

PERSPECTIVES ON FLOOD MANAGEMENT IN THE RHINE AND MEUSE RIVERS

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ABSTRACT

Flood management of the Rhine and Meuse is surrounded by major uncertainties. The central question is then: given the uncertainties, what is the best management strategy? Moreover, flood management cannot be considered independently from other river functions such as nature, agriculture, inland navigation and landscape values. This raises the need for integrated scenarios that consider possible futures in a coherent and consistent way. In the present project a scenario study was carried out in which physical modelling has been combined with socio-cultural theory. The focus of the study was on flood risk management. Existing climate, land use and socio-economic scenarios, as well as water management strategies have been structured using the Perspectives method. This resulted in integrated scenarios for water management, each representing a different view of the future, together with the corresponding water management style. These were put in a scenario matrix with combinations of world views and management styles, where these both match and mis-match. Using a suite of existing modelling tools the implications of each scenario for the water systems were evaluated. Finally, a comparison of different water management styles under different possible futures was made, showing the risk, cost and benefits of different strategies. The scenario analyses demonstrate that—at the scale of the entire Rhine basin—the influence of climate change on extreme floods is much stronger than the influence of land use changes. Flood risk management in the lower river deltas should not fully rely on flood mitigation measures in the upstream basin. It also becomes clear that no flood risk management strategy is superior in all respects and in all circumstances and that safety versus societal costs is really a policy dilemma: win-win situations cannot always be attained. Under changing climate conditions, the present-day type of management in the lower river reaches runs the risk of becoming an expensive attempt to fully control flood risk problems, while trying to avoid real choices, without actually solving the problems in a long-term view. Copyright © 2004 John Wiley & Sons, Ltd.

KEY WORDS: water management; floods; climate change; uncertainty; perspectives; integrated scenarios; landscape planning; Rhine; Meuse

INTRODUCTION

River flooding and flood risk reduction and mitigation have become major themes in the Rhine and Meuse basins over the past five years, while climate change is generally expected to lead to an increase in flood risk. Previous studies on the Rhine river (Kwadijk, 1993; Parmet *et al.*, 1995; Grabs *et al.*, 1997; Middelkoop, 2000; Middelkoop *et al.*, 2001a, 2002) have demonstrated that climate change may have considerable impact on floods, and also may affect water availability for other river functions. In response to the increasing awareness of flood risk, various flood protection measures, landscaping strategies and policy lines for flood prevention and protection have been put forward. Measures and strategies for flood risk reduction, however, do not stand alone, but should be considered within the context of all river functions.

River management is surrounded by major uncertainties. These uncertainties exist in the future physical boundary conditions for water management, such as uncertainties in the rate and magnitude of future climate change and

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sea level rise. Uncertainties are also introduced as a result of various yet-unknown socio-economic and agro-economic developments that will affect the hydrological cycle (land use changes, urbanization, and use of different crop types) or determine water demand (such as population growth, industrial expansion). These factors together determine possible futures that are envisaged, and can be coloured according to different visions or perspectives people may have. Depending on the perspectives of the future, different water management strategies may be adopted. The question that arises is then: which is, given the uncertain future, the best water management strategy? Therefore, the objectives of this project were to provide a method to formulate robust strategies for flood management.

PERSPECTIVES ON WATER MANAGEMENT

Scenarios can be helpful tools in developing, analysing and evaluating future strategies. Many different scenarios already exist in the fields of economy, demography, lifestyle, agriculture, physical environment and climate change. All these scenarios, however, differ in terms of underlying assumptions and perspectives. For integrated assessment studies in the Rhine and Meuse basins, therefore, methods are required to structure and inter-relate various categories of future developments into integrated and consistent sets of scenarios.

The basic concept in the present study was to produce a limited set of integrated scenarios that include climate and socio-economic developments in a coherent and consistent way. This was done using the Perspectives method, based on cultural theory (Thompson *et al.*, 1990), and developed by the TARGETS research group at RIVM in the Netherlands (Rotmans and De Vries, 1997). A 'perspective' is a consistent description of the perceptual screen through which people interpret the world, and which guides them in acting. Different perspectives are reflected by different choices concerning structural uncertainties. For the present study we used three perspectives, focusing either on environment (Egalitarian), control (Hierarchist) or economy (Individualist) (Figure 1). A perspective comprises both a world view (how people interpret the world) and a management style (how they act upon it). If the world view coincides with the management style (which means that the world has developed in accordance with the *a priori* expectations, and the management style has matched it), we speak of a utopia. Dystopias describe the situation when the world functions in a different way and develops differently from the way envisaged by the perspective. By making different combinations of worldviews and management styles, a matrix of perspective-based scenarios can be developed or existing scenarios can be interpreted and tested (Figure 2).

Since the Perspectives method was not developed with a specific focus on water management, the general descriptions of the recognized perspectives were converted to world views and management styles related to water management (Table I). In the case of flood management, different perspectives will consider different views on the rate and magnitude of climate change, land use changes, urban expansion and so forth. These factors are referred to

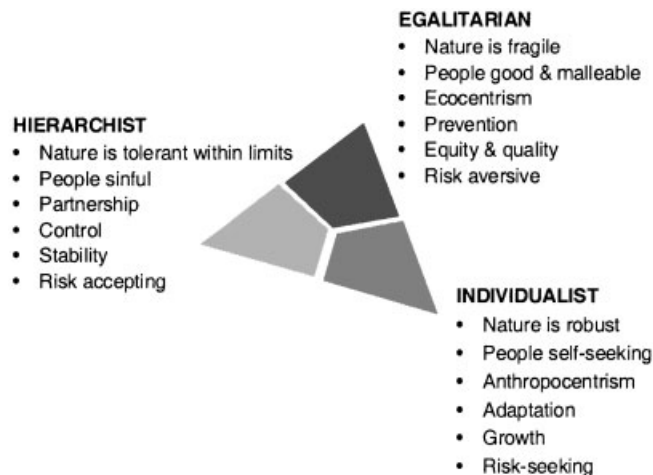


Figure 1. Perspectives and their view on the world

		World View / External Context		
		Egalitarian	Hierarchist	Individualist
Management Style	Egalitarian	UTOPIA	DYSTOPIA	DYSTOPIA
	Hierarchist	DYSTOPIA	UTOPIA	DYSTOPIA
	Individualist	DYSTOPIA	DYSTOPIA	UTOPIA

