Coping with complexity in integrated water management

On the road to Interactive Implementation

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Preface

This book finds its origin from my thesis *Coping with complexity in integrated water management*, which I defended on 11 January 2002 at the University of Twente, after labouring on it for about eight years. Professor C.B. Vreugdenhil was my supervisor. My thesis, published by Tauw bv, was distributed on a large scale and even reprinted in 2003. But by now, it has served its main purpose. It was time to do something about its two main disadvantages: it was written in Dutch and many readers thought it was long and tedious. This new publication is the result. Albert Einstein once said: "Let's make things as simple as possible, but not simpler than that". That is my motto. This may sound peculiar in a book about complexity, but simplicity has its own kind of beauty. Therefore, I have taken out most of the original text of the thesis, adapted the story line and added new insights. This has reduced the depth of the book, but it has strengthened its core issues.

What is this book about? It is about controlling processes in integrated water management. The process of painting a painting can serve as a metaphor here. In the creative process, the artist creates a painting, with only a rough idea of the end product in his mind. He starts by putting lines on the white canvas while gradually a composition emerges. During the painting process, adjustments are regularly made and sometimes parts are redefined. During this creative process, the artist finds himself at least at two alternate distances from his work. Most of the time, he is working on contours and details very close to the canvas. From time to time, he will take a few steps back to have a look at the whole picture and to assess the composition and its coherence. Re-inspired he will walk back towards the canvas to work out the details further.

These alternate distances are also clearly present in complex integrated issues. Much time is spent on working out the partial issues. Calculations are made, details designed, publications drawn up and so on. However, it is important to take a few steps backwards from time to time to see the whole picture. Integrated issues also have a composition.

This book is about taking a few steps backwards to collect information on the composition; information which is essential to good water management. In order to be able to control the process, it is desirable to collect information from close by and from a distance. Subsequently, it is possible to go through a learning process while an integrated project can – sometimes amazingly – take shape. This book tries to provide the spectacles required to see the whole picture; the spectacles are called the complex adaptive system.

The main point is the interaction between water and society. This interaction is complex by nature. By taking a few steps backwards, and by involving other aspects of the environmental policy, patterns of stability and instability may be discovered. Knowledge of these patterns contributes to good management.

The original thesis, on which this book is based, has also grown in interaction with the practice. As early as the late eighties, I had come up with ideas deviating from those expected of me at a technical consultancy. My thanks are due to Henk Hengeveld, director at Tauw, who stimulated and supported me from the very start, even in rough periods. Discussions with colleagues and peers helped me greatly, especially with Ton van der Maarel on the land subsidence in Groningen, Jan van Bakel on the edge of chaos and the beauty of determinism, Pim de Kwaadsteniet on ethics, Esther van Beurden on transition processes and Harry van Luijtelaar and André Oldenkamp on tacit knowledge. At Tauw, room was created for ideas outside the scope of current ways of thinking, which, among other things, led to Interactive Implementation, a principle on which I have worked closely with Jackie Straathof, Han de Wit, Pieter Lems, Roel Valkman and many other Tauw colleagues. Thanks to Bert van Ee, it

was possible to stay at home for continuous periods and concentrate on my thesis. He has also been an adamant advocate for this new book and its English translation.

One could say that the clients who had faith in me and supplied me with paid assignments even though my ideas were still in their infancy, showed most courage. It is quite impossible to list them all by name here, but I would like to mention Eilard Jacobs (groundwater plan Amsterdam), Paul Berends (Fourth policy document on water management and coastal management), Kees Vos (urban renewal De Vliert in 's-Hertogenbosch), Jan Luijten (Nijmegen Water Plan), Wout Veldstra (water projects in Groningen) and Bert Palsma (the water chain).
With the KIVI[1] working group Thales, the working group on water and philosophy, I have had some good debates on complexity. The discussions with Sybrand Tjallingii on dynamics and diversity, with Frans van de Ven on decision-making and policy, with Jan de Bor on time, with Gijsbert van der Heijden on creativity and with John Grin on methodology, all provided building blocks for my thesis and this book. I would also like to thank James van Lidth de Jeude, mayor of Deventer, who provided well-timed support with his enthusiastic approach to deterministic chaos and administration.

This book takes matters further than my thesis. Experience from the past few years has been incorporated, which was largely obtained within European projects such as Daywater, Water City International, Pure, Flows and Foresight Future Flooding. Thanks are due to Daniel Thevenot, Peter Steen Mikkelsen, Hans van Meerendonk, Peter Stahre, Hans van Hilten, Harry Bottenberg, Bert Kappe and Richard Ashley. Members of the working group Interface, e.g., Rebekah Brown, Phil Smith and Eva Csobod, have inspired me with regard to the link between water management and society. Special thanks to Richard Ashley who checked the whole manuscript of this book as a native speaker.

Finally, a word on the Chinese characters on the cover. Pronounced in Japanese, it says: "Chou You". I came across this term in August 1994, when I had been invited to hold a lecture in Tokyo on urban water management. Among other things, I was planning to talk about dealing with uncertainties (see also Section 5.4.3), using the division between cowardice, bravery and recklessness as presented in Aristotle's Ethics, in which bravery stands for the middle path. If you want to change something, you cannot afford to be a coward. Uncertainties have to be accepted. However, accepting too many uncertainties will result in recklessness which means that any attempted change process is bound to fail. It is an art finding the middle path: the road of bravery. I was under the assumption that this way of thinking was typically of the Western world, but a preliminary discussion with dr. Shoichi Fujita proved to me that it is also part of the Eastern philosophy. Many centuries ago, it was introduced in China and Japan by a great-grandson of Confucius. The two Chinese characters, pronounced very similarly in Chinese, mean the right practice as in the middle path between order and chaos. That is what coping with complexity is about. The characters may well present the shortest summary of the contents of this book.

Bathmen, 26 July 2005

[1] The Royal Institution of Engineers in the Netherlands

Contents

1 Integrated water management and complexity

1.1 Three reasons

The reasons for writing this book are based on three important field observations. These were the reasons for writing my thesis *Coping with complexity in integrated water management* and they also form the thread of the story line in this book.

1. Many plans never get off the ground. There is a clear awareness that water should be approached in an integrated way. Surface water, groundwater, water quality and water quantity should be considered together and in context to other fields of policy such as nature, traffic, agriculture, housing and recreation. This creates complex processes in which many actors are involved. However, because everything is connected to everything else, one often no longer sees the wood for the trees. Many uncertainties arise causing stagnation. There are also more and more rules which must be taken into account. All of this causes many processes to collapse under their own beauty and well-thought-out plans disappear into the desk drawer.
2. The interaction between water management and society is awkward. Measures to improve the water management must match the societal context. Support is essential. Previously, this was not too difficult because water managers had almost complete authority on the system they had to manage. In modern water management, however, measures are taken to manage the smallest details of the living environment and water managers have relatively little to say here. Out of this, a kind of dynamics emerges that is hard to fathom. It is not unusual that plans presented at so-called participation evenings are rejected on the basis of "emotional grounds".
3. The use of (computer) models has its limitations. The models have improved a great deal during the last years and it has become possible to create a better basis for policies and any subsequent measures. The models have also clearly contributed positively to the dimensioning of measures. However, in a number of processes the part played by models has been taken too far. Instead of an aid, they have come to be seen as the "naked truth". This is dangerous. Some people even think that it is possible to represent reality so accurately with models that they are able to make decisions completely on the basis of objective grounds, in other words, that one can make politics "rational"!

These three field observations are closely related. They all have in common that the complexity characteristic of integrated processes is seen as a nuisance and should therefore be reduced. But because this is not possible, processes run away with the plans. This means plans are not being executed, actors become emotional, and water managers continue to model until truth has been demonstrated. The main argument of this book is that complexity should not be combated, but it should be made manageable. This seems only a minor difference in approach, but in the field it results in a fundamentally different approach to integrated projects.

The approach presented in this book for coping with complexity in integrated projects is called Interactive Implementation (see Chapter 5). A vital aspect to this approach is that many theoretical problems can easily be solved in practice. Solutions to coping with complexity can be found in the field, where everything comes together. Matters change by taking action. This may sound logical, but for many integrated water projects it means breaking the trend. At the moment, there is a tendency to try and solve on paper as many uncertainties as possible within a project. This is becoming increasingly complicated.

This book distinguishes between complexity and complicatedness. Complexity is viewed as a healthy and natural feature of a developing system, perceptible in both societal and natural processes. Complexity is a precondition for change. Chapter 2, in which the science of complexity is explained, further describes this notion. Complicatedness is viewed as the result of human actions. In order to get a grip on processes, people think up systems, set up structures, and define rules. All these human concepts make it difficult for many people to find their way around processes, especially when they discover that everything is connected to everything else. They experience this as being complicated and each time something bothersome happens unexpectedly, new rules are added and the complicatedness increases. An important proposition in this book is that complicatedness is often the result of resisting complexity. By accepting the fact that processes are complex and that they cannot always be completely controlled, they become easier to deal with. In short: *by accepting that something is complex, it becomes simpler*. This book offers a number of guidelines for coping with complexity, based on much practical experience.

This introductory chapter first describes the three field observations in more detail. Second, the line of reasoning of this book is explained.

1.2 From plans to implementation

Many plans never get off the ground and many processes stagnate. Growing complexity seems to cause good intentions to evaporate. The question is whether complexity in water projects is actually increasing. The answer is not straightforward. Presumably, water projects have always been complex and it has simply taken us a long time to notice this. On the other hand, it is clear that the integratedness of water projects is increasing. Verbeek (1997) says that the increasing integratedness has made the water manager's work less transparent. He describes four factors which make it more difficult to arrive at a coordinated application of means in integrated water management:

- Sometimes the problems are unclear.
- The water system is complicated.
- The necessary means are distributed over many actors and therefore their availability is fragmented.
- The implementation of measures often causes new problems.

Previously, it seemed that there was a clear problem – for example: it is too wet – upon which water management was adjusted. In order to effect this, the water manager had complete authority over the watercourses and their embankments. When the measures had been carried out, the problem was solved. Nowadays, everything seems to be connected to everything else and it has become increasingly difficult to draw the line. Does the water manager have to be involved in everything and if so, does this leave time for him/her to deal with the 'real' water management? In the Netherlands, for instance, municipalities and water boards are working on urban water plans. Urban water plans are plans in which goals and means are worked out together for the many aspects of water management, pertaining to policies for surface water, groundwater, drinking water, sewerage, water treatment and ecology. Drinking water companies can also play an important role in drawing up an urban water plan. In its capacities as supervisor and groundwater manager, the province also is an important actor and if there is state water situated in the area, the Ministry of Transport, Public Works and Water

Management should also be involved. The officials writing the plan should involve the administrators and other services, interest groups, residents, etc, in the process. It is clear that water is no longer exclusively the work of water managers; architects and urban developers are also dealing with water, just like ecologists, environmental experts, project developers and many others. They are all working in a more integrated way and the different activities should be geared towards each other. An urban water plan may deal with management and maintenance of river banks; reducing emissions from the sewer system and from other sources; reducing groundwater nuisance and moisture; sustainable construction; fortifying ecological structures; creating subsidy schemes for rainwater harvesting in and around the home; fitting car washes; and indicating most suitable locations for new housing. Parties involved experience this as an increase in complexity. Against this background, it is difficult to draw up a coherent plan. It is even more difficult to actually carry out the measures described in the plan.

Why does water management have to become better integrated? Because this constitutes an added value. The first important added value can be found in reconciling the different aspects. By harmonising interventions in surface water or groundwater, both with regard to water quality and water quantity, means are more efficiently employed. For instance, when slightly contaminated stormwater from roofs is infiltrated into the subsoil instead of discharged to the surface water through a stormwater sewer:

- the discharge of stormwater to surface water is delayed and so is the discharge of surface water to the sea;
- less contaminants end up in the surface water;
- groundwater levels can rise; and
- the groundwater quality may be influenced.

By considering all these effects together, it is easier to match measures. The quality of water management can increase even more when it is attuned to other fields of policy, such as spatial planning, traffic, environment and nature. It is certainly possible to prevent interventions from hindering each other. In addition, in weighing issues, certain solutions can "score" extra if they are in line with the policy of many other fields, instead of just water management. A good example is the adjustment of the water management in De Vliert estate in 's-Hertogenbosch. During the replacement of the sewer system, the stormwater and wastewater were separated. An old traffic issue was also solved along the way. By adjusting the water system it had, in parallel, become possible to tackle the problems with rat-run traffic.

The integrated approach has another added value, which is the central theme in this book. Complex systems can have properties that simple systems do not have, because "the whole is more than the sum of its parts". When looking at the whole picture, patterns become visible that help formulate more successful interventions. This book gives many examples of these kinds of patterns. The science of complexity (see Chapter 2) provides the basis for them.

As such, the integratedness of projects is increasing and this has an important added value. However, in practice, this added value is only partially taken advantage of. Integrated plans are being made but rarely carried out. Vuurboom (2001) shows that of the measures formulated in urban water plans, only the simple ones are carried out. Going from plan to implementation appears to be difficult.

1.3 The interaction between water and society

It is difficult taking measures for the water manager when he/she cannot control all success factors him/herself. Take for instance the source-oriented approach of improving surface water quality. A large portion of the contamination is caused by diffuse sources, such as litter, dog faeces, pesticides, fertilizers, ducks, rubber from car tyres, and leaking engines.

Figure 1.1. Pond in the Lewenborg estate in Groningen. Water quality and behaviour are not two separate matters.

A source-oriented approach means taking measures to manage the smallest details of the water system and this means approaching and influencing many actors. This is not an easy task. More often than not, residents and companies will have to face limitations. They can no longer discharge their wastewater or they have to accept the occurrence of water nuisance now and then. Matters have really changed now. In the past, water managers used to carry out activities increasing the possibilities to utilise land, especially in the Netherlands. Where there was water, or where the land was very wet, land was made suitable for tilling or buildings. The water system was being adjusted to the needs of the people. Now, the water manager is more occupied with imposing limitations. Sometimes, human activities must make way for natural objectives or limitations must be imposed because land will be used as a stormwater retention area. In a number of cases, land is even returned to water. In order to attain the water quality objectives, companies and individual residents sometimes have to invest a great deal. In practice, water managers seem to have to get used to this new role.

This “getting used to” becomes especially clear during participation evenings for residents in the local community centre where matters are often wrongly communicated. Many professionals present their plans to residents on the basis of their own way of thinking, thus failing to connect with the residents’ reality. Without too much exaggeration, the following is

what often happens during participation evenings in the Netherlands: picture a large room with a hollow square setup where the residents are seated. There is a table on stage with the administrator behind it, flanked by officials and consultants. Usually, the consultants present the plans. The line of reasoning is as follows. There is a general problem, for instance, water nuisance, bad water quality, overfertilizing, odour, decreasing biodiversity, traffic noise, rat-run traffic, parking nuisance, contaminated soil, the use of pesticides, vandalism, dilapidation, or any other problem. The government has formulated a policy to tackle the problem: "And this is what we are going to do." Then the plans are explained. Often, these plans are very well put together. After various presentations, with too little time for residents' questions, there is a discussion, and it goes very badly. The residents' responses are disagreeable and irrational. "Residents just don't want to get it", say the professionals later, "they only think of their own interests."
The most striking aspect of such a meeting is that professionals peg down the discussion on the basis of their own way of thinking. They lay down the rules and determine which matters are going to be discussed or not. Social and psychological aspects of measures, including the past, are off-limits. Residents should stick to the pegs as proffered. This is highly frustrating to the residents, because the professionals dominate these subjects in knowledge and this makes their own opinions seem less relevant.

Van Woerkum (2000) calls this way of communicating *self-referential*. A government carrying out plans refers to its own tasks and opinions and wants to convince others of the accuracy of the ideas. Often, the notion "creating support" is used here. Without support, the plans cannot be carried out. However, it is not possible to *create* support. Support is an emergent property. It cannot be exacted, nor is it a permanent matter. It is subject to fluctuations and will diminish through careless communication. It is often the case that residents and companies have little *faith* in the government (Geldof et al., 2000), due to experiences in the past. It raises suspicion when the government suddenly tries to involve people in a planning process in a positive way. Apparently, if the faith of residents and companies is low, they are susceptible to so-called *peripheral stimuli*. These are messages and signals from all kinds of sources that are not always very subtle and often have an emotional component, causing the public to respond chaotically.

An awkward interaction between water and society is not necessarily purely the water professionals' fault. It can also be the result of the fact that just before the presentation of a water plan, there was a discussion about traffic. Residents are often confronted with plans for different matters at different times. All these plans are presented as being "integrated". Besides integrated water management, people are confronted with integrated traffic management, integrated health care, integrated zoning plans, etc. Many fields of policy are working on an integrated vision with the specific policy as the focal point. In other words, self-referentially. It often comes across as illogical to residents and they feel that there are inconsistencies between the various plans. Is no one concerned with the whole picture?

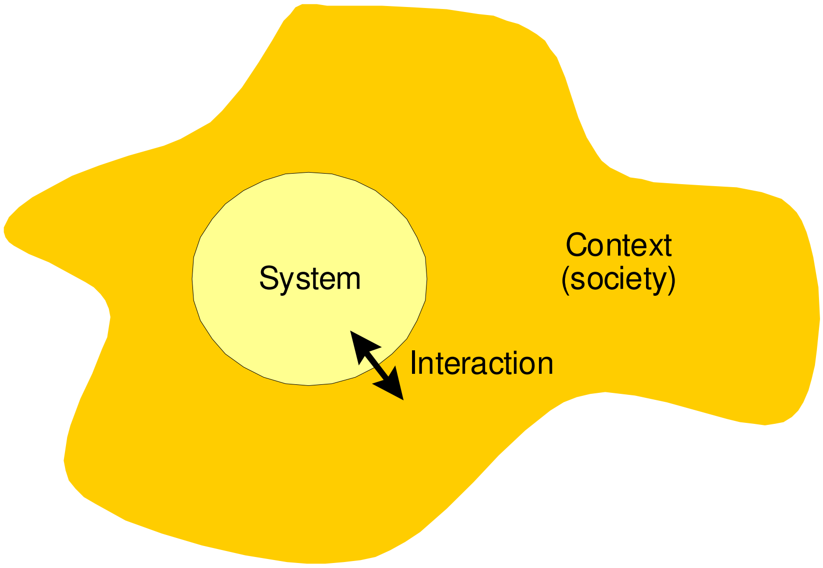

Figure 1.2. System and context.

Figure 1.2 schematically presents the essence of field observations concerning the awkward interaction between water and society. A water management issue is bound to the water system and has a relationship with the living environment, i.e., the context. There are actors, other fields of policy, a past and many other matters within this context. The water system is adjusted when needs are formulated by the context. Society wants good drinking water, wishes to start building or recreate somewhere on, along and in the water. However, the water system also places demands on the context. Water system and context influence each other, resulting in continuous developments. The main reason why there are problems in this area is that people are unfamiliar with the nature of the interaction between system and context. Often, it is underestimated. The nature of the interaction, or dynamics if you will, is erratic. This is called *nonlinear dynamics*. Sometimes there is little interaction and sometimes a great deal is happening all at the same time, much of which is unexpected. Unawareness of such nonlinear dynamics causes unpleasant surprises.

1.4 Limitations of models

The third field observation concerns the use of deterministic (computer) models. It is becoming more and more obvious that these models have limitations. It is important to be aware of this.
Why are models being used? Look around you, and you will see a complex world in which it is not easy to predict the outcome of interventions. Human action results in change and it is important that the intended effect is obtained. This can be verified through “trial and error”, but models can provide more direction for the interventions. In addition, learning experiences can be embedded explicitly in models. A model creates an abstract world alongside the real world – that we can hardly understand. This abstract world created by a rational process describes relations in an orderly fashion. For water management models, this order is usually derived from mathematics and laws of nature.

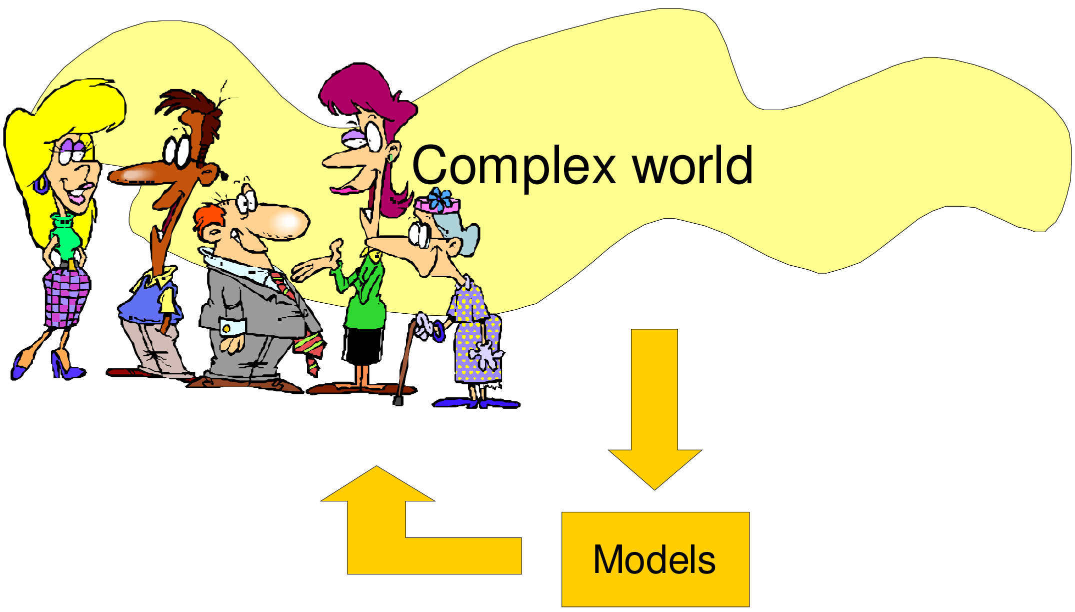

Figure 1.3. Models can be used to determine effective and efficient interventions in the complex world.

Models are often used as follows: a problem is identified. An unacceptable level of flood risk, for example. The first step is to determine the mechanisms contributing to the origin of the problem. In the case of flood risk, it may be of importance to have a look at the hydraulics of the watercourses, the groundwater flow, the possible effects of climate change and how spatial planning is influencing the water system. Then the cause-effect relationships are analysed by means of a model. The effectiveness and efficiency of possible interventions are mapped out and packages of measures compared. Decisions are made, mostly by administrators or politicians, on the basis of the insights obtained.

Models have much to offer in case of relatively simple issues. However, it is becoming increasingly difficult to make sound predictions for complex issues. Kellert (1993) describes this very clearly. Complex processes can display *chaos*, which means that even if a relation described in a model would be completely accurate, results of a second application could be considerably different. This phenomenon can occur as soon as the initial conditions of the second application are only slightly different from earlier conditions. Small variations in the initial conditions are intensified rather than toned down. The weather, for instance, shows chaotic behaviour, making it hard to make good predictions – and making it even impossible for the long term. Lorenz, discoverer of this principle, presented a paper in 1972 about the insights in the phenomenon of chaos in weather systems. The paper was entitled: "Does the Flap of a Butterfly's Wings in Brazil Set off a Tornado in Texas?" (Lorenz, 1993).
On the basis of empirical research into integrated water management issues, *analysis* may generate statements such as "Stormwater infiltration is sustainable and increases residents' involvement" or "Safety in areas along the river is increased by reinforcing and raising dykes along it". These relations can be observed in cases in the field, but the notions sustainable, involvement and safety can be given another meaning in other places. Despite a large similarity in conditions, the same measures can be considered unsustainable or unsafe somewhere else.

This finding is of major importance to research into coping with complexity in integrated water management because the model of the complex adaptive system (see Chapter 2) is used for the description of the processes in integrated water management as a whole. Complex adaptive systems exhibit a nonlinear dynamics (Holland, 1995), which means cause-effect relations are not always proportional. In linear dynamics, small causes result in small consequences and large causes in large consequences. This is different in nonlinear dynamics. Large causes can have both large consequences and little or none at all. The same goes for small causes. The fact that small causes can have large consequences may be the result of chaos.

Complex issues have much interaction between the many processes on many time and spatial scales. It is an impossible task to describe all relevant mechanisms accurately. The phenomenon of chaos makes it even more difficult. Analysis by means of deterministic models has its limitations. However, in practice, models are heavily relied on and often decision-making is based completely on the outcome of model calculations. Lindblom and Woodhouse (1993) have also observed this. They demonstrate that in many issues there is a tendency to use analysis *instead of* decision-making processes and not as *an aid to*. This means decision-makers are only needed to officially confirm the decisions. The thought behind this is that it must be possible to arrive at the best options through analysis. This may be possible for relatively simple issues, but it is not an option for complex processes because the analyses required will get out of hand. Lindblom and Woodhouse give an example in which the United States Congress received almost 400 reports on energy policies in one year, all from one institution, some 20,000 pages in total. Decision-makers will not be short of advice; they will be swamped by it. They still ask for it, because they *believe* that the objective truth regarding the best solution can be found through all this information. Once the best solution has been determined, it will be held on to no matter what, because much research was done to arrive at it. Information confirming the solution is admitted; information indicating that the wrong solution was opted for is rejected. Many decision-makers typically close their eyes to the fallibility of their eventual solution.

On the basis of the above considerations it would be better not to assume one objectively best solution to be found by model analysis for complex issues. It is better to accept the fact that there are parties with different views competing with each other. The parties provide *arguments* for their own views. The "game" that is played, eventually resulting in the decision-making, is not the weakness, but the strength of a democracy. Science contributes to reinforcing the arguments and can therefore contribute to the strengthening of the opposed views. Lindblom and Woodhouse (1993) conclude that science should *adapt* to developments in politics. Analysis can be useful if it systematically adapts to the characteristics of complex issues. Such characteristics include large uncertainties and many differences in opinion between parties. Complex issues are suitable for interactive problem-solving. "Analysis should be used to contribute to the quality of political interaction and not to replace it."
If this advice is not heeded and one objectively best solution is still sought after, you run the risk of ending up with a grey – average – compromise. Hermsen (2000) warns us about this and, in a discussion of the Dutch polder model[2], says: "The compromising politics characteristic of the polder model not only conceals the intrinsic discord in a democracy, but actually denies that a democracy exists thanks to the infinity of political and social differences. Such differences make a democracy into a dynamic form of society."

[2] The collaborative socioeconomic policy in the Netherlands introduced in 1982

1.5 Line of reasoning

This book discusses the three field observations within the context of the science of complexity. The added value gained when complexity is not combated but made manageable is investigated. Chapter 2 describes building blocks from the science of complexity, including the characteristics of complex adaptive systems. Chapter 3 deals with a practical case study. The thesis on which this book is based deals with three cases, but two have been left out to make the new book less bulky. The remaining case is the Nijmegen Water Plan. From the start of the introduction of this water plan in 1997, the insights from the science of complexity have been used.

In order to be able to determine an added value, it is important to know the relation to which it is obtained. Therefore, Chapter 4 introduces a reference model: the control system approach. This approach is noticeably present in current water management and can be characterised as an approach for combating complexity. The limitations of this reference model are mapped out and projected onto the three field observations described above. Chapter 5 outlines an approach for coping with complexity, which is called Interactive Implementation and which lifts a number of limitations of the control system approach.

Finally, Chapter 6 – as the summary to this book – discusses the problems of flood risk. Lately, flood risk has become a focal point for water management in many countries. Risk and risk perception are specifically dealt with. On the basis of the three field observations and the building blocks for coping with complexity, it will be shown how the safety of water systems can be increased.

Key to reading this book: those who are not really interested in the scientific background and merely wish to obtain practical insights are advised to skip Chapters 2 up to and including 4 and start reading Chapter 5 on Interactive Implementation.

2 Complex adaptive systems

2.1 Science of complexity and 'the whole picture'

The science of complexity is a product from the nineties and is evolving around *complex adaptive systems*. Gell-Man (1994) defines complex adaptive systems as systems that *learn* and *evolve*. Examples of complex adaptive systems in the natural world are the brain, immune systems, ecologies, cells, developing embryos, and ant colonies. In the human world, examples are cultural and social systems such as political parties and scientific societies (Waldrop, 1993), which main feature is that they adjust to changing circumstances. They adapt.

In order to be able to say more about the behaviour of 'the whole' in integrated water management, the model of the complex adaptive system is used for its description. The whole is seen as something which learns and evolves. It exhibits a constant development which can be both gradual and abrupt.
Holland (1995) states that complex adaptive systems can be considered at different aggregation levels. He sees the *aggregation* of different systems into one system – one whole – as an important feature. Different structures are found per aggregation level. Waldrop (1993) describes the following example. It is possible to look at people at cellular level. Each cell has a function and by looking at cells one can learn about the functioning of man, and other living organisms. Together, cells form tissue and organs are made of different kinds of tissue. Also by studying organs it is possible to learn about man. Man has different organs which could be considered as acting in a group. At an other level, different people together form a group. Society is made up of different groups of people. By studying people in groups and the interactions between groups, insight is also obtained into the functioning of man. Processes can be studied at different aggregation levels, while different relationships are sought at each level.

It is important to know that aggregation also takes place in evolution, with an increasing order of complexity. Oppenheim and Putnam described this as early as 1958. The order is: subatomic particles, atoms, molecules, living cells, multicellular living organisms, social groups, etc. In the course of evolution, it turns out that matters of a certain complexity always originate after and from matters of the previous level of complexity (Philipse, 2000).
Pirsig (1991) distinguishes between four processes here: physical (and chemical) processes, biological processes, social processes and intellectual processes. Physical and chemical processes take place all around us, even on the moon. Biological processes feature in life forms and social processes in complex life forms. Intellectual processes characterise man. Pirsig says that the development of physical processes into intellectual processes reflects the evolutionary direction with its ever increasing complexity.

As described earlier, water management has become more integrated, and possibly also more complex. Integrated water management can be seen as an aggregation of the coherent components of which it consists. Many components can be described with the model of the complex adaptive system. And so can the whole.
If this assumption is correct, the whole of processes in integrated management can be better understood by projecting knowledge on the behaviour of complex systems onto processes in integrated water management, so as to derive guidelines for steering strategies.

2.2 *Contours of complex adaptive systems*

The notion of a complex adaptive system was introduced by John Holland in his book "Adaptation in natural and artificial systems". The book was first published in 1975, but was not a success. The ideas did not appeal to people at the time (Waldrop, 1993). In 1992, it was published again with a few additions and became a bestseller: the time was right. Holland (1992) defines a complex adaptive system as a system that adapts its structure to a changing environment. He makes a distinction between the following elements:

E = the environment of the system (the context);
A = the structure of the system;
τ = the adaptive plan;
μ = the assessment values of the system.

An adaptive plan (τ) is made from within the system, weighing many alternative structures (A) against each other so that the environment of the system (E) is likely to have a positive development with regard to its assessment values (μ). If various environments (E) result in different structures (A) this constitutes a complex adaptive system. It is essential that the adaptive plan is drawn up from within. There is no 'manager' observing the whole from the outside and intervening, as the manager is part of the system himself. In addition, he tries to obtain knowledge on the behaviour of the whole and he develops ideas for adaptations to changes in the environment.

The complex adaptive system is the model for living systems and shows nonlinear behaviour. The many followers of the science of complexity make this nonlinear behaviour visible by doing computer simulations. Many agents interact with each other in these simulations. The rules for this can be both simple and complicated. The large quantities create complexity, whilst emergent[3] patterns are generated. These emergent patterns are characteristic for the behaviour of the agents *as a whole*. This is exactly the link to the subject of coping with complexity in integrated water management. Many agents are also distinguished in integrated issues in water management, which depend on each other and interact with each other. If the whole is more than the sum of its parts, then it is valuable to know about the behaviour of the whole.

It is likely that the model of the complex adaptive system fits into integrated water management or is at least recognized. This is apparent from the four properties of complex adaptive systems named by Holland and described by Waldrop (1993).

First, these systems have a *network structure* with many active processes alongside one another. They can be described as agents – the nodes of the network – with many interactions. Agents can be actors, neurons, opinions, cells, populations, and events. They influence each other directly or indirectly. Many agents in water management can be presented in a form of network. Second, these systems have *many organisational levels*, or aggregation levels, in which the networks at a lower level form the building blocks for the networks at a higher level. For example, a water board worker can form a small social network like a maintenance team with a few colleagues. Within the water board, various small networks can be found. There can be several maintenance teams, a secretariat, a technical service, an administrative board, etc. These smaller networks together form the water board, which in turn is a node in a

[3] Emergent patterns are patterns that are spontaneously generated from a complex process. They are not being exacted, but they are simply the result of many interactions. For example: the result of an open planning process is emergent, because issues are not laid down at the start of the planning process. The result is defined gradually.

larger network. The aggregated behaviour of the networks at a lower level is characteristic of the behaviour of the network at a higher level.
Third, the systems *anticipate* future developments: they make adaptive plans. From within the system, structures are built which help to respond to multiple developments from the outside. An important example in Dutch water management is the reorganisation of the water boards. Mergers take place in order to give the water boards a stronger position in the social network around integrated water management. Many water quantity boards and water quality boards have merged into integrated water boards.
Fourth, the systems are going through a *process of perpetual novelty*. By modifying, revising and re-arranging structures, complex adaptive systems never completely reach a state of calm. There may be *stable* behaviour, but there is still the continuous process of adaptation. Renewals can take place gradually, but they can also take place abruptly. In a short time span, complex adaptive systems can undergo a thorough change in structure. This notion is presented in the diagram of Figure 2.1.

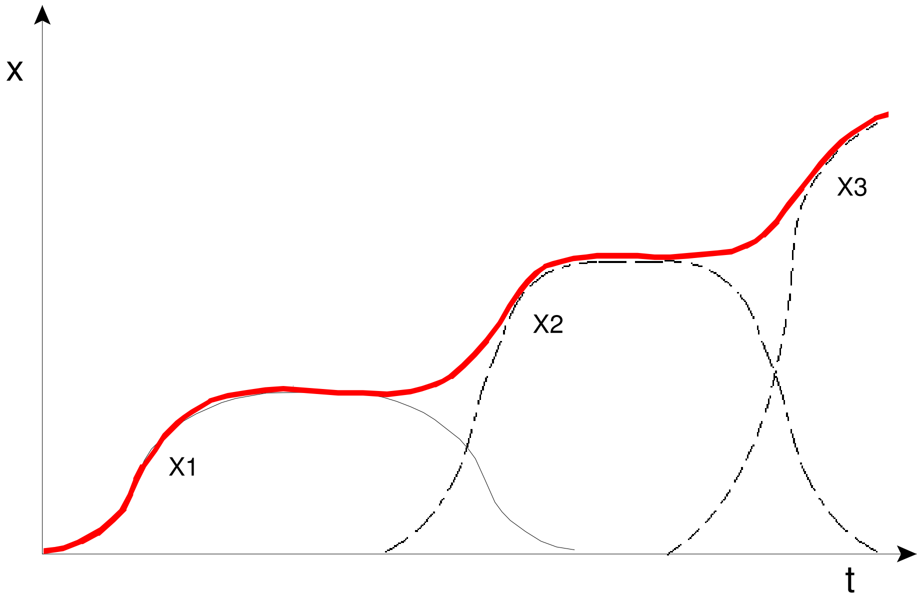

Figure 2.1. Evolution of x versus time (Prigogine and Stengers, 1985)

X in Figure 2.1 can be the entire population of a species within an eco-system. The population develops until the available niche is completely filled. Changing conditions make the possibilities for x1 less favourable and adaptation is necessary. If the adaptation is successful (x2), it will obtain a larger or entirely new niche. This process can repeat itself many times and is characteristic of evolving systems. The pattern that arises is characterised by long periods of stable behaviour followed by periods of quick developments. This pattern can be recognized in water management, for example in policy development.

Many kinds of systems can be represented by networks – with many organisational levels – and are also able to respond to influences from the environment. A model of little balls connected by springs will move if pushed; it shows dynamic behaviour. Each ball can be made up of even smaller balls with smaller springs in between. This does not make it a complex adaptive system. The essence of complex adaptive systems can mainly be found in the third and fourth property mentioned above. Complex adaptive systems do not only respond with regard to their behaviour, but they also adapt their structure. They do this continuously and anticipate possible developments in the environment. It is striking that they change the structures from within and that they are in a stable state at the same time. *Self-*

organisation plays an important part here (Prigogine and Stengers, 1985). These systems are also characterised by a high degree of complexity.

The above describes the main features of complex adaptive systems. However, before arriving at a complete definition of the complex adaptive system and working out its characteristics, the following section explains the terms complexity and self-organisation.

2.3 Complexity and self-organisation

Something is complex when it is composite or complicated. Based on Perrow (1986), De Leeuw (1994) defines complex systems as follows: "Complex systems are interwoven systems with many complicated, circular and unexpected interactions". This is not a clear definition. It confuses complexity with complicatedness. However, it does make clear that complexity has something to do both with the *structure* of a system in space (interwoven) and the *behaviour* in time (interactions). A complex system's structure is somewhere between simple – highly structured – and random. Based on Grassberger (1986), Alkemade (1992) arrives at this insight: "Disorder is largest in chaotic systems. But people do not always consider chaotic systems as the most complex. For instance, think of a 'random' (chaotic) pattern of dots. Because the dots are divided randomly over the surface, and a structure cannot be discovered, the complexity of such a pattern is considered low. Both patterns with a clearly detectable structure (like a chessboard) and patterns without any distinguishable pattern are not considered complex. Patterns with a recognizable structure which is not easy to discover, are considered complex. In other words, both completely orderly and completely chaotic systems are considered not very complex. The higher complexity is found in the middle".
A similar line of reasoning can be made for the behaviour of complex systems. Both systems that are orderly and act completely predictably and systems that have no recognizable patterns in their behaviour – with a completely random behaviour – are not considered complex. For behaviour, the higher complexity is also found somewhere in the middle.

Another possibility to approach the notion of complexity is provided by Cohen and Steward (1994), who link the notion of complexity to *information*. They say that the complexity of a system can be described as the quantity of information required to describe it. The more information required, the higher the complexity. Gell-Mann (1994) prefers the term *effective complexity* in this context. He defines this as the length of a scheme used to describe the patterns of the system structure or the system behaviour. On the basis of this approach, a relationship can be described between structure and order on the one hand and effective complexity on the other hand. This relationship is presented in Figure 2.2.

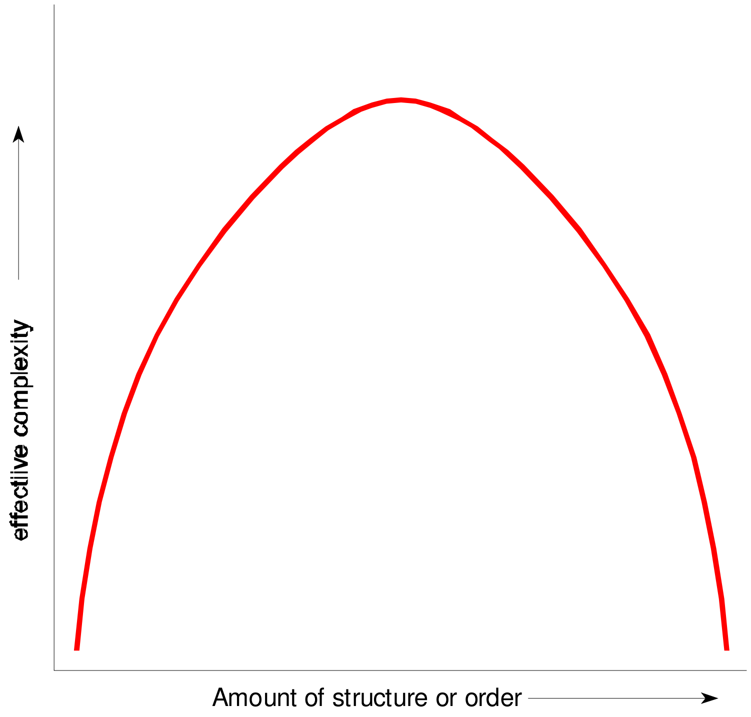

Figure 2.2. Relation between structure (or order) and effective complexity.

If there is no structure or order in the system or system behaviour, the attributes with which to describe the pattern can be brief; saying “none”. If there is an easily fathomable system with very predictable behaviour, the scheme can also be brief. For instance, if the behaviour of a slab of concrete is described for 10 minutes, the scheme can be brief. The effective complexity is small.
Somewhere in between there is a higher complexity, with systems interwoven with complex, circular and unexpected interaction. The supposed relation in Figure 2.2 is represented like an arch. Gell-Mann (1994) represents the course with two straight lines, like a pointed roof. However, the shape will not be further discussed here.

