CHALMERS
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Strategic Assessment of Sweden's Water

An exploratory study of municipal water supply, climate change, and population growth

Master's thesis in Industrial Ecology

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Global water use is increasing due to economic development, changing consumption patterns, and population growth. Meanwhile, changes in temperature and precipitation as a result of climate change are expected to decrease water availability while further increasing the demand for freshwater. Sweden only uses a small percentage of its water resources but the resources vary regionally and several regions are already experiencing recurring water stress. In Sweden, the responsibility to supply drinking water in urban areas is assigned to the municipalities, which includes managing strategic planning and securing future water supply. This means managing the challenges of climate change and population growth, which are both complex issues. This thesis has been an exploratory study of climate change effects, population growth, and water supply focusing on the municipal supply in Sweden. By using literature, reports from governmental agencies and interviewing five case municipalities, four thesis questions have been analyzed. Thesis question 1: Where is water stress likely in Sweden under climate change and population growth? Thesis question 2: What are the consequences of water stress for water quality management? Thesis question 3: How well is Sweden equipped to cope with changes in water quantity and quality? Thesis question 4: What potential do different water supply technologies and other solutions have in the Swedish context? The thesis work has resulted in a water stress factor for thesis question 1, showing that water stress will occur in southeast Sweden, particularly around the Stockholm region. The analysis of thesis question 2 produced a compilation of unwanted water quality effects found in the literature, a handbook aimed at municipalities, and examples from the case municipalities. Increasing DOM and DOC concentrations were found to be a hot spot in the Swedish literature. The increasing concentrations of harmful microorganisms was the unwanted effect most frequently mentioned by the case municipalities. Thesis question 3 resulted in four important factors in the analysis of whether Sweden can cope with changes in water quantity: water availability, water treatment and delivery system capacity, population growth and demand, and intermunicipal cooperation. For thesis question 4, alternative solutions and technologies from the literature are presented along with the solutions and technologies used or potentially used by the case municipalities. The case municipalities were likely to stay with the current water supply technologies and the case municipality Gotland has the most experience with alternative solutions for water supply. Even though Gotland uses desalination plants to boost the supply, the interviewees believed water retention measures would be the best direction for future expansion of the municipality's water supply.
Keywords: water supply, municipality, water resources, climate change, population growth, water quality

Contents

1 Introduction

1.1 Background

Global water use has increased drastically over the recent 100 years due to population growth, economic development, and changed consumption patterns. Water use is currently increasing by about 1% per year (UN World Water Assessment Programme, 2009). Meanwhile, climate change effects are becoming more visible and changes in temperature and precipitation are expected to increase the demand for freshwater while decreasing water availability (Jiménez Cisneros et al., 2014). Climate change effects coupled with population growth will most likely cause further water scarcity and water stress.

1.1.1 Freshwater resources and drinking water supply in Sweden

Sweden has good access to freshwater resources compared to other countries in the EU. Only about 1% of available freshwater is extracted for the water supply of industry, households, or agriculture (Eurostat, 2015). However, water resources vary across the country, and recent summers have had high temperatures and little precipitation, causing drought and water shortages. This was visible in the summer of 2018, when Sweden experienced an unusual number of days with heatwaves and forest fires. These events hint about the potential effects of climate change on Swedish water resources and consequentially on water supply.

Water governance in Sweden is a large web of actors following the Water Framework Directive mandated by the EU. Sweden is divided into five water districts led by one of the county administrative boards in each district. The county administrative boards are responsible for ensuring the national environmental laws are being followed and to act as a link between the local and national levels of water governance (The Water Authorities, n.d.). Municipalities have the responsibility to supply safe drinking water and wastewater treatment to urban areas as well as strategic planning to ensure the future drinking water supply (Swedish Agency for Marine and Water Management, 2018).

1.1.2 Water supply and municipal water supply

The most common ways of extracting water in Sweden are surface water extraction, groundwater extraction, and extraction using artificial groundwater recharge from surface water (Statistics Sweden, 2017b). The main users of water are industries, municipalities, households, and agriculture. An overview of the water extracted in Sweden can be seen in figure 1.1. The by far biggest user of water is the industry which uses 61% of freshwater extracted.

Municipalities supply water mainly towards households (75%) but also to municipal facilities and industries. On average, 88% of Swedish residents are connected to a municipal water supply. The percentage of residents connected is generally higher in densely populated municipalities. The drinking water produced by the municipalities is 60% surface water, 23% groundwater, and 17% surface water used for artificial groundwater recharge. About 24% of the produced water never reaches a user; it's either used to operate the water treatment plants or lost due to leaks in pipes (Statistics Sweden, 2017b).

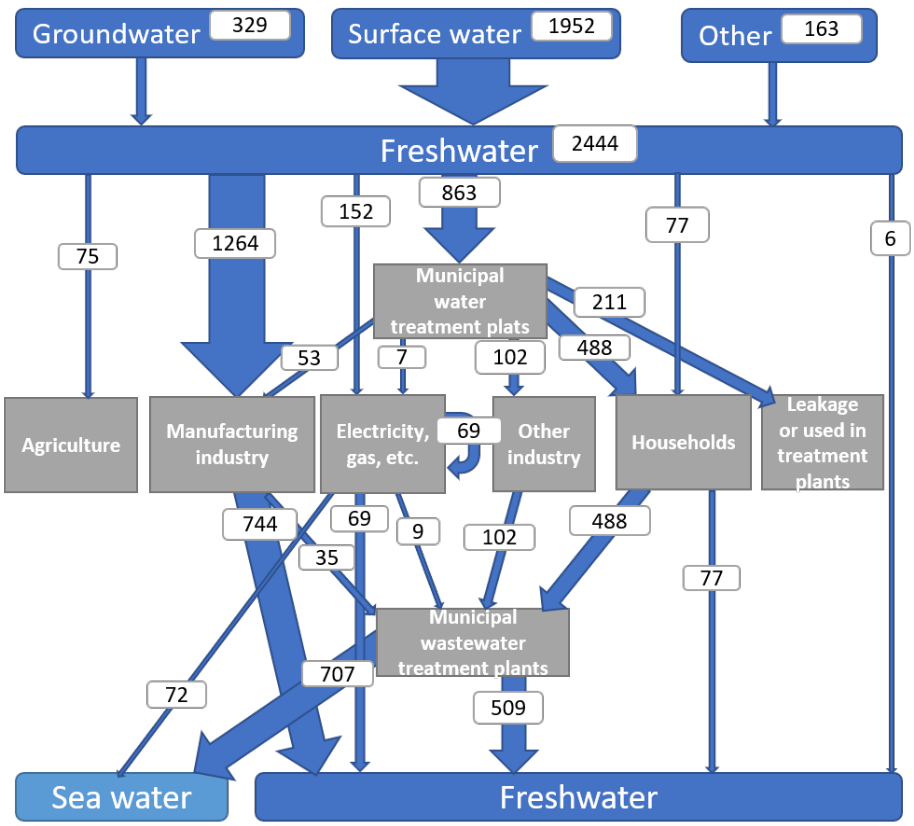

Figure 1.1: Freshwater flows in the Swedish technosphere in million cubic meters. The figure is recreated from a report by Statistics Sweden (2017b).

The strategic responsibility of a municipality includes dealing with future uncertainties such as climate change, population change, and economic constraints. Since municipalities in Sweden vary in size, land area and water resources, the ability to manage strategic planning varies as well (Sjöstrand et al., 2018). Many municipalities are a part of inter-municipal cooperations to manage these responsibilities or buys water from a neighboring municipality.

1.2 Aim & thesis questions

Some municipalities in Sweden are already experiencing water stress during the warmer part of the year. The annual average rise in temperature from climate change will cause a decrease in water availability and an increase in water demand, amplifying seasonal water stress. Additionally, the demand increases from a growing population. This thesis aims to determine how water stress from climate change and population growth will affect the municipal drinking water supply. To do this, the thesis will answer the following questions:

- TQ1: Where is water stress likely in Sweden under climate change and population growth?
- TQ2: What are the consequences of water stress for water quality and water quality management?
- TQ3: How well is Sweden equipped to cope with changes in water quantity and quality?
- TQ4: What potential do different water supply technologies and other solutions have in the Swedish context?

The questions will be answered by analyzing literature, reports from organizations and government agencies concerned with water resource management, and by interviewing representatives from five municipalities.

1.3 Terminology

Artificial groundwater recharge
Artificial groundwater recharge (in Swedish: konstgjord infiltration), or in some literature called managed aquifer recharge, is a method to enhance groundwater recharge by using surface water. Surface water is led to ponds to infiltrate through a sand or gravel aquifer where the water rests for a time until it is extracted from the aquifer as artificial groundwater (Swedish Water and Wastewater Association, n.d.). The method uses the natural process of infiltration to remove unwanted matter and pollutants, but sometimes water has to be treated before it is infiltrated. An illustration of artificial recharge can be seen in figure 1.2.

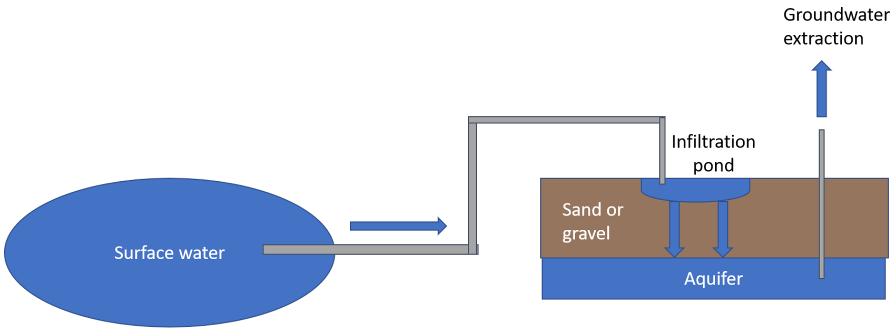

Figure 1.2: Illustration of using artificial groundwater recharge for drinking water supply. Surface water is led to a basin from where the water infiltrates through a sand or gravel aquifer. After a specified number of days, the water is extracted as artificial groundwater to use for drinking water.

Catchment area
An area of land and water which has the same point of outlet into a lake, river,the ocean, or a reservoir. A catchment area is often divided into sub-catchments (SMHI, 2020).

Water stress Water stress is defined by the European Environmental Agency as "Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of freshwater resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.)." (EEA, 2020).

Water treatment plant Water treatment plant, or henceforth WTP, has different names in the literature, such as water filtration plant or waterworks. In this thesis, WTP will include all plants or facilities which produce drinking water, regardless of the method of production.

2
Methods

The methodology of this thesis was to collect data and information on the thesis questions and then compile and analyze it. This section will first describe the data acquisition and thereafter the data analysis.

2.1 Data acquisition

The approach to acquire data and information was through interviews with five case municipalities, literature searches, and reports from organizations and agencies working with water-related issues.

2.1.1 Interviews

Five municipalities were chosen for interviews: Gothenburg, Gotland, Norrvatten, Tingsryd, and Älmhult. The selection of municipalities was based on having variations in municipalities based on the size, location, potential water stress, or other unique factors. As the thesis is done in Gothenburg and one of the supervisors work at Gothenburg's water and wastewater organization, this municipality was an obvious choice. Gotland was picked because it is currently experiencing water stress from low groundwater levels and tourism during the summer. Furthermore, Gotland has two desalination facilities, which is uncommon in Sweden. Norrvatten, which is a water supply organization in Stockholm county, was chosen because Stockholm county is densely populated and has considerable population growth. The municipalities Tingsryd and Älmhult are both situated in Kronoberg county, and the communication with the municipalities was provided through the Kronoberg county administrative board. Both municipalities have less than 20 thousand residents, making them small in comparison to the other case municipalities.

Interviewees were found by contacting municipalities directly, through country administrative boards, or the networks of the supervisors of the thesis. It would have been preferable if the interviewees had similar roles in the municipalities though this was hard to achieve. This was because not all municipalities have the same structures in their water and wastewater organizations, did not respond to attempts at contacting them, or not had the time or the will to be interviewed. It is difficult to determine how the answers for each municipality varied because of this. Additionally, the variation and details in the answers possibly depends on the difference in knowledge between interviewees, their openness, and how well the interviews were conducted. The interviewees, their roles, and the municipality they work in are presented in table 2.1.

Table 2.1: Interviewees contributing with interview data. The table lists the role, organisation, and municipality the interviewees work in.

Name	**Position**	**Municipality**
Mikael Tiouls	Water resources developer at Region Gotland	Gotland
Shadi El Habash	Water resources developer at Region Gotland	Gotland
Hans Clausen	Strategist at Göteborg Kretslopp och Vatten	Gothenburg
Joanna Friberg	Regional planer at Göteborgsregionen focusing on water supply, climate change, and vulnerability.	Gothenburg/ Gothenburg region
Lena Blom	Strategist, strategic coordinator at Göteborg Kretslopp och Vatten, and adjunct professor at Water Environment Technology department at Chalmer University of Technology	Gothenburg
Daniel Hellström	Head of Quality and Development at the local federation Norrvatten	14 municipalities in northern Stockholm
Carina Axelsson	Head of water and wastewater at Tingsryd municipality	Tingsryd
Helena Ahlberg	water and wastewater engineer at Älmhult municipality	Älmhult

The interviews were semi-structured by first asking the municipalities open questions about their municipality's water supply system and what their issues or challenges are to understanding the context a municipality is in. More detailed questions on the thesis questions were asked as the interview progressed. A draft of the report was sent to the interviewees to let them review the thesis work and some changes were made thereafter.

2.1.2 Literature

To put the thesis and the interview results into context, literature was used to cover the subject of climate change, population growth, water supply, water quality, and solutions for water supply increase. A thorough literature review was only made for TQ2 on water quality due to the time limit of the thesis work. The literature review used Scopus and used search words related to the thesis questions. The search words and further information on the literature review can be found in Appendix B.

2.1.3 Organisations and governmental agencies

Water supply and water governance are complex issues concerning many parts of society. Therefore, several different governmental agencies or organizations are involved in controlling and supporting water issues.

The Swedish Meteorological and Hydrological Institute has a series called *Klimatologi* on how climate change effects will develop in Sweden. The reports on regional climate change effects were used in the analysis of TQ1 together with data on population changes in municipalities from Statistics Sweden and reports on aquifers and groundwater Geological Survey of Sweden (Eveborn et al., 2017). Statistics Sweden has only projected population growth for the whole nation (Statistics Sweden, 2019b) but not for regions or municipalities, which would have been preferable. There was data on population growth in municipalities from 2016 to 2019 on the Statistics Sweden website, which was used in this thesis (Statistics Sweden, 2017a, Statistics Sweden, 2019a). An alternative would have been to compile the projected population growth made by the municipalities, but this would have been too time-consuming. In the analysis of TQ2, a handbook on drinking water supply and climate change effects created by the Swedish Food Agency (2019) was used together with the literature and the interview data. The handbook contains summaries on present unwanted effects on water quality caused by climate change effects.

To answer TQ3, data from the Sustainability Index Survey (in Swedish HBI) by SWWA was analyzed (Bäckström and Svensson, 2020, Swedish Water and Wastewater Association, 2020). The survey is sent to all municipalities in Sweden and attempts to assess the municipalities on different sustainability indexes. From the survey, the data of two parameters were acquired: water availability and production capacity (Bäckström and Svensson, 2020). The data, or survey answers, are anonymous and not entirely reliable. The questions in the survey may have been misinterpreted or not answered truthfully by the municipalities. Additionally, not all municipalities of Sweden participated in the survey. Data and conclusions from other reports and surveys by the SWWA were also used in the thesis. Data on drinking water production and production capacity in Älmhult and Göteborg was provided through personal communication (Ahlberg, 2020, Clausen, 2020).

2.2 Data analysis

2.2.1 TQ1: Where is water stress likely in Sweden under climate change and population growth?

This question was answered by quantifying the water stress caused by climate change effects and population growth by creating a water stress factor. Originally, there was no plan to calculate a water stress factor because it would be simplified representation and possibly misleading. However, calculating a simple water stress factor provided a useful preliminary ranking of where water stress in Sweden is likely to happen. Section 3 suggests how this analysis can be improved.

2.2.1.1 Analyzing climate change effects

To quantify the effects of climate change on water supply, a specific climate change effect was chosen: water availability (WA). The climate change effects affecting water supply can be divided into two climate indexes: temperature and precipitation (Swedish Food Agency, 2019). The annual average temperature and precipitation are projected to increase in all of Sweden, but increased precipitation (P) does not necessarily result in increasing water resources. A higher temperature and longer vegetation period will result in increased evapotranspiration (ET), thereby decreasing groundwater recharge (G) as well as runoff to lakes and rivers (R) (Eveborn et al., 2017).

$G + R = P - ET$

In climate models by SMHI (Eklund et al., 2015) WA is presented as the water remaining in catchments after P, ET, and snowmelt (S).

$WA = P + S - ET$

WA is considered a good indicator of the availability of both surface and groundwater resources after climate change effects.

In the report by SMHI (2015), each climate change effect is modeled after the climate scenarios RCP 4.5 and RCP 8.5 and for the periods 2021-2050 and 2069-2098. RCP 8.5 is the scenario of very little climate change mitigation (or "business as usual") and RCP 4.5 is the scenario of a significant reduction in emissions. In this thesis, the projections for RCP 8.5 was chosen to illustrate more prominent climate change effects. The period 202-2050 was chosen since it is most consistent with how far in the future municipalities have strategies. The model maps of WA during spring, summer, and autumn were overlapped with a map of Sweden's municipalities. Winter was excluded since no municipality would experience a decrease in WA during this season (Eklund et al., 2015) and water supply relying on small and for municipalities with limited supply storage seasonal variations are of great concern. Using Photoshop, it was visually determined which degree of change is the most dominant in each municipality. The decrease in WA for the three seasons in all municipalities is illustrated in a table (see Appendix A) and ranked after the average WA decrease.

2.2.1.2 Analyzing population growth

Population growth data from 2016 to 2019 by Statistics Sweden was used to quantify population growth for water stress. The annual average population growth was calculated as:

$\Delta P/year = P(2019) - P(2016)/3/P(2019).$

All municipalities were ranked according to the highest annual average population growth between 2016 to the end of 2019. The complete ranking can be found in Appendix A.

2.2.1.3 Water stress factor

Using the average decrease in WA, ΔWA, and the annual average population growth ΔP for each municipality, a water stress factor WS_F was created. It was calculated as

$$WS_F = |\Delta WA| * \Delta P.$$

2.2.2 TQ2: What are the consequences of water stress for water quality management?

The interviews together with literature and the handbook on drinking water supply and climate change (Swedish Food Agency, 2019) were used as a basis for answering this question. The consequences of water quality management were discussed by using examples from the interviews and the handbook by the Swedish Food Agency.

A literature review by Li et al. (2020) was used to represent the global research in the area of quality changes and climate change. To understand the Swedish research focus on water quality and climate change, an additional literature review was done. The municipal perspective on water quality changes was provided by the handbook (Swedish Food Agency, 2019) as well as the interviews. All quality changes and unwanted effects found were grouped based on the category of quality changes in the handbook (Swedish Food Agency, 2019) to provide an overview. The Swedish literature was done by grouping the articles found in Scopus to discover hot spots. All articles of interest are found in Appendix B.

2.2.3 TQ3: How well is Sweden equipped to cope with changes in surface water quantity?

This question is complex and different approaches could have been used to analyze it. Options considered were: how far have the case municipalities progressed in strategic work regarding climate change and population growth, if climate change effects from decreased WA is a part of their management plan, and how redundant the production is. For this thesis, it was concluded that a concrete way of assessing the ability to cope with changes in quantity over time, was to compare the projected population growth in each municipality with the spare capacity of the case municipalities' water supply. However, the data for this could not be acquired and a simpler approach was tried: to compare population growth over the latest years with the average daily production and average daily capacity. However, the data for this could not be acquired from the case municipalities with the exceptions of Gothenburg and Älmhult. The remaining municipalities could not provide this information due to security policies or not having access to it. The information could therefore not be used to make a comparison but rather to provide examples and a better description of some of the municipalities. This is contrasted against what the interviewees thought of climate change as a threat to water supply and some conclusions from the SWWA (Swedish Water and Wastewater Association, 2020). A large part of the analysis of TQ3 was to understand which factors are important in answering the question. Rather than answering the question itself, the results was a conclusion on what factors could be important to cope with changes in water quantity.

