right", one respondent tellingly recounted. The existence and general trust enjoyed by the Dutch expert knowledge institutes was therefore an essential component in enhancing the scientific credibility of the models applied in both case studies.

13.3.2 Importance of Addressing Scientific Uncertainties

The preceding section notwithstanding, it is also important to recognise that water resources modelling and uncertainty go hand in hand. There is no such thing as an exact model certain to return a result that is or will be precisely observed in reality. There will always be a degree of uncertainty involved, irrespective of which organisations build the model or the levels of public trust these organisations enjoy. In CM approaches, consideration must also be given to stakeholder perspectives of these uncertainties, as they too impact the credibility and transparency of the model and the overall approach. As noted by Brugnach, Tagg, Keil, and de Lange (2007), "uncertainty matters" to policy makers. It is a significant contributor to their distrust in models and their apprehension in basing policy decisions upon their outputs. Such sentiments can be extended to all stakeholders; who can be equally sceptical regarding any suggested (or implemented) policies founded upon uncertain modelling. Indeed, providing the opportunity to adequately address uncertainties with stakeholders is another oft-cited benefit of CM.

In both of the cases studied here, scientific uncertainties were present, but the manner in which they were dealt with differed significantly. In AZURE, the entire purpose of the Consortium Modelling approach was to enable its stakeholders to confront, accept and determine how best to either reduce or manage the scientific uncertainties inherent to subsurface modelling. This was how the consensus model was developed. For example, an important consideration in the development of the regional model was how AZURE would handle the anisotropic soil conditions in the Veluwe region. Much remains unknown about the physical realities in that region, in which case a consensus approach of how to model this area needed to be developed by the clients, utilising the advice and assistance of the modelling team and the regional advisors. AZURE's Consortium Modelling approach rendered all modelling uncertainties transparent to its involved stakeholders. In doing so, the approach also broadly conformed to Bots et al. (2011) information and model transparency 'rules' for collaborative model use. One only hopes that such clear acknowledgement of AZURE's residual uncertainties – as well as developing appropriate ways to manage these within project-specific contexts – is extended to any external model users that are now expected to make use of the model in their groundwater management activities.

Modelling uncertainties were managed differently in the DPR, with evaluations of these largely made independently by RWS experts and its research institute advisors. As indicated previously, the DPR's major focus was the formulation of the negotiated strategy rather than a scientific consensus. The scientific information used in the approach was largely uncontested. Nevertheless, uncertain choices still had to be made, with these having the potential to nurture future opposition to any plans upon which they are founded. Principal among these was the selection of the peak Rhine discharge in 2100 to 18,000 m^3/s. A review of the technical programme documentation reveals that the potential range for these flows is in the order of 17,000 – 22,000 m^3/s assuming unrestricted upstream flows from Germany, or 16,000 – 17,500 m^3/s assuming Germany takes every measure to restrict flows to current peak water levels (Schielen, 2013). One can see that the selection of 18,000 m^3/s is a reasonable choice to have been made. Nevertheless, it remains an uncertain (not to mention contested) assumption underpinning the *Blokkendoos* and the entire DPR assignment. This discharge may never be reached, particularly if any spatial river measures are taken in Germany in the coming 85 years to *reduce* current peak levels (perhaps at the negotiated request of the Dutch government). Any such reduction in anticipated peak flows would mean fewer measures need to be taken along the Waal, and some controversial 'backbone' measures may not even be required.

The uncertainty inherent to this assumption (among others) was seemingly never really confronted or managed with many lower-level stakeholders in the DPR. Rather, it was simply left to expert determination, and this constitutes somewhat of a missed opportunity within the approach. Indeed, the fact that several interview respondents felt the need to mention it as a potential issue is significant. There is now a potential for lower-level stakeholders to use these uncertain technical foundations to mobilise future opposition to the plans as they progress further towards implementation. The approach would have been significantly improved had such uncertainties and choices been collectively acknowledged and made transparent with a wider range of stakeholders during the approach. Doing so would have not only contributed to achieving greater strategy consensus and credibility, but also helped minimise any future conflict potentials.

The management of uncertainties in both case studies confirms it is absolutely essential for organising teams to adequately confront these with all stakeholders during CM approaches. Somewhat counter-intuitively, the DPR case demonstrates this is even the case in semi-structured problem contexts where the knowledge base is relatively certain. Not doing so sufficiently leaves these problems open to negatively traverse from residing firmly within semi-structured contexts to ones more defined by their completely unstructured nature.

13.3.3 Process Management Impartiality

Another element of particular importance demonstrated in the case studies is the role played by the process manager in building credibility, trust and acceptance. This is the individual who is typically responsible designing the process, facilitating meetings and liaising with the various stakeholder groups involved. To adequately perform the role therefore requires particular capabilities. For example, it is beneficial if the process manager has some knowledge of the topic under discussion; has the capacity to effectively track down, synthesise and summarise any relevant information; and above all is able to ensure that the process keeps moving and remains focussed on its purpose, whilst still balancing and respecting the needs of all the stakeholders involved (Bots et al., 2011). In performing this last function, process managers therefore ideally need to be impartial with respect to the assignment and at the very least be perceived by collaborating stakeholders as such (Mostert, 2003; Voinov & Bousquet, 2010). Naturally, this is much easier to achieve in those instances where an external process manager is engaged.

In the AZURE model development process, consortium process management was assigned to an independent external process manager. This was seen as a critical innovation within AZURE's Consortium Modelling approach as compared to its earlier manifestations. His independency ensured that no stakeholder felt the interests of any particular stakeholders were being preferenced over their own. This would have been much harder to achieve had the process manager been taken from any one particular client stakeholder, or even if he had been more closely associated with the modelling team, for whom its own particular modelling bias was on occasion an issue for some client stakeholders.

In the DPR, however, overall process management for the formulation of the VKS was assigned to members within the DPRPB, whilst provincial authorities took responsibility for coordinating the regional processes of wider stakeholder engagement. One could argue that the perceived loss of influence and sense of DPRPB/working group bias amongst municipal and other lower-level stakeholders was a direct result of the coordination of DPR processes by these officials and their respective biases to have these proceed according most to their affiliated interests. That is, within the strict DPRPB-determined constraints of the DPR (e.g. time, water safety assignment), regional provincial coordinators were able to ensure that its and other DPRPB/working group stakeholder interests were all generally met in the finalised VKS. This was likewise possible for those municipalities in the wider regional group whose interests largely coincided with those of the working group consensus. However, for those municipalities (and interest groups) whose views differed to this consensus, their preferences were simply too difficult to incorporate fully into the VKS. Rather, they were left to be qualified in the VKS text (e.g. via recommendations for further study; or formal registrations of their opposition to the strategy). This is not to say that an independent process manager in each DPR region would have necessarily yielded a strategy more acceptable to any dissatisfied lower-level stakeholders. It must also be recognised that even independent process managers may find it difficult to maintain their neutrality in a given process, especially once they develop their own understanding and viewpoints about the problem being addressed (Voinov & Bousquet, 2010). Nevertheless, it is possible that the inclusion of an external process manager could have helped to reduce the relative lack of lower-level stakeholder influence in the DPR, along with their perceptions of simply being carried along in the current of a largely predetermined planning process.