In solving complex social issues, there is often a large awareness of the fact that these issues are found between unstructured issues on the one hand and well-structured issues on the other hand. A good example can be found reading Eoyang and Conway (1999), who distinguish between three working areas for social issues: random, complex and simple. Table 2.1 presents a few characteristics.

Table 2.1. Three working areas in social issues, derived from Eoyang and Conway (1999).

	Random	Complex	Simple
Metaphor	Hot gas.	Living organism.	Machine.
Components (parts)	Infinite number. Each is unique.	Infinite number. Each is unique.	Finite number. Clear division.
The whole	Collection of parts. No patterns.	More than the sum of its parts. Emergent patterns.	Sum of its parts. Known by reduction.
Basis for decision-making	Intuition.	Patterns.	Facts and data.
Useful for	Unknown problems.	New issues.	Known issues.
Examples	Contacts with clients. Political changes.	Working together in teams. Innovation and creativity.	Production process. Quality control.
Role of the leader	Protection of self and others. Looking for patterns.	Managing 'edges', patterns, paradoxes, changes and actions.	Checking others' behaviour. Maintaining order.
Possible advantages	Pleasure. Flexibility. Freedom.	Good response. Great effects. Adaptation.	Efficiency. Reliability. Security.
Risks	Irrelevance. Miscommunication. Fear.	Reactive instead of proactive. Vagueness.	Rigidity. Insensitive to changes.

Table 2.1 shows how complex issues can be placed in relation to issues from random and simple processes. The table also provides insight in how to control matters, and offers a few guiding principles. There is also a clear warning in the table: complexity can be used as an excuse not to act proactively (anticipating problems). The current water policy calls for just that: a proactive attitude from water managers, especially when dealing with water in the context of spatial planning. It is therefore not possible to view integrated water management exclusively as a complex whole. There are many partial aspects fitting the category 'simple'.

Bak (1996) gives a simple definition of complexity and links it mainly to structure. He defines complex systems as systems with a high diversity (variability): "The variability may exist on a wide range of length scales. If we zoom closer and closer, or look out further and further, we find variability at each level of magnification, with more and more new details appearing."

On the basis of the previous definitions, the following definition is chosen for the complex system. *A system is complex when its structure has a large diversity. The structure is situated between random and simple.* This definition still says nothing about behaviour.

A feature of complex adaptive systems is that self-organisation takes place, which means stable structures arising without outside control. The principle of self-organisation is described by Belgian scientist Ilya Prigogine, who received a Nobel price in chemistry for this in 1977. Self-organisation is of the utmost importance to complex adaptive systems, but it is not a unique feature for them. Prigogine and Stengers (1985) show that even relatively simple chemical processes can display self-organisation.
Prigogine compared closed and open systems with each other. A closed and isolated system has no interaction with its surroundings. The Second Law of Thermodynamics applies to these kinds of systems, which says that entropy (~disorder) increases or remains the same in the course of time. Entropy does not become smaller, which means that thermal energy will not spontaneously flow from an area with a lower temperature to an area with a higher

temperature. When a glass falls from a table and breaks the Second Law says that, without adding energy, the fragments will not spontaneously come together again as a glass to fall back onto the original spot on the table (Hawking, 1991).

The Second Law of Thermodynamics concerns closed and isolated systems. However, many systems are not closed and isolated and can freely take up and release energy. It can therefore be observed that there are many processes with order besides those with increasing and constant entropy. Prigogine calls this process of spontaneous order *self-organisation* and its resulting structures *dissipative structures*. Prigogine and Stengers write: "We now know that far from equilibrium, new types of structures may originate spontaneously. In far-from-equilibrium conditions we may have transformation from disorder, from thermal chaos, into order. New dynamic states of matter may originate, in states that reflect the interaction of a given system with its surroundings. We have called these new structures dissipative structures to emphasize the constructive role of dissipative processes in their formation" (Prigogine and Stengers, 1984). All complex adaptive systems are dissipative structures but not all dissipative structures are complex adaptive systems.
Prigogine and Stengers say that when self-organisation occurs, we are dealing with a dynamic state far from the thermodynamic equilibrium. There are two kinds of forces active in such a system: entropy increasing forces and entropy decreasing forces. These forces keep each other in balance, which creates stability. Fluctuations from within and influences from outside cause disturbance. Structural adaptations ensure the system returns to a stable condition.

Self-organisation is important to water managers. Without water management there will still be water, water structures and biotopes. Structures of lakes, brooks, pools, rivers, estuaries, and aquifers organise themselves. Self-organisation in biological systems existed long before man came along. Water managers have to ensure that anthropogenic influences do not disturb the water systems too much. Through good facilities, they can ensure that water systems and "water chains"[4] can fulfil their functions. The more things take place through self-organisation, the more extensively water managers can steer.

The notion of self-organisation as described by Prigogine relates to physical, chemical and biological processes. However, it is also used in the description of social processes (see for instance Van Dijkum and De Tombe, 1992). The notion summons up recognition. Looking at the self-organising nature of people and groups of people provides insight into how to handle social issues. Social self-organisation is often seen as something positive and it is important to create good conditions for self-organisation. Various techniques and courses have been developed for this (Eoyang and Conway, 1999). Self-organisation is also important for what is called the *learning* organisation (see for instance Bomers, 1989). By considering organisations as groups of people that are going through a learning process together – a both improving and innovating process – guidelines for management can be derived.

[4] In this book, water chain means the processes involved in drinking water production and distribution, water use, sewerage and sewage treatment.

2.4 Complex adaptive systems and five characteristics

On the basis of the above, the following definition is proposed for a complex adaptive system. *A complex adaptive system is a dynamic system with stable behaviour which is characterised by a structure with a large diversity. It responds to and anticipates developments in the environment by changing its structure*. The stable behaviour is an important feature. It can display temporary instability, but it eventually turns back into a new stable situation. If this does not happen it perishes and is no longer a complex adaptive system. With regard to structure and behaviour, a complex adaptive system lies between random and simple.

The complex adaptive system can be used as a model for many dynamic systems. The science of complexity is, in fact, expanding. Research is being done on many fields such as health care, defence, economy, psychology, politics and artificial intelligence. The new concepts regularly arising from this research do not always serve clarity. Complexity has become an interdisciplinary concept. Some people see the science of complexity as an onset to the "theory of everything" (Horgan, 1995). Such comprehensiveness makes this field of research strong and vulnerable at the same time. By involving everything the integrated character becomes clear, but it also becomes harder to draw clear conclusions of a generic nature.
For the benefit of the research into coping with complexity in integrated water management, it is intended to keep the terminology as limited as possible. The next five sections discuss the following five characteristics of complex adaptive systems:

- Agents.
- Interactions.
- Attractors.
- The edge between order and chaos.
- Crises.

The first two are *network features*. In Section 2.2, complex adaptive systems were described as having a network structure. Networks consist of agents that interact. The agents can differ greatly in nature. In order to describe the cases in the next chapters thoroughly, it is necessary to make the agents and their mutual interactions more explicit. The third and fifth characteristics – attractors and crises – are *patterns* that are observed when simulations with complex adaptive systems are carried out. These two characteristics have partially been empirically confirmed. These patterns may provide guidelines for steering strategies. The fourth characteristic – the edge between order and chaos – can be seen as a *condition*. The 'viability' of complex adaptive systems demands attention for their conditions.

2.5 Agents

This section categorises agents as part of (1) physical, chemical and biological processes, (2) social processes and (3) intellectual processes, based on Pirsig (1991). Pirsig actually distinguishes between four groups, but this book classes the physical, chemical and biological processes in one group.
The first group consists of agents such as groundwater, aquifers, brooks, rivers, contamination, purification plants, pumping stations, algae, cells, plants, fish and otters, all of which are associated with water management. However, in the case of integrated water management, other fields of policy are also geared towards each other which means that agents that are not directly associated with water management can also be involved: cars,

roads, factories and housing. Therefore, agents from spatial planning, the environment and nature management are also important here.

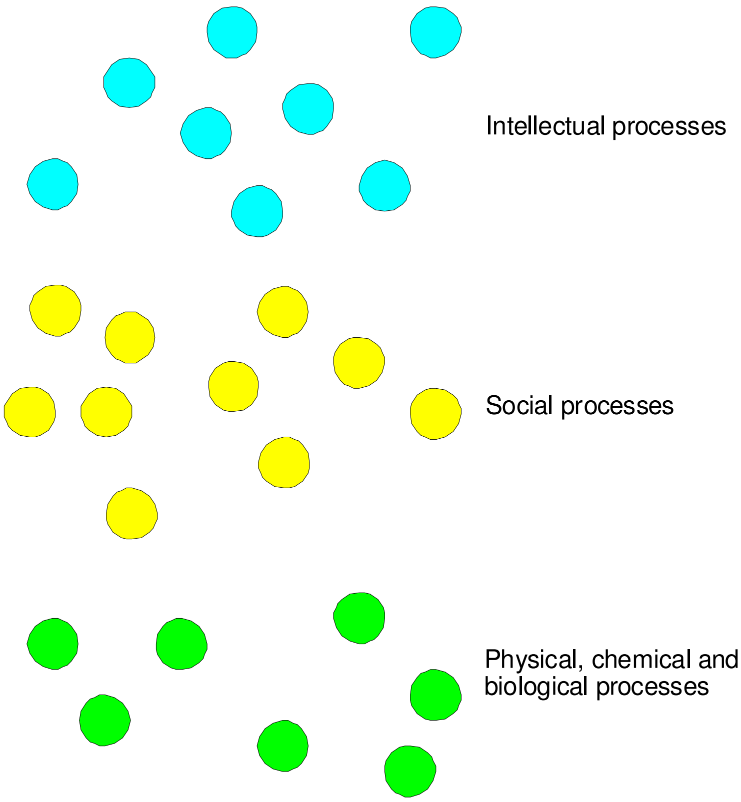

Figure 2.3. Three groups of agents.

The second group consists of actors. Actors can be people or groups of people, without exclusion. An actor's involvement in water management is not the same for everyone. On the basis of Habermas (1989), three arenas can be distinguished (Geldof et al., 2000). From the water manager's perspective, the first arena consists of the water managers jointly contributing to good water management within the scope of their tasks. The second arena consists of, for example, municipalities, urban developers, organisations, interest groups and foundations. These actors, who are only in part directly related to water, can be appreciated by the water managers and can also be addressed professionally. Communication in the second arena is less clear than among water managers, but in project-based situations it is possible to map them out well.
The resident symbolises the so-called "third arena with elusive communication flows" (Habermas, 1989). The third arena is the largest and most diffuse. All actors outside the first two arenas belong to the third arena.

The third group of processes deals with ideas, theories, opinions, experience, etc. All that is produced by the human mind belongs to the third group. Dawkins (1986) calls these components *memes*. "Examples of memes are tunes, ideas, catch-phrases, clothes fashions, ways of making pots or of building arches. Just as genes propagate themselves in the gene pool by leaping from body to body via sperm or eggs, so memes propagate themselves in the meme pool by leaping from brain to brain via a process which, in the broad sense, can be called imitation" (Dawkins, 1986).

Do emotions also belong to this group of agents? Frijda (1993) says that emotions have a clear physiological basis. Often, reason and emotion are considered in dichotomy: reason is associated with intelligent, stable and reliable behaviour while emotion is associated with confused, chaotic and unreliable behaviour. Nussbaum (1999) says that this dichotomy is too strict. She does not see emotions as irrational impulses, but rather as interesting thoughts on the world.

2.6 Interactions

The agents as presented in Figure 2.3 are not unrelated; they interact and influence each other. By mapping out the agents together with their interactions, networks become visible (see Figure 2.4).

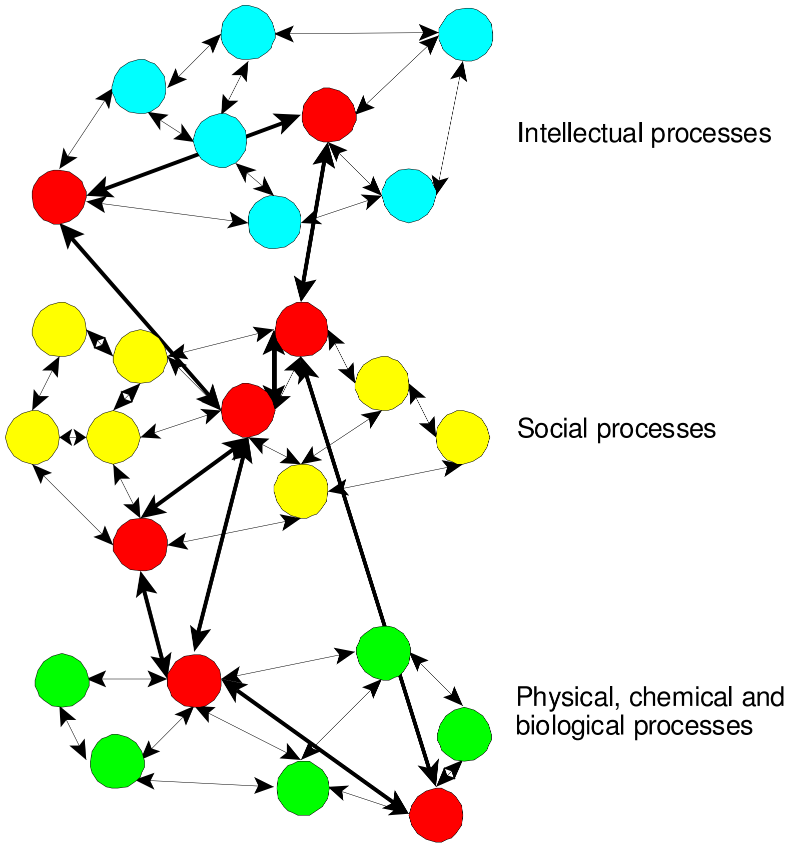

Figure 2.4. Agents and interaction in three groups.

Many biological, social and intellectual processes can be described as networks with many organisational levels. However, this does not mean that *all* processes can be described this way. First of all, not all agents are as equal as suggested by Figure 2.4, in which all nodes are the same size. Agents may differ greatly with regard to scope and impact. Secondly, many processes can hardly be presented as network processes. This mainly applies to the physical and chemical level. A groundwater system, for example, can be described well by means of a deterministic model which will schematise the system into a group of aquifers, levels of permeability and resistance, groundwater levels and groundwater flows. Model calculations can be done that have a high predictive value, because groundwater behaves almost completely according to Darcy's law. There is a linear relationship between differences in hydraulic head and the flow velocity of groundwater. Groundwater adjusts to changing conditions, *but its structure does not*. Subsystems in the groundwater interact but they do not adapt.

Describing processes in integrated water management as complex adaptive systems yields a more complete picture. The emergent patterns provide insight into the behaviour of the whole. This approach has advantages and disadvantages. In combination with other descriptions, for instance with deterministic models, it provides information which water managers can use for steering strategies. Deterministic models also have advantages and disadvantages. However, it is clear that, for good steering strategies, it is of importance to pay attention to advantages and disadvantages of different approaches and that there is much to be won by combining approaches.

Much research into the behaviour of complex adaptive systems involves the group of physical, chemical and biological processes and is greatly focused on the question of how order can arise from self-organisation and which mechanisms are the basis of evolution. Kaufmann (1993) has written a comprehensive book about this. Networks are formed with interaction between the different agents; energy, foods, wastes, information, etc. are exchanged. If there is neither too much nor too little interaction, in other words, if there is a kind of middle path, self-organisation occurs. Systems adapt and try to find niches. The interactions take place at different organisational levels.

In the group of social processes people and groups of people influence each other. Structures adapt and new groups are added, other groups disappear and the composition of groups changes. The role people and groups of people play in integrated issues also changes. Under certain *conditions* a social system functions as a network; where interdependencies increase, networks arise (De Bruijn and Ten Heuvelhof, 1995).

The actors influence each other, because they have ambitions which they try to achieve by interacting with others. They need the interaction because the means available to them are inadequate. Others, too, need to employ their means to attain set goals. The 'game' played here is also called *network steering*, which takes advantage of the relations between actors, the existing division of means, the rules of interaction, and perceptions (Klijn et al., 1993). There is no central steering; everyone is steering.

With regard to policy – as in integrated water management – the competent authorities play an important part. In network steering, the model of the network replaces the model of hierarchic relations in which the competent authorities steer processes top-down, as if it were a control system. The vertical line of state, province, municipality and water board has become less clear, just like the separation between different services of the same authority. Instead of network steering, this is also called diagonal policy (Cörvers and Slot, 1995). Godfroij and Nelissen (1993) pose that the image of the hierarchical relationship between an administrative authority and the administered society has been replaced by an image of *mutually dependent* relationships between authority and different actors in society. The mainly hierarchical relationships of old are being replaced by complex relational patterns with bottom-up and lateral relationships alongside hierarchical relationships. Influence is also spreading. The steering influence of the authorities is being complemented with a steering influence of a multitude of other actors (de Lange, 1995).

Teisman (1992) says that decisions in network steering are made from a pluricentre perspective. He describes three possible perspectives for processes in decision-making: the multicentre, the pluricentre and the unicentre perspective. Table 2.2 lists a few features of these perspectives. The columns in this table are in the same order as in Table 2.1.

Table 2.2. Three perspectives in decision-making (Teisman, 1992).

Multicentre Perspective	*Pluricentre Perspective*	*Unicentre Perspective*
Bottom-up.	Central and local entities with a mutually dependent relationship.	Hierarchical order. Top down.
Decentralisation. Many decisions are made by local actors.	Not central, nor decentral absolute rights to make decisions leads to satisfactory results.	One central entity defining problems and decisions.
The central entity should impose as little restrictions as possible.		This entity has a superordinate role and can impose its will.
Optimum results are obtained without intervention.	Not general interest, nor self-interest, but the common interest is the touchstone for assessing policies.	It is better capable than others to act in the general interest.
Rationality is not found in the general interest , but in the deliberate self-interest of autonomous actors.	Network as metaphor.	Mechanism: compulsion. Control system.
Market mechanism.		

Continuous adaptation takes place in the group of intellectual processes. Ideas are developed, theories composed, standards adjusted, views taken, etc. Memes influence each other and Dennett (1992) calls the resultative process *memetic evolution*. The interactions take place through people and through automated information processors such as computers and neural networks. However, man (still) plays the lead role. Ideas and opinions can diverge and converge.

When adaptation and renewal are taking place – change of perspectives – this is also referred to as *reframing* (Putnam and Holler,1992; Schön and Rein, 1995). The interaction between actors means a confrontation between different frames. Parties involved adjust their frames. A frame is an integrated whole of facts, values, theories and interests. Part of the old frame is maintained and part is 'exchanged' for or 'stretched' by new facts, values, theories and interests. Pirsig (1991) calls this *static quality* and *dynamic quality*. If people cling to old patterns (rules) this leads to static quality and if people are open to new insights and if they are willing to change, this leads to dynamic quality. Adaptation takes place through a combination of static and dynamic quality. Pirsig (1991) says: "That's the whole thing: to obtain static and dynamic quality simultaneously. If you don't have the static patterns of scientific knowledge to build upon, you're back with the cave man. But if you don't have the freedom to change those patterns you're blocked from any further growth."
Memetic evolution can take place both gradually and abruptly, as in improving learning and innovative learning (Bomers, 1989), or functional learning and substantial learning (Van Woerkum, 2000).

The interactions in the three groups influence the different agents so that structures are modified, revised and rearranged (Waldrop, 1993). There is a difference in tempo between the three groups (Dennett, 1992); they have different time scales. Adapting ideas often goes quicker than genetic adaptations through evolution.
This is an important fact, because the three groups of agents are not separate; they mutually interact, as shown by the thick arrows in Figure 2.4. In integrated issues, agents from the three groups with mutual interactions are important. A problem is encountered, for instance,

dehydration of the soil[5], which mainly affects nature areas. Actors that defend the interest of nature areas subsequently influence policy-forming and decision-making processes. They influence perceptions. During a gradual learning process, which takes a leap now and then, measures are eventually taken to decrease the dehydration. The agents from all three groups are important in this process.

2.7 Attractors

Complex adaptive systems possess many dynamics, but their behaviour as a whole is considered stable. Attractors, that is, *states of preference* (Krohn et al., 1990), play an important role here. If the condition of a system is near an attractor it will evolve towards the attractor. Basically, all dynamic systems have attractors. Linear dynamic systems have one attractor, which is called the state of equilibrium. A feature of dissipative structures – and therefore of complex adaptive systems – is that they have stable positions far away from what Prigogine and Stengers (1985) call the thermodynamic equilibrium. Without the presence of external influence, they will fall back to this thermodynamic equilibrium. Both the stable conditions far away from the thermodynamic equilibrium and the thermodynamic equilibrium itself are attractors.
Attractors are often described in state space, or phase space. This space is stretched by all possible system features. The route a system travels through this space is called a trajectory (Prigogine, 1997). A system goes from state to state. The trajectory becomes visible if the course of states the system follows in the phase space is drawn.

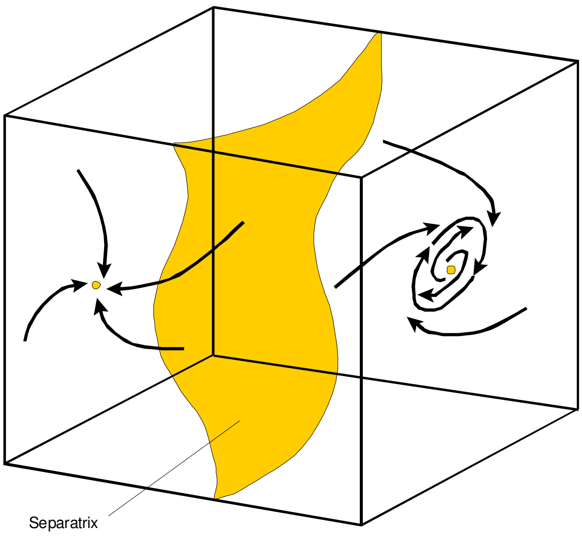

Figure 2.5. Schematic presentation of two attractors in a state space (Kaufmann, 1993)

Attractors can have different shapes: the point attractor, the circuit attractor, the torus attractor and the strange attractor (see for instance Czerwinski, 1998). Figure 2.5 presents two attractors (Kaufmann, 1993). In the phase space, an attractor is found in a basin of attraction that is separated from other basins of attraction by a separatrix. If the condition of a system is

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[5] In the Netherlands the strict control of surface water levels has a negative effect on nature that needs wet conditions. This is called *verdroging*. There is no term in English that describes the same process.

near a separatrix, it is possible to pass through the separatrix with a relatively small intervention such as a small change in structure and end up in a different basin of attraction. Such a condition near the separatrix is further referred to as a *critical point*. The trajectory to be followed can be chosen at a critical point, resulting in a kind of branching in the states into which the system can develop. A small intervention from the outside can make the system develop into the direction of a certain attractor. *Coincidence* may play a significant role here (Prigogine and Stengers, 1985). Once a system has launched the development in the direction of a certain attractor, it is unlikely that it will later develop in the direction of another attractor.
The analogy of branching in rivers can be used here. Suppose someone is drifting down the Rhine River from Germany on a raft. Some kilometres past the Dutch border, this person will come across a branch in the river. He will have to choose between the Pannerdensch Canal towards Arnhem on starboard and the Waal towards Nijmegen on the port side. Arnhem and Nijmegen can be seen as names for attractors in this analogy. The raft is located in the basin of attraction of one of the river branches, for instance that of Nijmegen. The person on the raft is not making a *conscious choice* and drifts along in the direction of Nijmegen. Suppose he regrets this afterwards and had wanted to go to Arnhem. He then has to paddle back against the current to the branch. This takes a great deal of effort. If he cannot paddle quicker than the Waal's current, he will not even succeed and is condemned to the Waal. In order to repair his 'error' he will have to paddle the whole way back to the branch. By paddling back halfway he will not have rectified 50% of the error. At the critical point, before the branching of the river, it would have been possible to drift down the Pannerdensch Canal with a little extra paddling.

This book considers attractors as stable dynamic patterns. No further distinction will be made between the various forms of attractors. It will suffice to describe possible attractors. Attractors do not have to be static. In complex adaptive systems, new attractors can arise and old attractors can disappear (see for instance Cohen and Steward, 1994). They can also become stronger or weaker. The changes are constant. The separatrices are not static entities.

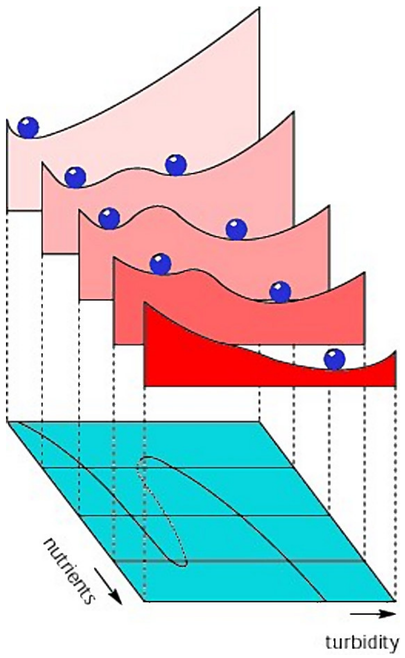

Figure 2.6. The relationship between nutrient loads and turbidity in a simulation of a surface water system (Scheffer, 1997).

Scheffer (1997) describes an example of a freshwater system with two attractors. He has characterised the behaviour of a lake – as an ecosystem – by means of a few nonlinear differential equations. Figure 2.6 shows his results.

Figure 2.6 is a so-called marble diagram, which plots the turbidity of the surface water against the amount of nutrients in the water. The diagram shows that if the concentration of nutrients is high, there is basically one attractor. The water is turbid then, with many algae which keep out the light. Water plants cannot grow and coarse fish dominate under these conditions; they swim over the lake bottom and stir up sludge causing the water to become even more turbid. In the marble diagram, the marble rolls into a stable, turbid, position.
If the concentration of nutrients is very low, there is also only one attractor. There are few algae in the water causing the water to be clear. Water plants grow on the bottom of the lake; a perfect place for pike, the natural enemy of coarse fish. The marble rolls to a stable, clear, position.
In the case of intermediate values for the concentration of nutrients, both attractors are active. The water can be both clear and turbid. Attractor reversal can occur through *outside* influences. The water can be clear, have water plants and pike. There may be a sewer overflow disturbing the stable situation, which may temporarily diminish the resistance against change and "the marble starts rolling to the right". In a short time span, the freshwater system will develop into turbid water. Attractor reversal can also occur as a result of too little possibilities for fish migration (Raat and Van den Bos, 1999). If the freshwater system is a ditch and pike cannot migrate to a large area of water, they will eat their own kind. This may destabilise the system when it is too closed and works itself into a critical situation.
The system may also develop into the other direction. If the nutrient load is reduced, the freshwater system may stay turbid. By means of active biological management (Hosper, 1997), for instance by clearing coarse fish, the system can get a push in the right direction and develop into clear water.

The example of attractors in an ecosystem of freshwater is limited to the agents in the group of physical, chemical and biological processes. Integrated water management goes beyond that. The interaction between the water system, the water chain and society is the central issue here, and calls for the involvement of agents from all three groups of processes. The policy area of water management is considered together with other policy areas such as spatial planning, environmental management and nature management. Scheffer (1999) says that "effective strategies for good and sustainable interaction between man and environment require insight in the coherent whole of society and nature. A whole that is more than the sum of its parts. Two coupled complex systems can each fall victim to cycles of chaos and catastrophic turns. Nowadays, there is a great deal of experience in ecology concerning the unravelling and modelling of such phenomena and the time is ripe to bundle our forces with scientists from other disciplines. Shared responsibility for developing an understanding of the interaction between society and nature, of the response of ecosystems to society and vice versa".

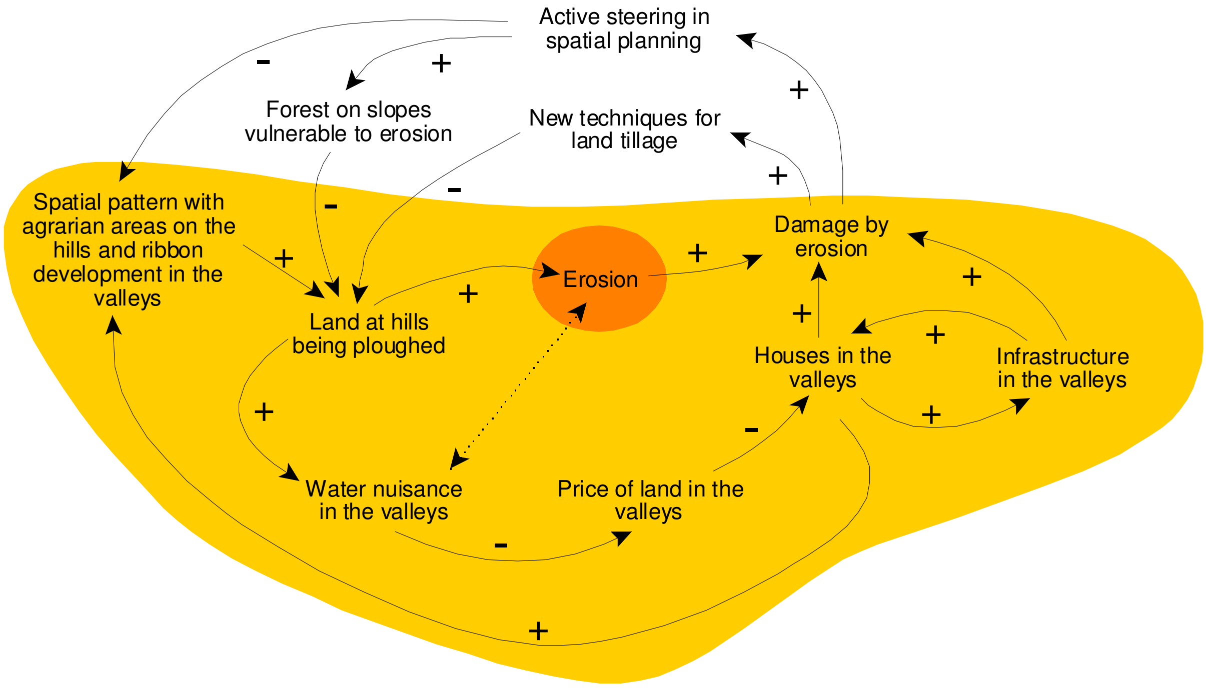

Figure 2.7. Mechanisms behind the origin of ribbon development in Flanders.

Figure 2.7 shows the connections between water and spatial planning. The example was derived from the study carried out by Charles et al. (2000) for the development of methods for the municipal water plans in Flanders. It shows that water (nuisance) plays a significant role in the order of construction in the Flemish landscape and that there is an attractor. This attractor is now considered unwanted. Figure 2.7 shows a selection of agents with their mutual interactions. The interaction is presented as arrows. An arrow with a plus sign means that if one increases in size, the other also increases in size. When processes reinforce themselves, this is a positive feedback and when processes keep each other in balance, this is a negative feedback. A similar order of agents and interactions is applied in *system dynamics* (Pugh, 1976; Meadows et al., 1992).

The agents in Figure 2.7 are related to physical, social, and intellectual processes. There are many interactions, which means the whole is developing. The mechanisms presented in Figure 2.7 explain the spatial patterns found in large parts of Flanders. Except for large cities such as Antwerp, Ghent, Bruges and Louvain, there are hardly any residential nuclei in Flanders. Housing is extensively distributed over the country, as ribbon development along roads.
Flanders is hilly. Originally the hills were forest land, but blooming agriculture has cleared more and more land. The land is being ploughed in preparation for cropping. However, ploughing greatly decreases the water uptake of the soil (Schmidt et al., 2000), increasing the surface runoff, causing water nuisance in the valleys. Therefore, the valleys are less suitable for agricultural tillage than the hills, which renders the land in the valleys cheaper. Many families and companies end up buying the cheaper land in the valleys to build houses and office buildings. Infrastructure is laid (roads, gas pipes, electricity, etc), which results in more construction. Gradually, – emergently – a pattern arises with agrarian areas on the hills and ribbon development in the valleys. With the increasing tillage, erosion increases. Moreover, if the economic value of the houses, companies and infrastructure in the valleys rises, the

erosive damage increases. Combating erosion is prioritised in the tackling of water problems in the Flemish municipalities.

The erosion issue in Flanders is a stable process in which the pattern of agriculture on the hills and the ribbon development in the valleys is the *attractor*. The spatial pattern is developing in a stable way towards that attractor. The agents in the shaded area reinforce each other. There is no negative feedback to reduce the ploughing of the land on the hills. This problem is persistent and hard to solve. The strategy to solve it is aimed at two objectives, the first being to reduce erosion by developing new techniques for land tillage. For instance, it is possible to insert seed directly into the soil without having to plough the land. This can reduce the surface runoff and erosion by 90% compared with conventional techniques (Schmidt et al, 2000). The second objective concerns spatial planning, where active steering by the higher authorities can break the process of increasing ribbon development and forests can be planted on the slopes most vulnerable to erosion.

Economist Arthur (1990) calls a persistent situation a *qwerty*, referring to the qwerty keyboard of typewriters (Waldrop, 1993). The qwerty keyboard was originally designed to minimise the risk of typebars clashing into each other at a high typing speed. Many people learned to type on a qwerty keyboard. Nowadays, typewriters with typebars are rarely used as most people write their texts on computers. However, the qwerty keyboard is still employed, despite the availability of many other kinds of keyboards that may work better for computers. We are stuck with the qwerty keyboard, as it were.
Arthur (1990) claims that in the case of a qwerty the course of states is *locked-in* into a basin of attraction. He provides many examples of qwerties in economic systems.

The description of attractors and qwerties, as described above, is neither true nor untrue. It can be used as a model for a better understanding of coherent processes. The model is an aid in the *diagnosis* of processes in a formulated issue.

2.8 The edge between order and chaos

Complex adaptive systems are open systems with a high degree of complexity. This complexity is somewhere between completely random and clear structures. The complex adaptive definition does not only pertain to the diversity in structure, but also to the behaviour. The behaviour also takes up a middle position, between order and chaos. If *accurate predictions* about the system behaviour can be made on the basis of the system knowledge this represents complete order and a deterministic model can be made. If the condition is known for one moment in time, it can be calculated for any moment in time, both for the future and the past. Descriptions of the solar system are close to this ideal order. Systems that are extremely sensitive to initial conditions are chaotic. In models for such systems, small differences in the initial conditions may result in large differences in the predictions (Kellert, 1993). Prigogine (1997) defines chaos on the basis of trajectories through the phase space. Chaos is "the behaviour of systems in which close trajectories separate exponentially in time."
An empirical observation in the science of complexity that may be of essence in coping with complexity is that complex adaptive systems do not evolve towards increasing or constant entropy as is the case with closed systems, but towards *increasing complexity* (Langton et al., 1992; Waldrop, 1993), maintaining themselves in the edge between order and chaos. The

system anticipates outside developments by changing structures (the adaptive plan), thus maintaining stability for a shorter or longer period.

System behaviour can be described by means of differential equations. Variables and parameters are used in these differential equations. The parameters in mathematical models of dynamic systems are mostly kept constant and the effect of different strains on the course of the variables is watched. Complex adaptive systems are described differently as these systems have *structural adaptations*. This means, for instance, that the parameters of the model change (see for instance Holland, 1998). This process is called adaptation.
What is the structure of systems described in integrated water management issues? Structure in this book is assumed to mean the set of rules used in interactions among actors and between actors and the water system. A rule could be: if the flood risk in an area is high, the dykes must be raised. Or: if new housing is being planned, the municipality and the water board must discuss the matter. An attractor always has a coherent and consistent set of rules. Within the context of technological change processes, Van de Poel (1998) calls a coherent set of rules a *technological regime*. By applying these rules, the physical structure of water systems changes and so does the organisational structure. These structures are emergent, with the basis for changing the rules lying in the group of intellectual processes. There are different views on the approach to issues and new theories can be developed. Rules based on these views or new theories may be inactive for a long time until they are appreciated and used.

The edge between order and chaos can be seen as a condition for complex adaptive systems. The adaptive capacity is small when there is too much or too little order, in other words, a low complexity. The edge between order and chaos provides a good balance between holding it back and letting go, which means that desired or necessary changes can be made. This also means a good relationship between static and dynamic quality.

A characteristic of the behaviour of complex adaptive systems is that both order and chaos can dominate. There are times when the system behaves in an orderly fashion and good predictions can be made about it. However, there are also times when chaos is dominating and the future manifests itself in a surprising way. Elements of order and chaos can continuously be seen in the behaviour. If order is dominating, the predictability is still limited and the past will still be noticeable in the present. When chaos dominates, there is still structure to be distinguished in the system.

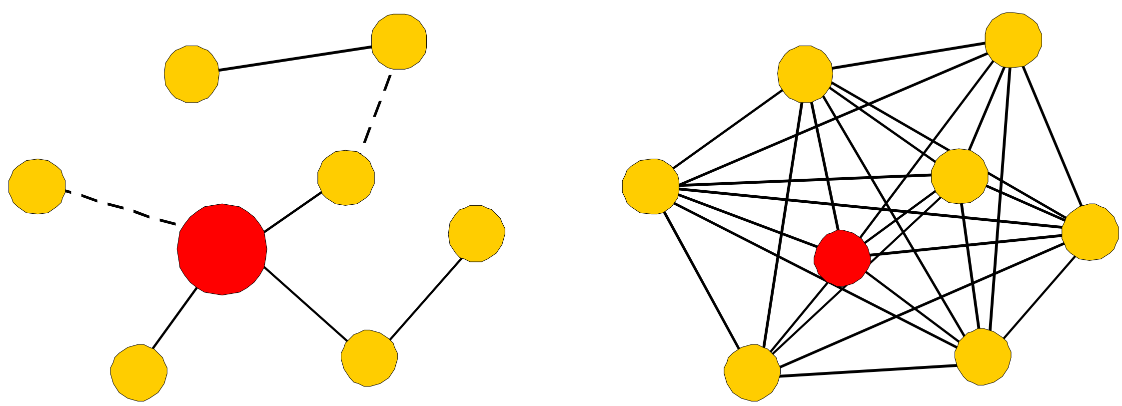

Figure 2.8. Schematic presentation of a scarcely linked network and a richly linked network.

The “discovery” of the edge between order and chaos means that there are specific conditions for the development of complex adaptive systems. An example is presented in Figure 2.8. If a network is scarcely linked, it cannot develop properly and it will no longer function as a network. If, on the other hand, there are too many links present, behaviour will be chaotic and the network will not really arrive at ‘solutions’ (Waldrop, 1993).
The scarcity or richness of network links can be used as a parameter in the diagnosis of systems. Developments are impeded when there is too much or too little of something. The proper proportions are a measure of health.

When a system can be described as a complex adaptive system, it is located at the edge between order and chaos. This is essential to steering strategies because they can be used in the edge of chaos to steer the degree in which fluctuations are accepted or suppressed. If there is too much chaos, structuring – suppressing – steering strategies are preferred. If there is too much order – in other words, an over-controlled system – “disrupting” actions might be useful. Such actions are achieved by initiating crises, for instance.

In the erosion example of Flanders, a pattern in the landscape emerges as a result of applying rules. Examples of rules are:

- To generate profit in agriculture, the land must be ploughed.
- Financial loss in agriculture mainly happens when the soil is too wet, as it is in the valleys. Agricultural areas are therefore mainly found on the hills.
- Construction is done where the land is cheap and where there is infrastructure such as roads, sewers, gas pipes, etc.
- Infrastructure is laid out where there is or is to be construction.

The current set of rules is under pressure because of the erosion, but also because of the changing opinions on the value of nature, for instance. The rules need to be adapted. Good management means ensuring that desired changes can be made without impairing the interests of, for instance, the farmers in the area. It is important to know that steering is done at the edge between order and chaos, in the presence of a tenacious attractor – a qwerty – and nonlinear dynamics. It will offer guidelines for steering strategies.

2.9 Crises

Crises occur in the behaviour of complex adaptive systems, causing huge changes in short periods of time. From a certain state of order, the system passes the edge towards chaos and then back to order again. Cohen and Steward (1994) talk about catastrophes in this context – referring to the catastrophe theory – and Bak and Paczuski (1993) about avalanches. However, this book uses the term *crises*.
The occurrence of crises can be seen as a nuisance and troublesome, but crises are of essential importance to the development of complex adaptive systems. Bak (1996) even poses that they are the only known mechanism explaining the self-organisation of complex systems. Crises develop into a critical state; in which “only a small change is required to flick the switch” (Cohen and Steward, 1994). A crisis occurs, often without an apparent advance warning.