2.2.4 TQ4: What potential do different water supply technologies have in the Swedish context?

To answer this question, the literature on supply increase was reviewed together with interview data from the case municipalities. The interviewees were asked what supply technology or solutions they would use, or were planning to use, to increase their current water supply.

The potential for a technology or a solution could be assessed based on costs, risk, legal frameworks, or environmental performance. Initially, the goal was to focus on the costs on different technologies using literature and project costs from the municipalities. This proved to be too extensive and time-consuming to do for all municipalities and technologies in this thesis. Instead, an example is shown in the form of research about the potential of water supply technologies on Gotland (Sjöstrand, 2019).

3

Results & Discussion

This chapter begins by briefly describing governmental agencies and organizations concerned with water questions, climate change, and population growth. Thereafter, introducing the case municipalities and lastly presenting the results for the thesis questions. The discussion for each thesis question is presented immediately after the results of each question.

3.1 Governmental Agencies and Organisations

This section shortly describes the role of governmental agencies and organizations working with water resources, water supply, climate change, and population growth.

Municipalities
Initially, water supply and wastewater treatment is a private responsibility. In urban and densely populated areas, this responsibility has been transferred to municipalities because of health, sanitary, and efficiency reasons. The responsibility entails providing drinking water which is safe and has good quality, following the guidelines by the Swedish Food Agency (Swedish Agency for Marine and Water Management, 2018). Additionally, it is the responsibility of a municipality to strategize for future access and supply of water.

Swedish Food Agency (Livsmedelsverket)
The Swedish Food Agency has a responsibility in coordinating on drinking water-related issues. The agency issues regulation on how drinking water should be managed and drinking water quality. Municipalities can get support and advice from the Swedish Food Agency on water supply. An example of a project the agency has done is KASKAD which is a project to help municipalities adapt water supply to climate change effects (Swedish Agency for Marine and Water Management, 2018).

Geological Survey of Sweden (Sveriges Geologiska Undersökning)
Geological Survey of Sweden, or SGU, is a governmental agency concerned with rock, soil, and groundwater in Sweden. The agency observes groundwater quality and levels (Swedish Agency for Marine and Water Management, 2018).

Swedish Meteorological and Hydrological Institute (Statens Meteorologiska och Hydrologiska Institut)
The governmental agency Swedish Meteorological and Hydrological Institute (SMHI)

provides knowledge in meteorology, hydrology, oceanology, and climatology. The agency reports on water flows and water levels. In its applied research has SMHI has created a report series on how climate change will affect Sweden, called Klimatologi.

Swedish Agency for Marine and Water Management (Havs- och Vattenmyndigheten) The Swedish Agency for Marine and Water Management has an overarching responsibility to plan sustainable management of ocean, lakes, and water resources. The agency supervises water organizations, environmental challenges such as eutrophication, and surface water quality issues (Swedish Agency for Marine and Water Management, 2018).

Swedish Environmental Protection Agency (Naturskyddsverket)
The Swedish Environmental Protection Agency is responsible for environmental goals, climate, and nature conservation. An example of what the agency does is contribute with knowledge of how ecosystems are affected by changes in water quality and quantity (Swedish Agency for Marine and Water Management, 2018).

Swedish Water and Wastewater Association (Svenskt Vatten) The Swedish Water and Wastewater Association SWWA is the trade organization for water and wastewater. The organization supports water suppliers with knowledge, education, and reports on water supply management. Statistics on water and wastewater are also managed by SWWA through the tool VASS (Swedish Water and Wastewater Association, 2019b). Every year SWWA sends out a survey to municipalities to assess how the municipalities perform in different sustainability indexes. The results of the survey can be used by municipalities to benchmark performance on sustainability.

Statistics Sweden (Statistiska Centralbyrån)
Statistics Sweden is a government agency providing statistics to support decision making, research, and private sectors. The agency has statistics on water extraction, water use, population changes, and projects population growth.

3.2 Description of case municipalities

This section describes the municipalities which have contributed with information and interviews to this thesis. For each municipality, the water supply, population, and challenges are briefly described. Most municipalities in Sweden have some sort of emergency supply, often in the form of groundwater. However, such water supply is not described or discussed in this thesis since the focus is on long-term supply and not short-term emergency supply. The location of each municipality can be seen in figure 3.1.

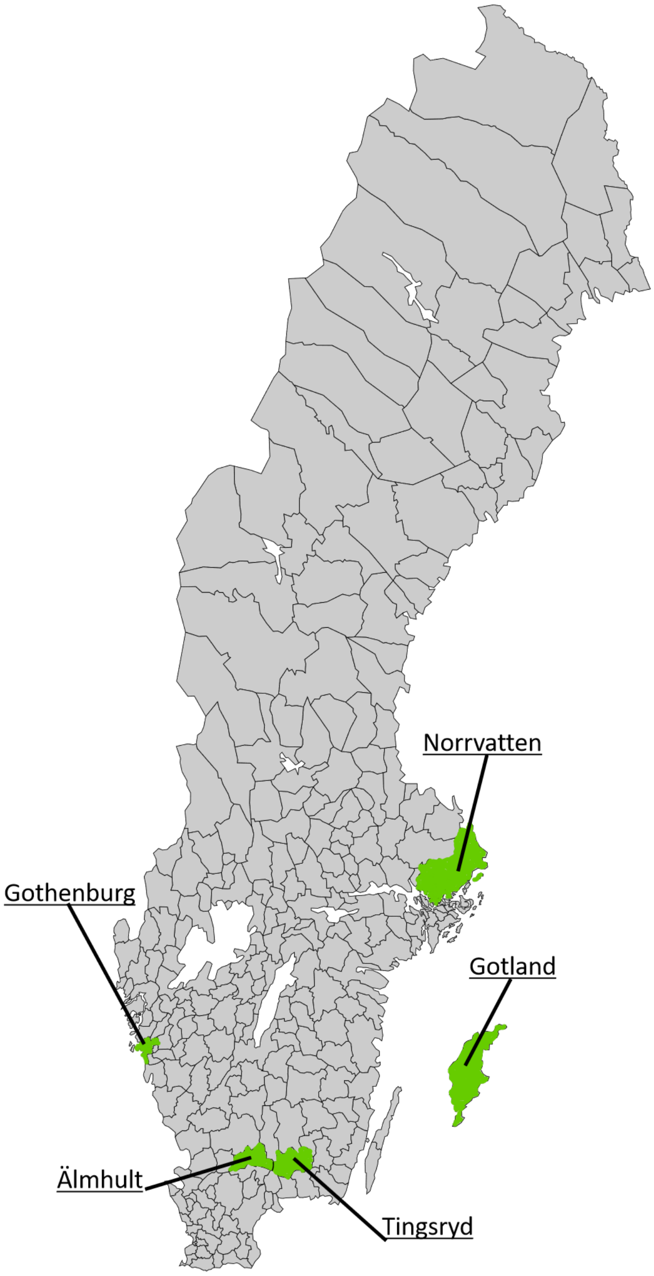

Figure 3.1: Map of Sweden's 290 municipalities showing the location of the case municipalities.

Gothenburg

Gothenburg, which is a part of Västra Götaland county on the southwest coast of Sweden, is the second-largest municipality in Sweden. It has about 580 000 residents and is expected to have 730 000 residents by 2040 (Gothenburg municipality, 2020). Gothenburg has two surface WTPs, Alelyckan and Lackarebäck, which both use water from the river Göta Älv. Raw water to Lackarebäck is first pumped to the lakes Delsjörarna before it is extracted to the WTP. When the water quality in the river is not adequate, the intake from the river is closed and water from the lakes is used as the raw water source for both Alelyckan and Lackarebäck. This happens about one-third of the time. The water supply system of Gothenburg is illustrated in figure 3.2. When the water level of the Delsjöarna lakes is low, water is pumped from the lake Rådasjön into Delsjöarna to be used for raw water extraction(Blom, 2020).

The municipality is a part of the local municipal federation Gothenburg Region, consisting of 13 municipalities to coordinate regional development and share experiences in several areas such as environment and education. One of the areas they work on is how the region's water supply should develop to manage climate change and population growth. The municipality can transfer water to five neighboring municipalities (Ale, Kungsbacka, Mölndal, Partille, and Öckerö) and receive water from three of them (Mölndal, Kungsbacka, and Partille). Two of the neighboring municipalities do not have any water production but rely completely on Gothenburg and another neighboring municipality (Gothenburg Region, 2014). A challenge for Gothenburg's water supply is being almost entirely dependent on a single raw water source, Göta Älv, which is exposed to different kinds of pollution (Blom, 2020)

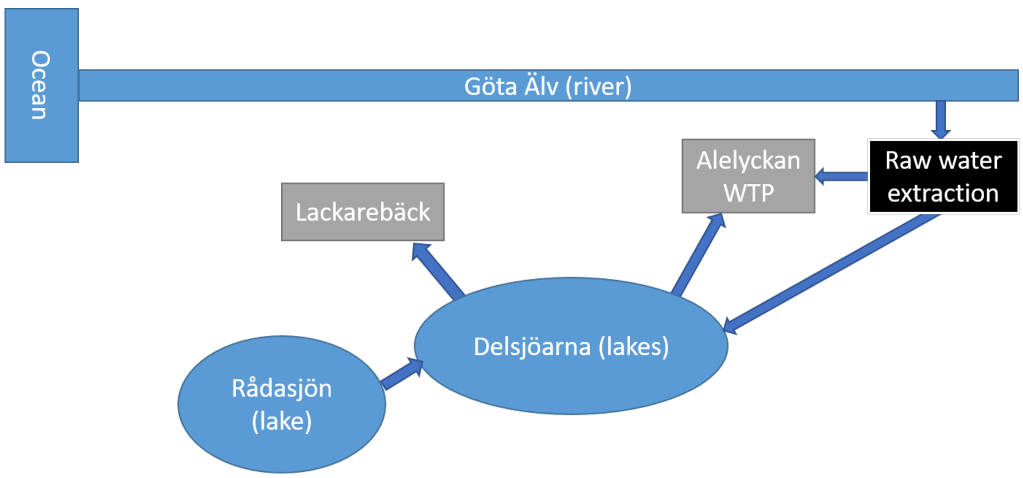

Figure 3.2: The water supply system in Gothenburg municipality. Raw water is extracted upstream in the river and led to the WTP Alelyckan and the lakes Delsjöarna. From Delsjöarna, the WTP Lackarbäck extracts raw water. When the river water quality is not adequate, the intake from the river is closed and only water from the lakes is used. When the water level in the lakes Delsjöarna is low, water from the lake Råda can be extracted.

Gotland

The municipality of Gotland, called Region Gotland because of its regional development responsibilities, consists of the island Gotland together with neighbouring smaller islands. About 60 000 people live in Gotland (Region Gotland, 2020) and the municipality is projected to have about 63 000 residents by 2029 (Statisticon, n.d.). However, the municipality has a lot of seasonal residents and tourists during the period May-September. A low percentage of residents are connected to the public water supply compared to the rest of Sweden; only 66% of the water used by households comes from the WTPs run by the municipality (Statistics Sweden, 2017b). Gotland usually experiences seasonal water stress because of tourism and difficult hydrogeological conditions for water storage. The islands have limited storage capacity in the water reservoirs. Because of thin soil layers, impermeable rock, and drainage from agriculture, much of the precipitation becomes runoff and goes into the ocean. There are 26 different WTPs on Gotland of which two are desalination plants, two are surface water plants, one treats water from a stone quarry, and the rest are groundwater treatment plants (Region Gotland, n.d.). They vary in size and location mostly depending on how and where aquifers are situated. Gotland's greatest water supply challenge is finding ways to increase the quantity of water on the island.

Norrvatten

Norrvatten is a federation of 14 municipalities in northern Stockholm county treating and supplying drinking water to the residents of the municipalities. The organization supplies water to about 700 000 people with one surface water plant with from Lake Mälaren. Norrvatten's challenges are that their production capacity is estimated to only manage the demand until about 2026-2030 (Hellström, 2020) and the need to strengthen barriers against microbiological and chemical pollution (Norrvatten, 2017). Stockholm county has in recent years experienced significant population growth, especially in 2015 when many immigrants came to Sweden (Hellström, 2020). Norrvatten and Stockholm Vatten och Avfall, which is the other big supplier of water in the Stockholm area, can transfer water between the distribution networks.

Tingsryd

Tingsryd is a municipality in Kronoberg county in southern Sweden and has about 12 000 residents and little population growth. The municipality has five WTPs where the largest provides water to 6000 residents through artificial recharge with water from a lake. Two of the remaining WTPs use artificial recharge from streams and the other two are groundwater treatment plants. A challenge for Tingsryd is that their main recipient of water is the food industry in the municipality. If the industry demand changes, the municipal water supply would have to adapt, and the industry is currently planning on expanding its activities (Tingsryd municipality, 2020).

Älmhult

Älmhult is a municipality in Kronoberg county and is nearing 18 000 residents (Statistics Sweden, 2019a). The municipality is experiencing a significant population growth with an annual increase of 2,07% since 2016 (table 3.2). Consequentially, the drinking water production is approaching its maximum capacity. Älmhult has one large WTP that uses artificial recharge and supplies water to 11 000 residents. The supply also consists of 8 smaller groundwater treatment plants. The artificial recharge plant uses surface water from Lake Möckeln. The infiltration facility is currently expanding to meet the demands of the projected population growth for 2030. The plant is being built so that it is possible to expand the production further if necessary, possibly supplying water to the projected population in 2050 (Ahlberg, 2020).

3.3 TQ1: Where in Sweden is water stress likely under climate change and population growth?

TQ1 is answered by first analyzing where water availability (WA) is likely to decrease and thereafter where in Sweden the population is increasing. Lastly, the decrease in WA and population growth is combined into a water stress factor.

3.3.1 Climate change effects

The climate change effect chosen as an indicator of water stress is water availability (WA). The municipal changes in WA are illustrated in figures 3.3-3.5. The figures illustrate the changes in WA for the period 2021-2050 compared to the reference period (1961-1990) using the climate change scenario RCP 8.5. A ranking of municipalities based on the average decrease in WA is presented in table 3.1, which displays the top 30 municipalities in the ranking. There are 290 municipalities in Sweden and the full ranking can be viewed in Appendix 1.

Table 3.1 shows that municipalities in the southeast part of Sweden will experience a decrease in WA. Norrtälje, Solna, Vaxholm, Österåker, Danderyd, Järfälla, Sundbyberg, and Täby are all part of the federation Norrvatten and in the top 30 rankings of decreased WA. The case municipality Gotland can also be seen on position 4 in the ranking.

3.3.2 Population growth

The population in Sweden in 2020 is 10.41 million and in 2050 it is predicted to grow to 11.93 million (Statistics Sweden, 2019b). However, population growth varies greatly between municipalities. The annual average population growth from 2016-2019 for municipalities is shown in table 3.2, which displays the 30 municipalities with most population growth. The ranking with all municipalities can be seen in Appendix 1.

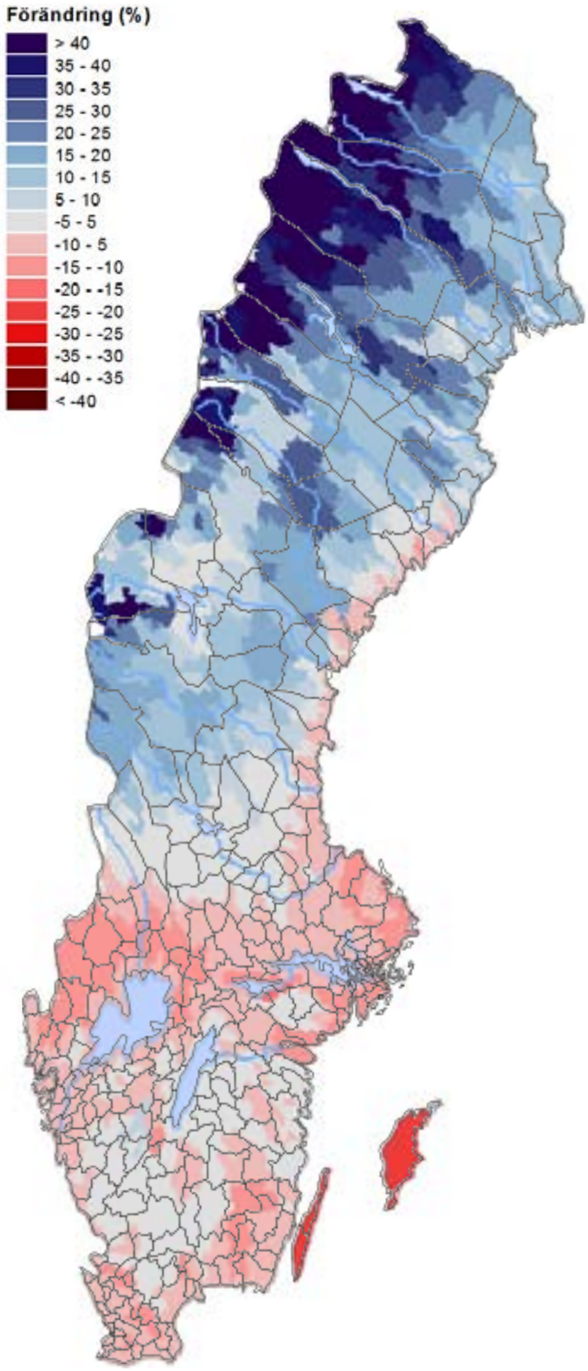

Figure 3.3: Decrease in WA for spring during 2021 - 2050 compared to the reference period 1961 - 1990.

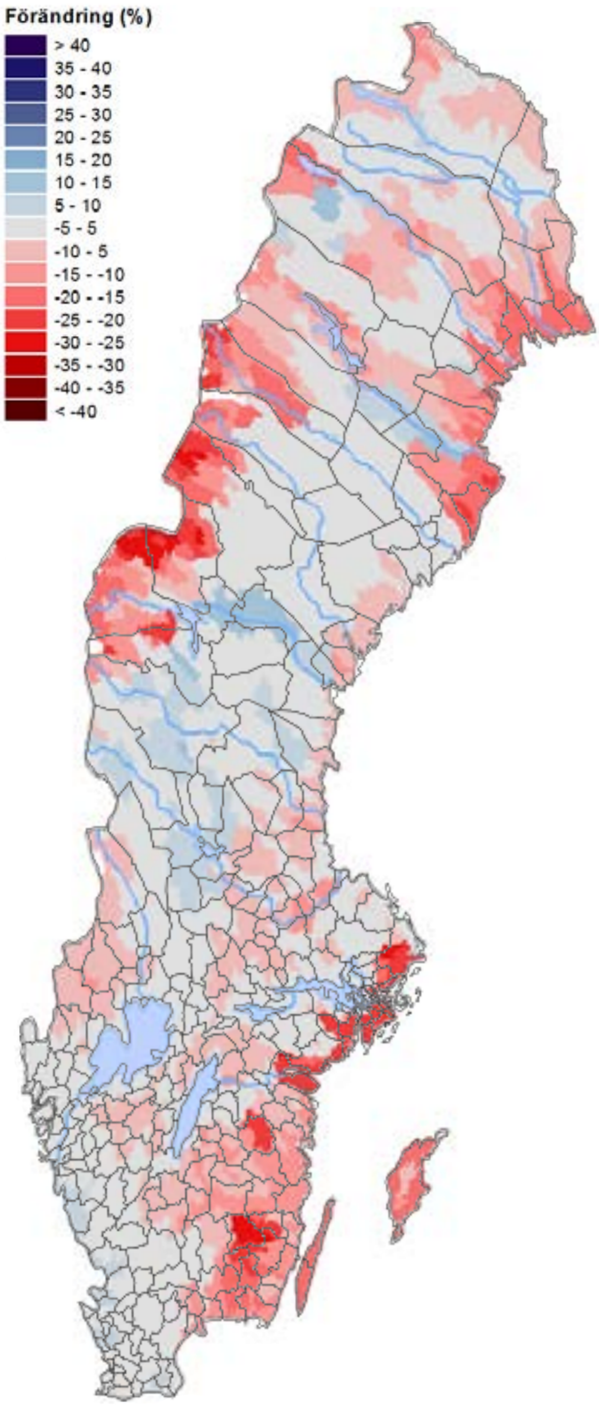

Figure 3.4: Decrease in WA for summer during 2021 - 2050 compared to the reference period 1961 - 1990.

