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Water Resource Management -

A qualitative study of Swedish municipalities water resource management

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Abstract

Today we are facing many challenges for achieving a sustainable future. One of the most important challenges is to ensure availability of water and sanitation for all. Water scarcity affects every continent in the world and approximately 1.1 billion people lack access to water. Such dilemmas have always existed, however, in recent years water scarcity has increased. With a growing population comes increased demand and consumption of clean freshwater causing more stress on the planet. Sweden is a country with plenty of available water resources but, due to droughts and less precipitation, it has experienced enormous negative effects on its water supply in recent years.

The aim of the study is to contribute with knowledge to what specific challenges Swedish municipalities face with water resource management towards reducing the risk of water shortage and climate change. A qualitative case study on Gotland municipality was conducted to answer the aim of the study. The analytical tool used were a SWOT-analysis which identifies strengths, weaknesses, opportunities and threats which is further used to establish the challenges of water resource management.

Many challenges have been identified towards achieving a long-term and sustainable water resource management. There is a need to continue their work and implementation of more actions. Many of the challenges presented are interconnected. It is also evident that many challenges are connected between different sectors and makes it important to work for an integrated management. The establishment of more interdisciplinary competence within the workforce would give opportunity to better understand, coordinate and implement strategies for cooperation in different sectors. The learning process and the awareness is incredibly significant to implement the right strategies and to engage stakeholders. However, research on other municipalities is necessary to make a more generalized result to the purpose of the study.

Abbreviations

AD - Adaptive Management

SDGs - Sustainable Development Goals

SWRQ - Seawater Reverse Osmosis

SGU - Geological Survey of Sweden (Sveriges Geologiska Undersökning)

SMHI - Swedish Meteorological and Hydrological Institute

TDS - Total Dissolved Solids

UN - United Nations

WWF - World Wildlife Fund

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1. Introduction

In 2015, the United Nations and its Member States adopted the 2030 Agenda for Sustainable Development. The agenda serves as an overarching guide for all member states to achieve a sustainable planet for the people now and in the future without impacting negatively on the planet's ecosystems. In the agenda, 17 Sustainable Development Goals (SDGs) have been agreed on that require action from all countries to reach the vision of a sustainable future. Examples of these goals are to prevent poverty, eradicate hunger, provide good health and well-being for everyone, ensure good quality education, reduce inequalities and have gender equality. (United Nations, a) All of the 17 SDGs need to be addressed by all countries and stakeholders in a collective action towards implementing the agenda. (United Nations, 2015)

Today, we are facing many challenges for achieving a sustainable future. Billions of people live in poverty and inequality amongst people is increasing. The right opportunities are unevenly distributed and the people having the hardest time are also those ones most affected by climate change that is one of our greatest challenges. It causes depletion of our natural resources and environmental degradation which in its turn affects the efforts put in by countries and stakeholders to solve these challenges. (United Nations, 2015)

One of the most important challenges is to provide availability and sustainable management of water and sanitation for everyone in the world. This is the sixth SDG that the United Nations and its member states agreed upon. (United Nations, 2015) Today, water scarcity affects every continent in the world. Approximately 1.1 billion people lack access to water and nearly 3 billion people experience a scarce water supply at least one month per year. Our planet is covered by 70% of water and, therefore, is seen as an abundant resource. The access to water should not be problematic as water is an abundant natural reserve. What causes this challenge is that the freshwater used for domestic, agricultural and industrial use only amounts up to 3% of all the water in the world. The majority of this is also unavailable as it is frozen in glaciers. Furthermore, people lack access to clean and fresh water as a result of an uneven distribution of the resource and of insufficient management tools and systems. (WWF, 2019)

Such dilemmas have always existed, however, in recent years water scarcity and water shortage have increased because of higher stress on water systems like rivers, lakes and streams. With a

growing population comes an increased demand and consumption of clean freshwater causing more stress on the planet's ecosystems. If the consumption rate and the demand for water keeps increasing at the same pace, the current situation will become worse and affect more people in the future. It has for example, been estimated that two-thirds of the world's population will face some sort of water shortages already by 2025. (WWF, 2019; United Nations, b) Climate change also causes extreme weather events where some regions are experiencing dryer climates and other regions see an increase in precipitation and heavy rain. This has led to some regions experiencing severe droughts and/or floods. (WWF, 2019) Most affected by this are developing countries who lack the means and capabilities of reducing the risks, but also do not have sufficient management systems in place. (United Nations, b) However, it is not only developing countries that are affected. Developed countries also struggle with minimizing the impact of climate change. It is expected that droughts and water shortage will increase in the future due to climate change. (WWF, 2019; United Nations, 2015)

Sweden is a country with plenty of available water resources, but, due to droughts and less precipitation in recent years, there have been enormous negative effects on the country's water supply. As an example, several regions have experienced groundwater shortage during the latest summer months. (SGU, 2017a, my translation; SGU, 2017b, my translation; The Local, 2019; Radio Sweden, 2016, my translation) The most affected are the coastal regions who struggle with saltwater intrusion in the municipal water supply. (OECD, 2013, p. 206; The Climate Change Post, 2019) Many local authorities have, in the last years, been forced to implement water irrigation prohibitions whilst others urged their citizens to be frugal when consuming water distributed to their home. (Svenskt Vatten, 2019, my translation) Since then, broad attention towards water shortage and water scarcity have emerged. Several agencies and companies are collectively working to spread information about being more sustainable and reducing the amount of water used. An example is the launch of a "smart textile-campaign" developed by the Swedish Environmental Protection Agency, the Swedish Consumer Agency, and the Swedish Chemicals Agency who urge people to be more climate smart when shopping clothes. One reason for this is the large amount of water it takes to produce a piece of clothing. This led clothing companies to lounge environmentally aware advertisements of clothes produced with less water. (Kemikalieinspektionen, 2019, my translation; Naturvårdsverket, 2019a, my translation; Naturvårdsverket, 2019b, my translation)

Since this is a rather new and emerging problem facing the country, authorities are still working on figuring out how to manage resources for both now and the future. To uphold a good water supply with freshwater accessible to the Swedish citizens, there would be great costs if the water quality and quantity got reduced significantly. (SGU, 2017b, my translation)

The society needs to be prepared for different types of stress that periodical droughts and other weather extremes can have. It is evident that tools and measures of such are not in existence so far since it is a rather new phenomenon. As of right now, the only means to reduce the risks of climate change affecting the waters quality and quantity have been to put in irrigation prohibitions, but if such events continue to occur, those means will not be enough. The scarcity of water resources is a local problem (Sverige Kommuner och Landsting, 2019, my translation) and therefore, tools, measures and adaptive strategies need to be implemented by municipalities.

1.1 Purpose

This study's purpose is to contribute with knowledge to what challenges Swedish municipalities face with water resource management towards reducing the risk of water shortage and climate change. To answer the research questions and to fulfil the purpose of this thesis, a qualitative case study of one municipality has been conducted. The analytical tool used were a SWOT-analysis which identifies strengths, weaknesses, opportunities and threats. The analytical tool is further used to establish the challenges of water resource management of local authorities.

1.2 Research questions

- What challenges do Swedish municipalities face with sustainable water resource management?
- Do municipalities in Sweden have adaptive strategies and if so, what are they?
- How are they using adaptive management to reduce water shortage risks?

1.3 Thesis deposition

The thesis is divided into seven parts. The first chapter consists of an introduction, the purpose of the study and its research questions. In the second chapter, a review of the existing literature is presented. The following chapter goes through the theoretical framework together with the analytical tool. In chapter four, the methodology is described, the case selection and further, a presentation of the chosen case. The fifth chapter consist of the result, leading into the discussion in chapter six and lastly, chapter seven consist of the conclusion.

2. Literature review

2.1 Climate change impacts on water resources

When reviewing the literature on water resources and the impacts of climate change and anthropogenic activity it is evident that it is hard to know what such impacts could be. Many researchers have dedicated time and effort into this type of research and still the result can not explicitly reveal the effects. Researchers have used multiple climate models to try and predict the impacts of climate change on water resources, but did so without a sufficient result. Several different future scenarios can be analysed from the result, but nevertheless, there is a great uncertainty. (Green et al., 2011) It is difficult to give a more definite prediction because climate change impacts can have both direct and indirect effects on water resources and can vary over time. Therefore, it can take years to discover and link it to climate change. Another reason for the uncertainty is that the topic has not been highlighted enough until recently. Although the research is not sufficient enough to give a certain result, researchers agree on the understanding that water resources used for domestic, agricultural and industrial consumption are vulnerable to climate change and to increased demand that comes with a growing population. (Garnier and Holman, 2019; Green et al., 2011)

Today, the extraction of water has turned into overexploitation at a rate that is not sustainable and can cause severe consequences. We use more water than is being recharged and many regions will experience constraints in water availability and a reduction in quality. Since the recharge of water expands over years, the sources used are not capable of keeping up with the withdrawal rate. This may have long-term consequences of a steady decrease of the water level in aquifers. (Foster and Chilton, 2003) In many cases, it has been shown that water scarcity caused by climate change and overexploitation of valuable resources can lead to environmental degradation and affect important ecosystems we are dependent on. (Navarro-Ortega et al., 2015) Further, water is a valuable resource for economic development, but overexploitation can affect that development negatively. Large costs are predicted to be enforced on communities that are dependent on sources with water shortage problems. Economically, there will be a cost to deepen wells or to develop and implement new technologies and other strategies to cope with water shortage. (Navarro-Ortega et al., 2015; Distefano and Kelly, 2017; Foster and Chilton, 2003) In other cases, there has been an increased risk of conflict over scarce

water resources. (Weiss, 2015) Furthermore, there is a worry amongst researchers regarding the decrease of water quality. This can be a result of salt intrusion, pollution caused by human activity, contamination of chemicals from the industrial sector, and fertilizers and pesticides used in agriculture that leak out into the soil and get carried away into water sources. (Navarro-Ortega et al., 2015; Foster and Chilton, 2003)

The importance of studying water resource management and the impact of climate change is because with a growing population and signs for climate variability we need to understand how water supply and water demand will be in the future. This way, adaptive measures can be put in place at the right time. Some regions that are projected to see an increasing population are already water stressed. Therefore, it is of the upmost importance to plan for how to develop a region for a future growing population and to plan for an increase in water demand when water resources might be scarce. (Garnier and Holman, 2019; Navarro-Ortega et al., 2015; Foster and Chilton, 2003) Significantly affected regions are touristic areas that in some countries have already experienced alterations in water availability during different seasons. The water resources may face difficulties recovering if they are put under heavy pressure due to less precipitation and overexploitation during certain periods like the summer months. (Gowreesunkar, Naqvi and Séraphin, 2018; Moghal and O'Connell, 2018)

Other researchers have studied the implications of climate change on water flow and water quality through climate simulations. The predictions cannot be seen as fully certain due to future uncertainties and not enough existing data. However, most of the studies could still conclude that we should be concerned about the future flow and quality of our freshwater and groundwater. Further, more research and knowledge would help policymakers and water managers in the development of adaptive strategies. (Wang, Li and Li, 2018; Walling, Chaudhang, Dhanya and Kumar, 2017; Dyer et al., 2013; Macura, Štefunková and Škrinár, 2016) Most of these studies have been conducted on cases in Asian countries. There is, however, an earlier study made by Younger et al. (2002) who studied the sensitivity of climate change on water flow and water quality in European aquifers. It was uncertain how the waterflow and quality would be affected by climate change, but they found that even with the best potential climate scenarios in their simulations, we should be concerned. They concluded that groundwater resource availability will be negatively affected, specifically in the low-and mid-latitude European aquifers that they used as case studies.

Even though the impacts on groundwater resources cannot be fully established, it is nevertheless certain that we will experience increased climate variability like droughts, floods, variability in precipitation and other extreme weather events. This has caused scientists all over the world to raise awareness about the necessity to improve knowledge and understanding of water resources and the effects of climate change. (Green et al., 2011; Granier and Holman, 2019; Younger et al., 2002) There is a need to understand the impacts before we develop adaptive strategies, otherwise it could lead to negative consequences. In an article by Giupponi, Gain and Farinosi (2018), they investigated an approach to assess the sixth SDG that could help in identifying problems within water management. This could further help in establishing strategies to be put in place at the right time. They stress the importance of first identifying priority areas before necessary policies can be identified. Future projections are necessary to be able to identify fundamental policies. Therefore, it is of the essence to gather information and build up a knowledge base.

Green et al. (2011) recognized that there is a research gap in this topic relating to the amount of literature that exists on surface water compared to groundwater. The reason for this, is due to surface water resources being easier to analyse and assess because it is more visible. Policy makers and water managers are, however, showing an increased interest in managing groundwater resources in a sustainable way after seeing that groundwater quality and quantity has been affected in many different regions worldwide. Reduced quality and quantity of groundwater used for drinking and for irrigation purposes in the agriculture and industry sector puts a lot of stress to secure human well-being, food security and production and at the same time, it degrades the environment. (Green et al., 2011) In Europe it is estimated that 75% of the European citizens depend on groundwater as their main water supply. (IGRAC) An increase in open dialogues between scientists, policy makers and water managers are being observed. Furthermore, involvement of stakeholders and transboundary and cross border cooperation is rising to develop and share adaptive strategies. (Green et al., 2011) In a study regarding the use of innovative ideas and technology in disaster management, Bojovic and Giupponi (2019) found social networks and collaboration important. It was seen that new knowledge was shared between organisations in different social networks which could lead to behavioural change. Bojovic and Giupponi stressed that there are many actors involved in disaster management playing important roles and these actors and stakeholders have to be recognised and encouraged to participate. Therefore, good communication and collaboration is crucial. Studies on groundwater resources have become more common in recent years, but there is still not enough

to make reliable assumptions on. Hence, Green et al. (2011) stresses the importance of conducting further research on groundwater resources.