Figure 2. Matrix of utopias and dystopias

Table I. World view and management styles according to the perspectives, applied to water management in the Rhine basin

	Egalitarian	Hierarchist	Individualist
World view	<ul style="list-style-type: none"> • Climate is very sensitive, large changes must be expected • Nature is vulnerable • Society will adapt to environment, not vice versa • Water functions will radically change • Public awareness of nature has increased • Economy and water use will decrease 	<ul style="list-style-type: none"> • Climate is sensitive, changes must be expected, additional research is required • Nature is vulnerable, but can be managed by defining adequate standards • Top-down regulation • Safety has priority • Uncertainty demands research 	<ul style="list-style-type: none"> • Climate is insensitive, some changes anticipated • Economy is more important than nature • Environment can be exploited for economic use • Water is considered as economic goods • Economy and water use will grow • Anti-regulation • Risk can be calculated and offers challenges
Management style	<ul style="list-style-type: none"> • Natural processes are guiding in water management; • Water guides landscape planning • Pro-active, sustainable water management with long time horizon (>50 years) • Prevention and adaptation instead of mitigation 	<ul style="list-style-type: none"> • Sustainable water management, win-win solutions and negotiation between different interests • Water is integral part of landscape planning • Water management should be based on standards • Strong (top-down) control by government (including EC) • River basin approach, also institutional • Time horizon in planning varies, depending on the function (10–50 years) 	<ul style="list-style-type: none"> • Cost-benefit analyses and economic risk assessment guide water management • Short time horizon in planning (10 years) • Governmental control is weak, role of supervisor • EC is monetary union, no further control • Privatization of water and water-related sectors

as ‘external context’ that lies outside the direct sphere of influence of water management. The world view thus includes a perception of the future development of these factors. Management styles include the way actions are taken for flood protection, and the choice of measures to be implemented, such as flood retention or landscaping in the floodplain area. A dystopia then occurs, for example, when the change in climate is different from the anticipated change according to a perspective, and the implemented management strategy is not in accordance with the climate-induced hydrological changes that have occurred.

METHODS

Establishment of perspective-based scenarios

As a first step the entries in the utopia–dystopia matrix for the three perspectives were defined as cases in terms of world views (external context) and management styles for the Rhine and Meuse basins. In an inventory analysis, a large number of existing plan studies, policy papers, scenario studies and other documents from various water-related sectors were analysed for this purpose, and the visions and management strategies of these were categorized according to the three perspectives. Also, expert meetings and interviews were held to convert all the existing scenarios into three coherent and consistent sets of world view and management style, according to the Egalitarian, Hierarchist and Individualist perspectives. From these results the utopia–dystopia matrix was filled in. The focus of this inventory was on Dutch water management, but a first exploration was made into water management in Germany and Belgium as well.

Climate change scenarios for the Netherlands were developed by KNMI (Können, 1999). The classic estimates consist of a low estimate, a central estimate and a high estimate. The range between the low and high estimates represented the model and emission uncertainty. A central estimate for Europe of a temperature change of +2°C for 2100 with respect to 1990 was adopted; the lower and high estimates were +1°C and +4°C, respectively (Table II). In addition, a dry scenario was considered where temperature and precipitation changes are uncoupled, in combination with the high estimate of the temperature rise. The construction of climate scenarios for the Rhine and Meuse basins was based on the Hadley Centre's high-resolution atmospheric General Circulation Model (UKHI) (Hulme *et al.*, 1994; Grabs *et al.*, 1997), which has been processed by the Climatic Research Unit, University of East Anglia, with the assistance of the Institute of Hydrology, Wallingford. Using the model, a control integration for present-day greenhouse gas concentrations was made, as well as a run with doubled CO₂ concentrations. From the results, climate change fields that indicate climate changes per degree of global warming were generated. These have been rescaled according to the presently assumed estimates for temperature rise according to the lower, central and upper estimates for both projection years 2050 and 2100, such that the resulting changes match well with the presently considered uncertainty range of climate change in this region (Können, 1999; Houghton *et al.*, 2001).

Using the results of this inventory, each case in the matrix was implemented in a quantitative way both for the development of external factors (such as climate change, sea level rise, land use changes, water demand) and water management style (such as flood-mitigating measures, nature rehabilitation, groundwater control, water level regulations).

Table II. Climate change projections to the years 2050 and 2100 for the Netherlands and their conversion to perspective world views (source: Können, 1999)

	Present	Low estimate wet		Central estimate wet		High estimate wet		High estimate dry	
		2050	2100	2050	2100	2050	2100	2050	2100
Temperature (°C)		+0.5	+1	+1	+2	+2	+4	+4	+2
Yearly precip	700–900 mm	+1.5%	+3%	+3%	+6%	+6%	+12%	–10%	–10%
Total summer precip	350–475 mm	+0.5%	+1%	+1%	+2%	+2%	+4%	–10%	–10%
Total winter precip	350–425 mm	+3%	+6%	+6%	+12%	+12%	+25%	–10%	–10%
Evap. summer	540–600 mm	+2%	+4%	+4%	+8%	+8%	+16%	+16%	+8%
Evap. winter (c. 100 mm)		+2%	+4%	+4%	+8%	+8%	+16%	+16%	+8%
Evap. year	620–720 mm	+2%	+4%	+4%	+8%	+8%	+16%	+16%	+8%
Absolute SLR (cm)		+10	+20	+25	+60	+45	+110	+110	+45
Wind speed		±5%	±5%	±5%	±5%	±5%	±5%	0 to –10%	0 to –10%
Perspective		Individualist		Hierarchist		Egalitarian-Wet		Egalitarian-Dry	



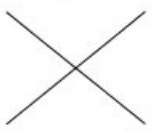







		External Context			
		EGA		HIE	IND
Management style	EGA	Dry  Case 4	Wet  Case 3		 Case 1
	HIE	 Case 6	 Case 7	Based on existing studies	
	IND	 Case 8	 Case 5		 Case 2

Figure 3. Utopia/dystopia matrix: cases indicated are calculated using the models

Modelling

The conditions and measures defined in each of the entries in the matrix were used for the hydrological simulation models as inputs (e.g. climate parameters), boundary conditions (e.g. land use maps), model parameters (e.g. runoff coefficients) or topographic lay-outs (measures in the flood plains). Ideally, the whole utopia/dystopia matrix (i.e. all combinations of world views and management styles) might be evaluated using the models. However, the stakeholder workshop demonstrated that some combinations represent unrealistic or less relevant cases. In addition, Hierarchist scenarios were extensively described in previous studies and in policy reports, and were therefore not calculated again. Therefore, it was decided to run the models for the most extreme cases to maintain sufficient variation in the results (Figure 3).