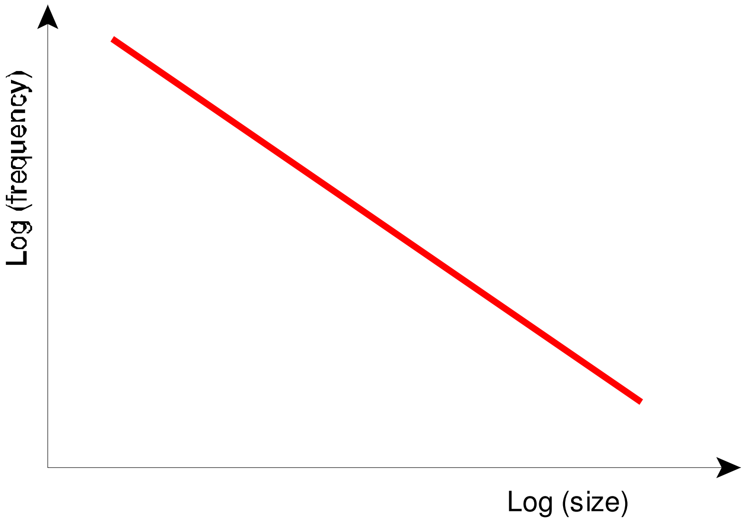

Figure 2.9. Relationship between size and frequency in crises in complex systems.

Because systems work themselves towards a critical condition and crises manifest themselves in systems capable of self-organisation, Bak (1996) speaks of *self-organized criticality*, or 'SOC' for short. He observed a fixed relation between the size and frequency in crises. This relation is presented in Figure 2.9. Small and large crises can occur, with small crises happening more often than large crises. When plotting the size[6] of crises on a logarithmic scale against their frequency (also on a log scale), a straight line is produced. Much research into self-organized criticality corroborates the relation presented in Figure 2.9. Bak (1996) put the results of a great deal of research into the book "How Nature Works", describing crises such as earthquakes, fluctuations in cotton prices, light from quasars, extinctions of animal and plant species during the history of earth, neuron activity in the brain, economic developments of in supply and demand, and the occurrence of shock waves and traffic jams on motorways. There, the same relationships are found again and again.

What is the importance of crises for the study described here about water systems? It is important that crises form a substantial behavioural characteristic of 'healthy' complex adaptive systems. Without crises, the system would not be adaptive. In other words, the theory on self-organized criticality follows up on Holling's observations from the seventies (Holling, 1973; Holling, 1986; Peterson, 2000). Natural systems do not have an equilibrium which keeps structures (biotopes) constant. They have succession with considerable dynamics. An ecosystem is continuously going through cycles of four phases, called: (1) Growth, (2) Conservation (3) Release and (4) Reorganization. In the first phase, a biotope is developing, using nutrients and other resources stored in a previous phase. The new biotope can conserve itself for a long time in phase two, in which the dominant species use the majority of the resources, with the coherence and mutual dependency of species increasing. In phase three, the biotope can no longer conserve the status quo and becomes unstable. Over a short period of time, the dominant species decreases in number, releasing a large part of the bound resources. This is a crisis. The resources become available in a different way in phase four and this creates possibilities for other species to develop (phase one) and start dominating. Certain resources can disappear from the system and new ones may become available.

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[6] For example, the size of an earthquake can be expressed in kJ.

In his analyses of natural systems, Holling shed new light on nature management. Nature management was mainly aimed at keeping biotopes in equilibrium as much as possible. In Yellowstone National Park, for instance, each forest fire was extinguished as quickly as possible. Holling said that forest fires are partly natural phenomena and can even be a precondition for stability. In this context, he introduced the term resilience as a measure for the disruption required to arrive at a structural change in a biotope. Within the science of complexity, the term resilience can be described as the resistance the system can muster against an attractor change. The stronger a system has nested in a basin of attraction, the more resilient it is.

The fact that crises are part of certain dynamic processes does not only apply to natural processes. Nagel and Paczuski (1995) have looked into the behaviour of cars on a motorway, as an example. If there are many cars on a motorway, shock waves are observed. In case of shock waves, cars have to brake to prevent hitting the car in front of them. Shock waves can be seen as crises, with small shock waves occurring regularly. Say a car is overtaking a truck at 120 km an hour, with the result that another car doing 130 km an hour in the same lane has to brake a bit, then minimally, the shock wave will involve two cars. However, it is possible that if one car brakes it causes another car to brake and a third car may have to come to a halt, etc. A traffic jam of 30 kilometres may well be the result.
Nagel and Paczuski (1995) have carried out simulations for which they plotted out the shock wave frequency against the number of cars involved. They found that the relationship presented in Figure 2.9 is characteristic of self-organized criticality. They also found that *this pattern cannot be suppressed* – and this is important to the research into coping with complexity. When measures are carried out in the simulated system that are aimed at preventing shock waves, it becomes unstable. Having cars drive at equal speed results in an increase in road capacity, however, if something goes wrong, traffic will completely jam. Bak (1996) therefore poses that it is better to learn to live with the occurrence of crises as they are characteristic of complex systems.

The systems described by Bak (1996) are not adaptive. The ecosystems investigated by Holling were. It is expected that human behaviour will change after a major catastrophe in traffic. People will change their rules, for instance, more people will be taking the train to work. However, a real attractor change is not expected to take place. The structural adaptation shifts the ruling attractor a bit and it will lose a bit of strength. The resilience of car use is too large for a greater structural adaptation to come from a minor crisis. However, in nonlinear systems a small intervention may have huge impact and vice versa.

Insights in the occurrence of crises are in two ways important to the research into "coping with complexity". First, crises go hand in hand with complex adaptive systems. Second, aiming the management of these systems at maintaining the equilibrium may exactly cause a large crisis – instability. Managing crises is therefore of utmost importance and it even offers opportunities to arrive at renewal purposefully (Stacey, 1996; van Slobbe, 2002).

Crises play an important role in the two examples discussed in Section 2.7, the freshwater system and the ribbon development in Flanders. A crisis occurs in the freshwater system when there is a combined sewer overflow and clear water becomes turbid in a short time span. The system can recover, but it can also remain turbid in a stable way. With regard to the ribbon development in Flanders, a crisis occurs when large quantities of water and mud end up in the houses in the valleys during an extreme storm. Emotions are released and local authorities are blamed for the fact that they have let this problem go on for too long. Measures that could not be discussed for a long time have suddenly become negotiable; and this can lead to an adaptation of the rules. It is difficult to climb out of the basin of attraction of the ribbon development attractor, but various structural adaptations can lead to improvement. If the steepest slopes are planted with trees, the situation will improve and if new techniques are introduced for land tillage, erosion can be reduced considerably (Schmidt et al., 2000). If spatial planning takes the erosion problem into account more, it can prevent new houses being built in places of high damage risk. Tension is rising in Flanders and the next extreme precipitation may cause a large crisis. For the time being, mitigating measures are being taken reducing the effects of erosion by gathering water and mud in large basins (Charles et al., 2000).

2.10 Coherence I (dynamic course)

The two remaining sections to this chapter provide representations of the characteristics of complex adaptive systems, while aiming for coherence. Attractors, the phenomena at the edge between order and chaos, and crises are in fact inter-dependent. This section presents a ‘model’ for the dynamic course of states of a complex adaptive system. The next section describes the behaviour of a complex adaptive system using the image of “the survival landscape”. This image is more like a metaphor than a model, but it helps reflect on the practice of developing strategies.
A complex adaptive system is dynamic, where the course of states cannot be determined in advance. Precise predictions of the system state at time *t* in the future cannot be made, however, patterns do have a predictive power (Kellert, 1993). There are patterns in the course of states.

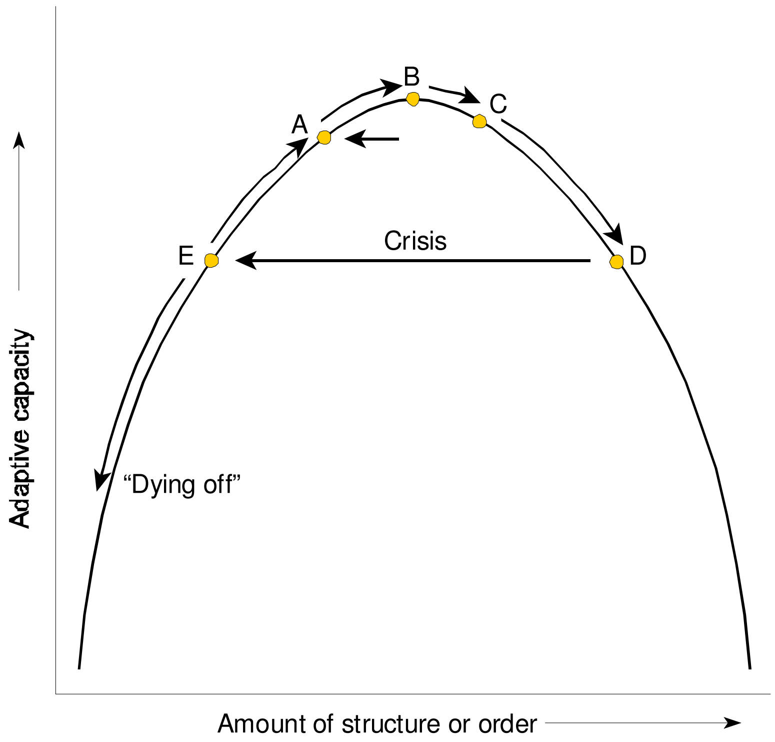

Figure 2.10. Course of states in a complex adaptive system.

Figure 2.10 (Geldof, 1994) presents the course of states in a complex adaptive system. The figure is derived from Figure 2.2. The horizontal axis shows the degree of structure or order; the vertical axis – this is different in Figure 2.2 – shows the adaptive capacity. In the area with a high effective complexity, referred to here as the edge between order and chaos, the system has a high adaptive capacity. It can adapt well to changing conditions because the structures have sufficient plasticity. Norman Packard, one of the founders of the chaos theory, says in Lewin (1993) that systems in the edge between order and chaos have a maximum capacity for processing information. A system with a high diversity has many structures and substructures and chances of producing "the right answer" to influences from the environment are better than with systems with a low diversity.

However, the system does not stand still at maximum effective complexity. It undergoes a cyclic process (see also Holling, 1973), in which structures change. Prigogine and Stengers (1985) call this "order by fluctuation". The behaviour from points A through E in Figure 2.10 is briefly described below.

In order to be able to better anticipate changes in the environment (A) – after a crisis –, an adaptive plan is drawn up from within the complex adaptive system. This usually means that the rules are adapted and by doing so the rules the interaction between actors, water system and water chain and among actors changes. If the adaptation is successful, this results in less tension with the environment (the context). The system is better able to allow for changes in the environment, which is called the adaptive capacity here. A stable course of states (B) develops in the direction of one attractor. The system states remain in one basin of attraction. After a while, the structural adaptations are no longer positive. The environment changes and the rules formulated in the adaptive plan create tension with the environment. Although the rules start becoming rigid (C), they are persistently adhered to, which decreases the adaptive capacity. It becomes harder and harder to react to changes in the environment. The tension between system and environment increases. The system is developing into a critical state (D), in which "only a small change is required to flick the switch" (Cohen and Steward, 1994). The crisis takes place in a short period of time. The system shifts into a condition (E) which is characterised by chaos. It is possible that the system cannot recover after this crisis and "withers", being no longer able to function as an open system. The entropy of the system then increases, in accordance with the Second Law of Thermodynamics. It is also possible that the system reorganises and develops in a new or adapted attractor. The rules are changed and the effective complexity increases.

The course of states is continuous, being a process of perpetual novelty. Crises can be large and small, corresponding with the relationship applicable to self-organized criticality.

The way the process is represented in Figure 2.10 does not show that structures change, attractors change or even completely disappear or merge. Figure 2.11 provides a different representation. This figure plots a system variable – which can be anything – against the tension[7] between system and environment. The variable is on the vertical axis and the tension between system and environment on the horizontal axis. Three lines are drawn: A, A' and B. These lines are partly continuous and partly discontinuous. In the continuous part of the lines the system behaves in a stable manner, in the discontinuous part the system is unstable. The transition from continuous to discontinuous represents the edge of stability, called "the edge of chaos" by Waldrop (1993) and Lewin (1993).

[7] Tension arises when the system does not fit (anymore) into the environment (context). For example, a dictatorship can maintain itself for many years and even many decades. However, due to suppression and violence a tension between the dictatorship (the system) and the people in the country (the environment) builds up. This tension consists of frustration, fear, hate, etc. In physical systems the tension can be expressed as energy.

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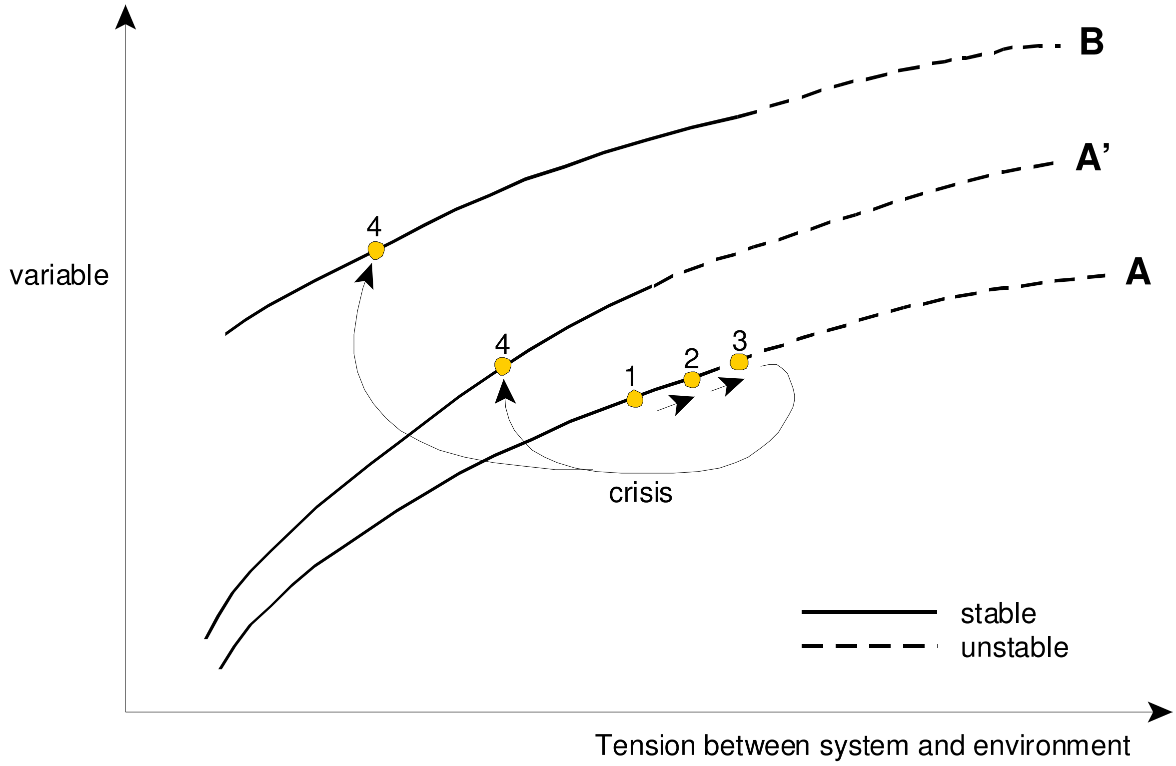


Figure 2.11. Behaviour of a complex adaptive system.

In Figure 2.11, the course of a dynamic process starts on line A, which means the system state is located in the basin of attraction of attractor A (point 1). Characteristic of the behaviour of a complex adaptive system is that it develops into the area of instability because of the impact of external influences (changes in the context). In ecosystems, certain species start dominating. These species use relatively many resources by way of which they enhance their position and territory. However, if conditions – the external influences – change or certain resources are no longer available, the dominant species can become extinct in a short period of time and make way for new species (Holling, 1973). A similar type of behaviour can be observed in social systems. Certain actors reinforce their position at favourable times, succeeding in realising their own goals, possibly at the cost of joint goals. They demand a great deal of ‘space’. If conditions change, the system will be under pressure and the need to adapt grows. In addition, people are inclined to seek out and push back boundaries.

In Figure 2.11, the system condition is slowly shifting to the right and will end up in point 2, from which it will continue to develop. The tension does not so much increase because the system is changing, but because the environment is changing. Previously unrecognized problems become visible and opinions on how to tackle problems in practice are developed. By stubbornly keeping the system in equilibrium a crisis may be suppressed for a time. But this is a matter of crisis postponement as, after due course of time, the system state ends up in the critical point and the system becomes unstable (point 3), thus commencing a period which is considered chaotic and disorderly.
Structural adaptations take place after – or during – the crisis. Rules are changed, which causes the attractor to change. The attractor ends up in a different place and the size of the basin of attraction changes. The system state then develops into the direction of point 4 on changed attractor A’. Attractor A’, however, may disappear or the system is undergoing such

strong outside influence that its behaviour is developing towards a new attractor B. There may even be an invisible attractor C. In point 4, the system recovers and a new stable period begins.

2.11 Coherence II (survival landscapes)

Actors in a complex environment make adaptive plans to end up in an attractive, in any case viable, position. When simulating complex adaptive systems, a parameter is usually introduced with which the attractiveness of a certain position can be expressed. This parameter is called *fitness* (see for instance Langton et al., 1992) and it is an assessment value. It is not so much about the fitness of a certain actor, but about the way in which the own structure *fits* the environment (the context). In case of high fitness, the tension between system and environment is low.

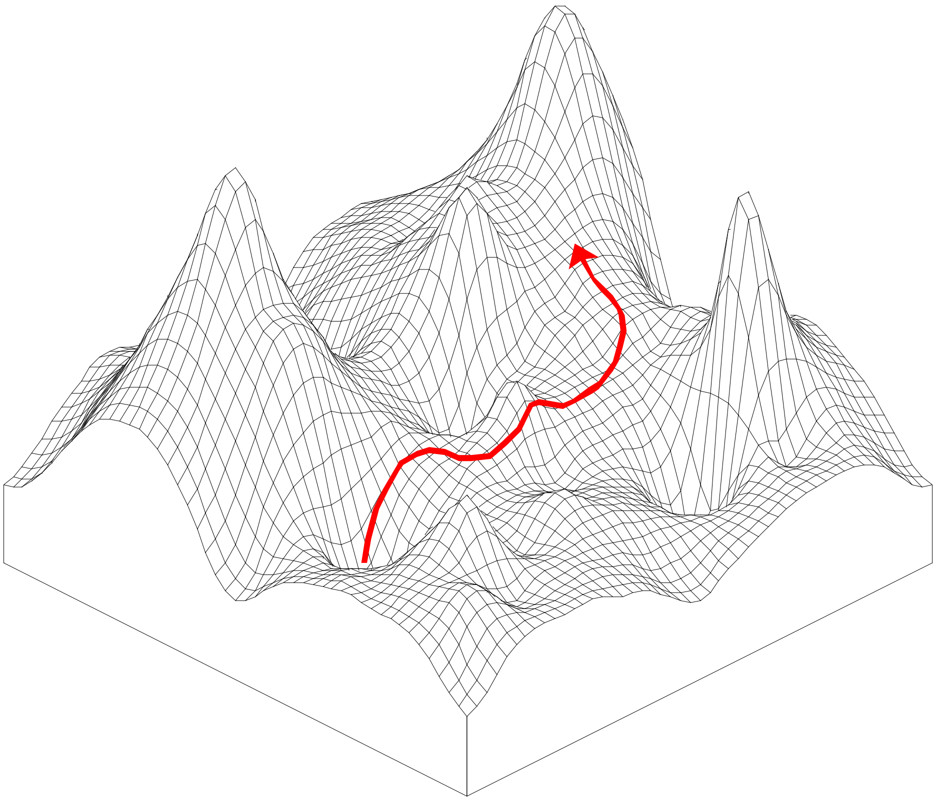


Figure 2.12. Representation of a survival landscape. Peaks are attractors and dips are repulsors.

It is possible to draw up the adaptive plan using "trial and error", changing the structure randomly and seeing whether the fitness increases or decreases. This way, successful structural changes are sustained. However, it is also possible to acquire knowledge of the situation and its dynamics so that a better founded adaptive plan is drawn up. The actor then focuses on what is called a *fitness landscape* or a *survival landscape* (Waldrop, 1993). This book uses the term survival landscape (see Figure 2.12), which is a representation of the phase space, in which the actor observes favourable and less favourable positions. The peaks in this landscape are the attractors – for simplicity's sake presented as a point – and the dips are the repulsors. In this landscape, actors (agents) try to take up a position as high as possible.

Using this representation, the impression may be created that the focus in a survival landscape is 'only' about optimisation, calculating the highest point. It is then a question of finding the highest point. However, matters are rather more difficult in complex adaptive systems. The four aspects listed below are important to the focus:

1. The entire landscape is *a priori* unknown. Actors see problems through their own frame and therefore only see a small part of the landscape. They can even be so myopic as only to see their 'own' peak.
2. Related to the previous aspect, different actors can have different opinions on the landscape. A peak to one actor may be a dip to another.
3. The landscape is not static, it moves. Peaks can become dips and dips can become peaks. Peaks can merge and, due to crises – catastrophes –, even disappear within a short period of time. There is not *one* complex adaptive system, but many complex adaptive systems, mutually linked and influencing each other. Intervention in one system influences the other system, for instance, an improvement to one system can mean deterioration to the other.
4. Changing attractors is not a simple matter. To travel from one peak to another – higher – one, often a dip has to be traversed. This requires great effort and, partly because of the interdependences, it is important to agree on the road to be followed, otherwise the actor ends up out of the frying pan into the fire. The occurrence of a crisis can make it easier to change attractors.

How peaks and dips and their developments are seen increases the insight of actors confronted with a complex integrated problem. This insight does not directly generate solutions, but it does offer guidelines to *navigate* through the landscape. If changes are necessary, steering strategies are employed: "Steering is aimed influencing" (De Leeuw, 1994).

The image arising from networks, attractors, the edge between order and chaos, crises and survival landscapes does summon up a *dilemma*. Is steering at all possible if patterns are generated through self-organisation and crises keep their fixed relationship? The steering actors are part of the complex adaptive system they want to influence. Can actors act proactively in an environment with emergent patterns? This book assumes they can. Actors can steer and can act proactively, because people can act *consciously*. They can explore future scenarios with models and they can figure out how complex adaptive systems function. They can view the system of which they are a part from an outside perspective (Habermas, 1989), which makes it possible to give direction to steering strategies.
The middle position is taken in dealing with complexity, somewhere between "trial and error" and deducing the best solution using a knowledge of the system; having characteristics of both strategies. Perhaps this should be called "intelligent trial and error."

3 Nijmegen water plan

3.1 Handling stormwater differently

Nijmegen (about 180,000 inhabitants) largely lies on a lateral moraine along the Waal River. Strollers through Nijmegen will only find surface water in its lower parts. In the upland parts, the water management is completely managed via the sewer system. The few ponds in upstream areas are not part of the natural water system, but are overflow structures of the sewer system. Seepage water of beautiful quality appears at the foot of the lateral moraine. This water partly flows into the Ooij polder (see Figure 3.1) and partly into the Maas-Waal Canal and Lindenholt and Dukenburg, the new housing estates on the west side of Nijmegen. An exceptional feature of Nijmegen is that in the city itself, groundwater is extracted for the production of drinking water.

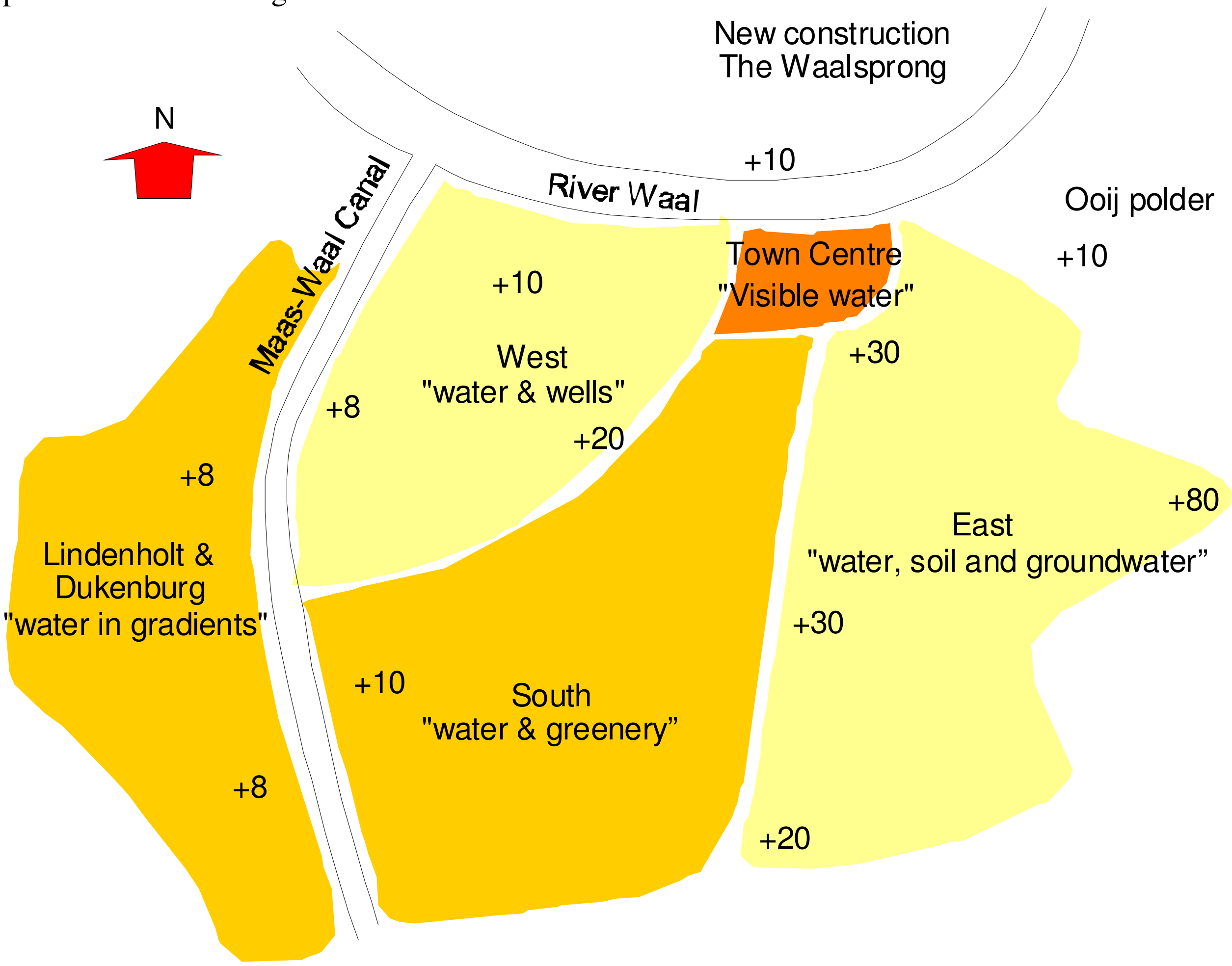


Figure 3.1. The Nijmegen water plan dividing Nijmegen up into five areas. Land heights are given in metres relative to the +NAP datum (Normal Amsterdam Level, equal to the average level of the North Sea).

At the start of 1997, when people started drawing up a water plan for Nijmegen, most stormwater from paved surfaces was discharged into the sewer system. This was causing combined sewer overflows[8] (CSOs) and a lower groundwater level. Because most of the surface runoff was being quickly transported to the Waal River, it could not contribute to the intermediate water system. At that time, people in the Netherlands were already thinking about handling stormwater differently. Although no official policy had been developed, many experiments were being done with techniques for infiltrating stormwater from the paved surface into the subsoil. Stormwater was no longer seen as wastewater, but as a resource. Stormwater is valuable. Stormwater discharge could become visible again. Where possible, stormwater was discharged with gutters to public green spaces where it could infiltrate into the subsoil. Or it was directly discharged to local surface water systems. The discharge of stormwater was no longer hidden from residents. These experiments were restricted to new estates. Until that time, examples in existing parts of towns were hard to find in the Netherlands.

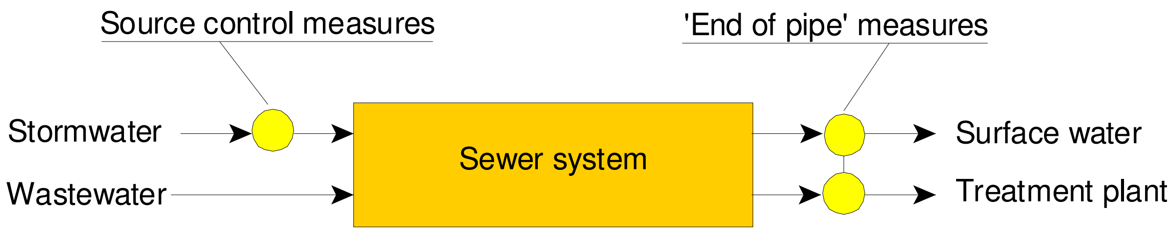


Figure 3.2. The principle of source control or 'end of pipe'

When improving urban water management a distinction is sometimes made between source control measures and 'end-of-pipe' measures. Figure 3.2 illustrates this distinction. Source control measures are aimed at the treatment of stormwater near the source, near where it falls from the sky. These measures are aimed at making or keeping the stormwater as clean as possible. Water runoff from roofs may contain zinc, therefore, filtering this contaminant is a source control measure. Sweeping the streets is also a source control measure, because it prevents additional contamination of the stormwater. Particularly in Europe, where most sewer systems are combined, source control measures prevent stormwater from flowing into the sewer system and mixing with sewage water. Source control measures use stormwater in and around the home, infiltrate it into the subsoil or discharge it directly to local surface water systems.
Only once stormwater is let into the sewer system are 'end-of-pipe' measures taken to improve the quality of the surface water. For instance, it is possible to increase storage in the sewer system so that more stormwater can be stored, resulting in a reduction of the combined sewer overflow. Or the treatment capacity of a sewage water treatment plant can be improved (SWTP).
The most important aspect of the Nijmegen water plan was changing from an 'end-of-pipe' approach to a source control approach. From the start, insights from the science of complexity were used. Implementing source control measures is a diffuse process and calls for intensive interaction with a large field of actors. The concept of Interactive Implementation (see Chapter 5) was used here for the first time.

[8] In a combined sewer system wastewater and stormwater are discharged into one sewer. When it is raining hard, the combined sewer system is not big enough to store all water. Then, a combined sewer overflow (CSO) takes place, where a mix of sludge, wastewater and stormwater is discharged into the surface water.

3.2 *Outline of the Nijmegen water plan*

On 27 June 2001, the Nijmegen water plan was officially laid down and presented to the public, thus ending the planning process which took more than four years. Planning had started in the spring of 1997. This does not mean that the process took too much time because a deadline was never set. The main reason for it taking so long was embedded in the approach. From the start, it was decided to have an interrelated planning and implementation process. Pilot projects were carried out, partly inspired by Tjallingii (1996), who describes the importance of learning processes in environmental planning. The Nijmegen water plan mainly pertains to parts of the *existing* town and participants were aware that the planning process would not be a straightforward process of thinking, reporting, deciding and implementing. It was clear that a learning process was needed using experiences from pilot projects to reduce *uncertainties* about effectiveness and about public support in carrying out measures.

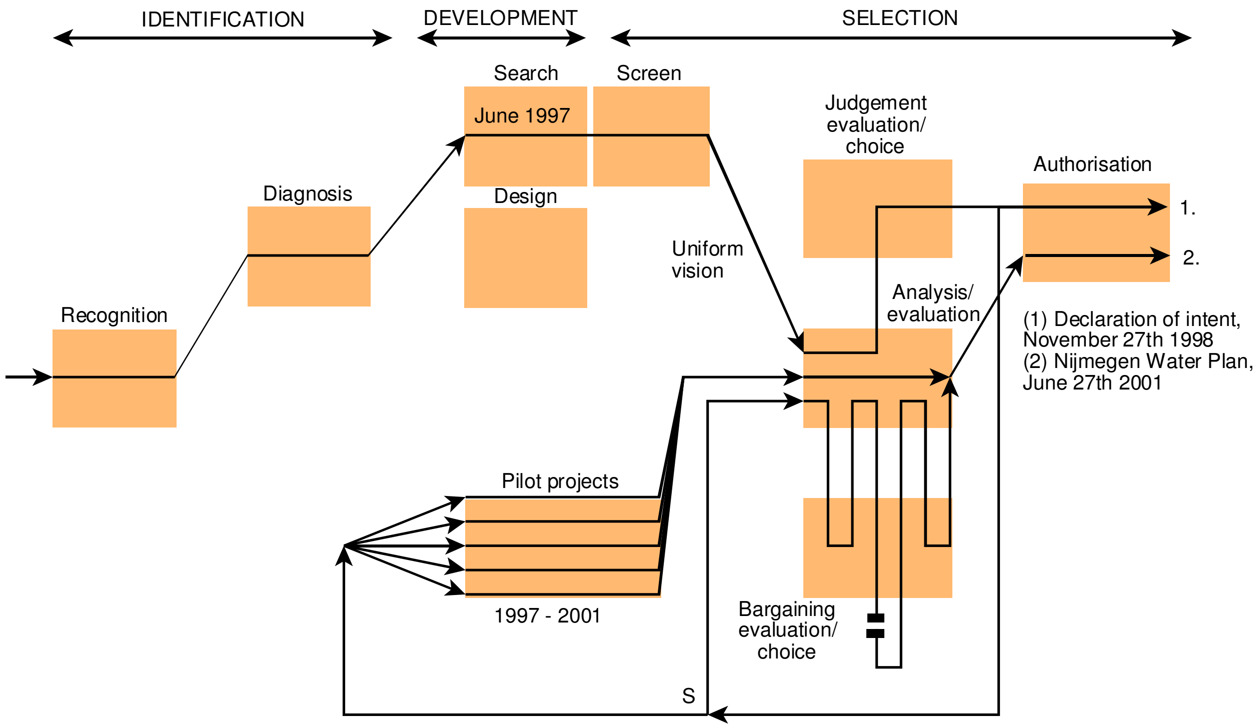


Figure 3.3. Course of the process for the Nijmegen water plan.

By filling in Mintzberg et al.'s model (1976), Figure 3.3 presents the process of arriving at the plan. This model distinguishes between three phases: identification, development and selection. These phases can be repeated any number of times. The original model contained another element; pilot projects. These pilot projects do not represent an independent stage in the planning process. They were not carried out consecutively, but in parallel to each other. This is what is so special about the Nijmegen water plan. During the time that many analyses were made and objectives and means were being negotiated, many pilot projects were started and completed. Therefore, Figure 3.3 contains a junction (S), indicating when processes started running in parallel to each other. The original Mintzberg model does not cater for pilot projects.

The procedure of identification, development and selection was followed twice in the entire planning process. The first time via *search, screen* and *judgement*, which yielded an intermediate product: the Nijmegen Local Water Memo (Geldof et al., 1998). The second

time it started at junction S, resulting in the Nijmegen Water Plan via *pilot projects*, *analysis* and *bargaining*. There is an interruption in the negotiating process with this procedure.
The two procedures are explained in the next two sections. Then, from Section 3.5 onwards, the process is described again, but this time using the five characteristics of complex adaptive systems. This is basically a re-description of the planning process, showing the contours of Interactive Implementation.

3.3 First procedure (Nijmegen Local Water Memo)

3.3.1 Previous history (recognition)

The idea to draw up a water plan for Nijmegen did not arise overnight. There were various reasons, partly from different actors. Three parts of the previous history that lead to the start of the Nijmegen water plan are related here.
The first part of the history is about image and quality of life. Nijmegen is looking for an image. Within the framework of developing a vision plan for Nijmegen in 2015, city debates were held with inhabitants. The overall idea obtained from the city debates is that "people from Nijmegen are just a little short of being able to be proud of their town". According to the project manager of the Nijmegen Local Water Memo, Jan Luijten: "Nijmegen is on the Waal River, but we are not doing enough with water". Since the eighties, the municipality has been consciously shaping Nijmegen's identity. Ien Dales, then mayor, initiated this by putting Nijmegen on the map as a "junction area". Also, much effort was made to increase the quality of living in the town. Important themes in the 2015 vision plan are quality of life, greenery and traffic.
Nijmegen's image was damaged by a soil and groundwater scandal. In 1995 and 1996, contaminated soil from four separate sites was moved all over the place without legal permits. This was discovered and became national headlines in 1997. Several people from the council saw drawing up a water plan as a chance to improve Nijmegen's image, especially with regard to the environment. Water was also seen as a medium to increase residents' *commitment* to the environment.
The second part of the history concerns the Waalsprong, a new estate in a polder on the north banks of the Waal. This estate is being built on a sustainable basis and water plays an important role here. Using the concept of "the two networks" (Claringbould and Tjallingii, 1993) a structure was designed in which water and greenery are important pillars of the spatial plan. Stormwater is kept inside the estate as long as possible, so that dry periods can be accommodated without bringing in additional water from the Waal. This is why the estate has large quantities of surface water. This development raised a number of questions with the council members. Why was a sustainable water system being laid in the Waalsprong and not in the existing town parts? Was it possible to improve the sustainability of the water system in existing parts of Nijmegen, on the south banks of the Waal?
The third part of the history concerns the Municipal Sewer Plan (Gemeentelijk Rioleringsplan, GRP). During the municipal elections in 1994, the city aldermen promised there would not be any tax increases. Shortly afterwards, the GRP was published (Municipality of Nijmegen and Haskoning, 1994), which contained plans – to meet the requirements – to reduce waste discharge from the sewer system by means of 'end-of-pipe' measures totalling about € 36 million. The majority of these plans concerned storage settling tanks. In order to be able to carry out the measures listed in the GRP it seemed unavoidable to raise the sewerage charges. This led to intense discussion in the municipal council. Against this background, drawing up the integrated water plan can be seen as a bright spot, because

the process towards the plan was expected to yield alternatives to the expensive measures. To some council members, "the measures cost a great deal of money and have no visible result".

3.3.2 City pond memo (diagnosis)

During the process of drawing up the Nijmegen water plan there was hardly any diagnosis (i.e., quantification of water problems). However, the quality of the city ponds was investigated (Van de Pas, 1996). This investigation showed that the quality of the water and water sediments was not good in many city ponds. However, it should be observed that some of the 'ponds' in Nijmegen are, strictly speaking, not ponds but overflow structures of the sewer system. In some places in the higher part of Nijmegen, ponds were dug and made watertight at the bottom because they are situated far above groundwater level. These ponds are almost exclusively filled with overflowing sewage water. During warm periods, the water quality is maintained by supplementing with groundwater and by fountains oxygenating the water. Despite the bad water quality, residents value most ponds highly.

3.3.3 Design of planning process, interviews and workshop (search and screen)

The actual start of the Nijmegen water plan was at the time of drawing up the city pond memo. Tauw Consultancy, Deventer, were asked for support and a method was agreed upon, consisting of two procedures. The first was to result in the Nijmegen local water memo and the second in the Nijmegen local water plan. The word 'local' instead of 'municipal' is used, because it is about local policy, and municipal borders often do not correspond with the borders of water systems. Moreover, it was not solely a plan by the Municipality of Nijmegen; the Province of Gelderland, Rivierenland Water Quality Board and the Polder Districts Betuwe and Groot Maas and Waal also played an important part.

The process diagram agreed upon is presented in Figure 3.4 (Geldof et al., 1998). This diagram was set up under the assumption that the whole can be seen as a complex adaptive process, as can be seen from the fact that matters are listed from general to more specific, that 'chaos' (divergence) is allowed for in the initial phase and that processes run parallel to each other. The process was also aimed at mapping out opportunities and bottlenecks. It is called a 'live' process, because there is no strict distinction between planning and implementation. During the planning stage, the actors involved are going through a process that smoothly switches over to the implementation of the actions listed in the plan.
The setup of the planning process assumes a limited number of actors involved in the first phase. The actors with a clear task in water management draw up the Nijmegen local water memo, which must contain an outline of the plan. Then, the process with a larger field of actors can be started. The organisation consisted of a working group, not a steering group. The official representatives in the working group, which firstly consisted of officials from the Municipality of Nijmegen, the Province of Gelderland, Rivierenland Water Quality Board and Polder District Groot Maas and Waal, ensured administrative feedback themselves. The working group was later expanded. The communication lines were very short for the municipality of Nijmegen. After the soil scandal in 1997, a so-called *Monday-morning* meeting was set up, during which three aldermen and three service directors exchanged information and took decisions. When necessary, the project manager of the plan could immediately report during this meeting and have decisions made.