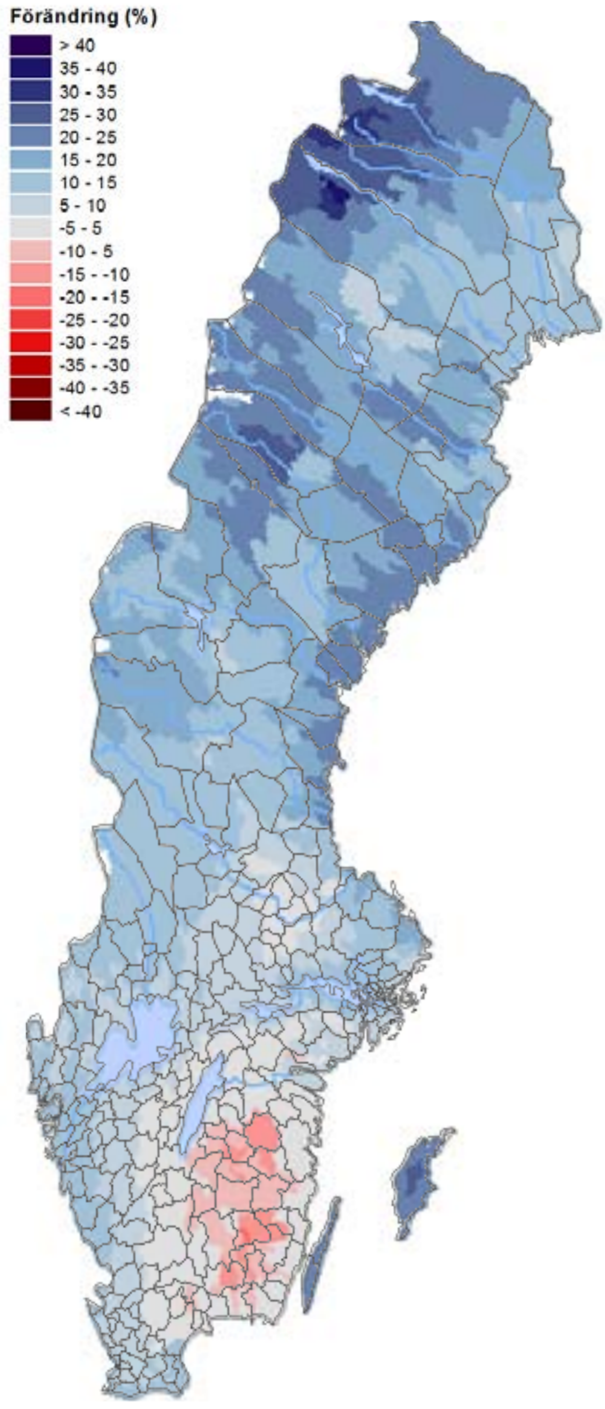

Figure 3.5: Decrease in WA for autumn during 2021 - 2050 compared to the reference period 1961 - 1990.

Table 3.1: Ranking of municipalities based on the average decrease in WA during spring, summer, and autumn. This table shows the 30 of 290 municipalities with most decrease in WA, the full ranking can be seen in Appendix 1.

No.	**Municipality**	**County**	**Spring** [-%]	**Summer** [-%]	**Autumn** [-%]	**Average** [-%]
1	Uppvidinge	Kronoberg	12,5	27,5	12,5	17,5
2	Lessebo	Kronoberg	12,5	22,5	12,5	15,8
3	Högsby	Kalmar	12,5	22,5	12,5	15,8
4	Kinda	Östergötland	7,5	22,5	12,5	14,2
5	Gotland	Gotland	22,5	17,5	0,0	13,3
6	Mörbylånga	Kalmar	22,5	17,5	0,0	13,3
7	Borgholm	Kalmar	22,5	17,5	0,0	13,3
8	Emmaboda	Kalmar	12,5	17,5	7,5	12,5
9	Trosa	Södermanland	12,5	22,5	0,0	11,7
10	Värmdö	Stockholm	12,5	22,5	0,0	11,7
11	Haninge	Stockholm	12,5	22,5	0,0	11,7
12	Nacka	Stockholm	12,5	22,5	0,0	11,7
13	Norrtälje	Stockholm	12,5	22,5	0,0	11,7
14	Solna	Stockholm	12,5	22,5	0,0	11,7
15	Huddinge	Stockholm	12,5	22,5	0,0	11,7
16	Österåker	Stockholm	12,5	22,5	0,0	11,7
17	Södertälje	Stockholm	12,5	22,5	0,0	11,7
18	Stockholm	Stockholm	12,5	22,5	0,0	11,7
19	Botkyrka	Stockholm	12,5	22,5	0,0	11,7
20	Vaxholm	Stockholm	12,5	22,5	0,0	11,7
21	Nyköping	Södermanland	12,5	22,5	0,0	11,7
22	Nynäshamn	Stockholm	12,5	22,5	0,0	11,7
23	Lidingö	Stockholm	12,5	22,5	0,0	11,7
24	Tyresö	Stockholm	12,5	22,5	0,0	11,7
25	Norrköping	Östergötland	12,5	22,5	0,0	11,7
26	Oxelösund	Södermanland	12,5	22,5	0,0	11,7
27	Sundbyberg	Stockholm	7,5	22,5	0,0	10,0
28	Järfälla	Stockholm	7,5	22,5	0,0	10,0
29	Täby	Stockholm	7,5	22,5	0,0	10,0
30	Danderyd	Stockholm	7,5	22,5	0,0	10,0

Table 3.2: Ranking of municipalities Sweden based on the population growth 2016-2019. The full ranking can be found in Appendix 1.

No.	Municipality	County	Population growth
1	Trosa	Södermanland	3,21%
2	Upplands-Bro	Stockholm	3,16%
3	Knivsta	Uppsala	3,00%
4	Sundbyberg	Stockholm	2,91%
5	Lekeberg	Örebro	2,61%
6	Järfälla	Stockholm	2,47%
7	Mölndal	Västra Götaland	2,42%
8	Habo	Jönköping	2,39%
9	Uppsala	Uppsala	2,39%
10	Värmdö	Stockholm	2,33%
11	Burlöv	Skåne	2,32%
12	Haninge	Stockholm	2,18%
13	Staffanstorp	Skåne	2,13%
14	Kungälv	Västra Götaland	2,13%
15	Svedala	Skåne	2,10%
16	Älmhult	Kronoberg	2,06%
17	Ale	Västra Götaland	2,00%
18	Örebro	Örebro	1,98%
19	Upplands Väsby	Stockholm	1,94%
20	Nacka	Stockholm	1,94%
21	Nykvarn	Stockholm	1,87%
22	Hammarö	Värmland	1,85%
23	Håbo	Uppsala	1,81%
24	Lund	Skåne	1,74%
25	Sigtuna	Stockholm	1,73%
26	Strängnäs	Södermanland	1,72%
27	Norrtälje	Stockholm	1,67%
28	Solna	Stockholm	1,66%
29	Huddinge	Stockholm	1,62%
30	Växjö	Kronoberg	1,61%

3.3.3 Water stress factor

The average decrease in WA and annual population growth are multiplied to create a water stress factor to understand which municipalities might experience water stress from both climate change effects and population growth. Table 3.3 shows the top 30 municipalities ranked by the calculated water stress factor.

Table 3.3: Preliminary ranking of municipalities based on the water stress. The top 30 municipalities are shown in order, the full ranking is presented in Appendix1.

No.	**Municipality**	**County**	**Water stress factor**
1	Trosa	Södermanland	37,49%
2	Sundbyberg	Stockholm	29,14%
3	Värmdö	Stockholm	27,16%
4	Haninge	Stockholm	25,42%
5	Järfälla	Stockholm	24,68%
6	Nacka	Stockholm	22,59%
7	Norrtälje	Stockholm	19,45%
8	Solna	Stockholm	19,32%
9	Huddinge	Stockholm	18,93%
10	Österåker	Stockholm	18,41%
11	Södertälje	Stockholm	17,26%
12	Stockholm	Stockholm	15,39%
13	Botkyrka	Stockholm	15,09%
14	Vaxholm	Stockholm	13,25%
15	Gotland	Gotland	12,56%
16	Nyköping	Södermanland	11,75%
17	Nynäshamn	Stockholm	11,70%
18	Täby	Stockholm	11,28%
19	Vallentuna	Stockholm	11,09%
20	Gnesta	Södermanland	11,07%
21	Lidingö	Stockholm	10,76%
22	Sollentuna	Stockholm	10,31%
23	Tyresö	Stockholm	10,11%
24	Örebro	Örebro	9,92%
25	Norrköping	Östergötland	9,64%
26	Eksjö	Jönköping	8,73%
27	Kalmar	Kalmar	8,73%
28	Mörbylånga	Kalmar	8,40%
29	Växsjö	Kronoberg	8,06%
30	Upplands-Bro	Stockholm	7,89%

Uppvidinge, which is ranked highest in WA decrease, is ranked 32 in water stress due to population growth of only 0,41%. Växjö, being ranked 71 in WA decrease with only -5%, is ranked 29 in water stress due to a population increase of 1,61%. Whether this is a fair assessment depends on what affects the water supply system most: population increase or decreasing WA. The water stress factor shows that especially municipalities in Stockholm county might experience water stress, as well as other municipalities in the south of Sweden.

3.3.4 Discussion

The water stress factor calculated in this thesis can function as a preliminary ranking to understand where in Sweden water stress might happen. The assessment is simplified and water stress depends on other factors as well. Firstly, some municipalities do not have water resources suitable for drinking water supply and rely on resources outside its borders or by the supply of a neighboring municipality.

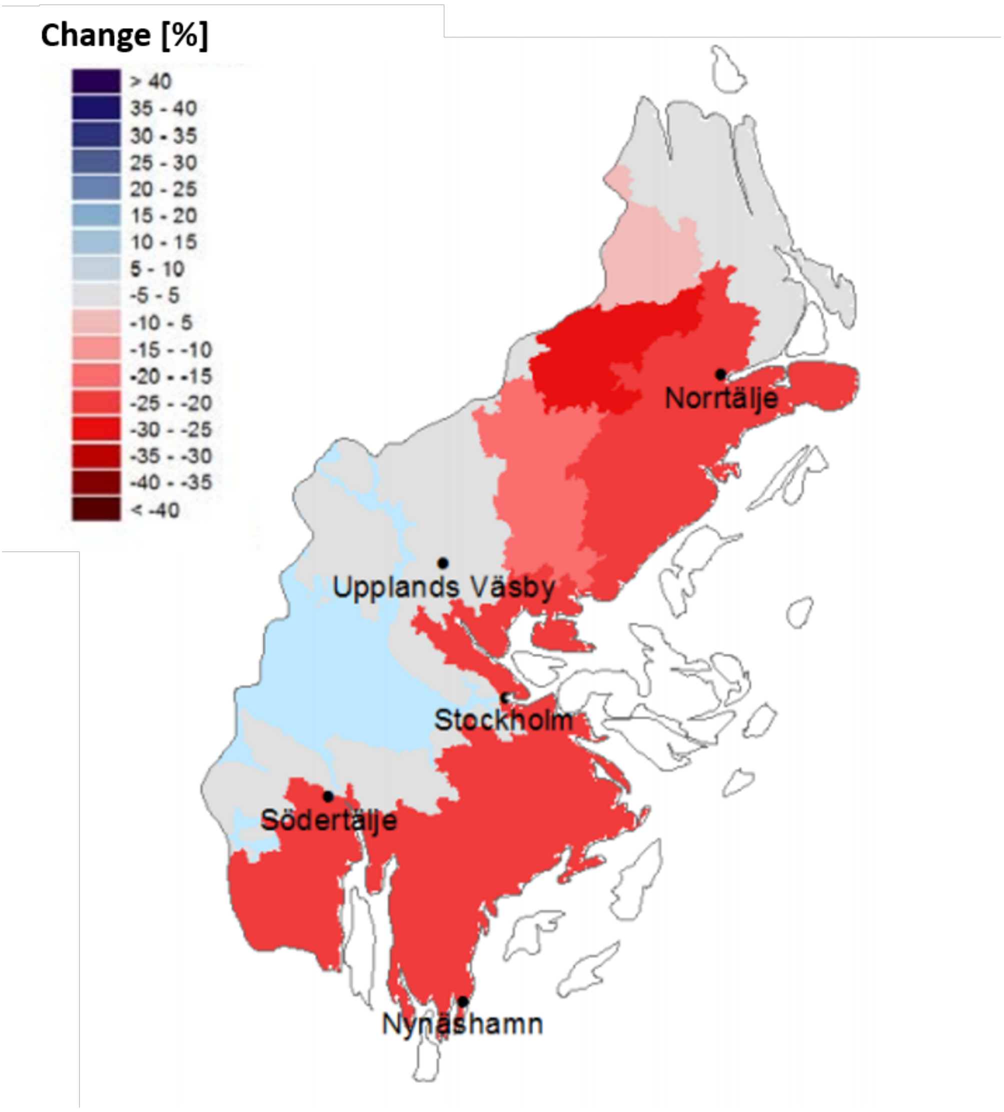

Figure 3.6: Decrease in water availability in Stockholm county during the summer. Around Lake Mälaren, it is visible that the change is smaller than the rest of the county (Asp et al., 2015).

For example, municipalities in Stockholm county mainly rely on lake Mälaren as a raw water source, which is not projected to have as much decrease in WA compared to many municipalities in Stockholm county, see figure 3.6 (Asp et al., 2015).

Better analysis can be made from ranking WA decrease after the major catchment areas in Sweden and connect them to drinking water supplies in the municipalities. However, the method used in the thesis is not completely invalid since decreased WA creates more demand for centralized supply systems from users (Hellström, 2020). Secondly, the water stress factor presented is based on the average WA decrease from spring to autumn but both WA and the demand vary over time, which is currently not represented in the analysis. All municipalities have increased WA during the winter, which is not represented in the factor. Thirdly, the water stress factor is misleading concerning municipalities with a large decrease in WA and a decreasing population. Of the municipalities with a decreasing population, the municipality with the most decrease of WA will be lowest in the ranking of water stress. This may not be representative since the municipality still will experience water stress from decreased WA. The water stress factor ranks municipalities with none or decreasing population change lower.

3.4 TQ2: What are the consequences of water stress from climate change and population growth on water quality management?

This section will present an overview of the water quality changes and unwanted effects from climate change effects and population growth encountered in the literature, the handbook by the Swedish Food Agency (2019), and the interviews. The unwanted effects have been grouped and are presented in table 3.4. The increased concentration of pharmaceuticals, pesticides, and herbicides has not been further studied since the effects did not appear in the municipal handbook or the interview and therefore seems to be less relevant than other unwanted effects.

Table 3.4: Unwanted effects on water quality due to climate change and population growth. The table shows the prevalence of effects in the international literature (Li, X., et al., 2020 and Jiménez Cisneros et al., 2014), Swedish literature, the handbook for municipalities on drinking water supply and climate change (Swedish Food Agency, 2019), and in the interview data.

Unwanted effects	**Literature**	**Swedish literature**	**Municipal handbook**	**Case municipalities**
Algal blooms, algal toxins, and cyanobacteria	x	x	x	Gothenburg Norrvatten
DOM, DOC, and brownification	x	x	x	Tingsryd
Warm water			x	Gothenburg Tingsryd
Microorganisms	x	x	x	Gothenburg Gotland Norrvatten Tingsryd
Saltwater intrusion	x		x	Gothenburg Gotland
Chemical pollution	x		x	Gothenburg Norrvatten

3.4.1 Algal blooms, algal toxins, and cyanobacteria

In the literature review by Li et al. (2020), the effects of eutrophication are concluded to be a hot spot in the literature on water quality and climate change. Algal blooms are expected to increase with higher temperatures and increased precipitation (Li et al., 2020). Algae are limited by nitrogen and phosphorus concentrations, which are also expected to increase on account of direct and indirect climate change effects as well as urban activities. Precipitation and increased sediment release due to higher temperatures will increase nutrient concentrations in water resources. Nitrogen loadings in particular are likely to be more sensitive to climate change effects (Wu and Malmström, 2015). Climate change effects will lengthen the vegetation period and increase agricultural activities, increasing the leaching of nitrogen and phosphorus into catchments (Swedish Food Agency, 2019).

Algal blooms can cause hypoxia, which increases the concentration of organic matter, which changes the smell and taste of water. Algal toxins created from algal blooms and cyanobacteria are hazardous for humans (Swedish Food Agency, 2019). The effects of algal blooms will be amplified when water quantity is low.

Among the case municipalities, both Gothenburg and Norrvatten are expecting algae and algal toxins to increase with climate change effects, especially when the weather is warm and dry. In Gothenburg, increased algae concentrations are currently not a challenge in water treatment, although filtration processes have to be intensified and carbon filters have to be replaced more often (Blom, 2020). In Norrvatten algal toxins are not a common occurrence and are removed with activated carbon. The interviewee from Norrvatten mentions that if cyanobacteria and algal toxins were to be more common, the WTP would have to install a permanent treatment step (Hellström, 2020).

3.4.2 DOM, DOC, and brownification

Increasing DOM and DOC concentrations due to climate change effects was a dominating subject in the Swedish literature review (see B.1). Increased DOC concentrations were also a hot spot in the international literature review by (Li et al., 2020) and mentioned as having an unwanted effect on drinking water quality and production.

DOM and DOC are expected to increase with higher temperatures and increased precipitation. However, because of milder winters and earlier snow melts the concentrations may increase in the winters and decrease in the summers (Tiwari et al., 2019). DOM and humic matter in water can cause changes in smell and taste of drinking water as well as changing the colour, called "brownification". DOM and DOC in drinking water can also promote the growth of microorganisms (Regan et al., 2017). Increased inflows of water into catchment will increase DOM and DOC in both groundwater and surface water.

The interviewee from Tingsryd (Axelsson, 2020) said that in the summer of 2018 the water exhibited higher turbidity, indicating an increase in organic matter.

3.4.3 Warm water

Warm water refers to when water is warm enough to change the experienced quality of it i.e. drinking water is perceived as less fresh and the taste changes when it is too warm. According to the Swedish Food Agency, drinking water should not be above 20°C (Swedish Food Agency, 2019).

Warm water is an unwanted effect of climate change mentioned by the interviewees from Gothenburg and Tingsryd. In the case of Tingsryd, the warm surface water is cooled down when it is infiltrated into the ground as the municipality uses artificial recharge for water supply (Axelsson, 2020). In Gothenburg, where only surface water is used, the problem of warm water is managed by mixing cooler water from the lake reservoirs Delsjöarna (see figure 3.2) with water from the river Göta Älv.

3.4.4 Microorganisms

Extreme rainfall events are expected to be the main driver of increased concentrations of microorganisms in freshwater, possibly causing waterborne diseases (Tornevi et al., 2014), but warmer water and lower water quantity might also increase the growth of some microorganisms (Swedish Food Agency, 2019). Groundwater is expected to be less affected by this than surface water, except for when the water table in aquifers is high (Swedish Food Agency, 2019).

Increased microbiological changes are expected by almost all case municipalities to affect water quality and water quality management after climate change effects. In Gotland, the interviewees expect increased microbiological activity but the treatment is deemed good enough to manage these changes (Tiouls, 2020). The water supply in Gothenburg relies on Göta Älv, but when the quality is not sufficient water is instead extracted from the lakes Delsjöarna. The interviewee from Gothenburg referred to the newly installed ultra filters as a way to mitigate microbiological contamination (Blom, 2020). At Norrvatten, the water treatment has in the past gotten remarks from the Swedish Food Agency on inadequate water quality. However, in the future expansion and renovation of the WTP, treatment steps are to be improved as well (Hellström, 2020).