Both case studies in this thesis lend further support to the notion that engaging an external, independent process manager has a high potential to lend additional credibility to collaborative processes. When governmental agencies act as facilitators of a collective process, it is inescapable that they will have their own stakes in the process (Voinov & Bousquet, 2010). External process managers will typically find it much easier to demonstrate their objectivity and foster trust among participating stakeholders than if they are drawn directly from stakeholders with specific interests in particular assignment outcomes.

13.4 Time-Related Impacts

As is no doubt evident to the reader by now, the various impacts of time-related factors were experienced in both case studies. During the AZURE development process, the untimeliness of interim results delivery contributed to consortium angst. In the DPR, several stakeholders alluded to the insufficient time allocated to complete the regional process and associated DPR support activities. Time pressures in both cases not only led to difficulties in keeping both models up-to-date, but also contributed to heightening frustrations between the various stakeholders and stakeholder groups. Particularly in the case of the DPR's long-term planning programmes, one would think that such time constraints could have played a much less influential role in the process. One cannot forget that the purpose of the collaborative exercise was to develop a safety strategy for the coming 85 years. Whether it was necessary that such strict planning deadlines were adhered to for such a long-term focussed assignment is debatable. These were arbitrary, self-imposed constraints. If additional beneficial outcomes (e.g. improved stakeholder acceptance) could have been realised through increasing stakeholder involvement and extending these deadlines, one could certainly argue that such extensions would have been both reasonable and constructive.

That being said, it is a relatively simple thing to suggest that the solution to such problems is to ensure that adequate time is provided in CM exercises. The sufficient political will to allow for this does not always exist (as the DPR example aptly demonstrates). Additional time generally leads to additional costs being incurred, which only serves to dissuade sponsors of these exercises from making such allowances. Moreover, the provision of sufficient time cannot be seen as a simple silver bullet in either collaborative or participatory exercises. It can also often lead to further complications, principal among which relates to the ability of these exercises to both stimulate and maintain the motivation and interest of the individuals involved. This was seen to play out to a degree in both case studies. During AZURE, consortium member motivation and enthusiasm for the project tended to wane as the development process progressed. Its quality and technical process management issues only served to further compound these tendencies. In the DPR, DPRPB respondents often reported that it was sometimes difficult to stimulate municipal and special interest involvement in the program. It is also unlikely that the lack of special interest group participation in the KBG was solely the result of a perceived 'action mismatch' for the group. Rather, for many the necessary time commitments may have simply been too great to motivate their participation in the programme.

Both cases demonstrate that time can be a double edged-sword in CM exercises. Too little and it severely impedes the ability of an approach to deliver any collaborative benefits. Too much and it can increase costs and reduce stakeholder motivation. Striking the right balance is critical when designing CM approaches, but one should remain mindful that these approaches need to remain somewhat open and flexible in terms of their allocated time and the processes they employ (Voinov & Bousquet, 2010). The latter will typically be iterative, and practitioners must be prepared for any unexpected changes in goals and priorities in their programmes (Voinov & Bousquet, 2010). Forcing stakeholders to follow predefined timetables, protocols and procedures in collaborative exercises will typically only serve to engender their frustration and demotivation. As is the case with many of the issues discussed in this chapter, the AZURE project was much more successful at applying these principles in practice than the approach adopted in the DPR.

13.5 Cultural Context

This discussion of important CM aspects that were illustrated by the case studies would be incomplete without a consideration of the specific Dutch cultural context within which the two approaches manifested. Every CM exercise has to operate within a particular national cultural context. This contributes associated patterns of emotion, thought and action that members of a national group and its related formal and informal institutions generally share in common. As Mostert (2003) notes, the cultural context "colours the ideas of its members, predisposes them towards certain types of behaviour and gives meaning to these behaviours." Applying a similar rationale, Hofstede (1991) identified five dimensions in which national cultures all tend to differ, namely:

- **Power Distance**: the degree to which members of a culture expect and accept (or reject) power differences.

- **Individualism**: the degree to which members of a culture see themselves as an individual or primarily as a member of a collective.
- **Masculinity**: the degree to which members of a culture are expected to be assertive and competitive.
- **Uncertainty Avoidance**: the degree to which members of a culture feel uncomfortable with unknown or unpredictable situations.
- **Timeframe**: a cultural predisposition to being either more short-term or long term focussed.

The first four of these hold particular implications for participatory methods (Mostert, 2003), including CM. For example, in countries with a high power difference index, authorities will typically not embrace participatory methods, and implementing such approaches could require strict regulations. Also, lower-level stakeholders will tend to be more passive or cynical, such that extra effort will likely be needed to mobilise their involvement. In more collectivist cultures, 'face-saving' is particularly an important concern, with the result that extracting consensus-generating concessions from stakeholders can be difficult. Thus, collaborative methods that involve more individualist open discussions and recognition of stakeholder differences may not be appropriate or succeed in such instances. In highly 'masculine cultures', social interactions will be typically more adversarial and competitive, and determining decisions through voting mechanisms may be preferred. Conversely, in more 'feminine cultures', consensus-based methods may be more appropriate. Finally, in countries where an avoidance of uncertainty is high, participants may have greater difficulties with the more unpredictable nature of collaborative processes. In such contexts, dealing with completely unstructured problems may be difficult, and it may be necessary to create boundaries to restrict these problems to being strictly semi-structured at any one time.

Both the cases studied in this research took place in the Netherlands. This is a country well recognised for its relatively low power difference, high individualism, low masculinity index, and low uncertainty avoidance. For example, the celebrated Dutch 'feminine' tradition of collaborative decision-making and consensus forming was clearly exhibited in both cases. In the AZURE consortium, decisions were taken collectively and only after 'unanimous' Go/No-Go positions were discussed, negotiated and reached by all the stakeholders involved. Strategy consensus within the DPR regional working group was achieved in a similar fashion. The province, water board and RWS discussed and negotiated a strategy that was able to balance RWS's safety focus, provincial preferences for spatial FRM measures and the water board's dyke strengthening requirements. Moreover, even though a more conditional or 'resigned' VKS consensus was only reached with some municipalities and special interest groups in the DPR, its processes were nevertheless intended to enable and help achieve consensus via its collective discussion forums. Indeed, even the expressed desire of these parties for greater influence within the DPR approach is an embodiment of reduced Dutch power differences and more individualist tendencies.