There are usually two main ways that researchers view how water resources are impacted by climate change and anthropogenic activity. Those are by considering the water quality and quantity. When considering water quantity, one looks at the amount of water that exists in an aquifer and how the recharge and discharge rates are compared to each other. Quality considers the state of water and can be impacted by the quantity. Together, quantity and quality make up the state of water resources. (OECD, 2017) Regions with more than one water resource generally do not encounter major issue with water supply if managed well. It becomes more of a concern for regions with only one source of supply, such as those depending solely on groundwater resources. With increased stress on groundwater levels, reduced water quality and the uncertainty of response time, (IGRAC) it is necessary to prepare for such consequences in vulnerable areas to avoid or reduce risks. As Green et al. (2011) emphasizes, recharge of groundwater is vulnerable to climate. The recharge process is dependent on many things related to precipitation, soil, vegetation and land-use, to name but a few. Garnier and Holman (2019) point out the value of wetlands as it is a natural storage of freshwater and helps to keep a high water quality. By letting water run through the vegetation in wetlands, sediments and other residue get filtered away. Many wetlands are destroyed for the purpose of building infrastructure and expanding urban areas. Therefore, land-use change can have immense effect on water quality and quantity. Preserving wetlands also works to secure certain ecosystems. However, there are both positive and negative consequences with such measures. Preserving and planting wetlands needs a long time before positive performance can be evaluated. This consequently leads to actors that instead focus on the short-term economic loss.

With the focus on water quality, one of the most considered risks is sea level rise and consequently, salt intrusion into groundwater resources near coastal areas. (Foster and Chilton, 2003; Jin et al., 2019) This would directly contaminate the water and be unusable for domestic consumption and irrigation purposes. Furthermore, salt intrusion and total-dissolved solids (TDS) contamination can also occur during dry seasons. When the groundwater level is low, it is drawn back into the storage unit which can cause salt and TDS to be drawn in and contaminate the source. (Green et al., 2011; Foster and Chilton, 2003; Jin et al., 2019)

Green et al. (2011) mentioned the example of the hot summer in Europe in 2003. Due to hot temperature, the discharge of freshwater became very low. With less precipitation there was

less water that could recharge the reservoirs and if it rained, the ground was too hard and could not soak up the water resulting in floods. Along the Rhine river, seawater intrusion took place which threatened many agricultural areas in the Netherlands. This case led to an increased knowledge of adaptive strategies to better prepare for hotter summers. Green et al. also points out the risk of contamination from agricultural and industrial practices where pesticides, fertilizers and hazardous chemicals risk being transported into the water. Without good regulations on proper chemical waste disposal, there may be an increase in severe water pollution causing environmental degradation of our ecosystems. If citizens use this contaminated water, there could be serious, adverse health effects on the population. An example where one can see the impact of severe pollution is the case of the chemical herbicide company called BT Kemi located in Teckomatorp, south of Sweden. In 1977, it was discovered that the company had buried thousands of barrels containing rest products of toxic substances and released contaminated water into the city river, leading to the contamination of soil and water in the area. Still, today, the municipality is working to decontaminate the polluted area. (Svalövs Kommun, 2019a, my translation; Svalövs Kommun, 2019b, my translation)

2.2 Adaptive strategies

So far, the literature review has discussed impacts of climate change on water resources and what could happen if we do not adapt to these changes. Another field within this topic examines the actual adaptive strategies that have been developed all over the world. Adaptive strategies for water management can be defined as "... a mix of structural and non-structural, regulatory and economic instruments, and education and awareness-raising to tackle short-, medium- and long-term impacts of climate change." (UN, 2010, p. 77) Adaptive strategies should be implemented at all levels; national, regional and local. For instance, Garnier and Holman (2019) express the importance of a well-functioning policy implementation at the EU level. Well developed and implemented policies on drinking water management helps to guide and set a framework for how national governments and later regional and local authorities can face resource related challenges. Since groundwater resources are hard to control, it is easy for communities to over-exploit and therefore, strategies for water management are necessary to develop and implement for a sustainable use.

When looking at adaptive strategies for water resource management, they are usually divided into two different fields that can be adopted by responsible authorities and actors. These are supply-side adaptive strategies and demand-side adaptive strategies. The supply-side strategies are developed to help manage the supply of water. Demand-side strategies help in making the demand more efficient or to reduce the over-use by consumers. These types of strategies ensure a good water quality and make certain that the quantity of water is sufficient in a sustainable way. (Garnier and Holman, 2019; Green et al., 2011) Supply-side responses are defined as "... those aimed at increasing water availability in order to ensure drinking water supply in the long term, taking also into account the competing demand from other sectors." (Garnier and Holman, 2019, p. 143) Demand-side responses are defined as "... regulating the demand or increasing water efficiency, in this way acting directly or indirectly on drinking water availability." (Garnier and Holman, 2019, p. 144)

Green et al. (2011) and Garnier and Holman (2019) have, in their research, compiled the most discussed and used adaptive strategies on water resource management. Focus on the ones mentioned by them will be the ground for this thesis literature review section. Most of the adaptive strategies that have been reviewed in the literature have been developed by different water management projects all over the world or by specialist researchers. Green et al. examined the adaptive strategies recommended by IPCC in their report from 2008 (Bates, Kundezewicz, Wu and Palutikof, 2008) and Garnier and Holman (2019). focused on the approaches identified by the Adapting Drinking Water resource to the Impacts of Climate change in Europe (ADWICE) project. The adaptive strategies have been summarized in table 1-3.

Table 1. Summarized recommended IPCC adaptive strategies with supply-side and demand-side responses (from Table 1 in Green et al., 2011, p. 552; from Table 3.4 in Bates et al., 2008, p. 49).

Supply-side adaptive strategies	**Demand-side adaptive strategies**
Increase storage capacity by building reservoirs and dams.	Improve water-use efficiency by recycling water.

Desalination of seawater.	Reduce water demand for irrigation by changing crops, irrigation methods and the area planted.
Expand rain-water storage.	Promote traditional practices for sustainable water use.
Prospect and extract groundwater.	Expand use of water markets to re-allocate water to highly valued use.
Develop new wells; deepen and maintain existing ones.	Expand use of economic incentives including metering and pricing to encourage water conservation.
Develop aquifer storage and recovery systems.	Introducing drip-feed irrigation technology.
Develop conjunctive use of surface water and groundwater resources.	License groundwater abstractions.
Develop surface water storage reservoirs, filled by wet season pumping, from surface water and groundwater.	Meter and price groundwater abstraction.
Develop artificial recharge schemes using treated wastewater.	
Develop groundwater management plans that manipulate groundwater storage (e.g. resting coastal wells in times of low groundwater levels).	
Develop groundwater protection strategies to avoid loss of groundwater resources from surface contamination.	

Manage soil to avoid land degradation to maintain and enhance groundwater recharge.

Table 2. Supply-side adaptive strategies summarized from Figure 2 in Garnier and Holman (2019, p. 143)

Supply-side adaptive strategies	**Examples of adaptive strategy measures**	**Reason**
Promotion of water infiltration and retention.	Change agricultural practices to gentler soil.	Reduces demand for irrigation
Diversification of supply sources.	Use several different water sources (smaller and larger).	Reduces stress on one single water resource.
	Reuse and/or recycle water.	
	Use treated brackish water or rainwater.	
	Desalination of seawater.	
Increase of water storage capacity.	Develop secure water storage capacity.	Securely stored water reduces uncertainty of water supply.
	Build reservoirs.	
Increase of water body and water infrastructure connectivity.	Implement technology monitoring and controlling water flow.	Improves recharge and discharge of water.
	Build connecting water infrastructure.	Possible to transport water from long distances.

Optimization and development of abstraction infrastructure.	Enhance existing wells or build new ones.	Optimizing existing infrastructure.

Table 3. Demand-side adaptive strategies summarized from Figure 2 in Garnier and Holman (2019, p. 143)

Demand-side adaptive strategies	**Examples of adaptive strategy measures**	**Reason**
Monitoring the consumption.	Install water meters.	Measures consumption.
		Gives data that could be used to develop regulations on consumption.
Regulating demand and consumption.	Restrict water consumption.	Reduces unnecessary use of water.
	Implement permits/licenses to use water.	Reduces stress on resources.
	Implement economic incentives and regulations (ex. Pricing, tariffs, quotas).	Pricing increases the value and helps reduce over-consumption.
	Increase awareness.	Raised awareness amongst consumers reduces over-consumption.
Water savings and water efficiency.	Use of water saving and efficiency technological solutions (e.g. products using less water, change irrigation systems, change crops to less water demanding crops).	Reduces water consumption.

Green et al. (2011) points out that some of these strategies are policy-driven whereas other approaches are fully technological solutions. This is something that Giordano (2009) also stated in his research. According to Giordano, technological solutions can create many opportunities to use water more efficiently and institutional solutions can help manage water resources in a sufficient way. He argues that solutions from both categorise are necessary and they need to be integrated with each other. If technological solutions make water use more efficient but also increase the use of water, they put even more stress on the water resources. Therefore, institutional solutions are necessary to implement together with technical solutions in order to prevent negative impacts from implemented adaptive measures. Within institutional solutions, Giordano categorized them into three approaches. The first is the collective approach in which actors and stakeholder cooperate and manage the resources together. The next is the instrumental approach which incorporates measures like regulations, licenses and pricing. The last approach deals with indirect measures that are mostly related to the energy and agricultural sectors. As was mentioned earlier, agricultural practices have a major impact on groundwater resources and better policy regulations need to be examined. Therefore, Garnier and Holman (2019) suggest that water resource management policies need to be integrated with policies in other sectors and open up the topic on a broader scale.

Collet, Ruelland, Estupina, Dezetter and Servat (2015) tested this approach through a scenario simulation from year 2021-2040 with the solution proposed to decrease water consumption by changing to crops demanding less water. There were some regions in Southern France where such a measure would be needed. However, the farmers were reluctant to change crops. Especially when it comes to vineyards, growers do not want to change crops that could affect the finished product. A further solution for reducing water consumption in the agricultural sector is to irrigate with recycled water. According to Collet et. al. it worked well in South Australia, a climate similar to that of the Mediterranean region.

One technological solution could be seawater desalination. This demands highly developed treatment plants that can handle such a complex and complicated process. Countries in the Middle Eastern region do not have enough groundwater sources due to the total dissolved solids (TDS) and therefore, most of the water used in homes, in the agricultural- and industrial sector come from desalinated seawater. In the United Arab Emirates, approximately 98% of the domestic use comes from desalinated water. This region has rapidly developed technologies to desalinate water in order to meet the demand for a growing population and to manage water

scarcity. For this reason, desalination of seawater is a good solution. However, in a long-term perspective this is not a sustainable solution. These factors have not been considered before and can have large environmental impacts. First, waste left from the desalination process, mostly consisting of inorganic salt and chemicals added during the treatment process, is often disposed back into the sea. If not carefully disposed in a proper way, it risks polluting nearby groundwater resources and can also impact the composition of soil and change the water cycle. Secondly, desalination means high production and maintenance costs of treatment plants. (Mohamed, Maraqa and Al Handaly, 2005) High costs in production usually result in higher prices of the commodity. Consequently, the price of water will increase which in the future will affect the price of food as food production is dependent on irrigation. Third, this method requires a lot of energy. This energy usually comes from fossil fuels resulting in greenhouse gas emissions and is seen as costly both economically and environmentally. (Quist-Jensen, Macedonio and Driolo, 2015) How high the cost is depends on the salinity. Water with high salinity demands higher energy consumption since the osmotic pressure needs to be overcome in order to force the water to detach from the salt. For example, surface water treatment needs approximately 0,6kWh/m3 whilst the most commonly used Seawater Reverse Osmosis (SWRO) desalination technology needs around 3kWh/m3. (Caldera, Bogdanov and Breyer, 2016; Caldera and Breyer, 2017; Caldera, Bogdanov and Breyer, 2018)

One way to reduce the environmental impact is to change the energy source to renewables. When the increased demand of desalinated seawater was estimated together with a comparison of the energy consumption from fossil fuels and renewable energies, it was found that SWRO treatment plants running on renewable energy could be priced competitively in the near future with SWRO treatment plants running on fossil fuels. It was estimated that the cost of water running on solar- and wind power would be around 1.0euros/m3 - 4.5euros/m3 where the most common cost was between 1.0 - 2.0euros/m3 and the cost of water running on fossil fuels is today 0.6euros/m3 - 1.9euros/m3. (Caldera et al., 2016; Calder & Breyer, 2017; Calder et al., 2018) However, as of today, renewable energy is not seen as reliable enough. Furthermore, for agricultural irrigation, the quality of this water source might not be good for the plants, crops and soil. Therefore, one needs to consider what crops can be irrigated by this type of water. (Quist-Jensen et al., 2015) Another way to minimize the environmental impacts is for water managers to reduce the disposal of the waste product back into the sea. Mohamed et al. (2005) also proposed the need for better regulated frameworks and policies that can improve the management of water products. Furthermore, new technologies are constantly developed and

Saeed et al. examined (2015) a microbial desalination cell technology where it is being incorporated into a wastewater treatment plant and generates energy to a desalination system. It is less energy consuming, reduces financial costs and can become a future tool. Advancements like this are important for future adaptation and it is expected that desalination of seawater will become a necessary strategy for European countries, especially in the Eastern Mediterranean region. Countries like Spain, Cyprus and Malta have already begun to use such methods to provide water in scarce regions. (Garnier and Holman, 2019) Similar results were found by Kumar, Del Vasto-Terrientes, Valls and Schuhmacher (2016). They looked at water imbalances between supply and demand in Spain, focusing on domestic, industrial and agricultural use. It showed that desalination and water recycling were the best alternatives for short and long-term planning. They specifically found the approach of desalination interesting since it is becoming more attractive in the Mediterranean region. The city of Barcelona is, for example, receiving almost a quarter of its water from desalinated water. However, Kumar et al. pointed out that water resource management is a complicated problem and there is no single best solution.

2.3 Adaptive strategies - implementation in reality

Most literature on water resource management and adaptive strategies touch upon how climate change will impact water resources and gives suggestions of potential adaptive strategies that are perceived as good for implementation in the future. However, not much literature has assessed the actual outcome of implemented adaptive strategies. Here one can see a research gap. A research study conducted by Charlton and Arnell, published in 2011, assessed water resource management plans on water resources in England. They looked at the balance between supply and demand of water resources and how they could be sustainable for the future. One such finding was water reservoirs. Both in Portsmouth and Bristol they saw that reservoirs had a positive impact on climate change adaptation. It was also encouraged as an adaptive measure to store water during the winter to use during the summer season when pressure on water resources got higher. Another measure taken by the Wessex community was to integrate the water supplies to reduce pressure on single resources. Due to a growing population and increased demand for water, Wessex acknowledged that other water resources would have been necessary if this integration measure would not have worked.