3.4.5 Saltwater intrusion

Saltwater intrusion is a type of chemical pollution (Swedish Food Agency, 2019). When water quantity in aquifers, lakes, and rivers in coastal areas is low, saltwater can intrude into freshwater resources (Jiménez Cisneros et al., 2014), which is more likely with climate change-induced sea-level rise (Swedish Food Agency, 2019).

The interviewees from Gotland and Gothenburg mentioned saltwater intrusion as a potential effect in water quality due to climate change. In Gothenburg, when the sea level is high and there are strong winds from the ocean, seawater can enter the river Göta Älv from the harbor entrance (Blom, 2020). When the concentration of salt becomes too high, the inlet from the river is closed and water from Delsjöarna is used. In Gotland, saltwater intrusion can occur when groundwater levels are low. Interviewees from Gotland did not mention a specific method to mitigate saltwater intrusion, but the municipality is trying to increase the water quantity in aquifers (Tiouls, 2020, El Habash, 2020), which would be a way to avoid it.

3.4.6 Chemical pollution

In Sweden there are many areas of land contaminated by industries and the pollution might reach water resources after heavy rainfalls, floods, or landslides (Swedish Food Agency, 2019). This is something that Gothenburg municipality is worried about since there are contaminated lands along the river Göta Älv (Blom, 2020). If the water is contaminated, the intake of water from Göta Älv has to cease.

Another type of chemical pollution that can occur from heavy rainfalls and extreme water flows is overflown sewage systems where untreated wastewater ends up in the raw water source. This was mentioned by the interviewee at Norrvatten (Hellström, 2020).

3.4.7 Discussion

In the Swedish literature review, DOM and DOC concentrations were the focus of most of the literature on water quality and climate change in Sweden. However, only Tingsryd mentioned increased turbidity, which can indicate increased organic matter. Many of the articles on DOM and DOC in the literature review focus on boreal landscapes, which are mostly located in the northern part of Sweden. This may be the reason DOM and DOC concentrations were not mentioned by the other case municipalities.

In the interview with Älmhult municipality, the interviewee did not mention any expected or experienced water quality changes from climate change effects, nor did the municipality's water supply have any challenges with water quality (Ahlberg, 2020). The result may be a sign of how the interview study might be insufficient. The interviewees were asked about challenges in water quality treatment which is a subjective question. If Älmhult is experiencing some quality changes, the interviewee might not think of them as challenges. The difference in answers between the case municipalities indicates that the role or personality of an interviewee affects their answer. Because of the potential faults in the interviews and the low number of case municipalities, the interview results are most useful to provide examples of water quality changes.

3.5 TQ3: How well is Sweden equipped to cope with changes in water quantity?

The thesis question is complex and many factors were be considered in answering it. From the literature, reports, and the interviews, four factors are deemed important to answer TQ3: water availability, water treatment and delivery system capacity, population growth and demand, and inter-municipal cooperation. Each factor is explained and examples from the municipalities are provided together with data from SWWA.

3.5.1 Water availability

The results of TQ1 show that large parts of Sweden will experience decreased water availability (WA) during the warmer months of the year. In southeast Sweden, this might also be an annual average decrease in WA (Eklund et al., 2015). Decreased WA not only results in less water available for drinking water supply but also increased demand from residents connected to municipal supply systems (Hellström, 2020). In the Sustainability Index Survey by SWWA, municipalities are asked if WA is currently sufficient and if it will be in the future. 11% of participants responded that WA is not enough today nor for the future, and 23% responded that it will not be enough in 20-30 years (Bäckström and Svensson, 2020), see figure 3.7. Although, it is difficult to draw conclusions based on the data (see 2.1.3).

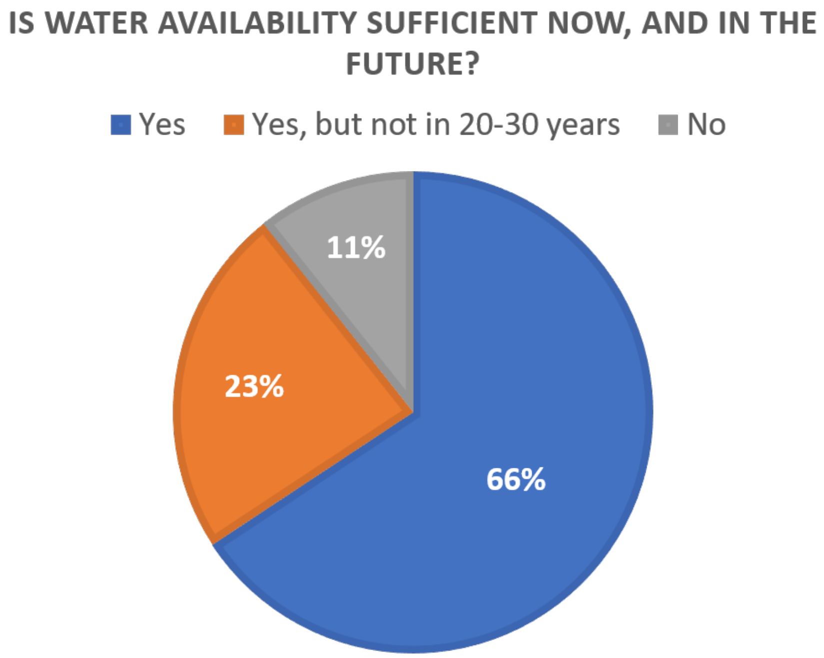

Figure 3.7: Data from the Sustainability Index Survey (Swedish Water and Wastewater Association, 2020 Bäckström and Svensson, 2020) on current and future water availability in municipalities.

Among the case municipalities, Gotland is having most problems with water quantity, one of their main challenges is increasing the water quantity to secure the water supply (Tiouls, 2020, El Habash, 2020). The annual precipitation is considered enough the meet the future demand, but drainage from agriculture, thin soil layers, and impermeable rock lead to run-off into the ocean (Dahlqvist et al., 2019). The storage capacity is not enough to store the precipitation from the winter and satisfy the needs in the summer. In Tingsryd 2018, one of the groundwater reservoirs almost ran out of water due to larger extractions and decreased recharge (Axelsson, 2020).

3.5.2 Water treatment and delivery system capacity

In the summer of 2018, many municipalities experienced not only decreased WA but also limitations in the water supply systems. Many days with heatwaves resulted in a higher demand, which the production in some municipalities could not handle. Water quantity and availability can both be seen as a part of the water supply system. However, this section covers the technical part of the system, rather than the natural system.

In the Sustainability Index Survey, municipalities were asked to provide the production utilization on the most intense day of production for their WTP serving most residents (Bäckström and Svensson, 2020), see figure 3.8. Regardless of size, many municipalities in Sweden are utilizing a large part of their production capacity. SWWA uses 80% as the passing grade for production utilization (Swedish Water and Wastewater Association, 2020), which many municipalities are above. This data is not entirely reliable(see section 2.1.3) and is only presented to understand that many municipalities' water supply is limited by other than water quantity.

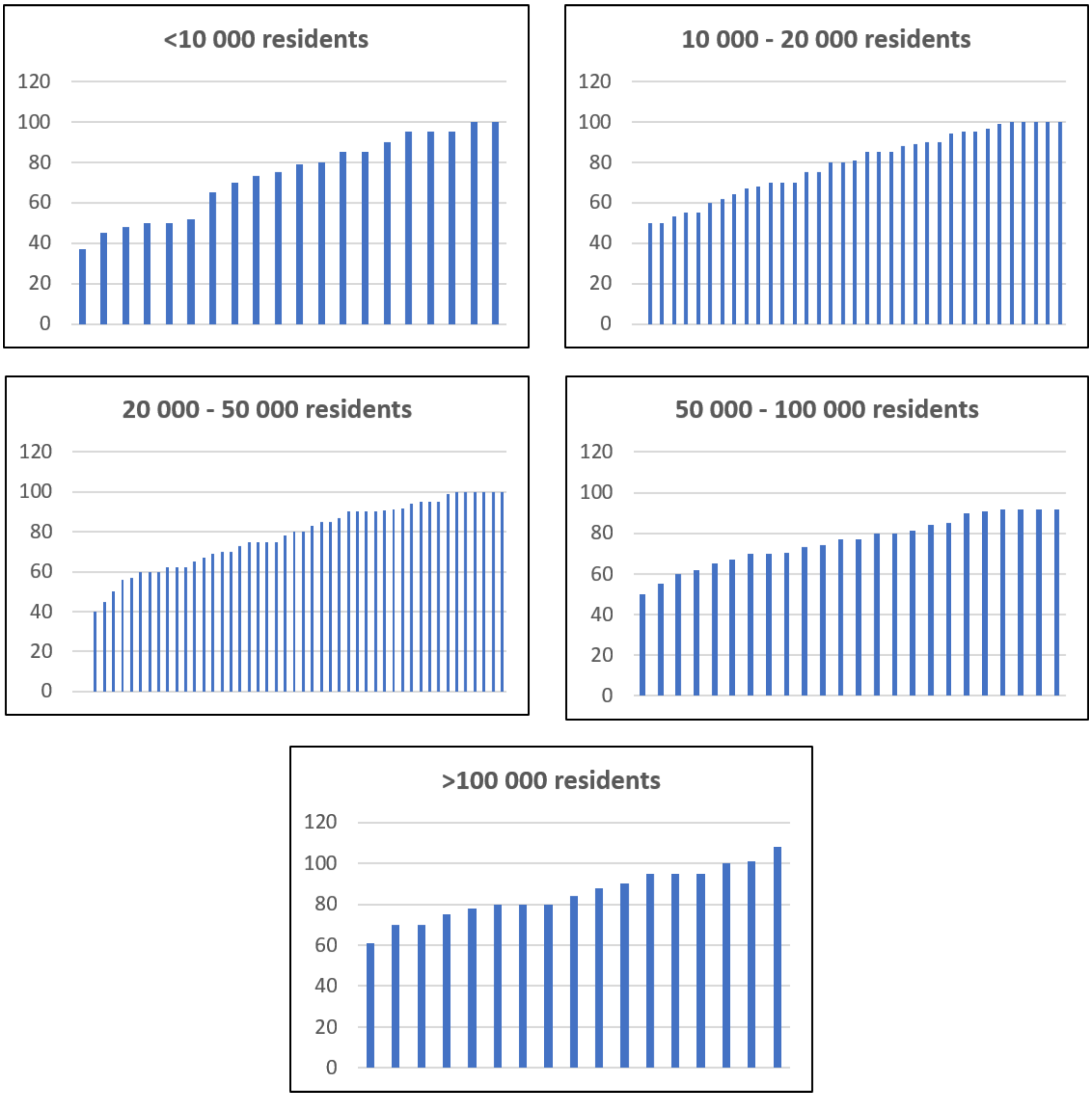

Figure 3.8: Data from the Sustainability Index Survey on the utilization of municipal water production capacity on the most intense day of production. The municipalities are grouped after the number of residents and each bar represents the utilization of one municipality.

There are different types of limitations in water supply, this variation became apparent in the interviews with the case municipalities. In the summer of 2018, Älmhult and Norrvatten did not experience any water shortages for the water supply, but both were near the production and treatment capacity of the WTPs. In Älmhult, the production would have failed to keep up with the demand unless the municipality had issued the prohibition against urban irrigation (Ahlberg, 2020). Älmhult is currently rebuilding its artificial recharge plant to manage the projected population growth, and Norrvatten is in the planning phase of doing the same (Hellström, 2020). In 2018, Tingsryd's WTP nearly reached its production capacity as well as the legal water extraction limit (Axelsson, 2020). According to SWWA, about a tenth of the WTPs utilizes over 90% of the legal limit (Swedish Water and Wastewater Association, 2015). In Gothenburg, it was the distribution network that limited water supply, and in some places, there was almost not enough pressure in the pipes to deliver water (Blom, 2020). When asked about water supply limitations, the interviewees form Gotland not only mentioned water quantity but also water quality (Tiouls, 2020). The groundwater on Gotland has an unusually high concentration of boron, which exceeds the allowed concentrations in Sweden. In the treatment to remove boron, the water production is less efficient thus further lowering water supply. Even though the case municipalities experienced issues in the summer of 2018, none of them failed in delivering water to their recipients. However, all of the municipalities, except Gothenburg, issued a prohibition of urban irrigation and urged citizens to be economic in their water use. Gothenburg also urged its citizens to not use too much water.

3.5.3 Population growth and demand

Population growth drives demand and consequentially increases the utilization of water supply capacity. It seems to be an important driver of expanding the water supply system since both Älmhult and Norrvatten are experiencing high population growth and are expanding the WTPs to meet the projected populations. Norrvatten is still in the planning phase and their current water work is currently managing supply for the projected population until 2026 - 2030. In Älmhult, the new WTP is nearly ready. It is built to manage the population growth until 2030 and in a way so it can be further expanded to manage the projected population in 2050. Since Gothenburg is trading water with nearby municipalities the supply utilization will also depend on the population growth in the surrounding municipalities. The population growth for the case municipalities can be seen in table 3.5 together with the municipalities in the Gothenburg water-transfer network and the municipalities in the federation Norrvatten.

Älmhult has the largest population growth of the municipalities and the expansion of Älmhult WTP was seen as being just in time for keeping up with demand (Älmhult municipality, n.d.). The average daily production of Älmhult WTP and Gothenburg's two WTPs are presented in figures 3.9 and 3.10 together with the production capacity and the population of each municipality. Note that the population-curve is on the secondary axis.

Table 3.5: Population growth in the case municipalities. Under Norrvatten, the municipalities in its water supply federation are listed. Under Gothenburg, the municipalities for which the supply system delivers to or receives water from are listed.

Municipality	**Population growth** [%]
Gotland	0,94
Göteborg	1,30
Ale	2,00
Öckerö	0,43
Partille	1,57
Mölndal	2,42
Kungsbacka	1,49
Norrvatten	-
Danderyd	0,35
Järfälla	2,47
Knivsta	3,00
Norrtälje	1,67
Sigtuna	1,73
Sollentuna	1,24
Solna	1,66
Sundbyberg	2,91
Täby	1,13
Upplands Bro	3,16
Upplands Väsby	1,94
Vallentuna	1,33
Vaxholms	1,14
Österåker	1,58
Tingsryd	0,01
Älmhult	2,06

As can be seen in table 3.5 and figure 3.10, large population growth has happened in Älmhult in the latest years. With the recent expansion, not visible in the figure, the production is estimated to manage the projected population growth until 2030. In figure 3.9 the capacity increase is from the installation of ultrafilters in WTP Lackarebäck. Both the population for Gothenburg municipality and the total population for Gothenburg and the five neighboring municipalities with transfer possibilities is presented.

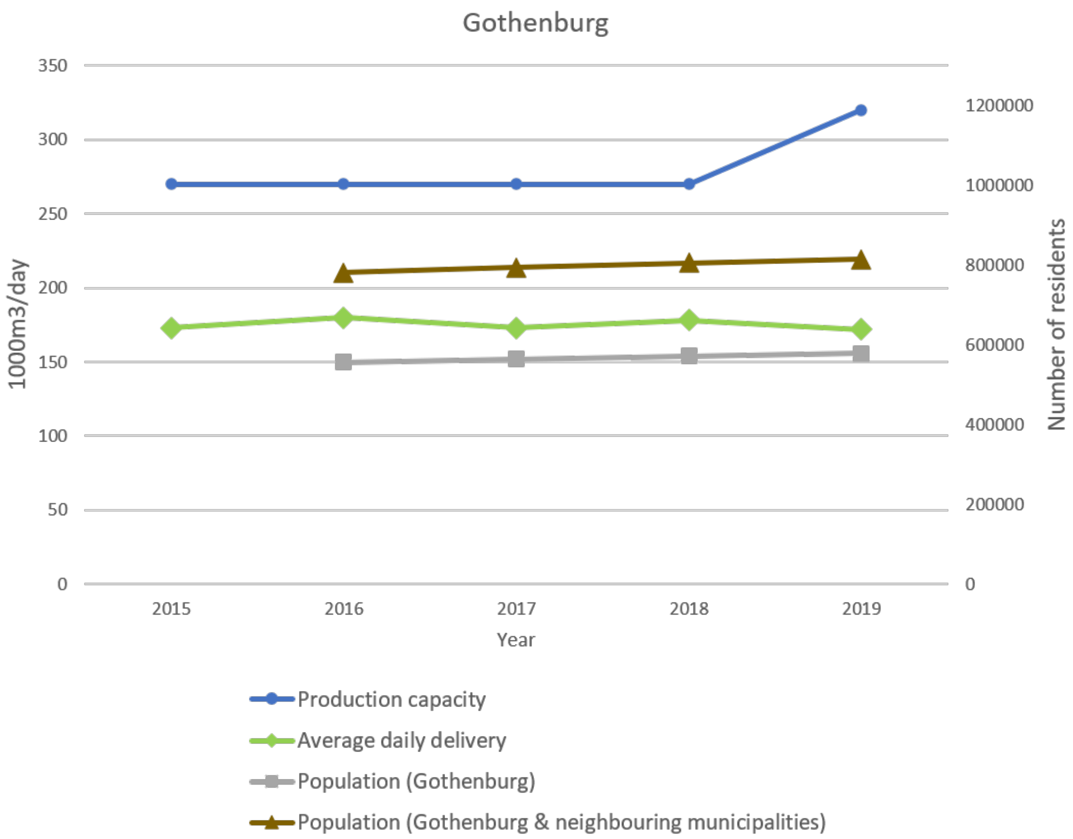

Figure 3.9: Average daily delivery and production capacity of water in the WTPs Alelyckan and Lackarebäck in Gothenburg. On the second axis is the municipality's population growth shown together with the total population of Gothenburg and the five neighbouring municipalities with transfer possibilities.

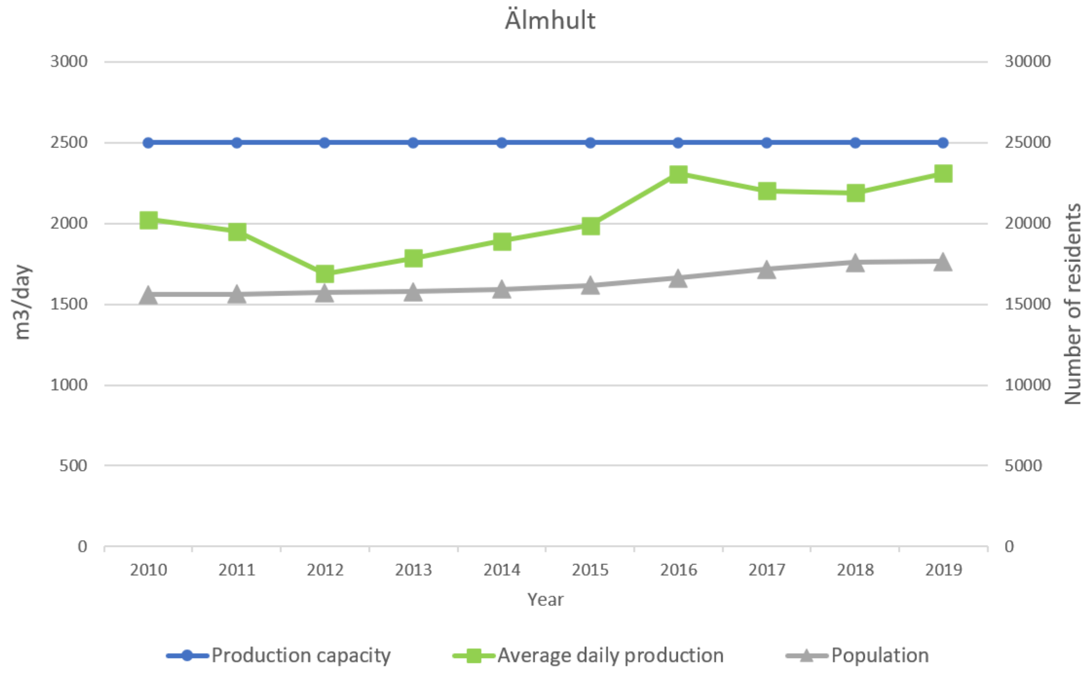

Figure 3.10: Average daily production and production capacity of Älmhult's largest WTP, and the municipality's population on the secondary axis.