In light of this, one must be particularly careful about assuming that either of the two studied approaches could be easily translated to other cultural contexts. Successes in the two approaches may have been in significant part due to the national cultural context in which they were both operating. In cultural contexts that differ widely from the Netherlands, both of these approaches may simply not be appropriate or effective at all, and require significant modification. By way of example, both approaches' generally egalitarian processes where stakeholders felt comfortable to express and defend their opinions would most likely be less successful in countries with high power distance or collectivist indices.

Bearing this in mind, it is also important not to misuse these notions of cultural difference and stereotype particular national cultures, or to blame or excuse failings of collaborative processes solely on the basis of national cultural difference. One must recognise that even amongst national contexts that share similar cultural dimension indices, the direct translation of either formal or informal institutions is difficult (de Jong, 2004). Also, one should always be careful when ascribing such notionally reductionist and 'monolithic' cultural characteristics to particular groups. Subcultures will inevitably exist within national groups that will exhibit different characteristics to the broader national culture (Mostert, 2003). Therefore, although one should keep the specific national cultural context in mind when designing and implementing CM approaches, it should never be viewed as the only factor determining whether an approach will be successful in achieving its outcomes or not.

13.6 Reflections on Collaborative Modelling 'Theory'

In light of the preceding findings, it is now proposed to briefly revisit the recommended 'guidelines', 'lessons learned' and 'best practices' for CM from the literature presented in Chapter 3 (refer Table 4). CM remains an emergent field in Water Resources Management, and these recommendations arguably comprise what could be considered its nascent theoretical foundations. Reflecting on these recommendations in combination with findings from this research suggests that some may not be relevant in all instances, or alternatively require additional qualification.

One must first recognise that the case studies confirmed many of these guidelines. For example, ensuring that involvement is both representative and appropriate to the task (Langsdale et al., 2013; Smith Korfmacher, 2001; Voinov & Gaddis, 2008) can be seen to provide the critical foundation for any collaborative exercise. Likewise, designing a process whereby contributions from stakeholders are truly valued and are permitted to influence modelling decisions (Langsdale et al., 2013; Smith Korfmacher, 2001) is essential in avoiding criticisms of bias and 'action mismatch'. Ensuring transparent modelling processes and addressing uncertainties (Smith Korfmacher, 2001; Voinov & Gaddis, 2008) is important for building credibility for modelling outputs, as is selecting the appropriate modelling tools to answer the necessary questions (Voinov & Gaddis, 2008). The case studies also confirmed the importance of having both participants and modellers approach these processes with humility (Langsdale et al., 2013); incorporating all forms of stakeholder knowledge (Voinov & Gaddis, 2008); and having organising teams with the necessary combination of collaborative skills and technical knowledge (Langsdale et al., 2013). Similarly, treating modelling exercises as an open and flexible iterative process was seen to be important in keeping stakeholders 'on side' and maximising opportunities for learning (Langsdale et al., 2013; Voinov & Gaddis, 2008). This list is non-exhaustive, but suffice it to say that many of these stipulated conditions were indeed corroborated by stakeholder experiences during both of these case studies.

However, a number of recommended practices are dependent on the purpose of the exercise and thus should not be applied indiscriminately. First and foremost is the suggestion that stakeholders should be continuously involved in as many modelling activities as possible (Langsdale et al., 2013; Smith Korfmacher, 2001; Voinov & Gaddis, 2008). Such a requirement is clearly dependent upon both the purposes of the exercise and the problem context. As noted earlier in relation to the DPR, in those instances where scientific knowledge is uncontested, reduced stakeholder participation in model development and model use can make sense. Nevertheless, the suggested requirement to involve stakeholders during the earliest agenda setting phases of CM remain valid (Smith Korfmacher, 2001), as do involving stakeholders in any results interpretation and strategy formulation activities (Langsdale et al., 2013; Voinov & Gaddis, 2008).

Another 'best practice' dependent upon the specific purpose of the exercise is ensuring the selection of software that is easy to learn and can be made available to all (Langsdale et al., 2013). As the AZURE case demonstrates, if direct stakeholder use of the software is not necessarily intended, then these models can be as sophisticated and complicated as their intended expert users require. This is likewise the case if the specific objective of the exercise is to develop a sophisticated technical model. Model availability also needs only extend to their intended users, which may or may not include the involved stakeholders. Furthermore, suggestions that models in CM should accommodate rapid modifications and new alternatives, as well as be able to simulate quickly (Langsdale et al., 2013), are entirely dependent upon the manner in which these models are used. If stakeholder use of models in interactive stakeholder settings is required, then such a requirement could make sense. In those instances when experts independently use the models, model modifications and simulation times may be much more time-flexible.

Finally, for those approaches whose purpose is to explicitly support decision-making, Voinov and Gaddis' (2008) recommendation that stakeholders should accept modelling methodologies before the presentation of results also holds true. This to a large extent occurred during the DPR, before stakeholders embarked on activities developing the possible measures to be included in the *Blokkendoos*. However, to this requirement the author would suggest a broader obligation to gain stakeholder acceptance for the decision-making processes more generally. Agreement over the modelling methodology may only be one ingredient in these processes. If stakeholders are to have any real influence in decision-making, it therefore makes sense that stakeholder support for these broader processes is also sought prior to their commencement. In the DPR, some stakeholders did not fully comprehend how its decisions were being made, or how they could best influence these.

13.7 Limitations and Future Research

13.7.1 Analytical Framework Limitations

This thesis used an extensive framework to assist in its analysis and assessments of the two studied approaches. Naturally, this raises questions as to whether each framework element was a determining feature in the approaches, and whether all are ultimately needed in the framework. Many elements were undoubtedly critical influencing factors for the collaborative processes implemented. These included the problem context structures, the purposes of the exercise, those elements listed under the more general headings of 'stakeholder involvement' (timing of involvement, levels of participation, participation mode, etc.) and 'organising team', as well as the time and financial resources each approach required. Indeed, modification to Basco Carrera's (unpublished-b) original expanded framework needed to be made to more fully capture the essence of the two approaches, including the delineation of stakeholder model users as being either direct, indirect or non-users, as well as the specific skill requirements demanded by such use. This was similarly the case for organising team requirements, where process management skills were another addition to the framework given their influential role in these approaches.

Other elements could be viewed as being less deterministic in the two cases. Nevertheless, several of these still significantly influenced collaborative elements in the approaches. For example, the cooperative decision-making context did not vary between the cases, so it may not seem important to distinguish these contexts as being such. However, other CM (or perhaps PM) approaches can still be applied in more conflicted or competitive contexts, which will necessarily impact their respective collaborative processes. Therefore, it remains a critical contextual condition. Indeed, the framework could be even further modified to also include the dominant cultural context dimensions, as these likely equally hold implications for participation levels and modes.

