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Introduction

This is one of Mistra-SWECIA project 4 working papers summarizing results from studies of risk perceptions, social learning and policy integration in the Stockholm Region Case Study.

The Working Paper, authored by Peter Rudberg, SEI, is based on his Master's Thesis work on the Stockholm region case study of project 4, complemented with an expanded study of climate change adaptation of organisations engaged in the water supply and waster water sector in the Stockholm region.

The working paper presents two major conclusions. First, factors influencing the feasibility and attractiveness of different adaptation options need to be included and analysed in order to understand the actual adaptation space of an organization. Second, due to the factors identified as influencing the adaptation space, it is unlikely, at present, that robust infrastructure solutions can be implemented in the WW sector of the Stockholm Region solely due to concerns of climate change.

The paper is published as both a SEI Working Paper as well as Mistra-SWECIA Working Paper No. 4. It is downloadable under the SEI web site:

<http://sei-international.org/mediamanager/documents/Publications/Climate-mitigation-adaptation/rudberg-adaptation-space-wp-100331b-sei.pdf>



Furthering the Understanding of the Adaptation Space of Organizations

A Case Study of Adaptation to Climate Change within the Water
Supply and Wastewater Sector of the Stockholm Region

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SUMMARY

This report investigates the adaptation to climate change that is taking place in the Water supply and Wastewater (WW) sector of the Stockholm Region. The adaptation process is analyzed in terms of building adaptive capacity and implementing adaptive decisions. Theories on organizational learning and the concept of an organization's adaptation space are used to understand the factors that influence the adaptation process and the capacity of the studied WW organizations to adapt to climate change. A case study approach has been used and by focusing the research on four regional WW organizations – that comprise a majority of the region's WW activities – it is argued that conclusions relevant to the region's WW sector as a whole can be made. Semi-structured interviews with the complete management board – in three out of four organizations – and official documents and reports, are the main sources of primary data for the analysis.

The results show that adaptation to climate change is occurring in the WW sector of the Stockholm Region. The adaptation is mainly taking the form of building adaptive capacity and there is only limited evidence of implementation of adaptive decisions. The research suggests that there are few technical and organizational limitations for adaptation to take place and that the main factors influencing the adaptation space of the sector is how the climate change issue and risks are interpreted and perceptions of how the WW organizations should function and use their limited economical resources. Two conclusions are drawn from these results: first, factors influencing the feasibility and attractiveness of different adaptation options need to be included and analysed in order to understand the actual adaptation space of an organization. Second, due to the factors identified as influencing the adaptation space, it is unlikely, at present, that robust infrastructure solutions – which have been suggested in the literature as a viable way to deal with the intrinsic uncertainties related to climate change – can be implemented in the WW sector of the Stockholm Region solely due to concerns of climate change.

Keywords: Adaptation space, building adaptive capacity, implementing adaptive decisions, water supply and wastewater sector

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ACRONYMS

IPCC	Intergovernmental Panel on Climate Change
SWWA	Swedish Water & Wastewater Association (Svenskt Vatten)
TAR	Third Assessment Report of the IPCC
WW	Water supply and Wastewater
SWSC	Stockholm Water and Sewage Cooperation Council (VAS-rådet)

1 INTRODUCTION

Since the publication of the first Intergovernmental Panel on Climate Change (IPCC) report in the year 1990 results from scientific research and observations of climate change have increasingly validated the climate change thesis. At a global scale we are now at a point where there is unequivocal evidence of warming of the climate system and we are certain that this warming is very likely due to the observed increase in anthropogenic greenhouse gas concentrations (IPCC 2007a: 229). Given that this is correct we also know that, due to the time it takes for the earth system to react to changes in radiative forcing, we are committed to further warming in the future (IPCC 2007c).

As a result of this understanding numerous assessments have been made and scientific reports written evaluating and arguing for the need to adapt to a changing climate. There are a range of publications at all scales, from the international to the national and regional level, with the clear message that adaptation of our society and ecosystems is necessary to reduce the negative effects of climate change now and in the future and that it should start already today (IPCC 2007a; RTK 2008; SOU 2007:60).

Within the scientific community, a body of literature focusing on adaptation to climate change has emerged where one of the key analytical concepts is vulnerability to climate change (Adger 2006; O'Brien *et al.* 2004; Yohe 2000). In this literature vulnerability is generally understood as a function of exposure, sensitivity and adaptive capacity (Schneider *et al.* 2001; Smit *et al.* 2001). Adaptive capacity is defined by the IPCC as “the ability of a system to adjust to climate change... to moderate potential damage, take advantage of opportunities or to cope with the consequences” (IPCC 2007b: 869).

In the Third Assessment Report of the IPCC (TAR) in 2001 adaptive capacity was identified as dependent upon factors such as wealth, technology, education, information, skills, infrastructure, access to resources, stability and management resources and it was argued that “an enhancement of adaptive capacity reduces vulnerability” (Smit *et al.* 2001: 879)

Since 2001, however, there have been developments that show that possessing high adaptive capacity does not in itself necessarily lead to adaptations that reduce vulnerability. One example of this are the effects of extreme heat waves that have been experienced in Europe and North America and resulted in disruption of infrastructure and high mortality rates even though these cities and regions have high adaptive capacity according to the factors mentioned above (Klinenberg 2002; Lagadec 2004; Poumadère *et al.* 2005). One result of this is that there has been an evolution in the conceptual thinking related to the process of adaptation which has been divided into both building adaptive capacity and implementing adaptive decisions. This reflects the fact that adaptive capacity can exist and be built without the capacity being used to reduce vulnerability (Adger 2005; Fussler and Klein 2006). More research has also been dedicated to understanding potential and real barriers to the implementation of adaptive decisions, such as perceptions of risk, complacency, institutional obstacles and social, financial and cultural constraints (IPCC 2007b).

This report builds on the work and conceptual model of organizational adaptation created by Berkhout *et al.* that has been developed and used to understand adaptation of different types of business organizations in the UK (Arnell 2006; Berkhout *et al.* 2006; Berkhout 2004; Hertin *et al.* 2003). The concept of “adaptation space” was introduced by Berkhout *et al.* and further developed by Arnell and Delaney and is defined, by the latter, as the set of options that are potentially available to an organization to deal with possible climate and other changes but specify that some “will be more feasible than others, for technical, legal, economic or cultural reasons” (2006: 229). In this report the concept of an organization’s adaptation space will be used paying attention to how feasible and attractive different adaptation options are to the organizations. This is identified as the actual adaptation space. The process of adaptation to climate change will also

be analyzed in terms of building adaptive capacity and implementing adaptive decisions in order to examine the adaptation that is taking place, or not, of the Water supply and Wastewater (WW) sector of the Stockholm region and reasons behind it.

The WW sector in Stockholm is responsible for the water supply, sewer and wastewater treatment systems of the region. These systems have developed since the mid 19th century in the Stockholm region and there are important amounts of money invested in them. For Sweden as a whole it is estimated that the cost of replacement of the complete sewer system alone would amount to 400 billion Swedish kronor (SOU 2007:60b). These systems have been built according to the present state of climate and in the recent report from the Swedish Commission on Climate and Vulnerability their exposure and sensitivity to the potential impacts of climate change, on a national level, are identified as substantial. This leads them to conclude that adaptation to climate change should start now (SOU 2007:60). In light of the results of the national assessment, a recent report confirms that the WW sector of the Stockholm Region faces similar challenges as Sweden as a whole (RTK 2009a).

1.1 Problem Statement

The WW sector in Stockholm is a sector that is vulnerable to various impacts of climate change. Studies indicate that climate change increases and creates multiple risks for water quality deterioration, increased leakage in the sewage system and landslides that could destroy the water distribution pipelines (SOU 2007:60). The effects of a disturbance on parts of the WW system are potentially high due to the costs of water related sickness, the effects of a prolonged lack of running water and disruption of societal functions (Tyréns 2009)

In the WW sector it can therefore be argued that planned anticipated adaptation is desirable to deal with many of the potential impacts of climate change since the costs involved if a risk materializes are high and the rate at which adaptive decisions can be implemented is low due to the large amount of infrastructure already in place (Mendelsohn 2006; Milly *et al.* 2008; SOU 2007:60). The Stockholm Region is a region with high adaptive capacity according to the indicators specified in the TAR in 2001 (RTK 2009b; Smit *et al.* 2001). As mentioned above, recent research and events have however indicated that an identified need for adaptation, and possessing high adaptive capacity, is no guarantee for actions to be taken that reduces vulnerability. There therefore seems to be more factors that influence if, how and when adaptation to climate change takes place that are not fully understood.

1.2 Overarching research questions and objective

- How, if at all, is the Water Supply and Wastewater sector in the Stockholm Region adapting to climate change?
- What factors can explain the adaptation that has occurred, or the lack of it?

This report sets out to examine adaptation to climate change in the WW sector of the Stockholm Region, Sweden. It has two specific aims. First, to provide an empirical case study of adaptation practices and processes that are taking place in the WW sector of the Stockholm Region. The analysis is done using the concepts of building adaptive capacity and implementing adaptive decisions. Second, it tries to scrutinize and shed light on the factors that influence the capacity of the organizations making up a majority of the region's WW sector to adapt. This is done using the above mentioned model of organizational adaptation and with a special focus on an organization's actual adaptation space.

2 THEORETICAL FRAMEWORK

Scholarly work on adaptation to environmental change feeds mainly from two academic disciplines – hazards and vulnerability studies and resilience theory (Nelson *et al.* 2007). The present report is focused on adaptation of the WW sector in the Stockholm Region and the main units of analysis are organizations. This means that the actor-centered view of the hazards and vulnerability tradition will be dominant.

2.1 Explanation of key theoretical concepts

Adaptation to climate change

There are many ways that adaptation can be characterized depending upon the manner in which it is carried out and its temporal and spatial characteristics (Smit *et al.* 2001). Anticipatory and reactive adaptation is one such characterization that has been made and is based upon when adaptation takes place in relation to experienced impacts related to climate change. Adaptation that takes place before impacts from climate change have been experienced, based upon knowledge and concern for climate change, are within this framework labeled anticipatory. If the adaptation takes place as a reaction to initial impacts of climate change it is understood to be reactive. This division is in a sense artificial since climate change and adaptation are both gradual phenomena and it is hard to pinpoint exactly when these events occur in relation to each other. Adaptation is therefore often seen as a mix of both reactive and anticipatory (Brooks and Adger 2004).

Building adaptive capacity and implementing adaptive decisions

Since the TAR in 2001 it is now acknowledged that the fact of possessing adaptive capacity is necessary but not always enough for actions and decision that reduce vulnerability to be taken (IPCC 2007b). Brooks and Adger, for example, observe that the implementation of a system's adaptive capacity can be frustrated by external barriers such as national regulations and economic policies which make certain adaptation strategies unviable (2004).

A distinction has therefore been made by several scholars in the field of adaptation to climate change between activities that build adaptive capacity and actions that implement that capacity to reduce a system's exposure or sensitivity to climatic hazards (Adger 2005; Fussel and Klein 2006). Fussel and Klein see activities such as scientific research, data collection, awareness raising, capacity building and the establishment of institutions, information networks and legal frameworks for action as 'facilitation' which are activities that enhance adaptive capacity (2006: 323). On the other hand, activities that reduce the risk of adverse climate impacts on a system are distinguished as 'implementation'. This is done by reducing the system's exposure or sensitivity to climatic threats or moderating relevant non-climatic factors.

The division of the adaptation process made by Fussel and Klein will be used in this report using the terminologies building adaptive capacity and implementing adaptive decisions. In relation to the WW sector in the Stockholm Region the author makes the distinction shown in Table 1.