Modelling was carried out using two categories of existing models. First, water balance models for the Rhine and Meuse basins (RHINEFLOW, MEUSEFLOW) (Kwadijk, 1993; Van Deursen, 1999) were applied to determine hydrological changes in response to changes in boundary conditions, such as changes in land use and climate change. Subsequently, the consequences of the hydrological changes for the user functions of the water systems were determined using a Decision Support System (DSS) for the Rhine branches (Silva *et al.*, 2000). This DSS allows a user to implement various sets of landscaping measures within the floodplain area to reduce water levels in the case of increased design discharge. Given these inputs, the DSS determines the implications of these measures in terms of water levels, cost, volumes of sand and clay to be removed, sanitation cost, changes in land use, nature, and landscape values.

Perspective-based landscaping strategies of the floodplains were based on variants and alternatives from the studies 'Landscape Planning for the Rhine' (LPR) (Silva and Kok, 1996; Termes *et al.*, 1998, 1999; Middelkoop and Buiteveld, 1999; Middelkoop *et al.*, 2001b) and 'Room for the River Rhine branches' (RvR) (Silva *et al.*, 2000). Each of these variants comprises a different choice and priority of the landscaping measures given in Figure 4. These landscaping alternatives and measures were categorized according to the perspectives, and subsequently evaluated using the Rhine branches DSS for different increases of design discharge, depending on the presumed climate change scenario. The analyses were completed with information from scenario studies for the Rhine and Meuse: 'Rijn op Termijn' (WL, 1998) and the IRMA-SPONGE study 'Living with Floods' (Vis *et al.*, 2002).

Evaluation of perspectives for water management

After completing the analyses for the entire utopia–dystopia matrix, the three scenario families (Egalitarian, Hierarchist and Individual management styles) were evaluated in terms of the hydrological situation, the consequences for the user functions and the characteristics of the water system. This was done by evaluating the results

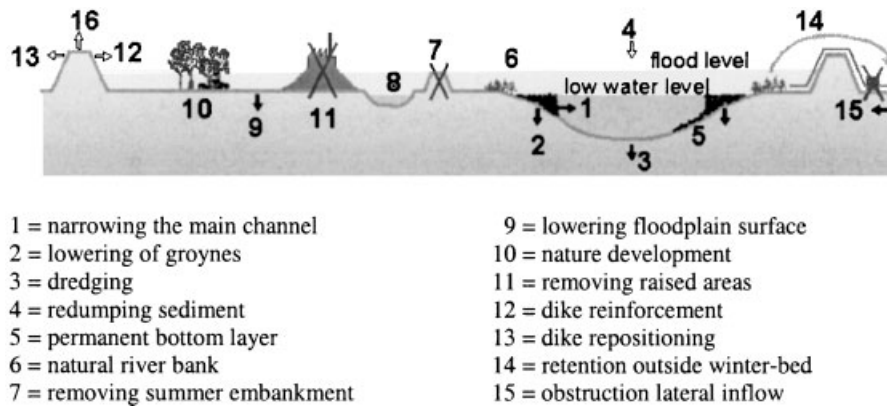


Figure 4. Schematic cross-section of the main river channel and the embanked floodplain. The numbers indicate the various measures for nature development, inland navigation and flood water level reduction that can be taken

Table III. Evaluation criteria for analysis of the perspective-based water management strategies

Criterion	Description
<i>Safety</i>	Probability that a catastrophic (in terms of risk impacts for humans) flooding of the river polders may occur.
<i>Nature</i>	Area of 'nature'. In the terrestrial models wet ecotopes and areas with a high biodiversity are valued high.
<i>Agriculture</i>	Area occupied by agriculture. In addition for the Netherlands damage to agriculture by drought or wetness is determined.
<i>Costs</i>	Costs of the measures taken.
<i>Economic benefits</i>	Qualitative valuation that depends on the definition of 'economic' sectors.
<i>Flexibility/reversibility</i>	Ability of the water system to adapt to the continuously changing conditions, without having taken irreversible measures such as lowering the floodplain or dyke raising.
<i>Quality of life</i>	Complex and ambiguous notion. Area of nature, the possibilities for recreation and preservation of cultural and landscape values are used as qualitative indicators.
<i>Resilience</i>	Ability of the river system, society and ecosystems in the area threatened by floods to recover from a flooding in the area. For the floodplains two measures are used: (1) height difference between flood water level and soil surface of a polder behind the river dyke and (2) ratio between the total inundated area over the area of the main channel (Middelkoop <i>et al.</i> , 2001b).

for each entry in the matrix in terms of the criteria indicated in Table III. By comparing the overall evaluation of the entries in different rows (management styles), we identified opportunities and risks of different water management styles for the Rhine and Meuse river basins.