'Information handling' elements are others that may not first appear to be influential in the two cases. The models were both physical system models, in which case the inclusion of this signifier may seem to make little sense if considering these cases in isolation. But if taken in a broader context where other CM approaches can use different model types (e.g. socio-physical system models); it nevertheless remains a key distinguishing feature for CM exercises. Furthermore, the software platform, information type, and delivery medium all can help determine which specific individuals can be involved in particular activities; either due to particular knowledge and skills requirements, or their location. Model simulation time (another framework addition from the author) is also a critical determinant as to whether these models are appropriate for direct use by non-modellers or in interactive face-to-face settings.

That being said, some contextual elements – although useful in providing a ready ex post summary for each of these case studies – appear to be superfluous to requirements to assist in ex ante CM approach selection. The decision-making level (i.e. whether the process is for planning, management or operational decision-making) largely determines which stakeholders to involve in CM exercises, but not so much the nature of the collaborative approach. For example, in management level decision-making, it may not be important to involve lower-level stakeholders, whereas there may be a much greater imperative to do so in planning exercises. In operational level decision-making, stakeholder collaboration may not even ever be required. Thus, decision level impacts could be covered during case-specific stakeholder analysis performed prior to the commencement of CM. This is likewise the case for the project's time horizon, scale of action and domain. None of these elements were ultimately deterministic for the collaborative *processes* in the approaches, but simply helped dictate which stakeholders were to be involved.

In addition to the above, this thesis has hopefully demonstrated that the analytical CM framework cannot be taken in isolation to assess the effectiveness or otherwise of these approaches. This was never its purpose. But it is nevertheless important that future practitioners remain cognisant of this fact when implementing future CM exercises. Certainly, one can establish the broad contexts and purposes for each approach; the modelling tool to be used; the skills, time and financial resources needed; and how and when stakeholders are to be involved. This is all important and useful information for any potential CM practitioners. However, with particular respects to the who, how and when of stakeholder involvement, one cannot establish from the framework which characteristics of their involvement stakeholders valued, or those they felt could have been modified and improved. Nor does it capture any case-specific contextual factors (e.g. time constraints, etc.) that may significantly impact approach outcomes. Consequently, other additions to the framework could perhaps be made to summarise and highlight these potential approach successes and pitfalls. These could include helpful suggestions by which to maintain or mitigate these.

Such changes notwithstanding, it remains essential for any CM approach presentations to be informed by wide-ranging stakeholder-based evaluations of their effectiveness. These may be quantitative; however, undertaking qualitative evaluations – although more time consuming – allow researchers to delve much deeper into the underlying reasons for the successes or limitations of each approach. In presenting such key information, future practitioners can then be made aware of any particular approach strengths or drawbacks, and modify implementations of the approach accordingly.

13.7.2 Representativeness of the Interviewed Respondents

Another methodological limitation, to the study, however, stems from its many findings being drawn directly from the responses of the interviewed respondents. Although ascertaining the detailed perspectives of those who had been most involved in each of these two CM exercises was one of the key objectives of the research, this naturally raises questions regarding the representativeness of these responses to the other stakeholders involved. In the case of AZURE, the relatively compact and self-contained nature of the consortium meant that it was a relatively uncomplicated exercise to identify all the individuals involved in the model development process, and to be sure to approach a representative from each individual organisation. Similarly, the fact that the model had only recently been completed and issued for use meant that the potential pool of external model users was equally small. As such, the author believes that AZURE stakeholder perspectives presented as part of this research are a realistic representation of the views and experiences of the stakeholders involved in the Consortium Modelling approach.

In the case of the DPR, the relatively broad nature of the programme along the Waal-Merwedes meant that the potential number of stakeholders participating in its Model-Supported Collaborative Planning approach was much larger. In terms of direct stakeholders participating in the regional process, there were notionally 23 municipalities (15 Waal and 8 Merwedes municipalities) involved, in addition to the province, RWS and water board. The potential pool of KBG members was also much larger (in the order of 50 organisations across the Rhine), as was the pool of stakeholders involved in any informing *WaalWeelde West* processes. Consequently, it was not feasible within the scope of this study to contact representatives from every stakeholder to ascertain their perspectives of the approach. Moreover, the specific focus of this study was most on the *modelling* aspects of the approach. This served to restrict the potential pool of stakeholders to contact regarding their experiences to those who had been directly exposed to, or informed, the development of the *Blokkendoos*; which were relatively few. Indeed, based upon the results of the author's snowballing technique, the two municipal representatives surveyed in this study were the only representatives from *any* Waal-Merwedes municipalities to have used the model (either directly or indirectly). Similarly, no KBG members were ever exposed to the redeveloped *Blokkendoos*, in which case surveying theirs and other municipal representatives' experiences regarding the modelling aspects of the approach made little sense.

Both these characteristics of the second case study hold very clear implications for the representativeness of the surveyed perspectives presented in this thesis. In the case of the DPRPB and the regional working group, such concerns are negligible as often more than one representative from each of the key stakeholders involved in these bodies was interviewed during the course of this research. However, once we traverse into the outer two 'Circles of Influence', the issue of representativeness must be confronted. The author recognises that the interviewed respondents from the municipalities and special interest groups cannot be considered to constitute a representative sample for all local government agencies and organisations involved in this programme. As such, one must treat any findings based upon their reflections with a degree of caution, particularly with respects to any findings relating to the broader non-modelling aspects of the Model-Supported Collaborative Planning approach. With respects to the municipalities, this study's model-user respondents represented two of the most actively involved municipal actors in the DPR, in which case their frustrations at not being able to be more involved or have more influence is understandable. It could be that for other, lesser-involved municipalities their reduced involvement and influence presented little issue. This is similarly the case for non-involved KBG members, whose lack of interest in participating in the programme could have been for a variety of reasons. Indeed, exploring the relative motivations, interest levels and broader perspectives on DPR participation from those stakeholders less involved in the modelling aspects of the approach would be a ripe topic for additional research.

13.7.3 Number of Case Studies

A further methodological constraint on this research was the restriction of the study to two CM case studies. Naturally it would have been desirable to critically analyse additional CM approaches, or perhaps even other manifestations of the same approaches, situated within different cultural contexts. Doing so would have provided a much broader foundation upon which to base many of the findings presented in this chapter. That being said, the author is unaware of other cases for these two approaches being applied outside of the Netherlands. Moreover, such research was well beyond the scope of an MSc study. Nevertheless, undertaking these studies provides further opportunities for additional research. To this end, the author notes that work to this effect is currently being undertaken as PhD research in association with Deltares.