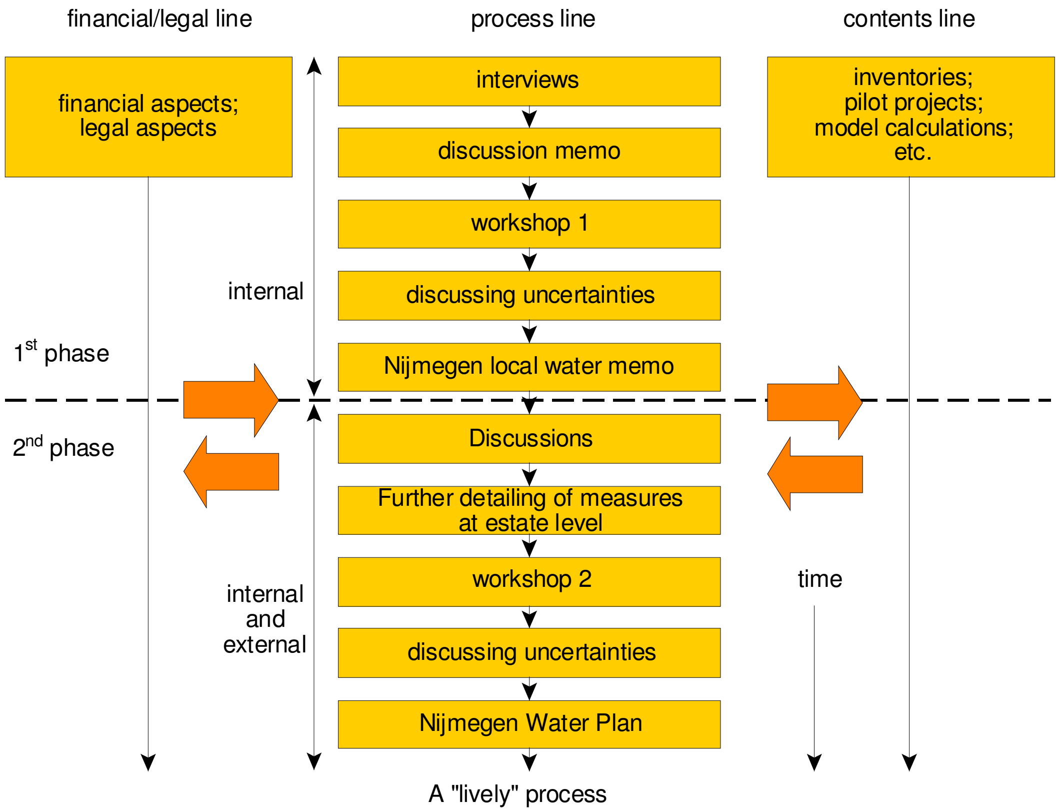


Figure 3.4. Planning process setup for the Nijmegen local water plan.

There are three lines in this process diagram (Figure 3.4), in which the process line is the central line. It was assumed that the subjects that will be described in the water plan are mapped out in this process line, while uncertainties, especially about effectiveness, development and support of the proposed measures, manifest themselves. There may also be financial and legal questions. Activities resulting in knowledge in support of the meeting – the negotiations – on the process line are started on the two parallel lines.

An objective was formulated at the start of the process. This objective (Geldof et al., 1998) stipulates that the plan must be inspiring for, and give direction to, the water management in Nijmegen. The plan should provide guidelines for the various actors involved in water projects. The objective also involved several pilot projects to be carried out, in order to:

- gain more experience in Nijmegen in "developing and maintaining healthy and resilient water systems, which will continue to guarantee sustainable use" (national policy);
- obtain information for the officials involved and administrators and residents.

The process was started by interviewing 19 officials and administrators in the Municipality of Nijmegen, the Province of Gelderland, Rivierenland Water Quality Board and Polder District Groot Maas and Waal. The point of the interviews was to search for possible measures and activities for the benefit of the water system and water chain in Nijmegen. The interviews were not based on any problem or objective in particular which allowed the interviewees much liberty to contribute their own views. This yielded a wide range of issues and solutions, partly contradicting each other. The input of the interviewees was put into four categories: maintaining, developing, preventing and repairing (Berends and Geldof, 1996). Table 3.1 gives an idea of the outcome of the interviews.

Table 3.1. A selection of values, leading principles and ideas discussed in the interviews.

Maintaining	Developing
• Carrying out the measures listed in the GRP. Building the planned storage settling tanks. • Nijmegen-Oost as popular neighbourhood situated on nice sandy soil. • Applying the stand-still principle for the Ooij polder. • Where possible, mowing banks less frequently to enhance a diverse vegetation • The lovely village of Hees, closed in by the city. • Housing project on the Waal harbour. • Lindenholt toad pool.	• Using the opportunities offered by the gradients and dynamics of the lateral moraine. • The Blue Transformation: limiting costs by hitching along with other projects. • Assigning differentiated functions to the city waters. • Treatment as close to the source as possible. • Communication to the residents: awareness of the importance of clean water. • Traffic as the carrier of economic activities. • Visibility of water in the renewal of Mariënburg in the town centre.
Preventing	**Repairing**
• 'Building up' the urban area leaving no space for the water system. • Pollution of stormwater runoff. • Mixing clean and dirty water. • Washing cars in the street, where stormwater runoff is discharged onto surface water or infiltrated into the soil. • Using zinc, copper, lead, hydrocarbon and other leaching materials. • Wasting water. • Overflowing on small and/or poorly flushable watercourses. • Annexation of banks by the owners of adjoining plots of land.	• Natural groundwater system. • Improving the water quality of city waters. • All water sediments of dredge spoil quality III or IV. • Open communication: fighting the corporate culture of testing in municipal services. • Remediating artificial ponds situated above groundwater level (internal overflow). • Replacing groundwater catchment by surface water catchment in the Ooij polder. • Repairing the rural character of Nijmegen-Oost. • Combating groundwater nuisance in Nijmegen-West.

A more complete overview of the interviews was given in the discussion memo sent to the 17 participants (from the municipality, province, water quality board and polder district) of the workshop on 11 June 1997. The aim of this workshop was to come to creative ideas, based on the interviews. The ideas from the interview were still very rough and it was necessary to make them more coherent.
Instead of covering up differences of opinion about what to do with the water system and water chain in Nijmegen, the workshop zoomed in on them and magnified them. This made the area of discussion visible and parties involved were thus stimulated to argue their viewpoints. During the morning of the workshop, presentations and discussions were held. The main differences of opinion concerned taking source control measures. It was debated whether source control measures were a solid alternative for storage settling tanks and whether the soil and groundwater would not be contaminated if urban stormwater was being infiltrated. Discussion also considered how to stimulate the actors involved to cooperate and how to meet the legal requirements in time.
During the afternoon of the workshop a creative process was initiated in which Nijmegen was divided up into five areas, defined by Tauw and the project leader (see Figure 3.1). The workshop participants were also divided up into five groups. Each group was mapping out possibilities and limitations for the water management within one of the five areas.

The Nijmegen Local Water Memo provided an idea of the creative session of the workshop and its results. Afterwards, the participants thought that the workshop had been very productive. The different backgrounds of the participants – technicians, managers, administrators, designers – ensured that different angles of the water issue in Nijmegen were discussed. All ideas of the five groups were related to the aspects of handling stormwater and the perception of water. If stormwater is no longer discharged in to the sewer, it becomes available for other – 'nicer' – things. Water can contribute to an increase in the quality of life in neighbourhoods and in sustainability of industrial areas.

From the interviews themes had been set for all five areas (see Figure 3.1). In the town centre of Nijmegen the theme was "visible water". The town centre runs steeply up from the Waal quay, at least by normal Dutch conditions. The area is perfect for water running through open gutters and art structures. The group dealing with the centre of Nijmegen discovered that by 2005 a large part of the public space was supposed to be renewed. In addition to the twelve large projects that were screened, five large open spaces in town were examined where less stormwater is flowing to the sewer system thanks to the 'depavement' of the surface. These depaved spaces can simultaneously function as infiltration areas.
Full-blown and brainstorm ideas were obtained for each area. These ideas, together with the results from the interviews and the impression from the discussions, have formed the basis for the Nijmegen Local Water Memo.

3.4 Second procedure (Nijmegen Water Plan)

3.4.1 Pilot projects

The second procedure took a considerably longer time than the first, running until June 2001. It was not a process in which activities were carried out one after the other. Many activities were taking place at the same time. Not much changed in the organisation. There was still no real steering group. The working group was increased, for instance by including representatives from the water companies. Under the town of Nijmegen there are two drinking water catchments, which influence the water system and anthropogenic influences can threaten the abstraction. In addition, many water companies focus on sustainable management. It was therefore of utmost importance to include the drinking water companies in the working group – two in the case of Nijmegen. It was considered an omission that the water companies were excluded from the first stage procedure. There was also a change in the administration, for instance in the Municipal Executive, which had a huge impact on the progress. Municipal elections and administrative crises contributed to the fact that all aldermen originally involved in the water plan were replaced.

Many pilot projects were started. This book outlines four. Six pilot projects were started during the planning process and this was a fast-growing number. When the water plan was issued in 2001 dozens of pilot projects had already been completed.

Stormwater project in the town centre
The Mariënburg shopping precinct in the town centre of Nijmegen was completely renewed. This opportunity was seized to treat the stormwater roof runoff differently and do something creative with it. It was decided to catch the stormwater in a basin below ground level, filtering it and then using it for the fountains on Koningsplein. The surplus of stormwater infiltrates into the subsoil.

Biezenstraat

Trust plays an important part in the Biezenstraat in Nijmegen-West. The municipality developed plans for the redevelopment of this street. Supplementary to sewer renovation, parking, speed ramps and greenery, plans were made to discharge stormwater visibly from impervious surfaces via open channels. Complete visible discharge requires open channels that are too large; causing problems for pedestrians, cyclists and people in wheel chairs. So part of the stormwater will be infiltrated into the subsoil.

During the presentation of the plans to the residents – plans which were already fairly detailed –, there was a great deal of discussion about parking and speed ramps. The plans for the water management – insofar as they were dealt with – were received negatively. “If water is infiltrated, basements will flood with water”, it was said. This was a peripheral stimulus (see Section 1.3). It appeared people had little faith in the plans presented by the municipality. This lack of faith was not so much caused by earlier experience with water management, but rather by negative experience with the municipality concerning parking problems. There is a brothel at the end of the Biezenstraat. The visitors of the brothel park their cars in the Biezenstraat which leaves fewer spaces for the residents. In the past, the municipality never adequately acted on this despite many complaints. The idea that basements can flood with water was used ‘transferably’ to express the residents’ displeasure.

Afterwards, employees from the municipality made house calls to discuss the matter further, which yielded a more subtle picture. Eventually, the stormwater plans were carried out in closer consultation with the residents and to their satisfaction.

Water weeks and water markets

From 27 March up to and including 5 April 1999, Nijmegen ‘water weeks’ were held. The objective was to make inhabitants of Nijmegen *water aware* (Municipality of Nijmegen, 1999). Aspects of the water weeks were: joint issue of a water paper, discounts on water-saving products, tours, exhibitions, a youth campaign, the start of an educational water programme, a water debate, and a water market (5 April) on the Waal quay. The water market was repeated on 18 March 2000. The number of parties contributing was impressive. In addition to the actors in the first arena[9], parties such as the Association for Environmental Education (IVN Rijk van Nijmegen), the Environmental Education Centre (Milieu Educatie Centrum), University of Nijmegen, HAN University (Hogeschool Arnhem Nijmegen), Old Town Foundation (Stichting Oude Stad), Nijmegen corporation (‘t Gilde Nijmegen), the Nature museum, the Nijmegen Swimming Pools (Nijmeegse Sportfondsenbaden), Fire Brigade Nijmegen, two large DIY-stores (Gamma and Praxis) and various garden centres were involved in the organisation.

Stimulation of rain barrels and infiltration

A plan to save drinking water was launched in Nijmegen. An important aspect was the so-called “financial water track.” The objective was to attempt to stimulate people financially to be more prudent with water. In other words, handling water well would yield financial savings. Within this framework, a campaign was started which allowed people to buy rain barrels from the municipality against a reduced price and which offered people compensation if they disconnected their own roofs and yards from the sewer system. Together, Rivierenland Water Quality Board and the municipality made available about € 4.50 per m^2 to private persons if they stopped discharging their stormwater runoff from paved surfaces to the sewer system. Many private persons used this option.

[9] See Section 2.5, for a description of the various arenas

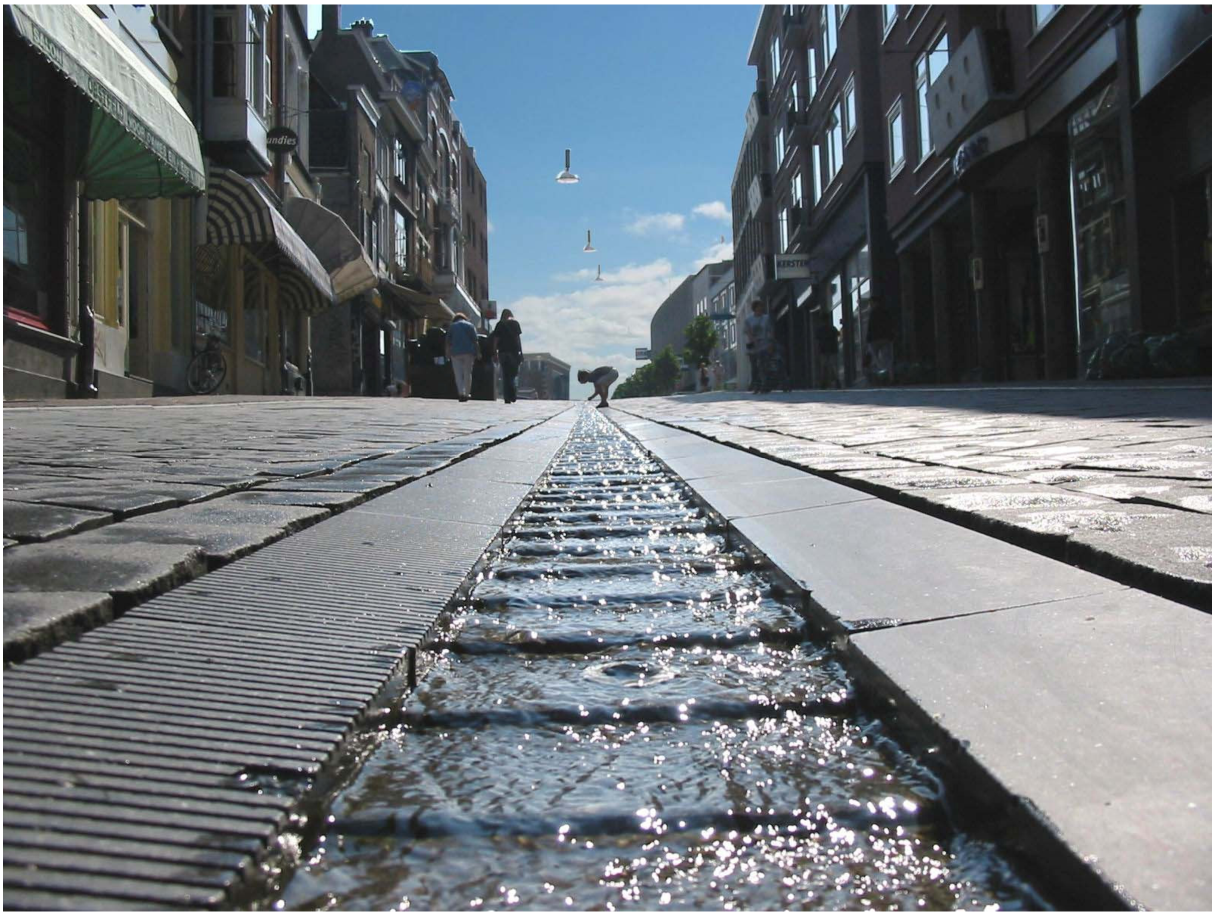


Figure 3.5. Open channel for discharging stormwater in Stikke Hezelstraat in the town centre of Nijmegen. The water is recycled. The open channel is lit at night.

3.4.2 Analysis and negotiations

In parallel with the pilot projects, the actors in the first arena carried out analyses and negotiated mainly about the development and management of the water chain (water catchment, sewer system and treatment). In addition to the municipality, the following parties were involved: the Province of Gelderland, Polder District Groot Maas and Waal, Polder District Betuwe, Public Works and Water Management (East Netherlands Department), Rivierenland Water Quality Board, Nuon Water, and Waterbedrijf Gelderland. There were eight parties in total.

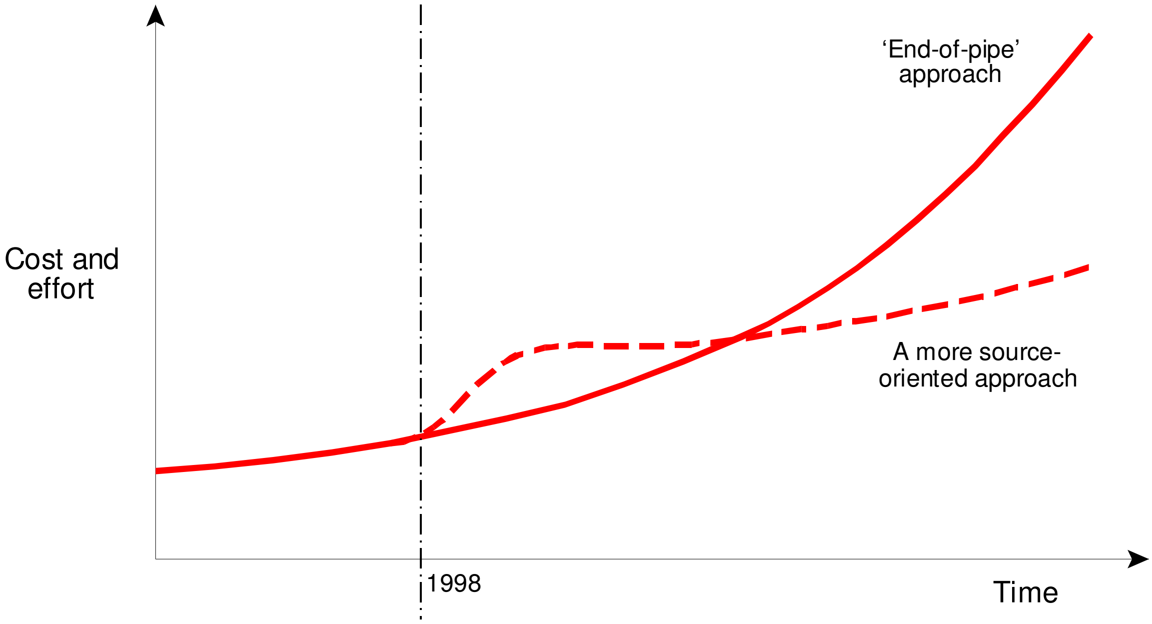


Figure 3.6. Schematic presentation of the dilemma in weighing source control measures and 'end of pipe' measures.

The main dilemma in the negotiations is outlined in Figure 3.6. Fairly soon it was clear to the parties involved that a source-oriented approach would offer better perspectives in the long term than an 'end of pipe' approach. By keeping stormwater clean and using it or infiltrating it where it falls, the groundwater supply is replenished, sewer overflow is prevented and water is discharged to the Waal more slowly. This approach can also contribute to the quality of the living environment, because visibly clean water has a high aesthetic value, which complies with the national policy. However, a source-oriented approach means that the administration will have to face extra costs and efforts in the short term. How should these extra costs and efforts be divided? And what is in it for the parties involved? The higher costs can mainly be explained by the fact that the techniques involved are very new and have not been used much. They have many extra safety measures.
Various studies were carried out to obtain a sense of quantities. These studies consisted of diagrams of the water system and water chain and investigated dose-effect relationships. Among other things, the following were investigated:

- Optimisation of water management in Nijmegen Zuid. The consequential costs of various combinations of source control measures and 'end of pipe' measures were estimated for Nijmegen Zuid.
- Quick Scan Nijmegen. The effects of source control measures and the construction of sewer settling basins on the waste discharge and the required size of the SWTPs were investigated with a highly simplified deterministic model of the sewer system and sewage treatment plants. If less storm water is discharged to the treatment plants, this can also lead to the more economic use of water.
- Opportunities for the so-called Blue Transformation. Mapping was carried out for which paved surfaces were easy, hard and impossible to disconnect from the sewer system; looking at the physical and social circumstances and at the location in relation to the sewer system.

On 27 November 1998, the administrators of the Municipality of Nijmegen, the Province of Gelderland, Polder District Groot Maas and Waal, Polder District Betuwe, Public Works and

Water Management, Rivierenland Water Quality Board, Nuon Water and Waterbedrijf Gelderland signed a *declaration of intent concerning urban water management*. This document states that the parties involved "intend to cooperate more on developing a sustainable water chain in Nijmegen in order to arrive at a healthy and resilient water system and an appealing living environment against the lowest social costs". Without laying down the outcome of the negotiations, the document has certainly set out the course to be followed. In addition to eight municipality administrators, eight children also signed their own declaration of intent on 27 November. These children have been coupled to the eight administrators and are allowed – at the initiative of the administrators – to verify progress.

3.4.3 Draft plan, final plan and finalisation

On 23 November 2000, the first version of the Nijmegen water plan was published (Geldof and Van Beurden, 2000), which was a draft for the workshop on 6 December 2000. During this workshop the plan was presented to various parties involved, mainly those from the first and second arena. In April 2001, after some adaptations, this was presented as a draft to the administrators. On 27 June 2001, again after adaptations, it was officially finalised and published.

3.5 Description based on complexity characteristics

3.5.1 Agents

The rest of this chapter describes the processes of the Nijmegen water plan again, but this time using the five characteristics of complex adaptive systems dealt with in Chapter 2. The description is not comprehensive. A working method is proposed for viewing processes of integrated issues through the spectacles of the science of complexity. This may result in a better understanding of the behaviour *as a whole*.

The agents in Figure 3.7 are ordered by distinguishing between physical, chemical and biological processes (I), social processes (II) and intellectual processes (III). The grey bars in between contain measures and activities influencing the processes. These are interventions and steering actions that are part of the adaptive plan (τ). They contribute to the *structural adaptations* that are so characteristic of complex adaptive systems. Between the first and second group, the interventions are related to direct steering. The actions of the actors change something in the water system and the water chain. The grey bar between the second and third group contains the interventions related to indirect steering. In indirect steering, the actors influence each other; anticipating the relationships between actors, the existing division of means, the interaction rules and perceptions (Klijn et al., 1993).

The figure also contains a column with the assessment values (μ) used in the project. By means of these assessment values, it can be verified whether interventions were successful from the perspective of the initiators of the water plan. The assessment values are only part of the norms and values from the group of intellectual processes.

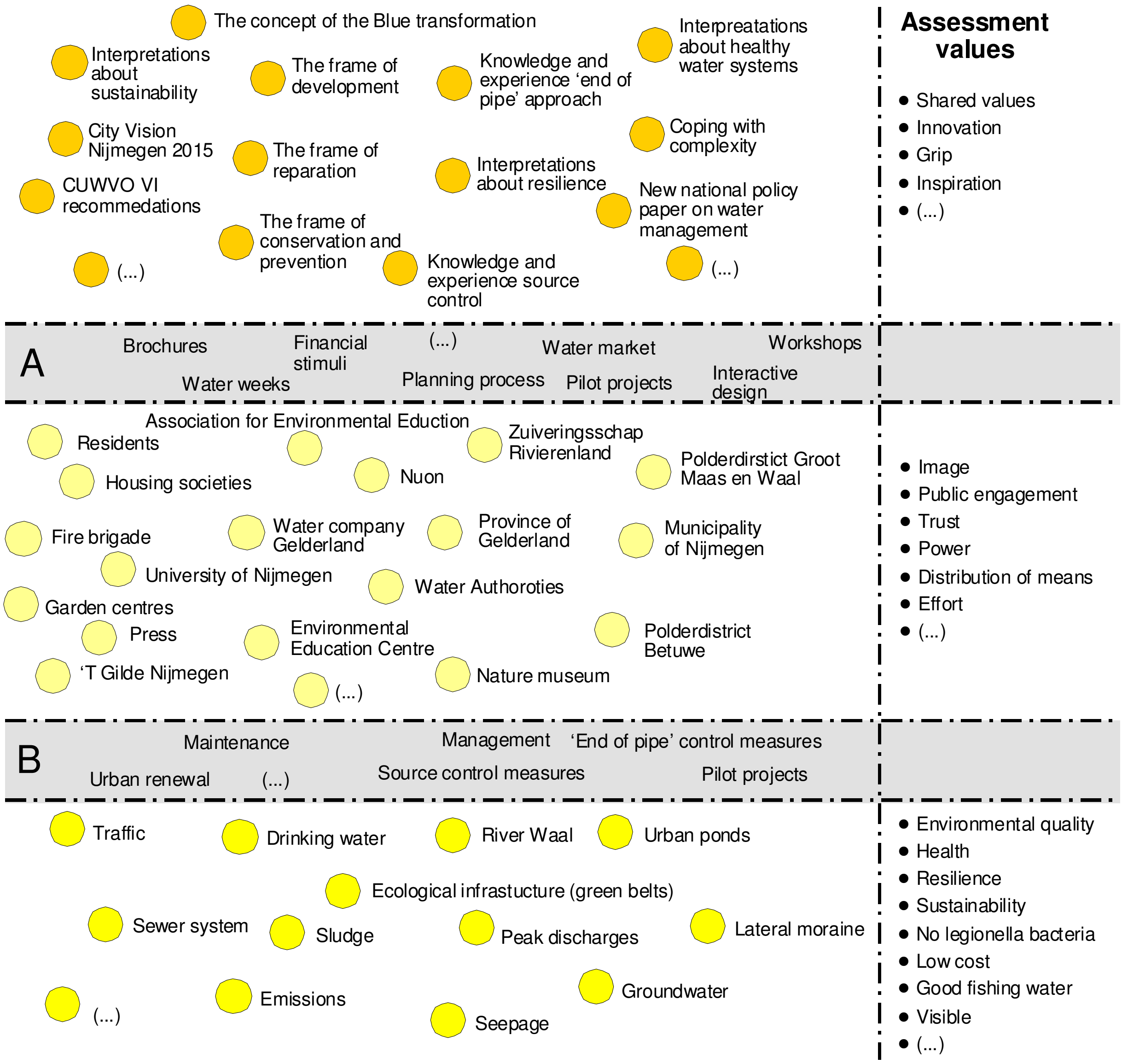


Figure 3.7. Agents in the Nijmegen water plan

The assessment values (μ) presented in Figure 3.7 are mostly described in Sections 3.2 up to and including 3.4. One additional assessment value was added. Next to the group of intellectual processes it says "shared norms and values". One of the characteristics of a network organisation is that different actors provide services to each other without any transaction costs (Fukuyama, 1999). This makes it important that actors within the same network trust each other – which was proven to be the case on several occasions during the pilot projects – and that they have shared norms and values. At the start of the planning process in Nijmegen only few norms and values were shared. Many residents, for example, experienced water "exclusively as something that comes out of the tap or causes nuisance when the roof gutter is leaking". Sharing norms and values on water management, therefore, can be seen as an assessment value with which to measure the success of the planning process.

3.5.2 Interaction

The agents in Figure 3.7 are related to each other. They influence each other. However, if all relations were mapped out, it would produce an unclear picture. In other words, the description of the processes is about finding the heart of the matter. Therefore, a selection of the agents has been made.
The relationship of the agents selected is presented in Figure 3.8. They have been presented similarly to the agents in the erosion problem in Flanders (see Figure 2.7). The arrows in the diagram present influence. The plus and minus signs present increases and decreases.

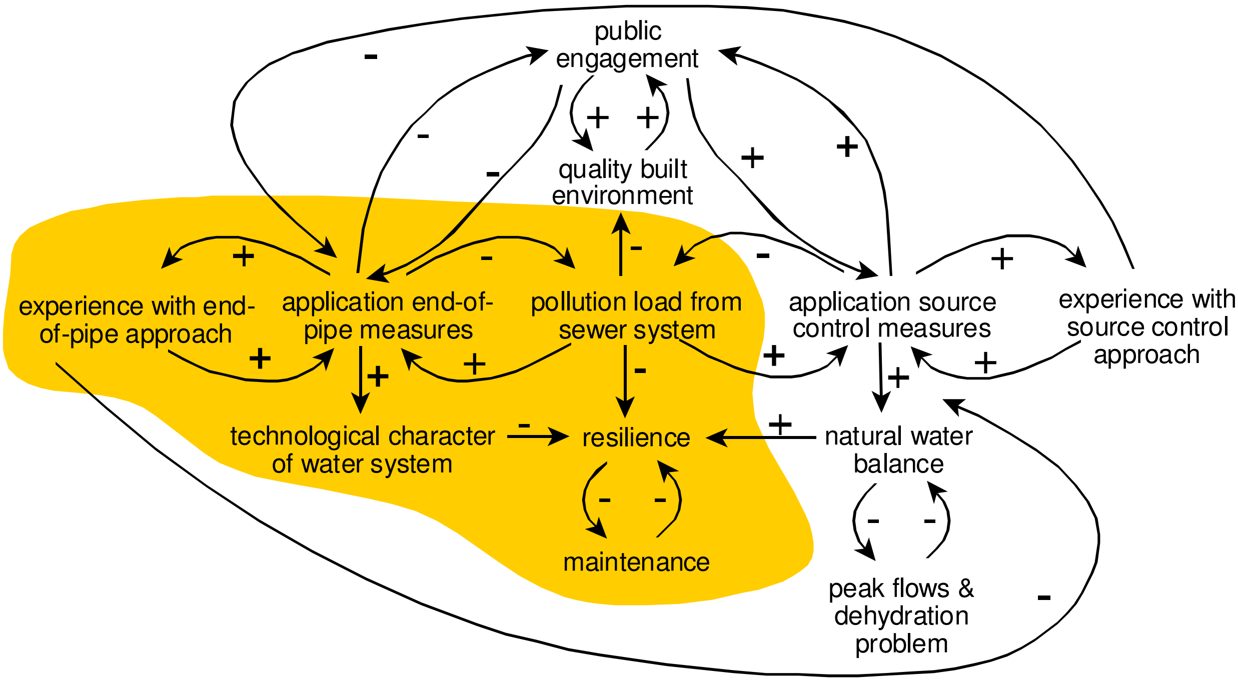


Figure 3.8. Interactions between agents forming the thread in the Nijmegen water plan.

The emissions from the sewer system take up a central position in Figure 3.8 because they were an important reason for starting the planning process in the first place. During heavy showers combined sewer overflows take place, which have an adverse effect on the water quality.
Contaminants also end up in the surface water via the sewer system in the parts of Nijmegen that have a separate sewer system instead of a combined system, as in the Lindenholt and Dukenburg estates on the west side of the Maas-Waal Canal,. Two approaches can be used to reduce emissions; the 'end of pipe' approach and the source control approach. It goes for both approaches that the more emissions, the more measures must be taken; and that the more measures taken, the greater the reduction of the emissions. When applying 'end of pipe' measures, knowledge and experience of the 'end of pipe' approach is increased. The techniques will have been tested and will be used more often as organisations will become more and more familiar with them. When emissions have to be reduced, the *uncertainties* of an 'end of pipe' approach are relatively small. Good materials are available, contractors are used to working with these materials, costs are easily estimated and the water quality manager accepts how the emission reduction is calculated.

A similar line of reasoning applies to the source control approach. When source control measures are frequently taken, knowledge and experience are increased and it becomes ever easier to take source control measures. However, experience in source control measures in the Netherlands, especially in existing urban areas, was limited at the start of the planning process for the Nijmegen water plan. The uncertainties were thus larger than with the ‘end of pipe’ approach.
In Figure 3.8, both approaches to emission reduction are related to the notion of resilience. By using ‘end of pipe’ techniques, the technological nature of the water system increases. Source control measures mostly increase the natural quality of the water system. A more source-oriented approach increases – according to national policy – the resilience of the water system. If stormwater from paved surfaces is infiltrated into the subsoil, it becomes cleaner and discharges more slowly into the surface water compared with discharging it through pipes. Peak discharges can thus be reduced and drought be combated at the same time.

Residents’ involvement is at the top of Figure 3.8. Residents have continuously played an important part in the planning process. The project team attempted to involve inhabitants of Nijmegen as much as possible in a number of pilot projects. In addition, there was much discussion about the role of the residents. Uncooperative residents can considerably limit the possibilities for taking source control measures, especially in the case of handling stormwater runoff from roofs. Residents’ opinions give direction to political and official actions. After all, a town primarily exists for the people. The quality of the living environment is an important factor here. The higher the quality of the living environment, the greater people’s attachment to this living environment; and the larger their commitment. This process reinforces itself, because committed people will sooner cooperate to maintain or increase the quality of the living environment.
Emissions from the sewer system decrease the quality of the living environment. For instance poor water quality decreases the positive perception and limits swimming, fish habitat and diversity.
The point of departure of Figure 3.8 is that ‘end of pipe’ measures diminish residents’ commitment because these measures do not require residents’ involvement; and it will fade away. The situation arises in which residents’ involvement is so small that the municipality and water boards are forced to take ‘end of pipe’ measures, as it were. In addition, since the eighties, the environment has more and more become the playground of professionals, keeping residents out. Achterhuis (1992) writes about the environmental specialist: “He seems, after all, to be the only one who can tell us about the state of the environment. While doing so, he preferably hides behind the objective requirements supposedly arising from his studies. Not he, but the environment says we are allowed less access in future. Our own sensory observations are completely insufficient to find out how the environment is doing. We can write off direct experience when it comes to the environment; we can no longer trust our own senses”. The possibilities for sensory observations with urban water management are decreasing anyway by laying underground facilities, hidden away from residents.
Taking source control measures offers possibilities to increase residents’ involvement, especially when the aesthetic value of water is increased. When residents are more involved, the chance of source control measures being successful is greater. In the ideal situation – a Utopia? – all inhabitants of Nijmegen will disconnect their own roofs and yards from the sewer system without expecting something in return from the municipality and water boards.

It is striking that the interactions described run crisscross through the three groups of processes (see also Figure 2.4). Social processes take up a central position here. People

influence intellectual agents and each other. They also influence the water chain, water system and surroundings.
It is also striking that the description of processes in coherence as shown in Figure 3.8 uncovers a view of desired and undesired processes. Figure 3.8 shows that residents' involvement is positive. Therefore, source control measures are also positive. This value judgement is a direct result of the *choice* of relations made visible.
Presenting agents and interactions between agents selectively may overlook interactions that do not contribute to a presupposed equality. This is popularly called the Bay of Pigs syndrome[10]. During the planning phase, this can be avoided by involving people with different views in the process.

3.5.3 Attractors

Processes can go through a stable pattern. The shaded area in Figure 3.8 shows this. At the start of the planning process, emission reduction was largely limited to 'end of pipe' measures, which led to more experience in this field, thus inhibiting the use of source control measures even more. Solutions were being chosen of a very technological nature. Aspects such as quality of the living environment and residents' involvement received little attention. This pattern, arising from a combination of negative and positive feedback, can be seen as an attractor. The processes develop towards an emission reduction, improving 'end of pipe' techniques along the way. It is a process of improving (functional) learning. Without any interventions aimed at innovative (substantial) learning, this process remains in the basin of attraction of 'end of pipe' measures for a long time. This can also be called a qwerty; the 'end of pipe' qwerty, which maintains itself in a stable way. To change to a different attractor is not easy, especially if the process is far away from the separatrix (see Section 2.7).

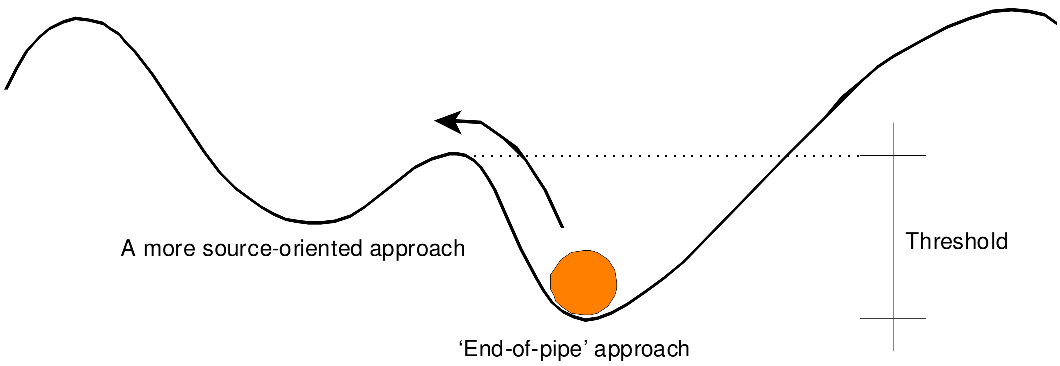


Figure 3.9. Marble diagram with two attractors.

This pattern of two attractors, an 'end of pipe' attractor and a source control attractor, is characteristic of the behaviour 'as a whole'. Not seeing this pattern may cause proposed measures in the water plan to be carried out inadequately or not at all. In order to effect an attractor change, a threshold must be overcome (see Figure 3.9). If source control measures are proposed, *resistance* against them arises. This is a natural mechanism, because without resistance, complex adaptive systems cannot display stable behaviour. The proposed measures

[10] This term refers to the unsuccessful invasion in the Bay of Pigs on Cuba on 17 April 1961 by about 1500 Cubans in exile, trained by the CIA, provided with weapons by the United States of America. In preparation for the invasion, the American government was so obsessed by the opportunities offered by it that they were no longer open to criticisms. Information about weaknesses in the plan was ignored.

result in structural adaptations (on all three levels). New knowledge is developed, actors are stimulated, the organisation is adapted, pilot setups are made, and much, much more. If these structural adaptations do not suffice and the process stays in the basin of attraction of the ambient attractor, the system is reorganised and the development towards a source control approach is stunted. The marble in the marble diagram will roll back. This is not necessarily a negative thing. During the planning process and the attempt to realise proposed measures, it may become clear that an 'end of pipe' approach has advantages previously unnoticed. As a consequence, 'end of pipe' techniques are opted for even more consciously.
It is also possible that a wide range of actors regret having failed to pursue the source control approach successfully and that the resistance against the change is viewed with irritation and thought irrational. Much depends on the partly conflicting values attributed by the various parties to the change and to the resistance.

3.5.4 The edge between order and chaos and crises

The change process in the realisation of the Nijmegen water plan can be characterised as a live process. Interventions were carried out that have effected a more source-oriented policy. In Nijmegen, this policy is not just described in the water plan, but it is alive and kicking for the actors involved. The policy and its implementation have much support.
The whole process can be described using the model of a complex adaptive system. The system behaviour is situated in the edge between order and chaos. At the start of the planning process, the source-oriented approach was not an essential – activated – part of this system. The planning process in Nijmegen was aimed at linking the source-oriented approach to the system, which involved various crises. Figure 3.10 presents the crises schematically.

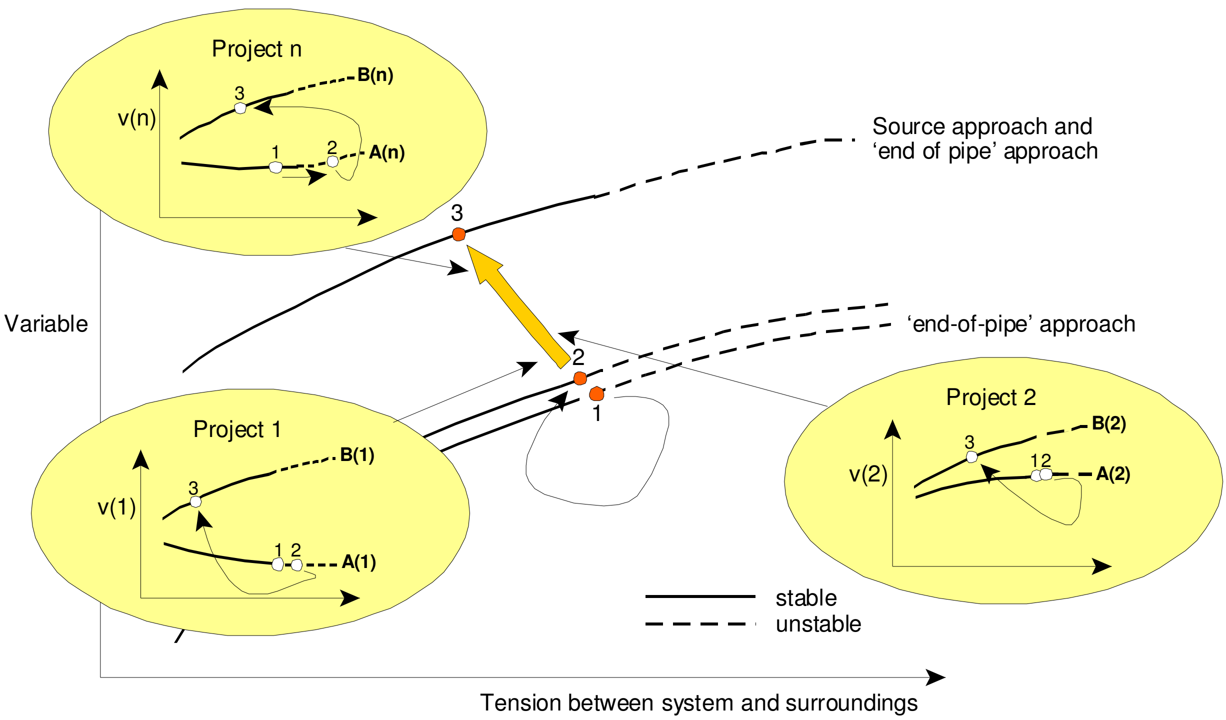


Figure 3.10. Course of the process on the scale of Nijmegen and the scale of pilot projects.