The research gap is still evident but there are some recent studies that have looked into the assessment of adaptive water management strategies from other perspectives. One such study was conducted by Schoeman, Allan and Finlayson (2019) using a river basin in Australia as a case study. They saw the importance of how different understandings of adaptive management can influence the learning process amongst policymakers and water managers. Schoeman et al. found that transformative adaptive management came with increased knowledge and through a process of learning while doing. However, the result showed that the understanding and practice of the concept alternated widely and therefore the effectiveness of the learning process varied between different actors. Further, there was another study published by Martinez-Alvarez, Garcia-Bastida, Martin-Gorris, and Soto-Garcia (2014). They explored the impact of adaptive management of irrigation farms in south east Spain. Due to water scarcity, farmers were forced to use other methods or use brackish or desalinated water for irrigation purposes.

Charlton and Arnell (2011) also identified that water managers seemed to rely more on supply responsive strategies since demand response strategies are more difficult to control. In this case they were referring to the uncertainty of monitoring measures and individual's willingness to reduce their demand. If demand strategies failed, the supply would not be enough and therefore, managers wanted to reduce the uncertainty by focusing on supply side measures. Even though there were several adaptive strategies that communities in England supported, they wished for better policies and methods that could help in guiding the implementation of better strategies in practice. In Foster and Chilton´s research (2003) they saw the same desire. Many regions want governmental agencies to take responsibility and argues that what needs to be implemented are stabile institutional frameworks, investment in new technology that manages water more efficiently, and economic incentives that reduces the use of water.

In a study conducted by Brown, Mahat and Ramirez (2019) they looked at the water shortage in the United States and how adaptive strategies can be used in the future to overcome this problem through a simulation approach. Their simulated response focused on how to reduce the use of water. They saw the potential problem of climate change impacting water supply negatively and how it creates an imbalance with increasing demand due to a growing population. Compared to Charlton and Arnell (2011), Brown et al. (2019) instead found that the use of reservoirs would not be enough to reduce the pressure on water resources and it was therefore not an attractive approach for water managers in the future. Considering the large size of the country and that each region will experience different effects of climate change,

measures need to be closely evaluated to enhance positive effects of the performance. Brown et. al. found that the use of water in the agricultural and industrial sector needs to be heavily reduced and suggested that farmers should change to less water demanding crops. The difference between Charlton and Arnell and Brown et al. is that they found one of the side-responses better than the other. As mentioned, water managers in England seemed to focus more on supply-side responses whilst demand-side responses in the United States would be better. The decision of which policies to implement depends on the evolvement of social and ecological systems. (Giupponi et al., 2018) It is therefore important to analyse and understand each region´s water resource capacity in order to implement adaptive strategies that work specifically for them.

To build further on the discussion of adaptive strategies and its implementation, it seems that the actual problem is related to costs more than the performance of the strategies. In a case brought up by Green et al. (2011) that focused on California, they found that the region would be able to adapt to climate change through above suggested strategies, yet the costs to implement the strategies would be too high. The state would have to redistribute and change their ways to supply water and install new technology which would entail high financial costs.

Cooperation between actors and stakeholder seems to be an essential component for a sustainable management of water resources. Esteban and Dinar (2012) considered how groundwater management could be enhanced through cooperation amongst users with environmental externalities. Specifically, they looked at water extraction from aquifers and how it impacted the water level of other aquifers nearby and how decisions of groundwater use affected ecosystems in that area. Esteban and Dinar did so through a game theory approach. Their results showed that cooperation is always a better option for farmers for a sustainable water resource usage and when considering the impact on ecosystems. When farmers saw the impact of their decisions on the groundwater resources and how it affected ecosystems, they were more prone to cooperation. However, they found that the incentive to cooperate decreased when the environmental degradation kept increasing. What they could see was that it had to do with stability. The farmers had the initial incentive to cooperate since the environment was still stable, but if environmental degradation kept increasing, their will to cooperate decreased. Esteban and Dinar highlight that cooperation is an important policy instrument. Developed countries have, in most cases, a well implemented water management system that helps protect valuable resources and have good legislative tools. A major problem identified is the lack of

knowledge amongst users in a community. By increasing user's knowledge about resource capacity and potential effects from overexploitation and bad management, groundwater resources can be better sustained. If the government implements better controlling measures like taxes, subsidies or technological tools that help users, it could help promote more cooperation. Lastly, Esteban and Dinar conclude that dividing the aquifers into sub-aquifers, where the users clearly see the physical distinguishments of the resources would help improve the above suggestions.

To conclude this chapter, it seems possible, emphasized by many researchers, to protect water resources from climate change, but that it depends on many factors. There is no single solution and it all depends on the resource system and the regions socio-economic situation. Sustaining water will only be possible with the involvement of all stakeholders reaching out to individuals and communities on a local and regional level and then towards the government for the need of good policy implementations.

3. Theoretical framework

3.1 Resilience and Adaptive Management (AM)

The concepts of Resilience and Adaptive Management (AM) took form after it was identified that ecosystems are not having one equilibrium state and develop constantly over time. It was found that systems respond to external effects and are therefore not developing in a constant way but rather have several equilibriums that depend on externalities. Therefore, it became interested in looking at the behaviour of systems and their preservation response. The equilibrium state stays as long as no external interference is made, but with the interference of human activity it became important to view how the equilibrium state shifted. (Holling, 1973)

With external changes, the ecosystem adapts and acts with it to be persistent and reach its stable state. However, if the external effects are too great, the system's conditions will change. One could see that ecosystems fight to withstand to a certain point and when that point is reached, the system devolves into a new state. From this, it was established that ecosystems are unstable and unpredictable and so the behaviour of ecological systems was defined according to resilience and stability. (Holling, 1973) Resilience is defined as "… the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and still persist." (Holling, 1973, p.17) Stability is defined as the ability of a system to return to the equilibrium state after some disturbance. With these definitions, it was further established that systems can be resilient but with low stability if they managed to persist change, but still have high fluctuation. Holling (1973) concludes that management approaches to resilience need to be susceptible and that we need to understand that future events are unexpected.

The idea of being open to the unexpected, and more so, uncertainty in a management approach is widely discussed by Carl Walters (1986). He found that resource management should be seen as an adaptive process with learning and understanding that leads to reduced uncertainty. With the shifted viewpoint of ecosystems resilience and stability, more research on ecosystem´s limitations were conducted. From this, several theories emerged and more pressure on governmental authorities led to increased managerial efforts of important resources.

The problem usually encountered when policy-makers and resource managers try to make decisions is that uncertainty of outcomes leads to almost no action. Instead of this leading to inadequate management, Walters (1986) saw that risks in adaptive management can lead to more understanding and learning about a resource system. Furthermore, with better understanding comes less uncertainty. Walters points out in his research that adaptive management is an iterative process and that policy-makers and managers should not be afraid of dealing with uncertainty. As it usually is, policy makers and managers often want to calculate and know all outcomes and risks before making a decision and before implementation. This often leads to poor action. If adaptive management is dealt with in the right way it leads to learning, understanding and further development of future steps. Through such a process, learning the impacts of one's adaptive strategies can be understood and lead to the development of new policies, tools and measures.

Walters (1986) also encouraged continuous development and use of predictive models. He is not advocating a single best model that calculates the best fit option. Models are merely predictive and cannot, when dealing with resource management, decide what is the best optional solution to a fixed problem. Instead, models should be used to analyse alternative options with different responses in order to understand systems more fully. In this way, an understanding is created of short-term and long-term responses and gives policy-makers and resource managers a way to act when needed which is referred to as active adaptation. The opposite is passive adaptation and takes place when policy-makers and managers rely on one single prediction with one best solution until something else has been proven. Difficulties with such an approach are that it is difficult for managers to know if and when their strategy does not work. Furthermore, Walters argues that adaptive management needs to be based on simple models. This is because complex models become more difficult to analyse and harder to estimate what parameters the outcomes depend on. By having an iterative process of management, the understanding of system behaviour increases, and one can benefit from change and can reduce uncertainties. Walters also points out that this is not the same as a trial-and-error approach, but is moreover a feedback approach.

Walters (1986) found that with conventional management, one often seeks to build predictions around a detailed understanding, searching for the best action that usually emphasizes short-term goals. With adaptive management one seeks to find several possibilities, to accept the existence of more alternative actions, assess future observations and aims for long-term

objectives. From this, the concept of adaptive management is seen as an approach for improving resource management that comes through learning from management outcomes and then adapting to what has been learned and understood.

3.2 Operational definition of Adaptive Management

Since Walters (1986) study, the concept of adaptive management has become a broadly discussed approach amongst decision-makers when facing uncertainty. However, Williams and Brown (2013) acknowledge its limitations towards success in reality even though it is still an evolving concept. Therefore, Williams and Brown presented an operational framework for adaptive management in a decision-making environment and further pointed out challenges and opportunities with using the concept in practice.

Williams and Brown´s (2013) adaptive management framework is divided into two parts with a deliberative phase and an iterative phase. In the first phase, the deliberative, important elements of the decision-making process are developed. This process includes 1) stakeholder engagement, 2) identification of objectives, 3) recognition of management options, 4) potential consequences of the management options, and lastly 5) instalment of monitoring systems. Williams and Brown put particular emphasize on the need of stakeholder engagement. If stakeholders refuse to agree on the above-mentioned elements decision-makers and resource managers risk the project to be stalled. Identification of objectives is necessary to measure the effects that different management actions have and the performance of these management strategies. Management alternatives are crucial for the process of making decisions, learning and adapting. Further, models are used to predict potential consequences of the alternative management strategies. The instalment of monitoring systems is important to knowing which ecological elements to monitor and how.

This leads into the iterative phase where the elements in the deliberative phase are put into a continuous process of decision-making and learning. When a decision has been taken, it is followed up through monitoring, which gives information on how decisions affected the resource. The last step of the iterative phase assessment is based on the data provided from the monitoring. In the assessment step, the performance of the decision is identified and evaluated. Knowledge for improving management actions is learned from assessing and comparing the

results generated from the models with the data of the actual response. The process of adaptive management can be described as a cycle (see figure 1.).

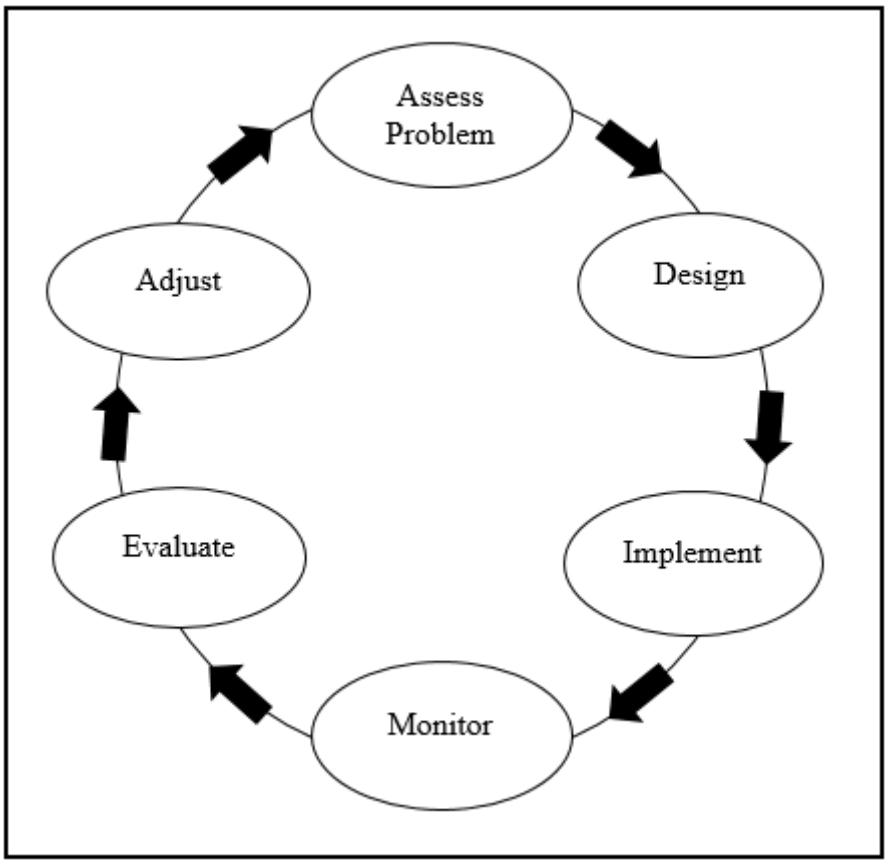

Figure 1. Figure modified from figure 3 in Williams and Brown (2013, p. 468).

Williams and Brown (2013) do specify difficulties with using adaptive management and mention climate change as one of them. Since climate change can cause unpredicted weather events, it is difficult to follow every step of the adaptive process. With new threats, the process starts over. Another difficulty with adaptive management is time-consuming steps like monitoring. This step requires more time to get accurate data to make a good decision. Further, organisations may find it difficult to transform a former behaviour into a way that is more collaborative and flexible.

One way to solve the above-mentioned problems is to see adaptive management not just as a recurrent process, but "as an ongoing process of planning and learning." (Williams and Brown, 2013, p. 475)

3.3 SWOT analysis

To establish the challenges that Swedish municipalities face with water resource management and adaptive strategies, a SWOT analysis will be used as an analytical tool. A SWOT analysis first appeared in Business Management as a simplistic tool used to identify factors important for a business or an organization to achieve its objectives. SWOT stands for Strengths, Weaknesses, Opportunities and Threats. Strengths and Weaknesses are internal factors which exist within businesses. Opportunities and Threats are factors existing outside of the business and externally can affect the achievement of its objectives if considered or not considered properly. If a business is fully aware of factors working in these four categorise, it contributes to knowing what strategies to implement to reach the objectives set by the management. (Kotler and Keller, 2016, p. 71) Even though the analytical tool was first set out to be used in business management, it has spread to be used in other fields including environmental science and resource management. (Metzger, Putt del Pino, Prowitt, Goodward and Perera, 2012)

3.3.1 Internal factors - Strengths and Weaknesses

The internal factors will be analysed to better understand what strengths and weaknesses the municipalities have regarding their water resource management strategies. Strengths and weaknesses are internal elements that the company, or in this case the municipality, have control over. (Kotler and Keller, 2016, p. 71) Here, the focus is to see what strengths exist within the strategies that the municipality implemented and further see what they lack.