13.7.4 Language Constraints

A last constraint in this study was the restriction of the language of communication between the researcher and any research material to the English language. Although the level of English in the Netherlands is generally high, it cannot be assumed that all respondents were comfortable communicating in this language. This could have led to situations where questions or responses were misinterpreted by both the subject and/or the researcher without their knowledge, thereby affecting the outcomes of the study.

14 Conclusion

Our understanding of Water Resources Management (WRM) problems has undergone a paradigm shift in recent decades. Rather than the relatively certain and uncontested problem definitions of yesteryear which could be approached in a purely technocratic fashion, WRM problems today are now increasingly recognised for their complexity. Consequently, our approaches for dealing with these problems have also had to evolve, and it is recognised that we must now integrate a variety of interests, perspectives and values into any potential solutions. Such approaches must also confront and manage the considerable uncertainties inherent to these complex problem situations. Stakeholder participation is therefore a critical component in dealing with complex problems, as individual experts or organisations alone cannot provide the necessary heterogeneity of values, knowledge and perspectives intrinsic to their potential solutions.

Collaborative Modelling (CM) offers a particularly promising set of approaches with which to confront WRM problems through direct stakeholder involvement in modelling activities. Given the ubiquitous nature of modelling in WRM, CM recognises that expert modellers often lack the capacity and authority to develop models and recommend solutions to these problems in isolation. Rather, CM recognises that the stakeholders themselves need to be engaged in many modelling activities, in order to help build consensus, acceptance and credibility for modelling outputs, or perhaps to improve, legitimise and democratise any decision-making for which these inform. As hopefully this thesis has demonstrated, achieving these (among other) potential benefits is highly dependent upon the processes and structures incorporated into each CM approach. It also rests upon the specifics of the broader context and objectives of the particular modelling exercise.

In Chapter 3, eight distinct CM approaches were identified via literature review. This thesis has examined two additional approaches from the Netherlands, neither of which readily conforms to any of these earlier examples. The most likely of the case studies to apply – AZURE as an example of Interactive Modelling – was found to too significantly diverge from the earlier approach due to its absence of *interactive* stakeholder use of the model. The two 'new' approaches have each been analysed in great detail to help identify which of their characteristics, structures, and processes have been most valued and appreciated by the stakeholders involved in these exercises, and which were viewed as having been critical to their achieving any stated objectives. An additional objective was to identify the broad enabling (or disabling) conditions that were of principal importance in each of the approaches. In having undertaken this analysis, it is hoped this research will assist future water managers determine whether, where, when and how to use similar approaches in future situations should they choose to do so.

14.1 Research Questions Answered

In meeting these objectives, the reader will recall that four research questions were posed in Chapter 2. Detailed answers to each of these questions are contained in the analytical findings presented in the respective case study and discussion chapters. The following paragraphs, however, recapitulate and summarise the author's key findings in relation to each question.

Q1.1 To which situations and contexts have the two approaches been applied and which were important for them achieving their objectives?

For AZURE's Consortium Modelling approach, the principal objective was model improvement – to develop the scientifically accurate and generalizable regional groundwater model – rather than policy making. Its local-regional scale of action defined the project, as did its flexible temporal coverage. Also, the model was developed to serve both groundwater management and policy-level decision-making. The approach was set within a collaborative decision-making context: every consortium actor was committed to building a consensus model and contributing financially towards achieving this goal. Although each of these factors contributed to the approach achieving its objectives, it is perhaps the last of these that most enabled it to do so.

For the Model-Supported Collaborative Planning approach in the DPR, the different values, opinions and perspectives of the various stakeholders dictated objectives to formulate the proposed FRM strategy. Scientific uncertainties still existed; however fully confronting these with stakeholders was not the focus of the approach. Its principal purposes were to support decision-making and to build stakeholder acceptance for the preferred strategy. The *Blokkendoos* model was not the main concern in the approach, but was only one of several inputs to be considered. The local-national character of the problem dictated stakeholder structures within the approach, as did the long-term time horizon of its FRM policy-making. The approach was set within a cooperative decision-making context for its key institutional actors collaborating to negotiate the compromise strategy. Strict DPR time constraints also placed stakeholders under constant pressure to complete activities within allotted timeframes. Each of the above factors was again important in determining the extent to which the approach achieved its objectives. However, the effects of competing stakeholder values, as well as the programme's strict time limitations are ultimately viewed as having greatest affected its outcomes.

Q1.2 When and how were different stakeholders involved during the two studied approaches? Did they find this level of involvement appropriate to achieve the objectives of the modelling exercises?

The Consortium Modelling approach's exclusive focus on model improvement meant that it made sense to limit stakeholder involvement to those institutional actors with the necessary geohydrological knowledge. These actors moreover enjoyed the broad trust of other, non-involved stakeholders to undertake model development. As an exercise in model co-construction, the approach demonstrated co-decision making levels of stakeholder collaboration. Client stakeholders were heavily involved and took decisions during every key model development phase: from project initiation and defining project objectives through to model completion. Stakeholders were divided into multiple smaller regional and expert sub-groups, ensuring that each stakeholder's voice could be heard. External regional technical experts were also engaged to act as interpreters between the clients and the modelling team, further boosting the clients' influence and control. A central representative core group of stakeholders was nominated to manage the day-to-day progress of the development process, coordinated by an independent external process manager. The process manager was also responsible for balancing all stakeholder interests and facilitating the formulation of the joint model consensus for the consortium as a whole. Such intensive stakeholder involvement, structures, support and decision-making processes placed client stakeholders firmly in command of the development process. As such, clients were generally satisfied with most outcomes of the approach, as well as their respective levels of influence and involvement throughout the process.

Model-Supported Collaborative Planning in the DPR used lower levels of stakeholder participation within its top-down approach. Large numbers of heterogeneous stakeholders were structured in a manner akin to the 'Circles of Influence' model, creating tiers of participation. National and regional government representatives set project objectives, before they collaborated during 'Front- and Back-End' inputs to co-design the various possible FRM measures and strategy. Those from municipal and special interest groups could also contribute via a number of participatory discussion forums, but were further removed from decision-making. In the Waal-Merwedes region, the DPR also tried to incorporate findings from the more bottom-up planning process of the concurrent *WaalWeelde West* programme. The DPR is to be broadly commended for involving such a wide range of relevant stakeholders in planning activities. However, more meaningful involvement for stakeholders from its outer circles of involvement could have improved the application of the 'Circles of Influence' model. Ultimately, national and regional government representatives were much more able to influence the modelling and planning agenda than their lower-level counterparts. Moreover, lower-level representatives clearly expressed that they would have liked to exert greater influence during the DPR. Stakeholder satisfaction directly reflected their respective levels of influence: stakeholders with greater influence were generally satisfied with their levels of participation and the programme's processes and outcomes, whilst those with less influence were less satisfied. This suggests that the application of a 'Circles of Influence' model could have been strengthened by increasing opportunities for more bottom-up planning, in addition to improving the integration of *WaalWeelde West*'s findings into the DPR.