CONTEMPORARY WATER MANAGEMENT IN PERSPECTIVE

With regard to water management of the Rhine and Meuse rivers, the perspectives can be characterized as in Table I. When the documents from the Netherlands are characterized in terms of the three perspectives, it appears that most of these can be categorized as the Hierarchist perspective, a few of them match the Egalitarian perspective and none can be considered as having the Individualist perspective (Figure 5). This indicates that the Dutch style of water management largely matches the Hierarchist management style. Moreover, many studies and policy documents have the same 'roots', as they were based on the same scenarios, or established by related institutions. The absence of the Individualist perspective in water-related studies may indicate that market-oriented sectors do not treat water management explicitly as a separate issue. Apparently, these sectors consider water as one of their (economic) boundary conditions, while water may be a less relevant issue to them when compared to other

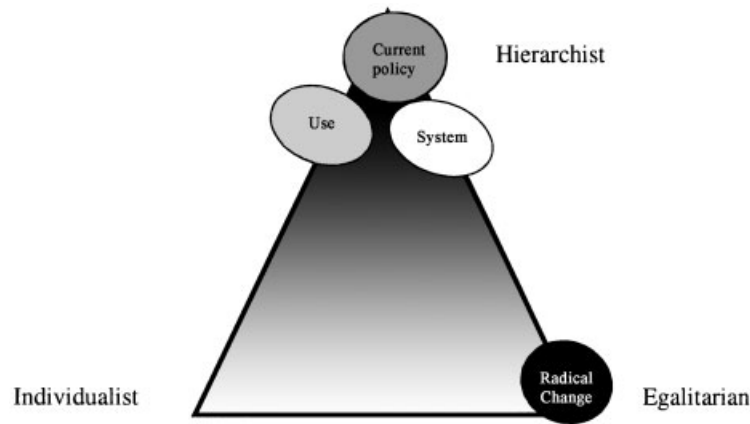


Figure 5. Clustering of existing studies according to perspectives on flood management

Table IV. Summary of differences and similarities in water management

	Netherlands	Belgium	Germany
Selection of crucial policy reports	<ul style="list-style-type: none"> • Bill on Embankment (Wet op de waterkering) • Room for the River • Water management in the 21st century 	<ul style="list-style-type: none"> • MINA-2 • Living Grensmaas (Flemish Preference Alternative) • Water Policy Plan Flanders 	<ul style="list-style-type: none"> • LAWa guidelines • Action Plan Flood Defence
General focus	<ul style="list-style-type: none"> • Integrated water management • Safety 	<ul style="list-style-type: none"> • Water quantity linked to drought problems 	<ul style="list-style-type: none"> • Improving retention capacity • Water quality
Organization	<ul style="list-style-type: none"> • Water management is institutionalized • Strong hierarchy and centralization 	<ul style="list-style-type: none"> • Water management recently recognized as a salient issue by the Flemish government • Decentralization 	<ul style="list-style-type: none"> • Water management of the Land Government will be harmonised in the LAWa • Decentralization
Common characteristics	<ul style="list-style-type: none"> • Ambition for integrated water management in the context of sustainable development • Awareness of flood risks • Awareness of the need for a river basin approach • Water management is insufficiently integrated in spatial planning • Small public interest 		

socio-economic factors. The definition of the Individualist perspective for the present study, therefore, was for a large part based on expert meetings.

During the inventory into existing studies, visions and strategies for Germany and Belgium we found surprisingly few written documents when compared to the Netherlands. Apparently, only a few German and Belgian studies have been published concerning long-term future developments of the Rhine and Meuse rivers. The available studies provide scenario descriptions, but these are essentially an exploration of the technical and physical limits of water management. Therefore, interviews with experts and stakeholders provided the main information on water management in the upstream basins. Because of their decentralized character, and the limited number of integrated studies, both Germany and Belgium seem to have a Hierarchist/Individualist based water management. The main results of the inventory, in terms of the differences and similarities between the national levels are summarized in Table IV.

IMPLEMENTATION OF PERSPECTIVES

The conversion of the climate and land use scenarios, as well as the flood management measures used for modelling to world views and management styles according to the Perspectives are shown in Tables II and V. The three Perspectives applied to the Rhine and Meuse can be characterized as follows.

Egalitarian

The Egalitarian envisages major climate changes, including a scenario with dry summers (Table V). The management style, therefore, aims at improving the natural resilience of the river system, which involves major

Table V. World views and management for landscaping of the floodplains according to the three perspectives

World view	Management style	Implementation
EGALITARIAN		
<ul style="list-style-type: none"> • Water systems should be sustainable and resilient • Rivers are the backbone of the main ecological structure in the NL • Preservation of landscape and cultural heritage • Different river branches can have different functions 	<ul style="list-style-type: none"> • Implement of target situation for ecological restoration • Large scale measures foreseen • Cost is not a limitation • Areas with high landscape and historic values should be preserved • Dyke raising is no option • Aiming at maximum resilience in flood protection • Retention within the NL • If required: change discharge distribution over the lower Rhine branches • Different river branches can have different functions 	<ul style="list-style-type: none"> • Concept of design discharge rejected, Peak flows of the Rhine at Lobith may be even higher than 18 000 m³/s • Resilience is the measure guiding landscape planning • Implement of target situation for ecological restoration • Agriculture disappears from the embanked floodplains • Allowable landscaping measures: lowering and widening the floodplain, digging side channels, removing minor embankments and other obstacles to flow • Measures can be implemented in short time • Areas with high landscape and historic values should be preserved • No dyke raising • Maximum flood retention within the NL • If required: change discharge distribution over the lower Rhine branches • Different river branches can have different functions
HIERARCHIST		
<ul style="list-style-type: none"> • Physical maximum flow of the Rhine = 18 000 m³/s • Safety has priority • Integral water management, with combination of user functions • Landscape planning is result of negotiations between sectors and users • Aim at 'win-win' solutions • Rivers are important backbones for nature development and main ecological structure in the NL • Resilience, flexibility and no-regret are leading principles 	<ul style="list-style-type: none"> • Safety has priority • Aim at ecological restoration: more nature areas • Area for agriculture strongly reduced • Integrated plans with combination of various landscaping measures • Landscape plans and implementation rate depends on negotiation between users • Cultural and historic valuable areas should be preserved • Dyke raising is last option • Some retention within the NL allowed 	<ul style="list-style-type: none"> • Design discharge Rhine and Meuse increase by about 5% (R) and 10% (M) • Landscape planning has existing plans as basis (RvR) • Resilience, flexibility and no-regret are guiding choice of measures • Larger areas with nature • Dyke raising only as last option (not excluded) • Cultural and historic valuable areas are preserved • Retention within NL (Rijnstrangen and Ooijpolder)