The distinction between different scale levels is essential in Figure 3.10. Two scale levels are presented; the scale level of all of Nijmegen and the scale level of the pilot projects (in a street, a neighbourhood or estate), because most crises occurred with the pilot projects. The crises described in Figure 3.10 occur when the tension between system and environment becomes too high. Rules are applied within the ensemble of water system, water chain and water actors, which result in a working method that gives rise to improper practice or matches the environment increasingly poorly because the environment changes. The more an environment changes while the rules remain constant, the higher the tension will rise.

At the scale level of Nijmegen, the process initiated in 1997 started in a crisis. This crisis mainly pertained to the soil scandal where contaminated soil was transported all over the place. Cost saving was the main consideration in this matter. Transporting the contaminated soil around was at odds with what was considered good. When it was discovered, it caused instability. Faith in politics diminished. At the start, the fierce reaction of the municipal council on the GRP also played a role. The combination of these events paved the way to drawing up a water plan. The image of the municipality in the field of the environment might be repaired and perhaps cheaper solutions could be found than the measures planned in the GRP to meet the requirements for emissions from sewer systems laid down by the water quality managers.

It was previously shown in Section 2.8 that when considering the structure of the system, the attention is mainly focused on rules, interactions between actors and between the actors and the water system and the water chain. Generally, when rules change, the structure of the agents also changes. These latter structural adaptations emerge from changing the rules.

In Nijmegen, the active rules were characteristic of the ‘end of pipe’ attractor. Examples are:

- If emission reduction is desired, this is best accomplished by taking measures in the sewer system or by constructing sewer settling basins.
- Departments can achieve sustainable development by optimising processes through their own tasks.
- Involving residents in projects in public space is not necessary and sometimes even undesirable. A limited involvement and provision of information will suffice.
- Good management is achieved by keeping the physical elements of a system in equilibrium as much as possible.

The above rules should not be taken too literally, because they have not been put in writing. They are not consciously described, but they form guidelines to the actions of actors involved in water management.

At the start of the process in 1997, these – and other – rules were under pressure. Promising alternatives for sewer settling basins presented themselves thanks to the integrated way of thinking that was going on in the Netherlands. It also became more and more clear that closer cooperation was necessary between different departments. Residents were growing more emancipated and were no longer accepting that all kinds of projects were being carried out in Nijmegen without the points of irritation being removed. The tension between system and environment was growing.

The planning process for the Nijmegen water plan took a real leap forward during the workshop on 11 June 1997 (point 2). During this workshop, the old regime of rules was discussed and the source-oriented approach was given a boost in the right direction. Initially, this led to a great deal of discussion, under some scepticism, but at the end of the day the participants showed much enthusiasm. Projects were named. In the period after 11 June 1997, the process of change continued. Around the middle of 2000, the actors involved felt that a critical point had been passed and that there was a new, stable, working environment.

In hindsight, there were no huge crises on the scale of Nijmegen during the process. The course from point 2 to point 3 in Figure 3.10 was comparatively gradual. There was a crisis during the discussion between partners – the interruption in Figure 3.3 – and changes in the Municipal Executive also caused some commotion. However, the transition from 'end of pipe' attractor to source control attractor went relatively smoothly. The real crises were experienced at the level of the pilot projects. A great deal went wrong and some periods were experienced as being chaotic. The process of the water plan was being carried by these partial processes, as it were.

For instance, in the case of the project in the Biezenstraat, the presentation of the plans for renewal was the start of a real crisis. There was obvious tension between how the municipality had operated in the past and how this was experienced by residents. This tension was released during the presentation and yielded fierce reactions fed by emotions. The event was used to make house calls afterwards to talk to the residents, during which promises were made and kept. Thanks to this, residents' faith grew and the plans for disconnecting paved surfaces in the public space and on private land could be carried out.

The regime of rules changed during the planning process. Again, they have not been put in writing, but the rules have roughly changed to:

- If emission reduction is desired, this is best accomplished by taking source control measures, changing the sewer system or by constructing sewer settling basins.
- Departments must primarily perform the works that go with their own tasks. However, they should look beyond these tasks to check whether cooperation will realise their own and other goals – or joint goals.
- Involving residents in projects in public space is desirable and results in more appreciation. This calls for active participation of residents.
- Good management is achieved by looking at the opportunities for desired changes in addition to keeping the physical elements in condition. It is a combination of maintaining, developing, preventing and repairing.

These rules differ greatly from the old rules and have huge consequences for the way in which actors approach each other and how the water partners and other actors deal with water systems and water chains.

The pattern of the crises is always the same. The crisis occurs when the rules within the system or subsystem no longer match the views – assessment values – of the environment. Whether it is a director who has soil transported around with a view to saving costs as the main objective, or municipal employees who take little account of residents' wishes in their planned activities, the tension between the rules and the environment increases. Sticking exclusively to 'end of pipe' measures for the reduction of emissions is also at odds with the broader – more integrated – views on water management.
An external factor – a reporter writing an article or a workshop about alternatives to 'end of pipe' measures – may push the system or subsystem over the edge so that it becomes unstable. Temporarily, it will then be even more open to external influences. This is when adaptation occurs in a dynamic process. In other words, the rules are adapted.

3.6 Steering and complexity

From the start of the planning process in Nijmegen steering was done on the basis of insights obtained from the science of complexity, in combination with experience from earlier projects. In other words, complexity was not combated but made manageable. The concluding part of this chapter briefly discusses a few characteristics of this way of handling matters. Chapter 5, which describes Interactive Implementation, will discuss it in more detail. The building blocks for steering are ordered based on the three field observations from Chapter 1.

3.6.1 From plans to implementation

Working in parallel
From the start, a plan was aimed for that would not end up at the back of a desk drawer. Measures named in the water plan must actually be carried out. The main precondition to achieve this was working in parallel. The activities of planning, design, implementation and maintenance were not carried out consecutively, but in parallel to each other. People worked on the plan for a period of four years, making and implementing designs, with much interaction with those responsible for maintenance. In parallel to this, the national policy also changed. In 1997, the source-oriented approach was not yet policy, and the accent was clearly on water quality and ecology. In 2002, the source-oriented approach had become official policy and the accent was on slowing down discharge and combating water nuisance. The latter was a direct result of the many floods in the second half of the nineties. By working in parallel, the complexity of the planning process was increased. More chaos was invited. This was viewed as an important precondition to change. An important point of departure with the parallel approach is that the answers to many questions can only partly be found on paper, with abstract models. In practice, out there where it is all happening, the answers unfold. People with practical experience make the difference between plan and implementation. People in the field do not only learn from the makers of plans, but also the other way around. They learn from each other. By having processes run in parallel with each other, they build experience together.

Switching between scales
In complex adaptive systems, processes happen at many organisational levels (aggregation levels). The nature of the processes can differ greatly, which was the case in the Nijmegen water plan. There are three scale levels in the process: (1) municipality and region, (2) estate or neighbourhood and (3) street, home or company. Already other processes are going on and other actors are active on each scale level. Other questions were also asked. On the smallest scale level individuals were disconnecting their house or using alternative water sources for their company. Any questions were of a practical and technical nature. Each activity had its own context. On the middle scale level, concrete ideas were being developed and there was much interaction.
Characteristic of the process of the Nijmegen water plan was that the three scale levels ran in parallel to each other, switching between scales. When individuals were sawing their downpipes and discussions with residents were held in community centres on the development of their neighbourhood, the municipality was working on their water policy at the same time. The switching between scales increased the complexity of the process.

Time perception
Complex adaptive systems consist of a whole set of processes with both positive and negative feedback. Mainly as a result of the positive feedback, history does not fade away. Memories are sustained and can – especially during a process in a community centre, like in the Biezenstraat – suddenly become alive again. The past cannot be neglected. This was actively taken into account in the process of the Nijmegen water plan – partly by learning it the hard

way. The previous history of the planning process strongly determined the course of the planning period.
In complex systems, time is the bearer of changes. There is a continuous process of change, in which not all matters can be exacted. Processes simply need the time that they need. Forcing matters hardly helps or is no use at all. Therefore, ample time was taken to draw up the water plan. It has taken four years and this time was really needed.
Another important issue in time perception is that each moment is not necessarily suitable for each activity. The survival landscape continuously moves and calls for acting at *the right moment*. In his book Ethics, Aristotle calls this *kairos*. This term manifests itself at the start of the planning process. Spring of 1997 was the right time to start the process, because of the commotion about the soil scandal and the GRP. Acting is most effective near a critical point.

An eye on attractors
The objective in Nijmegen was not so much in writing a water plan, but going through the actual transition; an attractor change. Attention was mainly focused on the process of change towards a more source-oriented approach. People were aware of the fact that the attractor change could only be realised if the activities together had the critical mass to break through the separatrix; in other words, to get over the bump in the marble diagram. The entire planning process was seen as navigating through a survival landscape with many differences in opinion about good water management.
Afterwards, it was concluded that even the idea of "coping with complexity" was an important attractor change in the group of intellectual processes. Viewing 'the whole' as a complex adaptive system made attractors visible. The awareness that thresholds had to be overcome was of essential importance to the process. It will keep the parties involved from becoming discouraged too soon.

Using crises
Crises are a valuable part of complex adaptive systems. They characterise moments of temporary instability. The essence is that when a crisis occurs, the moment must be seized. Energy is released and it becomes possible to steer effectively. Many crises took place within the various pilot projects. It is important to know that conflicts should not be avoided. Beating around the bush can only increase tension between system and environment and thus cause a process to fail completely. It is better to deal with them straight away. A hearty conflict will clear the air.
Using crises calls for *anticipation*. If a crisis takes place and a group of involved actors is seeking new stability, it is good to have a plan ready. People listen better at such a time and the situation offers good opportunities to actually carry out the plan.

Anchoring
A healthy process is characterised by a combination of static and dynamic qualities. Up until now in this book attention has mainly been aimed at the dynamic quality. How can structures change? However, the static quality is also important. The results must be anchored securely. Many examples of this can be found in the process around the Nijmegen water plan. Here are three: Firstly, the tangible changes effected by the pilot projects are clear anchors. Once implemented, something will not simply fall back into its original state. Secondly, on 27 November 1998 a declaration of intent was signed by the eight water partners. This is merely a piece of paper, but it does record the result of the negotiation process. The fact that eight children signed a declaration of intent at the same time is also an important anchor. Each year, the children, together with the alderman, look at what has been achieved in the practice of water management. Finally, the water plan itself, is an anchor which offers guidelines to the

many people who are involved in the development and management of the living environment in Nijmegen.

3.6.2 Interaction between water and society

Open process

In the interaction between water and society, the interaction between system and context takes up a central position (see Figure 1.2). In a complex adaptive system, changes in the context – the environment – result in changes to the system (see Section 2.2). The system adapts to its environment.

In Nijmegen, attention is primarily focused on coping with stormwater. According to a group of people involved, the present way of handling stormwater – the structure of rules – no longer matches their views on good water management. Mixing stormwater with wastewater in a mixed sewer system contributes to drought, higher peak discharges and bad water quality. They wanted to change the way urban stormwater was being handled. This requires an open process, without fixed results. This is a precondition.

But it creates a paradox. In order to go through a process creating support, the parties involved should be able to participate. However, it is not as if people are looking forward to handling stormwater differently. Many will even be against it. Perseverance is required to realise the ideas anyway. This is a paradox, an apparent contradiction, because being open to others' ideas and persevering go hand in hand. This is the main feature of adapting. Adapting is the *middle path,* between too open and too rigid. Results are not achieved when a process is too open and everyone can have their say in everything. The process will then end up "any which way the wind blows". However, doggedly pursuing ideas and not being sensitive to what others think will also not lead to a good result.

In Nijmegen, the first phase was pretty closed. A vision was drawn up with a limited group. The ideas from the vision were then put into many pilot projects. During the pilot projects, there was much interaction with residents and companies, which led to adaptations to the ideas. During the process of four years, it became clear what was feasible and acceptable. This is – as an emerging result – anchored in the water plan.

Coping with resistance

If a group of people wants to change something in a system or the system, this does not happen all by itself. There is resistance, both within the system and in the context. As stated in Section 3.5.3, resistance is a healthy characteristic of a complex adaptive system. Without resistance it becomes unstable. There is an analogy with the immune system of the human body. If elements alien to the system – possibly pathogens – enter the system the body tries to eliminate them. This is the same with new ideas about dealing with water. They are first considered as alien to the system. It is possible that the new ideas are simply bad and will only cause damage and should indeed be rejected. It is also possible that the ideas are good and will result in real improvements. In this case, the ideas will be modified, revised and rearranged because of the resistance. They will grow. Eventually they will be accepted.

This process, experienced in the planning process in Nijmegen, makes it clear that resistance is valuable and that it is worthwhile to cherish it. Eventually, resistance will ensure that the newly obtained structure remains stable and is anchored.

Values of water

If water professionals want to do something with water, they will use arguments. The surface water must be cleaner, the groundwater levels must be higher, biodiversity should increase or

damage caused by floods should decrease. All of these arguments were dealt with in Nijmegen, in different projects. They are highly self-referential, referring to the water system and the water chain and arise from the water professionals' official task. The trick is to make more values of water visible. Values that mean something to the 'normal' residents of Nijmegen. As long as the number of values is limited, there is a unilateral dependency. For the realisation of their ideas, water professionals are unilaterally dependent on residents' and companies' cooperation.
Discussion with the parties involved on the various pilot projects was not limited to water. Many aspects were introduced, such as traffic problems, social security, image of a neighbourhood and many more. Water was given a place in the whole of the aspects. This increased the complexity of the projects, creating mutual dependency.

Positive feedback
The process of the Nijmegen water plan was not only aimed at combating problems (negative feedback) but also at stimulating desired developments (positive feedback), such as increasing the involvement of residents and companies in their immediate living environment. A balance was consciously sought, as can be seen from Table 3.1. A good example of stimulation is the financial compensation for residents who disconnected their roofs from the sewer. Having an eye for positive feedback is of great importance to the process, because it both determines the rise of attractors – qwerties – and is the basis for attractor changes in complex adaptive systems. Positive feedback reinforces the process.

3.6.3 Coping with models

Reflecting on patterns
The role of deterministic models supported the process of developing the Nijmegen water plan. Lindblom and Woodhouse's (1993) warning against analysis taking the place of decision-making (see Section 1.4) has not been a problem in Nijmegen. Defined measures are not based on analysis, but they reinforce the arguments for choosing certain measures. During the process, several studies were conducted. The results have had the following impact:

- Demythologizing information. A great deal of information on complex issues is often incorrect or hearsay; the so-called urban legends. Thorough quantitative research can negate this information – which has a disturbing effect on the process. For instance, in the Biezenstraat, "word" was getting round that basements would flood with water if stormwater was infiltrated into the subsoil.
- Describing cause-effect relationships with their accompanying uncertainties. In order to determine measures, insight into cause-effect relationships is required. Questions must be answered such as: "How much paved surface must be disconnected from the sewer to arrive at an emission reduction of 50%?". By mapping uncertainties in these relations it also becomes clear what the possibilities are to reduce these by further measurements or further modelling.
- Making local optima visible. It is possible to conduct optimisation studies in areas of the survival landscape that are relatively calm. Kellert (1993) calls these areas *local determinism*. For instance, an optimisation study was conducted in Nijmegen into gearing the sewer system and treatment towards each other. After all, emissions do not only occur from combined sewer overflows. The SWTP effluent also causes unwanted substances to end up in the surface water. The possibilities for reducing the total emission by means of the optimum combination of measures in the sewer system and measures at the SWTP were explored.

During the planning process, patterns were reflected upon to build on steering actions in "the whole" of processes. These patterns were derived from the insights from the science of complexity. An orientation was made and a course was set between order and chaos using the pattern of attractors and repulsors. It was accepted that crises can display the pattern of self-organised criticality and can therefore never be completely suppressed.

Steering on experience

Progress was achieved by *doing*, in pilot projects, and not by thinking every detail through. Many questions can only be answered during or after the implementation. An important aspect is that complex adaptive systems can produce chaotic behaviour, which makes it completely *impossible* to think every detail through in advance. Uncertainties will always remain. These uncertainties are solved in practice, by people with experience. Experienced people always know more than they can put into words (Schön, 1991). This is not a weak point, but a strong point. They can read the landscape, sense what is going on and they know what they are dealing with. The whole of impressions moves them to action. Because they are much in the field, they are able to make connections instinctively and take the right decisions. Their insights transcend water. They know the people in the neighbourhood and know where *feasible* and *acceptable* can meet. They build trust. All this together constitutes experience. Experienced people have undergone a long learning process. With learning processes, sometimes a distinction is made between explicit and implicit knowledge (Capra, 2002; Van Twuiver, 2003). We get explicit knowledge from books, courses and computer models. This knowledge is reproducible, based on rules. We get implicit knowledge from experience, from life, and it is less simple to pass on. Much implicit knowledge is present in experienced employees of a water board or a municipality, but also in the residents involved, walkers and the angler who casts his float at the bridge every Saturday morning.

We waste much implicit knowledge in our society. And this is a point of concern. Capturing implicit knowledge yields answers to the nonlinear and unpredictable nature of complex environmental issues. Implicit knowledge provides answers to (?) the interdependence of water and society. Implicit knowledge was given due attention in the Nijmegen water plan.

Coping with uncertainties

In the delivery of the Nijmegen water plan, concepts were used that are not precisely defined; concepts such as sustainable, resilient, healthy and the quality of the living environment. No attempt was made to define these precisely, but they did play an important role. Different people have different views on these concepts, which may even conflict. By reflecting on these concepts from practice a shared picture will gradually emerge. By looking at an issue from different angles, ideas will continuously be adapted and innovative ideas will be gained. The result is a construction. It is never finished, but people are satisfied at a given moment, or, better still, a result has been obtained of which all parties are proud. Stacey (1996) says "the edge of chaos" at which stable behaviour becomes unstable behaviour is especially important in the creative processes. That is the critical point. That is where the system has most freedom and adaptive power.

Characteristic of this process is the introduction and reduction of uncertainties while the middle path is taken. It characterises the way in which operating on the edge between order and chaos was done in the planning process in Nijmegen. Many people hate uncertainties. Uncertainties are a source of unrest, especially when operating in a network in which the parties involved do not really trust each other. On the other hand, without uncertainties it is not possible to arrive at innovation. New is alien and uncertain. In the planning process the middle path between too much and too little uncertainty was taken consciously. This middle path was partly found by mapping out uncertainties using models and partly by reflecting on patterns in practice.

4 Control and containment

4.1 The control system as a reference model

The process carried out to develop the Nijmegen water plan makes clear that it is worthwhile to make complexity manageable instead of fighting it. Many actions that are related to the water plan resulted in an increase of the complexity of the process. This has changed people's ideas about water. In this chapter, we take a step back to consider what it means to reduce complexity. How does it work and why is it done? An approach aimed at checking and controlling processes is introduced. This approach is called the *control system approach*. It appears that this approach still takes up a prominent position in water management. This approach dismantles the reality as it presents itself to us – and which we sometimes hardly understand – and reduces it to a collection of control systems. This reduces complexity considerably and creates something we can fathom. However, for the sake of being complete, the different control systems are linked to each other, creating *complicatedness*. This complicatedness is a barrier to progress and thus a reason why plans do not get implemented. It appears difficult to tap into the value of the approach in a broad social field. Computer models are used to convince people. The introduction to this book discussed the distinction between complexity and complicatedness. With the control system approach, first complexity is reduced and then complicatedness is built. This 'detour' does not make it easier. However, the control system approach is valuable.

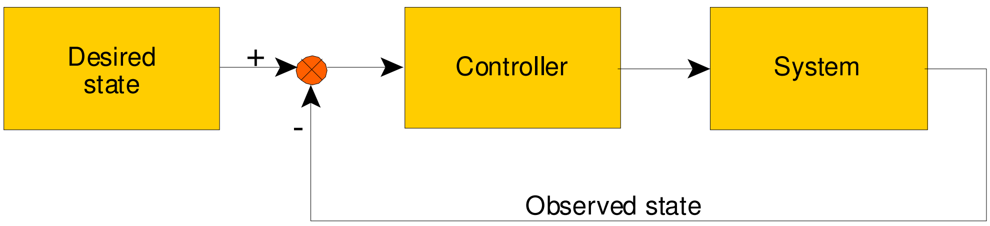


Figure 4.1. The principle of a control system with negative feedback.

What is a control system? The control system provides a model for checking and controlling processes. This is done using negative feedback (see Figure 4.1). In a control system, a system with variables is taken into consideration. In combination, these system variables describe the state of the system. This state must comply with a formulated *desired state*. By observing the system, the state of the system can be determined. This *observed state* is compared with the desired state by deducting the observed state from the desired state. If the observed state and the desired state are the same, the controller is fed with "0". If they are different, the controller is activated. The controller will then influence the system and make sure that the observed state meets the desired state.

For example, the system can be a polder with (outlet) ditches. The state of the system is then described by the water level at a location in the polder. If the water level is too high there may be water damage or boats cannot pass under bridges. If it is too low, there may be dehydration damage and fish can get into trouble. The water board therefore sets a target level. This target level is the desired value for the water level. Actions are taken both when the water levels are higher and lower than the target level. The pumps are switched on or water is let in. The larger the difference between the target level and the water level, the more intensive the action. This is how the water level is checked and controlled.

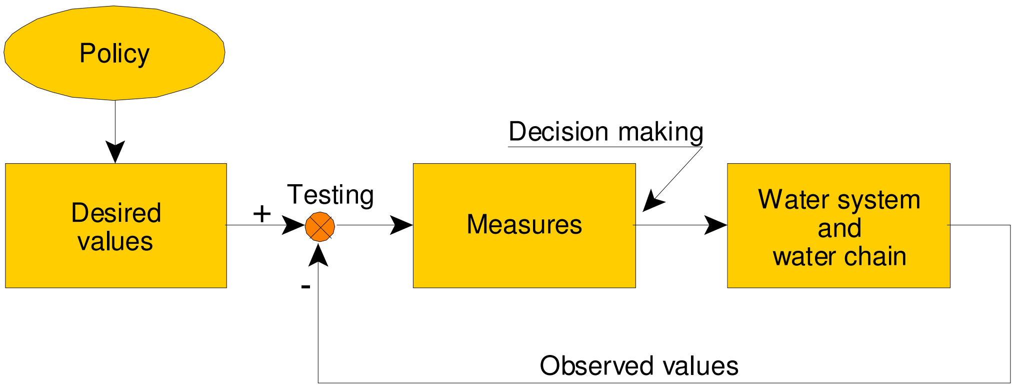


Figure 4.2. The control system as a model for planning.

The control model is also used in planning. This is presented in Figure 4.2. This figure presents the working method for composing a set of measures – in a plan – for the benefit of the functioning of the water system. This means that the condition of the water system matches the desired state. This desired state is described by the desired values (assessment values). The water system and water chain are observed, looking at water levels, groundwater levels, fluxes, ion compositions, emissions, species and quantities of flora and fauna, and much more. There are many possibilities. The observed values are compared with the desired values, which is called *testing*. If the observed values do not match the desired values, – that is, the observed values are worse – this is a bottleneck. Packages of measures are drawn up to solve the bottlenecks. These measures are described in the plan. After making decisions on the measures, they are carried out. It is expected that the measures to be taken will cause the observed values to match the desired values more and more over the course of time. This will be verified by assessment. Given the fact that there may be many uncertainties in the measures – both with regard to effect and support – the planning process is repeated after a while; after all, the process is a cycle. New insights arise which demand adaptation of the plan. The desired values may have changed in the mean time. For instance, standards may have become stricter, or a new policy may have been introduced.

4.2 Integrated planning

There are many variables that need steering in integrated issues. If n variables are steered (in other words, n observed values and n desired values), there are also n control systems. Figure 4.3 makes this clear.

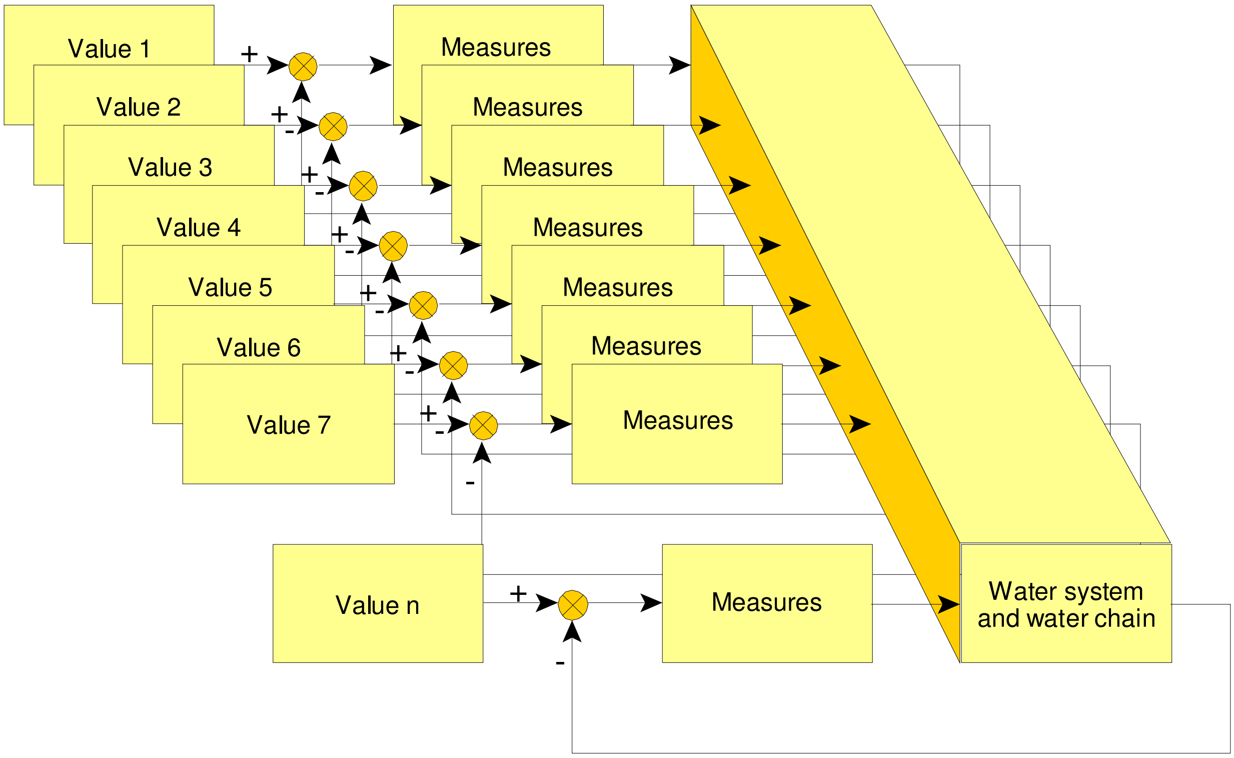


Figure 4.3. There are many control systems alongside each other in integrated issues. Complicatedness is emerging.

The working method in integrated planning at a regional or urban level is usually as follows: first, the desired values are derived so as to define them as goals. As the coherence with other fields of policy is also important in integrated water management, plans for the environment, spatial planning and landscaping are also considered. The water system is being observed. Observations are tested against the goals, yielding insight into the seriousness and size of a given problem. Measures are formulated in order to solve the identified bottlenecks. These measures are not taken separately, but together. That is where the power lies of an integrated approach. There are various techniques for achieving coherence. Different combinations of measures – variants – are usually compared, for example by using a technique for a multi-criteria analysis. Or by using optimisation techniques or carrying out risk analyses. Calculation models are used to determine the effects of a combination of measures.

Whichever techniques are used, they can all be traced back to the basis of utilitarism (Leijen, 1992). The coherent combination of measures should yield a maximum *useful* effect. A package of measures with a high efficiency (much effect against little cost), with much certainty, with results in the short term and which is favourable for many actors involved – in other words, with much support – is preferred over a package of measures that has these properties to a lesser extent.

The mutual comparison of measures is not solely aimed at determining which measures will and will not be carried out. The comparison may also be needed to determine an order of execution. There may be bottlenecks that require a quick execution of measures and there may be less acute bottlenecks. By relating the effectiveness of measures to the seriousness and extent of bottlenecks, a basis is created for drawing up priorities.

The most favourable package of measures is officially determined and then implemented. However, support must be obtained for a number of measures. In part, support can be created by the interaction within the planning process, but resistance may arise during the execution. After decision-making, information should be distributed effectively. If groups of actors do not cooperate voluntarily, legal action may be taken.

It will be regularly verified whether upon execution of measures, the observed values increasingly match the desired values, or whether the objectives are being attained. From the results of the verification the process is repeated after some time – usually at an interval of several years.

The control system offers clarity. However, it becomes less clear due to the increasing integratedness. The awareness that different processes with their own dynamics are happening at many scale levels, which are all interwoven, makes it difficult to adhere to clarity. Complicatedness is rising.

4.3 Control system approaches in practice

Looking at water plans, you will notice that the control system approach is often at the heart of the planning process. The approach can also be clearly recognized in the working method to be followed according to the European Water Framework Directive (EU Council, 1999). This framework directive stipulates that a *basin management plan* must be drawn up for all catchment areas. Because many catchment basins cross country borders, water managers from many European countries will have to work together so that measures upstream and downstream in a river are in the right proportions to each other. The working method for planning proposed in the framework directive is as follows:

1. Setting goals ("sound ecological condition")
2. Testing (colour chart)
3. Programmes of measures
4. Optimisation
5. Creating support
6. Execution.

The water managers must start by setting goals. Together, they must decide what a "sound ecological condition" is for the river involved and its surface waters. The current situation must be tested against this decision. This test is done with the aid of GIS, so that maps can be drawn up of the results of the test. If the current state matches a sound ecological condition, the area is shaded blue. If there is absolutely no sound ecological condition, the area is shaded red. Intermediate areas are shaded green, yellow and orange. Subsequently, measures are introduced in programmes formulated to tackle the red areas which have the highest priority. The measures are optimised and put into the basin management plan. This plan has to be ready in 2009. The ecological condition described in the plan should be efficiently reached in 2015.

The framework directive does not pay a great deal of attention as to how to create support. It does, however, state that when actors do not voluntarily work on realising the goals, the European member states should develop tools to enforce cooperation. Article 23 of the European Water Framework Directive says: "Member States shall determine penalties applicable to breaches of the national provisions adopted pursuant to this Directive. The penalties thus provided for shall be effective, proportionate and dissuasive."

The control system approach was also recognizable in the Nijmegen water plan. This approach matches the rules applicable within the ‘end of pipe’ attractor (see Section 3.5.3). In the initial phase of the process of the Nijmegen water plan, water management in the existing town was considered rather limited. The control system could clearly be recognized (see Figure 4.4).

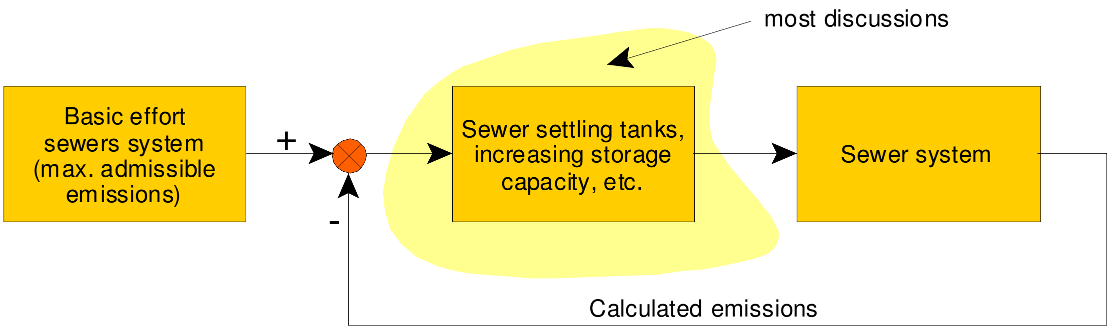


Figure 4.4. The control system of the emission reduction.

The reduction of the waste emissions from the sewer system to the surface water held a central position. The so-called “basic effort” had to be achieved. This basic effort roughly means that the emissions from the Dutch sewer systems must be reduced to 50% of the emissions of 1985. This basic effort was not debatable. Discussions mainly pertained to which combination of measures was the best.

4.4 Characterisation of the control system approach

Prigogine and Stengers (1985) call the approach described above the equilibrium approach. In this approach, one desired state of equilibrium is defined. It is attempted to match the actual state to the desired state of equilibrium. In the desired state of equilibrium, standards – the goals – are being met and this is therefore an ideal state. This ideal state must be effected in the most efficient way and subsequently maintained.

Testing will provide insight as to how far the current state is removed from the ideal state of equilibrium, while tacitly assuming linear dynamics. It is assumed that the further the current state is removed from the ideal equilibrium, the greater the bottleneck. It is also assumed that the more intensive the remedial measures are that are taken, the greater the effectiveness.

4.5 From plans to implementation

The control system approach clearly has its charm, but it also has its limitations. The rest of this chapter will verify these limitations and the role they play in the three field observations that are the thread of this book. Sometimes a caricature will be drawn of the control system approach. Certain properties will be exaggerated to outline the limitations more clearly. Subtleties will be introduced later, when it has become clear that the practice of integrated water management can benefit from both control systems and complex adaptive systems. It is good practice to reduce complexity now and then.

4.5.1 Serial approach

Why are plans not executed? An important explanation can be found in the fact that many professionals rigidly maintain the consecutiveness of activities within a process. This is a logical consequence of the control system approach, which involves a chain of policy, planning, design, implementation and maintenance (see Figure 4.5). This chain offers order. Its clear organisation contributes to the reduction of complexity.

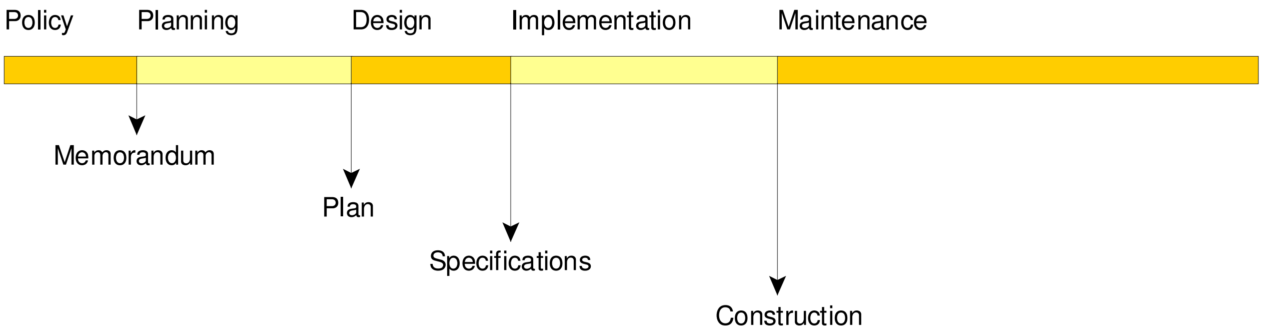


Figure 4.5. Standard phasing of a project (serial approach).

Policies are formulated at the national or European level,. These policies are laid down in memoranda, regulations or in directives. These formulated policies are the starting point for planning processes and goals. The goals describe the desired values for the control system approach. Packages of measures are composed in the planning process that aims at matching the observed state to the desired state efficiently and effectively. This is mostly done through interaction so that there is a great deal of support for the measures to be taken (see for instance Van Rooy, 1997). Upon decision-making, designs are drawn up and measures carried out. The results of the measures are left in the hands of those responsible for maintenance, who make sure that the state of the improved system is maintained, in equilibrium.

This serial approach is a strong concept, and is also an adequate tool for relatively simple processes. Simple, meaning linear, predictable and not too dependent on the context. The approach will fail in complex projects, because the complexity is overlooked. Parties involved are taken by surprise by the nonlinear dynamics and become discouraged. The practice is wilful and good intentions evaporate.
It is clear that the various actors involved in the individual activities of the chain described above are different. The people who draw up policies are different from the people who make plans. The people who make plans are usually not the same people who are responsible for the design, implementation and management. After each activity in the chain, a new group of people takes over the baton. A lot can go wrong here.

People who draw up policies give their ideas to the field workers when their memorandum has been laid down. They often fear – and rightly so – that their ideas will not be understood correctly in the field. They are not able to completely control the effects. It often happens that they set up a subsidy scheme to stimulate desired developments. This way, they can also tighten their hold on the process by setting conditions for the subsidy. The result is often that these subsidies restrict the process – like the straitjacket of a linear process – which often inhibits developments rather than stimulates them. Permits also often have a similar effect.

Project planners have the seemingly impossible task to compose packages of desired measures that cater for all uncertainties that may occur in practice. Certainties are being aimed for because when a planner completes a plan, others will take it from there. The result is that many supporting studies are carried out – mostly model studies – to be certain that the chosen solutions are indeed the best ones. This is why the planning process takes so long. People involved become impatient and suspicious. Despite the interaction in the planning process, residents and companies feel that matters are being decided in 'back rooms'. Support will then erode.
Decision-making is a sticky process, because financing measures that are partly invisible to people living in the area is hard. A remarkable phenomenon in this is that project planners aim for completeness and that they want to reach all water management goals within the planning period. This often results in costs that are too high and little political assent. Another retardant. Regularly, a plan is outdated before it is ready.

In the engineering world, it is usually the case that the people who draw up the designs are different from those who produced the plan. The result is that many subtleties from the planning phase are not translated into the design. This only becomes visible when implementation has started. The remark "this is not what we intended" is a common one from people who were interactively involved in the planning. Designers often draw up specifications without much time for reflection. They only have limited access to the abstract world of policy and planning. They are focused on the tender. They translate from abstract to concrete, but the significance of things is often beyond them.
The designs are used to apply for subsidies and permits. When these have been granted, nearly all elbowroom has been taken away for the rest of the chain. This makes it really hard for the people in the implementation stage to be creative. They have to stick to the rules and the rules are becoming stricter. A supervisor may discover during implementation that certain things were forgotten during the planning phase and the design phase. It can also become clear that matters could have been designed smarter – cheaper – or that changing circumstances have rendered a certain construction redundant. In spite of this, the design is carried out as earlier agreed, because otherwise the subsidies are lost or the permit withdrawn. This is frustrating to people involved in the execution, especially when they are creative and like to innovate. They are the ones who are faced with the complaints of residents who can see that matters are being handled illogically. They are the ones visible out there in the field, while the people at the start of the chain can hide in their offices.

Finally, the maintainer of the public space will be handed over the job upon completion. Often it turns out that the planning phase and the design phase have not adequately taken the maintenance aspects into account. Many objects are difficult to manage. Plus, cutbacks in the design often result in higher costs in maintenance. But the budget for maintenance has not been adapted to any cutbacks in the design. The result is that maintenance can only be carried out at a lesser level of quality than desirable. This is a matter of concern, because over the entire useful economic life of many civil engineering artefacts 20% of the costs are spent on their creation and 80% on their maintenance. Not taking maintenance aspects thoroughly into account is really a waste of money.
Those responsible for maintenance also have relatively little elbowroom. They have to keep the state of the system in equilibrium in a standardised way. This is called rational management. Managing activities are planned by means of a computer programme that determines priorities by comparing observed and desired states. In other words; a control system approach. Residents, however, often have other priorities. Maintenance is done in places where they do not think it necessary and nothing is done about issues they have been

complaining about for years. This is often the reason why those responsible for maintenance receive little appreciation.