3.3.2 External factors - Opportunities and Threats

The external factors are important to analyse as they may affect the municipality's adaptive strategies. Opportunities and threats are external elements and things that the municipality cannot control. With external elements you can only take advantage of them or try to protect from them. (Kotler and Keller, 2016, p. 71)

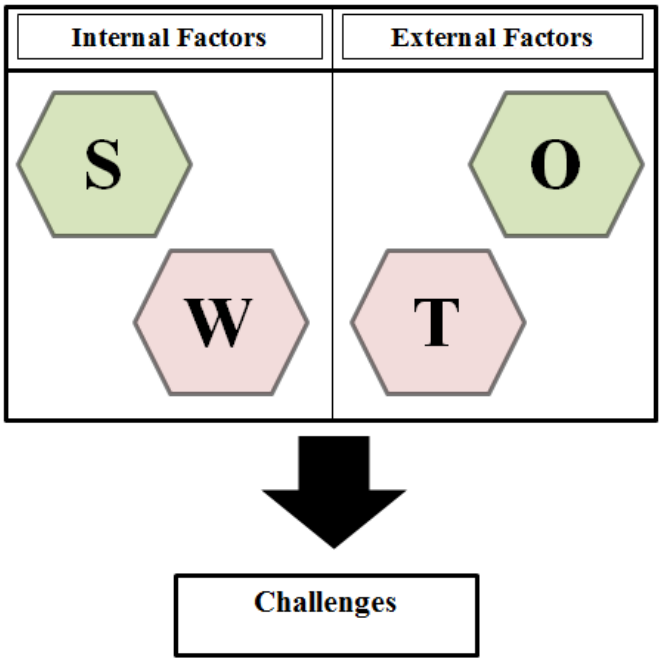

Figure 2. Figure of internal and external factor division of the SWOT-analysis elements leading to challenges.

The figure above illustrates how the identification of the four categories leads to the understanding what challenges that exist. When challenges have been established, it is easier to identify new insights that can be communicated to decision-makers.

4. Methodology

This thesis is based on a qualitative methodological approach and uses a descriptive case study as its research design. The purpose of this study is to contribute to the existing literature and get a deepened understanding of the challenges that the municipalities face in water resource management and adaptive strategies. A case study cannot generalize the result and be representative of a whole population. The aim of a case study is merely to provide new insights and understanding about something not yet well documented. (Bryman, 1989, p. 142-145)

4.1 Delimitations

The impacts of climate change and anthropogenic activity on water resources is becoming more acknowledged and the demand amongst researchers and water managers for better adaptive strategies are increasing. As seen in the literature review, most research has focused on countries and regions all over the world known for water scarcity. These regions include, for example, the Middle East, the Mediterranean region, Asia, and the United States. However, Sweden is a country that has, in recent years, experienced increased problems with water scarcity. Due to an increase in varying climate conditions with uncertain precipitation and extreme weather events like floods, droughts and dry seasons, Sweden needs a changed water resource management to reduce potential risk of climate change impact in the future. Little research exists on the implementation of adaptive strategies and water resource management in Sweden. Therefore, studying Sweden is of great interest. Furthermore, this thesis is delimited to investigate municipalities work since they are the responsible authority for water resource management on a local level and climate change impacts on water resources is seen as a regional and local problem.

4.2 Case selection

Since the aim is to study Swedish municipalities challenges regarding water resource management and implementation of adaptive strategies, all regions who have experienced water scarcity were considered. Sweden consist of 21 regions and is further divided into 290

municipalities. It was found that 15 out of 21 regions saw an increased risk of water shortage in 2019. In these regions, approximately 28 municipalities implemented an irrigation prohibition in the summer of 2019 and more than 40 municipalities requested their citizens to use less water and be more frugal. (Svenskt Vatten, 2019, my translation) Since 28 municipalities experienced a severe water scarcity during the summer months which led to the implementation of a water irrigation prohibition, these municipalities were further investigated. The case selected became Gotland municipality[1]. Gotland is a medium-large municipality that was one of the first municipalities to experience severe water shortage during the summer months. Their water management is also restricted due to their geographical location as it is an island. Further, it is a municipality with many, but small water sources which makes them dependent on all of them. Gotland has also paid close attention to the problem of water scarcity in their regional and municipal water resource management plans. From their water resource plans, one can see an extensive analysis of all their available and future potential water resources.

[1] Gotland is considered both a region and a municipality. Due to its location it was decided that Gotland is a municipality with certain extended power as a region. Therefore, it is called Gotland region but, in this thesis, it will be referred to as a municipality. (Lag (2010:630) om regionalt utvecklingsansvar. Retrieved at: http://www.notisum.se/rnp/sls/lag/20100630.htm)

Figure 3. Map over Sweden and Gotland. (Google, 2020a; Google, 2020b)

4.2.1 Gotland municipality

Gotland is an island located southeast of the mainland and it is the whole Gotland region that represents the municipality. In December 2018, the population living on Gotland was 59 249 and that year they had a population increase of approximately 650 people. (Region Gotland, 2019, my translation) During a 10-year period from 2018 – 2028, it is estimated that the population will have increased with 3 000 people. (Statisticon, 2018, my translation) Furthermore, Gotland is an attractive summer vacation destination, and in 2019, the number of visitors measured in "overlaying nights" increased by 2,4 % compared to 2018. (Tillväxtverket, 2019, my translation) Gotland municipality has a total area of 3 184 square kilometres and 30 square kilometres consist of water with sea water excluded. Most of the land consists of forests and farmland/agricultural land. (Regionfakta, 2019, my translation)

4. 3 Material and data collection

The empirical material consists of the municipality's Regional Water Supply plan and their Water and Waste plan. The second part of the material consists of a qualitative interview. Using both interviews and documents can contribute to the analysis and close a gap between for example official policy and what is done in practice. (Bryman, 1989, p. 124-125) The documents give a good understanding of the municipality's water sources, its actions and what challenges and opportunities exist with water resource management. The interview gave a more deepened discussion on the above-mentioned documents and an understanding of how the management process has developed and the complexity of their challenges. The Water and Waste plan includes drinking water, drainage, stormwater and wastewater whilst the Water Supply plan has been developed to highlight the municipality's water resources, effects of climate change and the municipality's need of improvement regarding water resource management. These two plans also highlight the municipality's actions and strategies.

The interview was semi structured and conducted over phone as the interviewer and the interviewee were in different countries. An interview guide was developed with questions under different themes (see appendix 2). The advantage of a semi structured interview is that the interview is followed by a schedule of different themes and not by precise questions. This way, potential questions can be asked during the interview if the interviewee takes up something of interest. (Bryman, 1989, p. 124-125) The interview guide was developed through the material of the municipality's Water Supply plan and Water and Waste plan. The municipal Water Supply plan and Water and Waste plan have both been developed during 2018. From an ethical perspective, the interviewee was asked if the interview could be recorded, informed that she is allowed to stop the interview at any time, and that she could be anonymous. The respondent approved of the interview being recorded and that her name could be used. Furthermore, the interview guide was sent beforehand to the respondent for her to be able to prepare and answer the questions as well as possible. This can have an impact on the result. However, this research is a descriptive analysis with no hidden agenda of the study. It was considered better for the respondent to prepare so she could provide good material for the purpose of this study. After the interview was held, the material was transcribed into text form (see appendix 3) to make it easier to analyse.

The selection of the interviewee was conducted through an initial contact with the municipality's customer service. After informing about the purpose of the study, the employee

gave me the contact information for the head of the Water and Waste department unit. The interviewee was contacted via email and agreed to take part of the study after which an interview via phone was settled.

Table 4. Material used for the result.[2]

Documents	**Interviewee**
Regional Water Supply plan (2018)	Susanne Pettersson - Head of the Water and Waste department unit
Water and Waste plan 2018-2030 (2018)	

The processing of the data was conducted through the concepts from the operational definition of adaptive management and the four categories of the SWOT analysis. These concepts were used to analyse the material to answer the research questions and the aim of this study. Through a review of such extensive material, the frame of the thesis and with the time limitation of the study, there is always a risk of missing something in the result. However, the material has been thoroughly handled and a good sample of the material has been selected. Not everything can be presented in the result but if something in the material has not been accounted for it is of minor importance to the actual result.

[2] The material was in Swedish and have been translated into English by the author.

5. Result

5.1 Gotland's water resources

Gotland has 27 water resources used within the public network. Out of these, 20 are groundwater resources, 2 are desalination plants, and the rest consist of surface water resources. The reason for using these many resources is because they are relatively small, and therefore, all of them are important for supplying water to the island's citizens within the municipal water network. If compared to the rest of Sweden, Gotland's water resources consist of 65 % groundwater resources, whilst Sweden in general consists of 40 % groundwater resources. Only 65 % of the citizens on Gotland are connected to the municipality's water supply network. Furthermore, it was estimated in 2015 that almost 21 million cubic meters of water/year was used, and only 3,8 million cubic meters of water/year was used in the public network. Out of the 3,8 million cubic meters produced by the municipality, 2,4 million cubic meters/year comes from groundwater sources (65 %), and 1,4 million comes from surface water sources (35 %). Most of the surface water comes from swamps that are all located in the northern part, and from a few lakes around Lojsta area. (Eklund, 2018)

5.2 Threats

5.2.1 Geographical location and capacity

Several threats have been identified. One of them being the municipality´s geographical location. Gotland is an island (Eklund, 2018; Region Gotland, 2018) consisting of limestone (Pettersson, 2019) which has an effect on the municipality´s water supply. (Eklund, 2018; Region Gotland, 2018) Due to this, the island always had issues with water shortage, and a hard time storing water. (Pettersson, 2019) Gotland has many groundwater resources, but they are small in size. This increases the threat of water shortage, leading to the use of any capable water sources. On top of that, they have no connecting municipalities. To improve and enhance their water supply, they do not have the possibility to connect their water supply network to neighbouring municipalities, as municipalities on the mainland can. (Eklund, 2018, p. 5 and

31) Gotland is made up of many small areas that all have different grids and networks, making makes water supply management more difficult. The municipality is trying to interconnect them to reduce inconvenience. This requires investigation and analysis in order to reach the best approach. (Pettersson, 2019) An example of an ongoing attempt is the one to connect the southwestern area Kvarnåkershamn to the capital city of Visby. This is only a temporary solution as Kvarnåkershamn will support the southern part of the island in the future. Therefore, Visby needs to find other water sources to provide drinking water. (Region Gotland, 2018, p. 44-45) Other small areas are already experiencing water shortage and have no way of enhancing their supply from other areas of the island. (Region Gotland, 2018)

5.2.2 Summer variations

Another threat to Gotland's water supply is the variation of water demand during different seasons. Most of the region is highly affected by tourism in the summer, causing a higher demand on the water supply than during the rest of the year. (Eklund, 2018; Region Gotland, 2018) The production of drinking water can be lower than the demand during this period, causing a need to move water from one treatment plant to another. Most of the tourism is located along the coast, and areas with the highest problem. This affects not only the need for drinking water, but also the need for water within agriculture, different industries and companies. According to Susanne Pettersson, this has led to a "sizing" of water between summer and winter time. (Pettersson, 2019)

> We always need to consider a proper sizing and always expect that there might be an exploitation around the coast line where people want to live but where there is absolutely no water, and if there is, it can contain salt. (Pettersson, 2019)

5.2.3 Quality

Some quality related threats are common to most municipalities in Sweden, like microorganisms and bacteria. Gotland also struggles with elevated levels of the element Boron due to its geographical location. The element can be found in bedrock, often found on the island. Other quality related issues are elevated levels of chloride. (Eklund, 2018, p. 19-22) However, a major threat to the quality of the water comes due to water shortage. Most of Gotland's water sources are groundwater and when the levels decrease, a contamination of salt

is common. If salt contaminates the water sources, it becomes unusable as drinking water. The threat becomes most relevant during the summer when water shortage is most obvious, and at the same time when the demand of water increases. (Eklund, 2018; Region Gotland, 2018) An example of such an area is Tofta, south of Visby, which is highly affected during high season. (Region Gotland, 2018, p. 65-66) Quality issues also arise for Gotland due to some water facilities only being used during short periods of the year. When used during the summer months, and almost standing still during the rest of the year, bacteria and microorganisms contaminate the water. Poor water quality can lead to negative health effects and poor taste. (Eklund, 2018, p. 33)

5.2.4 Climate change

Climate change is a growing concern to a long-term sustainable water resource management. (Eklund, 2018; Region Gotland, 2018) It is predicted that Gotland will experience higher temperatures, increased precipitation during winter, longer periods of droughts, sea level rise, and longer vegetation periods. All these issues threaten the water supply in different ways, and Gotland is highly affected since they already experience problems with water shortage. (Eklund, 2018, p. 42)

> For our part it has been apparent since the year 2015. In October 2015, I think we got 4 - 5-millimetre rain, which was almost nothing and then we already had a few years with dry summers. It was then in the autumn of 2015 that we need to get 1 - 2 meter of extra precipitation to be able to make it for year 2016. (Pettersson, 2019)

With longer periods of drought, the water levels will decrease and affect the water supply. (Eklund, 2018, p. 44) If followed by increased precipitation, the water will not be easily absorbed as the soil is too hard. Instead, water is led away and out to the Baltic Sea. Further, heavy rain can lead to the contamination of bacteria and microorganisms as they are washed in to the water sources. (Eklund, 2018, p. 44-46) Increased temperature can lead to eutrophication and algal blooming in surface water, producing less favourable conditions, leading to poor quality. (Region Gotland, 2018, p. 15) Warmer climate can also lead to longer vegetation periods. This is a threat as more water is necessary to irrigate plants that will grow for a longer period. In this case, it is not just the need to provide citizens with drinking water, but to make

sure the agricultural sector and the food industry´s water demand is met. Here, Gotland mentions that the choice of crops will play an essential role in the future. Further, municipal green areas like parks and soccer fields will also need more irrigation due to longer vegetation periods. (Eklund, 2018, p. 41) One positive feature seen by the Gotland municipality is a few industries attempt to decrease their water demand. However, Gotland municipality is worried that new businesses will emerge. In the Water Supply plan, Gotland municipality also mentions that longer vegetation periods increase the risk of contamination of fertilizers and pesticides. (Eklund, 2018, p. 41 and 45)

Climate change can lead to sea level rise, causing salt water intrusion. Further, with these climate changes predicted, there is a risk that the groundwater formation and the groundwater flow will change. This can cause issues when extracting water and therefore new methods need to be considered. Further, the change of flow can cause contaminated water to flow towards usable water sources. (Eklund, 2018; Region Gotland, 2018)