Adaptation space

The ADAPT project (Berkhout *et al.* 2004) created a framework for analyzing adaptation of organizations to direct and indirect impacts of climate change. One of the key differences from earlier work on adaptation to climate change is that the adaptation is analyzed from the viewpoint of organizations that are subject to a wide range of societal, market and climatic stressors and impacts. Climate change is in this sense only one of several stressors that an organization needs to adapt to. This, in the ADAPT project, is done by using a theory of organizational learning and applying it to adaptation to climate change (Cyert 1992; Levitt and March 1988; Nelson and Winter 1982). The resulting model

Table 1: Distinction made between building adaptive capacity and implementing adaptive decisions in the WW sector related to climate change (Inspired by Füssel and Klein (2006) and Adger *et al.* (2005))

Building adaptive capacity	Implementing adaptive decisions
<ul style="list-style-type: none"> • Research and reports on exposure and sensitivity of the WW sector • Enhancing cooperation regionally, nationally and internationally between WW organizations • Raising awareness of the climate change issue to relevant decision makers and the public • Increasing the organization’s human capacity in key areas such as research, planning and environmental scanning 	<ul style="list-style-type: none"> • Changes of the technology used to carry out WW services. For instance water purification and sewage treatment processes • Changes in standards such as raising the minimum connection level to the sewage system • Changes in planning of new urban areas such as increased capacity for rainwater drainage • Changes in investment programs to speed up renovations of the sewage system and increase separation of sewer and stormwater drainage

of the adaptation process (presented in Figure 2) has been developed and applied in the UK, mainly on companies in the housing and water sectors (Arnell 2006; Berkhout *et al.* 2006; Berkhout 2004; Hertin *et al.* 2003).

One of the key concepts developed in the ADAPT project framework is the concept of ‘adaptation space’ which in Berkhout *et al.* is defined as “the universe of existing adaptation measures and the area where clusters of adaptation options relevant to an organization are available” (2004: 9, 21). Available is in this context “not concerned with costs and benefits in any given option, but with technical and organizational practicability in principle” (Berkhout *et al.* 2006: 148). Berkhout *et al.* go on to explain that “the adaptation space is not static, but dynamic – growing and mutating as new options are generated, and as existing ones are replaced or become unattractive”(ibid.). Arnell and Delaney, who in their work test the conceptual model of Berkhout *et al.*, define the adaptation space of an organization as “the set of options potentially available to an organization to deal with possible climate and other changes. Some of the options...will be more feasible than others, for technical, legal, economic or cultural reasons, and some not perceived at all by the organization.” (2006: 229).

Both Berkhout *et al.* and Arnell and Delaney seem to view the adaptation space as what is potentially available to an organization to adapt to the effects of climate change. This is delimited by what is possible from a technical and organizational point of view but it is recognized that some of these options can become unattractive and that not all options are equally feasible. There is some discussion of contextual factors influencing the range of adaptation options available to a firm such as the market and regulatory context but only a limited analysis is carried out in which way this affects the adaptation space. In this report the adaptation space of organizations will therefore be investigated taking the definition of Berkhout *et al.* (2006) as the starting point but explicitly include the feasibility of the different options – as experienced by individuals in the organizations – as factors that restrict potential adaptation options of organizations. This is understood as the actual - as opposed to potential - adaptation space of an organization.

In the context of this study there are three publications using this framework that are particularly relevant since they deal with adaptation within the water sector (Arnell and Delaney 2006; Berkhout *et al.* 2006; Berkhout 2004). Within these publications the concepts used in this report – anticipatory and reactive adaptation and building adaptive capacity and implementing adaptive decisions – are also discussed to some extent. In Arnell and Delaney 2006 and Berkhout *et al.* 2004 there is no clear distinction made between reactive and anticipatory adaptation and in the latter paper even the usefulness of this distinction is questioned since adaptation is seen as a circular learning process carried out both in response to a climate signal, such as a flood event, and in anticipation of future flood events (2006: 153). In Berkhout *et al.* 2004 and 2006 there is no clear distinction between building adaptive capacity and implementing adaptive decision. Arnell and Delaney (2006: 243) do make a distinction

between these two concepts and see the first as an enhancement of the capacity to adapt to changing circumstances and the second as actual measures to alter infrastructure or operational practice to meet altered circumstances which is in line with the conceptualization made in this report.

2.2 Organizational Learning

An organization in this report is defined as a group of people intentionally organized to accomplish an overall, common goal or set of goals¹. With this definition political, ideological and business entities are seen as organizations and can be studied using the theory of organizational learning. The terms ‘organization’ and ‘company’ are therefore used interchangeably with the same meaning.

Adaptation within the organizational learning literature

Within the organizational learning literature, “routines” are seen as the basis of organizational behavior (Cyert 1992; Levitt and March 1988; Nelson and Winter 1982). The generic term routines include a very broad range of phenomena ranging from rules, procedures, and technologies to frameworks, cultures, and knowledge that guide the behavior of the organization. These routines are independent of the individual actors that execute them and can be seen as a way for organizations to encode lessons from history about successful behavior (Levitt and March 1988).

In an ideal situation the organizational routines are matched with and appropriate to the surroundings/environment of the organization. If there is a novel situation in the environment of the organization which leads to its routines not being appropriate or giving suboptimal outcomes, learning could take place through modification of these routines. Organizational learning could therefore be defined as a modification of the routines of an organization as a response to a changed environment. For learning to take place the signal of a novel situation has to be recognized and interpreted as significant. How the signal from the environment is interpreted depends upon the nature of the signal itself - how salient, frequent and unambiguous it is – and the frame of reference of the organization (Daft and Weick 2000).

The frame of reference of the organization is important since organizations have to interpret the signals they receive from the environment and could be defined as the collective cognitive map of the organization. Beliefs, politics, goals and perceptions are all factors that influence this cognitive map and could influence the organizational learning cycle (Daft and Weick 2000).

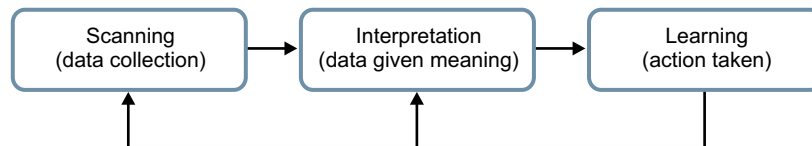


Figure 1 (From Daft and Weick 2000)

Organizational learning therefore depends both upon how strong and unambiguous the signal from the environment is and the frame of reference of the organization where the data is interpreted.

Modification of routines requires dynamic capabilities which are different from operational capabilities. Operational capabilities can be seen as the capabilities that enable an organization to carry out its normal or routine business activities. Dynamic capabilities are the capacity to change these operational capabilities or routines – a stable, collective and systematic activity through which organizations generate and modify their operating routines (Zollo and Winter 2002). All organizations are deemed to possess both capabilities but the balance between the two can vary since each presents advantages and drawbacks depending upon the environment.

1 Definition taken from http://managementhelp.org/org_thry/org_defin.htm 09-05-2009

In stable environments operational capabilities are superior since they allow the organization to carry out its core tasks efficiently with a minimal cost. The existing routines are appropriate to the environment and dynamic capabilities are in such circumstances less necessary and can represent an alternative cost to the organization. In less stable environment dynamic capabilities become more important for the organization to adapt and be in sync with its environment. “In a context where technological, regulatory and competitive conditions are subject to rapid change, persistence in the same operating routines quickly becomes hazardous.”(Zollo and Winter 2002: 8)

When it comes to the actual mechanism of change or adaptation of routines there are two main ways; trial-and-error experimentation and search and appraisal (March 1991; Nelson and Winter 1982). Trial and error experimentation leads to an accumulation of experience through experimentation of new operating routines and evaluation of its benefits and drawbacks. The process of search is more abstract and creative since it is based on the scanning of relevant knowledge and experience and reconstructing it to give a number of adaptation options that can fit the novel situation (Berkhout *et al.* 2006). This process is similar to a knowledge creation process where the organization creates and defines problems and then actively develops new knowledge to solve them (Nonaka 2005).

The adaptation options that are available and have been found through search and appraisal are increasingly codified –included in formal documents of the organization – and made explicit and are exposed to an internal selection process where the most appropriate alternative is discussed and selected. “In the first phases of generative variation and internal selection, the initial idea or novel insight needs to be made increasingly explicit in order to allow a debate on its merits”(Zollo and Winter 2002: 18). The performance implications of the adaptation options are evaluated with the view that they should not have negative performance implications for the organization.

The final step in the learning cycle is feedback from the environment which can be in the form of improved productivity or feedback from customers and institutions. In an ideal situation the feedback would result in actual performance improvements of the organization which gives evidence that the change or routines is positive and this in turn would create a positive feedback loop reinforcing the changed routines.

The process of organizational learning could be characterized according to the model of the adaptation process in figure 2 and is summarized in table 2.

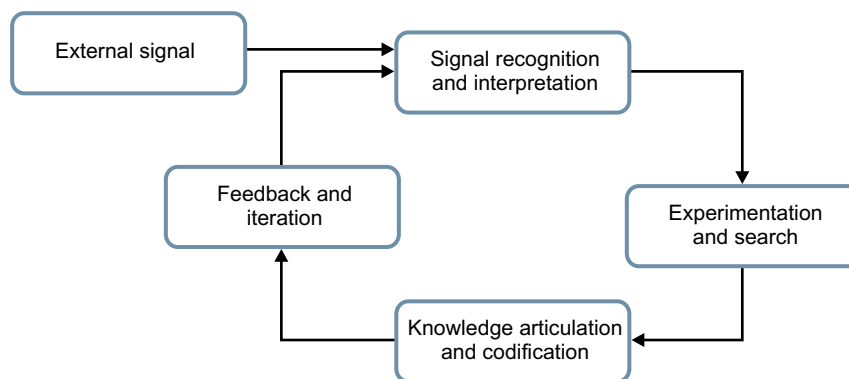


Figure 2 (From Berkhout *et al.* 2006)

Table 2: Summary of Organizational learning (Berkhout *et al.* 2006)

Organizations are based on operational routines
Learning takes place through modification of these routines
Routines are modified in response to novel situations (and adapted incrementally in response to feedback)
Modification requires dynamic capabilities (as opposed to operational)
Modification requires signal recognition of novel situation (interpretation depends upon frame of reference and is more likely recognized if signal is frequent, unambiguous and salient)
There are two mechanisms for the process of adaptation of routines which are trial-and-error experimentation and search and appraisal
Adaptation options are subjected to an internal selection process to reduce causal ambiguity between adaptation options and performance implications

Organizational learning and adaptation to climate change

The traditional focus for research on organizational learning has been business oriented organizations where little or no focus has been on ecological or climate factors. The main aim of the organization is usually to enhance profit in the future (Zollo and Winter 2002: 8). When there is a reference to environmental change it is usually “technological, regulatory and competitive conditions” (Zollo and Winter 2002: 8). There does, however, not seem to be any inherent reasons as to why this framework cannot be extended to include climate change. By applying this theory it is possible to study adaptation to climate change from the viewpoint of the organizations that are supposed to adapt. It also gives the possibility to apply and build on the accumulated experiences and knowledge of decades of organizational research dedicated to understanding how organizations function and adapt to changing conditions in their environment.

3 APPROACH AND RESEARCH DESIGN

When formulating the research questions for this report an extensive literary review was carried out and there was also the possibility to observe 13 focus group meetings with a total of 22 participants, divided into four groups. These groups were composed of representatives from the Stockholm region coming from municipalities, regional planning organizations, WW organizations and energy and insurance companies. These focus group meetings were organized by researchers in the Mistra-SWECIA research program on adaptation to climate change with the aim of exploring who the relevant stakeholders of the Stockholm Region are, their perceptions of climate change, opportunities and barriers for adaptation to climate change and the role of social learning in building adaptive capacity to climate change.

The focus group meetings provided the opportunity to approach this study with a relatively open mind and were an invaluable source of inspiration in order to understand the region, topic of study and to formulate relevant research questions. From an earlier review of vulnerability and adaptation to climate change in the Stockholm Region (RTK 2009a) two possible effects of climate change were identified with relevance to the WW sector: changing rain patterns – with the risk of increasing intensity

– and raising sea levels. WW organizations could be seriously affected by such changes since it could lead to deteriorated water quality, increased leakage in the system and increase the risk of floods.

In view of these issues it was natural to focus the research on the WW sector of the Stockholm region since it is likely that it will be challenged by climate change and will need to adapt to its effects. The WW sector largely depends upon actual physical systems to function well. In order for this sector to adapt to climate change it needs to both build adaptive capacity and implement adaptive decisions on its systems. This should provide the possibility to identify where the adaptation effort is at present and the type of adaptation that is being carried out.