Continues

Table V. Continued

World view	Management style	Implementation
INDIVIDUALIST		
<ul style="list-style-type: none"> Physical maximum flow of the Rhine = 18 000 m³/s, but the probability of its occurrence can be neglected Space is sparse and expensive No changes if not necessary 	<ul style="list-style-type: none"> Technical measures instead of space reservation Resistance instead resilience strategy 'Wait and verify'—short-term planning Present land use Cheapest measures, should pay for themselves (clay production and floodplain lowering) Preserve current landscape and historic areas using dyke raising (only at some areas needed) Dyke raising allowed No retention within NL 	<ul style="list-style-type: none"> Unchanged design discharge of the Rhine and Meuse Cost is most important criterion in choice for flood reduction measures Few measures taken Preservation of current land use Preservation of historically valuable areas Dyke raising allowed No retention within NL

changes to the landscape. The embanked floodplains are converted into nature areas, where large parts are lowered to increase the discharge capacity and to create wetlands at the same time. Agriculture is relocated from the floodplains. Behind the river dykes, large areas are allocated to serve as green rivers and for retention. Although these areas will not be needed for these purposes over many decades (depending on the climate scenario and the occurrence of floods), these regions lose their economic value. In general, large nature areas are established in the lower Rhine–Meuse delta.

Hierarchist

The Hierarchist is aware of climate change, but considers the central estimate of changes. The management style involves a complex process of design, planning and implementation. The plans serve many users, and are adapted to local conditions. The strategies seek for a reduction of flood risk along with nature development, while preserving the landscape simultaneously. The strategy aims at increasing the resilience the river system, but also attempts to maintain a high budgetary flexibility and to avoid irreversible measures such as dyke raising and floodplain lowering.

Individualist

The Individualist believes that climate is insensitive, represented by the lower estimate of the changes, which does not raise the need for major adaptation of the river system. In the Individualist management style, flood protection is obtained by increasing the resistance instead of by increasing the natural resilience. This is because in the individualist perspective land use planning is guided by market mechanisms. This leads to high land prices. Priority is given to the use of land for economic activities over reserving large areas for water retention, which potentially may not happen for many decades. Flood protection should be cheap, fast and implemented by technical structures, thus not hampering other land users and uses.

MODEL RESULTS

Hydrological changes

Figures 6 and 7 show the changes in the 10-daily water balance of the rivers Rhine and Meuse according to different combinations of external conditions (i.e. climate and land use change) and management measures (nature rehabilitation, increasing upstream infiltration). These figures indicate the changes in water availability and do not indicate the effect of retention on peak flows.

Three clusters of discharge regime emerge, which are valid for both the Rhine and Meuse. These regimes coincide with the climate changes characterizing the External context of the individual cases (cf. Figure 3):

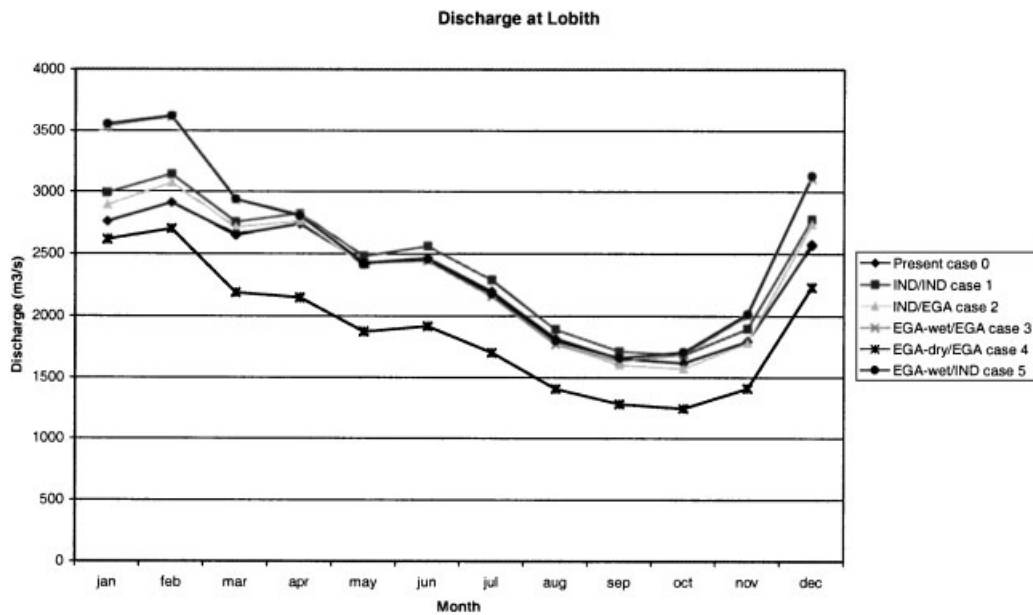


Figure 6. Discharges of the Rhine at the Lobith gauging station (in m^3/s) according to different perspectives

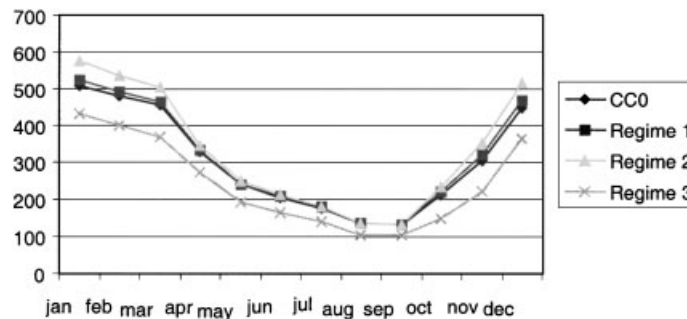


Figure 7. Discharges of the Meuse at the Borgharen gauging station (in m^3/s) according to different perspectives

- Regime 1: Case 0 (current situation), Case 1, and Case 2 (external context: IND);
- Regime 2: Case 3 and Case 5 (external context: EGA-wet);
- Regime 3: Case 4 and Case 6 (external context: EGA-dry).

