Towards a pragmatic approach for dealing with uncertainties in water management practice

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Abstract

Management of water resources is afflicted with uncertainties. Nowadays it is facing more and new uncertainties since pace and dimension of changes (e.g. climatic, demographic) are accelerating and are likely to increase even more in the future. Hence it is crucial to find pragmatic ways to deal with these uncertainties in water management. So far, decision-making under uncertainty in water management is based on either intuition, heuristics and experience of water managers or on expert assessments all of which are only of limited use for water managers in practice. We argue for an analytical yet pragmatic approach to enable practitioners to deal with uncertainties in a more explicit and systematic way and allow for better informed decisions. Our approach is based on the concept of framing, referring to the different ways in which people make sense of the world and of the uncertainties. We applied and tested recently developed parameters that aim to shed light on the framing of uncertainty in two sub-basins of the Rhine. We present and discuss the results of a series of stakeholder interactions in the two basins aimed at developing strategies for improving dealing with uncertainties. The strategies are synthesized in a cross-checking list based on the uncertainty framing parameters as a hands-on tool for systematically identifying improvement options when dealing with uncertainty in water management practice. We conclude with suggestions for testing the developed check-list as a tool for decision aid in water management practice.

Key words: water management, future uncertainties, framing of uncertainties, hands-on decision aid, tools for practice, robust strategies, social learning

1 Introduction

Water resource systems are complex systems characterized by multi-level interactions and non-linear changes over space and time (e.g. Pahl-Wostl, 2007). Different sectors and actors with different interests, objectives, and mental models are involved. All these conditions render water management issues highly uncertain. Uncertainty in this paper is defined as a situation in which there is not a unique and complete understanding of the system to be managed (following Brugnach *et al*., 2008). Management of water resources nowadays is facing more and new uncertainties since pace and dimension of changes, particularly climatic and demographic changes, are incremental and are likely to increase even more in the future. At the same time, decisions in water management are mostly taken in an expert driven way (e.g. Lowe *et al*., 2007). In the same way that decision-making processes are strongly influenced by expert assessments, addressing problems of uncertainty also happens in an expert mode. So far, uncertainties in water management have mostly been assessed from scientific points of view (see review by Walker *et al*., 2003 or Klauer and Brown, 2004). Scientific assessment and analysis of uncertainty is based on expert knowledge and hence it is often labour-intensive and technical and not always easily understandable, accessible or usable for practitioners on the ground (Brugnach *et al*., 2007, Groves & Lempert, 2007, Mc Culloch, 2007, Patt , 2007). In a nutshell, the usefulness of scientific analysis often clashes with requirements in practice.

Practitioners tend to deal with uncertainties in a more intuitive way (see e.g. Einsiedel, 1999, Friend and Hickling, 1997, see Gigerenzer and Selten, 2001a for a review of heuristics). This may be a simple non-analytical but nevertheless effective way of decision-making (Gigerenzer and Selten, 2001b: 7). Simplifications and biases may be helpful in taking decisions, but such heuristics are not always helpful in a broader context, especially in domains where decision-makers are confronted with novel situations as is the case when dealing with uncertainties (see Goldstein *et al*., 2001: 177). Acting on intuition based on years of experience does not help in such situations. Moreover, decision-making through heuristics is not transparent and can be hard to explain or justify which can create difficulties, particularly when decisions are being taken by public administration. Hosseini (2001:267) presents a range of cognitive simplification processes with regard to governmental problems which all hinder to take uncertainties into account. Information is misinterpreted or discomforted through ‘prior hypothesis bias’, similar to confirmation bias, and final estimates of values get biased towards an initial value through ‘adjustment and anchoring’ (*ibidem*). Moreover, leaders may engage in inappropriate discounting of negative information with respect to a prior commitment to a course of action in order to prolong their years in office (‘escalating commitment’) or they ‘reason by analogy’ which means that Analogies are drawn from simple situations to complex strategic problems thereby reducing the uncertainty involved in the complex problem (*ibidem*). The presented strategies or biases may be useful to be able to take a decision but are too simplistic to cope with uncertainty and complexity. More comprehensive, transparent and structured analytical approaches are needed on the ground to effectively deal with uncertainties.

With regard to structured approaches to support decision making in water management, numerous Decision Support Systems (DSS) and other decision aid tools (e.g. Multi-Criteria Analysis, Bayesian Belief Networks etc.) do exist already which are useful for their specific purposes. Drawbacks, however, are on the one hand that they are often rather rigid and lack flexibility in application and require sophisticated software and respective skills. Hence, analysis often is performed by scientists or other experts rather than by the practitioners themselves

(Messner *et al*., 2006: 70). On the other hand uncertainties are not necessarily addressed comprehensively. Either they are not assessed explicitly or are assessed only in a limited way; they may, for instance, regard uncertainties as restricted to probabilities, or model and data uncertainty, or uncertainty with respect to unforeseeable future developments that is addressed through a range of scenarios (*ibidem*). Frequently, uncertainties are made explicit but no strategies are conceived on how to deal with them (see Paneque Salgado *et al*., 2006).

In order to find ways to address the problem of uncertainties from the perspective of practitioners which are easy for them to apply we consider it essential to draw attention to how practitioners frame uncertainties, i.e. their understanding of an uncertainty, the differences in their points of views and how they think and feel about an uncertainty. In scientific analysis, the framing of the experts and scientists is taken for granted and neutral – whereas it is not – without considering that practitioners possibly and likely have a different view than scientists (Dewulf *et al*., 2005:123). Methods to assess and deal with uncertainty are developed from a scientific perspective, supposedly being objective and rational. Such scientific framing, however, may go past practitioners' needs. We argue for involving stakeholders at an earlier stage of problem solving and assess how they themselves conceive of the problems and the uncertainties. Understanding how water managers frame uncertainties is then a basis to develop a more tailored decision aid tool that meets their needs and allows them to take action possibly without additional scientific or other expert assessment and analysis. Our underlying assumption is that dealing with uncertainties in a more explicit and structured way allows for better informed decisions in water management. That way heuristics may be reflected upon and modified, and the drawbacks of actions based on intuition, biases and experience be overcome. That does, however, not mean that we argue for by-passing scientific evidence and analysis of uncertainties. Rather, we aim at making dealing with uncertainties more comprehensive through involving practitioners in an earlier stage of decision-making which is when uncertainties are getting framed. Beyond facilitating decision-making for practitioners, needs for scientific support can be identified more precisely as to where and what kind of scientific analysis is needed in order to make an informed decision.