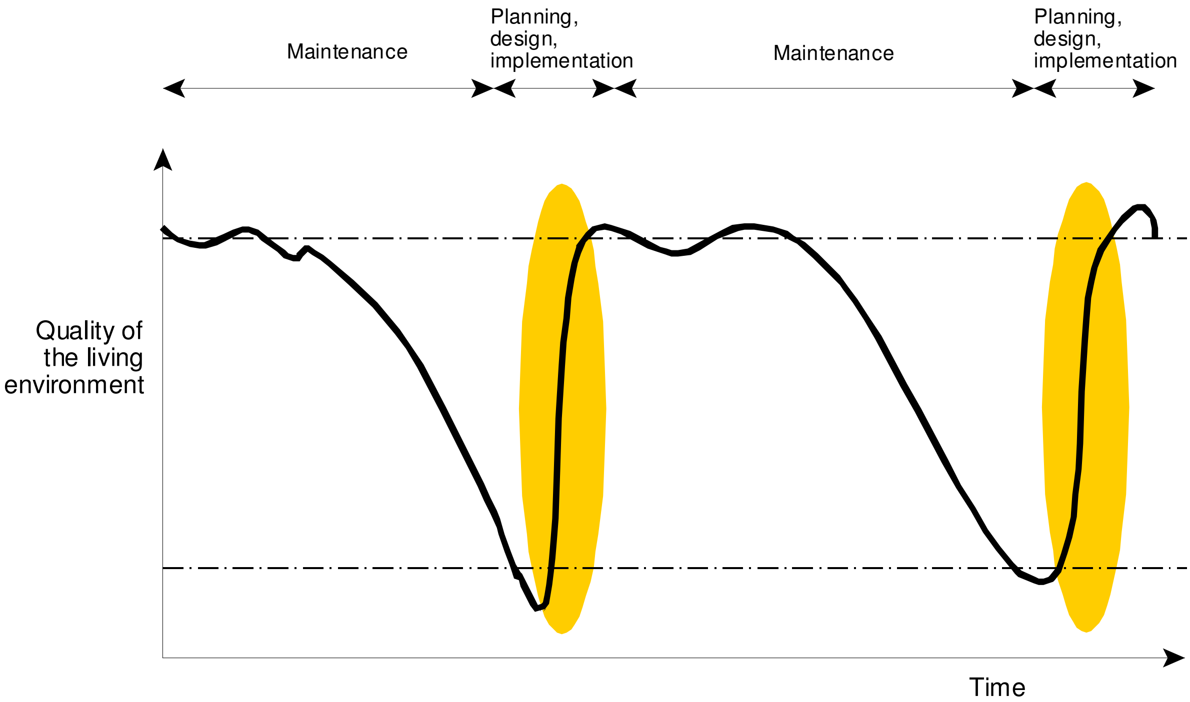


Figure 4.6. The yoyo effect in the quality of the living environment.

In many areas, the serial approach creates the pattern presented in Figure 4.6. In a relatively short time, a process is started of planning, design and implementation, if necessary. Then, the new situation is presented to those responsible for maintenance who try to maintain it as well as possible. However, the world is changing and the water system does not adapt adequately. After a while, adaptation is required. For example, many brooks in the Netherlands were straightened – because it was too wet – and are now being made to meander again, so as to increase the scenic value and slow down the water discharge. The pattern in Figure 4.6 can most strongly be recognized in residential areas, especially in those with current urban renewal. The quality of the living environment in these is slowly eroding.
When the problems are large and much priority is given to their solutions, the process of planning, design and implementation is started again, based on current policies. These fluctuations in the quality of the living environment can be characterised as the yoyo effect.

If you look at the chain from policy to maintenance, you will notice that the greatest freedom and thinking capacity is found at the front of the chain. The people who are active at the front of the chain are also appreciated most. They operate in an abstract world of rules, laws, models, goals, morals, thinking experiments and much more. At the end of the chain, restraints increase and there is relatively little appreciation. Nonetheless, people are making matters more concrete here and they are in direct contact with residents and companies.

The serial approach usually includes inadequate communication between the people in the links. The result is that policy development, planning, design, implementation and maintenance have become autonomous work fields in which planners communicate with planners and engineers with engineers. This is why many plans are never implemented. People simply make new plans, better than the last one and adapted to new policy. It also appears that much attention is paid to the support of a plan, through participation. However, if there is support of a plan this does not mean that there will also be support of its *implementation*. Even with plans with which everyone seems to agree, resistance may arise when concrete designs are presented or implementation is started. Only a few of the residents are interested in planning.

4.5.2 Scale problem

Besides water plans, plans are also drawn up for, e.g., spatial planning, environmental policy, agriculture and nature, and traffic. All these plans are becoming more integrated. It is a challenge to integrate all integrated approaches in which a spatial scale is outlined that seems *optimal* for the process of integration. This scale is not too large, because it would make the observations too abstract. Goals and measures must be concrete. The scale is not too small either, because then the integration will lose its spatial coherence. Somewhere at the scale of estate, municipality or district, the balance between concreteness and coherence is found. For the control system approach – see Figure 4.3 – this means that all processes are projected at this one scale level as much as possible. Processes at smaller scale levels are aggregated and processes at larger scale levels are, if necessary, differentiated. Parties involved can only influence that one scale level through interaction.

The strong point of this approach is that the different control systems are comparable on the space scale and can therefore be readily compared. This offers a solid basis for a multi-criteria analysis. However, it is insufficiently recognized that different processes are taking place at different scale levels. At each level, other types of questions are posed. Too few people feel actually involved in the specific scale level and do not take action until it is too late. The actual translation of the plans is done by designers who were hardly involved in the preliminaries. The result is that presupposed support may melt like snow in summer.

4.5.3 Time perception

What is striking about the control system approach is that there is no room for the history of an area. As only negative feedback is taken into account, history fades away. The present and future are recognized, in which the future should be better than the present. Measures are taken for this. It is remarkable that the history is not taken into account because most counter-arguments are drawn from the past, especially in processes of change. At some point or other, “certain promises were made but never kept” or “this has been tried before without any success”. Even more importantly, events in the past have given objects in the landscape historical significance. People link stories to places (Herngreen, 2001). These stories have value. If this is overlooked, people who have been involved in the planning will get the impression that they are not taken seriously.

The difference between present and future is often rather artificial within plans. In many planning processes goals are set for the future, for instance for 2015. The idea is that these goals should be achieved. Later, when the goals have been reached, everything will be much better. The goals are preferably clear-cut. How does this work? The essence of the control system approach is that the present, i.e., the observed state, is compared with the future, i.e., the desired state. As it were, time is flattened and parties involved are faced with a stack of bottlenecks of the present, for which measures are formulated. Advanced planning strategies and prioritising techniques are required to repair the time eliminated to some extent. The result is a time line from now to later, with the measures required to meet the goals neatly grouped along it. The grouping is the result of negotiating ambition and cost division (see Figure 4.7).

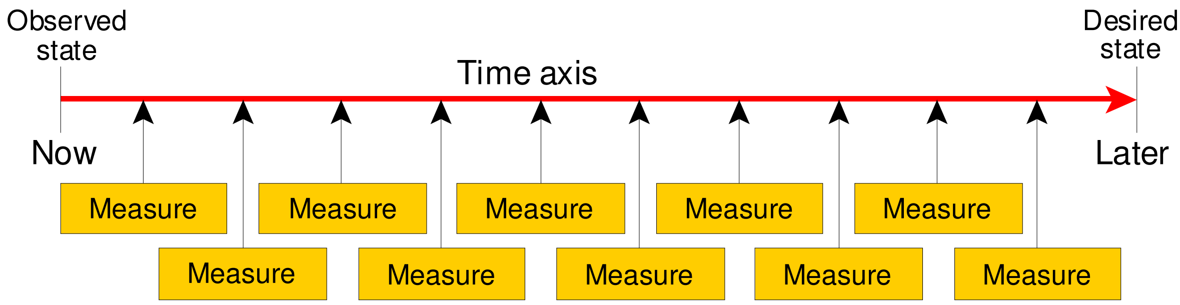


Figure 4.7. Perception of time in the control system approach, with prioritised measures neatly grouped along the time axis.

In this working method, time is considered an obstacle because it separates us from the goals. Therefore, action groups often try to speed matters up: "We want the standards to be met in 2010 instead of 2015!" The expression "more haste, less speed" applies here. If processes do not receive the time they need, there will be disruptions. Processes will be slowed down because they cannot be completely controlled – in the case of a complex adaptive system. Unforeseen developments will take place. This will ultimately result in disappointment because the goals are not reached.
Another result of this approach is that the present is hardly appreciated or not at all. The present only knows problems. Hopes are set on the future. To put it in the Dutch entertainer Hans Dorrestijn's words: "We waste our years of youth by gazing into the distance. And later we waste even more years by resentfully looking back in time".

Unexpected developments in the process cause measures to be carried out in a different order from that of the plan. In practice, the first measure is carried out according to the plan – soon after it has been issued – and maybe also the second measure. Provided there is enough support. However, changed circumstances lead to the execution of measures 14 and 33. And if there is a spatial development that could not have been foreseen at all, the focus is shifted completely and the planning is forsaken altogether. The plan then disappears into the desk drawer without so much as a second glance. This often happens as soon as the year has passed.

4.5.4 The working of attractors

Attractors in complex adaptive systems are the result of processes with negative and positive feedback. Both kinds of feedback influence each other and create tenacious situations. In the control system approach, there is mainly attention for processes with a negative feedback, because these offer a footing for control. The result, however, is that attractors are simply not observed. Parties involved are then surprised by their effect. Nothing goes as planned.

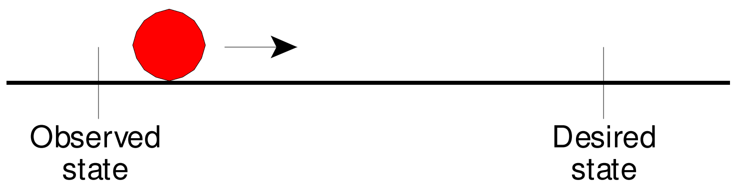


Figure 4.8. The marble diagram for a linear process.

The control system approach is represented by the marble diagram as given in Figure 4.8. The marble rolls in the direction of a state that is more favourable and which matches the current policy. All measures can be taken at any time and can thus be prioritised on the basis of their effectiveness and efficiency. The fact that the landscape has slopes and is constantly on the move is overlooked. The behaviour of 'the whole' is not taken into consideration, at least not consciously.

It is important to realise that the control system approach with its serial approach is an attractor itself and that thinking in attractors calls for a structural way of thinking. The organisation in the water world and the training of new workers is geared towards control. The fact that people at the start of the chain of serial planning receive more appreciation than people at the end of the chain is a difficult situation to break through. The fact that matters were different in Nijmegen does not mean that the new attractor has actually been reached.

4.5.5 The effect of crises

In the control system approach, crises are seen as undesirable and are therefore avoided. Plans with much support are aimed for. If the plans presented are well-founded, it should be possible to convince people of their value. Preferably, win-win situations are sought out; solutions from which everyone can benefit.
Conflicts are avoided in many plans, but this is exactly why the planning process may be so fitful. For instance, discussions arise too late in the process. First, an inventory is drawn up of the existing state and the goals are mapped out. This goes smoothly and harmoniously. Everyone wants a safe and sustainable living environment. After testing, packages of measures are composed, and this also leads to little discussion. However, when responsibilities and costs are brought into the picture – by which time many months have already passed – there are fierce reactions and serious negotiations have to be conducted. Costs are regarded too high and some people want to shirk their responsibilities. It is a logical process, but nevertheless surprising to some. Real win-win situations are rare. Ambitions will perish because there is relatively little time left.

One of the fundamental aspects of the control system approach is that it offers a basis for reaching goals effectively and efficiently. Organisations can be founded and optimised based on the model of a control system. This way, less time and money is wasted. The problem, however, is that an organisation must be able to change along with its changing environment. Ashby (1965) describes the necessity of having buffers for this. If there is too little elbow room there will be disasters. Processes that are designed too strictly for temporary goals lead to many new problems.
In water management, this insight was more clearly visible at the end of the nineties when it became apparent that the optimised water systems were not capable of cushioning the consequences of urbanisation and could not offer a solid foundation for safety as awareness

grew about climate change and sea level rise. In the past, attention was too focussed on the control and containment of water. Water systems were designed too tightly for the current design standards. Ever more sophisticated computer models could reduce the sizes of water infrastructure even more to save costs. This line of reasoning came to an end after the Dutch flooding in the mid-nineties. The current policy says that water should be given room. It should not be hemmed in. This line of reasoning can also be followed in the organisation of water management and the tight planning. At the front of the chain of the serial approach, the elbow room for the rest of the chain is reduced. This is another reason why a great deal goes wrong. However, this does not pose a break in unfortunate trends just yet. The tendency is to continue to optimise processes further by means of benchmarks.

4.5.6 Anchoring

The strong point of the control system approach is the anchoring of the results obtained, especially the reduction of complexity as it makes it possible to act transparently. Many see the approach as concrete, because goals are concrete. However, attention is often too focused on order and structure, whilst there is little consideration of the chaos required for change. This is often the reason why developments people were hoping for do not take place.

4.6 Interaction between water and society

4.6.1 Open or closed process?

A major characteristic of the interaction between water managers and other actors in the control system approach is that it works from the inside to the outside. Communication is self-referential. Water professionals set goals based on current policy, after which packages of measures are composed to reach the goals. In other words, the goals are more or less fixed as they are derived from national or European policy. Others may participate in discussions, but only those regarding the measures. That is where there is some elbow room left in the planning process.

However, experience teaches us that a process with fixed goals will eventually result in a plan with little support. Many people do not want to be involved. By carrying out an analysis of integrated projects in the Netherlands, Glasbergen and Driessen (1993) show that parties are more willing to take part in a planning process when there is more room for their own interests to be heard. “Laying down project goals in advance will (…) keep actors from participating in the process.” They have observed that with a number of plans the goals were determined during the planning process and sometimes even afterwards. Goals develop during the process. However, this does not fit in with a control system approach.

The interaction between water and society is turbulent because the idea that social processes can be controlled and managed is still too strong. The nonlinear dynamics of the interaction is hardly recognized or not at all. The reduction of complexity unfolds a game in which the water goals take up a central position. The outside world is viewed from this position and connection to the context is sought. This method needs to be adapted, just like the idea that *the sun orbits around the earth*. It is better to put the living environment in the central position and then to see what water can contribute to it. This way, water is only one of the aspects of environmental policy and real integration has thus been achieved.

4.6.2 Coping with resistance

In the control system approach, resistance is considered undesirable. People who raise objections are often seen as opponents. Herngreen (2001) describes an example of a participation evening. It is an evening for which the professionals – managers of a nature reserve – had prepared well for the resistance that could arise. He describes the situation at the end of the evening. "The residents went home dissatisfied. They had had the feeling that they were no match for so much expertise and trained eloquence. That they were not taken seriously. That the initiators were insufferably pulling all the strings by knowing the situation, knowing how to handle it, and having the power to execute their plans. (…) The managers, on the other hand, were reasonably satisfied. It had been hard; the emotional resistance was greater and partly different than foreseen, but their arguments had been kept in one piece with regard to content. Any objections were fragmentary, vague, not objective, irrational, conflicting with each other, and they could not be classified under recognized sector interests and could therefore not be considered valid." Afterwards, it often turns out that resistance returns and is more vehement in a later phase of the process, when the plans have to be carried out. Often, it is too late then to make a success of the project.

4.6.3 Standards and perceptions

Concrete standards are a characteristic of the control system approach. When standards are indisputably right and there is enough money available, a high quality of the living environment is feasible. This is an ideal situation that hardly matches reality. People have different perceptions of the right thing to do and there is never enough money. Often, water professionals use the standard as their point of departure, but residents and companies in the area concerned have a completely different perception of the problem being tackled. Water professionals often forget that perceptions of problems are determined by many more factors than the actual behaviour of water systems. For instance, in projects of dike strengthening, besides the actual risk, the risk perception by residents is determined by:

- Time. Especially when floods are incidental, people forget about them. The opposite is also possible. Stories from the past can suddenly be current again.
- The willingness with which people exposed themselves to the risk. If people have chosen willingly to live or work in a certain area, their acceptance of risks is often greater than of those who did not have a choice or of those who were faced with a gradually increasing risk in the course of time.
- The way in which the effects of the flood can be influenced by the behaviour of the residents. It is often possible to flee in time and to limit the damage by retrofitting the house.
- The degree in which the disadvantages of the area are compensated by its advantages. Those who live in flood plains run flood risks, but it may by very appealing to live there on account of the scenic landscape and beautiful greenery, low price of houses, social cohesion, places suitable for swimming and nice routes to walk your dog. These advantages sometimes outweigh the disadvantage of the higher flood risk.
- The attention the media gives to the problem, how it is described in newspapers, or on the radio or television. This may increase dissatisfaction or cause the risk to be underestimated.
- The degree in which people trust the local government and how they communicate. A government that communicates openly, makes clear agreements and sticks to them, is

trusted more than a government which creates the impression that all kinds of iffy things are going on behind the scenes.

With the control system approach, it is difficult to take all these factors into account. Practice shows that measures are firstly based on the standards to be later polished up following public interactions. Sometimes this cannot be done in any other way, for instance when the government must ensure the safety of a deep polder with a high population density. However, many examples can also be named that require a different method. It is the other perceptions that people have of a problem that causes resistance.

The standards used for deriving measures involve the physical, chemical and biological aspects of water management. Water levels must be curbed, the water quality must be restored, or a certain natural objective is striven for. A good example here is the way in which the "sound ecological condition" of surface water must be determined according to the European Water Framework Directive. However, the problem is that other actors do not feel directly responsible when measures are formulated to meet the standards. This does not relate to their way of thinking; the frame through which they look at processes. They can see the values of water, but they give them different meanings. If the professionals are not capable of connecting to the different ways of thinking and if they cannot imagine how others feel about something, it becomes very difficult indeed to complete a project successfully.

4.7 Coping with models

4.7.1 Model predictions

With the control system approach, the complexity of an integrated issue is reduced. This is necessary, because reality as it presents itself to us offers little guidance. Everything is connected to everything else and processes behave in a fitful and unpredictable manner. The nonlinear dynamics that is so characteristic of complex adaptive processes is reduced to nothing. The issue is trimmed down until something remains that can be comprehended. Computer models can be made then, to make predictions. This is in itself a healthy working method, as long as the relativity of the model outcomes is acknowledged. However, this often goes wrong in practice. Too much value is attached to the predictive value of models. Cartesian based model outcomes that are the product of a rational thinking process are seen as the most reliable source of knowledge. They can be traced back to the building blocks of mathematics, which must be true on account of the beautiful logic. The model outcomes offer security. Reality, which often shows something other than the models predict, produces model noise. The trick is to keep the model noise as small as possible. This can be done in two ways: by limiting the system to be considered or by improving the models. The next chapter – on Interactive Implementation – argues that it is more sensible to choose the first option and not to try and put the complete integratedness of a complex issue into a model. However, the practice shows more examples of the second option.

By giving model outcomes a central position, the same effect is obtained as in participation processes. The sun orbits around the earth. From where we stand on the ground with both feet, we supply a vision of the entire solar system. It is better to give reality a central position and to view models as tools with which to provide a more precise representation of smaller parts. Models sharpen the mind and offer guidelines to support arguments. They are indeed valuable.

An important reason to use models as a tool – the earth orbits around the sun – is the fact that what is seen as noise for models, can be an important source of information in reality. Chaos is not without structure (Gleick, 1989) and particularly the fact that various outcomes are possible offers extra room for influence. Uncertainty about the future offers room for its interpretation. Various scenarios are possible for the future.

4.7.2 Disappearing experience

Different people are active in the chain of the serial approach. As stated before, people who are working on plans are not always involved in their implementation. Designers and those responsible for maintenance are often strangers to each other. The baton that they hand down consists of packages of explicit knowledge (see Section 3.6.3). Knowledge is lost with each baton that is handed down. Each product in the chain is produced by the thinking frames of experts. It is formulated in the jargon of experts, each using their own angle. Often, the result is not what was intended. It resembles a game I remember from primary school: the children would sit in a circle and the first child would whisper a sentence in the ear of the second child. The second child would whisper it in the ear of the third child. When the sentence had passed round the circle, it was a different sentence altogether. Such distortions are undesirable for integrated environmental projects. By the faulty transfer of knowledge, the chain has become vulnerable to mistakes and fraud. Possible response is extra control and containment. But is this the right thing to do? One possible flaw in this process lies in the fact that the transfer is limited to explicit knowledge. It is important to pay more attention to the practical experience of people and the functioning of implicit knowledge.

Dreyfus & Dreyfus (1986) describe five levels of learning. In this book these five levels are reduced to three: novice, competent and expert. All learners start at the level of the novice. Characteristic of this first level is learning *rules* that can be applied away from the context. Someone who is learning to drive a car will practise steering and shifting gears. This is knowledge that is important in both slow and heavy traffic. Someone who starts learning about water management can carry out measurements and simple calculations, and can follow instructions such as: “On 1 March the polder target level must be set at 2.10 metres below sea level” These actions do not require any interpretation. This is different with the medium level of learning, the level of competence, which requires a correct interpretation. Competent people can carry out complex tasks. They weigh different options against each other, depending on context, and take decisions. They still do this analytically, based on rules. Competent car drivers shift gear at the right time and choose the smartest route using the information handed to them. Competent water managers negotiate with municipalities on the requirements for the sewer system and introduce water in spatial planning. This puts water on the agenda. Their contribution mainly consists of explicit knowledge covered by current water policy and administrative decisions. They remain within the rules of the familiar game. People who reach the highest level, the level of expert, no longer act exclusively analytically. They oversee ‘the whole’ and regularly take decisions using their intuition. They use their implicit knowledge. The experienced car driver shifts gear automatically and can prevent accidents in critical situations. The experienced driver can react alertly in unexpected situations. Water managers at the level of expert play the game of the environmental policy, can empathise with other work fields than water, and respond quickly in unexpected situations. They are committed and feel responsible for the result. Experts can be found in the maintenance crew, the policy department, the management and in the canteen. They represent added value.

Characteristic of the control system approach is that the input of people is capped to the level of competence. Terms used in this respect are: rationalisation, “back to the core tasks”, cutbacks, increasing efficiency, benchmarking and upscaling. Control and containment are the central terms here. The level of competence is rule-oriented, seen as objective and can therefore be better controlled. It is possible to formulate hard and concrete standards and goals. Actions can be automated at this level and this has many advantages. Plus, it will suffice, at least when society remains as it is. But society changes; it is complex by nature and changes continually; always taking water managers by surprise. It is the experts who can provide the answers then, circumventing the existing rules. However, they increasingly play a less important part.

4.7.3 The role of uncertainties

The term uncertainty has been used several times in this book. This term plays an important role in handling complicated issues well. Administrators who have to take a decision often want to know how much a certain solution costs, how efficient it is and what its uncertainties are. Too much uncertainty is undesirable.

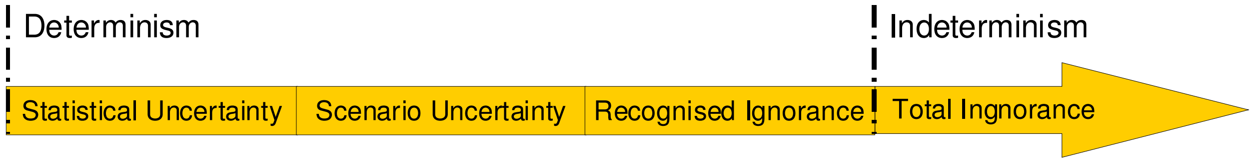


Figure 4.9. Various forms of uncertainty, from statistical uncertainty to total ignorance (Walker et al., 2003).

Figure 4.9 shows a classification into the different forms of uncertainty. The first two are coupled to working with models. Statistical uncertainty manifests itself when models are calibrated and verified using measuring sequences. There is scenario uncertainty when various development trends are possible, for instance in relation to the climate. It is a matter of recognized ignorance when it is a known fact that knowledge is lacking or hard to transfer, as with implicit knowledge. With total ignorance, we do not know what we do not know. This last category is very large with complex adaptive processes.
Characteristic of the control system approach is that attention is mainly aimed at the first two forms of uncertainty. The state space which can be described with some accuracy by means of deterministic models is heavily relied on. The uncertainties are kept as small as possible. You could even get the impression that some would rather do something wrong and be certain about it than do something that *might* be right. This is alarming. In order to make any progress, it is important to pay attention to all four forms of uncertainty. The processes of which we only know little often have the largest manoeuvrability. Those who study our history will learn that the largest changes came about from the unexpected.

4.8 Conclusion

Water issues are often approached as control systems. This suffices for relatively simple issues, but when complexity increases the approach shows severe shortcomings. The reduction of complexity causes essential processes to be missed and reality flows *around* the water policy, as it were. Clinging too tightly to the model of the control system explains why plans are not being implemented and it also explains the awkward interaction between water management and society. In addition, it explains the huge fixation on computer models. It is the trick to develop a working method that does not reduce complexity *and* retains the advantages of the control system approach. Because the control system approach clearly has its strong points.

5 Interactive Implementation

5.1 Renovation as a metaphor

Interactive Implementation is a working method for handling complexity instead of reducing it. Complexity is seen as a condition for change. The concept of Interactive Implementation has arisen from the confrontation of insights from the science of complexity with the practice of integrated environmental projects. This is not just about policy, planning and design, but also about implementation and maintenance. It gives the implementation rather than the planning for a more central position.

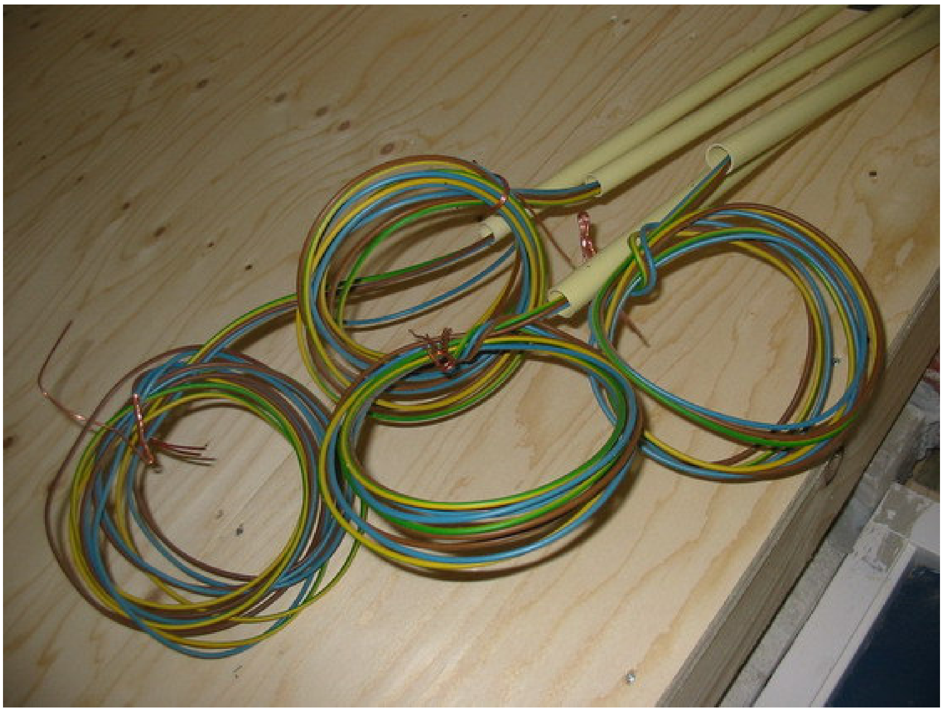


Figure 5.1. Detail of a renovation in Bathmen, the Netherlands. The fitter is laying new electricity wires.

A metaphor for Interactive Implementation is the renovation of a house. Characteristic of a renovation is that there is already a house, but it no longer meets the current requirements. The house is extremely neglected, too small for the current number of occupants, badly insulated or was "vandalized" in the seventies – by replacing panelled doors, leaded windows, hardboard joinery, and so on. A process is then started with the following characteristics:

- The occupants develop a rough vision which gets them enthusiastic. Drawing up a detailed plan is not possible because there is little knowledge on the current state. What is the quality of the supporting beam like? Can parts of the original fireplace still be found?
- Construction, living and maintenance run parallel. The house is tackled project by project. First the bathroom, then the kitchen, etc. Meanwhile, the occupants live in the house. It takes a great deal of communication to maintain a good atmosphere between the

occupants; because the process involves emotions. Maintenance is done where necessary. The line between renovation and maintenance is hard to draw.
- Plans are adapted continually. The further the process progresses, the sharper the insights become. In addition, new details in the house are discovered. The old floor beams are still behind the heraklite boards, and they are in good condition. It is decided to install an extra toilet after all. New sound-proof boards have just been introduced on the market. The end result is partly a surprise.
- The process takes longer than planned. The renovation is never truly finished. It is perceived as a process of perpetual novelty with fits and starts. A renovation does not have a clear starting point and end point. Besides the fact that it takes longer, it is also often more expensive than thought at the onset.
- The process is nonlinear and has many uncertainties, which are not only technical by nature, but also psychological, social, economic, legal and aesthetic. It takes courage to start such a process and perseverance to keep going. It is important to have interim milestones that mark and anchor the climbing line in the process. To have a reason to celebrate.

Renovations are often a combined effort of contractors, fitters, handymen and the occupants of the house. This requires a great deal of communication and thinking a few steps ahead. The pieces of the puzzle have to fall into place in the course of time. This is why contractors and fitters sometimes distinguish between the people for the *large jobs* and the people for the *small jobs*. The large jobs are the laying of complete, new, housing estates or utility construction. The people who work in these projects are highly specialised. There are fitters for the laying of electricity wires, the laying of pipes, and installing radiators. They work according to drawing (specifications). The small jobs are renovations; for which the more experienced people are used, who can see the whole picture. They are less specialised and partly work according to drawing. In consultation with the occupants, they determine what goes where. The trick is not to have too many discussions, nor too few.

Many projects in the living environment, such as urban renewal and river restoration, resemble a renovation more than they do new construction. After all, there is an important part of the existing situation that will be maintained. People are already living in the area and those that maintain it are active. Projects with these characteristics are perfect for Interactive Implementation. The processes of the Nijmegen water plan are a good example of this. The control system approach is better suited for new construction. The serial approach is then appropriate. According to the policy, housing must be built somewhere. The architect makes a plan and ensures that specifications are drawn up. Then, the contractor begins and builds the houses. When they are ready, the residents will move in. After a while, they will start doing maintenance.

Interactive Implementation is a wide concept that can give direction to many processes in the living environment. This book is primarily focused on water.

5.2 From plans to implementation

5.2.1 Working in parallel

The main feature of Interactive Implementation is that people are working in parallel, represented in the diagram of Figure 5.2. People work in parallel in the case of renovations, but also in the case of processes such as in Nijmegen (see Chapter 3). First, a vision is drawn up. This is necessary, because the direction of the development must be known. In drawing up the vision, actors are involved that have a formal task and responsibility in water management. Extensive interaction during the forming of the vision is not required. With the process of the Nijmegen water plan the vision was drawn up in one day, on 11 June 1997, after some preparation. The vision makes people enthusiastic, provides the desired direction and offers enough elbow room for other actors to bring in their own ideas.

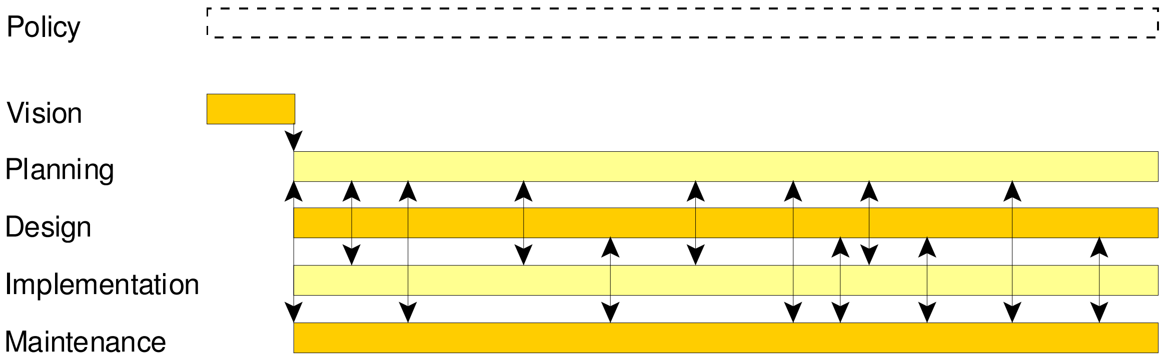


Figure 5.2. The principle of working in parallel in Interactive Implementation. The activities are on the vertical axis, time on the horizontal axis.

After drawing up the vision, planning, design, implementation and maintenance run in parallel. Many meetings take place between the people who are involved in the different activities. They are going through a mutual learning process; learning from each other. The 'interactive' notion mainly pertains to the interaction between planners, designers, those who implement and maintain. The motto of Interactive Implementation therefore is: "Not after one another, but beside one another." Residents, companies and actors from civil society are involved in the process on many occasions. Not just in the planning phase. There is a great deal of interaction with residents and companies in projects at the smaller scale level in particular.

Chapter 3 mainly focused on the interaction between planning and implementation. This section will zoom in on the interaction between design and maintenance. Design and maintenance represent – especially in the serial approach – two different frames of thinking. Design is aimed at change and development. Maintenance is primarily aimed at keeping matters in good condition; in equilibrium. Keeping a system in equilibrium in a changing world can only be done temporararily. Figure 4.5 illustrates this. New problems will arise and the quality of the living environment will decrease. Only a new design process can improve quality again. The area will undergo a quality stimulus, interrupting the downward spiral – the qwerty (see Section 2.7).

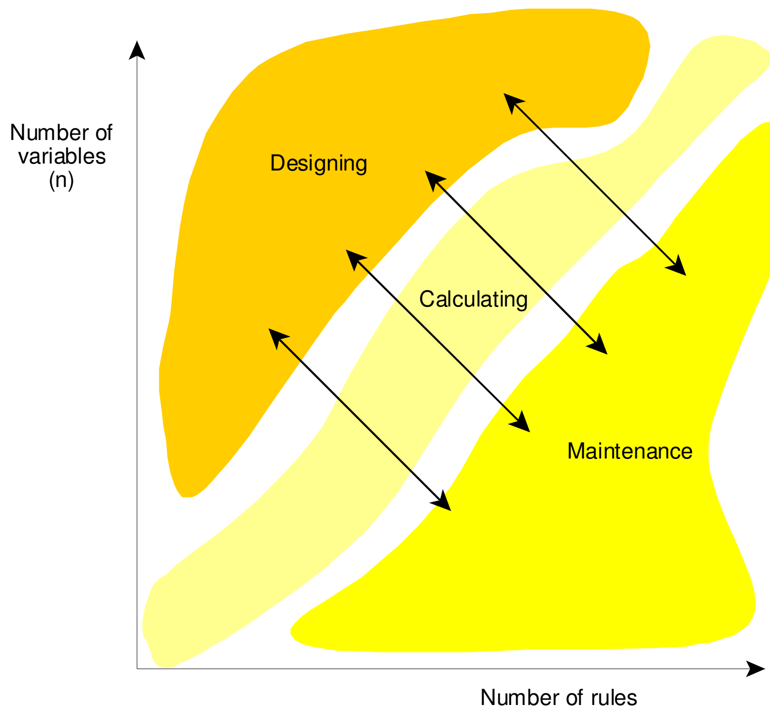


Figure 5.3. Three zones: designing, calculating and maintenance. Interactive Implementation is aimed at an improved match between design and maintenance.

Figure 5.3 characterises the difference between design and maintenance, in which the activities are related to the relationship between the number of variables and rules in an issue. Examples of maintenance rules are: "clean the ditches in October" or "try to solve problems when people complain." A design rule is: "the watercourse has to fit into the landscape." There are hard rules, that have to be fulfilled, and there are soft rules, that merely point out possibilities. Rules can be very subjective. A coherent set of rules is called a technological regime (see Section 2.8). Characteristic of a design process is that there are many degrees of freedom. There are more variables than strict rules, which creates room for creativity. The maintenance process has more rules than variables. Strict maintenance is necessary for keeping a water system into equilibrium. In addition, various actors have wishes and demands. Those responsible for maintenance often have to negotiate between these actors. They cannot give everyone what they want. Choices will have to be made, and this calls also for a form of creativity. In the design process, creativity can be addressed as *creativity of freedom.* In the maintenance process, it can be addressed as *creativity of limitation*. Both are valuable.
In Figure 5.3, a zone is placed between design and maintenance in which the number of variables is – about – the same as the number of rules. In this zone, it is possible to carry out calculations and to determine the optimum solution.

In a serial approach, design and maintenance follow each other. The different forms of creativity do not reinforce each other, but they dampen each other. Designs are made that are difficult to manage and those responsible for maintenance therefore, justly so, shoot holes in the designs when confronted with them. This negative attitude causes designers to shun those who do maintenance even more. This is a qwerty. With Interactive Implementation and the related parallel approach, designers and those who do the maintenance operate beside one another. They work together for a longer period of time, sharing a barstool, so to speak. This may reinforce their individual insights. Maintenance aspects are expressly included in the design. This is called *maintenance by design*. In addition, those responsible for maintenance will keep the state of the living environment in equilibrium less frenetically. If improvement is possible, structural adaptations are made. This is called *design by maintenance*. This way, the living environment adapts to the changing pattern of needs. The system is more sensitive to context and the result is an emergent property.

It is remarkable that, in the past, both designers and those responsible for maintenance have had their eye on the middle zone in Figure 5.3 for the urban living environment, in which zone the number of variables is more or less equal to the number of rules. Designers – mainly urban developers and architects – had their eye on it in the seventies. Large handbooks were written for designing. Fixed design rules were defined with which the best designs could be made. This resulted in uniform housing estates in the Netherlands, with little identity, at the expense of creativity. Fortunately, these views were subsequently rejected. Those responsible for maintenance sought out the middle zone mainly in the eighties and nineties. It was called rational management. The responsibility for planning and allocation of budgets was delegated to a computer model, which was also at the expense of creativity. Residents' appreciation for maintenance decreased. These views are now also being rejected. The field lies open to Interactive Implementation, but much water will flow through the Rhine before designing by maintenance and maintenance by design actually belong to daily practice.

In Figure 5.2 policy is also in a parallel position. This is realistic, because policies are never finished. They are always changing, as history has shown us. In addition, policy renewal does not take place in The Hague, London or Brussels. It takes place in the field. Experienced people, who work actively in practice, see possibilities for doing something differently than usual and start experimenting. A good example of this is dealing with stormwater differently. Until 1998, there was no policy for this in the Netherlands. In the early nineties, a small group of people was experimenting with new techniques in urban water management. Stormwater was no longer discharged to the sewer, but infiltrated into the subsoil. At first, the new ideas were not welcomed, especially by policy officers. In 1992, people still angrily left the room during a presentation on source control techniques. However, the positive experiences led to a turnaround by 1995. It had suddenly become sustainable to view stormwater as a source rather than as wastewater. In 1998, official policy was drawn up and further implemented. However, the point of attention now is that handling stormwater differently has become a doctrine.

5.2.2 Switching between scales

By working in parallel it has become possible to be active on different scales at the same time. The scale problem outlined in Section 4.5.2, characteristic of the control system approach, can thus be solved. The process of the Nijmegen water plan illustrates this. The diagram in Figure 5.4 shows the difference between the control system approach and Interactive Implementation.