Regime 1 has characteristics similar to the current situation. According to the external context IND the hydrological inputs in terms of rainfall and temperature change only little. Slightly higher maximum and Q95 values are due to a large increase in urban area, which decreases infiltration and increases direct runoff. Regime 2 is characterized by a considerable increase of high discharges, leading to higher maximum discharge, Q95 and mean discharge. This is mainly due to the precipitation increase associated with the climate scenario envisaged in the EGA-wet world view. Remarkably, minimum discharges are only slightly higher than in the current situation. This regime does not seem to be sensitive to management styles. Both the EGA (Case 3) and the HIE management styles (Case 5) do not provide enough retention and storage in the upstream catchment to mitigate the effects of the increased precipitation. Obviously, extremely high discharges occur when all retention and reservoirs in the catchment are full, which is the case in a totally saturated catchment. Increased precipitation will in those cases always result in increased discharges, and in this situation it will be very difficult to find capacity for extra water storage (cf. Van Deursen *et al.*, 2002). Regime 3 is characterized by a significant decrease in discharge volumes. Again, the

reason for this is the climate change occurring in the EGA-dry perspective that combines a substantial decrease in precipitation with a temperature rise. This drastically reduces the amount of water available for runoff, resulting in decreased mean and minimum flows.

Implications of floodplain landscaping strategies

Depending on the development of future climate and the extent and effectiveness of upstream measures in the Rhine basin, the design discharge may remain more or less unchanged, or it may increase to extremes as 18 000 m³/s. The implications of the landscaping strategies according to the different perspectives have therefore been evaluated for design discharges increasing step-wise from 16 000 m³/s to 18 000 m³/s with a 500 m³/s interval. Figure 8 shows the implications of different strategies in landscape planning of the floodplains for the design water levels for the main Rhine river distributary. The reference is the present-day level that would occur for a Rhine discharge of 15 000 m³/s; the graphs indicate the changes from this reference level. The effects of these strategies in terms of areas of floodplain lowering, cost and total length of dyke raising are given in Table VI.

EVALUATION OF THE PERSPECTIVES

The results obtained using the landscape planning DSS for the entire utopia–dystopia matrix are summarized in a qualitative way in Table VII using a five-point scale: very negative (– –) (i.e. unfavourable) to very positive (++) (i.e. favourable). Using this table as a basis we evaluated the three scenario families in terms of the central statement ‘water management according to perspective X results in ...’. By confronting each management style with different futures, both utopian and dystopian, overall conclusions could be derived for each perspective and associated management style.

Egalitarian management style

The Egalitarian strategy is focused on the causes of water problems, instead of dealing with symptoms and effects (Individualist) or focusing on actors (Hierarchist). The approach to uncertainty associated with this perspective can be characterized as aiming at a high resilience of the water system. This involves major environmental and landscaping measures, resulting in sustainable solutions with resilient water systems for flooding, and major restoration and expansion of nature. However, the implementation costs involved are high, and other—mainly economic—functions (such as industrial and urban expansion, inland navigation, agriculture) are subordinate to the protection and expansion of water and nature. In dystopian situations, when no flood calamities happen, the drastic measures and large costs have been to no purpose. The positive side effects involve large areas of nature and a higher quality of life. A negative side effect may be that due to the scarcity of space in the Netherlands, the increasing demands for room for nature and water may indirectly increase the pressure on other nature reserve areas. Although many landscaping measures are costly and irreversible (digging away floodplains, transforming agriculture areas into nature), it is a strategy more flexible than the Individualist, in the sense that it allows for changing to another water management strategy, if time proves that the risks are smaller than perceived today. The management strategy is robust, as illustrated by the similarity of the evaluation results along the rows in Table VII; apparently, the impacts of the management measures are larger than those caused by changing boundary conditions, including climate. The Egalitarian faith is that economic austerity in combination with psychological and socio-cultural well-being will result in the long-term stabilization or even curbing of climate change, thereby reducing the long-term water risks. In other words, this management style suggests favourable futures if one does not mind high costs.

Hierarchist management style

The Hierarchist aims at so-called ‘win–win’ situations, but thereby avoids making real choices, and some of the futures associated with this management strategy run the risk of becoming ‘lose–lose’ situations. Hierarchistic water management is a time consuming and expensive strategy, but it does not yield firm safety guarantees. Furthermore, the Hierarchist strategy implies regular adjustment, which is a major cause for the high expenses.