In this paper, we present a structured but simple approach to enable practitioners to deal with uncertainties in a more explicit and systematic way to prepare and allow for better informed decisions. The approach is based on the concept of framing that is how people make sense of the world. Dewulf et al. state that there is a "*small but growing literature on the framing of environmental issues that reveals differences in how stakeholders form interpretations of what is at stake and what should be done*" (Dewulf *et al*., 2005: 117). Here, the concept of framing is used for analysing uncertainties in water management. Recently, in an ex-post analysis Isendahl et al. (in press) developed parameters that aim to shed light on the framing of uncertainty. We tested those parameters in two case studies of the EU research project NeWater[1] through a series of stakeholder interactions for the development of strategies to improve dealing with uncertainty. In the Dutch Kromme Rijn and the German Wupper, both sub-basins of the Rhine, uncertainties of water management practice were captured and analyzed over several months and strategies to improve dealing with uncertainty derived along concrete examples of uncertainty.

The results section of this paper presents the main results from the discussions on uncertainty in the Wupper and Kromme Rijn along the framing parameters. The results are generated from the specific examples of uncertainty that were analyzed in the discussions. First the strategies the

[1] NeWater, New Approaches for Adaptive Water Management under Uncertainty, funded by the 6th Framework Programme of the European Commission, contract n° 511179. www.newater.info

participants came up with during the research phase are presented for each framing parameter to illustrate the applicability of the framing parameters in active analysis (as opposed to the ex-post analysis they were derived from). These results are then analyzed and supplemented by findings from the authors. From these two sections together we derive a cross-checking list for dealing with uncertainties (table 4) which contains the abstracted and condensed findings. We discuss the use of the framing parameters and the cross-checking list for water management practice and conclude with suggestions for testing that check-list as a tool for decision aid in water management practice.

2 Conceptual background

In water management complexity and ambiguity play an important role. Uncertainties arise in the interplay of natural and human processes with multi-level, non-linear and hence often unpredictable behaviours. Uncertainty in this paper is defined as a situation in which there is not a unique and complete understanding of the system to be managed (following Brugnach *et al*., 2008). This emphasizes the importance of complexity and unpredictability of the system which increase the probability of ambiguity, i.e. not having one clear single understanding of the system. It also highlights the importance of the concept of framing in a context where different actors and organizations interact with their respective interests, values, responsibilities etc. rendering decision-making no easy task. Classical decision theory primarily deals with structuring a decision as a set of well defined options which may have different consequences. Uncertainties are taken into account by probabilistic statements on sets of options and consequences (Kreps, 1988) structuring approaches and giving probabilities to action options. Framing starts earlier, prior to decision-making. "*The framing concept draws the attention to the concrete interactions where actors bring in their conceptions of problems and possible solutions, and how they affect each other's frames in and through a developing relationship*" (Dewulf *et al*., 2005: 117). Thus the concept of framing comprises a dynamic interactive process taking into account different conceptions. This is opposed to most applications of decision theory and decision-making processes where framing tends to be already fixed or taken as a given, mostly taking on the scientist's, convenor's or organizer's framing. With the concept of framing it is possible to assess uncertainties before the actual decision-making process starts. It addresses the process that *leads* to decision-making, which has not achieved much attention yet.

Framing means that people make sense of the world in different ways in that they cannot and do not consider all details and information of a certain situation but select the elements of their interest and concern (e.g. Dewulf *et al*., in press, Dewulf *et al*., 2004, Gray 2003, Pahl-Wostl *et al*., 2007). This holds especially true for uncertainties. There are a lot of concepts around framing but little evidence in relation with uncertainties. Recently, Isendahl et al. (in press) developed an approach in close relation with practitioners in water management (Dewulf *et al*., 2008) to shed light on framing processes regarding uncertainty. They derived a set of parameters (see table 1) in an ex-post analysis of narratives of water managers in several European river basins as key aspects of how an actor relates to an uncertainty emerging from recurring issues throughout cases of water resources management in several European river basins in the NeWater project (see Isendahl *et al*., in press).

Table 1: Parameters of framing (after Isendahl *et al*., in press)

Parameter	**Definition**

Positioning	Positioning as the evaluative quality people attach to uncertainties
Urgency	Urgency related to the point of time for taking a decision in the uncertainty situation or to the time frame within which a decision is supposed to have an effect
Responsibility	Responsibility for having caused and/or dealing with the uncertainty, including the perceived scope of influence on the uncertainty situations
Trustworthiness	How trusting actors are towards components of an uncertain situation, e.g. towards data, methods or other actors, including patterns of communication and dependency between actors.

The list of parameters is added by a differentiation between types of uncertainty from Brugnach *et al*. (2008) which had been used as a structuring device in the empirical research the framing parameters are based on. According to the distinction of Brugnach *et al*. uncertainty may be framed as unpredictability, incomplete knowledge or multiple knowledge frames (table 2).