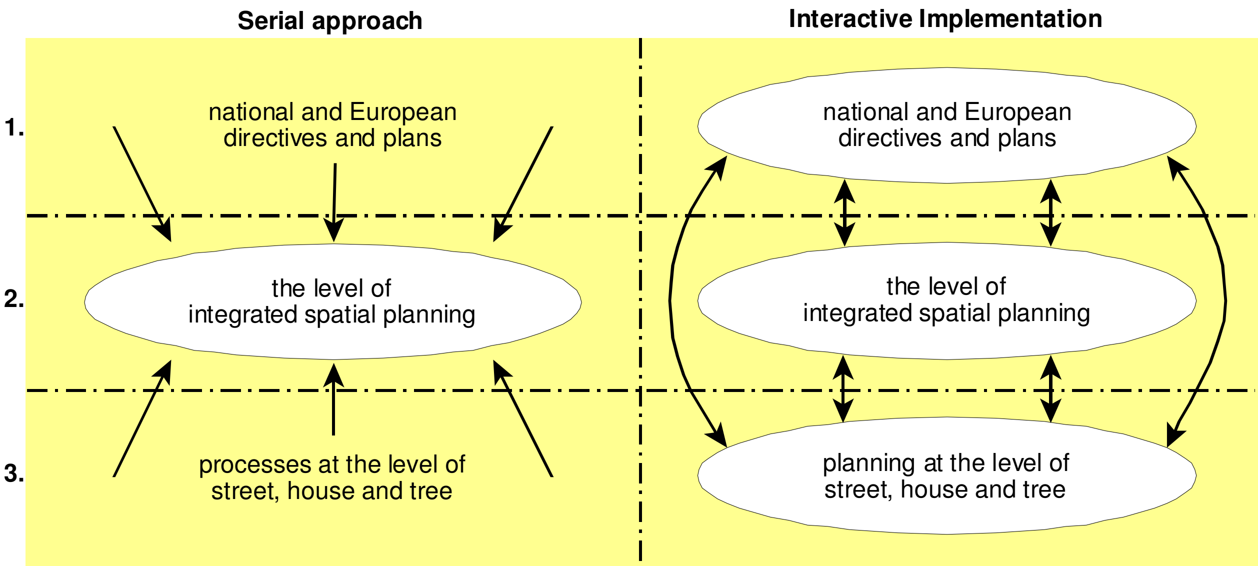


Figure 5.4. Schematic presentation of differences between the control system approach and Interactive Implementation when dealing with different scale levels.

With Interactive Implementation it is less important to achieve planning at one ideal scale level. Plans are made and implemented at various scale levels, while considering other kinds of processes and structures at each scale level. This way, less information is lost. In particular the dissolution of information at the smaller scale levels is prevented. After all, plans are also made on the smaller scale of street, home and tree. These plans are of a different nature than the plans at the higher scale levels, but they are no less valuable. They are often more integrated than plans at higher scale levels because the integration of regional plans often costs a great deal of effort, sometimes resulting in complicated multi-criteria considerations, while integration is more a matter of course at the smaller scale level. Real integration takes place on this scale level and it can even be hard for many people not to consider integration. Everything is connected to everything else. People have stories at the smaller scale level. It is a fascinating scale level, because of the huge diversity in structures, colours, views. Culture becomes visible at this scale level and inspiration is bubbling to the surface for poems when the confrontation is sought with the environment and with time. Not everything is equally valuable to everyone, but there is a spontaneous order at the micro-level which is worth understanding.

A large innovation task for the next years is matching the scale level of integrated regional plans to the scale level of street, home and tree. This is where most is to be gained in spatial quality. After all, the logical first reaction to Interactive Implementation is: "It is impossible to include all plans of all individuals in integrated planning. There is simply too little manpower and *it will just take too much time*!"
It is important to consider this reaction for a moment. Is it true that there is not enough manpower? People and groups of people develop ideas and theories from sources such as facts, values, norms, views, experience and much more. Their ideas and theories are used as building blocks for knowledge systems. In the usual approaches for planning mainly the knowledge systems immediately available to professionals are used. Using knowledge systems observed in small-scale levels means an expansion of the knowledge systems. In addition, it creates the possibility of increasing the capacity of information processing. Manpower increases by involving more people in the planning process! It is merely necessary

to approach people where they can contribute most, which is mostly at the scale level of their immediate living environment. In Nijmegen, thirty-five groups from the civil society were involved in the process. Examples are environmental groups, educational institutions and housing corporations. These groups all have their own network for approaching people. The trick is to use these networks well.

For policy and planning, it is quite unusual to operate in parallel on different scale levels, that is, to include the scale level of individuals. Of course policies are geared towards each other at the national, provincial and municipal levels. Designers are more used to working in parallel, as they speak of *designing through the scales*. When urban developers draw designs for new areas, they will focus on details and on the outline at the same time. They will switch between the different scale levels. Past, present and future are also taken into account so that it is possible to relate values to many time scales and points in time. Good designers respect that what is there and the values it represents. The design which is finally produced is not the best design objectively speaking, but it is something that the parties involved can be proud of. A good design emerges from a brisk consideration of arguments and, in combination with creativity, it will result in something the designer will have a good feeling about. If this good feeling is transferred to other people, the design can be translated into physical actions.

5.2.3 Perception of time

A feature of Interactive Implementation is that there is more focus on history, just like with renovations. Stories are connected to objects in the living environment and those who do not take this into account, will be faced with much unexpected resistance against plans. In addition, time is seen as the bearer of change. Time is not seen as an obstacle between now and later. The present is valuable and the process of change is also valuable. The fixation on the future is less strong.

Figure 5.5. Bicycle tour with residents and those responsible for maintenance through the Lewenborg estate on 12 November 2002.

A technique for "harvesting history" was used in the Lewenborg estate in Groningen. This estate had many problems with its water quality, in addition to traffic problems, social issues, overdue maintenance, differences of opinion about chopping trees, and many more issues. Residents' faith in the municipality and water board was little. In the past, scenarios had occurred that worsened the relationship. Because of this, the residents received the Lewenborg water plan of the municipality and water board with scepticism. The plan contained beautiful ideas for ecological improvement of the water system – especially around the estate – but no attention had been paid to the problems experienced by the residents with the ponds receiving combined sewer overflows.

A new process was started. First, a participation evening was organised for the residents of the estate, during which they were able to put forth their views on "how to do it differently" and events from the past were openly discussed. This is necessary. During this evening, a working group was set up of residents and employees of the municipality and water board. This working group was going to work out the ideas for the water management. Beforehand, it was made clear that for all phases (planning, design, implementation and maintenance) cooperation and shared responsibility were the operative words.

The first action of the working group was cycling through the estate (see Figure 5.5). About 150 pictures were taken during this bicycle tour, which were put on a CD-ROM and distributed to the members of the working group. The members selected 10 pictures each to tell their story. One specific evening, the stories were presented. It was striking that some of the members of the working group had made completely different selections from the series of pictures and that the stories greatly differed. Even though everyone had cycled the same route, they had been looking through different glasses. This made the working group members realise that it can be worth one's while to zoom in on each other's way of thinking. Besides bad experiences from the past, the good stories that are valuable to the design process will also surface. Ponds that once were designed using almost identical techniques, had obtained their own identity. Opening up history proved very valuable.

Then, in accordance with the principle of Interactive Implementation, the planning, design, implementation and maintenance was carried out in parallel as much as possible. It was observed that while the municipality and the water board paid more attention to taking measures, the residents paid more attention to maintenance. This is yet another matter which is related to a different perception of time. As one of the Lewenborg residents put it: "You shouldn't get us interested in how it's going to be, but in how it's going to stay!"

With complex processes one should give the processes the time they need. Visions should not be prematurely translated into standardised goals. Nor should haste be made to achieve these goals; more haste, less speed. Still, progress is wanted because the parties involved do not want to have to wait too long.

There are two kinds of time in the process of policy to maintenance, called chronological time and kairological[11] time by Lewis Mumford (Achterhuis, 1992). Chronological time is determined by the clock and can be used for planning. Events and measures can be ordered in the chronological time. The kairological time is derived from knowledge, sensitivity and experience and is determined by "the right moments". Not all actions can be done at any given moment. It is often essential to act at the right moment and sometimes it is better not to act. This is what makes steering so very difficult, but more realistic and effective at the same time.

[11] Kairos = the right moment.

With Interactive Implementation it is also important not to pay attention to water projects too often nor too sparsely. If residents and companies are involved in projects too often, they will be annoyed at having to turn up for each trifle. However, if they are not involved often enough, they will become suspicious. “They are up to something again”. The same goes for administrators and politicians. They cannot be involved in all projects, although water projects do offer a good opportunity to receive positive media attention. This dilemma was solved in Nijmegen by distinguishing between two kinds of projects: rhythm projects and tempo projects. *Rhythm projects* are notable projects that call for a ‘celebration’. They involve an opening of a construction of some sort, they are appealing to the press, and they offer opportunities to come into contact again with residents and companies. The aim is to complete a rhythm project once every six months; for the experience value. *Tempo projects* determine the progress in the improvement of the water management. Sometimes, the water part is hidden far away in renovation projects or adaptations to the traffic structure. By paying attention to water in all projects in Nijmegen, this becomes more a matter of course in the course of time. With tempo projects, the highest environmental efficiency is often obtained, but this is too quickly forgotten without any rhythm projects. The rhythm projects support the tempo projects.

5.2.4 An eye on attractors

It is of great importance with Interactive Implementation to oversee ‘the whole’. If for instance a water manager wants to change something, he or she will have to see the whole picture and all partial processes. Figure 5.6 shows how this works.

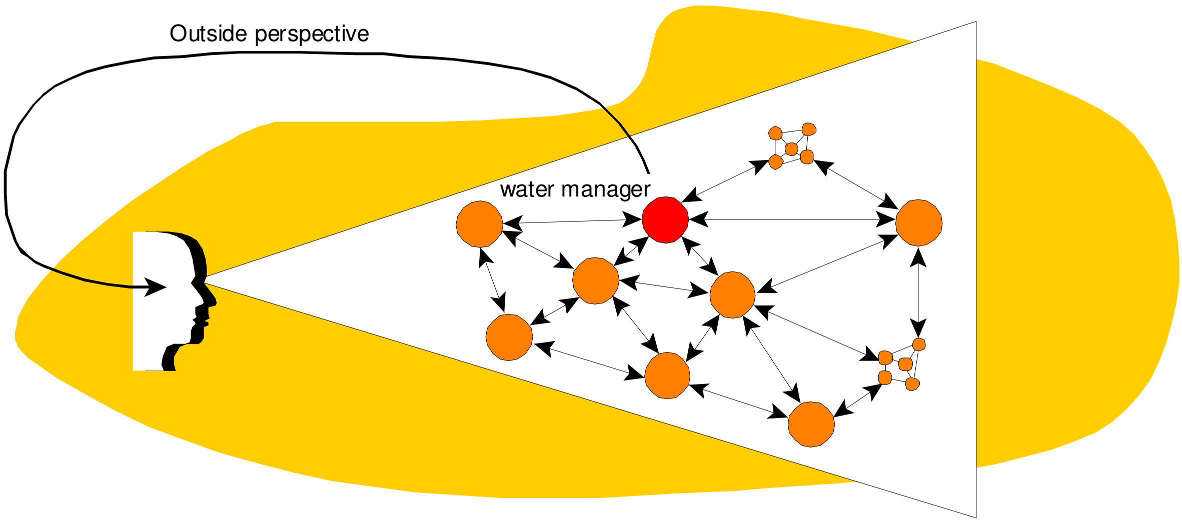


Figure 5.6. The water manager seeing the complex adaptive system of ‘the whole’, of which he himself is part.

In order to be able to oversee the whole of processes, the water manager uses an *outside perspective* (Habermas, 1989). He (or she) will view the whole from a distance, like an artist taking a few steps back to judge the composition of the painting. He will try to see the survival landscape with its attractors and repulsors in movement. These will help him to understand the outline of the whole. Then, he will work out and support his strategy at a lower aggregation level. The manager regularly changes his perspective and observes different patterns at each aggregation level. That is the main feature of complexity. He uses the combination of information he receives on the various aggregation levels to steer processes as well as possible; not just reacting, but also anticipating.

Attractors are made visible by drawing diagrams such as Figure 3.8, which renders them explicit. However, experienced people will recognize them implicitly. It is important to know them because neglecting attractors will predictably result in disappointment.
When attractors are observed, it is important to question whether an attractor change – a transition – is really desirable because this requires measures that have the critical mass to get over the bump. It is possible that the right moment – the kairos – for the change has not arrived yet. If it is decided to go for an attractor change, the parallel working method of Interactive Implementation offers the building blocks for it.

5.2.5 Using crises

The main thing about coping with crises is that they can hardly be suppressed or not at all. They are an important feature of the behaviour of complex adaptive systems. They characterise moments when the system – or a subsystem – becomes unstable. It is therefore better to use them.

With regard to crises in physical, chemical and biological processes, such as the occurrence of floods or the death of vast quantities of fish, people have become aware for a few years now that these can only be partly controlled. When measures are taken to improve matters, the system will adapt and develop back towards a critical situation. This pattern is highly visible in flood issues. When measures are taken to increase safety in an area, people will adapt to the new situation. Because the situation has become safer, they undertake more activities in the area. Mostly, the result is that 'unsafety' is increased. The world is not in equilibrium. Often, a structural change – an attractor change – is necessary to really improve the situation. Such insight does not mean that measures should not be taken, but it means that we should be careful when making statements about safety. Statements such as "this area is now safe again" and "we have everything under control" result in high expectations that cannot be fulfilled.

In intellectual processes crises can be linked to creativity (Stacey, 1996). Problems are often not solved because the parties involved are stuck in their way of thinking. A crisis can be seen as a source of new inspiration. Changes usually start as creative processes in the intellectual domain. New ideas are developed. If these are strong, they will survive any criticism when presented to a broader group of actors. They will grow. Particularly by testing them in practice, more people will become convinced of their value. A so-called snowball effect. Not until a change has been reached in the group of social processes, will something actually change on a large scale in the group of physical, chemical and biological processes.

5.2.6 Anchoring

Table 2.1 already warned against the fact that processes aimed at dealing with complexity can come across as vague to the parties involved. It is therefore of importance with Interactive Implementation to keep an eye on the anchoring of results. If too many people are allowed to participate, the chances are that insights and arguments keep bouncing back and forth without actually achieving anything. With Interactive Implementation, anchoring mainly takes place by carrying out concrete projects resulting in tangible objects. Plans that are being developed on the various scale levels also ensure anchoring.

In participative processes concerning water in the city, Van Eijk (2003) uses the so-called 4C assessment method. The four Cs pertain to concept, contact, contract and continuity. In a good process, all four are monitored. Van Eijk has established that there are usually no problems with the first two Cs in most projects. There usually is a good *concept* and participation also receives sufficient attention; the *contact* with a broad field of actors. However, processes are often not anchored enough. Too little *contract* and too little static quality. If *continuity* is also missing – continually other people are involved in the project and they are working behind the scenes for too long – the marble in the marble landscape will roll back.

5.3 Interaction between water and society

5.3.1 Open process

Figure 1.2 takes up a central position in the interaction between water and society. People are working on a water system (and/or water chain). Water professionals want to take measures to have the system function better. However, the water system is embedded in an environment in which many processes take place and in which water only plays a partial role. The environment – the context – continuously changes and it is important that the water system adapts to these changes. This adapting is all about a middle path. If the environment (society) is listened to too much, water plans will become "any which way the wind blows". On the other hand, if the environment is not listened to enough, there will be no support and the various disciplines in the living environment will work at cross-purposes to each other.

In the history of water management, roughly three stages can be distinguished. They are described by Lems and Valkman (2003) as basic water management, functional water management and contextual water management. *Basic water management* characterises the way in which water management was dealt with up until the mid-eighties. Back then, water managers had relatively little interaction with people from other disciplines. There was no need for such interaction, because they had complete control over the objects they were managing. They were working within their own field of expertise and were good at it. This also applied to the municipalities who took care of the sewer system. If, for instance, a housing estate was being built, the water managers made sure that a reliable water system was laid. The interaction with the context was relatively simple. This changed after the introduction of integrated water management when people started paying more attention to the interaction with the context. The principle of *functional water management* was introduced, which means that more people can have a say in water management. Functions are laid down in interaction with the environment. For instance, for surface water near a town it is determined to give part of it a natural function and another part a recreational function. It is then the water professionals' task to realise these functions. This is not always easy, especially when water is also given the function of bathing water, which must meet high standards. The essence of functional water management is that the interaction is mainly aimed from the outside to the inside. The environment influences the water system, but water professionals do not actively influence the environment. Functional water management fits the control system approach well and is the model for water management to date.
We now find ourselves in the transition phase to *contextual water management*, which has a real interaction between system and context and also takes into account its nonlinear

dynamics. This is necessary because the new water policy can only be implemented successfully if water professionals can influence the environment. Non-point sources can only be combated if a large field of actors is involved. Room for water can only be found if spatial planning can be influenced and landowners are prepared to accept restrictions on the use of their land. The working method of Interactive Implementation is related to this kind of issue (see Table 5.1), which resembles renovation more than new construction.

Table 5.1. The nature of issues in water management (indicative)

Basic water management	• Water level management • Tackling point sources • Traditional management of river banks and watercourses • Sewer system management and sewage treatment
Functional water management	• Spatial planning programmes • Nature development • Sewer system and water quality • Drinking water catchment
Contextual water management	• Tackling non-point sources • Combating dehydration (see section 2.6) • Water and urban renewal • Water policy 21st century

Processes in contextual water management have the features of complex adaptive systems. There are networks on many scale levels and adaptive plans are drawn up to anticipate changes in the context. A continuous renewal process is the result. Developments take place on the edge between order and chaos and attractors and crises manifest themselves.
By definition, such processes are open. This does not mean that everyone must always be involved. Cörvers and Slot (1995) say that an open planning process can only be used when the following conditions have been met:

- The result cannot be known.
- All actors involved must be prepared to come to solutions.
- The actors involved must be able to operate in an equitable way.

In all other cases, it is better to have a more closed process. Especially when a qwerty must be broken it is important to persist despite resistance from the environment, so as to prevent solutions that are "neither flesh, nor good red herring".
In addition to the communication with the parties involved, the power of Interactive Implementation lies especially in the express cooperation between planners, designers, implementers and those responsible for maintenance from the various disciplines, where the control system approach experiences real problems.

5.3.2 Coping with resistance

In Interactive Implementation, resistance is seen as a healthy feature of a complex system and conflicts are not avoided. A rule of thumb in practice is that 60% of the resistance expected by professionals in any given process is presupposed. Often, it is simply assumed that "they do not want to cooperate". Upon inquiry it often appears that "they" do want to cooperate. In addition, 30% of the resistance was created in the past, as the result of negative experiences. These negative experiences minimise people's faith and their willingness to cooperate. This resistance can be conquered by being open about the past (see also Section 5.2.3). By showing that something works – *the* feature of Interactive Implementation – trust is won. The other

10% can be divided up into unreal and real resistance. Unreal resistance comes from people who like being difficult. They often show up at participation evenings to nag. They mainly pay attention to procedures. Despite the fact that they are exclusively negative, they still have a clear function. An example of this is the process of the adaptation of the water system in the De Vliert estate in 's-Hertogenbosch. Together with the residents and according to the principle of Interactive Implementation, a system was developed to infiltrate as much stormwater as possible into gardens and public green spaces and to partly visibly discharge it onto the surface water through ground structures (Geldof et al., 2000). The process was started in September 1997 with a participation evening in the community centre "De Slinger". The turnout was considerable. More than one hundred residents showed up at the community centre. During that evening, the municipality gave its vision and ideas. Expressly no plan was being presented. There was no plan. Residents were asked to draw up their own designs. They could put their names down for a walk through the estate ten days later on a Saturday afternoon, followed by a workshop during which they could draw up their own designs. During the discussion at the participation evening there was a great deal of scepticism at first. Remarks were made along the lines of "The municipality will have their own plan ready by now!" and "Where can I get a complaint form when things go wrong?" This was unreal resistance and other residents were starting to get annoyed over the complaints from the smaller group. It triggered the others to respond more positively. Many residents felt that the officials *really* meant it and were annoyed by the residents who cheaply tried to ridicule the municipality's ideas. This caused the mood in the community centre to be extra positive. Besides this unreal resistance there is also real resistance, which comes from those people involved who have good reasons to be against the ideas. It is important to take this kind of resistance seriously. By seeking out such resistance instead of beating around the bush about it, new insights can be obtained and the quality of the plans can improve.

Avoiding resistance often has to do with wanting to avoid conflicts. This can be disastrous for a process. Conflicts – crises – are part of the process. There may be self-organized criticality (see Section 2.9). If people have a relationship, there will be conflicts. This is healthy. Small conflicts occur often and large conflicts occur occasionally. Tension builds when conflicts are suppressed in complex processes. This may cause instability that cannot be repaired. The process will end in disappointment, while matters seemed to be going so well. In a healthy relationship, small corrections take place regularly and people adapt to each other. That is the essence of adaptation.

Resistance may result in objectives not being achieved. This especially applies in the case of unilateral dependency. For instance, in existing urban areas, water professionals unilaterally depend on residents in disconnecting roof surface from the sewer system. If the residents do not want to cooperate, nothing will happen. In the Netherlands, it is the law that everyone living within 40 metres of a sewer has the right to discharge stormwater into that sewer. However, by not restricting attention to water alone, but involving parking issues, traffic safety, litter and social safety, a *mutual dependency* is created. Many residents will want to see these issues resolved, but have to depend on the municipality for this. This mutual dependency, obtained by increasing the complexity, is a condition to arrive at shared solutions. In the above-mentioned De Vliert estate in's-Hertogenbosch nearly all residents cooperated in disconnecting their roof surfaces. Afterwards, they were especially positive about the executed plan because the problem of rat-run traffic through the estate was solved and the playing opportunities for their children were increased.

5.3.3 Water values

The control system approach is aimed at standards or goals that are hardly or not at all debatable. This is a major difference with Interactive Implementation, in which people are involved who have different opinions and who look at the water issues through different frames. They have different domains of values. The goal is to have the parties involved empathise with each other's values. The fact that people do not empathise with each other's way of thinking is the basis for much misunderstanding, preventing good solutions from being achieved in practice.

In order to give ideas about water a full place in environmental policy, it is important to map out the values of water as completely as possible, so that many people can recognize something of themselves in it. After all, values are less fixed than standards and they are not shared by everyone. De Kwaadsteniet (1996) poses that values have no general applicability and that they are always subjective: "A value expresses a relationship between subject and object (which may also be a process or movement). Awarding value to something requires *involvement*. Because values are not objective, they must always be discussed. They must be kept alive. This is part of the process. When values have become fixed, they have become standards. In many cases, it is better to work with values instead of standards, as standards may cause distance: the water quality can be tested against standards from behind the desk. Awarding value on the basis of standards happens a great deal in water management. If the water quality amply meets the standards, it soon is valuable. Is there any seepage? Then it is valuable. Any orchids or common sundew? Sacred! There is some truth to this. But for real appreciation one must see, smell, feel, taste, in short: experience. And experience is always subjective."

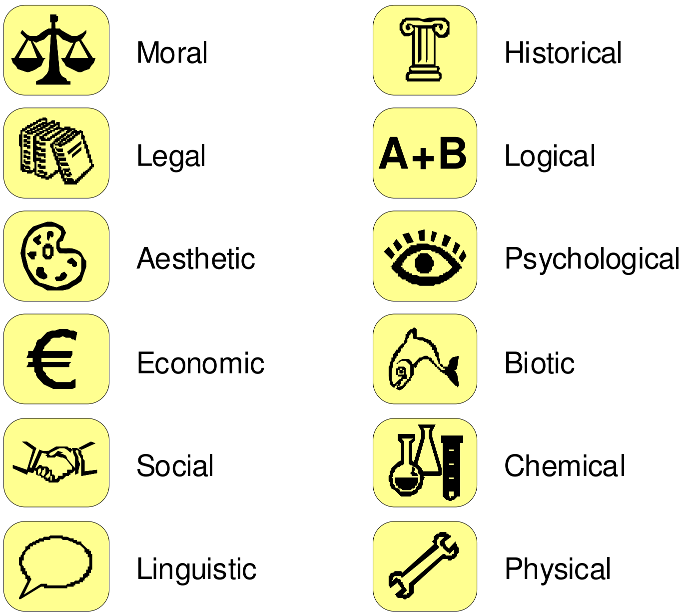


Figure 5.7. Twelve aspects, according to Lems and Valkman, 2003

In order to map out values of water in Interactive Implementation a working method was developed that systematically draws up an inventory of *aspects* of the water issue (Lems and Valkman, 2003). This working method uses the aspect theory (Kalsbeek, 1970). Figure 5.7 lists twelve aspects. All twelve play a role, but not everyone thinks they are all equally important.

People attach different values to these aspects. Those listed are ordered from low (physical) to high (moral), which can be seen as a refinement to the division by Pirsig (1991). The essence of the structure is that the higher aspects are carried by the lower aspects. Without the lower aspects they cannot exist.

Most aspects in Figure 5.7 do not need further explanation, which is why only a few are dealt with here. Psychological aspects relate to sensory observations. The pond smells, the water in the brook ripples, or happiness is experienced by sitting at the water edge. They are aimed at the individual. Logical aspects are abstract representations of reality. They are thinking models with which goals and working methods are described. An example is the Dutch 21st Century water management slogan for reducing floods "hold it back, slow it down, and then release it". A statement such as "infiltrating urban stormwater increases sustainability" is also logical. Each discipline has its own logic. Linguistic aspects are aimed at the way information is presented. This can be done in the form of reports, maps, field experiments, speeches, and poems. The use of language takes up a central position here and it should be taken into account that in practice, small causes can have large consequences. Often, jargon is – subconsciously – used and this irritates others or something is completely misunderstood. The chosen words may also be subconsciously aggressive. Rosenberg (1998) provides many examples of this in his book on non-violent communication. Moral aspects, finally, are aimed at views on right and wrong. The control system approach assumes utilitarism (see Section 4.2), but various forms of ethics exist beside each other. Examples of moral aspects are sustainability, health, democracy, safety and trust.

People are often specialised in one or more aspects. Water professionals know much about physical, chemical and biotic aspects. Lawyers know more about the legal aspects and architects and urban developers mostly aim for aesthetic aspects. People have the tendency to make the aspects they know most about *absolute*. This is a healthy principle. It is only to be expected of people to fight for the aspects within their own field of expertise. However, it is undesirable that they close themselves off from other disciplines. Therefore, in Interactive Implementation people work in parallel to each other. Compared with the serial approach, this has a clear added value when people from different disciplines actually work together. It is therefore necessary that the various aspects are connected.
Someone who is primarily looking at a project through the glasses of the economic aspects and who needs to get a clear picture of the costs and benefits can *deepen* his or her insights via the lower aspects (physical up to and including social). Or he or she can *unlock* the economic aspects through the higher aspects (aesthetic, legal and moral). If people from all disciplines deepen as well as unlock their aspects, the required connection will be achieved. More people will attach values to the aspects involved.

It is clear that it does not suffice for water professionals to limit their attention to physical, chemical and biotic aspects. If these are elaborated without unlocking them via higher aspects, it becomes difficult to get the desired measures for improving the water management accepted in a broad social field. They simply do not match the perceptions of, for instance, residents and politicians.
This is still a relatively common phenomenon in the water world. Water professionals determine what the best measures are on the basis of the values they share. Then they try to create support for them. This is what self-referential communication is all about (see also Section 1.3). Despite nice brochures and slick campaigns the necessity of taking water measures hardly registers in the other actors as a consequence.

With regard to the logical aspects, deepening and opening up aspects can prevent the use of doctrines. Infiltrating urban stormwater, for instance, is often sustainable but not in all cases. If it causes unacceptable contamination of the soil and groundwater (deepening) it is better not to infiltrate. If it is too expensive or it simply does not fit in the culture of the area (unlocking) other solutions are preferred. By involving the context the logical aspect comes alive and doctrines are avoided.

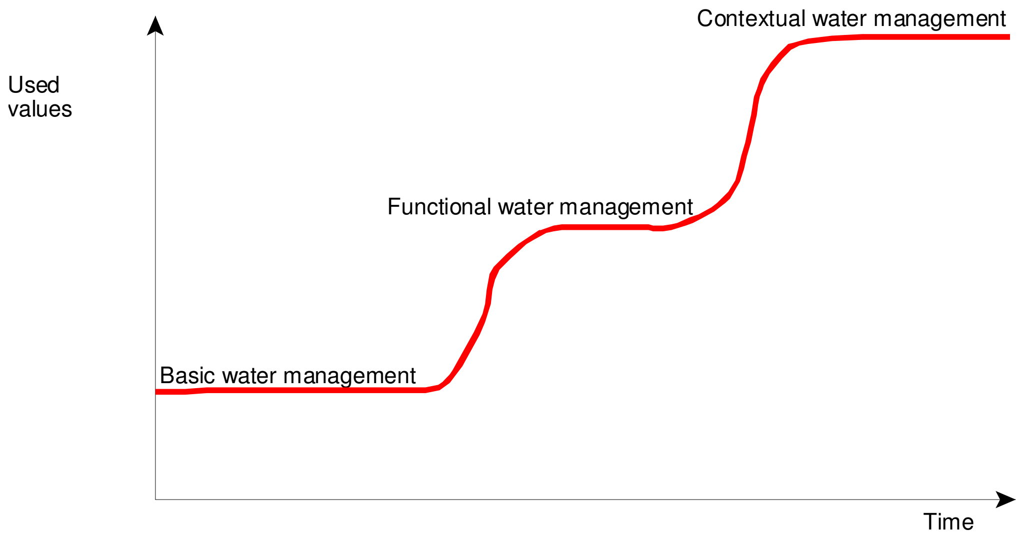


Figure 5.8. More and more values are being used in the development of water management, which increases complexity (see also Figure 2.1).

Deepening and unlocking aspects can take place by systematically going through the aspects bottom-up with the parties involved from various disciplines. This was done in various water projects and it appeared to release a great deal of energy. It is a revelation to many people when they discover that there are many different ways of looking at a particular problem. Problems become clearer and the context is better understood. It becomes easier to separate the main issues from the side-issues. Plus, experience has taught us that the input from the parties involved reaches beyond their own aspects. Aspects which are thought hardly to play a role are also dealt with.

The process in which the parties involved deepen and unlock each others' aspects is characterised by a high degree of complexity and therefore the patterns of complex adaptive systems – network forming, attractors, crises, developments on the edge between order and chaos – become visible. The nonlinear dynamics of the interaction between water and society can be recognized. By viewing these properties as healthy and stopping any processes for suppressing them, a step is made towards contextual water management, using many values (see Figure 5.8).

5.4 Coping with models

5.4.1 Reflecting on patterns

The core of dealing with complexity is that it must be made manageable. In addition to deterministic models, the model of the complex adaptive system is used to understand more of reality as it presents itself to us. Instead of having a knowledge-based system in two layers, as presented in Figure 1.3, we have a knowledge-based system of three layers. As it were, the complex adaptive system forms a buffer between the models and the complex world.

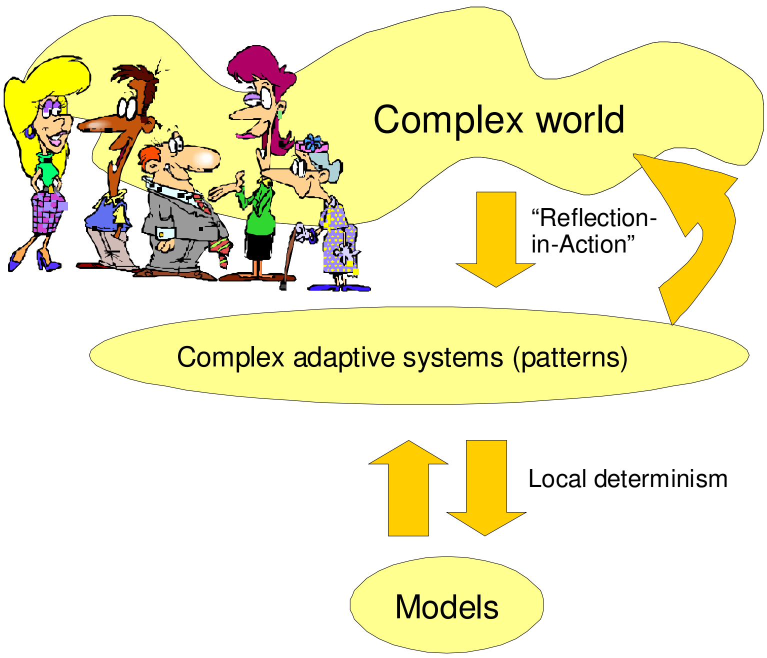


Figure 5.9. The complex adaptive system as a ‘buffer’ between models and the complex world.

The complex world in Figure 5.9 represents reality. Coherence is a matter of course in this world. Everything is connected to everything else and everything is continuously changing. In order to get more grip on 'the whole' in complex issues, the model of the complex adaptive system can be used. This model can make patterns visible; patterns of attractors, repulsors and crises, i.e., the elements in the survival landscape (see Section 2.11). These patterns do not arise despite complexity, but thanks to complexity. They are characteristics of a learning and evolving system. Those who understand the patterns of stability and instability and know the underlying mechanisms, possess insights that are essential to steering processes. Although the model of the complex adaptive system has a predictive value, predictions cannot be made with it. That is to say, it is not possible to say which state will occur at what point in time on the basis of the obtained insights. For such predictions it is necessary to use models that zoom in on a small area within the larger picture. Kellert (1993) calls this area local determinism (see also Section 3.6.3). Attention is restricted to processes that have a clear pattern and that have linear dynamics when the context is ignored. This means: small manipulations result in small consequences and large manipulations in large consequences. This process can be called local orientation (see Figure 5.10).

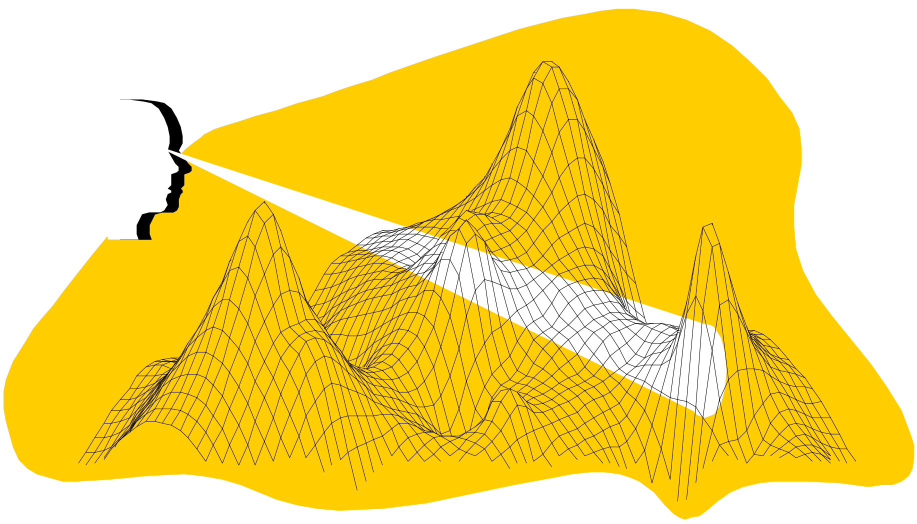


Figure 5.10. Local orientation in the survival landscape.

For local orientation, deterministic models are used to support the effectiveness and efficiency of packages of measures. Groundwater models can be used to determine whether the discontinuation of drinking water extraction will cause groundwater nuisance in housing estates. A model of the sewer system can verify how much the waste discharge is reduced if roof runoff is infiltrated into the subsoil. Surface water models can determine the effectiveness of retention and the improvement of the water quality if contamination sources are removed. The insights – mainly in physical, chemical and biotic aspects – are indispensable to the process. They determine the expertise of the water professional and contribute to taking better decisions.

However, with complex issues it is important to zoom out again after having made detailed calculations and to view the whole. After all, water is only one of the elements in the living environment. There may be traffic experts with model results on changes in traffic flows and spatial planners who calculated how the demand for space is going to develop in the next period. These processes together determine the survival landscape. There is no unique correct solution, as various solutions can come into the picture depending on the domain of values. The political dimension of the environmental policy is unfolding. And it is an illusion to think that the best decision can be inferred from the information obtained from local orientation. Decisions are made in a process that has more similarities to negotiation than to inference. In addition, for Interactive Implementation these decisions are taken at various scale levels, in different networks of actors and at several points in time. It is an adaptive process. Reflection on patterns offers insight into the behaviour of the whole.

Reflection on patterns forms the basis for interaction between the complex adaptive system and the complex world. Schön (1991) calls this Reflection-in-Action. People have both feet in practice and change things. They want to do this as well as possible. They therefore explore the issue they want to tackle broadly and look at it from various angles – frames. This looking at it from different angles is a continuous process. They see patterns and use the results from local orientations. When they have developed a feeling for what the direction of the solution should be, they will work it out and test it. Sometimes this works well, and sometimes it results in disappointment. Just like in a renovation, surprising developments may occur. They adapt their patterns on the basis of experience. The result emerges, as a combination of what was intended and coincidence.

Table 5.2. Various forms of plans (derived from Christensen, 1985).

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="2">Goals</th></tr>
<tr><th>Agreement</th><th>Disagreement</th></tr>
<tr><td rowspan="2">Measures</td><td>Known</td><td>Optimisation (I)
• Predictability
• Equality
• Liability
• Efficiency
• Effectiveness</td><td>Negotiation (II)
• Accommodating different preferences</td></tr>
<tr><td>Unknown</td><td>Experimenting (III)
• Innovation
• Solutions</td><td>Chaos (IV)
• Discovering patterns</td></tr>
</table>

Table 5.2 shows the leap made from the control system approach to Interactive Implementation. There are four quadrants in the table that vary from the degree in which there is agreement on the goals and the degree in which there is knowledge about measures. A few characteristics are described per quadrant (Christensen, 1985). In the first quadrant, the parties involved agree on the goals to be set and it is known which types of measures can be taken to achieve them. A control system approach suffices in this quadrant of local orientation. Concrete actions are taken here. This clarity is not present in the other three quadrants and it takes negotiations to have people with different preferences work together and investigation to develop new techniques or to verify whether certain measures can be taken. New insights are obtained all the time and new developments are taking place. This is partly chaos. Processes around complex issues in the living environment occur in all four quadrants. However, Christensen (1985) observes that a great deal goes wrong in practice because processes are treated as if they belong to quadrant I whereas they really belong to one of the other quadrants. She calls this pretending that there is agreement on goals *premature consensus*. Taking measures that are partly unknown, she calls *premature implementation*. The control system approach is primarily aimed at quadrant I. Supported by the model of the complex adaptive system, the Interactive Implementation is aimed at all four quadrants.

5.4.2 Experienced steering

In Interactive Implementation good water management is not seen as a one-off optimisation, but rather as a learning process. The higher level of learning (the expert) becomes more important (see Section 4.7.2). Solutions to complex issues are found in the field. In practice, people reflect on patterns. They can be made explicit in part, but they will remain partly implicit. The higher the level of learning, the larger the input of implicit knowledge. This is called “tacit knowledge”. The knowledge is present, but cannot be put into words immediately. It is, of course, important to develop new explicit knowledge, but the tacit knowledge of the real expert should also be valued for its true worth.

Important is the fact that real innovation arises from the interaction between implicit and explicit knowledge (Nonaka and Takeuchi, 1995; Capra, 2002). To be able to work out complex issues such as increasing the safety of water systems in practice, attention must also be paid to the different forms of knowledge transfer (see Table 5.3). Roughly, this means that the parties involved in water management should become more active in the field and less stuck behind their computers. All information processed through the computer is explicit.

Table 5.3. Four forms of knowledge transfer (Nonaka and Takeuchi, 1995)

From/to	Implicit knowledge	Explicit knowledge
Implicit knowledge	Socialisation	Externalisation
Explicit knowledge	Internalisation	Combination

People at the highest level of learning – the experts – often arrive at solutions using their intuition. Not by following set rules, but on the basis of patterns they can recognize by experience. This paves the way for innovation and timely response to things that are going wrong (kairos). Experience greatly contributes to being able to anticipate developments with a high degree of uncertainty.
Within this framework, the definition of *responsibility* becomes broader. Often, responsibility is linked to carrying out one's own tasks well, according to the rules. This is indeed important, but a fundamental issue is missing here. When something does go wrong and everyone has stuck to the rules, no one is responsible. You can hide behind the rules. In change processes, problem situations arise that have not occurred before. These situations cannot be solved by applying existing rules. Nothing happens if there is no one who can oversee the whole situation and who is willing to act outside the scope of existing rules. This is characteristic of the stagnation to be observed in the implementation of many policies. People are waiting for each other. A new definition of real responsibility could be: "if necessary, taking action outside the scope of rules and being willing to answer for the consequences".

5.4.3 Coping with uncertainties

Section 4.7.3 describes the various forms of uncertainty. It was observed that the control system approach primarily focuses attention to the first two forms: statistical uncertainty and scenario uncertainty. The largest changeability – and therefore the largest steerability – is found in the processes characterised by recognised ignorance and total ignorance. These are the processes that take place in quadrants II, III, and IV of Table 5.2. In complex processes, it is best to set out a course between too much and too little uncertainty. If no uncertainties are accepted nothing will change. It is an attitude of rather doing something wrong and being certain about it than doing something that might actually be right. On the other hand, it is also important that there are not too many uncertainties at play because processes will then predictably go wrong.