The WW sector in Stockholm consists of several municipal and regional WW organizations. Within the scope of this report it was not possible to conduct research in all WW organizations of the Stockholm Region. It was therefore decided to concentrate on regional WW organizations, which in this report is defined as WW organizations delivering services to three or more municipalities. In the region there are a total of five regional WW organizations according to this definition. Four of these were chosen since they represent two cases of the whole chain of WW activities which includes water production, distribution and sewage treatment and discharge. Norrvatten, Roslagsvatten and Käppala carry out these functions in the northern part of the Stockholm region. Stockholm Vatten performs these three functions in Stockholm and Haninge municipalities and provide water to the southern parts of the region. Stockholm Vatten also collect and purify sewage water partially or completely in eight municipalities. (See maps 1 and 2 in appendix 3). It is argued that together these four regional WW organizations represent such a large share of the WW services of the Stockholm region that they are representative of the region as a whole.

From interviews with representatives of these four regional WW organizations there was a decision to expand the selection of organizations to analyze and include the Swedish Water & Wastewater Association (SWWA). Documents from Stockholm Water and Sewage Cooperation Council (SWSC) were also analyzed although no interviews were carried out there. These two additional organizations were added since it became obvious that they were relevant from the interviews that were carried out with the regional WW organizations. Results from these two organizations are used to complement the information gathered from the regional WW organizations that represent the four primary units of analysis of the case study.

3.1 Data collection

The interview questions were created based on the model of the adaptation process (figure 2) and by extracting a number of relevant theoretical themes from the literature of adaptation to climate change and organizational learning – explained in Section 2. What is presented as two separate steps in the model (figure 2) - experimentation and search and knowledge articulation and codification - are in this report combined, and is presented in the results section, as one step: search for and articulation of possible solutions. This was done since the two steps are closely related and it was deemed more appropriate to carry out the analysis and present the results in this way. Appendix 1 presents these themes and the actual questions resulting from this operationalization. The resulting interview guide was used to conduct semi-structured interviews with the complete company management board in three out of four companies (5-7 people in each company). In total 25 interviews were carried out, generally about one hour long, between December 2008 and March 2009 that were transcribed in full by the author shortly afterwards.

In the fourth company, Stockholm Vatten, it was not possible to interview the complete management of the company since the management board considered that providing two respondents would suffice to acquire a comprehensive picture of the company. The results presented from Stockholm Vatten therefore come from fewer sources than the other three companies which mean that it was not possible to obtain an equally thorough understanding of the organization. Having said this, the two respondents were however key informants since the first works with issues relating to climate change and the sec-

and represented the views of the management, documents and sources were also used to complement the interviews and provide further understanding of Stockholm Vatten.

There was a decision to focus on the complete top level management since earlier research suggests that search and assessment learning is predominant in adaptation to climate change and that this takes place in management levels (Berkhout *et al.* 2006). In the first two companies, Roslagsvatten and Norrvatten, there were also interviews with two members of operational staff as well, both to check if this assumption was correct and to interview operational staff that had been identified as important. In Käppala this was not deemed necessary since the relevant individuals were part of the management of the company and the previous interviews with operational staff had not given results different from that of the management.

After the initial interviews with the four regional WW organizations three additional interviews in the Swedish WW trade organization SWWA were carried out with key individuals identified from the previous interviews. The questions were slightly modified to fit the fact that they were directed to the trade organization, which does not carry out WW services itself.

The large amount of interviews conducted in the four regional WW organizations and the SWWA gave a good insight into the companies and the Stockholm WW sector in general. Written documents - such as strategic documents, reports, referrals, owner directives and annual reports - were analyzed and contrasted with interviews results where possible. This means that the results, to a high degree, have been triangulated due to the range and width of sources used.

3.2 Analysis and presentation of results

From the interview results reply categories were created, which are presented as bar graphs, in order to give an overview of the types of replies that were given. The first bar chart (figure 3) depicts results from all respondents while three additional charts (figure 4-6) present results from each organization. Results from Stockholm Vatten were not presented in this way since replies from only two respondents would make little sense to present in a bar chart.

The main advantage of presenting the results in graphic form is to give the reader a quick overview, access to the primary data results and a chance to analyze the data on his/her own. It gives some sort of access to the primary data results. The main problem with this is that nuanced and in many cases complex answers are represented in one single reply category. The main results and conclusions illustrated in the charts are however analyzed separately using quotations to illustrate the variation, connections and significance of the results. By presenting the replies in bar graphs and using them to guide the qualitative analysis the expectation is that the reader will be able to gain both an overview of the results and understand the complexities and nuances that exist within each category. (For further information about the reply categories see appendix 2.)

The categories are based on recurring types of answers from the interviewees. Questions 4 and 6 are not represented in the charts due to the fact that question 4 was not appropriate to ask, most of the time, since there were few actual changes that the interviewees could comment on. The few times comments were made they could usually be placed under question 7 as one of the factors influencing the organization's adaptation possibilities. Question 6, on the other hand, was usually interpreted very narrowly by the interview subjects to mean the allowances for nitrogen and phosphorus emissions or similar strict interpretations that were deemed to be of less relevance to the research question.

There was also a selection of questions where it would make sense to create reply categories and show the results in charts. Questions 3A and 3B were excluded from the charts since the results show actual adaptation measures that have been arrived at by compiling responses and, where possible, comparing them to written documents. It was deemed that the individual answers, from these two questions, should not be represented in charts since all representatives of a company might not be aware of the adaptation measures taken by the company.

Prior to finishing the work on the report all interviewees were invited to a seminar where the main findings of the research were presented. Several representatives from three of the regional WW organizations were present and given the opportunity to question the findings and provide further insights into the issues being studied. The main impression from the author and one co-researcher present was that the representatives present agreed or at least did not disagree with the main results. There were however additional nuances raised that were later incorporated into the results. Prior to the final deadline, excerpts of the work directly related to each organization were also sent out to one or two representatives of the four organizations to give the possibility to comment on the conclusions and correct possible misinterpretations. Some clarifications were made as a result of feedback from the organizations.

4 THE WW SECTOR OF THE STOCKHOLM REGION

The Stockholm Region consists of 26 municipalities of varying size and population. In total there are approximately two million people living in the region (RTK 2009b).

The municipalities of the Stockholm Region are responsible for the provision of public WW services and the charges for these services are decided by the political leadership in the assembly of each municipality or set of municipalities that have joined forces and created joint WW organizations providing these services (DS 2004: 31). If the WW organization is its own fiscal entity the budget is approved each year by the municipal political assembly. There are however strict laws on how the WW charges are to be set and the WW organizations are not allowed to make profit (SFS 2006: 412).

There are three core services that are carried out by the WW sector that are analyzed in this report:

- Water production (extraction, purification and distribution)
- Construction and maintenance of the sewage system for drainage of both rain and stormwater and wastewater from households and industry
- Sewage treatment and release into a recipient (water body)

When comparing the WW organizations it should be acknowledged that there are differences in the level of risk associated with the services that are being delivered. In the case of water production there are large scale, high impact societal risks associated with a failure to produce adequate water for the population of the Stockholm Region (Tyréns 2009). Problems related with stormwater discharge and the sewage system could be significant but are generally more local scale and an economic risk with flooding of properties. Risks associated with sewage treatment are mainly environmental and primarily occur in the water body where the sewage water is released. There is also an economical risk from fines if the allowances of pollutants are exceeded.

Particularly related to water production there are a number of risks that the WW sector has to deal with that are largely unrelated to climate change. One such example is the risk of a ship accident in Mälaren that could lead to the release of fuel close to the intake of water for water production. There are also many diffuse leakages of nutrients, pollution and medicine compounds that influence the quality of drinking water at present.

The main source of freshwater is Lake Mälaren which provides water to approximately 1.7 million of the region's inhabitants. The main recipient of the region's wastewater is the Baltic Sea.

Apart from climate change, there are a number of drivers and risks in the Stockholm region which have or could have an impact on the WW sector. The population of the Stockholm Region is growing very rapidly and the projections are that in the year 2030 the population of the region will have grown with between 315,000 and 535,000 inhabitants (RTK 2008). This population growth leads to

an increased load on the WW system and services have to be delivered to larger geographical areas when new residential areas are planned and constructed.

A second driver is the move towards increased environmental regulations related to the passing of the EU Water Framework Directive (EC 2000). In Sweden this has translated into the creation of 5 regional water authorities and their overarching objective is that all water bodies should reach “good ecological status” by 2015 or should at least not experience decreasing water status (Vattenmyndigheterna 2008). There are a number of exceptions to these objectives but the proposed measures in the “Northern Baltic Water Authority” – which the Stockholm Region is part of - to reach these goals include a 50% decrease of the allowance for nitrogen and phosphorus release of treated sewage water into the recipient water body (Vattenmyndigheterna 2009).

4.1 Possible impacts of climate change

All possible impacts are expected to happen during this century and should be most marked towards its end. The information in this section comes from the regional assessment of the possible impacts of climate change in the Stockholm region (RTK 2009a).

One of the major possible effects of climate change on the climate of the region is a change in the precipitation pattern. It is expected that there could be an increase of the volume of rain of 10 percent over the year. This increase would however be unevenly divided since there could be an increase of precipitation during the winter of 40 percent while the summer months could see a decrease of rain by down to 20 percent. The risk of extreme precipitation events increases over the whole year. The sea level is expected to increase by 18 to 59 cm over the century (IPCC 2007a) with the risk of an even higher increase due to uncertainties in the rate of melting of the glaciers of the Arctic and Antarctic. One important geological characteristic of the region in relation to this increase of sea levels is that the region is raising approximately 39 cm per century as a result of the latest glacial period. This moderates the expected increase of sea levels in the region and it could range from a relative decrease of the sea level of 21 cm to an increase of 20 cm if the IPCC scenarios are correct.

It is also probable that there will be an increase of average temperature of around 3-4 ° C. This increase is, however, also unevenly divided and will be more marked during winter, it is, for instance, calculated that there will be an increase of the lowest temperatures during winter of around 12° C. This means that if the lowest temperatures registered at present during winter are -20 ° C, towards the second half of this century they will most likely be less than -10 ° C. This will lead to a substantial decrease of the period with snow and ice cover in the region and the precipitation that falls will increasingly be in the form of rain.

For the WW sector the potential impacts from climate change are numerous:

- Water production – numerous risks that exist already today increase mainly the risk of decreased water quality. This is both long term deterioration and acute situations with decreased water quality that the present water treatment facilities could have problems handling. It is important to note that no absolute shortage of water is expected in the region. Lake Mälaren is however connected to the Baltic Sea, separated by locks, and a sea level rise greater than the land rise in the region would increase the risk of salt water intrusion which has the potential of making the water in the lake undrinkable with the present water purification technology.
- Sewage system – the main risk is in relation to the drainage of rain and stormwater since heavier rain could lead to an increase in the number of local floods in built areas and properties when the sewage system does not have the capacity to lead away sufficient amounts of rain water.
- Sewage collection and treatment – Increased heavy precipitation events increases the risk for overflow discharge of unpurified water when the volume of sewage water is larger than what the sewage facility can handle. More ice and snow free winters would lead to increased leakage into the system which increases the volume of water that needs to be treated and also lowers the temperature of the sewage water which decreases the efficiency of the sewage treatment.

4.2 Regional water companies studied

Norrvatten

Norrvatten produces water for approximately 500,000 people. It is a municipal association consisting of 13 municipalities in the northern part of the Stockholm Region.

Roslagsvatten

Roslagsvatten is a company that has taken over the municipal responsibilities of providing WW services in four municipalities in the north of Stockholm - with a total population of 80,000. The main part of the water is purchased from Norrvatten and the company is responsible for the sewer system and treats and discharges approximately 70 percent of the sewage water in its own purification plants. The rest is treated by Käppalaförbundet.

Käppalaförbundet

Käppalaförbundet treats and discharges the sewage water of approximately 400,000 customers. In addition they also treat sewage water from industries, hospitals and offices that equates to an additional 120,000 customers. It has a maximum capacity of 700,000 customers. It is also a municipal association consisting of 11 municipalities mainly from the north and east of Stockholm.

Stockholm Vatten

Stockholm Vatten is the responsible WW organization for Stockholm and Huddinge municipalities. Water is produced and delivered to an additional 9 municipalities, in total water is produced for around one million people. Sewage water is treated partially or completely from an additional 6 municipalities.

For an overview of the regional WW organizations see maps 1 and 2 in appendix 3.