3.5.4 Inter-municipal cooperation

In the Sustainability Index Survey by SWWA, it was concluded that small municipalities not part of inter-municipal cooperation is less likely to manage strategic planning and does not have the resources to make the necessary investments for sustainability (Swedish Water and Wastewater Association, 2020). The Public State Report on drinking water supply also states that increased cooperation across the municipality borders is an important factor in securing future water supply (Dricksvattenutredningen, 2016).

Cooperation between municipalities can take different forms. Norrvatten is a federation of 14 municipalities that has the responsibility to supply water to the residents (Norrvatten, 2017). Gothenburg is a part of the cooperation Gothenburg Region but each municipality still manages its water supply. Gothenburg municipality can buy and sell water to and from neighboring municipalities but Gothenburg Region coordinates the strategic planning of the water supply (Gothenburg Region, 2014).

One of the main reasons to enter cooperation or a federation is that municipality borders are not adapted after water resources and not all municipalities have resources suitable for supply (Gothenburg Region, 2014). The interviewees from

Gothenburg expressed the value of being a part of regional cooperation.

3.5.5 Discussion

It is difficult to answer the question of how well the municipalities of Sweden can cope with changes in water quality. The question is complex with many aspects and this thesis has explored four of them: water availability (WA), water supply capacity, population growth and demand, and inter-municipal cooperation.

Regarding WA, Gotland is a municipality already experiencing inadequate water supply during the warmer part of the year. Despite this, the interviewees believe that the net precipitation on the island is enough to meet the future water supply (Tiouls, 2020). However, it is uncertain whether this applies to the 11% of municipalities that answered "no" in the Sustainability Index Survey on whether the current WA is adequate to meet the demand.

Several municipalities in Sweden already utilize a large part of the production capacity and the example of Älmhult shows that rapid changes in population can be difficult to keep up with. Figure 3.10 shows that only a few years of increased population growth can result in insufficient production capacity. Sudden population growth is also a challenge because of the time it takes to decide on, plan, and build a new WTP. Neither the Älmhult, Gothenburg or Stockholm interviewees were worried about decreasing water quantity, they were more worried about how water supply can meet the demands during warm and dry seasons

Two of the case municipalities are significantly smaller than the others: Älmhult and Tingsryd. None of the interviewees in the two municipalities mentioned that as a challenge in securing future water supply or any plans on increasing cooperation. However, this was not specifically asked in the interviews. The open question was: “what challenges does the municipality have in securing the future water supply?”.

Even though none of the case municipalities failed in delivering water to the residents, it was necessary to either issue an irrigation ban, urge residents to use less water or both. Irrigation bans are a recurring measure in some municipalities.

3.6 TQ4: What potential do different water supply technologies and other solutions have in the Swedish context?

For TQ4, this thesis has compiled what technologies and solutions there are to increase water supply. Some alternative solutions for water supply from the literature are presented and thereafter the solutions from the case municipalities are compiled and described.

3.6.1 Alternative water supply systems

Under climate change effects and population growth, many municipalities and cities are looking beyond traditional water extraction to increase water supply. Examples of this were found in the literature, specifically case studies from Mexico (Mautner et al., 2020), Qatar (Ahmad and Al-Ghouti, 2020), Australia (Bekele et al., 2018), and Los Angeles (Ashoori et al., 2015). Solutions assessed in these case studies are: repairing water supply distribution network, importing water, wastewater treatment and using non-potable water for irrigation, desalination, demand-side management, and different methods of managed aquifer recharge (MAR). Examples of MAR methods mentioned are infiltrating treated wastewater to aquifers and enhancing groundwater recharge from rainfall.

3.6.2 Swedish water supply system and solutions

The most common ways of supplying drinking water in Sweden are surface water extraction, groundwater extraction, and extracting surface water for artificial recharge. These technologies are presented here in the Swedish context with arguments on their potential during climate change and population growth. Other solutions that have come up in the interviews with the municipalities are also listed and discussed.

3.6.3 Groundwater extraction

Most of the WTPs in Sweden use groundwater extraction and the majority of those plants supply water to less than 2000 residents (Swedish Water and Wastewater Association, n.d.). Groundwater quality is generally better than surface water and requires fewer steps in the treatment process. Groundwater extraction use has somewhat decreased in the favor of surface water extraction (Statistics Sweden, 2017b), perhaps following trends in population growth in favour of larger cities.

Water supply using groundwater will be more challenging in southeast Sweden where annual average WA will decrease. Most of the municipal water supply is using larger aquifers for which the minimum and maximum levels will increase in the north of Sweden and decrease in the south (Vikberg et al., 2015). In Gotland, supply is increased by finding new aquifers suitable for supply and potentially enhancing recharge with water retention measures to mitigate against decreasing water quantities (Tiouls, 2020).

3.6.4 Surface water extraction

Of the 1600 WTPs in Sweden, only 170 are treating surface water, even though surface water extraction constitutes about 70% of the Swedish water supply. Generally, surface WTPs are larger and supply water to more residents than groundwater treatment plants. Surface water is often of poorer quality and requires more steps in the treatment process to ensure healthy water with good taste (Swedish Water and Wastewater Association, n.d.).

The case municipalities using a surface water treatment, Gothenburg and Stockholm, are not worried about the availability of water from climate change and population growth. However, it is important to note that these municipalities use water from two of the largest lakes in Sweden, Vänern (origin of Göta Älv) and Mälaren. Surface water is also dependent on groundwater recharge. In southeast Sweden, where the annual water availability decreases, so will surface water quantity. Regarding water quality, it is possible to add or improve treatment steps to ensure good quality (Swedish Food Agency, 2019).

3.6.5 Artificial groundwater recharge

About 130 WTPs are using artificial groundwater recharge in Sweden. In the literature, different types of groundwater enhancement are called managed aquifer recharge (MAR). MAR is mentioned in the literature as a technology to mitigate low water quantity in aquifers also avoiding unwanted effects such as saltwater intrusion (Bekele et al., 2018).

Since artificial groundwater recharge in Sweden is dependent on surface water, the parts of Sweden that will experience decreasing WA might also experience less surface water to use for artificial recharge. The case municipalities using artificial recharge are satisfied with the technique and did not mention any future challenges with the technique. It provides water with good quality and taste, and infiltration into the ground keeps the water temperature down (Ahlberg, 2020, Axelsson, 2020).

3.6.6 Desalination

Desalination plants are proliferating globally as an alternative for increasing water supply. The main driver for using desalination for water supply is a lack of freshwater resources (Pinto and Marques, 2017). The key benefit of desalination is that the method does not put any stress on freshwater resources and could potentially provide an almost unlimited quantity of water. However, it is a costly and energy-intense process (Pinto and Marques, 2017).

There are only a few desalination treatment plants in Sweden, of which Gotland manages two. The desalination for drinking water is done with brackish water from Östersjön through reverse osmosis. Desalination is 25 times more costly than groundwater extraction in Gotland. Desalination plants have high unit costs which can depend on the location of the plant (Sjöstrand, 2019). One of the interviewees from Gotland does not think desalination is the solution for Gotland's water scarcity, but rather a complement to the current supply. If possible, it is also preferable to use freshwater for supply rather than seawater (Tiouls, 2020).

3.6.7 Treatment of wastewater

A circular solution to increase water supply is to treat wastewater for non-potable use such as irrigation. This option was considered for Gotland (Sjöstrand, 2019) and is thought to have potential both in terms of costs and increasing WA. However, the greatest barrier for using it is how people feel about using former wastewater. According to the interviewees at Gotland, residents in Gotland are more open to it than the rest of Sweden, but the level of acceptance is currently not sufficient to be an option in increasing water availability (Tiouls, 2020).

3.6.8 Inter-municipal transfers

Some municipalities build their water distribution network across municipal borders. Gothenburg region is a good example of this as the network stretches over a total of 8 municipalities and the municipalities trade water between each other. Norrvatten can transfer water to and from the Stockholm region's other large supplier, Stockholm Avfall och Vatten. However, in the summer of 2018 when Norrvatten would have needed transfers from the neighbouring organization, both were nearing the water production capacity. Gothenburg is moving forward with regionalization; new water supply is planned with the whole region in mind and with increasing transfers between municipalities. The transfers are also good for redundancy. If production must slow down in Gothenburg due to quality changes it is possible to buy water from Kungsbacka or Mölndal (Blom, 2020).

3.6.9 Demand side management

None of the case municipalities named demand-side management as a long-term solution to an increasing water supply. However, during the summer of 2018, 30% of municipalities prohibited urban irrigation (Sjökvist et al., 2019) and urged their citizens to be economic in their water use. This was introduced again in many municipalities in the summer of 2019 in some municipalities, it happens every year. Some municipalities created information campaigns or urged their residents to be economic with water use in the summer of 2018. In Gothenburg, a decrease in water use was visible (Blom, 2020) and at Norrvatten it was not visible (Hellström, 2020).

3.6.10 Leak management

Leaks in water distribution systems are difficult to avoid (Malm et al., 2015) and lead to water losses, loss of profits, and possibly pollution or put a load on the wastewater systems. Leaks were only tangentially mentioned by the interviewees but are an important factor to bring up. About 15% of produced water in Sweden is lost in leaks (Swedish Water and Wastewater Association, 2019a). This also varies greatly between municipalities, both how much is lost but also how costly leaks are to repair. Pipes underneath urban areas are often more costly and complicated to replace and repair than those in less populated areas (Friberg, 2020). This is possibly represented in the municipalities Gothenburg and Gotland. Gotland, which is less densely populated and has a problem with water quantity only has about 11% leaks (Tiouls, 2020). Gothenburg, which is densely populated and has larger water resources has about 23% leaks. In a case study on Gothenburg, it was shown to be more cost-effective to manage leaks in a reactive approach even though the city has a high percentage of leaks (Malm et al., 2015).

3.6.11 Water retention

To increase WA, different water retention methods can be used for adapting to extreme events such as drought and floods, as well as restoring ecosystems and landscapes (European Commission, 2019). There are measures for both urban and rural landscapes.

In Gotland, where water quantity is limiting the supply system, studies are underway on how groundwater recharge can be increased. Together with the Swedish Environmental Research Institute, the region has created a test site for different water retention methods. If runoff can be directed to surface and groundwater reservoirs, the precipitation is expected to be enough for future supply. One urban retention method brought up in the interview was connecting rainfall harvested from rooftops to a groundwater reservoir. The interviewees saw potential in water retaining methods to manage the future demand since it is preferable to use freshwater and the region will have enough precipitation (Tiouls, 2020, El Habash, 2020). None of the other case municipalities named water retention as a solution for water stress, most likely since water quantity is not limiting water supply as severely as in Gotland.

Rainfall harvesting from domestic roofs is a type of urban water retention measure (European Commission, 2019) and small scale managed aquifer recharge where rainfall is led from house roofs to groundwater wells to enhance the recharge. This method is being tested on Gotland and the recharge it supplies is marginal, but the interviewee thinks there is potential in such solutions as well (Tiouls, 2020).

3.6.12 Water supply increase in the case municipalities

The current and either potential or planned water supply of each case municipality is presented in table 3.6. The options labeled *new resource* means that future technology or solution would require a new water resource.

The municipality of Gothenburg is currently not planning to expand its production but instead investigating how the regional organization can increase the water supply. The Gothenburg region is considering expanding the supply in neighboring municipalities to Gothenburg. Alternatives explored are either to expand the current artificial recharge in Kungsbacka or using artificial recharge in Lerum. Gotland, which is currently mostly dependent on groundwater extractions, foresees most potential in finding new aquifers for groundwater extraction coupled with retaining precipitation and runoff on the island. The municipality is complementing the current supply with two desalination facilities. Norrvatten is planning to expand its current surface water treatment to meet the future demand for water and quality. The food industry in Tingsryd wants to expand their business, so expanding the largest WTP (artificial recharge) with infiltration from a supplementary stream or lake is considered Tingsryd municipality, 2020. The municipality of Älmhult is in the end phase of expanding the artificial groundwater recharge supply to meet the future demand from the projected population increase.

Table 3.6: Water supply technologies and solutions in the case municipalities. The table shows the current and planned/potential use of technologies and solutions for water supply in the case municipalities

Technology/solution	Used by:	Potential or planned supply increase by:
Surface water extraction	Gothenburg	Norrvatten
	Norrvatten	
	Gotland	
Groundwater extraction	Gotland	Gotland (new resource)
	Tingsryd	
	Älmhult	
Artificial recharge	Tingsryd	(Gothenburg region)
	Älmhult	Tingsryd (new resource)
		Älmhult
Alternative solutions		
Desalination of brackish water	Gotland	
Water retention measures (Rainwater harvesting)		Gotland
Alternatives for irrigation (e.g. treatment of wastewater)		Gotland
		Norrvatten
Inter-municipal transfers	Gothenburg	Gothenburg
	Norrvatten	Norrvatten
Leak management	All	All
Demand side management (tactical, e.g. inform users or irrigation ban)	All	All

3.6.13 Discussion

Most of the solutions found in the literature were mentioned in the interviews. However, most of them were mentioned by the interviewees from Gotland, which is not surprising since the municipality is relatively large and has long had a problem with water supply. It is possible that solutions explored and used on Gotland, such as desalination and water retention measures, will be more common in municipalities in southeast or coastal municipalities that are already experiencing seasonal water shortages.

Table 3.6 shows that the case municipalities are more likely to stay with the current water supply technology. This is also not surprising since the solutions in place are often chosen based on the resources available. Taking only the interviews into consideration, artificial groundwater recharge seems to have a lot of potential in increasing the supply of water. However, the percentage of water supplied from artificial recharge has been more or less stagnant in Sweden (Statistics Sweden, 2017b). Water supply in a municipality is unique and depends on the resources available, location of the municipality, and size of production. Therefore, the supply increase will probably develop differently in each municipality. A study by Sjöstrand (2019) created a marginal abatement cost curve (MACC) for Gotland on different measures to increase water quantity and supply. Figure 3.11 shows the cost of supply interventions that can be made by the municipality.

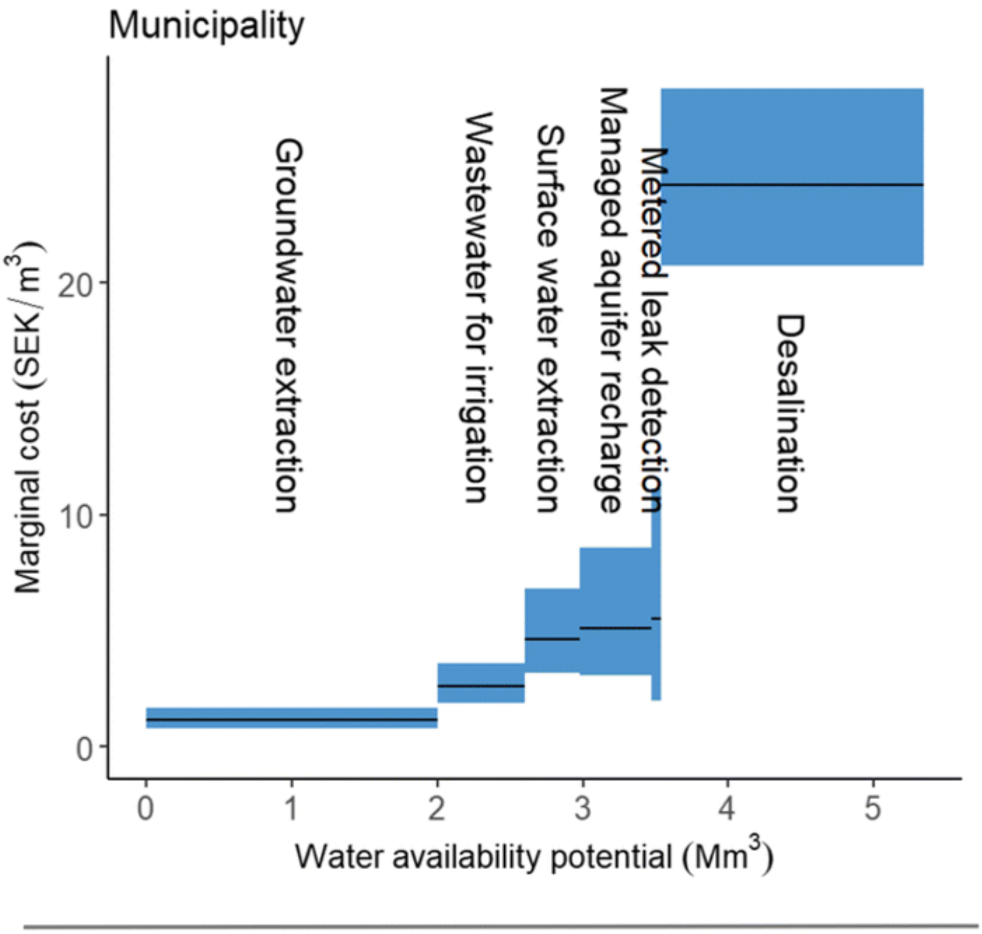

Figure 3.11: Marginal abatement cost curve for municipal measures to increase water availability on Gotland (Sjöstrand, 2019). The figure is from Sjöstrand (2019).

On Gotland, groundwater extraction is a supply option with both high potentials for supply increase and low costs (Sjöstrand, 2019). However, a study like this would look different in a municipality like Gothenburg, which has large surface water resources and a higher number of residents.

It is not certain that the best solution to increase water supply in a municipality is through municipal interventions. In the same study by (Sjöstrand, 2019) supply increase solutions for agriculture, households, and industry are presented as well. Figure 3.12 shows that options for irrigation in agriculture have the potential to increase supply on Gotland. In this study, the most cost-efficient solution is retrofitting shower heads to reduce the use, an action controlled by households. Tingsryd mentioned cooperation with the food industry as a way to increase water supply (Axelsson, 2020), but such cooperation was not mentioned by the other municipalities. This may be due to the format of the interviews.

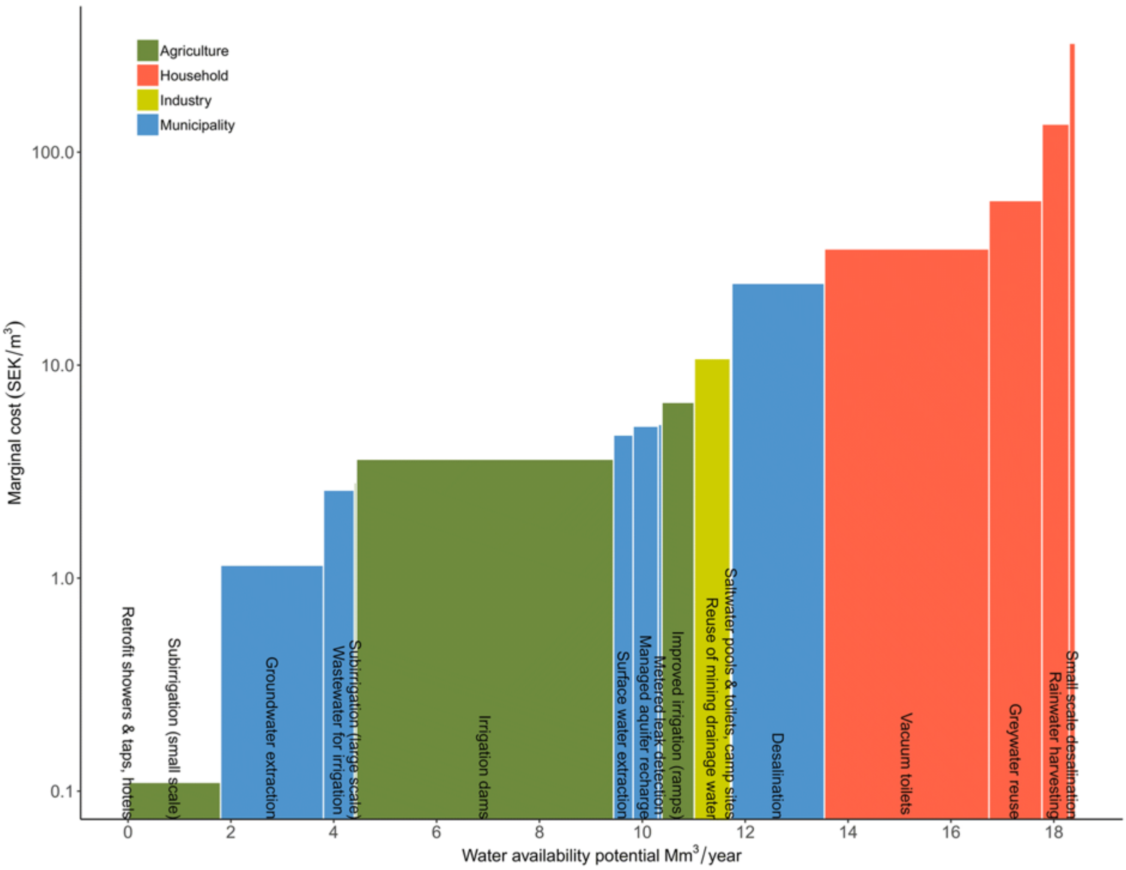

Figure 3.12: Marginal abatement cost curve for measures to increase water availability on Gotland (Sjöstrand, 2019). The figure agricultural, household, industrial and municipal measures to increase water availability

4
Conclusions and future studies

This thesis has attempted to answer four questions about Sweden's water future after climate change effects and population growth.

