Managing Domestic Wells in Sweden

Investigating the role of domestic wells in ensuring a reliable drinking water supply and assessing their vulnerability to climate change

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Abstract

Domestic wells provide drinking water for a significant proportion of the population in Sweden, especially in rural areas where public water supplies are not available (Drage, 2022; Hjerne et al., 2021). Domestic wells typically lack regulation (Gunnarsdottir et al., 2020; Stoll et al., 2011), with owners being responsible for maintaining and ensuring water safety (Socialstyrelsen, 2008). Examining individual drinking water supplies is crucial for sustainable development, given their heavy reliance on groundwater sources (Maxe, 2007). Recent studies on climate change impacts have emphasized groundwater-related concerns (Stoll et al., 2011). Therefore, it is imperative to conduct research, plan, and manage domestic water sources to enhance national drinking water security and reduce vulnerability to disruptions. Domestic wells are particularly vulnerable to changes in groundwater quality and quantity, which can lead to water scarcity, affecting a significant portion of the population (Rodhe et al., 2006).

In order to address the study's aim of examining the current state of domestic well management by municipalities and contributing to the understanding of drinking water and domestic wells, especially in terms of their vulnerability to climate change impacts, an online survey was distributed to all municipalities in Sweden. Additionally, four semi-structured interviews were conducted with representatives from municipalities and County Administrative Boards. Thematic analysis was performed on the collected data to gain insights into the opportunities and challenges municipalities face in their efforts to achieve sustainable objectives and ensure universal access to clean water.

The study reveals that domestic wells in Sweden have not yet received specific attention from authorities, and comprehensive regulations addressing issues such as water quality and quantity deficiencies are lacking. Nonetheless, the survey indicates a growing recognition of the need to address these challenges, particularly in southern municipalities and areas with scarce groundwater resources. This highlights the urgency of promoting sustainable water management and achieving sustainable drinking water solutions in regions heavily reliant on groundwater.

Keywords: *"Domestic wells", "Individual drinking water supply", "Climate change", "Sustainable development", "Drinking water management", "resilience water supply, "Climate adaption", "Sweden"*

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Alice Stenfelt

Abbreviations

Swedish agencies or organisations	English translation	Abbreviations	SFS number
Sveriges geologiska undersökning	Sweden's Geological Survey	SGU	
Boverket	The Swedish National Board of Housing, Building, and Planning	BBR	
Socialstyrelsen	The National Board of Social Affairs and Health	SOS	
Livsmedelsverket	The Swedish Food Agency	SLV	
Sveriges Kommuner och Regioner	The Swedish Association of Local Authorities and Regions	SKR	
Svensk Författningssamling	Swedish Code of Statutes	SFS	
Vattenmyndigheten	Water authority		
Kommun	Municipality		
Länsstyrelse	County Administrative Board		
Laws			
Lag om allmänna vattentjänster	The Public Water Services Act	LAV	SFS 2006:412
Miljöbalk	The Environmental Code		SFS 1998:808
Plan- och Bygglag	The Planning and Building Act		SFS 2010:900

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1 Introduction

1.1 Problem Statement

In Sweden, the abundance of clean water has long been perceived as an infinite resource, often taken for granted (Gunnarsdottir et al., 2020). However, the rapidly changing reality caused by climate change necessitates our immediate attention. The domestic wells, which are frequently overlooked, serve as the sole source of drinking water worldwide and play a significant role in Sweden, where a substantial portion of the population relies on or utilizes water from these wells (Drage, 2022; Hjerne et al., 2021). The vulnerability of these wells to natural processes underscores the urgent need to address the challenges posed by climate change and safeguard these essential water sources (Vikberg et al., 2015). In Sweden, domestic wells are privately owned and predominantly found in sparsely populated areas, posing challenges for monitoring and protection. Unlike regulated water sources, domestic wells often lack oversight, placing the responsibility for water maintenance and safety solely on individual owners (Socialstyrelsen, 2008). Consequently, many well owners lack resources to protect water quality, leading to widespread groundwater contamination (Gunnarsdottir et al., 2020; Schimanke et al., 2022; Stoll et al., 2011).

While previous studies in Sweden have primarily focused on surface water and municipal water networks, recent attention has turned to groundwater-related issues in the context of climate change (Göteborgsregionen, 2020; Stoll et al., 2011). These studies highlight the urgent need to research, plan, and manage domestic water sources to enhance national drinking water security and establish resilient water supplies that reduce vulnerability to disturbances. Groundwater bodies are highly susceptible to the impacts of climate change, leading to water stress and compromising the availability and quality of drinking water (Butler et al., 2017; EEA, 2018), putting a significant proportion of the population at risk of water scarcity and poor water quality (Rodhe et al., 2006). Access to clean drinking water is not only vital for individual health and well-being, but also for the overall prosperity and survival of societies (Naturvårdsverket, 2021).