Table 2: Uncertainty categorization by Brugnach *et al*. (2008)

Type of uncertainty (knowledge relationship)	
Unpredictability	▪ unpredictable system behaviour
Incomplete knowledge	▪ lack of information ▪ unreliable information ▪ lack of theoretical understanding ▪ ignorance
Multiple knowledge frames	▪ different and/or conflicting ways of understanding the system ▪ different values and beliefs ▪ different judgement about seriousness of situation, growth potential of problems, priority of actions or interventions

The type of uncertainty together with the four framing parameters form a set of five parameters which was used as a grid for analysis and strategy development in the case studies presented in this paper. The parameters provide a set of potentially relevant aspects for getting a grip on framing of uncertainty. They are not mutually exclusive and the sequence does not imply and ranking in importance. They give shape as to how an actor perceives an uncertainty.

3 Methods

To analyse strategies for dealing with uncertainties several stakeholder interventions were undertaken in the context of the project NeWater. The NeWater project (New Approaches for Adaptive Water Management under Uncertainty) (2005-2009) and aimed at analysing and

fomenting processes of transition to more adaptive processes of water management. The development of concepts and tools that guide an integrated analysis and support a stepwise process of change in water management was the cornerstone of research activities. In this context, exploratory research was undertaken on uncertainties in water management in the form of a series of workshops and interviews in sub-basins of the Rhine, the German Wupper and the Dutch Kromme Rijn. This paper presents part of the results of the interventions. The results are evaluated qualitatively.

The Wupper basin is located in the German state of North Rhine Westphalia, which is characterised by industrial uses and a high density of population. Since decades, the anthropogenic development of the region has influenced the rivers in their use and appearance. Dams provide the region with drinking water. The Wupper is mainly managed by one water authority, which also coordinates different water uses in the Wupper basin. At state level there is the regional government and districts and municipalities at lower levels. Besides there are numerous and diverse water users and organizations in the Wupper basin. The region faces the challenge to implement the EU Water Framework Directive (WFD). At the time of the present research the water authority had started to lead a participatory process in a subcatchment of the Wupper as a pilot project for the implementation of the WFD, which then fed into the formal decision-making process at the regional government. The main aim was to restore the fish population and reach a better ecological status as required by the WFD. (www.newater.info, Möllenkamp *et al*., 2006)

The Kromme Rijn subcatchment drains the water from the surrounding hilly and sandy area of about 50m a.s.l. The land use in the catchment is diverse: woodland, a nature reserve, several large estates and some villages. The lower part is largely used for pastures and horticulture. Water in the Kromme Rijn is managed mainly by the waterboard. Further actors that play a role in water management decisions are the national and provincial governments as well as the municipalities. Stakeholders are also represented by farmers' organizations, nature federations or drinking water companies. The water board is responsible for several water areas for each of which they have to set up and implement a water area plan. The Kromme Rijn water area plan served as a pilot project for setting that plan up in a participatory way. (www.newater.info, van Walsum *et al*., 2006)

The stakeholder groups comprised representatives of public administration or other official entities responsible for the water management at regional and local level (table 3).

Table 3: Participants in the case studies

Wupper: 5 participants	**Kromme Rijn: 3 participants**
• Water authority (2) • Regional government (2) • Public administration of a municipality in the basin (1)	• Water board (2) • Public administration of a municipality in the basin (1)

In each case study, two group meetings were performed over the length of a year and individual interviews with the participants of the group meetings in between. In the first group session, the participants were asked to report on situations of uncertainty in their work life and to structure them according to the Uncertainty Matrix by Brugnach *et al*. (2008) which was elaborated on the

basis of the categories of table 2. From the set of examples the participants chose two to four examples they were interested in learning more about and working with.

The thematic focus of the examples of the two case studies differs due to differences in organizational structure and the local problems at hand. In the Dutch Kromme Rijn issues around the development of a regional water plan[2] prevail since the group of participants had been working together on that plan for the past months. The most discussed example is an uncertainty about the water supply for agriculture in the area. The water supply at that time did not meet the growing demands for irrigation for the fruit farmers in the region. The channels have to be broadened in order to increase water supply. The respective ground required for that, however, mostly belongs to the cattle farmers who do not need more water. Moreover, in the beginning of the problem discussion there was confusion and uncertainty about the responsibility for increasing the water supply as it had never been a problem before. The water authority was assumed to be responsible by habit of its regulation of the water supply but in fact it is not its duty to ensure sufficient water for everybody's needs. These and more problems and uncertainties were to be accommodated in the regional water plan.

Selected uncertainty situations in the Kromme Rijn:

1. Uncertainty with regard to the responsibility for water supply in the context of the regional water plan
2. Uncertainty due to contradictory advice. Example of renaturation of river banks where the ministries for agriculture and the one for nature conservation gave contradictory advice on how to proceed and the water authority had to take a decision.
3. Uncertainty of more general character referring to (negative) coincidences and surprises.

In the Wupper, the range of situations is broader since the participants formed less of a coherent group than in the Kromme Rijn.

Selected uncertainties in the Wupper:

1. Uncertainty in the modelling of eco-systems with regard to the assessment of the good ecological status required by the EU Water Framework Directive (WFD), i.e. how to best assess and describe natural processes through a model.
2. Uncertainty about the implementation of a new participation process as required by the WFD, i.e. whom to involve to which extent with which kind of procedure.
3. Uncertainty of more general character about societal behaviour under pressure, e.g. in times of catastrophes like severe accidents or floodings. That means it is not about the reaction of the competent authority or emergency measures but about the influence society or societal organizations may be able to develop in such times and how that then influences decision-making of the responsible entity.
4. Uncertainty about the consideration of possible aggravation of flooding due to climate change in the flood risk maps. Currently, a fixed additional climate change mark-up is added which is not seen as satisfactory as it holds high uncertainty.