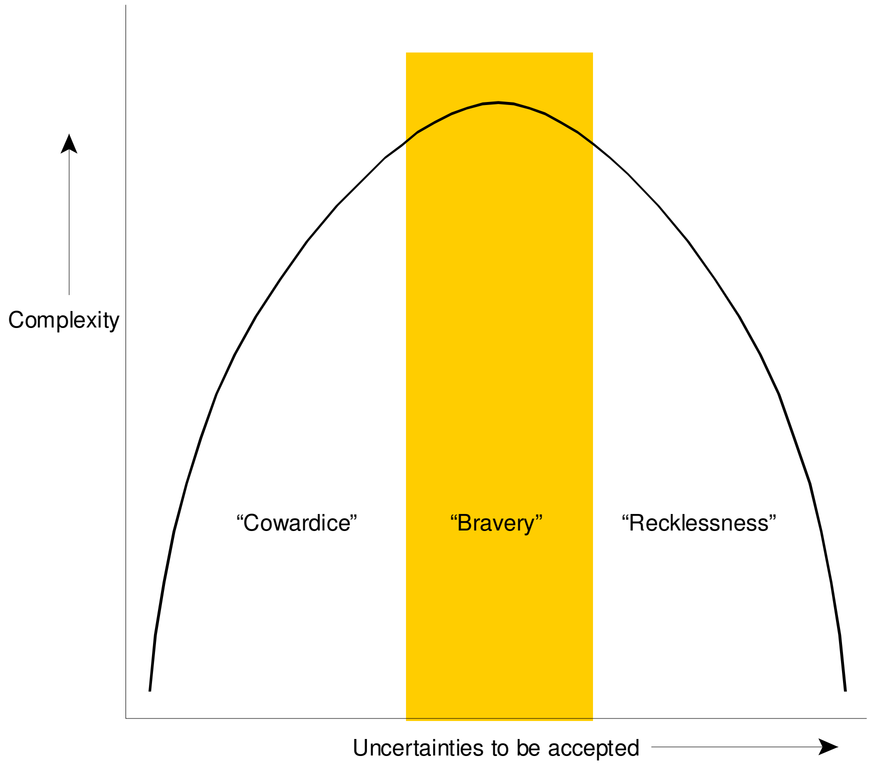


Figure 5.11. Relationship between complexity and uncertainties to be accepted, with Aristotle's terminology (Geldof, 1997).

This intermediate course is the symbol for the edge between order and chaos. In Figure 5.11, the horizontal axis shows uncertainties accepted in the desired change process. The vertical axis shows the complexity of the process. If no uncertainties were accepted in the process this would reflect a working method that is not very complex. Maximum certainty is obtained when everything is done as it is always done. Nothing really changes. However, when too many uncertainties are accepted – ignoring them as it were – this also does not reflect a complex working method. So many changes are made simultaneously that something predictably goes wrong. Probably the project fails and it is decided to continue as before: "We tried it and it was no success". Nothing has changed. It is the trick to find the middle path, introducing innovation without ending up in a situation in which the uncertainties have become unmanageable. This situation is characterised by maximum complexity. Figure 5.11 uses Aristotle's terminology; in his book Ethics, he advocates bravery, which he sees as the middle path between recklessness and cowardice (Leijen, 1992).

The middle path is not calculated, but it emerges by making plans with both many and few uncertainties. Iteratively, structural adaptations are determined. On the middle path, the parties involved feel that uncertainties are manageable and that there are enough opportunities to reduce uncertainties through further investigation.
The middle path is the most complex because *choices* have to be made. Not everything that is possible is also carried out. Choices will anchor the process. If no choices are made, too many balls are being juggled at the same time. If the focus is too restricted, contact with context is lost. It is a question of constantly observing and consciously weighing whether to intervene or not. It becomes clear in this process that continually investigating how to reduce the statistical uncertainty and scenario uncertainty results in stagnation. The middle path says something about the uncertainties of 'the whole' and a healthy balance between the different forms of uncertainty is a condition for this.

5.5 Conclusions

The method of Interactive Implementation is based on the characteristics of complex adaptive systems. The whole of processes is seen as learning and evolving. This makes patterns visible that will help navigation through the survival landscape of integrated water projects. The structure of the method is not as straightforward as with the control system approach and it also requires experience. In particular, processes with many actors cannot be completed according to a plan with a fixed number of steps. However, examples make it clear that Interactive Implementation offers good guidelines for getting plans actually implemented and improving the interaction between water management and society.

The preface sketches a metaphor for Interactive Implementation. A painter creates a painting by being active at two distances from the canvas. The real painting process takes place close to the canvas, but the painter will take a few steps back to have a look at the whole picture – the composition – from time to time. The action close to the canvas results in local orientation. That is where the control system approach finds its value. Reflecting the whole results in a good composition. That is where the strength of Interactive Implementation lies. The whole is more than the sum of its parts.

6 Flood risk

6.1 Problem description

In this concluding and summarising chapter, elements of coping with complexity in integrated water management are projected on the issue of flood risk. The structure of the sections represents the order of the chapters of this book. The central question is: how are we to cope with flood risk if instead of combating the complexity of the issue we make it manageable? In the nineties, there were many floods in the Netherlands, at least in comparison to previous decades. In 1993 and 1995, the large rivers flooded and around the turn of the century, there was much damage throughout the country caused by extreme quantities of rain (see Figure 6.1). For a long time, people thought that water management in the Netherlands was able to manage peak discharges well. Policies were therefore primarily aimed at combating contamination of water and drought. From December 1993, people were once again aware of the possible failure of dikes and the consequences this may have for people who live in adjacent areas.

Figure 6.1. Water nuisance in the West of the Netherlands (De Lier), September 1998 (photo: Martijn Beekman)

The extent of the damage might have been worse compared to events elsewhere in Europe. In the late summer of 2000, there was a period of heavy precipitation in the Alps. Usually, it snows in the Alps, but this year it rained which resulted in large mud slides causing much damage especially in Switzerland and Italy. Not much later rivers in England were overflowing their banks. In Ukraine in 1998, there was a real disaster (Voloshchuk &

Boychenko, 2000). Many people died. The economic damage was enormous. At the time of writing, May 2004, there are floods caused by heavy rainfall in Haiti and the Dominican Republic. Hundreds have died.
Despite the fact that other events in Europe – and in other parts of the world – are even more terrifying, the situation in the Netherlands requires special attention. Large parts of the Netherlands are below sea level, in polders, where there is little opportunity of fleeing the water. The fact that the problem is growing due to changes in climate and a rising sea level makes it extra vital to take measures.

Water nuisance mainly hits the headlines when land is flooded with water from the sea or the large rivers, resulting in impressive pictures. But it happens on many scale levels. Water nuisance also happens in smaller regional water systems. When watercourses cannot process the water they overflow their banks. When stormwater is not discharged quickly after a heavy shower, land is flooded. The principle of *shifting one's problems onto others* plays a role here. If people living in higher parts of the land discharge their water quickly and efficiently, this may result in nuisance in the lower parts. Sometimes sewer systems in urban areas cannot process the stormwater and streets become flooded. In case of combined sewer systems this results in public health risks because the flood water will consist of a mixture of stormwater, wastewater and disturbed sewage solids. Groundwater nuisance also occurs in urban areas when groundwater levels rise and the water seeps into basements and crawl spaces under houses. This has consequences for the living climate. On the smallest scale level residents are faced with leaking water pipes or roof gutters.
Besides nuisance, water often also causes damage. Sometimes even lives are threatened. Damage occurs on all scale levels, danger to life occurs along the sea and the large rivers. People drown. It is important to realise that drowning is not necessarily connected to water nuisance. Many people – especially children – drown because they seek out surface water and then behave recklessly.

6.2 Risk and risk perception

Water nuisance is a societal problem. Water cannot be completely controlled which is why there is always a *probability* that land is flooded unintentionally or that groundwater flows into basements and crawl spaces. On all scale levels, the *consequences* are either accepted by society or not. If not, people intervene. Measures are also taken to prevent events with unacceptable consequences from happening in future. This is the principle of anticipation, or acting proactively. The combination of probability and consequence determines the *risk*. A much used definition of risk is: probability times consequence. Probability represents the hazard, consequence the vulnerability.

People who develop activities in an area with risks let their behaviour be influenced by these risks. If they think the risks are high, they adapt their activities to this. People living in a flood plain are often very aware of the risks and will take them into account when decorating their house, for instance, no parquet flooring on the ground floor. When the water levels in the river are rising, they will follow the rise of the water levels closely and take the right precautions. People living behind the dike or at a higher level usually have a much lower perception of the risk and their behaviour will be less influenced by it.
People's behaviour on the basis of risks differs greatly. One person may try to avoid risks as much as possible, another will behave more carefully and a third will ignore the risk or even think it agreeable. Adams (1995) poses that people weigh the 'reward' they receive for taking

risks against their perception of danger. This behaviour emerges from the consideration: "The balancing act (…) is analogous to the behaviour of a thermostatically controlled system. The setting of the thermostat varies from one individual to another, from one culture to another. Some like it hot (…) others like it cool (…). But no one wants absolute zero." Many people seek out risks. Wildavsky (1988) says it a bit more romantically: "Conceiving a safety without risk is like seeking love without courting the danger of rejection."
This is where the notion of *risk perception* comes into the picture. Section 4.6.3 already described that residents' risk perception is determined by many factors such as time, voluntary actions, opportunities for adapting behaviour, advantages of living in the area and the degree to which people trust the local government. The perceptions people have can thus greatly deviate from the risks calculated on the basis of statistics. Administrators and politicians, who have to take decisions on taking measures, also have their own perceptions of risks. They are not only faced with flood risks, but also with risks related to storms, earthquakes, fires, soil and groundwater contamination, fine dust, nuclear power plants, machines, traffic, storage of fireworks, gatherings of large groups of people (football stadiums, pop concerts, public venues), food and eating behaviour, crimes, and many other issues. The topicality of a risk greatly determines the willingness to invest.

On the one hand, people's *safety* is determined by the various risks together and on the other hand by their risk perceptions and related behaviour. Situations are safe when (1) the risks are of an acceptable level and (2) people's behaviour matches the risk level.

6.3 Complex adaptive

The issue described above, from wet socks to danger to life, can be seen as complex and adaptive. There are many agents here at various levels of organisation (scale levels). Combined, they form networks that are going through continuous development. The central system concerns surface water, groundwater and the urban water chain of drinking water catchment, drinking water use, sewage and treatment. Water professionals and the parties directly involved are active in this system, with their own facts, values, theories and interests. The structures that arise are the result of rules that are applied (see Section 2.8), with which adaptive plans are drawn up to anticipate the future. An example of such a rule is: dikes along large rivers must be designed for river discharges that in theory occur once every 1250 years. Among other things, the *context* of the system consists of other risks, spatial planning, traffic, the economic conditions, stories, and many more issues. Developments take place in the context. The context makes each subsystem unique. Developments in the context (the environment) result in structural adaptations in the system. Views are adjusted, actors influence each other and measures are taken. The system *adapts*. If the economic climate is good and the need for land high, various attempts will be made to reclaim land from water, curtailing water further. After floods occur, committees are formed and rules change. This game is perpetuous and it illustrates how people have a love-hate relationship with water. Most of the time water is friendly enough. It is a condition for natural processes. It is nice to spend your time near water. When the weather is hot, water cools us down. Culture is created and people meet in and around water. Cities situated on water have additional opportunities for economic development. Water is beautiful to look at. Water is a precondition and a right (see Figure 5.7). However, sometimes water is not so friendly and situations may arise that are even life threatening.

System and context go through a continuous development; while measures are taken in response to high-risk situations. These measures make situations safer. But because society is not in equilibrium, it takes advantage of the new situation. For instance, new houses are built in the area concerned, increasing the risks again.

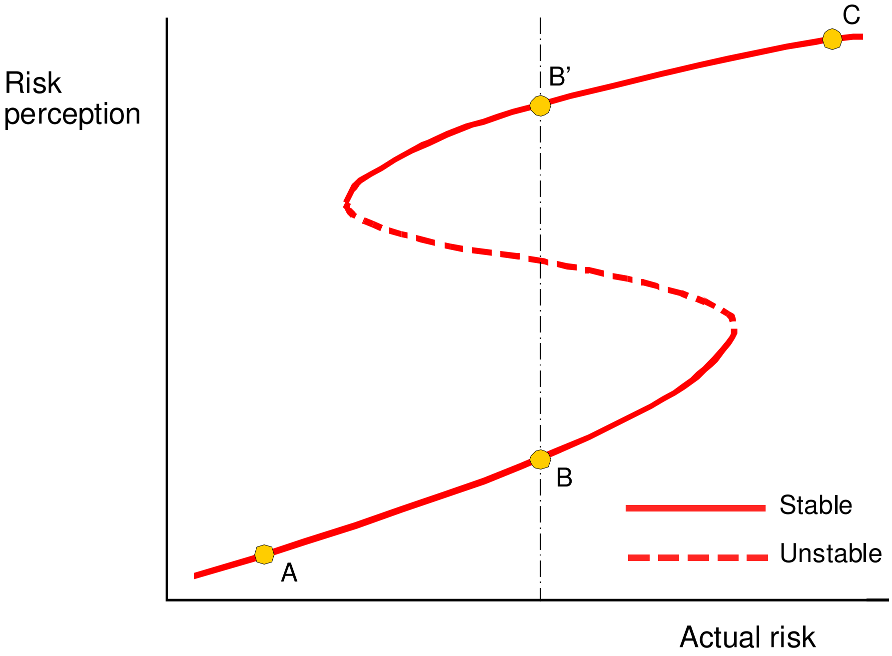


Figure 6.2. The nonlinear relationship between actual risk and risk perception, with two attractors.

The effect of possible attractors is presented in Figure 6.2. The actual risk is plotted against the risk perception of residents, administrators and politicians. The horizontal axis shows the technical – system-oriented – dimension of risk and the vertical axis relates to the context; how residents weigh risks in their actions. The term *actual* risk is used here. Actual risk is more dynamic than the risk statistically calculated by water professionals. The actual situation is based on the latest information. If there are heavy floods in Germany and a flood wave is moving through the Rhine towards the Netherlands, the actual risk increases.
With very low risks (point A) the behaviour of people is not influenced. With very high risks (point C), when it is clear that there is a huge risk of things going wrong, everyone agrees that action should be taken. In other words, there is consensus in risk perception. With intermediate values there are different stable states existing beside each other. It is possible that people underestimate the risks (point B), but it is also possible that they overestimate the risks (point B'). People may overestimate when they are involuntarily exposed to the risks, when there are no possibilities of limiting the consequences of an event through behaviour, when the risks are hardly compensated by the advantages, or the local government is distrusted and the press is making a mountain out of a molehill. In the case of water issues, state B is usually found. The friendly side of water dominates as long as nothing happens. It is hard for the government to take risk-reducing measures in this situation, especially when cultural values such as old dike houses are at stake. The situation may differ per location and per scale level.

The combination of B and B' in Figure 6.2 is characteristic of the *bungee jump society* (Boutellier, 2002). People feel restricted in their freedom in this situation if the government lays down restrictive rules. They want to do everything they want to anywhere and at anytime (B). But when something goes wrong (B') they hold the government responsible and they think that insufficient measures were taken to control the risks. People want the freedom of the free fall and the security of the cord, as it were. The government itself has initiated this situation in the past by taking on more and more responsibilities. People have now grown accustomed to having high-quality water from the tap and they are used to the fact that nuclear power plants keep working, that chlorine trains cross the country without problems and that there are no floods. These have all become the work fields of professionals. This is a qwerty, a lock-in.

Both the natural and the social processes around water nuisance can be described as complex adaptive processes. It should be clear that a system can never be without risks. Events and crises will always occur. Nature and society cannot be completely controlled. Events may display the pattern of self-organized criticality (see Figure 6.3). Small events with a little bit of nuisance can happen every day, such as a leaky roof gutter or getting wet socks when getting out of the car. Events that flood large plots of land and during which people are drowned happen only occasionally.

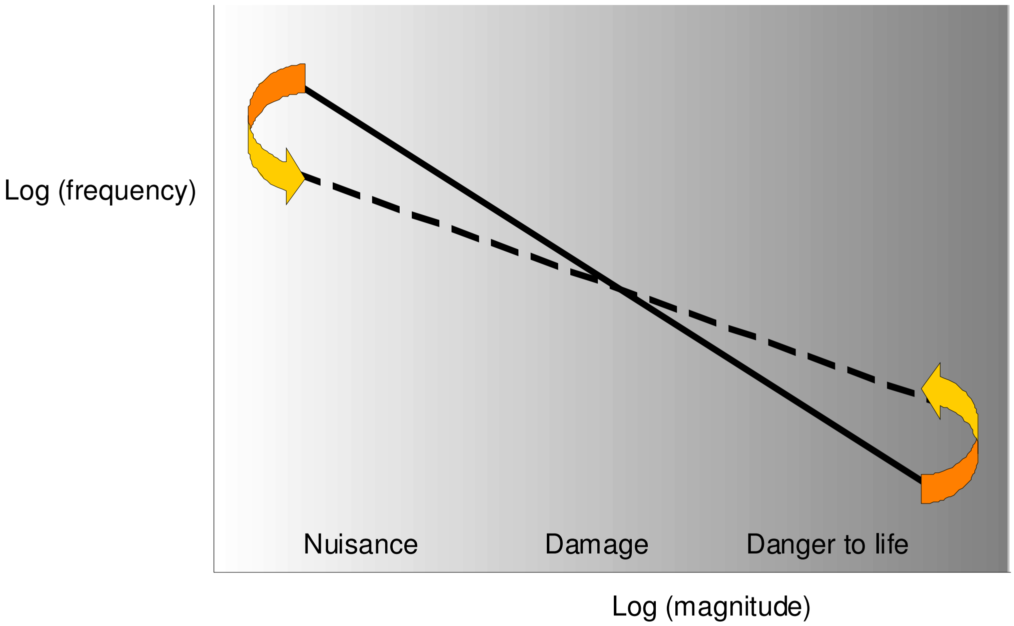


Figure 6.3. Theoretical relationship between the magnitude and frequency and possible effect of control measures (dotted line).

The coherence and persistence of a complex adaptive system can be so strong that the continuous line in Figure 6.3 does not move downwards after taking technical measures but rotates instead, onto the position of the dotted line. Nuisance and damage caused by frequent events then decrease but when something really goes wrong the consequences are much greater. In the Netherlands, this is already happening in the diked areas along the large rivers. People behind the dikes can live there as if there is no river nearby. They almost have the same degree of comfort as people living high up in the hills. Economic activity is increasing in those areas. However, when things do go wrong, large areas will be flooded quickly. The ground level in the adjacent polders is situated many metres below the water level of the river. The making of dikes initiated natural morphological processes. The river has risen and the ground level in the polders has dropped – partly due to peat excavations. The social morphology also continued to develop.

6.4 Control and containment

The issue described above has all the features of complexity. A possible strategy for coping with this complexity is by reducing it. This means that the context and most factors of risk perception are going to be excluded. Generic measures on the basis of fixed standards will then be the goal and attention will primarily be aimed at controlling the water system. A *control system approach* is arising.
The first step is to lay down the standards. Standards can be probability values or risks. In the Netherlands, standards for regional surface water have been laid down that allow grasslands to flood once every 10 years and urban areas once every century. The water manager is responsible up until these standards are exceeded; anything above is considered outside their control. On the basis of the standards, a check is made to see whether the current situation complies (testing). Packages of measures are formulated for any bottlenecks. The situation at the end of the 21st century is anticipated; that is, the climate change and the rising of the sea level. In the Netherlands the strategy of "hold it back, slow it down and then release it" is used for this. Then the measures are implemented. Pumps are made larger, watercourses are widened and plots of land are prepared for water retention. In 2015, the Dutch water system must be back on track.

Typical of this approach is – especially when standards play such an important part – that the bungee jump society continues to exist. It would make sense to place responsibility for small-scale problems with residents, while they accept part of the nuisance. The government then prevents and deals with the more sizeable problems. However, the standards cause actions to veer in a completely different direction. Water management is adapted to the standard so that there are no more problems. Residents and companies only experience the friendly side of water; which they then consider natural.
If a situation arises which is worse than the standard, no one is responsible. If the rules are met, everyone can hide behind them. However, people will ask for compensation when they undergo damage and claim that the government has paid too little attention to the safety of the area involved. They want more control.
In a control system approach the attractor of the bungee jump society makes it difficult for the government to attract support for measures. There are not enough angles that connect with other fields of policy. Many people do see the high costs of adapting water management, but they fail to see the effectiveness of it. Traffic and smoking cost more lives. The result is that water policy ends up in the mere margins of environmental policy and remains dependent on heavy precipitation and disasters to be briefly revived. Those who see through the present attractors know that the deadline of 2015 for Dutch water management to be back on track is not going to be met this way. The implementation is stagnating. "More haste, less speed," and this is a disappointment. "It all came down to money", will be said in hindsight and "people in the risk areas act irrationally."

What is special about the control system approach on the one hand is that people understand that nature cannot be completely controlled. It is an axiom that floods can never be prevented completely. On the other hand, people do not acknowledge that it is also not possible to control social dynamics. Just like nature its dynamics is nonlinear. Society is not in equilibrium. Those who do not realise this will be unpleasantly surprised by it.

If there is a self-organized criticality as presented in Figure 6.3, this results in an approach unilaterally based on standards from a less safe situation. Small nuisance situations, in the domain of local and minor damage are then being suppressed. This causes people to be less aware of the fact that things *can* go wrong and to adapt to the newly obtained luxury situation. It is possible that the consequences of an extreme event are larger because people are not mentally prepared for it.

6.5 From plans to implementation

From the above, it is clear that something has to change. It is not desirable to remain within the basin of attraction of the bungee jump society. Whichever way the government deals with matters, it will always be wrong. The qwerty must be broken and this means that – besides reducing risks – people who stay in a specific area should gear their behaviour towards the risks. They should make *conscious* choices. Beck (1992) describes this as a reflexive society, in which attention is not unilaterally focused on water. Responsibilities are divided more honestly. The S curve in Figure 6.2 will then change, but it is hard to say how. It would be a utopia to expect it to become a straight line.
It is also true, in case of self-organized criticality, that there should be clear communication that floods will always continue to occur. They belong to a healthy water management system. By suppressing small events, the consequences of large events may become more severe. Even though this is hard to prove scientifically, it does match the feeling many people have when dealing with risks. After all, did not people start driving more carelessly after they started wearing seat belts and the brakes of their cars were equipped with anti-lock systems?

Dealing with flood risks differently has the characteristics of a *transition*, a fundamental change with a clear direction, but no clear outcome. It calls for a process that may take many decades (Rotmans, 2003). This process is characterised by perseverance and bravery in little steps. A clear direction on the one hand and much openness on the other hand, right on the edge of order and chaos.
Increasing safety is more like a – long-term – renovation than like building new houses. The working method of Interactive Implementation is perfect for tackling water nuisance.

The serial approach certainly does not work when going through a transition. Working out a balanced strategy through policy and planning, which is to be finished in the Netherlands by 2015 is impossible. The parallel approach of Interactive Implementation (see Section 5.2.1) offers better perspective for this. Policy-makers, planners, designers, those responsible for implementation and maintenance and managers, work together and try to obtain as many tangible results as possible, so as to *anchor* their efforts. The marble in the marble landscape should not roll back.

Table 6.1. Six different work fields (A to F) for handling flood risk

Scale level / naturalness	Artificial	Natural
Sea and large rivers	A	B
Regional water systems	C	D
Local water systems	E	F

Switching between scales (see Section 5.2.2) does not mean working from large water systems towards details, but that parallel processes are started at various scale levels. Table 6.1 shows three scale levels. On each scale level, different questions are asked and the proportion between generic policy and local differentiation varies. Table 6.1 also distinguishes between artificial[12] and natural water systems. Especially in the Netherlands, there are plenty of examples of land that would be flooded without active human intervention – such as raising dikes and pumping water. Such areas require a different approach than areas in which water can run off naturally.

In places where much water is gathered and people depend completely on dikes or dunes (working field A) an active attitude of the government is required. If a dike bursts and a polder with thousands of residents is quickly filled with water, this is a real disaster. In the Netherlands this presents an irreversible situation. A choice must be made between staying or moving. If the deep polders – most of which are situated below sea level - remain inhabited, the water system must be controlled. Those who do not believe that man can shape the landscape are better off moving house. The showpiece of these areas is land created by man. The following two points of attention are important in order to be able to implement plans in these areas from the perspective of coping with complexity. First, the posterity discussion must be kept alive. The question is: “Do people still want to live here in 300 years’ time?” If the answer to this question is yes, we must guard against the development of activities that people may regret in a few decades’ time. This requires economic vision and making clear choices. Second, if plans are implemented somewhere, residents should especially be involved in their details; mapping out both the friendly and the unfriendly side of water. It is desirable that residents *consciously* weigh the pros and cons of living in a high-risk area. It is characteristic of high-risk areas to have an attractive living environment exactly because of the presence of water.

There is more elbow room for the water managers in regional water systems (working fields C and D). In these areas the consequences of floods are often smaller. The principle of shifting one’s problems onto others is a central issue in these areas. In consultation with the people who live, work or recreate there the extent of acceptable nuisance can be determined. This is the opposite of the standardisation of the control system approach. Events with small consequences are made a subject of discussion and measures are taken against severe events. The aim is to retain water down to the smallest details of the water system. This is achieved by increasing the complexity of the issue and by looking at more aspects of the environmental policy than the water aspects alone. This creates mutual dependency (see Section 5.3.2). This also applies to rivers with no dikes and adjacent areas higher than the low water bed (working field B), where there are also good opportunities to look beyond water alone and to draw up plans with an added value so that they are actually carried out. It is possible to opt for a more natural water management in these areas – the principle of feasibility is not a must here – and there are also more opportunities to influence risk perception.

At the local level of street, home and tree (working fields E and F), water is only a small part. It is a feat to fully include water here. A feat that would reach the parties involved most directly. If people are living in an area with risks, three types of measures can be taken: (1) measures to prevent water nuisance, (2) measures to reduce the effects and (3) measures to facilitate repair and damage settlement. These measures relate to before, during and after the event. By building dikes, laying retention areas and quickly pumping water away, flood risks

[12] Artificial means: in polder areas, below sea level or river level. This is about 60% of the Netherlands.

are reduced. By laying escape routes and facilities in and around homes, having sandbags ready, and starting an information system, damage can be limited. Through compensation funds and insurance, damage can effectively be dealt with afterwards. By determining the various measures in consultation with the parties involved and making the financial consequences visible, conscious choices can be made. This is essential to break the bungee jump qwerty.

It is important for water professionals to have the water management on track in 2015 so as to be able to calculate the required effort to be taken. It is not practical to communicate such a target year widely in public. Forcing the matter does not help since it has clear features of a complex adaptive process. Maybe if heavy floods take place regularly in the next few years, the deadline of 2015 can be met. If there are no such floods, which is, after all, the preferred scenario, it is better to adapt the tempo to what is possible. “Less haste, more speed.” Actions should be taken at the right moment (see Section 5.2.3), which cannot be defined precisely *a priori.*

6.6 Interaction between water and society

The above makes clear that there is a complex interaction between water and society. Measures do not come to life until residents, companies and politics see their value. An approach in which first the water professionals determine generically the most effective solution does not work.

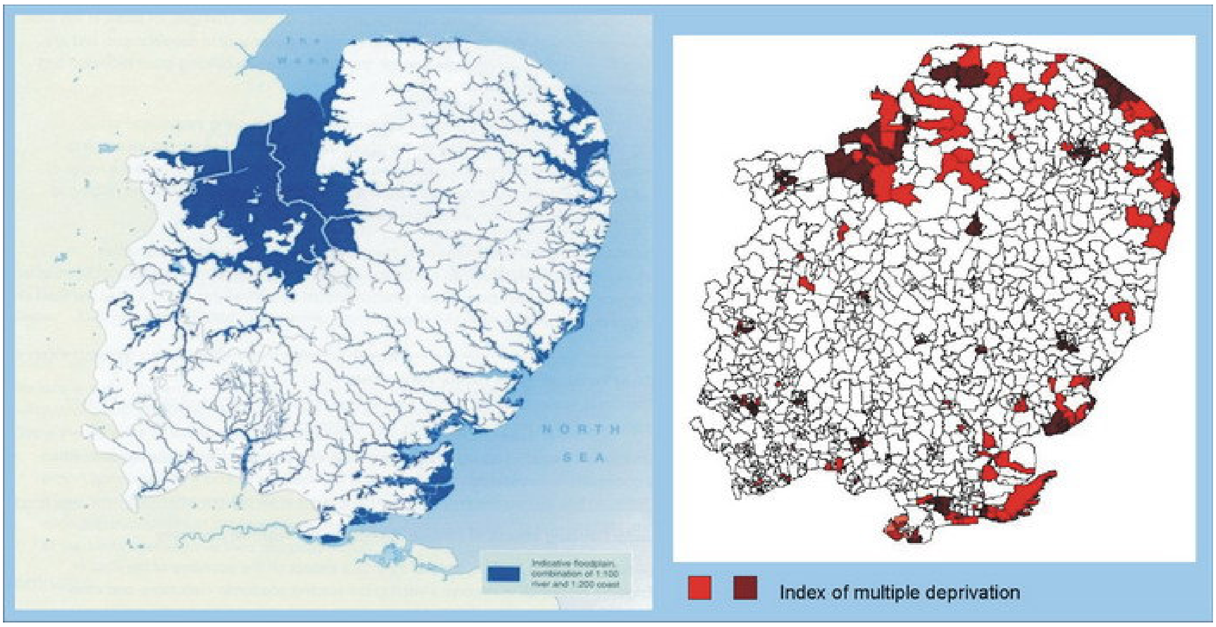


Figure 6.4. Two maps of East Anglia in England. On the left, a map with flood risks (dark) and on the right the areas at a social disadvantage (dark). (source: Government Office for the East of England).

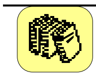
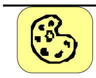
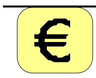
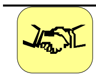
Figure 6.4 shows that resistance can arise from other considerations than water management alone. The figure shows that there is a strong relationship between flood risks and social position. In East Anglia, the areas at a social disadvantage (multiple deprivation) rather

closely match the areas that are threatened by rivers and the sea. Any proposals for reducing the protection levels in high-risk areas are quickly interpreted as a social injustice.
Patterns such as in Figure 6.4 can be observed regularly. People are often most vulnerable in areas where risks are highest (Bankhoff et al., 2004). This illustrates the necessity of looking beyond the water management aspects with issues of water nuisance and including the context. *Real* resistance (see Section 5.3.2) is often caused by the fact that people feel closely involved in processes that have nothing to do with water management directly.

The nature of the interaction between flood risk and society calls for contextual water management (see Section 5.3.1), in which various processes are taking place at the different scale levels. Each scale level has its own questions. Naturally, this is an open process. It is complex and adaptive. This does not mean that everyone should always join in the discussion. Hajer (2000) suggests that democracy can be explained in three ways: as a representation, as a controlling system, and as deliberation. It is all about the right proportions and this may very well pose the biggest challenge.

The FLOWS project funded via Interreg IIIb, in which governments and researchers from England, Norway, Sweden, Germany and the Netherlands are working together on a strategy for learning to live with flood risks, sees transition as a *learning process*. Kolb's learning cycle (1984) is used in this project. This cycle consists of four phases: (1) concrete experience, (2) reflective observing, (3) abstract conceptualisation and (4) active experimentation. Each human being has a preference for a certain phase from the learning cycle. There are doers, dreamers, thinkers and deciders. The difference between the control system approach and Interactive Implementation is clear. In the control system approach, measures mainly come from abstract conceptualisation and active experimentation. This can be seen as a game of ping pong between thinkers and deciders. The learning cycle is not closed. In Interactive Implementation more attention is paid to reflective observing and concrete experience. Dreamers and doers are more involved in the process. In particular the latter group is of importance because about half of all people learn best by doing.
In order to embed water management measures socially, it is important that the parties involved learn about each other's values. Table 6.2 provides an example of the aspects that come into the picture when we look beyond water alone.

Table 6.2. Aspects from a fictitious project (a small village in a flood plain).

	**Moral**	Safety is the most important issue. The aim is a resilient and sustainable water system. Shifting one's problems onto others must be prevented. The aim should be a joint responsibility. Trust is important.
	**Legal**	The land-use plan will be adapted in the short term. Two new residents ("from town") have taken legal action and demand better protection against the water.
	**Aesthetic**	Appealing landscape with space and lowland riparian forests. Old houses. Much spatial quality. Disturbing elements are on the other side of the water. Raising the dike is seen as a deterioration of the landscape.
	**Economic**	Residents' income is relatively low. However, houses are relatively cheap and good facilities are near. The residents have difficulties insuring objects threatened by water. Measures to improve the water management are expensive with rather low yields – in residents' perception. There is potential to increase the recreation in the area.
	**Social**	There is a close community with relatively many intellectuals. People meet along the river. Many residents also have a boat. The average age is rising. The number of tourists is growing (especially cyclists and hikers). This is seen as a positive development.

Linguistic	Political language is poorly understood by residents. There is too much jargon. Details such as street names are often misspelled and mispronounced by planners. The term resilience is confusing. At some points in the village (artworks) the highest water level is presented.
Historical	There are some archaeological values. Some dike houses are very valuable. Some of the families has been living there for many generations. There are many local legends. Some of the forefathers are real heroes. Also, the residents have had bad experiences with the local government.
Logical	The motto: “hold it back, slow it down and then release it”. Residents believe that it is better to take measures in Germany, because it is upstream. Maintaining a design standard of 1250 years.
Psychological	It is a wide landscape. It is lovely being near water. Relatively calm. There is some noise from the railway bridge nearby. Nice air to breathe. The threat from the water is felt when the water level is high.
Biotic	The value of natural development in the flood plains is not visible. In its current condition, its natural value is already very high. There are many types of red lists. Some residents experience nuisance from geese.
Chemical	The quality of milk after a flood is being questioned. In two locations, materials are stored that may cause danger in case of a flood. There are plans to store contaminated sludge in deep holes near the village.
Physical	In the current situation, floods occur about once every five years. In part, homes are decorated taking this fact into account. The houses are damp, mainly due to bad walls, floors and foundation. Most of the houses are situated on river dunes. Damage mainly occurs with agricultural companies. The escape route floods too quickly. There are plans for a new traffic route.

Table 6.2 shows that much more is going on in a specific area than just risks and measures reducing those risks. By involving the context in the issue, versatility is increased and new solutions can be found. Each aspect is unique. Water policy comes to life when all aspects and the actors who value these aspects are involved.
Logical aspects such as “hold it back, slow it down and then release it” become more powerful or are undermined by confronting them with other logical aspects and by projecting them onto other aspects through the mechanisms of deepening and opening up (see Section 5.3.3).

There are positive and negative values attached to water. The positive values are present 365 days a year. After all, these values are easier to communicate than the negative values that only show themselves occasionally. The friendly side of water is the rule; the unfriendly side is the exception. In order to have the process sink in it is important to map out both the positive and the negative values.

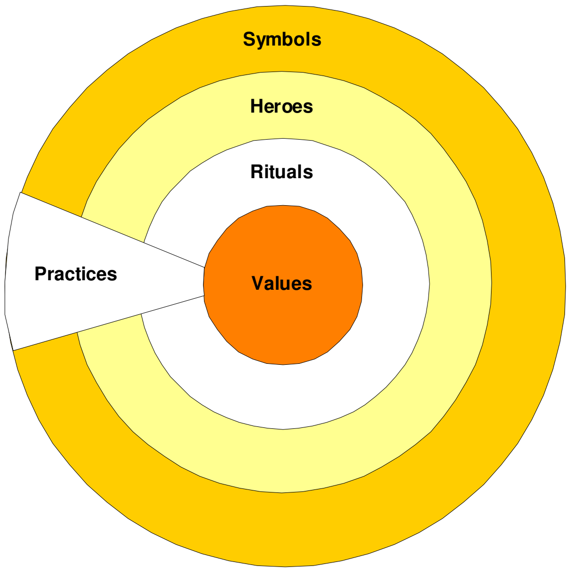


Figure 6.5. Hofstede's culture model (1998).

Anchoring of the results of the transition is broad. In addition to tangible results (measures) and signed contracts, it is important that there is social anchoring in the culture. This can be achieved in various ways. Hofstede (1998) uses the so-called onion model for culture (see Figure 6.5). The values of a culture are found in the core. Around the core, you will find the practical rings of rituals, heroes and symbols. Symbols are closest to the surface. Values change by making elements in the landscape visible which in turn make the risks visible, by bringing stories from the past to life, and by laying down agreements on the prevention and settling of damage. This makes it less easy for the marble to roll back towards the bungee jump society.

6.7 Handling models

Interactive Implementation uses the model of the complex adaptive system as a 'buffer' between deterministic (and statistical) models and the complex world (see Figure 5.9). The signalled attractors and the pattern of self-organized criticality dominate the process. They determine the nonlinear dynamics that, if this is not taken into account, can cause disappointment. Both natural and social processes cannot be wholly controlled.

Practice teaches us that many people can observe the complex patterns well. They find them easier to understand – and often even more logical – than statistical statements about probability and consequence. This mainly applies to administrators and politicians. Choices can be made by reflecting on patterns in practice.

That does not mean that calculations with deterministic and statistical models should not be made. These remain important. Water professionals must put in their knowledge on the physical, chemical and biotic aspects as well as possible, so that choices can be supported thoroughly. If necessary, verification is made of which cause-effect relations apply on the basis of local orientation (see Figure 5.10). What is the effectiveness of the laying of a retention area? What morphological processes can be expected? Does it make sense to increase the capacities of pumping stations? How quickly will a polder fill up with water if the dike bursts at location x? What will be the effect on the groundwater? Will more basements be flooded? What will be the effect on the water quality of the proposed measures? What types of nature can be created? The answers to these questions are all relevant and they support the process. With the right models that are available nowadays and with the possibilities offered by GIS, the quality of policy, planning, design, implementation and maintenance can be increased.

The outcome of models is a form of explicit knowledge, but it is not enough. It is also important to pay attention to implicit knowledge. Particularly at the start of transition the role of experts (see Section 5.4.2) is of vital importance. In order to get matters actually off the ground, answers should be sought that can be found in the field. For example, if land must be bought for laying retention areas in a regional water system, it is vital that there are people around who spend much time in the field, who know what is going on and who can sense go or no-go situations and who are trusted. They will join that which is feasible with what is acceptable. In addition, experts cannot be avoided in situations in which things go wrong or threaten to go wrong. Being able to take decisions within a few minutes can mean the difference between a disaster and no disaster. In short, against all trends it is important to pay more attention to the value of implicit knowledge.

With regard to uncertainties, it is undesirable to continue ever more detailed model calculations for too long and too precisely. It focuses the attention too much on statistical uncertainty and scenario uncertainty (see Figure 4.9), while the biggest changeability is found in ignorance. Moreover, sometimes parties involved can see right through calculation results in a project. Often GIS maps with calculation results are shown to very experienced people – such as farmers who have faced the dynamics of an area every day for decades – and they respond by saying: “I don’t believe the results. They don’t correspond to my experiences”. Often, these people are right, which means there is a flaw in the model. The culvert turns out to be a weir. By reflecting on the uncertainties of ‘the whole’ and setting out a course of bravery (see Section 5.4.3) progress can be made.

6.8 Epilogue

This concluding chapter shows some characteristics of the complexity of issues around flood risk and offers a few guidelines for coping with them. Many elements from the previous chapters return in this chapter. It is not a comprehensive overview. It is only a sketch of the situation. However, it shows that it is necessary to break free from an approach that resembles the control system approach too closely as this will only result in disappointment – and predictably so. But breaking free is not so easy. Thinking within a control system is a qwerty in itself. Interactive Implementation offers possibilities to break free from this way of thinking and makes it possible to close the huge gap between techniques and society. This requires great effort. But it is worth it.

In the last few years, the principle of Interactive Implementation has been used in many projects. In hindsight, many people ask themselves: "Is this all there is to it?" and this brings us back to the start of this book: when you accept that something is complex, it becomes easier to deal with. By treating complex processes as complex processes, complicatedness is prevented. Also, the parties involved enjoy it more. The control system approach is primarily aimed at negative feedback, suppressing undesired processes. Interactive Implementation is also aimed at positive feedback which makes it possible to use opportunities to their fullest advantage and stimulate desired processes.
The health of "the whole" is determined by how the negative and positive feedbacks encroach upon each other. It characterises the reality met in practice which may hold true beauty to the keen observer. It teaches us to respect the comprehensiveness of nature and culture. By adopting a somewhat modest attitude and accepting that we are only a small cog in a larger system, we can have more impact.

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