Q1.3 What minimum technical, modelling, or other skills and resources (if any) were needed by the different stakeholders and organising teams for each of the two approaches?

The Consortium Modelling approach was predicated upon its client representatives possessing sufficient geohydrological knowledge. Even with the inclusion of regional advisors to interpret the most technical aspects of model construction, stakeholders nevertheless needed an adequate baseline understanding of hydrological processes and groundwater modelling concepts to contribute. Many consortium stakeholders were also the eventual direct users of the highly sophisticated model, which requires specialist computing skills. The Consortium Modelling approach was not targeted at technical lay-people.

In the DPR, stakeholders could possess much lower levels of technical knowledge, in this case regarding river hydraulics. Rather, specific local and regional knowledge of the areas along the Waal-Merwedes were of greatest importance to enable more integrated development planning. Direct use of the *Blokkendoos* model required only basic computer skills, however stakeholders generally felt that a minimum level of technical knowledge was nevertheless required to fully comprehend the implications of its inputs and outputs. For this reason the majority of its use was left to contracted expert advisors.

In addition to 'hard' technical skills, participants in both case studies also relied upon 'soft' skills in each approach. Communication and negotiation skills were an obvious necessity, but equally so were a preparedness to be flexible, open-minded, willing to share information and accommodating towards others' perspectives. Such 'soft' skills were equally critical for the organising teams in both approaches, who also required effective process management and impartial group facilitation skills. In AZURE, the inclusion of a specialist process manager directly contributed these qualities to the approach and encouraged and supported all client and modelling stakeholders to likewise display them. This was particularly important given the dominance of hydrologists and modellers in the development process, neither of which are groups of individuals traditionally recognised for demonstrating such qualities. In the DPR, specialist process management was not deemed necessary, with government agency officials providing these services. However, the lack of impartial process management arguably impacted on the overall credibility of this approach, and its collaborative planning processes may have also benefitted from specialist external process management.

Both case studies also demonstrated the financial commitment and considerable time resources effective collaboration demands. The Consortium Modelling approach took 3 years of intensive involvement for all those involved. Its outcomes would not have achieved the degree of success they did without this level of commitment from stakeholders, nor without their flexibility and willingness to grant both time and budget extensions as they became required. Likewise, the strict 2-2.5 years made available for collaborative strategy formulation in the DPR was arguably insufficient, particularly if any measures to increase lower-level stakeholder influence were to be implemented. Indeed, the comparable but more bottom-up approach in *WaalWeelde West* was expected to take 4.5-5 years to complete. This demonstrates the importance of allowing for both plenty of time and flexibility in such planning approaches if they are to build the necessary stakeholder consensus, support and acceptance for the developed plans.

Q2.1 What are the perspectives of the different stakeholders regarding the effectiveness (or otherwise) of the two studied approaches/tools in achieving any potential collaborative benefits?

The interviewed stakeholders generally agreed that both of the adopted approaches were able to deliver broad collaborative benefits. However, stakeholder praise for the Consortium Modelling approach was much stronger (and widespread) than for the Model-Supported Collaborative Planning approach.

Both approaches were praised for their abilities to improve model quality, in particular for the local knowledge that was incorporated into model inputs. This also helped increase model credibility and transparency for stakeholders. Stakeholders similarly recounted that each approach facilitated collaborative learning, including the ability to both gain insights into others' perspectives as well as improving their technical understanding of the water resources system behaviour. In specific relation to the *Blokkendoos*, non-technical stakeholders found the ability of the model to simplify and effectively communicate complex hydraulic processes one of the key successes of the model-supported approach.

Both approaches were also deemed to have helped generate consensus through the cooperation of their *collaborating* stakeholders. In AZURE, an effective and successful modelling consensus was reached through the collaborative management of all scientific uncertainties. In the DPR, VKS consensus was achieved amongst the parties involved in the regional working group. These stakeholders also agreed that the latter approach contributed to improved decision-making. But a similar consensus was not achieved with all lower-level DPR stakeholders. These groups' reduced influence rather led to increased perceptions of bias and 'action mismatch' for some stakeholders.

Finally, stakeholder conflict was observed to arise in both approaches. In AZURE, most tensions stemmed from the poor technical quality and technical process management of the modelling team during the project. Indeed, both these facets were considered the root causes for any of its negative outcomes, and not the collaborative Consortium Modelling approach itself. In the DPR, disagreements and stakeholder conflict regarding the various strategy alternatives were far more fundamental features of the approach. For both approaches, their generally cooperative contexts enabled stakeholders to effectively confront, manage or mitigate most disagreements to varying extents. In AZURE, this was largely successful given the structures, processes and support provided by the Consortium Modelling approach. In the DPR, confronting, managing or mitigating disagreements were also effective for its most involved stakeholders in the working group. However, the reduced involvement and influence of lower-level stakeholders in the approach led to some tensions and frustrations persisting between these and working group stakeholders, much to the detriment of the approach.

14.2 Case-Specific Recommendations

In light of these key analytical findings, several case-specific recommendations are suggested to improve or enhance future implementations of each approach. Some relate more to the approach in general, whilst others are more focussed on the specifics of the modelling software utilised.

14.2.1 Consortium Modelling

For the largely successful Consortium Modelling approach, it is recommended to ensure that sound technical process and quality management are implemented during model construction activities. More common sense than actual approach improvements, these two issues were the root cause for almost all stakeholder dissatisfaction and frustration in AZURE. Even with a particularly strong CM approach, if the technical delivery and management of the model is not completed well and falls short in stakeholder expectations, considerable stakeholder displeasure and ill feelings can result. Model transparency outcomes can also be negatively impacted. In relation to the iMOD modelling software, the author encourages Deltares and future groundwater modelling consortia to consider reinstating and utilising dormant software features that would encourage both more individual and group stakeholder interaction with the model. This is particularly with regards to its application in any subsequent policy-making exercises. That being said, these are all generally extremely minor criticisms of what is a largely successful and strong collaborative approach to model development.