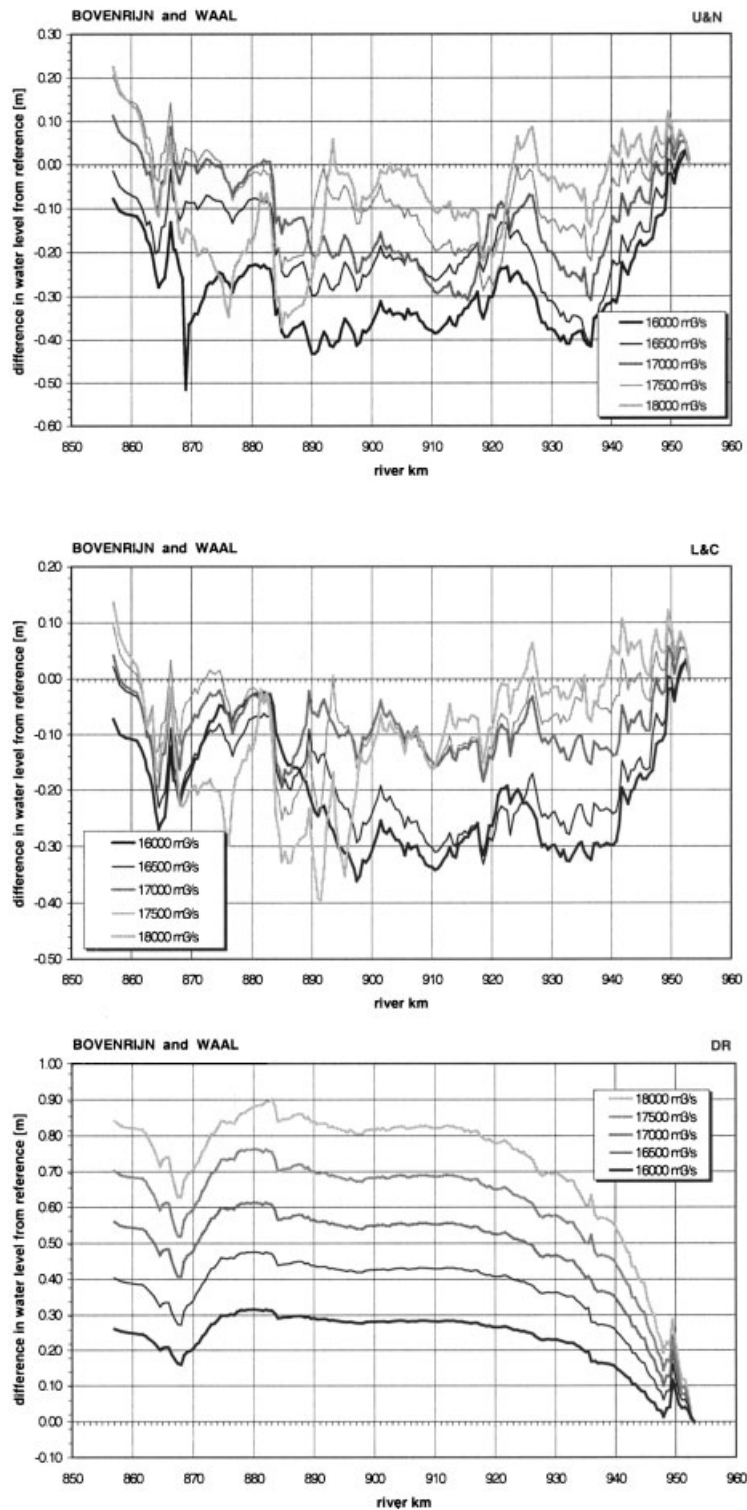


Figure 8. Examples of the DSS model output: water levels resulting from different design discharges under different strategies for landscape planning along the Nederrijn-Waal river. The codes refer to the RvR study: U&N strategy—aims at lowering the floodplain and restoration of floodplain nature (Egalitarian management style); L&C strategy—aims at preserving valuable landscapes (Hierarchist); DR—a dyke raising strategy (Individualist)

Table VI. Implications of different floodplain landscaping strategies for increasing design discharge

Strategy ^a	Design discharge (m ³ /s)					
	15 000	16 000	16 500	17 000	17 500	18 000
U&N (EGA)						
Area floodplain lowering (ha)	0	8403	8583	9294	9721	10 560
Cost (MEuro)	0	3614	3947	4296	4514	5059
Dyke raising (km)	0	19	4	12	25	36
L&C (HIE)						
Area floodplain lowering (ha)	0	5768	6562	7277	7872	8162
Cost (MEuro)	0	2747	3439	3809	4178	4572
Dyke raising (km)	0	42	5	15	18	58
DR (IND)						
Area floodplain lowering (ha)	0	0	0	0	0	0
Cost (MEuro)	0	253	445	513	682	756
Dyke raising (km)	0	294	314	316	319	319

^a U&N = strategy aimed at lowering the floodplain and restoring floodplain nature (Egalitarian); L&C = strategy aimed at preserving valuable landscapes (Hierarchist); DR = dyke raising strategy (Individualist).

Table VII. Qualitative evaluation of the utopia–dystopia matrix for the rivers

Management style	Function	External context				Overall
		EGA-dry	EGA-wet	HIE	IND	
EGA	Nature	+	++	++	++	++
	Agriculture	--	--	--	--	--
	Safety	++	+	++	++	++
	Landscape	++	++	++	++	++
	Resilience	++	++	++	++	++
	Flexibility	--	--	--	--	--
	Cost	--	--	--	--	--
	Economy	--	--	--	--	--
HIE	Nature	0	+	+	+	+
	Agriculture	--	-	-	-	-
	Safety	++	-	0	+	0
	Landscape	+	+	+	+	+
	Resilience	+	+	+	+	+
	Flexibility	-	0	-	+	-
	Cost	-	--	-	-	-
	Economy	-	--	-	-	-
IND	Nature	--	0	0	-	-
	Agriculture	-	-	+	+	0
	Safety	++	--	-	0	-
	Landscape	0	0	0	0	0
	Resilience	0	--	-	0	-
	Flexibility	++	-	-	++	+
	Cost	++	+	0	++	+
	Economy	+	-	0	+	0

Because the Hierarchist tries to serve all functions while being confronted with limited financial and land resources, it is likely that the final solution is sub-optimal for all functions. If climate change appears to be insignificant, the costs have been for nothing. Nevertheless, over time, this compromise strategy may have the most public support. This water management strategy can be characterized as reactive, fully ‘controlled’ by external factors and incidents, as stakeholders’ interests may change in response to events. The risk associated with this

management style is that it gets stuck in conferences and sluggish decision-making, and that only a few measures are actually implemented, among which are likely to be those that are acceptable but not effective. This strategy is actually not so much a vision on water policy, but on how to organize water management. The Hierarchist management style actually addresses uncertainty associated with future developments through incrementalism (versus drastic measures) thereby implicitly creating the flexibility to change to another management style.

In the case of moderate climate change, the high cost of these complex landscaping measures will result in a high pay-off: reduction of flood risk coincides with gains for other river functions. However, in the case of a major climate change the character of the landscaping strategies has to be sacrificed to flood protection by taking large-scale measures. This may nullify the initial gains of the landscaping plans, and further raises the implementation cost. The overall character of this perspective, i.e. avoiding real choices and attempting to implement multi-purpose integrated plans, results in neither optimal scores nor minimum scores along the rows in Table VII.