- TQ1: Where is water stress likely in Sweden under climate change and population growth?
- TQ2: What are the consequences of water stress for water quality management?
- TQ3: How well is Sweden equipped to cope with changes in water quantity and quality?
- TQ4: What potential do different water supply technologies and other solutions have in the Swedish context?

In TQ1 a water stress factor was calculated to make a preliminary ranking of which municipalities might experience water stress from climate change and population growth. According to the water stress factor, municipalities in southeast Sweden in counties Södermanland, Stockholm, and Gotland will experience more water stress than the rest of Sweden. However, the water stress factor is misleading because WA is being determined by how it will change inside municipal borders rather than after catchments and drinking water resources.

In TQ2, unwanted effects on water quality were grouped and potential changes were described with examples from the case municipalities. DOM and DOC concentration is a hot spot in the Swedish literature, but only one municipality mentioned organic matter as a water quality change. Älmhult was the only municipality not having any water quality challenges. This may be an indication of how interview questions and interviewees affect the result. All the other municipalities mentioned increasing microbiological activity as a consequence of climate change. Installing more powerful treatment has been done in Gothenburg and is expected to be done in Norrvatten to deal with quality changes.

In TQ3, water availability (WA), water supply capacity, population growth and demand, and inter-municipal cooperation were concluded to be factors important in assessing whether Sweden's municipalities can cope with decreased water quantity. It was concluded that many municipalities are and will be experiencing too little WA to satisfy the demands during the summer. Furthermore, water supply capacity in many municipalities is not enough ta manage sudden demand increases from population growth and water quantity. Water supply limitations in the case municipalities are water quantity, legal water extraction limit, distribution network, water quality requirements, and production capacity. Inter-municipal cooperation is important because of the distribution of water resources and the difficulty of future challenges. Small municipalities not part of inter-municipal cooperation is less likely to manage strategic issues, however, none of the small case municipalities mentioned this as a problem.

In TQ4, different solutions and technologies for increasing water supply were explored. The case municipalities are most likely to expand the current supply technology. In Gotland, alternative solutions to increase supply are tested, but the interviewees said that water retention measures are preferable to desalination.

4.1 Future studies

The analysis in this thesis was simple regarding the complexity of water supply, each thesis question could have been explored on it is own in more detail. For TQ1, the suggestion is to redo the water stress factor by pairing catchment areas and drinking water resources with municipalities, rather than use the municipal borders. With an improved ranking, the municipalities likely to experience water stress should be further examined using GIS data and hydrological modelling. With detailed hydrological models and data on the demand for water, water stress can be predicted with greater temporal and spatial precision.

The factors found important in TQ3 were based on what was said during the interviews and reports. Other factors could be more relevant which could be determined by a future study. An interview study focusing on what is important in coping with water quality changes could be done.

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A

TQ1: Rankings of municipalities

A.1 Ranking by WA decrease

Table A.1: Complete ranking of municipalities by average WA decrease from used in TQ1.

No.	Municipality	County	Spring [-%]	Summer [-%]	Autumn [-%]	Average [-%]
1	Uppvidinge	Kronoberg	12,5	27,5	12,5	17,5
2	Lessebo	Kronoberg	12,5	22,5	12,5	15,8
3	Högsby	Kalmar	12,5	22,5	12,5	15,8
4	Kinda	Östergötland	7,5	22,5	12,5	14,2
5	Gotland	Gotland	22,5	17,5	0,0	13,3
6	Mörbylånga	Kalmar	22,5	17,5	0,0	13,3
7	Borgholm	Kalmar	22,5	17,5	0,0	13,3
8	Emmaboda	Kalmar	12,5	17,5	7,5	12,5
9	Trosa	Södermanland	12,5	22,5	0,0	11,7
10	Värmdö	Stockholm	12,5	22,5	0,0	11,7
11	Haninge	Stockholm	12,5	22,5	0,0	11,7
12	Nacka	Stockholm	12,5	22,5	0,0	11,7
13	Norrtälje	Stockholm	12,5	22,5	0,0	11,7
14	Solna	Stockholm	12,5	22,5	0,0	11,7
15	Huddinge	Stockholm	12,5	22,5	0,0	11,7
16	Österåker	Stockholm	12,5	22,5	0,0	11,7
17	Södertälje	Stockholm	12,5	22,5	0,0	11,7
18	Stockholm	Stockholm	12,5	22,5	0,0	11,7
19	Botkyrka	Stockholm	12,5	22,5	0,0	11,7
20	Vaxholm	Stockholm	12,5	22,5	0,0	11,7
21	Nyköping	Södermanland	12,5	22,5	0,0	11,7
22	Nynäshamn	Stockholm	12,5	22,5	0,0	11,7
23	Lidingö	Stockholm	12,5	22,5	0,0	11,7
24	Tyresö	Stockholm	12,5	22,5	0,0	11,7
25	Norrköping	Östergötland	12,5	22,5	0,0	11,7
26	Oxelösund	Södermanland	12,5	22,5	0,0	11,7
27	Sundbyberg	Stockholm	7,5	22,5	0,0	10,0
28	Järfälla	Stockholm	7,5	22,5	0,0	10,0

29	Täby	Stockholm	7,5	22,5	0,0	10,0
30	Danderyd	Stockholm	7,5	22,5	0,0	10,0
31	Sävsjö	Jönköping	7,5	12,5	7,5	9,2
32	Vetlanda	Jönköping	7,5	12,5	7,5	9,2
33	Tingsryd	Kronoberg	7,5	12,5	7,5	9,2
34	Hultsfred	Kalmar	7,5	12,5	7,5	9,2
35	Vallentuna	Stockholm	7,5	17,5	0,0	8,3
36	Sollentuna	Stockholm	7,5	17,5	0,0	8,3
37	Gnesta	Södermanland	0,0	22,5	0,0	7,5
38	Eksjö	Jönköping	7,5	7,5	7,5	7,5
39	Kalmar	Kalmar	7,5	12,5	0,0	6,7
40	Ydre	Östergötland	0,0	12,5	7,5	6,7
41	Kil	Värmland	12,5	7,5	0,0	6,7
42	Ronneby	Blekinge	7,5	12,5	0,0	6,7
43	Årjäng	Värmland	12,5	7,5	0,0	6,7
44	Karlshamn	Blekinge	7,5	12,5	0,0	6,7
45	Dals-Ed	Västra Götaland	12,5	7,5	0,0	6,7
46	Eda	Värmland	12,5	7,5	0,0	6,7
47	Karlskrona	Blekinge	7,5	12,5	0,0	6,7
48	Forshaga	Värmland	12,5	7,5	0,0	6,7
49	Nybro	Kalmar	7,5	12,5	0,0	6,7
50	Olofström	Blekinge	7,5	12,5	0,0	6,7
51	Arvika	Värmland	12,5	7,5	0,0	6,7
52	Sölvesborg	Blekinge	7,5	12,5	0,0	6,7
53	Vimmerby	Kalmar	0,0	12,5	7,5	6,7
54	Sunne	Värmland	12,5	7,5	0,0	6,7
55	Säffle	Värmland	12,5	7,5	0,0	6,7
56	Bengtsfors	Västra Götaland	12,5	7,5	0,0	6,7
57	Luleå	Norrbotten	0,0	17,5	0,0	5,8
58	Robertsfors	Västerbotten	0,0	17,5	0,0	5,8
59	Storuman	Västerbotten	0,0	17,5	0,0	5,8
60	Haparanda	Norrbotten	0,0	17,5	0,0	5,8
61	kalix	Norrbotten	0,0	17,5	0,0	5,8
62	Örebro	Örebro	7,5	7,5	0,0	5,0
63	Växsjö	Kronoberg	0,0	7,5	7,5	5,0
64	Halstahammar	Västmanland	7,5	7,5	0,0	5,0
65	Aneby	Jönköping	0,0	7,5	7,5	5,0
66	Nässjö	Jönköping	0,0	7,5	7,5	5,0
67	Bromölla	Skåne	7,5	7,5	0,0	5,0
68	Hallsberg	Örebro	7,5	7,5	0,0	5,0
69	Finspång	Östergötland	7,5	7,5	0,0	5,0
70	Mullsjö	Jönköping	7,5	7,5	0,0	5,0
71	Tranås	Jönköping	0,0	7,5	7,5	5,0
72	Falköping	Västra Götaland	7,5	7,5	0,0	5,0

73	Sandviken	Gävleborg	7,5	7,5	0,0	5,0
74	Torsås	Kalmar	7,5	7,5	0,0	5,0
75	Tidaholm	Västra Götaland	7,5	7,5	0,0	5,0
76	Nora	Örebro	7,5	7,5	0,0	5,0
77	Karlsbo	Västra Götaland	7,5	7,5	0,0	5,0
78	Herrljunga	Västra Götaland	7,5	7,5	0,0	5,0
79	Mönsterås	Kalmar	7,5	7,5	0,0	5,0
80	Surahamma	Västmanland	7,5	7,5	0,0	5,0
81	Laxå	Örebro	7,5	7,5	0,0	5,0
82	Fagersta	Västmanland	7,5	7,5	0,0	5,0
83	Lindesberg	Örebro	7,5	7,5	0,0	5,0
84	Skara	Västra Götaland	7,5	7,5	0,0	5,0
85	Skinnskatteberg	Västmanland	7,5	7,5	0,0	5,0
86	Söderhamn	Gävleborg	7,5	7,5	0,0	5,0
87	Norberg	Västmanland	7,5	7,5	0,0	5,0
88	Kramfors	Västernorrland	7,5	7,5	0,0	5,0
89	Ljusnarsberg	Örebro	7,5	7,5	0,0	5,0
90	Åre	Jämtland	0,0	12,5	0,0	4,2
91	Karlstad	Värmland	12,5	0,0	0,0	4,2
92	Örkelljunga	Skåne	12,5	0,0	0,0	4,2
93	Hörby	Skåne	12,5	0,0	0,0	4,2
94	Ängelholm	Skåne	12,5	0,0	0,0	4,2
95	Perstorp	Skåne	12,5	0,0	0,0	4,2
96	Östhammar	Uppsala	12,5	0,0	0,0	4,2
97	Munkedal	Västra Götaland	12,5	0,0	0,0	4,2
98	Arboga	Västmanland	12,5	0,0	0,0	4,2
99	Salem	Stockholm	12,5	0,0	0,0	4,2
100	Piteå	Norrbotten	0,0	12,5	0,0	4,2
101	Västervik	Kalmar	0,0	12,5	0,0	4,2
102	Krokom	Jämtland	0,0	12,5	0,0	4,2
103	Degerfors	Örebro	12,5	0,0	0,0	4,2
104	Skellefteå	Västerbotten	0,0	12,5	0,0	4,2
105	Munkfors	Värmland	12,5	0,0	0,0	4,2
106	Oskarhamn	Kalmar	0,0	12,5	0,0	4,2
107	Boden	Norrbotten	0,0	12,5	0,0	4,2
108	Gullspång	Västra Götaland	12,5	0,0	0,0	4,2
109	Karlskoga	Örebro	12,5	0,0	0,0	4,2
110	Storfors	Värmland	12,5	0,0	0,0	4,2
111	Filipstad	Värmland	12,5	0,0	0,0	4,2
112	Upplands-Bro	Stockholm	7,5	0,0	0,0	2,5
113	Knivsta	Uppsala	7,5	0,0	0,0	2,5
114	Lekeberg	Örebro	7,5	0,0	0,0	2,5
115	Mölndal	Västra Götaland	7,5	0,0	0,0	2,5
116	Uppsala	Uppsala	7,5	0,0	0,0	2,5

117	Burlöv	Skåne	7,5	0,0	0,0	2,5
118	Staffanstorp	Skåne	7,5	0,0	0,0	2,5
119	Kungälv	Västra Götaland	7,5	0,0	0,0	2,5
120	Svedala	Skåne	7,5	0,0	0,0	2,5
121	Ale	Västra Götaland	7,5	0,0	0,0	2,5
122	Upplands Väsby	Stockholm	7,5	0,0	0,0	2,5
123	Nykvarn	Stockholm	7,5	0,0	0,0	2,5
124	Hammarö	Värmland	7,5	0,0	0,0	2,5
125	Håbo	Uppsala	7,5	0,0	0,0	2,5
126	Lund	Skåne	7,5	0,0	0,0	2,5
127	Sigtuna	Stockholm	7,5	0,0	0,0	2,5
128	Strängnäs	Södermanland	7,5	0,0	0,0	2,5
129	Enköping	Uppsala	7,5	0,0	0,0	2,5
130	Helsingborg	Skåne	7,5	0,0	0,0	2,5
131	Partille	Västra Götaland	7,5	0,0	0,0	2,5
132	Malmö	Skåne	7,5	0,0	0,0	2,5
133	Laholm	Halland	7,5	0,0	0,0	2,5
134	Kungsbacka	Halland	7,5	0,0	0,0	2,5
135	Lerum	Västra Götaland	7,5	0,0	0,0	2,5
136	Ekerö	Stockholm	7,5	0,0	0,0	2,5
137	Västerås	Västmanland	7,5	0,0	0,0	2,5
138	Vårgårda	Västra Götaland	7,5	0,0	0,0	2,5
139	Varberg	Halland	7,5	0,0	0,0	2,5
140	Lomma	Skåne	7,5	0,0	0,0	2,5
141	Vaggeryd	Jönköping	0,0	7,5	0,0	2,5
142	Höganäs	Skåne	7,5	0,0	0,0	2,5
143	Kävlinge	Skåne	7,5	0,0	0,0	2,5
144	Göteborg	Västra Götaland	7,5	0,0	0,0	2,5
145	Vellinge	Skåne	7,5	0,0	0,0	2,5
146	Ystad	Skåne	7,5	0,0	0,0	2,5
147	Stenungsund	Västra Götaland	7,5	0,0	0,0	2,5
148	Bjuv	Skåne	7,5	0,0	0,0	2,5
149	Höör	Skåne	7,5	0,0	0,0	2,5
150	Åstorp	Skåne	7,5	0,0	0,0	2,5
151	Trelleborg	Skåne	7,5	0,0	0,0	2,5
152	Båstad	Skåne	7,5	0,0	0,0	2,5
153	Landskrona	Skåne	7,5	0,0	0,0	2,5
154	Klippan	Skåne	7,5	0,0	0,0	2,5
155	Alingsås	Västra Götaland	7,5	0,0	0,0	2,5
156	Skurup	Skåne	7,5	0,0	0,0	2,5
157	Eskilstuna	Södermanland	7,5	0,0	0,0	2,5
158	Falun	Dalarna	0,0	7,5	0,0	2,5
159	Kristianstad	Skåne	7,5	0,0	0,0	2,5
160	Tjörn	Västra Götaland	7,5	0,0	0,0	2,5

161	Lilla Edet	Västra Götaland	7,5	0,0	0,0	2,5
162	Uddevalla	Västra Götaland	7,5	0,0	0,0	2,5
163	Eslöv	Skåne	7,5	0,0	0,0	2,5
164	Sjöbo	Skåne	7,5	0,0	0,0	2,5
165	Kungsör	Västmanland	7,5	0,0	0,0	2,5
166	Gävle	Gävleborg	7,5	0,0	0,0	2,5
167	Svalöv	Skåne	7,5	0,0	0,0	2,5
168	Härryda	Västra Götaland	7,5	0,0	0,0	2,5
169	Sala	Västmanland	7,5	0,0	0,0	2,5
170	Trollhättan	Västra Götaland	7,5	0,0	0,0	2,5
171	Heby	Uppsala	7,5	0,0	0,0	2,5
172	Tanum	Västra Götaland	7,5	0,0	0,0	2,5
173	Värnamo	Jönköping	0,0	7,5	0,0	2,5
174	Tierp	Uppsala	7,5	0,0	0,0	2,5
175	Tomelilla	Skåne	7,5	0,0	0,0	2,5
176	Söderköping	Östergötland	0,0	7,5	0,0	2,5
177	Kumla	Örebro	7,5	0,0	0,0	2,5
178	Borlänge	Dalarna	0,0	7,5	0,0	2,5
179	Vara	Västra Götaland	0,0	7,5	0,0	2,5
180	Ockelbo	Gävleborg	0,0	7,5	0,0	2,5
181	Gnosjö	Jönköping	0,0	7,5	0,0	2,5
182	Öckerö	Västra Götaland	7,5	0,0	0,0	2,5
183	Mariestad	Västra Götaland	7,5	0,0	0,0	2,5
184	Valdemarsvik	Östergötland	0,0	7,5	0,0	2,5
185	Köping	Västmanland	7,5	0,0	0,0	2,5
186	Strömstad	Västra Götaland	7,5	0,0	0,0	2,5
187	Orust	Västra Götaland	7,5	0,0	0,0	2,5
188	Motala	Östergötland	0,0	7,5	0,0	2,5
189	Essunga	Västra Götaland	0,0	7,5	0,0	2,5
190	Askersund	Örebro	0,0	7,5	0,0	2,5
191	Hofors	Gävleborg	7,5	0,0	0,0	2,5
192	Lysekil	Västra Götaland	7,5	0,0	0,0	2,5
193	Säter	Dalarna	0,0	7,5	0,0	2,5
194	Älvkakarleby	Uppsala	7,5	0,0	0,0	2,5
195	Avesta	Dalarna	0,0	7,5	0,0	2,5
196	Hedemora	Dalarna	0,0	7,5	0,0	2,5
197	Mellerud	Västra Götaland	7,5	0,0	0,0	2,5
198	Smedjebacken	Dalarna	0,0	7,5	0,0	2,5
199	Grums	Värmland	7,5	0,0	0,0	2,5
200	Färgelanda	Västra Götaland	7,5	0,0	0,0	2,5
201	Härnösand	Västernorrland	0,0	7,5	0,0	2,5
202	Götene	Västra Götaland	7,5	0,0	0,0	2,5
203	Åtvidaberg	Östergötland	0,0	7,5	0,0	2,5
204	Sorsele	Västerbotten	0,0	7,5	0,0	2,5