14.2.2 Model-Supported Collaborative Planning

The DPR's Model-Supported Collaborative Planning approach involved much larger numbers of stakeholders, organised into radiating 'circles' of involvement. This made sense. However, given approach objectives to build stakeholder consensus, support and acceptance, its structural and process weaknesses arose from the absence of lower-level stakeholders from inner 'circles' as well as the levels of participation each 'circle' permitted. It is recommended that future applications of the approach ensure that representative and nominated lower-level stakeholders are also included in the regional working group. This would assist in building stronger linkages between the 'circles' – which in the DPR tended to be weak – and would result in a collaborative structure more in keeping with the intention of Werick and Whipple's (1994) original 'Circles of Influence' model. In addition, the author recommends replacing outer 'circle' discussion forums with collaborative co-designing workshops – more like those in *WaalWeelde West* – to devolve policy design responsibilities to lower levels. This would increase lower-level stakeholders' influence in the planning process and reduce any instances of 'action mismatch'.

Implementing these strategies would likely improve both the motivation and satisfaction of those stakeholders who were situated in outer 'circles'. Furthermore, reconceptualising the approach's structure of stakeholder involvement as 'Circles of Collaboration' – rather than as 'Circles of Influence' – might also assist practitioners to gain a better understanding of the improved approach. Although understandably initiated in a top-down fashion, the DPR would have benefitted from implementing more collaborative bottom-up processes, such as those displayed during *WaalWeelde West*. As an ancillary note, it would also have been both beneficial and practical had *WaalWeelde West* processes been directly integrated into the DPR's given the presence and similar objectives of the two programmes. Keeping them separate and more at arm's length only served to generate confusion and uncertainty for the local stakeholders involved in both programmes.

In specific relation to future *Blokkendoos*-type models, these should respect the principle of including *every* stakeholder-devised measure in the model database, rather than simply those most likely. Likewise, key model uncertainties should be collaboratively confronted and managed with *all* stakeholders, to avoid later discrediting of the model or its developed strategies. Finally, model developers could focus additional attention on further improving *Blokkendoos* accessibility to non-technical users. Viable ways to increase direct stakeholder engagement with the model include reducing the technical 'feel' of the interface and enhancing the manner in which it communicates information regarding spatial measures and strategies; the latter perhaps via the inclusion of three-dimensional landscape visualisations.

14.3 Collaboration Over Participation, Among Other Considerations

Notwithstanding the preceding case-specific conclusions and recommendations, one can conclude from both case studies that stakeholders appreciate the chance to collaborate when given opportunities to do so. It was only when lower levels of participation displaced more collaborative forms that stakeholder dissatisfaction with either approach emerged. This strikes at the very foundation of CM; namely who, how and when stakeholders are involved in these exercises. Whom it is appropriate to involve will always depend upon problem contexts, problem structures and objectives. A collaborative technocratic approach may be valid when the purpose of the CM exercise is to research and analyse the complexity of the water resources system. Similarly, reduced stakeholder involvement in model construction makes sense when the scientific knowledge base is relatively certain and stakeholders will not directly use the model. However, broad stakeholder involvement is imperative whenever clarifying stakeholder values, democratising policy-making, or direct stakeholder use of the model are primary concerns.

Whatever the situation, appropriately representative stakeholders must be introduced as early as possible in the process, when any objectives and assumptions specific to the exercise are set. Only then can one ensure that the relevant stakeholder interests will be served. For these CM approaches, particular attention must also be paid to levels of stakeholder participation. In such planning and development processes, these levels must be sufficient for truly representative stakeholders to meaningfully influence outcomes, as well as generate and maintain the necessary stakeholder interest and respect for the approach. Given sufficient financial resources and time, higher levels of participation are preferred, with the defining threshold lying between discussion and co-designing inputs for any relevant stakeholders. It should also be recognised that the cost and time implications for conducting co-designing workshops in place of participatory discussion or consultation forums need not necessarily be significant. These could even save money and time in the long run by avoiding the need for costly supplementary participatory processes, lengthy legal challenges or perhaps ultimately rework. CM practitioners are thus strongly encouraged to accommodate – as a minimum – co-designing inputs for relevant stakeholders in these approaches as is necessary to achieve all project objectives. If necessary, such collaboration can be structured using a 'Circles of Influence' model to limit total stakeholder numbers in any individual stakeholder forum, provided that sufficiently strong linkages are maintained between the 'circles'.

Other enabling factors were also important determinants in these two CM approaches. One cannot underestimate the positive and constructive role experts played in constructing the models used, as well as their roles in interpreting technical information and advising less-expert stakeholders. The involvement of experts is therefore crucial in building model and approach credibility. However, fruitful expert involvement also depends upon their perceived neutrality and the amounts of stakeholder trust and respect they command. In addition, experts in these exercises must ensure that they confront any scientific uncertainties underpinning the modelling assignments collectively with all stakeholders. These are not choices that should reside solely within the experts' domain, but rather have consensus approaches to them identified with stakeholders; informed by expert advice. This reduces the propensity for complex CM problems to drift towards (or remain in) completely unstructured territories, and maximises model credibility.

More prosaically, one cannot underestimate the importance of sound process management to CM. This needs to be impartial to help build stakeholder acceptance for approach outcomes and reduce perceptions of bias, and is much easier to achieve in those instances when an external process manager is engaged. Proper technical management of model construction activities is similarly important. Ensuring model versions are error-free and functioning when required is crucial in achieving project objectives. Therefore, sufficient time must be allowed for during CM for both collaborative *and* model-building processes. Neither of these can be rushed, and CM approaches must be kept flexible and open to potential stakeholder-driven changes to their procedures, priorities, or even their defining objectives. That being said, allowing too much time in CM exercises could lead to complications, specifically their ability to stimulate and maintain stakeholder motivation and interest. Striking the right balance is critical. For the Consortium Modelling approach, a 2-3 year timeframe appears appropriate. When using Model-Supported Collaborative Planning, more time will likely be required (in the order of 3-5 years). However, relevant timeframes will be dependent upon the specific scale of the problem being addressed, as well as the numbers of potential stakeholders involved.

A final factor common to both case studies that should not be ignored is the particular 'national cultural context' in which both these approaches manifested. This may constitute a critical enabling condition for each of the approaches. Dutch culture is well known for its particular strength in collaborative decision-making and consensus forming, both of which featured heavily in each approach. Practitioners must be careful assuming that either of the two approaches can be easily translated to different cultural contexts that do not share similar traditions. The same can be said for any of the other potentially instrumental dimensions of Dutch culture, including its relative individualism, low power difference and low uncertainty avoidance.

In light of these findings, many of the recommended guidelines for CM exercises presented in the literature have been confirmed through case studies of these two approaches. However, some have been shown to be more dependent upon the specific purpose of the CM exercise or its problem context, or a combination of both. These relate most to suggestions that stakeholders should be continuously involved in as many modelling activities as possible; or that the selection and performance of modelling software should facilitate stakeholder use of models. Moreover, it is recommended that any guidelines that call for stakeholder acceptance of modelling methodologies be augmented with a requirement for the acceptance of decision-making processes within these approaches more generally. This is particularly relevant to any CM approaches where the specific purpose is to support decision-making. Care must be taken when applying these guidelines to actual CM exercises, and practitioners must realise that not all of these will always apply in all instances.