5.2.5 Contamination and pollution

Agricultural activities can cause fertilizers and pesticides to leak into water sources. As already mentioned, intrusion of saltwater can occur with low levels of groundwater. Changing water flow and increased precipitation can also cause contamination of bacteria and microorganisms. (Eklund, 2018, p. 54 and 45) In the Water and Waste plan, Gotland indicates that summer guests are bathing in a limestone quarry used as a water source. This water gets contaminated by soap and creams used by the guests. (Region Gotland, 2018, p. 33) There is also a threat of an increased responsibility in supplying more residents with drinking water. Areas defined as “planning areas” can, in the future, be entitled to the public network. This entails that Gotland municipality will be responsible in providing residents in these defined areas with water. (Region Gotland, 2018, p. 9, 14 and 25)

5.2.6 Conflicting interests

Another threat to the municipality´s water supply is the conflicting interests between different sectors. (Eklund, 2018; Region Gotland, 2018) The conflicting areas are, for example, domestic, agriculture, food industry and limestone industry. This becomes especially sensitive during dry months. The municipality is responsible for delivering drinking water to

the citizens, and the food industry is thus in need of a stable supply of water to irrigate crops for a stable and good harvest. In 2018, during a dry period, the food industry was heavily affected, causing a significant loss of that year's harvest. Sweden had also adopted a strategy to increase food production, leading to increased irrigation. However, no irrigation is allowed with groundwater. If so, an appeal must be made that is thoroughly reviewed. Further, it is estimated, by a report made by the Swedish Board of Agriculture, that the need for irrigation water is 7,5 million m3/year and the availability of irrigation water amounts up to 5 million m3/year. (Eklund, 2018, p. 33-35) With increasing issues of water supply, the municipality is worried about industries and farms interest in being connected to the public network. As temperatures increase, a need for more water for animal care is predicted. This is, however, nothing the municipality is obligated to do. They are only obligated to supply water for domestic use, which is specified in the Law of Public Water Services. Nevertheless, laws and regulations may change in the future and is therefore considered a concern. (Eklund, 2018, p. 37) It is specified that when different sectors are in conflict with each other, drinking water shall be prioritised by the municipality. (Region Gotland, 2018, p. 17)

The municipality can decide about sourcing a new water resource or to enhance an already existing one. However, these decisions can become problematic if the water resources are already prioritized for natural reserves to preserve ecosystems and natural habitats. (Eklund, 2018, p. 36-37; Region Gotland, 2018, p. 17) "When it comes to nature conservation, we have definitely started to feel a competition". (Pettersson, 2019) There are already plans to implement natural reserves around water sources used by the municipality. The county's government has given indications about reconsidering their water property in these areas. (Pettersson, 2019)

All of the above-mentioned conflicting interests are thought to increase when the formation of groundwater decreases, and the groundwater levels start to sink. The groundwater sources are already under pressure, and therefore, this is seen as a major threat. (Eklund, 2018; Region Gotland, 2018)

5.2.7 Water shortage and build-up areas

The island is in an expansive phase, and it is predicted that settlements will increase with 20% from 2015 – 2045. (Eklund, 2018, p. 39) Water shortage threatens the expansion and

development of cities and towns. There is a housing shortage on the island, especially around Visby and the southern part of the island. Since there is not enough water to supply more residents in these areas, expansion cannot happen. Water and waste supply need to be developed in these areas first. Tourism is also thought to increase. (Region Gotland, 2018) Coastal areas are attractive for their location, and even though these areas are sparsely built and are responsible for their own water supply, it still increases the demand for water that does not exist. (Eklund, 2018) Plans of expanding and building a new cruise ship dock are under development and the only solution to supply water to this dock is to connect it to the public water and waste network. (Region Gotland, 2018, p. 45)

5.3 Weaknesses

5.3.1 Technical difficulties and renovations

Some of the water treatment plants and facilities on the island are aging and need to be restored or rebuilt. Their capacity is not enough and cannot supply the citizens with the water they need. (Region Gotland, 2018) It is also known that water is lost in the public water network. This is due to leakage of the pipes and maintenance work performed on facilities and pipes. Gotland's loss of public water is estimated to 10,5 %, and it is smaller than the rest of Sweden with 24 % loss of public water. As they already suffer from severe water shortage, the municipality has performed work to reduce the loss of water in the public network. This is, however, work that needs to be continued. (Eklund, 2018, p. 33) Further, the knowledge about the facilities and the public water network is lacking which makes it difficult to estimate where actions are needed. There is also a lack of knowledge regarding the capacity of distributing water to citizens in certain regions. Areas that suffered from poorly delivered water are known, as the issues have been analysed. In other regions where such an issue has not yet appeared, the full capacity of the public water supply network is still unknown. The southern part of Gotland is a region where the capacity is known as it suffers from water shortage. (Region Gotland, 2018, p. 13) Poor quality of water threatens the pace of water production as the technic have difficulties dealing with this water. (Region Gotland, 2018)

5.3.2 Lack of water protection

Most of Gotland's water sources lack sufficient protection and water protection areas are a necessary measure to sustain the water supply in the future. (Eklund, 2018; Region Gotland, 2018) A major threat to poor water protection is contamination and pollution, if the source is located in an area with the risk of substances flowing down. (Eklund, 2018, p. 45-46) Most sources also lack the permission to extract water and are an uncertain asset if it is decided that extraction is not allowed. (Region Gotland, 2018, p. 11) However, (a strength is that) the municipality knows which sources need protection. (Region Gotland, 2018) Gotland municipality does say that a revision for how to introduce water protection will be necessary in the near future. In the Regional Water Supply plan (Eklund, 2018), it is mentioned that the work for implementing water protection is on a large-scale. They have identified a few sources that might require priority, like Slite and Stånga. How they are supposed to prioritise protection for water sources will depend on several factors including size, vulnerability and risk. (Eklund, 2018, p. 57)

According to Susanne Pettersson (2019), Gotland municipality does provide most citizens with drinking water from approved protected areas.

> ...when one talks about water protection areas they always refer to how many water sources that has water protection areas so then it is the amount that counts. Considering that then Gotland is doing equally bad as the rest of Sweden on approximately 40 % but if one looks at how many of our subscribers that gets water from a water source with a modern water protection area, then we are at 95 %. (Pettersson, 2019)

5.3.3 No emergency water management plan

Gotland lacks a water plan in case of emergencies. For major disturbances, there is no plan for how to secure the safe delivery of water for citizens and important businesses on the island. There is a plan for short disturbances but in the case of longer periods concerning important water sources out of use is not yet outlined. (Eklund, 2018, p. 31)

> Let's say we would end up in a time of war or that we get cut off from the mainland for several days, then we will not be able to use the emergency power

> particularly long. That we could do for max one day but after that we do not have enough diesel and that is also something we have incorporated into our risk analysis. (Pettersson, 2019)

With this argument, Pettersson wants to note that even with the use of big water treatment plants, smaller water sources will stay in use for their emergency plan as they demand less energy. (Pettersson, 2019)

5.3.4 Limited resources

Gotland municipality has identified a limitation of resources regarding budgets and co-workers. With limited resources, it is difficult to fix all issues related to their water supply management. Actions will need to be prioritised and that means both geographically and timely. (Region Gotland, 2018, p. 15) In reaction to it, the municipality has started to increase their personnel. In the fall of 2019, they hired a coordinator in their water and waste department to deal with climate change. (Pettersson, 2019)

5.3.5 Lack of knowledge

There is a knowledge gap in several aspects. First, there is varying knowledge about the amount of water in their water sources. More knowledge is necessary regarding the natural water availability, water treatment plants and wells. This is necessary to secure a sustainable water supply for the future. Therefore, knowledge about factors restricting the water supply is required. There are also plans to terminate the use of certain water sources and their water treatment plants, in order to connect areas dependent on those to other areas with a water supply network. Knowledge about the capacity and how to act with this is lacking. (Region Gotland, 2018) One such example is the decision to terminate the water network in Roma and connect the area to Visby's or Tofta's network. However, lack of knowledge regarding the future capacity keeps the decision in a stall. There are also resources on the northern part of the island that need to be used in a higher extent. Research for how to do this and its capacity is, therefore, also important. (Region Gotland, 2018, p. 57)

Further, Gotland municipality mentions the need to understand more about the irrigation of crops. The water used for irrigation in the food industry needs to have a certain quality. The

municipality has defined directions for what kind of quality. However, the type of water quality might differ depending on the type of crops. This is interesting from a future perspective. (Eklund, 2018, p. 34-35) Another gap of knowledge applies to water withdrawal. As Gotland suffers from water shortage and other limitations to supply water in a sustainable way, this is very important. The municipality has specified that it is of interest to know more about the localisation, the amount, and patterns of withdrawals to be able to monitor them and create a balance to not over-exploit resources. In addition, they specify an interest knowing more about industries water usage and their withdrawals. Even if these sectors are responsible for their own water supply, conflicting interests can cause problems for the municipalities water supply management. (Eklund, 2018; Region Gotland, 2018) Moreover, as property owners are responsible for their own water supply, knowledge about private wells and other water sources are limited for the municipality. Some areas might not be able to provide themselves with good enough drinking water. Even if they are not connected to the public network, it is of interest for the municipality to identify them. (Region Gotland, 2018)

5.4 Strengths

5.4.1 Knowledge

Gotland municipality has a strong desire to increase their knowledge in areas where they lack information or understanding. This is expressed in the Regional Water Supply plan and Water and Waste plan, and in the interview with Susanne Pettersson. The municipality wants to be able to create a holistic perspective to reach a balanced water resource management. This way the municipality states they can balance between prioritised matters. Gotland expresses, for example, the need to understand population growth on the island to plan for future water supply scenarios with an increased demand for water. This way they would be able to implement action at the right time with a long-term sustainable perspective. (Eklund, 2018; Region Gotland, 2018)

Pettersson explains that the will to increase their awareness comes from the understanding that they, as a municipality, must solve their issues locally. (Eklund, 2018; Region Gotland, 2018) “From 2000 - 2015 we could not agree so instead we just hoped that the problem would solve itself or that someone else would come and solve it for us.” (Pettersson, 2019) Gotland was

one of the first municipalities to be affected by water shortage, and realised they needed to obtain information and knowledge on their own. Pettersson explains in the interview that they have spent a lot of resources to develop a long-term and sustainable water resource management system that considers climate change. Extensive risk analysis is something that helped the municipality to decrease the knowledge gap and a method they rely a lot on before performing actions. Further, the municipality received 2,5 million Swedish crowns from the government for investments in water and waste. One million of this is being used for the measuring instruments in wells to learn more about groundwater resources. (Pettersson, 2019) "So one can see larger awareness in our business and also that water is not an inexhaustible resource and that we need to take care of it and find a balance in our groundwater resources." (Pettersson, 2019)

5.4.2 Communication

Gotland municipality shows clarity in what they hope to achieve, and have discussions about other possible solutions in case their plan does not work out. The municipality has expressed a desire to use the water sources they already have by increasing the capacity or by finding new groundwater sources. If this is not possible they have discussed the need to use water infiltration where water will be treated through a brackish water plant and mixed with the water from their already available sources. (Eklund, 2018; Region Gotland, 2018)

Further, it is expressed by the municipality that they want to keep their documents and reports updated to provide useful material for the municipality's working groups. They specify that with executed actions, new conditions are created with another starting point than before. Therefore, the material needs to be updated with new information. (Eklund, 2018, p. 9-10) This is done at every year's budgetary meeting. (Region Gotland, 2018, p. 3) They also manifest that long-term sustainable solutions are a priority and should be flexible over time. The municipality wants to avoid solutions and actions that are created on a frequent basis. Such solutions would not support long-term sustainable water resource management, as solutions would be produced when a problem occurs. Gotland also states that planning in an organisation is changeable, and new developments, decisions, and actions need to be accounted for on a regular basis. (Eklund, 2018; Region Gotland, 2018)

The municipality also strives to avoid and remove actions that do not match their plans. What this means is that actions and plans are reviewed to create coherence. This applies to both their Water and Waste plan and Water Supply plan. (Eklund, 2018; Region Gotland, 2018) What has been proposed is to implement a working group to look over issues like this (Region Gotland, 2018, p. 19).

Gotland municipality has expressed a will to increase their communication with the inhabitants, businesses, visitors and other authorities. This will increase knowledge and understanding of water availability and water stress amongst all users. An advisory role for citizens and businesses has been suggested by the municipality to be created in order to manage this. This way, they can reduce the use of water amongst consumers. Further, they want to be able to support private water suppliers with information to help create better water management on the whole island. (Region Gotland, 2018) The water saving campaign mentioned by Pettersson in the interview, managed to save 20 % of the municipal water during the period of the campaign. However, they do not believe that this solution is permanent and, are therefore, considering other solutions to encourage water saving in the domestic sector by installing water use measures or monitoring stations in people's homes. (Eklund, 2018, p. 39)

Another strength in Gotland municipality's water resource management is their solution for areas with immense water shortage. Already during the 1980s, the municipality implemented takeaway stations for farmers. If they are without water during dry periods, they can buy water at the stations. This solution is first and foremost used for agricultural purposes, but can be used for domestic use if residents with private wells suffer from water shortage. (Eklund, 2018, p.32)

5.4.3 Creating opportunity

Gotland lacks a water reservoir. However, they are trying to create this in other ways. Pettersson informs that through investment in different water sources and their capacity they can develop and increase their reservoirs. Today, the water sources are pushed to the max, but with improvements in the water sources they can stay at a capacity of 60-70 %. Smaller sources would also still be used. This way the municipality can cover the need and still work up their reservoirs. Again, risk analysis is important to increase their understanding of where they can increase capacity and not. (Pettersson, 2019)

Gotland also started an attempt this year to use, what they call, limestone fat block water as a resource. This is something Pettersson expressed in the interview as another way of getting water into their grids as water resources are difficult to find on the island. (Pettersson, 2019)

5.5 Opportunities

5.5.1 Renovate, build up and increase capacity

The municipality will have the possibility to renovate or build up new and/or existing water treatment plants and facilities. This is mentioned as a weakness as there is not enough knowledge to what is the best option for different areas. However, if they get more knowledge and information, a decision about what to do would be easier. That would help the municipality to know which areas that can be connected with each other, and which areas are better with a local water supply. Water treatment plants and sources with low capacity could be terminated if these areas can be supplied through a connection with a bigger area. (Region Gotland, 2018) One such thought is to renovate or build up a new water treatment plant in Lärbro that can treat water from several different sources. This way, the municipality would be able to secure a more stable drinking water supply for the citizens. Further, this would mean that small nearby water treatment plants with low capacity can be terminated. (Region Gotland,2018, p. 30, 33 and 37) Similar solutions are being thought of in other areas. In the northern part of Gotland, it might not be possible to supply water from local water treatment plants and, therefore, water needs to be delivered from other areas. Investments in such solutions needs to be economically justifiable. It is especially important in this area as the water demand is predicted to increase five times from the demand today. Bästeträsk is located in the northern part and is the biggest lake on the island. This source supplies three areas (Fårösund, Fårö and Bunge). However, as mentioned previously as a weakness, this will need more investigation for future use to supply other areas of northern Gotland. (Region Gotland, 2018)

Capacity might also have to be improved through the infiltration of surface water to the groundwater assets. If they cannot increase the withdrawal from other sources in an area with an already full extraction according to its capacity, infiltration might be a necessary option.