Details of the selected uncertainty situations were elicited through individual interviews with the same participants, each situation along the framing parameters. For the semi-structured interview guide see Appendix I. The results of the interviews served as a basis for the final group

[2] Dutch watergebiedsplan

discussion which focused on identifying intervention moments and developing strategies for improving dealing with uncertainties along the parameters. The analysis draws special attention to controversial issues and possible differences in framing between the participants. Reliability of data as part of trustworthiness is omitted in the present analysis since it was either not a problem or did not play a role at all in the uncertainty situations of the Wupper and the Kromme Rijn. This may, however, well be the case in other regions with less intense or elaborated acquisition and processing of data. The same applies to the perceived scope of influence as part of the responsibility parameter. The participants of the researched case studies reported to be satisfied with their possibilities to take influence on the uncertainty situations. This may of course be different with other people or situations.

The interactions were performed in the participants' native language. The evaluation is based on audio files, transcripts and notes taken during the meetings which were cross-checked with the participants. Direct citations were used to highlight particular framings. Quotations have been translated into English for presentation in this paper. Partly the original quotation is added as a footnote to highlight a particular phrasing in Dutch or German. The contributions of the individual and group meetings in the case studies reflect the participants' opinions and not necessarily the one of the entity they belong to. They are quoted per case study as WUP for Wupper and KR for Kromme Rijn respectively.

4 Participants' strategies

The strategies for improving how to deal with uncertainties presented in the following were developed along the framing parameters in the two case studies. The ideas reflect the participants' point of view mainly with regard to the selected uncertainty situations. Due to the limited scope here not all contributions from the participants are presented in detail. Emphasis is given on examples that are salient in terms of robust strategies or which are controversial. The latter are then discussed in section 5. Practitioners' perspectives and differences between the case studies are highlighted and underlined by direct quotations.

4.1 Type of uncertainty - Unpredictability

Unpredictability may stem from complex system behaviour and is difficult to overcome (see Brugnach *et al*., 2008). Knowledge about cause-effect relationships and system dynamics can then only be obtained up to a certain limit. An attempt to manage irreducible uncertainties due to unpredictability at least to a certain extent is given by building scenarios, monitoring and evaluation in order to assess a range of possible outcomes, and trace changes in system and enhance the overall understanding of the system behaviour (WUP/KR).

Such approaches are not possible for negative coincidences and surprises such as an unforeseen natural catastrophe or a sudden shift in opinion of a stakeholder in a participatory process. These are a special form of unpredictability which requires different strategies to deal with. Coincidences may be positive as well, e.g. unforeseen increase in financial resources or unexpected willingness from a stakeholder to collaborate but the threat of encountering a negative one balances out the possible gain of a positive one (KR). The principal aim with regard to coincidences is hence preventing them, for which thorough planning and preparation is seen as helpful (KR). When for instance organizing a process, the idea is to start in a broad approach and then funnel[3] and filter things out, thereby reducing the chance of encountering uncertainties and

[3] Dutch: trechteren

negative surprises (KR). Other important means to deal with coincidences is seen in constant communication with all involved actors and in remaining flexible in order to be able to cope with surprises that cannot be prevented from happening (KR). In the Wupper, precautionary measures plus a quick reaction in a given situation is seen as essential with regard to unforeseen events.

4.2 Type of uncertainty - Incomplete Knowledge

Incomplete knowledge refers to knowledge gaps that may be closed. One strategy to do so is to solidify or condense information. Regarding the aim to fill knowledge gaps the question was discussed whether for decision-makers from public administration it was sometimes better to know less, in order to not create more uncertainty. In the Kromme Rijn the opinion is that over the long run this would only mean a shifting[4] of problems. However, where communication of uncertainty from water authority or public administration is likely to provoke or increase the uncertainty on the side of the receiver of the message, e.g. a water user or the broad public, it is deemed better in the Wupper case to not communicate that uncertainty then. This particularly refers to situations of high delicacy and uncertainty that are likely to create panic in the public if communicated (WUP).

Another strategy to get a basis for sound decision-making that was discussed extensively in the Wupper case is modelling. Despite the inherent limits of system complexity to accurately depict reality and modelling techniques being far from perfect, the Wupper participants attach great importance to describing environmental system processes through models. They argue that currently no alternative to modelling can be conceived in terms of getting a basis for decision-making since issues are connected in such a complex way today that decisions cannot be taken intuitively anymore.

4.3 Type of uncertainty - Multiple Knowledge Frames

Uncertainty due to multiple knowledge frames is likely to happen in multi-actor settings as people make sense of issues in diverging ways (Dewulf *et al*., 2004). Differently conceptualised options have then to be balanced out[5] in order to come to a decision (WUP, KR). This is seen as positive in the case studies since it triggers thinking about a situation and leads to more conscious decision-making. Communication was considered as the main strategy for dealing with differences in views and knowledge (WUP, KR, see section 4.8).

An example of differing views emerged in the Wupper case regarding the uncertainty around how to incorporate climate change threats into flood risk maps which is difficult due to lack of concrete data. There are several opinions which include assigning a global additional mark-up in water level to the flood areas as has been done in other regions in Germany (without scientific assessment and hence the risk of complaints by affected residents), assigning a mark-up to public constructions such as dikes or weirs where private persons are not concerned with their rights (where, however, indirectly everybody is affected through payments with tax money) and waiting for better scientific proof before taking action. The latter has been chosen so far by the public administration after balancing out the different options.

4.4 Urgency

The urgency to deal with an uncertainty is often coupled with a deadline for taking a decision, which puts stress to the decision-maker (WUP, KR). However, the Kromme Rijn participants

[4] Dutch: doorschuijven
[5] Dutch: afwegen. German: abwägen

regard deadlines as a good means to enforce a decision and therewith resolve the uncertainty, similar to solving a normative uncertainty according to Newig *et al*. (2005). Beyond deadlines, it is considered as important in both case studies to take a decision at a certain moment and act upon that decision. However, how to determine that moment is a delicate issue. To the question 'when do you know enough to take a decision?' the case studies came up with different solutions. In the example of flood risks in the Wupper, and the question of how much time to give to the researchers for producing more reliable data on regional climate change impacts, the participants put forward that the decision should be with the researchers since they could better estimate it. The Kromme Rijn participants are more action oriented and would rather take a preliminary decision and design a time frame for its revision as applied in their water area plan.