4.3 Regional and national bodies

Swedish Water & Wastewater Association

SWWA is the trade organization of WW organizations in Sweden. It carries out and coordinates research related to the WW sector and represents the sector in Sweden and abroad. SWWA is in many ways the organization that sets the standard of the WW sector in Sweden for most issues where it is necessary and practical for general guidelines to exist. This is done through publications where best practice and advice is given on everything from how TV inspections of the sewage system should be carried out, safety handbooks for water producers to what levels of rain discharge the sewage system should be able to handle without overflowing (SvensktVatten 2009). In some specific areas, such as what levels the sewage system is supposed to handle without overflowing, the SWWA recommendations are used by the WW board of the Swedish state, which is similar to a court instance, in disputes between WW organizations and individuals that have experienced flooding from the sewage system (VAnämnd 1993). In relation to what intensity of rain the sewage systems should be able to handle it can therefore be seen as the norm setter in the WW sector.

Stockholm Water and Sewage Cooperation Council

The Stockholm Water and Sewage Cooperation Council (SWSC) is a council of cooperation of the WW organizations in the Stockholm Region where strategic and common issues of the region are discussed and coordinated. The SWSC has an annual meeting and has a standing committee that meets around six times a year to work on common projects with relevance to the WW sector in Stockholm as a whole.

5 ADAPTATION OF THE WW SECTOR IN THE STOCKHOLM REGION

In the region as a whole and related to the WW sector generally there is a high level of openness and cooperation between the different WW organizations regionally and nationally. Many respondents, especially from Käppalaförbundet, spoke of the increased cooperation regionally, during the last decade or so, as an important improvement in the possibility to adapt to impacts of climate change. The Stockholm Water and Sewage Cooperation council has been working since 2005 to coordinate regional WW questions (VASrådet 2009). Norrvatten, Roslagsvatten and Käppala cooperate and have recurring meetings to discuss and work on common issues. There are also biannual meetings between the executives of the five regional WW organizations in the region where issues of mutual concern are discussed and experiences are exchanged. Although climate change is only one of the issues that are potentially discussed the mechanisms that have been put in place for cooperation still represent actions that build the adaptive capacity of the region generally.

Water production

In the region there have been several activities that could be characterized as building the adaptive capacity to deal with climate change. SWSC has produced several reports dedicated to questions of relevance to the issue of climate change. Recently there have been two reports produced focusing on the economic impacts of water related sickness and trying to estimate the value of Lake Mälaren (Morrison 2009; Tyréns 2009). There has also been a report investigating the potential impact from sewage and surface water flows for the purification of water where climate change was identified as one of the major threats to the water quality (Ekvall 2008). SWWA has, on a national level, prioritized research on water purification techniques and protection of reserve drinking water resources in light of climate change which means that their research grants will be geared towards research dedicated to this which could be used by the organizations in the region.

Stockholm Vatten and Norrvatten have both had representatives working in different parts of the Swedish Commission on Climate and Vulnerability which could be seen as raising the capacity of the two organizations to adapt to climate change since the inhouse expertise is strengthened. The person responsible for research into risks related to water quality in Norrvatten has increasingly concentrated on conducting research related to climate change and water quality. Improved models are being developed to calculate risks that could increase with climate change such as overflow discharge close to the water intake. There are several plans on how the water purification plant could be modified to deal with increased risks related to climate change. Norrvatten has also brought up the issue and risks with climate change to its political steering committee and included a broadsheet on the issue in its annual report of 2008.

There have been developments related to water production that are primarily part of general water safety work such as the installment of a reserve power generator at Norrvatten and the passing of the Water protection Act of Easter Mälaren in 2009. The act introduces general safety regulations aimed at reducing the risks of pollutants reaching the three main water intakes in Lake Mälaren. Some respondents identified the current debate and concern with climate change as a possible factor working in favor of these changes. There has also been an improvement of the water purification technology in Norrvatten in 2003 in response to trends of deteriorated water quality in Mälaren. These trends are mainly due to increased levels of algae and organic matter in the water. This change can partially be characterized as an implementation of an adaptive decision since the levels of organic matter, to some extent, are dependent upon the precipitation pattern which will likely change with climate change.

Sewage system

In Roslagsvatten there are examples of steps that build the adaptive capacity of the organization since one person has recently been given the responsibility to plan and coordinate the rain and storm-

water discharge strategies of the municipalities. There are a number of reasons behind this but concerns of climate change were identified as one of several issues leading to this decision. Roslagsvatten has also implemented a change in their taxation system in relation to stormwater discharge which is charged separately. This change is due to changed WW laws but was identified as a possibility to charge separately in the future if further investments would be necessary to deal with increased precipitation volumes. SWWA has also prioritized research on stormwater discharge in light of climate change which means that their research grants will be geared towards research dedicated to this which could be used by the organizations in the region.

In relation to constructions of new urban areas there are some examples of implementing adaptive decisions where climate change has been one out of several factors influencing the decision. The minimum connection level to the sewage system of Stockholm Vatten has been raised with about 0.6 meters. This was due to concerns that the present level is too low, even with the present variability of the Baltic Sea and Lake Mälaren, and concerns that future levels might be even higher with climate change. In one of the municipalities serviced by Roslagsvatten, the minimum level for new urban areas next to the Baltic Sea has also been raised with approximately 0.5 meters compared to earlier levels. Respondents in Roslagsvatten could not remember any formal decision to do so but it rather seemed to exist an informal consensus that this should be done in new areas. This is also due to concerns that the present level is too low and that future sea levels might be even higher with climate change. In Roslagsvatten there has also been a shift in the planning of new areas with higher safety levels with regards to drainage of stormwater discharge. There is again an informal practice to start to investigate how 50 and 100 year rains could affect the new urban area being planned. Suggestions are also being made to the municipal planners that new areas should be planned so that streets can work as water conducts during heavy precipitation events.

Sewage treatment

With respect to sewage treatment there are few activities that can be related to concerns or impacts of climate change. Käppalaförbundet is, however, actively working on improving the regional cooperation with the eleven municipalities that send sewage water to their facilities. This is due to a number of reasons but negative impacts from climate change were identified as one of the issues that could be dealt with in the future. One main priority is that the municipalities reduce the leakage of their sewage system since this reduces the volumes of water that reaches the sewage treatment facilities. There has been a change in the fee structure so that associated municipalities pay a fee that is partly correlated to the volumes of water that come from their sewage system. This change was not related to climate change but it was identified that it could work as a signal to the municipalities that they should increase the rate of renovation of the sewage system which would lead to reduced leakage.

The WW sector as a whole

For the region as a whole the results show that some adaptation is taking place in the WW sector of the Stockholm Region at present. It also appears that the adaptation activities that are taking place are mainly activities aimed at building the adaptive capacity of the region. The region has come relatively far in this work with good channels of cooperation between the WW organizations in the region and some work carried out on a regional scale to evaluate the exposure and sensitivity of the WW sector to possible impacts of climate change. A couple of regional organizations have also enhanced their capacity in key areas related to climate change such as stormwater discharge and research is increasingly being focused on issues related to climate change.

There are also examples of implementations of adaptive decisions in the region. The clearest examples are the raising of minimum connection levels to the sewage system for new urban areas in a couple of municipalities and the change of purification techniques in Norrvatten. In the decision to implement these changes it is also apparent that concern about possible impacts of climate change were part of the decision but not the main reason for this implementation to take place. In the case of

raising the minimum connection levels the levels were deemed too low even in the present climate and the water quality of Lake Mälaren depends upon several factors of which climate change is only one.

5.1 Factors influencing the ability to adapt

This part of the analysis is focused on trying to understand the issues that influence the feasibility and attractiveness of the available adaptation options. This indicates the actual adaptation space available to the WW organizations to adapt to climate change. This is done by structuring the analysis according to the steps of the model of the adaptation process suggested by Berkhout et al. (2006) and slightly modified to contain three steps: awareness and interpretation of climate change; search for and articulation of possible solutions; and feedback from adaptations. The main part of this section is dedicated to search for and articulation of possible adaptation options since this is where the majority of relevant findings were made.

Awareness and interpretation of climate change signals

The interviews show that the main signals of climate change comes in the form of written material, mainly from the news but also reports and scientific material from SWWA and universities. There is also much information coming from conferences and meetings outside of the organization. As shown in figure 3, around half of the interviewees clearly stated that they have not seen any effects of climate change. The normal argument was that any variability or extreme events seen in the region lately have happened before and that no conclusion could be drawn if it was due to climate change or not. Four stated that they have seen effects that could be connected to climate change but did not draw a clear connection and rather spoke in very general terms that there could be a connection. The rest either did not mention having seen any effects or discussed the issue without drawing any clear conclusions if one could see any effects of climate change or not. Most signs of climate change are therefore indirect – in written form and not experienced - and the adaptation being carried out by these organizations at present could therefore be characterized as largely anticipatory based on the respondents' answers.

When it comes to how the signal is interpreted most respondents expressed the view that it will affect their business activity and gave relevant examples of how it could happen. Some respondents had a more hypothetical view of the issue but were able to indicate how climate change could impact their business if the climate change hypothesis turned out to be true. The remaining respondents either recognized that there could be effects but stressed the uncertainties related to the climate change issue or had not finished forming an opinion about the climate change issue and therefore found it hard to comment on its impacts.

When asked if they believed that the actions that their organization was taking was enough most respondents said yes with different nuances such as there will be time to implement further changes, the available information made it hard to do more and that the development needed to be followed further. The respondents that said “No” stressed that there could be more communication, cooperation and focus on the issue.

Search for and articulation of possible solutions

Most respondents were aware of how climate change could affect their business activity and viewed climate change as an issue the organization would have to adapt to. Most interviewees were also able to identify possible solutions to these issues. Different adaptation options included changes in the purifying technology for water, changes in the planning of new areas and physical changes to the WW infrastructure. In this search for possible adaptation options within the organization there however seemed to be different factors that influence the feasibility and attractiveness of the different options. This was obvious in the answers to questions 4 and 7 relating to the factors that influence the possibility of the organization to adapt. The different categories that are presented below are the result of the reply categories created based on the respondent's answers to these two questions. All quotes in

the following sections are from different interviewees and have been selected since they clearly and concisely illustrate the general findings and arguments that are made.

Economic factors

When asked about factors that influence the company's adaptation possibilities the most common answer was that economic factors was either important or the most important issue. It was however clear from the answers that there is not a lack of economic resources in absolute terms but rather how increased costs, which would come from adaptation, would be received by the politicians of the municipalities that decided the WW charge rate. Increased costs due to adaptation would in the end be reflected by an increase in the WW charge rate that each municipality takes from its inhabitants. This concern was eloquently expressed by one of the respondents who referred to the issue as price-sensitive politics.

We are still talking about price levels where it is not price sensitivity because people don't have enough money, it is more a question of price sensitive politics. I believe that this could be an inhibiting factor (Respondent H)

The fact that investments would have to be made today for adaptations to effects of climate change that would probably be felt in the second half of this century was also identified as a problem. More specifically it is the time lag between investments and benefits from these investments which made many respondents believe it would be hard to convince politicians and the public in general of the necessity to implement changes today. This was clearly expressed by one of the respondents in the following way:

It is still hard for us to say that we need to raise the fees by 20% in order to make investments that we will benefit from in 50 years time. (Respondent U)

Trying to include adaptation to climate change in new projects means going away from the standard way of working which leads to losses of time, energy and money. Both trying to convince the relevant actors that it is necessary and to figure out how this adaptation should be included and pay the extra money needed for it. Adaptation is to some extent perceived as an additional cost that you do not receive benefits from.

It is always hard to convince and push through [adaptations] when it detours from the standard norms. Then it always costs more time and energy...more time put on investigation does not generate any money. (Respondent K)

Market demands to construct new residential areas in attractive areas unfit for housing and with a density that does not allow enough space for water to drain on the surface were also mentioned as inhibiting factors. It was commented that there are many economic interests to build centrally, but that centrally located land that is not yet constructed is often not suitable for construction. The other big factor is the interest of individuals to live close to the sea which at times lead to urban areas being constructed on unsuitable land occasionally even on land lower than normal sea level.

Everybody wants to live close to the sea. In a new area in Österåker municipality the whole area is practically under sea level. (Respondent L)

The fact that economic factors are so important could also partially explain why so much adaptation takes the form of building adaptive capacity at the moment since, in the WW sector, it is considerably more expensive to implement adaptive decisions than to build adaptive capacity. One respondent eloquently described this difference in the following way:

It is as usual, it is very easy to write reports and have opinions but it is hard to make decisions that cost money. (Respondent U)

Priority

Relating to all of these is the question of priority which was mentioned directly by three people and came out in the discussion from several more. This also relates to economic issues since the municipal politicians who in the end decide where the limited resources of the municipality should be invested have to decide between a range of societal needs such as schools, other infrastructure investments and housing for the elderly. It was also mentioned that no elections are won on WW issues which could be a reason as to why there is limited attention being given to it.