This is something Gotland is not doing now, but other regions in Sweden are. An area identified on Gotland with this possibility is Kappelshamn. (Region Gotland, 2018, p. 29)

5.5.2 Technical solutions

Gotland municipality started to think about new technical solutions to help solve water shortage and have a more sustainable water supply management. (Eklund, 2018; Region Gotland, 2018) One such thing is to design and implement new technical solutions that can stand against seasonal variations. As the demand for water becomes high during summer compared to the rest of the year, a technique that can adapt to high variations of demand without affecting the capacity of quality of the water is necessary. This technical solution is not yet created within the municipality, but the discussion shows an openness to new ideas. (Region Gotland, 2018)

Gotland has already installed two desalination plants to supply water from the Baltic Sea. They are located in Herrvik, and the largest plant is located in Kvarnåkershamn and opened in 2019. (Eklund, 2018; Region Gotland, 2018) The decision to invest in desalination plants came from the fact that new groundwater sources could not be found. The desalination plant is higher in energy cost, but should not be compared to plants in southern Europe. The salt level in the Baltic Sea is lower. Further, the desalination technique is already used on two of their groundwater sources. They do it to treat water from pesticides and dioxins and Boron. To prevent the environmental impact, the municipality uses renewable energy and have installed solar panels on the desalination facilities. The energy used for the membranes in the plants comes from energy reusable technic which saves energy costs. (Pettersson, 2019) Water is supposed to be supplied from groundwater and surface water. However, if the water shortage becomes to considerable, water from the desalination plants will be used and mixed up to the water from the primary sources. There is also an idea amongst private water suppliers to use desalination technique to sustain a stable water supply. This is presumably not going to be implemented as maintenance would become too expensive. (Eklund, 2018, p. 25)

5.5.3 Water saving actions

Gotland also started to think about using water saving techniques. (Eklund, 2018, p. 39 and 65) It is an opportunity for the municipality to implement water saving actions to reduce the use of water amongst consumers. This solution is only temporary, until actions for how to improve

the capacity can be implemented. (Region Gotland, 2018, p. 29) Water irrigation prohibitions was first implemented in 2016 as it was the toughest year they had experienced. The prohibition is now introduced from the 1st of April each year. At this time the municipality also had to perform a depressurization. (Pettersson, 2019)

The municipality works a lot with behavioural change and used media to encourage people to be more frugal with water. Citizens were encouraged to take shorter showers and to fill up their washing machine and dishwasher. Gotland initiated a campaign with a short movie screened at the cinema and in schools. A competition on Instagram was released in order to reach the youth, and information was spread at different events. (Pettersson, 2019)

5.5.4 Cooperation

There are opportunities that include cooperation between the municipality and industries. One of these being already implemented is the cooperation with limestone quarries. Two limestone companies have already stressed a will for cooperation. It has been identified that a large amount of freshwater is led out to the Baltic Sea from limestone industries. This is a source that could be used to improve capacity in the municipal water supply network. The cooperation also shows that there are opportunities to find other sources of water. (Eklund, 2018; Region Gotland, 2018) Old quarries are further being used as water storage. (Eklund, 2018)

> They have a lot of opportunities to collect the water in the quarries that they have finished mining. So instead of pumping out the groundwater and the surface water we are now trying to make them pump it to these quarries, so we can take water from there in the summers. (Pettersson, 2019)

Additionally, cooperation between municipalities, regions and other countries is necessary. A lot can be learned from each other, and it opens for knowledge sharing. New ideas, solutions and actions could be discovered. (Pettersson, 2019)

5.5.5 New solutions

Gotland has established takeaway stations for individual use of water in areas with severe water shortage. (Region Gotland, 2018, p. 69) There is also the opportunity to use other crops that

demand less water and that could survive during longer periods of fall weather. Further, there are opportunities to change harvest routines to reduce the amount of water required. (Eklund, 2018, p. 41 and 47) It is under discussion that water led away by different industries should be investigated, in case it can be reused in some way. (Eklund, 2018, p. 35-36)

5.5.6 New decisions and regulations

So far, water shortage has been treated as a local issue, but with more municipalities and regions being affected, national attention has increased. It gives more support, energy and motivation for municipalities to solve local issues. The government appointed the Swedish Meteorological Hydrological Institute (SMHI) as responsible to create climate reports for each county. It has also pushed for regional Water Supply plans to be developed by every region. The government also distributes 45 million swedish crowns to municipalities who applies for funding. (Pettersson, 2019)

5.6 Actions

In their Water and Waste plan and Water Supply plan, the municipality has demonstrated actions they want to implement to improve their water resource management. These will be listed below for easier viewing. They are not listed in a prioritized order and the actions and strategies they want to perform do not all have a concrete plan on how to be implemented. (Eklund, 2018; Region Gotland, 2018; Pettersson, 2019)

Table 5. Summary of Gotland municipality's strategies and actions from the Water Supply plan, Water and Waste plan and the interview with Susanne Pettersson. (Eklund, 2018; Region Gotland, 2018; Pettersson, 2019)

Strategies and actions	**Explanation of the strategies and actions**
Review all projects.	To make sure they correspond to the Water and Waste Plans.

	To ensure a harmonic work.
Establish a communication plan for Water and Waste planning.	To establish a digital platform on the municipality's webpage.
	The platform is to communicate information to the ones depending on their services.
	A map displaying the progress of the development of Water and Waste services is a concrete example of what this communication plan will contain.
Create a working group within Water and Waste planning.	To conduct ongoing reviews of the plan, its strategies and actions so it stays coherent.
Establish an advisory role within Water and Waste.	The expectation with this role is to help stakeholders, like citizens, businesses and visitors, to be part of the development of Water and Waste plans.
	The role should be detached from the region's and municipality's responsibility as an authority.
Establish a management routine between administrations to help coordinate matters of Water and Waste supply.	This coordinated routine would be supported from authorities and actors like SGU, the county government, and the military defence.
Establish an investigation about the development of a new water treatment plant, or if investment should go to improving and renovating existing treating plants.	This investment is depending on what type of water sources found.

	In the case of increasing the water supply in Visby, this investment depends on if freshwater sources are found. If so, reflection about building a new treatment plant or expanding an existing one in Tingstäde and Visby is of importance.
Actions to improve and renew existing facilities when necessary.	
Establish a future investigation to improve the water supply network to resist climate change.	
Continue the cooperation with SGU and their examination of groundwater level changes, and how they are affected in relation to geology, topography and climate.	On Gotland, SGU have four measuring stations in use.
Continue the cooperation with the county government.	Ten measuring stations are implemented by the county government. These stations will measure the change of groundwater levels and provide SGU with additional data for their national project.
	Statistical values to make long-term prognosis can be used for a prognosis of how much water will be needed for the summer. It is useful to implement temporary prohibitions at the right time.
	Will help the municipality understand how water sources react to climate change.
Monitor drinking water resources.	This action is to secure resources from community planning and environmental hazards as the island is expanding. Makes it a priority to protect vulnerable water resources possible.

Develop an emergency Water Supply plan.	An emergency plan exist but consist of more technical solution, like where to provide water stations and which areas and sectors to prioritise.
Increase cooperation with other municipalities, regions and countries with similar issues to increase knowledge.	Include knowledge sharing about water supply for domestic, industrial and agricultural use, and for private water supply owners.
	Cooperation should help guide in creating solutions and concrete actions to secure a long-term sustainable water supply.
Establish water protection for vulnerable water resources, and initiate monitoring/supervision to make sure the protection is followed.	
Set up an investigation to explore local support of water and waste supply.	
Establish increased water supply to Fårö by the development of water sources and a water treatment plant, or expand the network from Fårösund.	
Initiate risk analysis for water sources and action plans for water protection.	
Investigate further possibility of freshwater withdrawal from Bästeträsk.	
Establish water protection areas and protection of water sources.	

Interconnect areas with low water supply capacity with areas of higher capacity.	
Implement water saving actions during vulnerable periods.	
Support private water supply owners with informations, and help in creating private community facilities.	
Increase the supply of water through the permission of groundwater discharge.	Apply for the permission to discharge groundwater.

6. Discussion

6.1 Challenges

Climate change is one of Gotland's biggest challenges in working towards having a sustainable water resource management. As mentioned in the literature review, the impacts of climate change are difficult to predict. (Green et al., 2011; Garnier and Holman, 2019) Nevertheless, it is anticipated that climate change will lead to higher temperatures on Gotland, increased precipitation, longer periods of droughts, sea level rise and longer vegetation periods. (Eklund, 2018, p. 42) Due to this, Gotland municipality has shown concern about these issues. More knowledge about the impacts are necessary according to researchers (Green et al., 2011; Garnier and Holman, 2019; Younger et al., 2002), which Gotland municipality has also expressed. (Eklund, 2018; Region Gotland, 2018; Pettersson, 2019) Green et al. (2011) had earlier identified a research gap regarding scientific knowledge about groundwater. However, they saw an increased interest amongst actors and stakeholders in managing their groundwater resources in a more responsible way once their groundwater had become negatively impacted. As mentioned by Susanne Pettersson (2019), Gotland municipality did not initially start interesting themselves in how to manage their resources in a more sustainable way. It was not until they were heavily affected by a water shortage in 2015 that the realisation of a changed approach was necessary. The majority of Gotland's water resources consist of groundwater and therefore, it became very urgent. Since then, the municipality has been able to increase their knowledge on how to manage their water resources. Many of their actions displayed in the result are to initiate more investigations and conduct risk analysis. With this they hope to understand more about climate change impacts on their water resources and how to make them resilient. Further, the hope is to know which local sources to invest in and where to interconnect the water supply network. This desire to increase understanding and knowledge can be viewed as a strength to dealing with the challenge.

Using adaptive strategies, one of Giordano's (2009) institutional solutions for a sustainable water resource management, is cooperation. According to him, actors and stakeholders should collectively manage resources together. Gotland has initiated and taken part in many cooperation's to improve their water resource management. One such cooperation is between

the Geological Survey of Sweden (SGU), the Swedish Meteorological and Hydrological Institute (SMHI), and the county government to measure groundwater level change. (Eklund, 2019; Region Gotland, 2018; Pettersson, 2019) The cooperation between the municipality and limestone industries to reduce wastewater and improve capacity in the municipal water supply network also demonstrates a collective approach.

Another challenge is the issue with a well working water supply network. Most areas in Gotland are spread out and sparsely built which means that most areas have a local water supply. In vulnerable areas, like along the coast and in the northern and southern parts of the island, local distribution is not enough. One solution is to connect the local water supply networks with each other to help recharge and discharge water easier. (Gotland Region, 2018; Eklund, 2018) In the literature, this is defined as a supply-side action. (Garnier and Holman, 2019) Some local sources would then be terminated as the larger grid would be sufficient. Nevertheless, Gotland will have to improve the network from leakage. The municipality has already managed to reduce leakage within their water supply network compared to the whole of Sweden, but since they already struggle with supplying water, leakage is something that needs to be further reduced.

Gotland municipality also faces the future challenge of not being able to withdraw water from their water sources. (Region Gotland, 2018) Their license can be removed if it comes in conflict with natural reserves and important ecosystems that will have to be preserved. Gotland feels more pressure regarding this which is also stated as a growing concern in the literature review. (Weiss, 2015) One further issue is that Gotland does not hold many licenses that allows them to withdraw water from certain resources. (Region Gotland, 2018) It can, therefore, be decided that they need to apply for a license before withdrawal is allowed again.

The threat of conflicting interests is a major challenge. Even though there is a risk of increased conflict between different sectors, the biggest challenge here would be the conflict between natural reserves and the municipality's need to supply water. The reason behind this is because the different sectors have the opportunity to collaborate and work collectively to distribute and share the available water resources if they can agree. It will be a difficult task, but the opportunity exists. If areas with valuable water resources are decided to be protected as natural reserves, there is nothing that the municipality can do.

As it is estimated that an expansion in cities and coastal areas will increase by 20% between 2015-2045, it is important to consider how to secure a long-term sustainable water resource management. The expansion of cities and coastal areas is important for economic development on Gotland and to do so, water availability is necessary. It is expressed by Green et al. (2011) that regions with few types of water resources are the ones that will suffer the most from climate change. As Gotland mostly depends on groundwater resources, this becomes an evident issue and can come to be very costly according to Navarro-Ortega et al. (2015), Distefano and Kelly (2017), and Foster and Chilton (2003). Without a sufficient supply of water, the expansion plans mentioned in the result, (Region Gotland, 2018) cannot take place. This is the reason for Gotland investing in desalination plants as they could not find new groundwater resources. To supply water for a growing population and to follow through with their expansion plans, it was a necessary decision. This is something Garnier and Holman (2019) discussed in their research. As Mohamed et al. (2005) and Quist-Jensen et al. (2015) mentions, desalination plants are costly, both financially and in energy. However, the Baltic Sea has lower levels of salt, which makes the plants less costly compared to the studies made in the Middle East and in Southern Europe. Further, Gotland uses renewable energy to run their facilities which Caldera et al. (2016) and Caldera and Breyer (2017), when doing a comparative analysis, found that the costs of the facilities were not much higher than those running on fossil fuels. Further, the technology is continuously developing which Saeed et al. (2015) expressed.