4.5 Positioning

Uncertainty is acknowledged as a fact of life in both cases studies. Per se, however, it is regarded as something negative in both case studies, e.g. "*I surely like certainty; I prefer not to have uncertainty. Dealing with uncertainty is rather cumbersome*" (KR). Ultimately the aim is to gain certainty, secure as many things as possible and try to avoid or reduce uncertainties: "*You cannot really say that you want to have and keep the excitement of the uncertainty*" (WUP).

Despite uncertainties having a negative stance for most of the participants, there is agreement regarding dealing with uncertainty about the importance to be open minded (KR) and think positively towards dealing with uncertainties (WUP). A positive aspect of uncertainties is the perception as a challenge and option to learn something new, make more conscious decisions and get over the uncertainty: *"I have the chance to resolve the uncertainty"* (WUP). In the Kromme Rijn an advantage of uncertainties is seen in having situations that are still open and where "*you can still change things about*" (KR). Likewise, a member of the regional administration in the Wupper states that in general, he is prepared to encounter uncertainties, and that he likes the space for action it leaves despite a certain responsibility that comes along with that, "*since you can not always back up your decisions with norms and regulations*" (WUP).

4.6 Responsibility - for having caused uncertainty

There are no huge discrepancies in the two case studies between the perceived responsibility for having caused the uncertainty and the responsibility for dealing with it. The participants of the workshops see uncertainty as something given or part of the process. Specific persons are rarely seen responsible for having caused an uncertain situation, but rather situational complex circumstances (WUP) or an unclear situation of responsibility for a certain task (in this case water supply in the KR).

4.7 Responsibility - for dealing with uncertainty

In terms of dealing with the uncertainties, usually the officially responsible entity for the respective task, normally public administration, is seen as responsible in both Wupper and Kromme Rijn. Others may participate and give their opinion but not have the final decision (KR, WUP). One suggestion in the Wupper regarding the issue of climate change and possible impacts in the Wupper is to allocate the responsibility at a higher, i.e. national, level (WUP) since climate change is not a regional problem and research and coordination tasks are perceived to be performed better at a higher level.

The Wupper participants pointed out the dilemma of increased scope for action but at the same time increased responsibility which dealing with situations of uncertainty allows or requires. This freedom for action can then also result in a deliberate decision to not take action as long as

scientific proof (here, regional climate change impacts) is not clear or to delegate responsibilities to higher levels (WUP).

4.8 Trustworthiness - Communication

Trust among actors is important as lack of trust leads to uncertainty and instability in relationships (WUP/KR). Constant open, honest, and transparent communication is seen as a crucial means to enable and ensure trust among people. Not only communication per se, but specifically communication of uncertainty is seen useful by a participant in the Wupper for increasing trust: "*Admitting an uncertainty can also lead to understanding on the other side*". Communicating one's own uncertainties to others, however, is not a generally accepted strategy. Uncertainties of public authorities for instance, in both case studies, are usually first discussed internally or with experts closely involved in the issue at hand, and only then is the result communicated to the public. "*With the broad public it does not make sense to discuss issues that are too technical and complex for them*" (WUP). A participant of the Kromme Rijn, by contrast considers communication with the public as very important "*since people often have good ideas*" and sees communication not only as giving information but also asking for reactions (KR). In the Wupper it is stressed that regarding communication of one's own uncertainties one should in any case not pretend to be certain when one is not. This goes in line with the participants' findings in Wardekker *et al*. (2008: 631) that one role of uncertainty information is to prevent false certainty. How people take up a message, including an uncertainty, furthermore depends on one's attitude, use of language, and leadership (KR). The importance of language in communication of uncertainties is also highlighted by Janssen *et al*. (2004: 9). In a communication process, the Kromme Rijn participants stressed, it is important to (re-)consider one's own role and the role of others involved.

4.9 Trustworthiness - Involvement of actors

Involvement of relevant actors is crucial in trust building. However, in participative processes not all participants may be highly motivated to contribute, for several reasons, one major one being that the initiative for the process often does not come from them (WUP, KR). However, it is not seen as advisable to simply bypass such stakeholders since they might nevertheless claim their stakes at a later phase of the project (WUP). An approach for the solution of such problems is envisaged in making the stakes clear to the respective potential contributors (WUP).

Another problem encountered in public meetings, both case studies report, is unexpected negative contributions which may be detrimental for the trustworthiness of the organizers of the respective meeting, i.e. mostly water authorities.

4.10 Trustworthiness - Expectation towards others

In multi-actor settings one's action often implies expectations towards others involved, for instance to comply with certain rules, to collaborate or to voice disagreement. In coping with an uncertainty making expectations clear can enable the disclosure of options for mutual aid. One example in the Kromme Rijn showed that else a lock-in situation may be provoked where nobody does anything because everybody assumes somebody else to be responsible. In the Kromme Rijn that applied to the situation of a demand of increase in water supply for agriculture in the region.

Making an expectation explicit may also express a certain trust in the other one to meet the expectation. In the Wupper this applies to expectations regarding data accuracy and model projections (e.g. climate change impacts) directed towards researchers. The researchers are

trusted to be able to get to sufficiently certain data (WUP). As an example of expectations of the public towards them the participants of the water board in the Wupper stated that they are expected to be responsible and able to secure them from flooding. This goes in line with findings from Michael (1973: 115) on members of e.g. an organization demanding or at least expecting certainty from their leaders. Likewise project organizers seek certainty as they expect the involved stakeholders to expect certainty from them (KR).