205	Simrishamn	Skåne	7,5	0,0	0,0	2,5
206	Åmål	Västra Götaland	7,5	0,0	0,0	2,5
207	Töreboda	Västra Götaland	7,5	0,0	0,0	2,5
208	Kristinehamn	Värmland	7,5	0,0	0,0	2,5
209	Hällefors	Örebro	7,5	0,0	0,0	2,5
210	Överkalix	Norrbotten	0,0	7,5	0,0	2,5
211	Hagfors	Värmland	7,5	0,0	0,0	2,5
212	Arvidsjaur	Norrbotten	0,0	7,5	0,0	2,5
213	Torsby	Värmland	0,0	7,5	0,0	2,5
214	Övertorneå	Norrbotten	0,0	7,5	0,0	2,5
215	Habo	Jönköping	0,0	0,0	0,0	0,0
216	Älmhult	Kronoberg	0,0	0,0	0,0	0,0
217	Umeå	Västerbotten	0,0	0,0	0,0	0,0
218	Linköping	Östergötland	0,0	0,0	0,0	0,0
219	Östra Göinge	Skåne	0,0	0,0	0,0	0,0
220	Bollebygd	Västra Götaland	0,0	0,0	0,0	0,0
221	Jönköping	Jönköping	0,0	0,0	0,0	0,0
222	Skövde	Västra Götaland	0,0	0,0	0,0	0,0
223	Mjölby	Östergötland	0,0	0,0	0,0	0,0
224	Östersund	Jämtland	0,0	0,0	0,0	0,0
225	Falkenberg	Halland	0,0	0,0	0,0	0,0
226	Markaryd	Kronoberg	0,0	0,0	0,0	0,0
227	Katrineholm	Södermanland	0,0	0,0	0,0	0,0
228	Ulricehamn	Västra Götaland	0,0	0,0	0,0	0,0
229	Borås	Västra Götaland	0,0	0,0	0,0	0,0
230	Halmstad	Halland	0,0	0,0	0,0	0,0
231	Lidköping	Västra Götaland	0,0	0,0	0,0	0,0
232	Ljungby	Kronoberg	0,0	0,0	0,0	0,0
233	Leksand	Dalarna	0,0	0,0	0,0	0,0
234	Mark	Västra Götaland	0,0	0,0	0,0	0,0
235	Hjo	Västra Götaland	0,0	0,0	0,0	0,0
236	Gislaved	Jönköping	0,0	0,0	0,0	0,0
237	Alvesta	Kronoberg	0,0	0,0	0,0	0,0
238	Vänersborg	Västra Götaland	0,0	0,0	0,0	0,0
239	Vadstena	Östergötland	0,0	0,0	0,0	0,0
240	Boxholm	Östergötland	0,0	0,0	0,0	0,0
241	Vännäs	Västerbotten	0,0	0,0	0,0	0,0
242	Gagnef	Dalarna	0,0	0,0	0,0	0,0
243	Tibro	Västra Götaland	0,0	0,0	0,0	0,0
244	Rättvik	Dalarna	0,0	0,0	0,0	0,0
245	Tranemo	Västra Götaland	0,0	0,0	0,0	0,0
246	Sundsvall	Västernorrland	0,0	0,0	0,0	0,0
247	Hässleholm	Skåne	0,0	0,0	0,0	0,0
248	Orsa	Dalarna	0,0	0,0	0,0	0,0

249	Osby	Skåne	0,0	0,0	0,0	0,0
250	Svenljunga	Västra Götaland	0,0	0,0	0,0	0,0
251	Mora	Dalarna	0,0	0,0	0,0	0,0
252	Hudiksvall	Gävleborg	0,0	0,0	0,0	0,0
253	Lycksele	Västerbotten	0,0	0,0	0,0	0,0
254	Ovanåker	Gävleborg	0,0	0,0	0,0	0,0
255	Nordmaling	Västerbotten	0,0	0,0	0,0	0,0
256	Vingåker	Södermanland	0,0	0,0	0,0	0,0
257	Örnsköldsvik	Västernorrland	0,0	0,0	0,0	0,0
258	Ödeshög	Östergötland	0,0	0,0	0,0	0,0
259	Vindeln	Västerbotten	0,0	0,0	0,0	0,0
260	Älvdalen	Dalarna	0,0	0,0	0,0	0,0
261	Timrå	Västernorrland	0,0	0,0	0,0	0,0
262	Malung-Sälen	Dalarna	0,0	0,0	0,0	0,0
263	Ludvika	Dalarna	0,0	0,0	0,0	0,0
264	Bollnäs	Gävleborg	0,0	0,0	0,0	0,0
265	Sotenäs	Västra Götaland	0,0	0,0	0,0	0,0
266	Malå	Västerbotten	0,0	0,0	0,0	0,0
267	Berg	Jämtland	0,0	0,0	0,0	0,0
268	Nordanstig	Gävleborg	0,0	0,0	0,0	0,0
269	Grästorp	Västra Götaland	0,0	0,0	0,0	0,0
270	Pajala	Norrbotten	0,0	0,0	0,0	0,0
271	Ljusdal	Gävleborg	0,0	0,0	0,0	0,0
272	Hylte	Halland	0,0	0,0	0,0	0,0
273	Bjurholm	Västerbotten	0,0	0,0	0,0	0,0
274	Härjedalen	Jämtland	0,0	0,0	0,0	0,0
275	Kiruna	Norrbotten	0,0	0,0	0,0	0,0
276	Älvsbyn	Norrbotten	0,0	0,0	0,0	0,0
277	Vansbro	Dalarna	0,0	0,0	0,0	0,0
278	Strömsund	Jämtland	0,0	0,0	0,0	0,0
279	Flen	Södermanland	0,0	0,0	0,0	0,0
280	Ånge	Västernorrland	0,0	0,0	0,0	0,0
281	Vilhelmina	Västerbotten	0,0	0,0	0,0	0,0
282	Ragunda	Jämtland	0,0	0,0	0,0	0,0
283	Bräcke	Jämtland	0,0	0,0	0,0	0,0
284	Gällivare	Norrbotten	0,0	0,0	0,0	0,0
285	Åsele	Västerbotten	0,0	0,0	0,0	0,0
286	Sollefteå	Västernorrland	0,0	0,0	0,0	0,0
287	Arjeplog	Norrbotten	0,0	0,0	0,0	0,0
288	Norsjö	Västerbotten	0,0	0,0	0,0	0,0
289	Jokkmokk	Norrbotten	0,0	0,0	0,0	0,0
290	Dorotea	Västerbotten	0,0	0,0	0,0	0,0

A.2 Ranking by population growth

Table A.2: Complete ranking of municipalities based on population growth during 2016 - 2019

No.	Municipality	County	Population Increase
1	Trosa	Södermanland	3,21%
2	Upplands-Bro	Stockholm	3,16%
3	Knivsta	Uppsala	3,00%
4	Sundbyberg	Stockholm	2,91%
5	Lekeberg	Örebro	2,61%
6	Järfälla	Stockholm	2,47%
7	Mölndal	Västra Götaland	2,42%
8	Habo	Jönköping	2,39%
9	Uppsala	Uppsala	2,39%
10	Värmdö	Stockholm	2,33%
11	Burlöv	Skåne	2,32%
12	Haninge	Stockholm	2,18%
13	Staffanstorp	Skåne	2,13%
14	Kungälv	Västra Götaland	2,13%
15	Svedala	Skåne	2,10%
16	Älmhult	Kronoberg	2,06%
17	Ale	Västra Götaland	2,00%
18	Örebro	Örebro	1,98%
19	Upplands Väsby	Stockholm	1,94%
20	Nacka	Stockholm	1,94%
21	Nykvarn	Stockholm	1,87%
22	Hammarö	Värmland	1,85%
23	Håbo	Uppsala	1,81%
24	Lund	Skåne	1,74%
25	Sigtuna	Stockholm	1,73%
26	Strängnäs	Södermanland	1,72%
27	Norrtälje	Stockholm	1,67%
28	Solna	Stockholm	1,66%
29	Huddinge	Stockholm	1,62%
30	Växsjö	Kronoberg	1,61%
31	Enköping	Uppsala	1,61%
32	Österåker	Stockholm	1,58%
33	Helsingborg	Skåne	1,58%
34	Partille	Västra Götaland	1,57%
35	Umeå	Västerbotten	1,54%
36	Malmö	Skåne	1,54%
37	Laholm	Halland	1,51%
38	Kungsbacka	Halland	1,49%

39	Linköping	Östergötland	1,48%
40	Lerum	Västra Götaland	1,48%
41	Södertälje	Stockholm	1,48%
42	Gnesta	Södermanland	1,48%
43	Östra Göinge	Skåne	1,45%
44	Ekerö	Stockholm	1,45%
45	Västerås	Västmanland	1,45%
46	Vårgårda	Västra Götaland	1,43%
47	Åre	Jämtland	1,42%
48	Bollebygd	Västra Götaland	1,42%
49	Varberg	Halland	1,39%
50	Lomma	Skåne	1,36%
51	Vaggeryd	Jönköping	1,36%
52	Jönköping	Jönköping	1,36%
53	Vallentuna	Stockholm	1,33%
54	Halstahammar	Västmanland	1,33%
55	Höganäs	Skåne	1,32%
56	Stockholm	Stockholm	1,32%
57	Kalmar	Kalmar	1,31%
58	Kävlinge	Skåne	1,31%
59	Göteborg	Västra Götaland	1,30%
60	Botkyrka	Stockholm	1,29%
61	Karlstad	Värmland	1,27%
62	Vellinge	Skåne	1,27%
63	Sollentuna	Stockholm	1,24%
64	Skövde	Västra Götaland	1,23%
65	Örkelljunga	Skåne	1,22%
66	Mjölby	Östergötland	1,21%
67	Ystad	Skåne	1,18%
68	Aneby	Jönköping	1,18%
69	Eksjö	Jönköping	1,16%
70	Stenungsund	Västra Götaland	1,14%
71	Vaxholm	Stockholm	1,14%
72	Täby	Stockholm	1,13%
73	Bjuv	Skåne	1,09%
74	Höör	Skåne	1,09%
75	Åstorp	Skåne	1,07%
76	Östersund	Jämtland	1,07%
77	Trelleborg	Skåne	1,06%
78	Båstad	Skåne	1,05%
79	Landskrona	Skåne	1,05%
80	Klippan	Skåne	1,04%
81	Alingsås	Västra Götaland	1,03%
82	Falkenberg	Halland	1,01%

83	Markaryd	Kronoberg	1,01%
84	Nyköping	Södermanland	1,01%
85	Katrineholm	Södermanland	1,01%
86	Nynäshamn	Stockholm	1,00%
87	Skurup	Skåne	1,00%
88	Eskilstuna	Södermanland	0,99%
89	Falun	Dalarna	0,98%
90	Ulricehamn	Västra Götaland	0,97%
91	Kristianstad	Skåne	0,96%
92	Tjörn	Västra Götaland	0,95%
93	Gotland	Gotland	0,94%
94	Lilla Edet	Västra Götaland	0,93%
95	Uddevalla	Västra Götaland	0,93%
96	Lidingö	Stockholm	0,92%
97	Ydre	Östergötland	0,92%
98	Borås	Västra Götaland	0,91%
99	Eslöv	Skåne	0,91%
100	Sjöbo	Skåne	0,90%
101	Kungsör	Västmanland	0,89%
102	Hörby	Skåne	0,88%
103	Halmstad	Halland	0,87%
104	Tyresö	Stockholm	0,87%
105	Ängelholm	Skåne	0,86%
106	Gävle	Gävleborg	0,84%
107	Norrköping	Östergötland	0,83%
108	Perstorp	Skåne	0,82%
109	Svalöv	Skåne	0,82%
110	Härryda	Västra Götaland	0,78%
111	Lidköping	Västra Götaland	0,76%
112	Nässjö	Jönköping	0,76%
113	Sala	Västmanland	0,76%
114	Sävsjö	Jönköping	0,73%
115	Trollhättan	Västra Götaland	0,73%
116	Heby	Uppsala	0,70%
117	Ljungby	Kronoberg	0,69%
118	Kil	Värmland	0,69%
119	Leksand	Dalarna	0,66%
120	Tanum	Västra Götaland	0,65%
121	Bromölla	Skåne	0,64%
122	Mörbylånga	Kalmar	0,63%
123	Hallsberg	Örebro	0,63%
124	Värnamo	Jönköping	0,63%
125	Tierp	Uppsala	0,62%
126	Tomelilla	Skåne	0,61%

127	Mark	Västra Götaland	0,61%
128	Luleå	Norrbotten	0,60%
129	Hjo	Västra Götaland	0,59%
130	Söderköping	Östergötland	0,59%
131	Östhammar	Uppsala	0,59%
132	Munkedal	Västra Götaland	0,59%
133	Kumla	Örebro	0,59%
134	Gislaved	Jönköping	0,58%
135	Arboga	Västmanland	0,57%
136	Alvesta	Kronoberg	0,57%
137	Borlänge	Dalarna	0,57%
138	Finspång	Östergötland	0,56%
139	Vänersborg	Västra Götaland	0,56%
140	Vadstena	Östergötland	0,56%
141	Ronneby	Blekinge	0,56%
142	Vara	Västra Götaland	0,53%
143	Ockelbo	Gävleborg	0,53%
144	Boxholm	Östergötland	0,52%
145	Vännäs	Västerbotten	0,50%
146	Gnosjö	Jönköping	0,45%
147	Gagnef	Dalarna	0,44%
148	Öckerö	Västra Götaland	0,43%
149	Mullsjö	Jönköping	0,43%
150	Mariestad	Västra Götaland	0,42%
151	Årjäng	Värmland	0,42%
152	Tibro	Västra Götaland	0,42%
153	Uppvidinge	Kronoberg	0,41%
154	Tranås	Jönköping	0,41%
155	Rättvik	Dalarna	0,41%
156	Emmaboda	Kalmar	0,40%
157	Valdemarsvik	Östergötland	0,40%
158	Tranemo	Västra Götaland	0,40%
159	Falköping	Västra Götaland	0,39%
160	Salem	Stockholm	0,38%
161	Köping	Västmanland	0,37%
162	Strömstad	Västra Götaland	0,37%
163	Sundsvall	Västernorrland	0,36%
164	Danderyd	Stockholm	0,35%
165	Orust	Västra Götaland	0,35%
166	Karlshamn	Blekinge	0,35%
167	Hässleholm	Skåne	0,34%
168	Vetlanda	Jönköping	0,34%
169	Motala	Östergötland	0,32%
170	Piteå	Norrbotten	0,32%

171	Dals-Ed	Västra Götaland	0,31%
172	Orsa	Dalarna	0,31%
173	Eda	Värmland	0,30%
174	Osby	Skåne	0,29%
175	Svenljunga	Västra Götaland	0,28%
176	Västervik	Kalmar	0,28%
177	Krokom	Jämtland	0,27%
178	Essunga	Västra Götaland	0,26%
179	Karlskrona	Blekinge	0,25%
180	Kinda	Östergötland	0,24%
181	Sandviken	Gävleborg	0,24%
182	Askersund	Örebro	0,23%
183	Mora	Dalarna	0,23%
184	Hudiksvall	Gävleborg	0,23%
185	Degerfors	Örebro	0,22%
186	Torsås	Kalmar	0,22%
187	Lycksele	Västerbotten	0,22%
188	Ovanåker	Gävleborg	0,21%
189	Forshaga	Värmland	0,21%
190	Tidaholm	Västra Götaland	0,20%
191	Nora	Örebro	0,20%
192	Karlsbo	Västra Götaland	0,17%
193	Herrljunga	Västra Götaland	0,17%
194	Hofors	Gävleborg	0,16%
195	Mönsterås	Kalmar	0,15%
196	Skellefteå	Västerbotten	0,14%
197	Nordmaling	Västerbotten	0,13%
198	Lysekil	Västra Götaland	0,12%
199	Munkfors	Värmland	0,12%
200	Oskarhamn	Kalmar	0,11%
201	Nybro	Kalmar	0,10%
202	Vingåker	Södermanland	0,10%
203	Olofström	Blekinge	0,09%
204	Säter	Dalarna	0,09%
205	Oxelösund	Södermanland	0,08%
206	Arvika	Värmland	0,08%
207	Surahamma	Västmanland	0,08%
208	Älvkakarleby	Uppsala	0,07%
209	Avesta	Dalarna	0,07%
210	Sölvesborg	Blekinge	0,06%
211	Örnsköldsvik	Västernorrland	0,06%
212	Boden	Norrbotten	0,04%
213	Ödeshög	Östergötland	0,02%
214	Vimmerby	Kalmar	0,02%

215	Vindeln	Västerbotten	0,02%
216	Älvdalen	Dalarna	0,01%
217	Timrå	Västernorrland	0,01%
218	Tingsryd	Kronoberg	0,01%
219	Hedemora	Dalarna	0,00%
220	Mellerud	Västra Götaland	-0,01%
221	Malung-Sälen	Dalarna	-0,02%
222	Ludvika	Dalarna	-0,02%
223	Bollnäs	Gävleborg	-0,03%
224	Sotenäs	Västra Götaland	-0,03%
225	Smedjebacken	Dalarna	-0,04%
226	Lessebo	Kronoberg	-0,04%
227	Grums	Värmland	-0,05%
228	Färgelanda	Västra Götaland	-0,07%
229	Laxå	Örebro	-0,09%
230	Malå	Västerbotten	-0,10%
231	Gullspång	Västra Götaland	-0,11%
232	Härnösand	Västernorrland	-0,11%
233	Götene	Västra Götaland	-0,12%
234	Robertsfors	Västerbotten	-0,12%
235	Berg	Jämtland	-0,13%
236	Fagersta	Västmanland	-0,15%
237	Karlskoga	Örebro	-0,15%
238	Nordanstig	Gävleborg	-0,16%
239	Grästorp	Västra Götaland	-0,17%
240	Pajala	Norrbotten	-0,19%
241	Borgholm	Kalmar	-0,19%
242	Lindesberg	Örebro	-0,20%
243	Ljusdal	Gävleborg	-0,23%
244	Storuman	Västerbotten	-0,26%
245	Skara	Västra Götaland	-0,28%
246	Hylte	Halland	-0,29%
247	Bjurholm	Västerbotten	-0,30%
248	Sunne	Värmland	-0,32%
249	Storfors	Värmland	-0,33%
250	Åtvidaberg	Östergötland	-0,34%
251	Härjedalen	Jämtland	-0,35%
252	Skinnskatteberg	Västmanland	-0,37%
253	Säffle	Värmland	-0,37%
254	Kiruna	Norrbotten	-0,38%
255	Söderhamn	Gävleborg	-0,41%
256	Älvsbyn	Norrbotten	-0,42%
257	Norberg	Västmanland	-0,42%
258	Vansbro	Dalarna	-0,43%

259	Sorsele	Västerbotten	-0,43%
260	Bengtsfors	Västra Götaland	-0,44%
261	Simrishamn	Skåne	-0,45%
262	Strömsund	Jämtland	-0,45%
263	Åmål	Västra Götaland	-0,45%
264	Flen	Södermanland	-0,49%
265	Töreboda	Västra Götaland	-0,54%
266	Kristinehamn	Värmland	-0,55%
267	Kramfors	Västernorrland	-0,57%
268	Haparanda	Norrbotten	-0,58%
269	Ånge	Västernorrland	-0,58%
270	Vilhelmina	Västerbotten	-0,61%
271	kalix	Norrbotten	-0,61%
272	Ragunda	Jämtland	-0,62%
273	Högsby	Kalmar	-0,67%
274	Bräcke	Jämtland	-0,72%
275	Hällefors	Örebro	-0,73%
276	Överkalix	Norrbotten	-0,74%
277	Hagfors	Värmland	-0,76%
278	Gällivare	Norrbotten	-0,76%
279	Hultsfred	Kalmar	-0,79%
280	Filipstad	Värmland	-0,86%
281	Åsele	Västerbotten	-0,92%
282	Sollefteå	Västernorrland	-0,96%
283	Arjeplog	Norrbotten	-1,02%
284	Norsjö	Västerbotten	-1,03%
285	Arvidsjaur	Norrbotten	-1,07%
286	Jokkmokk	Norrbotten	-1,16%
287	Torsby	Värmland	-1,42%
288	Övertorneå	Norrbotten	-1,57%
289	Ljusnarsberg	Örebro	-1,62%
290	Dorotea	Västerbotten	-2,05%

A.3 Ranking by water stress factor

Table A.3: Complete ranking of municipalities based on the water stress factor calculated in TQ1.