Gotland municipality further needs to develop an emergency plan as they have specified. There is always a risk of longer disruptions to regions water sources and therefore, it is necessary to know how to react in case of emergency. Pettersson does mention a few hints about where water supply could come from. According to her, Gotland municipality is trying to build up a reservoir through providing water from different sources. One challenge already mentioned is that Gotland mostly depends on groundwater and does not have many other resources. However, with desalination facilities they have managed to solve parts of this issue which Pettersson sees as potential. Today their water sources run to a capacity of 100 %, but if they could build up their capacity and water sources, they could supply the island without using full capacity. In this way, the leftover percent could be used in building up the reservoirs together with the capacity of some smaller local water supply facilities. One can see tendencies for the development of an emergency plan for longer interruption. Aside from this, Gotland still needs to specify which sectors will receive water first and how much.

6.2 Adaptive strategies

The challenges that the municipality is facing are demanding. However, they are using several adaptive strategies to cope with the issues and have plans for more. From the result one can see that the municipality uses both supply-side strategies and demand-side strategies. Some are long-term solutions such as investing in new technologies like desalination plants, whilst others are more temporary strategies like water saving actions. As the problem first got attention in 2015, the municipality is in the starting phase of re-developing their water resource management. They have come a long way to increase their knowledge about the impacts of climate change and are in the discussion of implementing new strategies. One significant discussion has evolved around connecting their water infrastructure.

On the demand-side they have discussed the use of changing crops to those that demand less water for irrigation and can stand longer periods of autumn. Further, they have discussed implementing measuring technology in consumers' homes to increase their awareness about water usage. However, nothing has been mentioned about regulating the demand amongst consumers through metering and pricing. This can only be speculated about, but it might be because they are still in their starting phase and looking into other strategies that would not impact consumers in such a way. Another demand-side strategy that the municipality mentioned is the use of water saving techniques. The literature review does bring up some examples for such water saving techniques that might become of valuable interest for the municipality in the future. One such thing is to promote drip-feed irrigation systems within the agricultural sector. (Bates et al., 2008; Green et al., 2011)

One can see a will within the municipality to improve their water resource management and to make it sustainable in the long-term. However, more knowledge is necessary to know how the strategies discussed will impact their water resources. To do this, some good examples of actions are mentioned by the municipality which are listed in section 5.6. Examples of these are different investigations in water supply and resource management, risk analysis, and cooperative actions. It is of the upmost importance that the municipality acquires more resources within their department. Therefore, the action to create a working group and an advisory role within water and waste is of essence. Further, they want to implement a management routine between administrations to coordinate matters of water and waste. These

two actions are very important as they will help in the evaluation and implementation of other strategies.

One of their strengths is that they show a clear vision of a long-term sustainable water resource management and what strategies and actions they would need to reach this goal. Further, they do show an understanding of their threats and what challenges they encounter.

6.3 Adaptive management

Walters (1986) argued that resource management should be seen as an adaptive process with learning and understanding that leads to reduced uncertainty. Since the problem of water shortage emerged in 2015, Gotland municipality has reduced uncertainty by increasing their knowledge of how water resources might be impacted by climate change. They have also conducted many investigations to increase knowledge about the impact of a growing population, increased tourism, and which local water supply networks to connect to improve their capacity on the island.

They have engaged in collaboration with external authorities to gather information about their groundwater resources. The hope is that with the measuring stations in their groundwater resources put in place by SGU and the county government, the municipality will be able to know for the summer 2020 when to put in short-term responses like water saving actions on time. To have this understanding and response is seen by Walters (1986) as active adaptation. From the result it seems more like the municipality has a feedback approach that Walter´s encourages more than a trial-and-error approach. Further, Gotland is seeking many possibilities to solve the challenges they face and not just relying on one solution.

Looking into the operational definition developed by Williams and Brown (2013), it seems like the municipality is in the deliberative phase. One important part of this phase is to engage stakeholders. Esteban and Dinar (2012) also saw cooperation between actors and stakeholders as an essential component for a sustainable water resource management. Gotland municipality has engaged with some stakeholders like the collaboration with the limestone sector to improve the availability of water resources. More engagement with stakeholders is believed to be

necessary if they want to continue the implementation of certain strategies discussed. One such thing is, for example, to change crops within the agricultural sector. In Collet et als. (2015) study they saw a reluctance amongst farmers to change crops which would become a problem if the municipality wants to push for such strategies. Gotland would have to engage farmers in their plans and collectively find a solution. The municipality is somewhat in between the stages of recognising management options, their consequences and the installation of monitoring systems. As most of their actions and strategies discussed in the result have not yet been implemented, they are still trying to learn more about their options and when best to implement them. The instalment of the measuring systems in their groundwater also implies that they are in the deliberative phase. As the municipality is not yet in the iterative phase, not many decisions and actions have so far been implemented that can be followed upon and assessed. However, one reason for this can also be, as Williams and Brown mention, that adaptive management is difficult when dealing with climate change. Monitoring the climate change impacts on the municipality's groundwater resources is time-consuming which can cause the municipality to be caught in the deliberative phase. Since this issue was first discovered a few years ago, it could be anticipated that they are in this phase. Another difficulty with adaptive management is for organisations to transform their behaviour into a more collaborative and flexible way. For Gotland municipality it seems to be the other way around. They show a desire to change their behaviour. Williams and Brown (2013) also did define adaptive management as an ongoing process of planning and learning which goes hand in hand with what Gotland municipality is currently doing. In this way it looks like the municipality fulfils the definition of having an adaptive management.

7. Conclusion

It is evident that there is a lack of knowledge within the municipality, but also within the research community, about what impacts climate change will have on water resources. However, with increased risk and more obvious consequences a will to prevent this has seemed to come.

Gotland municipality faces many challenges towards a long-term and sustainable water resource management. They do have adaptive strategies in place, but need to continue their work and implement more of their actions to reach a sustainable water resource management. Many of the challenges presented in the previous chapter are interconnected and solving one issue will not be enough. It is also evident that many challenges are connected between different sectors. Water shortage does not only affect water resource management, but also food production, the agricultural sector, different industries like limestone companies and the energy sector. Therefore, it is important to consider the interconnection between them and work for an integrated management. The establishment of a working group and getting more personnel resources within the municipality will be crucial. More expertise and competence within the workforce would give the opportunity to better understand, coordinate and implement strategies, of for example, conflicting interests. A beneficial thing would be if the workforce could include interdisciplinary expertise and competence within different sectors. The cooperation and the involvement of stakeholders would become easier.

If the municipality will use adaptive management to reduce the risks of water shortage is hard to say. They are still in an early stage of the adaptive management process. Therefore, it can first be known when they enter the iterative phase and start to assess their actions and make adjustments accordingly. However, the learning process and the awareness is incredibly significant to implement the right strategies and to engage stakeholders. To inform and teach stakeholders, actors and citizens to participate in the development and to have good communication and collaboration is vital. Gotland does show a process of increased knowledge and understanding, leading to reduced uncertainty which is seen as an adaptive process. They want to engage stakeholders, are open for more cooperation and try to find new solutions to the

challenges they face. One can see a will and an interest in understanding different systems like water cycles and climate change impacts through their actions.

This research used one case study that investigated and highlighted insights in an emerging problem that has not yet been well documented. One limitation with this study is that the result cannot be generalized and represent all municipalities in Sweden. Each region is different and has different conditions in their strengths, weaknesses, opportunities and threats. Therefore, it is important to investigate other municipalities in Sweden. This thesis contributes with what challenges Gotland municipality has, but it would be of interest to see how that compares to other regions. Is Gotland at the forefront or do other municipalities also have equally extensive work? It would also be of interest to see economic conditions for implementing adaptive strategies in municipalities. Gotland did not incorporate this in their material as it would be too comprehensive. Instead, they referred to financial statements within each project. This would present a further understanding of municipalities possibilities for their sustainable water resource management.

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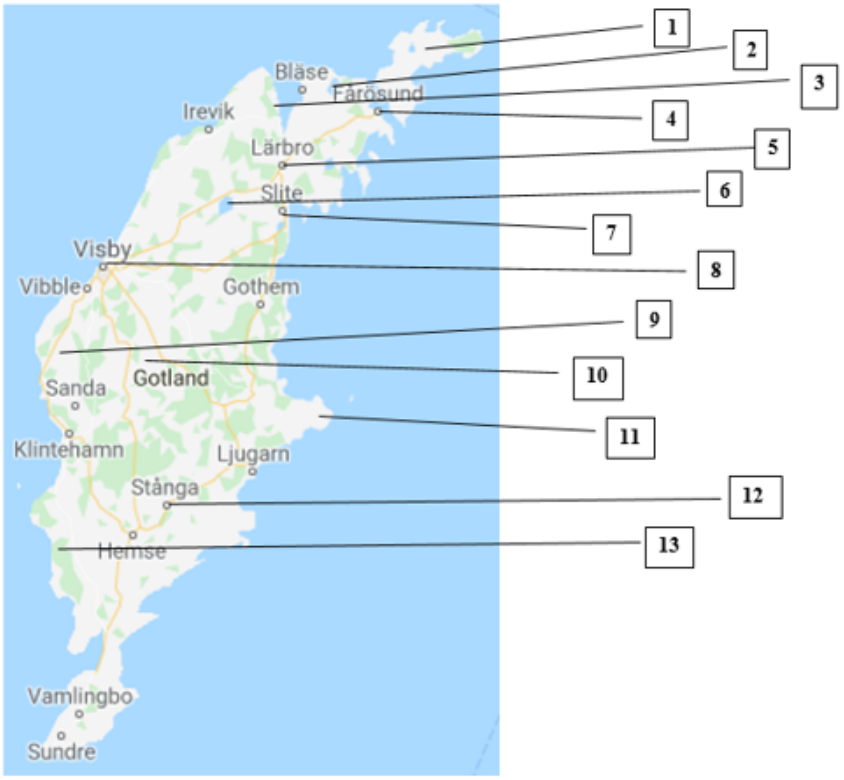
Appendix 1.

Map over Gotland



1	Fårö
2	Bästeträsk
3	Kappelshamn
4	Fårösund
5	Lärbro
6	Tingstäde
7	Slite
8	Visby
9	Tofta
10	Roma
11	Herrvik
12	Stånga
13	Kvarnåkershamn

Google. (2020b)

Appendix 2.

Interview questions/schedule

- Could you tell me how Gotland have been affected by water shortage recently?
- What water resources are you dependent on?
- Will the water resources used now be enough for future use?
- What are the main challenges with your water resource management?
- What strategies and actions have you implemented?
- Are strategies and actions evaluated and if so, how?
- What strategies and action would you need for a sustainable water resource management?
- Can you tell me about your desalination plants?
- How does your water emergency plan look like?
- Can you feel a conflict in the interest of water resources on Gotland? If so, how?
- How do you work with increasing knowledge and understanding around a sustainable water resource management?
- How do you work with water protection areas?
- How is climate change affecting your resource management and how do you work with preventing its effects?
- Would you like more guidance and help from other authority levels (e.g. government, county government)?

Appendix 3.

Interview Translation: Gotland municipality

Interviewer: Linnéa Sundberg **
Interviewed: Susanne Pettersson --

** How has Gotland Region been affected by water shortage/scarcity the last years?

-- Gotland has actually always had problems with water shortage/scarcity due to it being a limestone island and in general has a hard time storing water. However, the last years we in the whole of Sweden have experiencing a water level reduction and climate variations. For our part it has been apparent since the year 2015. In October 2015 I think we got 4 - 5millimetre rain, which was almost nothing and then we already had a few years with dry summers. It was then in the autumn of 2015 that we need to get 1 - 2 meter of extra precipitation to be able to make it for year 2016. So, then we were thinking a little that we needed to invest more for the levels to increase and we introduced tougher water irrigation prohibitions from the year 2016. In the recent years we have introduced the water irrigation prohibitions from the beginning of the summer or from the July month but now we introduce it from the 1st of April every year. And then we also did something that we never done before. We went out and encouraged people to change their behaviour and to think about how long they shower, to turn of the water when they are brushing their teeth. To really fill up the washing machine and dishwasher before starting it, so yes, trying to have people change their behaviour. So besides having the water irrigation prohibition, we work with changing behaviour as well. I think that is what I wanted to say.

** Okey, so then how did you inform the citizens to be more frugal? Did you announce it on your webpage or how?

-- Yes, there is information on our webpage and it is still there from 2016, 2017 and 2018 but beyond that we also created a movie that we showed on the cinemas here on Gotland. We did

it and… oh and we also showed this movie when we went to the schools. We called some schools on the island and asked if we could come and then the teachers picked out a few classes that they thought would be good to inform about this, often it was between the grades 3 - 5. So, we went to the schools and showed them the movie that we also showed at the cinemas and then we talked about water not being an inexhaustible resource. Everyone has help to be more frugal and at the same time there is a big focus on the global objectives/goals, so the teachers have also done a great job with talking about and working with goal 16, water. Furthermore, we had an Instagram competition for the older kids where they could send in their answers and advice and then we picked a winner. Ehm, we went to several different events and sport events. Almedalen for example, and then we have the advantage of living on an island and that we have a smaller area which made us get the attention from media, both newspapers and the radio. So, I talked a lot on the radio and encouraged people to help us save water and try not to have a big impact. But 2016 was the toughest of years and then we also had to do a depressurization. And then you really got to feel it as a private person that you for example could not shower on the second floor, it was only possible to do that on the first floor. It has also showed people that if we do not help each other to save water and to get more water into our grids, then we will have to once again do a depressurization that there is no one who wants to experience.

** Ah that is very interesting. I wanted to get to the strategies that you have been working on. So, then you have worked a lot with reducing the demand for water. How is it regarding your water resources and increasing their capacity and the supply? I saw in your water distribution plan that you have been thinking about using desalination techniques to be able to use water from the Baltic Sea. How is that work going?

-- Your questions are mainly built on the water distribution plan that the County government developed. There is also a new Water and Waste plan that applies for the years 2018 - 2030. We also have from before an expansion plan so now we spent a lot of resources to make a 30-year plan to get in more water in our grids. We have worked a lot with SPO and have made searches over Gotland at two occasions and in these recent days we have been dealing with water properties/estates as a water sources that we found by doing these searches. For the second water source we found we will have our first dialog meeting with the property owners in the area. In our plan we are also trying to cooperate with the lime industry which we have not done before. They have a lot of opportunities to collect the water in the quarries that they

have finished mining. So instead of pumping out the groundwater and the surface water we are now trying to make them pump it to these quarries, so we can take water from there in the summers. And then the idea of desalination. We have also this year started an attempt, which is in an early stage at the moment, but we are trying to see how we can make use of what we call our lime fat block water as a resource. So, we are trying in many different ways to get more water into our grids because we need that. If not, we are in need of a reservoir which we do not have as of today.