4.11 Trustworthiness - Dependence on others

In a multi-party process, reaching a goal may depend on the goodwill of the partners involved, as the Kromme Rijn example of broadening water supply channels shows. The uncertainty is whether the ground-owning farmers will collaborate because otherwise a) the project could be blocked entirely or b) the objectives would have to be forced by authority - which probably would not contribute to acceptance at stakeholder level, or c) a completely new solution for the area would need to be considered (KR). As a pragmatic approach the water board in the Kromme Rijn decided to approach the 65 concerned land owners individually in order to enhance understanding and enable negotiation for acquiring the ground.

5 Towards a hands-on decision aid

In this section we discuss the participants' strategies and add or modify them where appropriate in order to develop adaptive and robust strategies that promise to perform relatively well across a wide range of plausible future states (for the concept of robustness see also Groves and Lempert, 2007) and to be applicable in water management practice while taking into account long-term implications. These options are summed up in table 4. The strategies in the table are to be read as possibly entry points to detect options for changes, not as an exhaustive list that has to be assessed from top to bottom. For one situation of uncertainty it may be advisable to consider several options together and not be fixed on only one. This applies to options both within and between framing parameters. The situations may differ in focus of attention. In one situation responsibility issues may be more salient, in another urgency for instance. However the case may be, we consider it useful to take into consideration all framing parameters in order to improve dealing with the uncertainty situation.

Framing differences are abound throughout all framing parameters. The distinction of a certain dominating category or type of uncertainty in an uncertainty situation for instance reflects the framing of the respective actor and his conviction towards the manageability of the uncertainty. We argue that one should be aware of that, accept that somebody else may have a different but equally valid view on the same problem and be open to reframe one's own view.

Essential for enabling reframing is trust among the actors involved. An important role for enhancing trust is seen in open and transparent communication and interaction with other actors. As has been stressed by the Kromme Rijn participants, mutual understanding can not be taken for granted and should always be checked back with one's correspondent. We judge it as promising sign that communication plays an important role in both case studies as the main strategy to both deal with issues of framing differences due to multiple knowledge frames as well as to ensure and maintain trust among actors. The case study examples reveal different patterns of communication such as information sharing, asking questions, dialogue or negotiation (WUP, KR). A salient finding throughout the case studies is the differentiation of communication with the public. The general stance is to inform the public and allow for discussion in public only after having discussed internally or with experts. On the one hand this has to do with the view

towards lay people as not being able to conceptualise and understand uncertainties, which is very frequent among scientists as well (see Frewer *et al*., 2003). On the other it relates to the image the decision-makers and particularly public administration (as well as scientists) have or think they have, i.e. to be knowledgeable about things (WUP, see also Bergkamp *et al*., 2003). We consider early involvement of organized stakeholders as well as the public in general important in order to make processes more transparent and allow for taking a wide range of ideas and perspectives from the start. We would rather opt for letting the public take part in the uncertainty considerations than hiding uncertainties from them in order to not unsettle them.

Expectations towards others are an important aspect of trust. In the discussion about climate change and its possible impacts, the Wupper participants expect scientists to develop adequate means to obtain more detailed and reliable information. On the one hand that reflects a trust in science to advance sufficiently in the predictions of the future. On the other, as we do not consider that option as realistic (see also Bergkamp *et al*., 2003, Wardekker *et al*., 2008), the participants' expectations indirectly mirror a responsibility of the researchers for communicating differently on climate change research and possible results. As pointed out by Patt (2007), scientific framing of uncertainties influences how decision-makers frame uncertainties. Many authors also highlight the need for more tailored communication of uncertainty to make it more useful for decision-makers (Bergkamp *et al*., 2003, Patt, 2007, Wardekker *et al*., 2008). This opens up two new boxes of discussion: a) about the role of science for policy and b) on the options for climate change adaptation, mitigation and climate proofing which is beyond the scope of this paper despite being highly relevant and interesting questions.

Another example of the importance of scientific evidence in decision-taking is modelling. Modelling was a prominent strategy in managing uncertainty, particularly in the Wupper case. It can indeed be a strong tool for to better understanding coherences and dynamics of a system. We argue that nonetheless that often model calculations are shielding a decision on values. With regard to climate change, for instance, major efforts are put into regionalizing the global (already rather uncertain) models to reduce the uncertainty of regional climate forecasts. Such a focus may prevent people from taking action and discussing and deciding on priorities and which values to foster and which goods to protect. That makes dealing with uncertainty a matter of choices and priorities. This is evident also in the discussion of putting a mark-up on flooding areas in the Wupper. Besides the conceived approaches by the authorities (see section 4.3), a logical consequence in this respect would be to not only conceive possible strategies at administration level but to include residents of the area into the discussion since they are the ones who will be affected, either by flooding or by payments for precautionary measures (see also Pahl-Wostl, 2006). Instead responsibilities for dealing with uncertainties associated with climate change are mainly delegated to higher administrative levels and science.

A good example of an adaptive iterative approach for dealing with uncertainty under time pressure, particularly with regard to unpredictability issues we consider the example of the Kromme Rijn to not leave an uncertainty untouched for too long but draw an intermediate line and go on from there as applied in the implementation of their water area plan. These kinds of strategies also make it easier for decision-makers "*to agree on a single policy despite their different expectations about the future*" (Groves and Lempert, 2007: 83). We suggest extending this generally to complex situations in terms of deliberately drawing internal intermediate deadlines for oneself and splitting goals and tasks in subparts in order to make progress and not get stuck over a huge uncertainty that is not possible to solve at once. Multi-actor settings

complicate situations since actors can seldom define and decide things autonomously and independently.