It is a question of priority that always has to be made when those types of measures [for improved water quality] are compared to the need for old people's housing and hospitals. (Respondent A)

Knowledge

Knowledge - and the limitations to knowledge due to the uncertainties inherent in the climate change issue - was brought up as the second most important factor relating to adaptation to climate change. The respondents usually mentioned the importance of having relevant knowledge and information and that this was communicated to the relevant actors which could be decision makers and in the end the public. All interviewees agreed on the fact that with a good and relevant knowledge base necessary investment decisions would be made by the political steering committee. It was however commented that this is usually hard to provide due to the uncertainties related to climate change information in terms of how large the effects will be and when they will come. The knowledge base is also closely related to the economic factors since it is the basis on which decisions and priorities on investments are made.

we need to be sufficiently sure on the state of knowledge to make changes and new investments. (Respondent H)

There was little direct questioning of the climate change issue during the interviews although some respondents indicated that they still believed the climate change hypothesis to be unconfirmed and a couple responded said that they were still trying to make up their mind regarding climate change. Many respondents however indicated that they had participated in or listened to discussions where the whole concept of climate change had been questioned. This could lead to discussions of whether the climate change issue is a real threat or not and even if it exists as a phenomena. There is therefore uncertainty both regarding how large the effects will be and when they will come but also on a more fundamental level regarding the sheer existence of climate change as a phenomena and if it poses a threat to the organization.

The problem you can get when claiming that it is a real threat, a significant risk is that someone else might claim it is not...when discussing future issues it is always hard to prove since it has not yet taken place. (Respondent F)

Lack of influence

Lack of influence on issues that affect the operations of the WW organization was commented on by several as an important factor limiting their ability to adapt. For water production several stressors were identified that have an impact on the water quality of Lake Mälaren and that water producing companies have little control over. There are several sewage treatment plants and industrial and agricultural activities around Lake Mälaren which lead to leakage of various chemicals and other compounds that affect the quality of the water of Mälaren. The passing of the water protection act of Eastern Mälaren and the EC water framework directive were both seen as factors that could lead to less stress on Lake Mälaren in the future.

Indirect effects [are the most important factors] nutrients from agricultural lands but also treated sewage water...the water directive has set fancy targets for Lake Mälaren...if we succeed with them I think we should be ok. (Respondent D)

For planning and building of new urban areas there is a great deal of cooperation between different parts of the municipal administration and it was argued that it is crucial that all parts of the municipality share the same understanding that new urban areas should not be constructed in low lying areas, and in such a way that they can handle stormwater discharges without floods. Käppalaförbundet raised similar concerns in relation to the sewage treatment facilities and the fact that communication was sometimes lacking between Käppalaförbundet and the municipalities that send their sewage water to the company to make sure that the sewage system worked properly.

The relation to the municipalities and the planning, environment and exploitation offices [is an important factor], that we all agree not to construct in low lying areas. (Respondent M)

Regional cooperation

Regional cooperation and rules and regulations were raised as the best way of dealing with the issue of lacking influence. The presence of many forums of dialogue in the region was seen as a positive factor for this. One example of this is the Stockholm Water and Sewage Cooperation Council that, on a regular basis, convenes all the WW operators in the region and also deals with cooperation between the different regional WW organizations.

I think that there is a trend the last three/four years towards regional planning and decisions...I believe this is the most important factor; that you bring up these issues in the regional forums. (Respondent S)

In the communication with the municipalities, the question of resources and priorities did however also surface in this respect. Some respondents from Käppalaförbundet commented that, at times, it is hard to open the correct channels of communication with the municipalities since the climate change issue does not seem to be prioritized and the municipalities work with very trimmed-down organizations where most efforts need to be dedicated to daily affairs.

It often feels like the municipalities work under strong demands of cost efficiency and have trimmed-down organizations. It is hard to allocate resources to open communication pathways and allocate the appropriate types of resources from the municipalities. (Respondent O)

Rules and regulations

Rules and regulations relate both to regional cooperation and economic factors since they are a way of achieving acceptance for the extra cost of adaptation to climate change and making sure that all actors are carrying out the same measures. One of the most important of these issues relates to the recommendations that are given by SWWA as to how intense rain the sewage system should handle. The recommendation is that the sewage system should be dimensioned in such a way that it manages to drain a rain that statistically appears once during every 10 year period (SvensktVatten 2004). This is referred to as a '10-year rainfall event'. This is only a recommendation but it is used by the state WW board in disputes between WW organizations and individuals that have experienced flooding from the sewage system and can therefore be seen as norm setting in the WW sector (VAnämd 1993).

Particularly in Roslagsvatten there was a consensus that they could only follow the norm set by SWWA and that the trade organization would need to change the volume of the 10-year rainfall event which would allow Roslagsvatten to increase the dimensioning of the pipes of the sewage system in preparation for the possibility of more intense rains. This was again related to economic factors since adaptation is an extra cost and guidelines from SWWA would be a way of justifying these extra costs.

In the end it is a question of economy, if you were to plan for worse scenarios it would mean larger dimensions and higher costs. Again it depends very much on what the trade organization [SWWA] says we have to handle, we cannot really build bigger and better than that. (Respondent J)

In interviews with SWWA it however became obvious that it is not a straightforward task to change the volume of the 10-year rainfall event since at present no dramatic changes can be seen in the intensity

of precipitation (Dahlström 2006). SWWA is currently working on trying to produce a ‘climate factor’ to account for changes in rain intensity due to climate change. The main message is nevertheless that even if a climate change factor was added to the dimensioning of the pipes there is always the risk – even without climate change – that there could be more intense rain than what the sewage system is dimensioned for. The recommended solution by SWWA is therefore to always plan new areas in such a way that the possibility for surface drainage exists in case of extreme precipitation events. It was also stated that such solutions sometimes conflict with interests to construct on unsuitable but high value land in, for example, urban centers.

independently if you put on a climate factor of 25% or 50% when calculating the dimensions, there will be a point when those levels are crossed as well...Our main message is that it is crucial for us [the WW people] to enter early in the planning process for this type of open solutions, but then you need to accept that it takes space and proper levels [which excludes some land which could be very attractive to construct on]. (Respondent V)

Technology

A couple of respondents raised the issue of access to appropriate technology to purify water and stressed that there would be an adjustment time of at least two years between the decision to adopt a new technology for water purification and when it can be installed which could be problematic if the changes in water quality happened quickly.

There is technology to deal with most issues of water production. The problem could appear in the time it takes to implement the technology. It usually takes at least two years to make a big technical shift. (Respondent T)

Feedback from adaptations

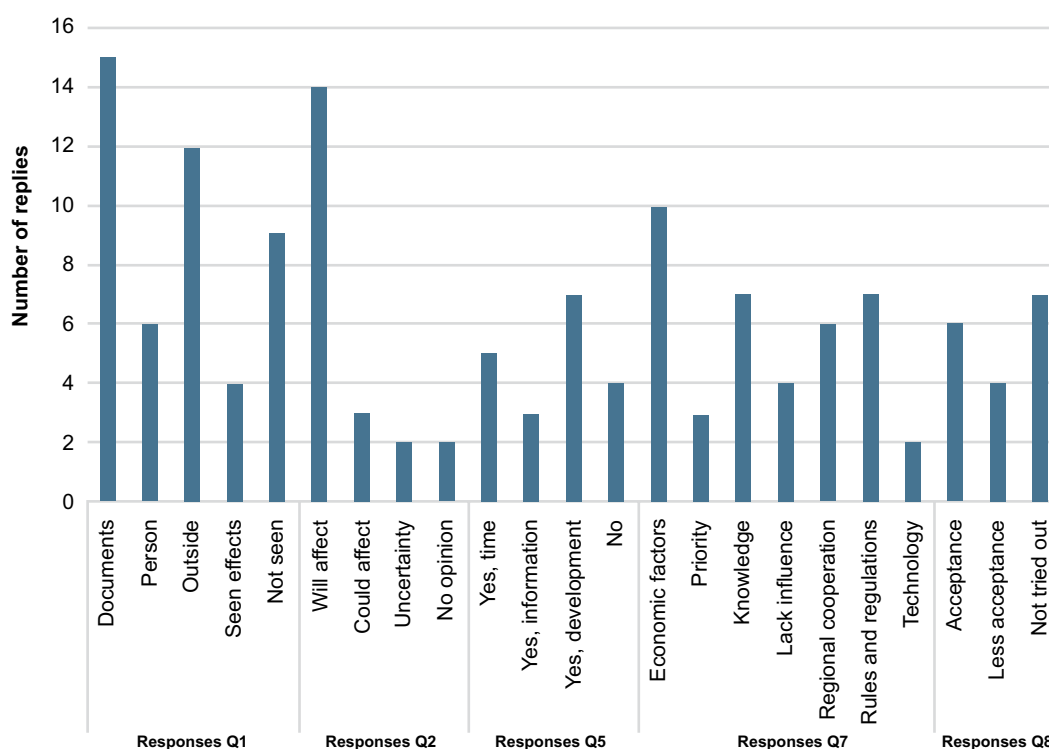
There were few implementations of adaptive decision that the organizations had carried out where there could be any feedback from the environment. This meant that the replies to this question often related to the issue of climate change in general. The general view was however that there was acceptance both from the public and the political steering committees when the issue of climate change was discussed. In terms of actual changes where there had been feedback from the environment the main adaptation is related to the change of minimum connection levels to the sewage system. In the case of Stockholm Vatten, who raised the minimum connection level with approximately 0.6 meters, the first reaction was very negative, mainly from housing companies since it reduces the amount of land that can be constructed on or forces the housing companies to take extra measures that increases the cost of production. With time however and due to the intense reporting of the climate change issue it seems to have been accepted.

In the beginning there was an outcry but I believe that it is 100% accepted now. (Respondent U)

5.2 Differences between the organizations

According to the theory of organizational learning, explained in section 2.2, learning in an organization to a large extent depends upon the frame of reference of the organization and the strength of the signal from the environment. Since the climate change signal is indirect, ambiguous and contested, the company frame of reference could potentially be an important factor explaining why adaptation takes place or not. The company frame of reference could also be important when adaptation options are evaluated with the view that they should not have negative performance implications for the organization. Even though the WW organizations all operate within the same region there are differences between the organizations in their setup and leadership and the services they carry out. It is possible that these differences affect the frame of reference of these organizations which in turn could influence how they interpret the climate change signal and the internal selection process between adaptation options and performance implications. This is why results from each company are presented and briefly analyzed in this section.

Figure 3: Chart showing replies from the four WW organizations (21 respondents)



Note: The total number of replies registered into reply categories for each question does not necessarily match the total number of respondents. This is due to the fact that some respondents gave several replies to the same question that fit into different categories. There were also times where the respondent started to talk about mitigation which was not the focus of the study. In cases of doubt when categorizing answers the systematic action has been to leave out replies from the reply categories and not represent them in the charts. This also applies to figures 4, 5 and 6.

Käppalaförbundet

In Käppalaförbundet views on impacts of climate change are divided since it is seen as a concern by some respondents while others are still working on forming an opinion of the climate change issue. Most respondents also said that they could not comment on feedback since the issue has not really been raised. Käppalaförbundet also stands out as the organization where economic factors are seen by very few (only one person) as one of the most important factors relating to adaptation to climate change whereas regional cooperation and lack of influence are seen as important and limiting factors for the organization to be able to adapt.

There are a number of issues that can explain these results from the interviews. There are at least three main ways that Käppala could be affected by climate change: increased risk of flooding of the facilities due to raising sea levels, increased risk of overflow discharge, and increase in leakage into the sewage pipes due to changing precipitation patterns.

The physical facilities seem to be well protected from sea level rise, one respondent said he had done some investigations on his own and looked at effects of sea level rise and that the sewage plant could withstand a three meter rise in sea level with only moderate changes. The question of in leakage into the pipelines was identified as a possible problem. This is however not the responsibility of Käppala but depends upon the individual municipalities that are connected to Käppala. Cost of renovation works on the pipelines would therefore not be paid by Käppala but the individual municipalities. Any changes on

the sewage facilities of Käppala would be relatively modest in comparison to the cost of renovating the sewage system of the municipalities.