No.	Municipality	County	Water stress factor
1	Trosa	Södermanland	37,49%
2	Sundbyberg	Stockholm	29,14%
3	Värmdö	Stockholm	27,16%
4	Haninge	Stockholm	25,42%

5	Järfälla	Stockholm	24,68%
6	Nacka	Stockholm	22,59%
7	Norrtälje	Stockholm	19,45%
8	Solna	Stockholm	19,32%
9	Huddinge	Stockholm	18,93%
10	Österåker	Stockholm	18,41%
11	Södertälje	Stockholm	17,26%
12	Stockholm	Stockholm	15,39%
13	Botkyrka	Stockholm	15,09%
14	Vaxholm	Stockholm	13,25%
15	Gotland	Gotland	12,56%
16	Nyköping	Södermanland	11,75%
17	Nynäshamn	Stockholm	11,70%
18	Täby	Stockholm	11,28%
19	Vallentuna	Stockholm	11,09%
20	Gnesta	Södermanland	11,07%
21	Lidingö	Stockholm	10,76%
22	Sollentuna	Stockholm	10,31%
23	Tyresö	Stockholm	10,11%
24	Örebro	Örebro	9,92%
25	Norrköping	Östergötland	9,64%
26	Eksjö	Jönköping	8,73%
27	Kalmar	Kalmar	8,73%
28	Mörbylånga	Kalmar	8,40%
29	Växsjö	Kronoberg	8,06%
30	Upplands-Bro	Stockholm	7,89%
31	Knivsta	Uppsala	7,49%
32	Uppvidinge	Kronoberg	7,24%
33	Sävsjö	Jönköping	6,70%
34	Halstahammar	Västmanland	6,63%
35	Lekeberg	Örebro	6,54%
36	Ydre	Östergötland	6,11%
37	Mölndal	Västra Götaland	6,05%
38	Uppsala	Uppsala	5,98%
39	Åre	Jämtland	5,92%
40	Aneby	Jönköping	5,88%
41	Burlöv	Skåne	5,79%
42	Staffanstorp	Skåne	5,32%
43	Kungälv	Västra Götaland	5,32%
44	Karlstad	Värmland	5,30%
45	Svedala	Skåne	5,25%
46	Örkelljunga	Skåne	5,08%
47	Emmaboda	Kalmar	5,04%
48	Ale	Västra Götaland	5,00%

49	Upplands Väsby	Stockholm	4,84%
50	Nykvarn	Stockholm	4,67%
51	Hammarö	Värmland	4,62%
52	Kil	Värmland	4,58%
53	Håbo	Uppsala	4,53%
54	Lund	Skåne	4,36%
55	Sigtuna	Stockholm	4,32%
56	Strängnäs	Södermanland	4,29%
57	Enköping	Uppsala	4,02%
58	Helsingborg	Skåne	3,94%
59	Partille	Västra Götaland	3,93%
60	Malmö	Skåne	3,84%
61	Nässjö	Jönköping	3,80%
62	Laholm	Halland	3,77%
63	Kungsbacka	Halland	3,72%
64	Lerum	Västra Götaland	3,71%
65	Ronneby	Blekinge	3,71%
66	Hörby	Skåne	3,67%
67	Ekerö	Stockholm	3,63%
68	Västerås	Västmanland	3,62%
69	Ängelholm	Skåne	3,59%
70	Vårgårda	Västra Götaland	3,58%
71	Danderyd	Stockholm	3,54%
72	Luleå	Norrbotten	3,51%
73	Varberg	Halland	3,47%
74	Kinda	Östergötland	3,44%
75	Perstorp	Skåne	3,43%
76	Lomma	Skåne	3,41%
77	Vaggeryd	Jönköping	3,40%
78	Höganäs	Skåne	3,31%
79	Kävlinge	Skåne	3,27%
80	Göteborg	Västra Götaland	3,25%
81	Bromölla	Skåne	3,22%
82	Vellinge	Skåne	3,17%
83	Vetlanda	Jönköping	3,14%
84	Hallsberg	Örebro	3,13%
85	Ystad	Skåne	2,95%
86	Stenungsund	Västra Götaland	2,85%
87	Årjäng	Värmland	2,81%
88	Finspång	Östergötland	2,80%
89	Bjuv	Skåne	2,72%
90	Höör	Skåne	2,72%
91	Åstorp	Skåne	2,68%
92	Trelleborg	Skåne	2,65%

93	Båstad	Skåne	2,62%
94	Landskrona	Skåne	2,62%
95	Klippan	Skåne	2,59%
96	Alingsås	Västra Götaland	2,58%
97	Skurup	Skåne	2,49%
98	Eskilstuna	Södermanland	2,46%
99	Östhammar	Uppsala	2,46%
100	Munkedal	Västra Götaland	2,45%
101	Falun	Dalarna	2,44%
102	Kristianstad	Skåne	2,40%
103	Tjörn	Västra Götaland	2,38%
104	Arboga	Västmanland	2,38%
105	Lilla Edet	Västra Götaland	2,32%
106	Uddevalla	Västra Götaland	2,32%
107	Karlshamn	Blekinge	2,31%
108	Eslöv	Skåne	2,26%
109	Sjöbo	Skåne	2,24%
110	Kungsör	Västmanland	2,23%
111	Mullsjö	Jönköping	2,15%
112	Gävle	Gävleborg	2,11%
113	Dals-Ed	Västra Götaland	2,09%
114	Svalöv	Skåne	2,05%
115	Tranås	Jönköping	2,04%
116	Eda	Värmland	1,98%
117	Härryda	Västra Götaland	1,96%
118	Falköping	Västra Götaland	1,93%
119	Sala	Västmanland	1,90%
120	Trollhättan	Västra Götaland	1,82%
121	Heby	Uppsala	1,74%
122	Karlskrona	Blekinge	1,65%
123	Tanum	Västra Götaland	1,63%
124	Salem	Stockholm	1,56%
125	Värnamo	Jönköping	1,56%
126	Tierp	Uppsala	1,54%
127	Tomelilla	Skåne	1,53%
128	Söderköping	Östergötland	1,48%
129	Kumla	Örebro	1,46%
130	Borlänge	Dalarna	1,41%
131	Forshaga	Värmland	1,40%
132	Piteå	Norrbotten	1,34%
133	Vara	Västra Götaland	1,32%
134	Ockelbo	Gävleborg	1,32%
135	Sandviken	Gävleborg	1,21%
136	Västervik	Kalmar	1,15%

137	Gnosjö	Jönköping	1,12%
138	Krokom	Jämtland	1,11%
139	Torsås	Kalmar	1,09%
140	Öckerö	Västra Götaland	1,08%
141	Mariestad	Västra Götaland	1,06%
142	Tidaholm	Västra Götaland	1,02%
143	Nora	Örebro	1,00%
144	Valdemarsvik	Östergötland	0,99%
145	Oxelösund	Södermanland	0,95%
146	Köping	Västmanland	0,93%
147	Strömstad	Västra Götaland	0,93%
148	Degerfors	Örebro	0,91%
149	Orust	Västra Götaland	0,88%
150	Karlsbo	Västra Götaland	0,84%
151	Herrljunga	Västra Götaland	0,83%
152	Motala	Östergötland	0,80%
153	Mönsterås	Kalmar	0,77%
154	Nybro	Kalmar	0,68%
155	Essunga	Västra Götaland	0,64%
156	Olofström	Blekinge	0,61%
157	Skellefteå	Västerbotten	0,58%
158	Askersund	Örebro	0,58%
159	Arvika	Värmland	0,52%
160	Munkfors	Värmland	0,48%
161	Oskarhamn	Kalmar	0,44%
162	Sölvesborg	Blekinge	0,42%
163	Hofors	Gävleborg	0,39%
164	Surahamma	Västmanland	0,38%
165	Lysekil	Västra Götaland	0,30%
166	Säter	Dalarna	0,23%
167	Älvkakarleby	Uppsala	0,18%
168	Avesta	Dalarna	0,17%
169	Vimmerby	Kalmar	0,16%
170	Boden	Norrbotten	0,15%
171	Tingsryd	Kronoberg	0,05%
172	Habo	Jönköping	0,00%
173	Älmhult	Kronoberg	0,00%
174	Umeå	Västerbotten	0,00%
175	Linköping	Östergötland	0,00%
176	Östra Göinge	Skåne	0,00%
177	Bollebygd	Västra Götaland	0,00%
178	Jönköping	Jönköping	0,00%
179	Skövde	Västra Götaland	0,00%
180	Mjölby	Östergötland	0,00%

181	Östersund	Jämtland	0,00%
182	Falkenberg	Halland	0,00%
183	Markaryd	Kronoberg	0,00%
184	Katrineholm	Södermanland	0,00%
185	Ulricehamn	Västra Götaland	0,00%
186	Borås	Västra Götaland	0,00%
187	Halmstad	Halland	0,00%
188	Lidköping	Västra Götaland	0,00%
189	Ljungby	Kronoberg	0,00%
190	Leksand	Dalarna	0,00%
191	Mark	Västra Götaland	0,00%
192	Hjo	Västra Götaland	0,00%
193	Gislaved	Jönköping	0,00%
194	Alvesta	Kronoberg	0,00%
195	Vänersborg	Västra Götaland	0,00%
196	Vadstena	Östergötland	0,00%
197	Boxholm	Östergötland	0,00%
198	Vännäs	Västerbotten	0,00%
199	Gagnef	Dalarna	0,00%
200	Tibro	Västra Götaland	0,00%
201	Rättvik	Dalarna	0,00%
202	Tranemo	Västra Götaland	0,00%
203	Sundsvall	Västernorrland	0,00%
204	Hässleholm	Skåne	0,00%
205	Orsa	Dalarna	0,00%
206	Osby	Skåne	0,00%
207	Svenljunga	Västra Götaland	0,00%
208	Mora	Dalarna	0,00%
209	Hudiksvall	Gävleborg	0,00%
210	Lycksele	Västerbotten	0,00%
211	Ovanåker	Gävleborg	0,00%
212	Nordmaling	Västerbotten	0,00%
213	Vingåker	Södermanland	0,00%
214	Örnsköldsvik	Västernorrland	0,00%
215	Ödeshög	Östergötland	0,00%
216	Vindeln	Västerbotten	0,00%
217	Älvdalen	Dalarna	0,00%
218	Timrå	Västernorrland	0,00%
219	Malung-Sälen	Dalarna	0,00%
220	Ludvika	Dalarna	0,00%
221	Bollnäs	Gävleborg	0,00%
222	Sotenäs	Västra Götaland	0,00%
223	Malå	Västerbotten	0,00%
224	Berg	Jämtland	0,00%

225	Nordanstig	Gävleborg	0,00%
226	Grästorp	Västra Götaland	0,00%
227	Pajala	Norrbotten	0,00%
228	Ljusdal	Gävleborg	0,00%
229	Hylte	Halland	0,00%
230	Bjurholm	Västerbotten	0,00%
231	Härjedalen	Jämtland	0,00%
232	Kiruna	Norrbotten	0,00%
233	Älvsbyn	Norrbotten	0,00%
234	Vansbro	Dalarna	0,00%
235	Strömsund	Jämtland	0,00%
236	Flen	Södermanland	0,00%
237	Ånge	Västernorrland	0,00%
238	Vilhelmina	Västerbotten	0,00%
239	Ragunda	Jämtland	0,00%
240	Bräcke	Jämtland	0,00%
241	Gällivare	Norrbotten	0,00%
242	Åsele	Västerbotten	0,00%
243	Sollefteå	Västernorrland	0,00%
244	Arjeplog	Norrbotten	0,00%
245	Norsjö	Västerbotten	0,00%
246	Jokkmokk	Norrbotten	0,00%
247	Dorotea	Västerbotten	0,00%
248	Hedemora	Dalarna	-0,01%
249	Mellerud	Västra Götaland	-0,03%
250	Smedjebacken	Dalarna	-0,09%
251	Grums	Värmland	-0,13%
252	Färgelanda	Västra Götaland	-0,18%
253	Härnösand	Västernorrland	-0,28%
254	Götene	Västra Götaland	-0,30%
255	Laxå	Örebro	-0,44%
256	Gullspång	Västra Götaland	-0,44%
257	Karlskoga	Örebro	-0,61%
258	Lessebo	Kronoberg	-0,66%
259	Robertsfors	Västerbotten	-0,72%
260	Fagersta	Västmanland	-0,73%
261	Åtvidaberg	Östergötland	-0,85%
262	Lindesberg	Örebro	-1,01%
263	Sorsele	Västerbotten	-1,08%
264	Simrishamn	Skåne	-1,12%
265	Åmål	Västra Götaland	-1,13%
266	Töreboda	Västra Götaland	-1,34%
267	Storfors	Värmland	-1,37%
268	Kristinehamn	Värmland	-1,38%

269	Skara	Västra Götaland	-1,41%
270	Storuman	Västerbotten	-1,52%
271	Hällefors	Örebro	-1,82%
272	Skinnskatteberg	Västmanland	-1,84%
273	Överkalix	Norrbotten	-1,85%
274	Hagfors	Värmland	-1,90%
275	Söderhamn	Gävleborg	-2,03%
276	Norberg	Västmanland	-2,10%
277	Sunne	Värmland	-2,15%
278	Säffle	Värmland	-2,49%
279	Borgholm	Kalmar	-2,52%
280	Arvidsjaur	Norrbotten	-2,66%
281	Kramfors	Västernorrland	-2,83%
282	Bengtsfors	Västra Götaland	-2,95%
283	Haparanda	Norrbotten	-3,37%
284	Torsby	Värmland	-3,54%
285	kalix	Norrbotten	-3,55%
286	Filipstad	Värmland	-3,57%
287	Övertorneå	Norrbotten	-3,91%
288	Hultsfred	Kalmar	-7,20%
289	Ljusnarsberg	Örebro	-8,12%
290	Högsby	Kalmar	-10,59%

B

Literature review

TQ2
The literature review in TQ2 first focused on the international and Swedish literature. For the international literature:
2020-04-09: water quality + climate change: limited search to "review". This search provided the paper *A scientometric review of the research on the impacts of climate change on water quality during 1998–2018* (Li et al., 2020). The Swedish literature review used the following search words:
2020-04-10:water quality + climate change + Sweden: 81 results, 34 relevant topic or published published after 2009.

Table B.1: Literature used for the Swedish literature review in TQ2.

Unwanted effect	**Author**	**Year**	**Title**
DOM, DOC, and browning	Tiwari, T. Sponseller, R.A., Laudon, H.	2019	Contrasting responses in dissolved organic carbon to extreme climate events from adjacent boreal landscapes in Northern Sweden
	Tiwari, T. Sponseller, R.A., Laudon, H.	2018	Extreme Climate Effects on Dissolved Organic Carbon Concentrations During Snowmelt
	Huser, B.J., Futter, M.N., Wang, R. Fölster, J.	2018	Persistent and widespread long-term phosphorus declines in Boreal lakes in Sweden
	Li, P., Holden, J., Irvine, B., Mu, X.	2017	Erosion of Northern Hemisphere blanket peatlands under 21st-century climate change
	Köhler, S.J., Lavonen, E., Keucken, A., (. . .), Spanjer, T., Persson, K.	2016	Upgrading coagulation with hollow-fibre nanofiltration for improved organic matter removal during surface water treatment
	Weyhenmeyer, G.A., Müller, R.A., Norman, M., Tranvik, L.J.	2016	Sensitivity of freshwaters to browning in response to future climate

	Hytteborn, J.K., Temnerud, J., Alexander, R.B., (. . .), Dahné, J., Bishop, K.H.	2015	Patterns and predictability in the intra-annual organic carbon variability across the boreal and hemiboreal landscape
	Ledesma, J.L.J., Grabs, T., Bishop, K.H., Schiff, S.L., Köhler, S.J.	2015	Potential for long-term transfer of dissolved organic carbon from riparian zones to streams in boreal catchments
	Oni, S.K., Futter M.N., Bishop, K., (. . .), Ottosson-Löfvenius,M., Laudon, H.	2013	Long-term patterns in dissolved organic carbon, major elements and trace metals in boreal headwater catchments: Trends, mechanisms and heterogeneity
	Laudon, H., Tetzlaff, D., Soulsby, C., (. . .), Mcdonnel, J.J., Mcguire, K.	2013	Change in winter climate will affect dissolved organic carbon and water fluxes in mid-to-high latitude catchments
	Ledesma, J.L.J., Köhlers, S.J., Futter, M.N.	2012	Long-term dynamics of dissolved organic carbon: Implications for drinking water supply
	Haei, M., Öquist, M.G., Ilstedt, U., Laudon, H.	2012	The influence of soil frost on the quality of dissolved organic carbon in a boreal forest soil: Combining field and laboratory experiments
	Erlandsson, M., Cory, N., Fölster, J., (. . .) Weyhenmeyer, G.A., Bishop, K.	2011	Increasing dissolved organic carbon redefines the extent of surface water acidification and helps resolve a classic controversy
	Tuvendal, M., Elmqvist, T.	2011	Ecosystem services linking social and ecological systems: River brownification and the response of downstream stakeholders
	Reader, H.E., Stedmon, C.A., Kritzberg, E.S.	2014	Seasonal contribution of terrestrial organic matter and biological oxygen demand to the Baltic Sea from three contrasting river catchments

	Kothawala, D.N., Stedmon, C.A., Müller, R.A., Weyhenmeyer, G.A., Köhler, S.J., Tranvik, L.J.	2014	Controls of dissolved organic matter quality: Evidence from a large-scale boreal lake survey
Nutrients	Huser, B.J., Futter, M.N., Wang, R. Fölster, J.	2017	Persistent and widespread long-term phosphorus declines in Boreal lakes in Sweden
	Bergström, L., Kirchmann, H., Djodjic, F., (. . .), Svanbäck, A., Villa, A.	2015	Turnover and losses of phosphorus in swedish agricultural soils: Long-term changes, leaching trends, and mitigation measures
	Jia, Y., Ehlert, L., Wahlskog, C., Lundberg, A., Maurice, C.	2017	Water quality of stormwater generated from an airport in a cold climate, function of an infiltration pond, and sampling strategy with limited resources
	Wu, J., Malmström M.E.	2015	Nutrient loadings from urban catchments under climate change scenarios: Case studies in Stockholm, Sweden
Cyanobacteria	Markensten, H., Moore, K., Persson, I.	2010	Simulated lake phytoplankton composition shifts toward cyanobacteria dominance in a future warmer climate
Stormwater	Borris, M., Leonhardt, G., Marsalek, J., Österslund, H., Viklander, M.	2016	Source-Based Modeling Of Urban Stormwater Quality Response to the Selected Scenarios Combining Future Changes in Climate and Socio-Economic Factors
	Borris, M., Viklander, M., Gustafsson, A.-M., Marsalek, J.	2013	Modelling the effects of changes in rainfall event characteristics on TSS loads in urban runoff
	Borris, M., Viklander, M., Gustafsson, A.-M., Marsalek, J.	2013	Simulating future trends in urban stormwater quality or changing climate, urban land use and environmental controls
Impacts from forestry	Laudon, H., Kuglerová, L., Sponseller, R.A., (. . .), Egnell, G., Ågren, A.M.	2016	The role of biogeochemical hotspots, landscape heterogeneity, and hydrological connectivity for minimizing forestry effects on water quality

	Zanchi, G., Blyazid, S., Akselsson, C., Yu, L.	2014	Modelling the effects of management intensification on multiple forest services: A Swedish case study
	Laudon, H., Sponseller, R.A., Lucas, R.W., Futter, M.N., (. . .) Ring, E., Högberg, P.	2011	Consequences of more intensive forestry for the sustainable management of forest soils and waters
	Johansson, J., Ranius, T.	2018	Biomass outtake and bioenergy development in Sweden: the role of policy and economic presumptions
Microbio-logical impact	Rusinol, M., Fernandez-Cassi, X., Hundesa, A., (. . .) Bofill-Mas, S., Girones, R.	2014	Application of human and animal viral microbial source tracking tools in fresh and marine waters from five different geographical areas
	Tornevi, A., Bergstedt, O., Forsberg, B.	2014	Precipitation effects on microbial pollution in a river: Lag structures and seasonal effect modification
Pesticides & herbicides	Steffens, K., Jarvis, N., Lewan, E., Lindström, B., Kreuger, J., Kjellström, E., Moeys, J.	2014	Direct and indirect effects of climate change on herbicide leaching - A regional scale assessment in Sweden

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