Individualist management style

The Individualistic management style can be characterized as passive, and displaying a short-term vision with respect to water management measures. The Individualist aims at reducing cost and stimulating economic benefits, thereby accepting a relatively high, calculated risk. Measures will be implemented as adaptations to changing conditions. However, large adjustments to accommodate an unforeseen drastic climate change will not be possible. This is because this management style leaves little physical space for adaptation. Consequently, it will be difficult to change to another management style, for example, because irreversible damage has been done to natural systems in the floodplains, or potential retention areas have been occupied by other functions. In the short term, compared to the others this strategy is relatively cheap. However, there is the risk of amplifying feedbacks if the world develops differently from how the Individualist assumes (e.g. materialistic growth inducing further climate change). The world associated with Individualistic management is thus extremely vulnerable to calamities, i.e. low probability events happening. In the case of extreme flooding, because of high economic value and damage potential along the rivers the economic impacts are large. The future associated with the Individualistic management strategy is characterized as wealthy, but even in the utopian case it results in a lower quality of life in the broader non-materialistic sense. In the case of water management, it is obvious that the Individualistic approach to uncertainty should be characterized as risk-taking. In summary, there are low short-term costs, but high long-term risks.

If the climate does not change (or only a minor change occurs) this management strategy turns out to be the most efficient economically. However, if the rate and magnitude of climate change are larger than anticipated there is a considerable risk associated with this management style. In that situation it will be very difficult to protect the land from flooding: there is no space left for retention polders and there is little time and money for lowering the embanked floodplains. The only option is further raising of the river dykes and accommodating higher flood water levels. This leads to a situation with very low resilience and increased damage potential. In all cases, nature does not benefit at all from measures taken by the individualist. The risk-seeking character of the individualist is well illustrated by the high variability of the evaluation scores along the rows in Table VII: high scores in case of ideal external context, but low scores in case of dystopias. This strategy may be regarded as not robust.

DISCUSSION

Water management strategies

A major difficulty in the 'cost-benefit' assessment is the weighing of advantages against disadvantages, because they are of a different kind. The balance between safety versus costs is a real policy dilemma that cannot be solved by using an ingenious water management strategy. Political decisions on water management involve necessary trade-offs on normative grounds. None of the water management strategies discussed is preferred, because every management style has its own drawbacks and disadvantages.

The main differences between the extreme perspectives of Egalitarian and Individualist are their inherent choices on the implementation cost and accepted risk. The Hierarchist may take an intermediate position. The key question is then whether insights associated with the present project would advocate a different water management style. If Hierarchist water management proves to be more expensive than Egalitarian water management, the

Egalitarian management style is advocated, because the latter yields more safety and nature at lower costs. However, if the Hierarchist management style appears more risky than the Individualist, the Individualistic management strategy is preferred, because it is less costly, and leaves more room for other functions. Similar comparisons may be made on the basis of, for example, resilience, ecological values, or the possibility of combining different functions at all places within the water systems.

The majority of current policy plans on water management in the Netherlands fall within the Hierarchist perspective for their management style. It is shifting from Hierarchist to Egalitarian in terms of assumptions pertaining to external context and world view. However, the Hierarchist management style, aiming at win-win situations, is not *a priori* the most robust for the lower reaches of the rivers. In the case of a serious climate change ($>2^{\circ}\text{C}$ temperature rise in the next 50 years), there may be no possibilities left for finding win-win solutions for all water functions. Also, the complexity of the planning process may result in a slow response in the case of severe climate change. Still, the current research results do not provide enough evidence to underpin the need to adopt a different water management strategy. At present a switch to the Individualistic management style is not advocated, because scientific knowledge indicates that it would be unwise to neglect the possibility of serious climate change in view of the current level of uncertainty. From a safety point of view, it can be advocated to switch to the Egalitarian management style, because it is the most robust strategy, but it is doubted whether society is ready/willing to pay the costs in financial terms and in terms of spatial claims. However, it is clear that it would be a bad policy to put all one's eggs in the Hierarchist basket. The Hierarchist water management strategy has to be continuously evaluated in terms of relative risk (compared to the Individualist water management strategy) and relative costs (compared to the Egalitarian water management strategy).

Methodology and concepts

The present study has demonstrated that the top-down approach using the concepts and typology of the Perspective methods did fit to the 'case' of water management in the Rhine and Meuse basins. The Perspective-based analysis of these studies demonstrated well the position of current policy in water management in the Netherlands, Belgium and Germany in a wider perspective. Also, from the viewpoint of the stakeholders the three Perspectives indeed consider the full spectrum of 'possible' or 'thinkable' scenarios. The Egalitarian envisages a worst-case situation in terms of climate change, (both wet and dry extreme events may occur); the Hierarchist represents the visions that seek the most plausible scenario, the central estimate, the most likely or most manageable future; the Individualist explores the consequences of short-term orientation and a risk-taking attitude. However, the three Perspectives do not fully discriminate between all differences in water management when considering the international dimension. Additional dimensions for characterization differences in national management styles are therefore needed.

CONCLUSIONS AND RECOMMENDATIONS

At the scale of the entire Rhine basin, climate change impacts cannot be compensated by land use changes, as the influence of climate change on extreme floods is much stronger than the influence of land use measures. Flood risk management in the lower river deltas cannot be based on the assumption that extreme floods can be prevented by upstream measures, because it is not certain that upstream flood retention measures will be implemented *and* that they are as effective as anticipated, especially under very extreme flow conditions.

Current Dutch flood risk management can be characterized as complying with a Hierarchist management style, while German and Belgian management styles have common characteristics with an Individualistic style. The three cultural Perspectives applied in the present study, however, do not fully discriminate between all differences in water management with regard to the international dimension. Additional dimensions for characterization differences in national management styles are therefore needed. Under changing climate conditions, the Hierarchist type of management in the lower river reaches runs the risk of becoming an expensive attempt to fully control flood risk problems, without actually solving the problems in a long-term view. No flood risk management strategy is superior in all respects and in all circumstances. Flood risk management is not merely a technical optimization problem: safety versus societal costs is really a policy dilemma; win-win situations cannot always be attained.

Integration of water management and spatial planning is essential, because spatial claims often collide with claims for water management, which is likely to result in higher risks and higher costs.

Considering the present-day and future uncertainties for water management in the Rhine and Meuse basins, research should be aimed more at defining integrated and coherent scenarios that can underpin adequate water management strategies given the uncertainties. This should be done by combining *social* sciences with *natural* sciences, and by combining physical/mathematical modelling tools with expert sessions and participatory stakeholder processes. Perspective-based flood risk management scenarios should not only consider the temporal dimension with different lines of future development, but should also take into account differences in management styles within the river basin.

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