If the scenario is similar to today but with some increase in the intensity of rain, then there are no huge investments that are necessary. I cannot see that there would be any economic problems. (Respondent P)

Another reason for the limited focus on economic factors directly related to the organization could be related to the mindset of the organization and its steering board. There was only one respondent that expressed these views explicitly but most respondents did not foresee any problems of being able to get the approval of investments if the management board felt it was necessary.

That is a positioning that we have made [both company and political steering committee], that it can cost... if we are choosing between the price and the environment, then we choose the environment. (Respondent S)

Even though the issue of in leakage into the sewage system is not directly in the hands of Käppala the possibility to influence exists. There is a basic contract that all municipalities sign with Käppala, there are channels of communication open with the municipalities and the fee structure that all municipalities use to divide the cost of running Käppala has one fixed part, related to amount of inhabitants, and one mobile part related to the amount of water that reaches Käppala from the sewage system of each municipality. Even though the surplus charge that a municipality has to pay due to in leakage is relatively small, the fee structure is seen as a way of creating incentives for the municipalities to invest in renovating their sewage system.

It gives a red flag to the municipalities... it is more of a message to the municipalities that it costs more. (Respondent P)

When it comes to actual changes to routines or codification there have been few if any changes. There was an awareness of the climate change issue among several respondents and it is one of the issues that they include in their environmental scanning. It was really only in relation to a possible investment around the period 2015-2020 to be able to handle temporary high flows that could lead to overflow discharge of sewage water that the issue has surfaced. It was also stated that possible effects of climate change would be included in the calculations but not the main reason for the investment. A larger amount of connected individuals – which increases the sensitivity of the facility – would be the main reason.

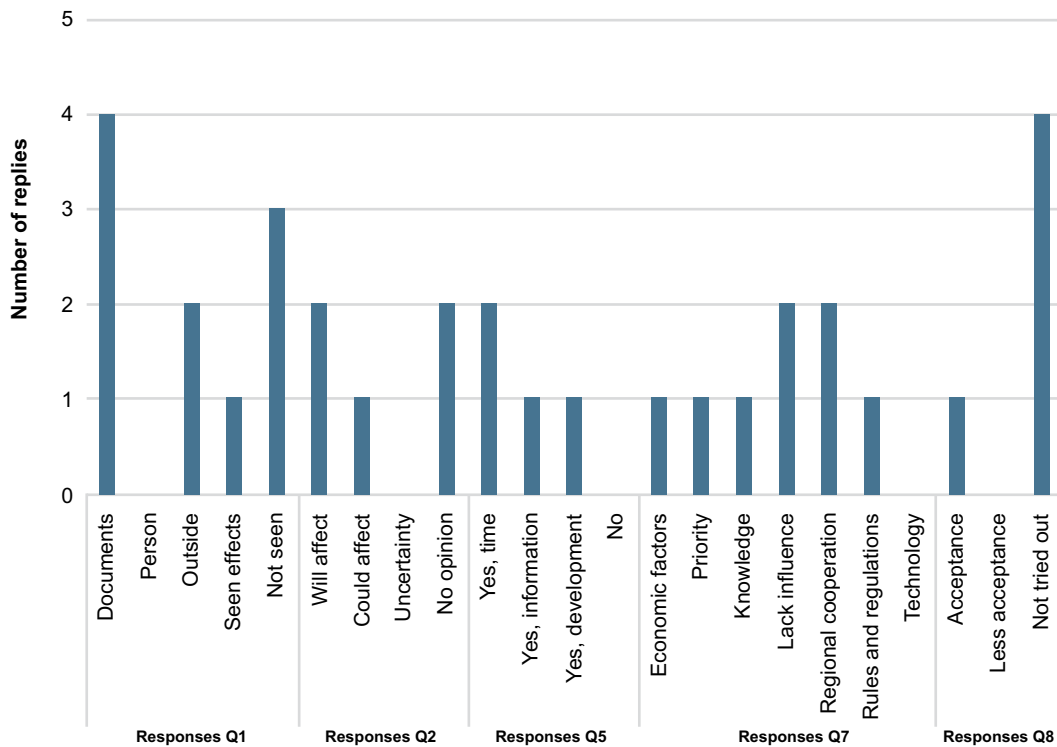
Then [with more people connected] we are closer to the maximum capacity of the sewage facility, we will be more sensitive to more intense rain which needs to be included in the calculations. (Respondent P)

Many respondents made references to the strategic document Käppala 2020 which deals with strategic challenges during the next 10 years. The document is being worked on at present and several respondents believed effects of climate change would or could be included in it. In the first draft of the plan there is only references to mitigation issues related to climate change and not adaptation to possible effects (Käppalaförbundet 2009). The respondents however stressed that it was an organic and evolving document that could change over the coming months.

Roslagsvatten

Before presenting the results it is important to point out that the results could have been influenced by the fact that the author sent a report that he had written on the effects of climate change to the COE when asking for the possibility to conduct interviews (RTK 2009a). This was done to show that the author had done previous work related to climate change and to improve the possibilities to conduct interviews within the company. The COE sent this report to all the people later interviewed with the request that they read it before the interview. This could have had some influence on the replies to

Figure 4: Chart showing replies from Käppala (5 respondents)



Note: See note of figure 3.

question 2 and given the respondents a chance to think through issues of climate change related to their organization in a way that respondents from the other organizations were not able to do.

In Roslagsvatten respondents gave similar importance to economic factors, regional cooperation and rules and regulations related to adaptation. There is an awareness of climate change within the company that is mainly expressed through informal discussions between colleagues.

You discuss it during coffee breaks, meet colleagues when you work on dimensions in projects (Respondent K)

It is in relation to surface water drainage that the biggest shift in routines has taken place related to climate change. There is an increased attention on the capacity to drain surface water in new planned areas and in transformed peripheral residential areas. There is more scrutiny before granting construction permissions and in new residential areas planners have started to look at how a 50- or 100-year rainfall event would affect the planned areas. Work is also ongoing with several municipalities to create surface water drainage planning strategies which is something that has been missing until now. One person within the organization has also been given responsibility for working with stormwater drainage planning which shows more resources are being spent on it.

You do not take it for granted anymore that they [transformed peripheral residential areas] will be able to handle the rainwater discharge. We have changed the planning of some areas due to that. (Respondent H)

These changes in routines is due to a number of reasons, there are more demands for treatment of rainwater and with more densely populated areas, solving rainwater discharge becomes more important. The realization that the problems could get worse with climate change has however also been an influence.

some dimensions and investments would probably not have been made if you did not expect the future to be more demanding than today. (Respondent H)

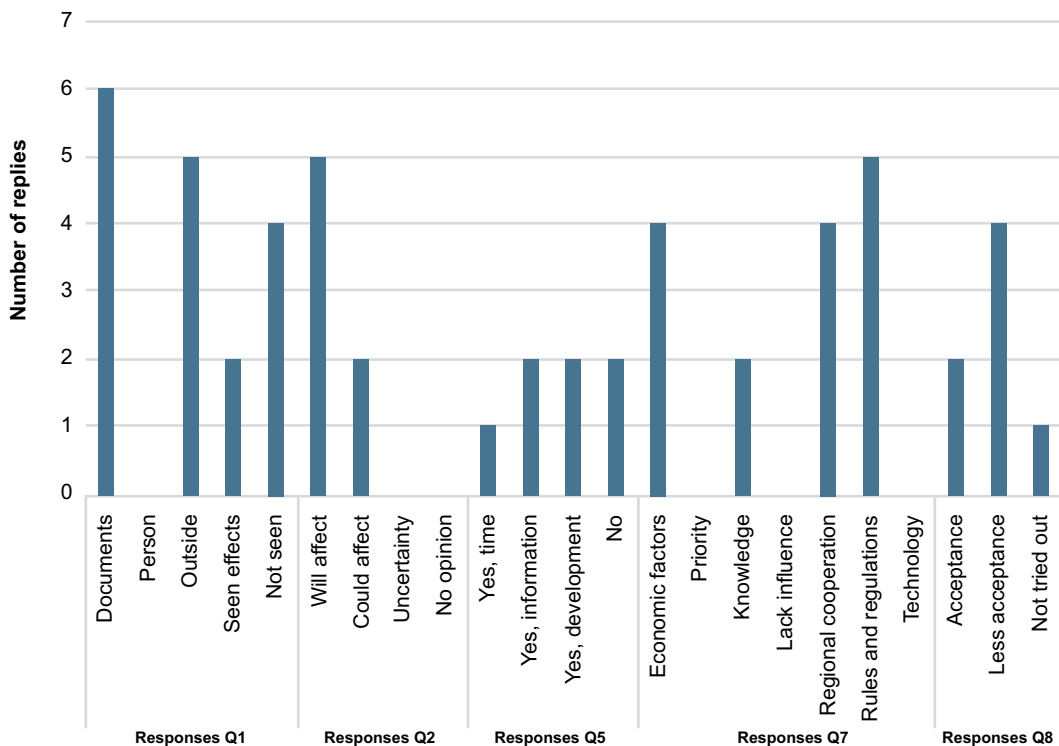
As has been mentioned the second important change in routines is related to the general increase in the levels when planning new areas close to the Baltic Sea in Österåker municipality. These modifications of routines have however not been codified but are rather a change in behavior that has come about from the information flow about climate change and discussions in the company.

It is not included in policies or guidelines for planning or our guidelines. But it is discussed in all new constructions and planning of new areas. (Respondent H)

In terms of changing the actual dimensions of the pipelines for the drainage system there was a consensus that this could not be done by the company alone but has to be based on new recommendations from SWWA. Cooperation was also stressed due to the fact that there are so many different parts of the municipality that are included in the planning process of new urban areas. Economic factors were also seen as important since any deviation from the standard would lead to extra costs that would have to be justified. The question of economy, cooperation and rules and regulations therefore in a sense all converge and affect each other.

It is necessary to make all parts of the societal planning process realize that it [adaptation] is necessary. There will be a couple of houses less or a larger ditch for it to work in the long run. So far it usually does not happen due to economical reasons (Respondent L)

Figure 5: Chart showing replies from Roslagsvatten (7 respondents)



Note: See note of figure 3.

Norrvatten

The results from Norrvatten indicate that there is a very high awareness of the climate change issue and shows how one co-worker who is an expert on effects of climate change related to water has managed to spread that knowledge within the organization. All respondents referred to one co-worker within the organization as one of their main sources of information on the climate change issue (except for the co-worker in question). The person in question was also one of the participants in the Swedish Climate and Vulnerability Commission. They all also indicated that climate change would affect their activities and could give relevant examples on how this would happen. There was a high level of agreement that they were doing enough at the moment but that there was a need to follow the development. The issue of climate change and the risks associated with it has also been presented to the political steering committee a couple of times. One respondent explained it in the following way:

Despite us being controlled by the political steering committee the important questions are identified by the civil servants in the organization and raised to the politicians. (Respondent E)

There are a number of studies and investigations going into issues related to climate change and several changes to improve the security of water production that are either in progress or have come far. There is a person investigating the possibility to reactivate the coal filters in the water purification plant in case there is an increased risk for waterborne infectious organisms entering the plant. There are models of both water movements in Mälaren and microbiological risk assessment that are used to assess this risk. In case of increased risk due to extreme precipitation or overflow discharge in nearby purification plants the aim is to be able to reactivate the coal filters and add extra amounts of chlorine to the water to neutralize the increased risk.

In the general safety and risk work – which does not necessarily have a direct connection to climate change – climate change is still a good argument for necessary investments that might not otherwise be made. One example that was brought up is the Water Safety Plan which creates the possibility of having real time sensors measuring the water quality

The climate change issue has made it easier to work with this type of systems... to get the necessary money to invest from the owners, it is a good argument. (Respondent C)

The main issue that makes Norrvatten stand out is that cooperation and rules and regulations are not identified as important factors even though some respondents referred to it when talking about a lack of influence on long term trends in water quality. All respondents had a high confidence that technological changes could treat any type of water but that they did not want to experience a situation of having to change the water purification techniques due to the high costs this would entail. Economic factors were raised as an important factor by most respondents since investments in new technology would have to be paid by increased water fees. This issue was however seen as important but not paramount and there was a general agreement that with proper analytical work on trends and future needs it would be possible to get the necessary funding for investments. A couple of respondents also discussed that even if possible future necessary investments are large in absolute terms, if you divide it with the number of clients that are served the extra cost is relatively small and that the present fee is very reduced.