As could be seen, the participants in the case studies do not voice identical views on uncertainty. Positioning towards uncertainties turned out to be a highly personal matter. A common thread though through both cases which goes in line with findings in literature (e.g. Friend and Hickling, 1997, Sigel, 2007) is that uncertainties are regarded as something negative. Despite the expressed attitude to see in uncertainties as well a positive challenge the prevailing line of action that shows from the examples rather is to prepare well and avoid uncertainties as far as possible. The overall aim for dealing with uncertainty is presented as primarily trying to prevent it and once faced with an uncertainty to reduce or eliminate it to eventually attain as much certainty as possible. Friend and Hickling (1997: 3) remark that it is common experience that carefully prepared plans can quickly loose their relevance under the pressure and dynamics of day-to-day events. As, moreover, it is not possible to transform every uncertainty into a certainty (e.g. Bergkamp *et al*., 2003, Wardekker *et al*., 2008), particularly those stemming from system variability and complexity, we advocate the adoption of a more positive stance towards uncertainty. Beyond acknowledging and accepting uncertainties we state that a mind switch is required abandoning the idea of uncertainty as a something negative that has to be avoided and reduced by all means. We suggest to instead even look out for uncertainties in order to not get too wedged in conventional habits, but attain and maintain a certain level of mindfulness.

Table 4: Cross-checking list for improving dealing with uncertainty

Framing parameters	**Options for improving dealing with uncertainties**
Type of uncertainty	▪ Unpredictability: thorough planning in the beginning, good organization and preparation including emergency plans, monitoring and evaluation, modelling, scenario development, precautionary measures, being flexible & able to improvise ▪ Lack of knowledge: get as knowledgeable as possible about the situation, that is narrow down, solidify and condense information, modelling. ▪ Multiple knowledge frames: communication (different patterns) ▪ Reframe/ Switch to another framing category of the UM by Brugnach et al. (2008)
Urgency	▪ Prioritize uncertainty situations ▪ Compare with other issues at hand and make yourself an urgency list of things to tackle ▪ Design a deadline to draw a line and enforce a decision rather than constantly postpone taking action due to perceived lack of knowledge and certainty ▪ Actors' differences in urgency perception may be indications for high or low performance in solving the uncertainty situation – establish agenda/list with stepwise tasks and goals and a timeline for all involved actors
Positioning	▪ Acknowledge uncertainties as a fact of life ▪ Get a more positive stance towards uncertainties. Look out for positive aspects an uncertainty situation ▪ Be more daring and take on responsibility involved in being confronted with an uncertain future with multiple possible outcomes ▪ Maintain a level of mindfulness by looking out for uncertainties to avoid getting wedged in traditional habits ▪ Always leave some space for improvisation and positive coincidences ▪ Find other people who frame the uncertainty more positively ▪ Think about what exactly is it that bothers you in the situation

Responsibility	Responsibility for having caused an uncertainty: ▪ Acknowledge situational and system complexity Responsibility for dealing with an uncertainty: ▪ Check out who is responsible for what by law to get a clearer picture. If appropriate cross-check if that is the best distribution or if responsibilities may be shifted ▪ Check if you or other actors could help to solve the situation, e.g. take over some responsibility (e.g. shift to higher level), split tasks etc., i.e. strive for shared responsibility ▪ If responsibility not taken over (by anyone), start communication process with the actor/entity perceived as responsible
Trustworthiness	Trust towards other actors: ▪ Ensure involvement of all relevant actors ▪ Ensure and maintain open, honest and transparent communication among actors ▪ Get clear about each other's ideas, stakes and expectations and verify with the respective actor if the expectations are likely to be met or not ▪ Engage in dialogue with other actors for discussion of differences in framing ▪ Rethink the role (and related communication pattern) of each, e.g. who is proposing, who is answering things, who is consulted, informed etc.) ▪ Transparent (and early) communication of uncertainties

6 Discussion

Isendahl et al. (in press) had pointed out that uncertainties are framed in different ways and derived parameters of importance in the framing process. The application of the framing parameters in case studies of water management showed that they are accessible and understandable for practitioners. It served as a means to detect similarities or disagreements in framings.

Applying the framing parameters interactively moreover allowed for developing options for improvement along the parameters. The discussions in the case studies showed, however, that coming to options for improving dealing with uncertainty based on an assessment of framing parameters is not self-evident. One's framing has to be questioned and contrasted against that of others, especially given the fact that most times uncertainties have to be dealt with in multi-actor constellations. As the findings stem from a series of interactions involving numerous discussions and cross-questions over the time of the research in both case studies it is difficult to tell which thoughts of the participants' "were already there" and which ones have developed through the research by posing questions and discussing in groups. Moreover, it reflects strategies that were voiced to be desirable but it is not self-evident that they will actually all be followed in practice. As Rouse and Morris (1986: 352) point out there is always the possibility of a distortion between what people think or say and what they eventually actually do.

The strategy discussions in the investigated case studies also point to the limits in assessing uncertainty situations and developing strategies for improving dealing with uncertainty along the proposed parameters. There are certain types of uncertainty to which it is difficult to apply all parameters. That is particularly the case for examples of uncertainty due to unpredictability. In the Kromme Rijn case, uncertainty due to (negative) surprises or coincidences was discussed. These are difficult to relate to all framing parameters, particularly responsibility, urgency and trustworthiness, since they refer to a hypothetic state in the future that cannot be assessed or evaluated by parameters in the present (unpredictability by definition). Coincidences can not be

prepared for (KR). For such uncertainties the strategies necessarily have to be limited to those regarding the type of uncertainty of unpredictability.