14.4 Limitations and Future Research

The above findings notwithstanding, this thesis has also helped to recognise those elements of the applied analytical framework that were more or less influential in determining the structures and processes of the two approaches. In general, most elements were found to significantly impact approach structures and processes, aside from several case-specific contextual elements. The latter group included those elements relating to the problem time horizon, its scale of action, domain and decision-making level. Although useful in summarising contextual information for a given CM exercise, none of these elements were seen to critically determine the makeup of the approaches in and of themselves. That is, they each simply impacted which stakeholders were to be included in these exercises: information that would be typically captured through robust stakeholder analysis. A potential addition to the framework has also been identified, to include for those cultural dimensions that may impact on the contexts in which a CM approach can be successfully implemented.

This research has also revealed the limitations of the analytical CM framework with regards to assessing the effectiveness or otherwise of these approaches. This was never its purpose, but it is nevertheless important that future practitioners remain cognisant of this when implementing future CM exercises. Rather, the framework must be used in combination with a review of previous stakeholder reflections of their experiences to properly establish the strengths and pitfalls of these approaches, and to modify future implementations accordingly. Alternatively, additional provisions could be made within the analytical framework to include for this information, summarising and highlighting these strengths and weaknesses and providing helpful suggestions by which to maintain or mitigate these.

In addition to the afore-mentioned cultural constraints, other methodological limitations to the study were the representativeness of the interviewed respondents, particularly in the case of the DPR; the restricted number of case studies upon which to draw any generalizable conclusions; and the restriction of all communication in this research to English. Not much could be done regarding the third limitation within the context of this independent research. However, the preceding two both offer ripe opportunities for future research. Additional lower-level stakeholders could be surveyed regarding their experiences in the DPR, and other CM approaches could be analysed to see if they confirm or contest the findings presented in these pages. In doing so, the ultimate development of a useful toolkit to help CM practitioners select and implement the most appropriate CM approach to their purpose may eventually be realised.

14.5 Closing Remarks

The Consortium Modelling and Model-Supported Collaborative Planning approaches presented in this thesis provide two alternative and contrasting examples of CM from the Netherlands. Several findings within this study echo many of the various principles and guidelines laid down for such exercises by previous scholars. Detailed stakeholder accounts of their experiences during the two cases nevertheless demonstrate there remains a need to prompt and remind CM practitioners of many of these principles, as well as demonstrating the increased gains that can be achieved through raising levels of stakeholder participation. The specific case study of the DPR has additionally helped to clarify the practical means by which larger numbers of stakeholders can be accommodated within a robust and meaningful CM structure and process.

This thesis has hopefully highlighted and clarified for the reader significant features and issues presented by each of the two CM approaches. As the march towards strengthening stakeholder involvement in WRM seems set to continue, finding ways to more effectively devolve design- and decision-making powers to stakeholders will only receive greater attention. CM offers particular promise in this regard, and future practitioners will hopefully benefit from the insights presented within these pages; applying them to any similar CM exercises they may choose to implement in the future.

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Appendix A

Semi-Structured Interview Question Schedule

Appendix A:
Semi-Structured Interview Question Schedule

GENERAL

1. Tell me about your background, and how you have been involved in the case study.

THE MODEL, STAKEHOLDERS & PROCESS

The Model

2. Tell me about the model (e.g. the problems it seeks to address, the scale it operates at and the decision-making level it supports) and your involvement with it.

Stakeholder Involvement

3. Tell me about your views on stakeholder involvement in WRM (and for modelling activities in particular), and how you saw these views reflected in this project.

4. Do you think that you or any other stakeholders should have been more (or less) involved in the process? What would have been the benefits of doing so?

5. How was it determined who was involved in the CM approach, and who wasn't? Why do you think these choices were made? How willing were you to be involved?

Model Development

6. Tell me about how stakeholders were involved during the model development process (including all phases), focussing on both the activities you were involved in and the manner in which this involvement manifested itself.

7. How satisfied were you with this level of involvement?

8. How were any decisions made during the modelling process?

9. What skills or knowledge do you think were necessary for stakeholder involvement in model development? Did all stakeholders demonstrate these skills?

10. What skills or knowledge do you think were necessary for the organising/model-building team to drive the development process? Did these individuals demonstrate these skills?

Model Use

11. Tell me about how you/other stakeholders have been involved in the use of the model. Have any other stakeholders been included in this use? How have users have found the experience of using the model (e.g. ease of use, user interface, presentation of results)?

12. What skills or knowledge do you think are/were necessary for stakeholder involvement in model use activities? Did all stakeholders demonstrate these skills?

PARTICIPATORY OBJECTIVES, BENEFITS & LIMITATIONS

General

13. Tell me about your prior experience of working in multi-actor settings (and modelling, where appropriate).

Participatory Objectives

14. What do you think were the main objectives of developing or using the model *jointly with others*?

Decision-Making/Model Improvement:

15. To what extent do you think that both model or project outcomes have been improved or not as a result of stakeholder participation in modelling and/or decision-making?
    - Model quality (accuracy)
    - Integrating cross-sector perspectives and local knowledge
    - Capturing system complexity
    - Managing uncertainties
    - Proposing innovative measures, strategies or other actions
    - Generating consensus

Learning:

16. To what extent do you think you obtained a better understanding of the perspectives & interests of the other stakeholders, or of the water system itself as a result of your involvement?
    - Most important new insights obtained
    - Importance of this learning

Conflict Mediation/Building Cooperation:

17. How would you describe the relationships between the various involved stakeholders prior to, during, and following the model development process (e.g. in terms of differing interests, levels of cooperation, any disagreements, etc.)?
    - Did any conflicts or disagreements between the parties increase or decrease as a result of the process? How?
    - Have channels of communication and cooperation opened up between the parties that otherwise would not have as a result of the process?

Credibility, Transparency, Democracy, Ownership

18. Describe how trustworthy or accurate you believe the model to be.
    - How likely will you be to use the model to undertake future tasks?

19. To what extent would you say you understand what the model does and how it works?

20. Describe the degree to which the model and the overall approach represented yours and other stakeholders' interests.
    - Were any stakeholders' interests more represented than others? Whose and how?

21. How satisfied were you with the level of control/influence that you/other stakeholders could exert during the approach?
    - Was there too much/not enough expert involvement or control?

SUMMARY QUESTION

22. Overall, do you view this modelling process as a success or failure? Why?
    - To what extent did you find the process useful or not?
    - Would you become involved in a similar process in the future?