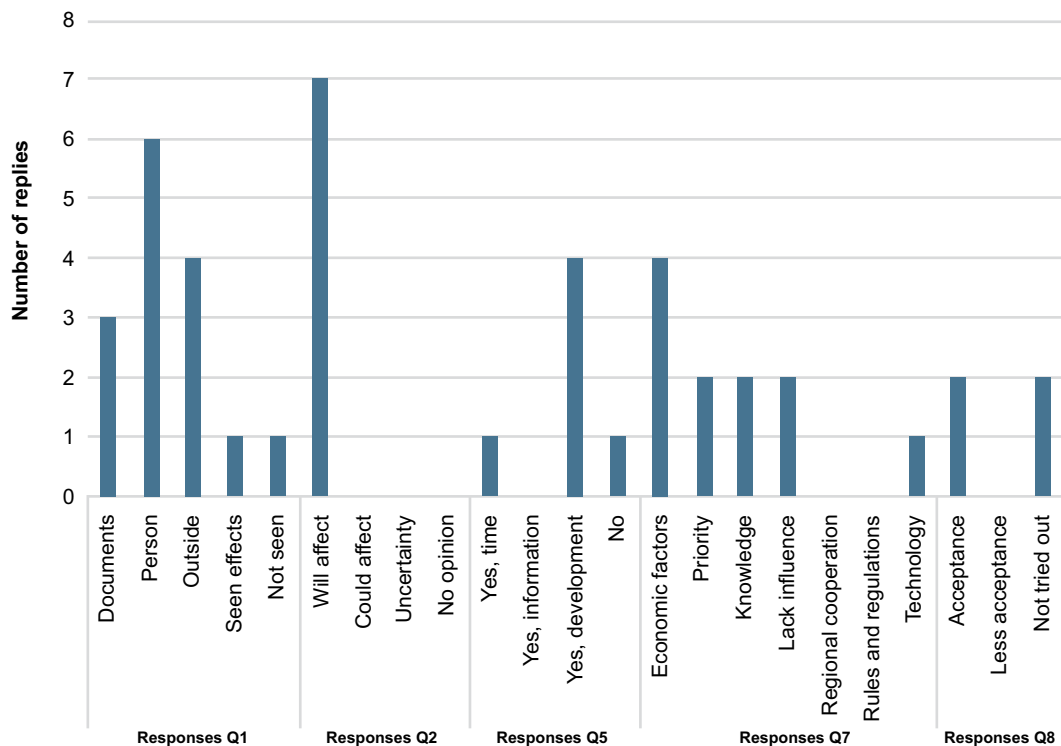
If the point comes when we need investments and we have good theoretical studies supporting the project [showing negative trends] I cannot see that it would be a huge problem to get the necessary funding. (Respondent C)

Norrvatten shows examples of codification – that the issue has been included in formal documents of the organization – and has even dedicated a part of the organization's annual report 2007 to the issue of climate change with the heading "Lake Mälaren has to be protected and the production of drinking water adapted to climate change". (Norrvatten 2008)

In 2003 there was a change in the purification process of water that had taken around ten years to implement. The change consisted in changing the type of chlorine added and introducing two new steps in the purification process, UV-disinfection and carbon filter. The most important reason for the change was to decrease byproducts from algae and humus that impacted on the smell and taste of the produced water. This change resulted in an increase of the charge of water of 25 öre per cubic meter of water. This can be characterized as an implementation of an adaptive decision since the levels of organic matter at least partially can be connected to climate change through a changing precipitation pattern. One example of this is the extreme precipitation event that occurred in the year 2000. Similar events are likely to be more common in a changing climate. The extreme precipitation resulted in very high levels of humus and loose organic materials in Lake Mälaren (Wallin 2002).

The level of organic matter in the water is principally a variable of the landuse in the catchment area, amount and variation of precipitation and its pH value. The greenhouse effect increases the level of organic matter... (respondent D)

Figure 6: Chart showing replies from Norrvatten (7 respondents)



Note: See note of figure 3.

Stockholm Vatten

In the two interviews carried out in this organization the main impression was that the uncertainties relating to the effects of climate change are so important that it makes it very hard or impossible to make investment based on information on climate change.

The scenarios are so different that it is not sufficient basis for us to act and make big changes in the infrastructure...it could be that the circulation of the Gulf Stream shifts...then we will not get warming but rather cooling. (Respondent T)

There was an insistence on factual evidence from both respondents in order to be able to come to decisions that would lead to extra costs related to adaptation. Two main questions related both the risk of making investments that would prove to be excessive with hindsight and the problem of making an investment when the timing of impact was not certain. Both interviewees insisted on how expensive it would be to adapt the WW system to climate change which was seen as a reason to wait before you take any major decisions to adapt.

Before you take such decisions [of large investments] you really need to know that [more] rain is coming and above all there is almost a need for it to have happened for the politicians, this is a problem. We are talking about such large quantities of money. (Respondent U)

In terms of actual changes to routines the main change relates to the minimum connection level to the WW system that has been substantially raised for new constructions. This is an adaptation both to present day levels since the allowed levels are too low with regard to present variability. The risk of raising sea levels due to climate change however also influenced the decision. One of the respondents has participated in the work of the Climate and Vulnerability Commission and there is some codification that has taken place in the answers to referrals (StockholmVatten 2007). It was not possible to evaluate to what extent this knowledge has been extended throughout the organization due to the limited amount of interviews that could be carried out.

In terms of written documents, one of the main issues that set Stockholm Vatten apart from the other organizations is that in 2007 it was given very strict owner directives from the municipality of Stockholm to work towards increased cost effectiveness in order to decrease the charges for the WW service. "It is assumed that Stockholm Vatten focus their work on carrying out reductions of their charges, the company is to be significantly rationalized and focus on its core business" (Stockholm-Stad 2007: 11)

Company frame of reference and possible implications for adaptation

In terms of adaptation activities there are differences that can be observed between the organizations. Norrvatten is dedicating a relatively important part of its resources to building adaptive capacity and has implemented an adaptive decision related to climate change that has increased the fees of the organization. Roslagsvatten has in some ways both built its adaptive capacity and implemented adaptive decisions where climate change is one of many factors leading to such activities. Stockholm Vatten has implemented an adaptive decision that does not affect the fees of the organization since it results in increased costs that are ultimately taken by building companies. In Käppala there have been few activities related to concerns of climate change.

There are several different variables that could explain these differences. One is the different levels of risk associated with the various WW services, another could be the presence or lack of key individuals within the organization that have managed to raise the issue of climate change broadly in the organization. The low level of risk associated with sewage treatment and the limited exposure to climate change could be an important factor explaining the low level of awareness of climate change and the limited activities in Käppalaförbundet. In Norrvatten one key individual has managed to raise the issue of adaptation to climate change within its organization which can partially explain why they have come far in their work on adapting to climate change.

Economic issues were however raised as the most important factor influencing the actual adaptation space of organizations by the interviewees. It should therefore be able to explain some of the observed differences in adaptation behavior between these organizations. The respondents from the organization with the strongest focus on cost reduction were those that spoke the most of the uncertainties related to climate change information. They also insisted on the necessity of 'facts' to be able to make important investments for adaptation. There are therefore indications that in an organization with a strong focus on cost reduction the requirements on the knowledge base of climate change necessary to be able to implement costly adaptive decisions increase.

6 DISCUSSION

The results indicate that adaptation is taking place in the WW sector of the Stockholm Region at present. It is also clear that the adaptation activities that are taking place are mainly activities aimed at building the adaptive capacity of the region. There are examples of implementations of adaptive decisions where possible effects from climate change are one of several considerations that led to such decisions.

The research shows that there is a wide range of possible options for the organizations to adapt to climate change. This makes the delimitation of the potential adaptation space broad since the knowledge, technology and organizational capacity exists within the organizations for a range of possible adaptations. It is, for instance, not likely that there will be a shortage of water in the Stockholm Region even with climate change and several respondents pointed out that there is technology to purify almost any water to make it potable. There are also no technological barriers to limit the leakage in the sewage system and for sewage treatment. Organizational issues are neither one of the main factors limiting the adaptation space of the WW organizations in the Stockholm Region. The coordination within the region and with the municipalities also functions well even though there are matters that could be improved.

The research however points towards several factors that make different adaptation options less feasible or attractive and which could be seen to restrict the actual adaptation space of the WW organizations in the Stockholm Region at present. There are doubts about the climate change issue within some organizations and in their surrounding and substantial uncertainties about what the effects will be and when these effects will have a significant impact on the WW sector. From the respondent's answers it can be concluded that the adaptation taking place in Stockholm by the WW organizations is largely perceived to be anticipatory since most interviewees do not believe to have experienced any effects of climate change. The signal from the environment of the organization is therefore indirect, weak, unclear and even contested.

In the region the WW organizations are restricted by price sensitive politics connected to the fact that WW charges are set by the municipal politicians that have to balance the WW charges with all the charges and taxes of their municipality. Since the climate change signal is so ambiguous and the possible impacts uncertain both in time and size the issue of price sensitive politics also appears to be influential since, in accordance with the theory of organizational learning, possible adaptation options are evaluated in relation to their performance implications. In the WW sector implementation of adaptive decisions are generally very expensive in absolute terms and if one of the main objectives of the organization is to keep the charges as low as possible it is probable that this leads to the exclusion of some alternatives of implementation of adaptive options that are expensive. This could be a partial explanation as to why most of the adaptation taking place in the Stockholm Region is aimed at building adaptive capacity which is less resource intensive.

It appears that the issue of price sensitive politics exists generally in the region but with differences between the different WW organizations. In one WW organization it has been translated into explicit and strong cost efficiency demands. In another organization cost is not seen as an important limiting factor. Due to the important uncertainties related to climate change information the organizations cannot be sure that investments will be cost efficient or profitable, for the company or society at large. This limits the possibilities to implement costly adaptations to climate change and is particularly the case if investments have to show profitability in the short term.

The time lag between the investments that are needed today and the expected benefits from adaptation is another factor that limits the possibilities to implement adaptive decision. Market demands and pressures to exploit valuable but unsuitable land from a WW perspective are other factors that are particularly limiting in relation to the sewage system. Actors interacting with the WW organizations when constructing new areas are reluctant to exclude attractive land from construction and to

increase the costs of these constructions in order to adapt to climate change without clear guidelines justifying the additional costs. From the results of this study it therefore seems justified to explicitly analyze the factors that influence the feasibility or attractiveness of the adaptation options to be able to understand the actual adaptation space of an organization and in extension the adaptation options that can be pursued.

Although the study is focused on the WW sector in the Stockholm Region there are some general implications that can be drawn with the results in view. In an area with high adaptive capacity, which is the case of the Stockholm region, an evaluation of the adaptation space of the unit or system of interest – including factors that make some options more feasible than others – could be a way to further the understanding of adaptation and the shape the process takes. Some of the noteworthy factors such as market demands to construct in centric areas that are not always suited for construction can be expected to exist in many other parts of the world. One of the most important factors identified as influencing adaptation in this case study is the nature of the climate change signal which is similar all over the world. There are large intrinsic uncertainties related to the possible effects of climate change that will most likely never be eliminated (IPCC 2007a). It could be expected that other regions similar to the Stockholm Region, and that have not yet experienced serious weather events that have been connected to climate change, will exhibit similarities in their adaptation space. It also remains to be seen to what extent ‘price sensitive politics’ is an important factor restricting the adaptation space in other regions where there is municipal control over the WW organizations and in what ways it differs, if at all, in areas with privately owned and run WW organizations.

Results also show that, at least in the Stockholm Region, the distinction between anticipatory and reactive adaptation can be made based on the respondent’s answers. This distinction was questioned by Berkhout *et al.* (2006) but can be useful in the view of the author, if it is possible to make, when trying to understand the adaptation space of organizations since it is so intimately related to the type and strength of the signal from the environment that the organization receives and how it is interpreted.