For the other uncertainty situations that were discussed in the case studies the framing parameters appeared to make sense. Moreover, the participants' findings suggest that it is worthwhile looking at differences in framing in order to develop a new understanding of the situation and new action options. These new action options are translated into practical recommendations shown in table 4. We propose to use the list as a hands-on aid for practitioners in water management which they may apply when stuck in an uncertainty situation (or before actually getting stuck). If used interactively with several actors, the list serves as a tool to make framings and framing differences explicit and deal with them constructively through the strategy options proposed for each parameter. It also serves as a tool to identify knowledge gaps where water managers would need support from experts or scientists in order to be able to understand uncertainties with a more complex background and be able to take action with regard to them.

As for the purpose of assessing the parameters the respective insights and results on the ground, i.e. improved options to deal with uncertainties, are one objective. As relevant is the very process of assessing the parameters, especially in interaction with others. This helps to make framing differences explicit, hitherto largely disregarded in water management and scientific analysis, and enables reflection and reframing. That way it contributes to social learning which is considered as crucial for water management that is performing well over the long-run.

7 Conclusions

We have argued that a difference in framing of uncertainties makes a difference in dealing with them and that structured, analytical yet pragmatic approaches are needed to effectively deal with uncertainties in water management practice. As a first step towards that goal it is thus important to make framing of uncertainty explicit and identify possible framing differences. The application of the framing parameters in the two case studies showed to be a good means for that purpose and particularly to detect similarities or disagreements in framings. The assessment of the framing parameters helped raising the awareness among the participants on the various aspects of an uncertainty situation and was of use for fostering reflection and discussion on framing and strategies.

As a tool for preparing and structuring decision-making under uncertainty in water management practice we developed a cross-checking list along the framing parameters. The list does not require major scientific knowledge or assessment. It is designed to be easily applicable for practitioners in water management in order to improve dealing with uncertainties by making it more systematic and structured. Owing to having been developed in close relation with practitioners and along practical examples of uncertainty we hope it may thus successfully serve as a guiding tool for water managers for situations of uncertainty. The cross-checking list is not meant to be a solution in itself but a grid to develop intervention options and come to decisions when facing uncertainty in water management practice. The list constitutes a non-rigid tool that can and should be used in a flexible way. In that it addresses the search of Bergkamp *et al.* (2003) for "*a middle way between planned and top-down technocratic management and the more laissez-faire reliance on spontaneous actions*". The list is no panacea for all uncertainties and does not aim at replacing scientific analysis and expert knowledge. It should rather be seen as help to identify the gaps from a practitioners' perspective and allow more tailored scientific analyses and decision support.

To the disappointment of most of the participants of the case studies investigated in this study, acknowledging complexity makes clear once again, and as is widely being argued in literature, that not every uncertainty may be overcome completely and transformed into a certainty. That also implies that dealing with uncertainties in the end is a matter of choices and priorities, which to date are often not being taken in the sedulous search for certainty. We believe that a general mind switch is needed towards a more positive stance regarding uncertainty. This requires that water managers not only acknowledge uncertainties as such but abandon the idea of uncertainty as a negative thing one has to get rid off as fast as possible. Instead uncertainties may be even searched for in order to attain and maintain a certain level of mindfulness. The list of parameters and suggested strategies may be used as a tool for detecting uncertainties, making them explicit and deal with them in a constructive and flexible way so that sound decision-making is enabled.

8 Appendix I: Semi-structured interview grid on the framing parameters

The following questions in English are translated from the originals in German and Dutch that were used in the case studies.

1. Which further actors are involved or play a role in the respective uncertainty situation? (as stakeholder, originator or decision-maker) (Anonymous reply possible)
2. Cause: Due to what or whom did the uncertainty situation arise? / Whose "fault" is it that an uncertainty situation arose?
3. a) Please describe the kind of exchange of information with other actors with regard to the uncertainty situation (with whom, how often, what for)
   b) Do you depend on the provision of information or data from others in order to be solve the uncertainty situation? → Y/N → If yes, from whom and what for?
4. a) What is your aim in terms of dealing with the uncertainty situation (also general answer possible)
   b) Whom do you see as responsible for dealing with the uncertainty situation?
   c) How do you currently deal with the uncertainty situation? Do you (or your entity) follow any formal procedure (e.g. from your entity) in that, respectively is there a standardized procedure or method or model to do so?
   d) If yes, do you consider that procedure as adequate and sufficient?
   e) What do you consider as important in terms of dealing with the uncertainty situation? Where do you see potential or need for improvement? (with regard to the current strategy or in general)
   f) How high do you estimate your own options to take influence in the uncertainty situation? → High – middle – low. Please explain
   g) How would you like the other involved actors to behave with regard to dealing with the uncertainty situation?
   h) Are the responsibilities, as you see them, currently being followed? What should be improved in that respect?

5. a) What is your positioning towards the uncertainty situation? What feelings does the uncertainty situation provoke in you? (Only give examples for the interviewee when there is no immediate answer → e.g. threat, annoyance, chance, risk, challenge)
   b) Is the uncertainty situation all in all rather positive or negative for you & why?
6. a) Do you (or would you) communicate the uncertainties you perceive towards stakeholders or the public? → Y/N → Please explain
   b) Do you communicate on how you yourself (or your entity) deal/s with the uncertainties? If yes with whom? If no why not?
   c) How important do you consider communication and/or collaboration with regard to dealing with uncertainty? Please explain
      A- with other involved actors or experts?
      B – with the public?
7. What role do financial resources play with regard to the uncertainty situation? Do you depend on financial support of others for dealing with the uncertainty situation?
8. Time line: When or within what time line does the uncertainty situation require a decision or action to be taken? → Now/ short term (> 0 < 6 months), middle term (> 6 months < 5 years), long term (> 5 years), "timeless"/ no deadline. Please explain
9. a) How important is it for you or your entity to solve the uncertainty situation & why? (Expected negative impacts?)
   b) How important is it to solve the uncertainty situation in more general terms, i.e. for the public or society? Please explain
10. Any additional remarks or questions from your side?

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