** Okey, so how is the work going to develop a reservoir?

-- When you wrote to me about this, then you read that we had a smaller desalination plant on the island that is made to produce 500 cubic meter water per day. Now in June month we started the big plant on the south of Gotland which has a meter production of 5000 cubic per day… (UNCLEAR)... this water plant will help us with the production, but we will not be able to have another water source, so this will be our reservoir. We will invest in several different water sources but then we will not push them to their highest capacity, today we are pressuring them to 110 %. But we might be able to stay at a capacity of 60 - 70 % and then we will be able to cover our entire need. So, we are trying to work with risk analysis and try to predict what happens if one water resource falls out/short and what other water sources we then have that can cover the need. So even if we get water plants with a high production we will not stop using our small groundwater resources. Because if the water plants for some reason would stand still, we would need to have reasonable drinking water supply on the south of Gotland with the help of Visby and the small groundwater resources. So, it is in this way that we are trying to increase and develop our reservoirs.

** Okey, so what do you see as threats and possibilities with your water resource management? For example, with desalination techniques it demands a high amount of energy to produce water and then there is also a problem with rest products after the water has been desalinated. You are mentioning a little about this in the Water Supply plan.

-- Why politics finally took this decision to build a desalination facility is because we have tried to find larger groundwater resources on the island for more than 40 years, but we have found nothing. We also tried to drill without success. So, the basis of the decision was that if we want to be able to live on this island then we need to be able to offer our citizens and our

tourists' water. We do not have any other choice. Yes, it costs more energy to produce but it is not a very high energy cost. One cannot compare our plant to the ones in the southern Europe because we do not have the same level of salt in the Baltic Sea. Another thing, when we are talking about energy costs, is that we are already using this desalination technique on two of our groundwater resources. This we do because they have, for different reasons, pesticides or dioxins and we also have natural substances like Boron in Sweden. So, the technique is used to clear out these substances from the water. So, we already today have a high energy cost on our ground water in comparison with the mainland. So, the energy cost for saltwater and our groundwater will not be that different. However, the risk or threat that I can see would be if the plant is so big and it would stand still for a certain amount of time. That means a huge quantity of water that will be lost. Today we have for example have a lot of power failures, but we do have emergency power for this reason. However, let's say we would end up in a time of war or that we get cut off from the mainland for several days, then we will not be able to use the emergency power particularly long. That we could do for max one day but after that we do not have enough diesel and that is also something we have incorporated into our risk analysis. With this said, we cannot take away our small water sources because they are not as high in energy demand as the big plants if we would have to pump water over the whole island without using the big plants.

** Okey, that is very interesting, and I did not consider yet the difference of salt levels in the water here in Sweden compared to southern Europe but that is true.

-- Yes, and then from the first plants that were built there has been a lot of development happening so that we take with us and also, we are always working to re-new energy. And our plant is the same as the one they have on Borgholm municipality in Sandvik on Öland. So, they have a whole oasis of inventions since they started with this even before us. For them their energy costs have ended up lower than calculated. Furthermore, both them and us have put sun power cells on our plants and also the membranes used in the plants comes from a energy reusable technique so we are re-using a lot of the energy for our other treatment plants and that has done a lot for the energy cost. With this we will also see in the future a huge development towards the use of less energy demanding technology.

** Oh, so this is something I want to touch upon regarding the integration of several sectors such as energy, agriculture and water supply. It sounds like you are working continuously on

developing new approaches to use. Would you say this is a iterative or knowledge-learning process?

-- One should remember that we consider ourselves as a pretty small water and waste organisation here on Gotland, so we are not dealing with very crazy innovative solutions. We rely a lot on already developed technique, but we do a lot of analysis and follow up on things and after that we perform the actions, also water is not always water. It can give a lot…(UNCLEAR)... between the water sources so we can know how to keep it clean before it is distributed on the grid. Gotland consists on many small municipalities and that one can feel through all different grid branches. Now we are trying to connect them all on Gotland and that of course gives some reactions, so yes, we are putting a lot of effort on analysis and follow up thing.

** Okey, this is something that I have encountered a lot that there is a necessity to improve the knowledge regarding water resource management due to climate change. For some municipalities this is easier than for others especially for smaller ones where actions are not taken due to too little knowledge.

-- Yes, we have also been there. That is why we are where we are today. From 2000 - 2015 we could not agree so instead we just hoped that the problem would solve itself or that someone else would come and solve it for us. The groundwater levels kept on decreasing more and more and we also noticed that more people started to shift in where they wanted to live. More people wanted to move into the city or live near the coast where there is definitely no water. We realized in 2015 that we, maybe was not the worst off, but we were definitely one of the first together with Öland to be affected. That is when we realized that we needed to get the knowledge on our own because no one will come and save us. So, we have been in that situation too but in the last years we have spent a lot of resources to develop our way on a long-term and to consider the climate.

** This could lead us into my next question. I have read a lot about regions demanding help through the implementation of national policies. Is this also something you would want more of or do you think it is up to every region to solve their problems?

-- I think we should a bit more jointly decisions in Sweden but equally as much on the local level. The climate does not only exist on Gotland. However, it can be tougher here because we are a little lime stone island and we cannot store rain water, but it is a more national position and Gotland has received extremely much help this last years because other regions have been affected as well, like Stockholm, Örebro and Jönköping. The issue gets a little more national attention and that helps us other smaller municipalities to get the support, energy and motivation do more on a local and regional level.

** Have you any thought of what you would like to see for help on a national level?

-- In fact, some things have already been done. The government has put SMHI on the task, around 2015/2016, to do climate reports for each county. They have also put all the county´s to develop a regional Water Supply plan and they have been giving extra aid that we have been able to apply for and that can help in solving some issues. I also see it is not just knowledge that we need but also financial means because water and waste systems in Sweden has not been maintained for many many years now. So, every water and waste organisation in Sweden needs to rebuild their water and waste-grids but also to make sure that the facilities and plants that we have can deal with the climate variations that we will experience more in the future. For example, daily water and the problem of flooding. So, it is not just knowledge but also…, as they have done now with distributing 45 million swedish crowns were Gotland got 2,5 million swedish crowns, so we have the possibility to apply for funding to be able to make improvements.

** That is also something I found in the literature that there is a need for financial support to be able to implement the plans. Is that what you feel like you need the most?

-- Yes, it is, but also of course knowledge but the knowledge bank has seen an extreme increase these last years, so I think the smaller municipalities needs more financial support but also, we municipalities need to work together and learn from each other a lot more than what we have done before. (UNCLEAR)... that is why we see in the next generation that there are six big companies to be able to manage the challenges that is coming with drinking water supply. But this is just own thoughts about the future, no one of us knows for sure. But we can feel in the collective sense that we need to work together, and we are more than happy to meet and discuss with each other.

** I was thinking about the effort of preventing climate change and we have already touched upon it a little, but I saw in the Water Supply plan that you have identified some needs but that the implementation of actions not has reached the level that you wished for. It though feels like you have done a lot. What do you think is meant with this in the plan?

-- I was thinking about it when I saw the question. I have partly been involved in developing this plan. When we did this plan we at the same time developed… it is a little special here since this is only consisting of one municipality, but at the same time we were developing our Water and Waste plan. I do not know exactly what to answer to this.

** Okey so what I reacted on in the Water Supply plan and of interest to discuss is that it felt like you had identified the problems and need but you did not yet have any strategies or actions to put forward. However, during this interview I feel like you do have strategies and actions.

-- Oh well yes that we do have but we did not completely have that clear for us during the time we were developing the plan due to the Water and Waste plan being developed at the same time. Because before we had not yet identified the needs, it was more before that we had a expansion plan and then water and waste organisation came second so we had to try and find water. Now it is a little the other way around. Due to the last years being severe our board has even made drain connections in certain areas even if they are within the so-called activity area. And there is a paragraph in the law that states that if one can do it in this way it gives a better vision strategically for municipalities to have their infrastructure in place before the expansion starts. This is not how it has been before. What we also had not done then and that we are doing now in these days is a big risk analysis on all our water sources with consideration to climate and how-to climate adjust these so that for example with the risk of floods, there is no contaminated water running down in the wells. So, these kind of actions and approaches is something we are doing now that did not have during the development of the Water Supply plan. A lot has happened in these last years.

** Okey, well that is true since these plans were developed a few years ago. I have seen it in other municipalities as well like Östhammars municipality where I am from. I know they want to expand but they do not have the infrastructure for it yet.

-- And that is a completely political question, but it still has worked and seems to be taken seriously. Politicians likes to look over new expansion plans, and that water and waste wants to. They do not want to slow down any processes, but it must be understood that it is not solving the question about water and waste to just sit here. It must be built before and for our part we need to make sure there is a water source that we can take water from. So, a lot has happened about how we work today.

** I do not know if I brought this up before, but Gotland is a touristic region. Are you affected a lot by tourism and is it something you incorporate in your risk analysis?

-- One can say that we "sizing" our need of water after July month, so we always consider the summer sizing and the winter sizing. We always need to consider a proper sizing and always expect that there might be an exploitation around the coast line where people want to live but where there is absolutely no water and if there is it is salty. At the same time, we cannot consider to small sizes/areas during the summer since that would mean to little consumption during the winter. There are some areas where we had to tell them no we will not because they live too far away from each other and there is too much tourism, so we cannot reach them with our water and waste systems. They live so far away from each other, so we cannot make use of the paragraphs that states that municipalities have an obligation to provide with water and waste. We cannot unfortunately justify this because it would be too little consumption in the winter and then we cannot guarantee that we deliver fresh and healthy water.

** I saw that you have a lot of individual/separate and private water sources so are they used in the touristic areas where you cannot provide water and waste systems?

-- No but many people, including myself, lives on the middle of the island and so we also use individual and private and so that is different from situation to situation, but we do have a lot of private sources on Gotland, approximately 40 % still has private sources. But then we also know that most people want to move towards Visby and its surroundings and there is a lot of expansion going on in here, it is really incredible, so we are becoming more and more who are connected to the grid and then more and more summer cottages that use private sources.

Also, those summer cottages who lies collected in an area of 10-15 also has a demand according to the Water Service Act to get water from the municipality.

** So, I have got the answers that I was looking for but do you have anything you would like to add?

-- I would like to comment on the question regarding water protection areas. It is very interesting, and it is a discussion I had before, and one can say whatever they want, but when one talks about water protection areas they always refer to how many water sources that has water protection areas so then it is the amount that counts. Considering that then Gotland is doing equally bad as the rest of Sweden on approximately 40 % but if one looks at how many of our subscribers that gets water from a water source with a modern water protection area, then we are at 95 %. This is discussed a lot within the county government because we have to cover the whole of Gotland which is a big geographical area. Then we have a few smaller water sources here and there in for example touristic areas where we still yet have not got a new water protection area. We are working on it and it will take some time also because there is a high competition every time one wants to build a new water protection area. I can sometimes feel like it would be easier to just build a huge dumpster before we could build a water protection area haha but we really do have competition. But the most people on Gotland who get their drinking water from us gets it from an approved water protection area. And lastly we talked about climate change and there we have just in these recent days hired a person who is a coordinator and who will deal with questions regarding climate change, so we are also increasing our resources in that sense too.

** Oh okey, then I can continue on this with conflicts between nature conservation and drinking water. How is it with that?

-- When it comes to nature conservation, we have definitely started to feel a competition. For example, we are talking water from a lake or a swamp and here the county government wants to develop a very big Natura 2000 area east of the swamp. Here we have gotten a few indications if they are going to make a new trial/consideration of our water property. At another lake called, the West Swamp, in the north west part of the island there is plans on developing another big Natura 2000 area. There we have a line from our grid passing and regarding this one we have got a lot of remittances/referrals. So we are starting to feel a

conflict with nature conservation but before we only felt it towards the expansion of settlements/buildings, agriculture and the lime industry. But these new conflicts, which is nice that you have discovered is something that is slowly increasing.

** Oh that is good that I decided to mention it in the end then. Cause I have seen that a lot of ecosystems are and can come to be affected by the exploitation of water resources and also with the increased pressure or climate change. And it is also interesting because it feels like you have developed a somewhat good plan and that you are making a lot of risk analysis which is not always the case in other regions or municipalities.

-- Yes, and this is also something that has changed a great deal in the last years where we are conducting more risk analysis than before. And there is, also more demands today than it have been before… (UNCLEAR)... from the Environmental Code law and the global objectives/goals which is helping one to try and look further in the future than just trying to solve the problem for today. So, it is also interesting when working within this. It is not just to try and get water out in our grid today, we also need to do these investigations and analysis and considerations to get water for the next generation.

** Yes, I have seen that you have these short -term goals for 2030 and 2050 in the Water Supply plan but it must be difficult to make this analysis on a long-term basis.

-- It is hard, but we are trying. For example, with these 2,5 million swedish crowns that we get from the government for water and waste system investments. 1 million of them will be used to put down measuring instruments in many of the wells to learn more about groundwater sources so that we do not overexploit them and eventually get salt water in them. This is something that would not have been considered 10 years ago. Then one would just have kept on pumping until it all would have been used. So, one can see a bigger awareness in our business and that water is not an inexhaustible resource and that we need to take care of it and find a balance in our groundwater sources. If we make it there we must stop pumping because then it needs time to recover or to be able to slow down before we get there. So, this is what we are going to try to learn about our three of our high-water sources.

** This measure instruments, is that a cooperation with SGU?

-- Yes, we will… SGU has a lot of measuring instruments on Gotland but they are in water sources we are not using. Our water resources are being used and with that we can get another picture, so we are cooperating with SGU and SMHI because they in their turn uses these values to make long-term prognosis that we can use, statistically, already at the end of the year to let us know how water, ehm, how much water will be needed for the summer 2020. In this way we can implement prohibitions at the right time, so we do not have to annoy people to early.

** Ah well then you are also working towards predicting when to put in your strategies at the right time.

-- Exactly, this is a change that has come in recent years where we are very considerate about taking care of our water sources. So, we want to learn as much as possible as we can about how they react with different precipitations and so forth.