There are also further implications that can be drawn from this work relating to current arguments that are made for necessary adaptation. Milly *et al.* argue that stationary water management, based on historic records, is no longer appropriate due to climate change (2008). Hallegatte has a similar stance and claims that long lived infrastructure, such as that of the WW sector, needs to take possible impacts of climate change into account already today. The intrinsic uncertainties related to climate change and its effects however mean, according to him, that this requires a shift of practices and decision-making frameworks and that instead of optimizing future infrastructure it should be made more robust to possible changes in climatic conditions (2009). Dessai and Hulme speculate that robustness to climate change uncertainties usually means higher costs and pose the rhetoric question if robust adaptation options are socially, environmentally and economically acceptable (2007). The results from this study indicate that at present the actual adaptation space of the WW sector of the Stockholm Region is such that it makes it unlikely that robust, and more expensive, adaptation options for the WW system can be implemented solely on the ground of possible impacts from climate change. This conclusion seems to hold more for some WW organizations in the region than others but generally it can be concluded that organizational or technological barriers are not the main explanation for this. The reasons behind this are rather due to how the climate change issue and risks are interpreted and perceptions of how the WW organizations should function and use their limited economical resources.

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9 APPENDICES

Appendix 1 Operationalization and interview questions

Starting question: What questions are you working with right now?

Model of the adaptation process	Theoretical themes	Interview questions
Signal recognition and interpretation	1. Signals of climate change (recognition, salience/frequency, interpretation) from environment (physical, regulatory, market) Appraisal of climate change as constituting a novel situation or not	1. In what ways have you become aware of climate change and the effects it has/might have on your company? 2. How do you perceive the information and signs of climate change in relation to your business activity? How is it perceived within your company?
	2. Evidence of search and appraisal, change of routines and codification Organizational changes and changes in environmental scanning Steps that build adaptive capacity	3A. Does your company at present work with the climate change issue and its possible effects? Do you collect and evaluate information about climate change and the effects it could have on your business? Have you implemented any changes within the company taking this into account?
Search for and articulation of possible solutions	Changes to systems and standards Implementing adaptive decisions	3B. Have you implemented any actual measures/changes within your systems or standards as a reaction on experienced or expected effects of climate change? 4. Have you encountered any problems in the implementation? What type? Are there measures that you have considered and not carried out? (Why?) 5. Do you think it is enough?
	3. Internal selection between adaptation options and performance implications 4. Climate signals in relation to other drivers and signals for change	6. Are possible adaptation measures evaluated in relation to company goals and performance objectives? 7. What factors, according to you, influence the company's adaptation possibilities?
Feedback and iteration	5. Feedback, positive or negative, from the environment (physical, regulatory, market)	8. Do you perceive to be getting any feedback from adopted adaptation measure?

Ending question: Is there anything else that you want to include or bring up?

Appendix 2 Response categories

Question 1

1. Written documents (media, articles)
2. Person within company
3. Through outside conference, cooperation, information meeting regional or national body (Svenskt Vatten, VAS rådet, University, Regional Water company meeting NRK, CEO meetings)
4. Seen effects that could be connected to climate change
5. Not seen any effects connected to climate change

Question 2

6. Will affect, gave relevant examples
7. Could affect, gave relevant examples
8. Could affect, gave relevant examples but stressed uncertainty in time and impact
9. Not finished forming an clear opinion about the climate change issue

Question 3 (A and B)

Individual answers not presented in bar graphs since the questions were aimed at finding out what adaptation measures have been initiated by the organization as a whole (presented in the first part of section 5).

Question 4

Not presented in bar graphs since it was often hard for respondents to relate to the question (if there had been few changes implemented). When they responded the answers were similar to the replies to question 7 and have been included in the response categories for that question.

Question 5

10. Yes, we have time to implement changes/ not much more needed right now
11. Yes, information and other factors limit possibility to do more
12. Yes, but we need to follow the development
13. No, could communicate the issue more/ more cooperation/ could focus on the issue more

Question 6

Not presented in bar graphs since it was not always asked and some respondents had trouble answering the question. The ones that did generally interpreted the question narrowly to mean allowance limits of pollutants or similar interpretations that were deemed of less relevance to the research question.

Question 7

14. Economic factors
15. Priority
16. Knowledge and information influenced by uncertainty (both relevant and to relevant actors)
17. Affected by factors/actors without direct possibility to influence
18. Regional cooperation and common understanding
19. Rules and regulations, laws and concessions
20. Technology

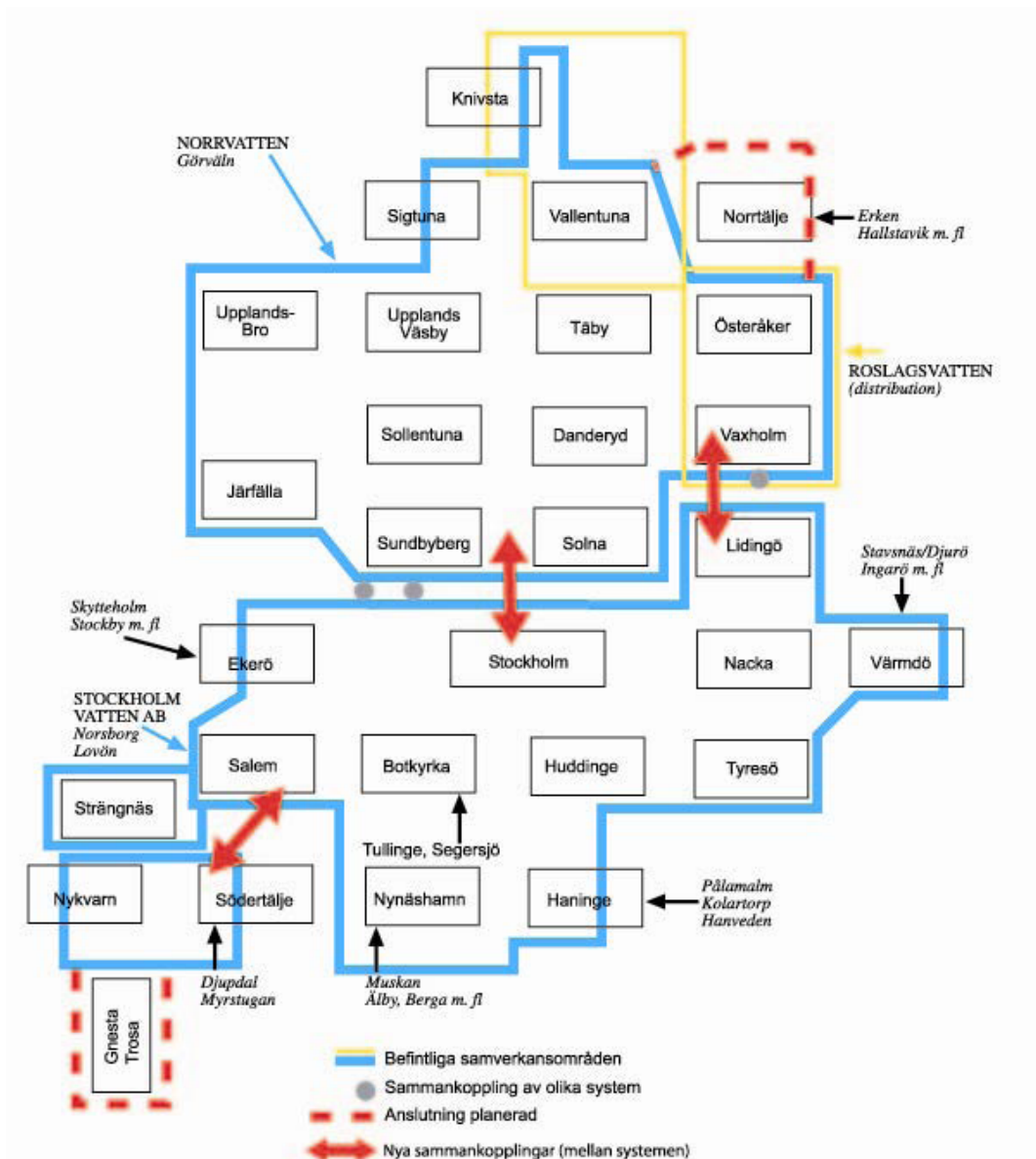
Question 8

21. The issue is taken seriously/acceptance
22. Hard to get full acceptance/trustworthiness
23. Issue not brought up/not relevant/ too abstract

Appendix 3 Maps of the WW system of the Stockholm region

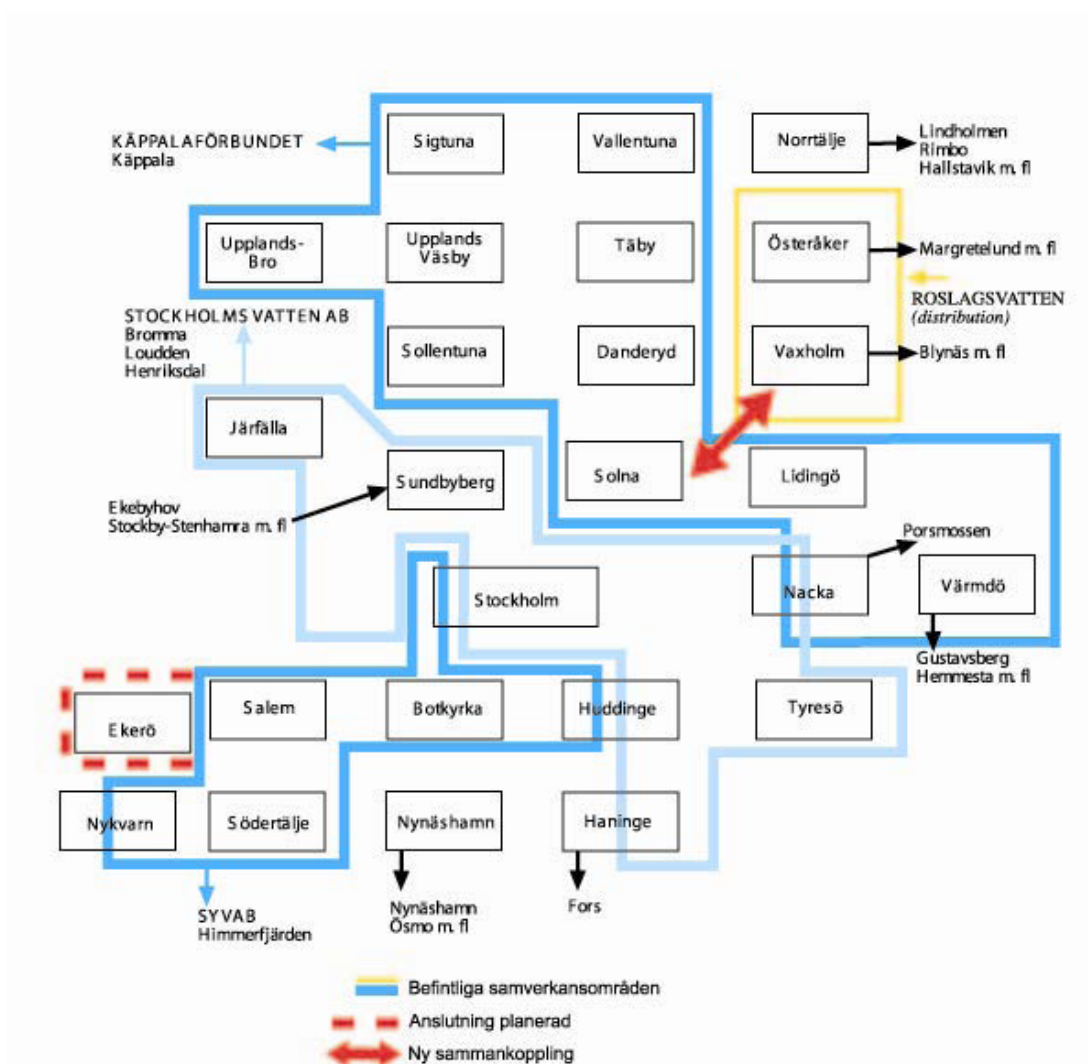
Map 1 showing the distribution areas of water produced by mainly Norrvatten and Stockholm Vatten. Most squares represent a municipality of the Stockholm Region (3 municipalities are from other Regions).

Source: Regionplane- och Trafikkontoret Stockholms Läns Landsting



Map 2 showing the collection area of sewage water in the Stockholm Region by Käppala, Stockholm Vatten, Roslagsvatten and SYVAB.

Source: Regionplane- och Trafikkontoret Stockholms Läns Landsting



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