Numerous factors, including population growth, increased demands for resources, pollution, and urbanization, pose significant challenges to water availability and quality, exacerbating the risks associated with climate change (EEA, 2018). As the impacts of climate change become increasingly apparent, proactive planning and strategies are essential to minimize its effects on all drinking water supplies. This involves both reducing greenhouse gas emissions and implementing adaptive measures to protect natural and human systems from the consequences of climate change. These strategies need to be implemented at various levels, from global to local, to effectively address the challenges we currently face (Biesbroek et al., 2009; Butler et al., 2017). By recognizing the vulnerabilities of domestic wells and the importance of sustainable water management in the face of climate change, action can be motivated to secure clean drinking water for present and future generations.

1.2 Aim

The aim of the study is to assess the vulnerability of domestic wells in terms of water quality and quantity as a result of climate change impacts. The study will also identify the role for municipalities in achieving sustainability goals and a reliable drinking water supply for domestic wells users.

1.2.1 Research Questions

1. Are there geographical differences in the challenges experienced by municipalities related to the quantity and quality of water from domestic wells?
2. How are domestic wells currently regulated and managed by municipalities, and what measures are being taken to address problems associated with domestic wells?
3. Can municipalities contribute to ensuring a sustainable and safe drinking water supply for domestic well users and are there any measures that need to be taken?

2 Background

2.1 Drinking Water Sustainability Goals

Drinking Water plays a crucial role and permeates all pillars of sustainability, including social, environmental, and economic dimensions. It is essential for maintaining a sustainable environment and supporting society as a whole. Disruptions to water availability and quality can have a significant impact on the functioning of our societies. Effectively managing water resources and ensuring clean water is not only an environmental and social concern but also an economic benefit to society. The economic benefits of good water management and investment in clean water often outweigh the associated costs (Vattenmyndigheten Södra Österjön, 2022). To avoid negative impacts on ecological, social, and economic systems, it is essential to strengthening the resilience of drinking water systems to enable them to adapt to change and maintain service levels to society (Barthel et al., 2017) by strengthening resilience to reduce the risk of serious consequences (Kjellström et al., 2014).

The United Nations Global Sustainability Development Goal number 6 aims to ensure universal and equitable access to safe and affordable drinking water for all by 2030 (FN-förbundet, n.d.; Gunnarsdottir et al., 2020), including those served by domestic drinking water supplies (Gunnarsdottir et al., 2017). This goal encompasses all dimensions of sustainable development and serves as the basis for long-term and sustainable water use (Regeringskalnsliet, n.d.). The Swedish Parliament has also established an Environmental Target System, known as the "Generationsmålet," to prevent environmental problems from being passed on to future generations (Naturvårdsverket, 2021). The system includes 16 environmental quality goals, and one of them is "Groundwater of good quality", which affects the work of authorities, County Administrative Boards, and municipalities in finding different ways to achieve the environmental goals (Sveriges miljömål, 2023). The goal is to ensure that the quality and availability of groundwater do not limit its use for public or domestic drinking water supply (Naturvårdsverket, 2021). The goal also includes three sub-goals, which aim to (1) protect and maintain stable groundwater levels and ensure that drinking water meets quality standards (Sundén et al., 2010). (2) to prevent human influence on groundwater bodies from endangering access to or quality of water supply (SOU, 2000:52). And (3) seeks to achieve a good environment and ecosystem for plants and animals dependent on groundwater to prevent negative environmental consequences, to avoid competition between water consumption and nature's own water needs (EEA, 2018).

2.2 Domestic Drinking Water Supply in Sweden

It is estimated that around 1.2 million people get their water from domestic wells (Chen et al., 2021; SGU, 2016) and an equal number are estimated to use it part-time (Maxe, 2007). In rural areas where public water supplies are not available, domestic drinking water supplies like domestic wells are commonly used (Drage, 2022). The division between municipal and domestic drinking water supplies has emerged due

to the impracticality and costliness of connecting dispersed or agglomerated settlements to public drinking water infrastructure (Göteborgsregionen, 2020). Apart from permanent residences and transient populations like tourists or summerhouse dwellers (Gunnarsdottir et al., 2017), domestic wells can also be used by the agricultural, industrial, and service sectors (Kalmar Länsstyrelse, 2022). While most of their water use comes from surface water, groundwater and domestic wells are common. Particularly in agriculture, which can lead to significant withdrawals of groundwater. However, in some areas depending on local conditions, domestic wells used by private individuals can also, together or alone, contribute a significant proportion of groundwater withdrawals (Drage, 2022). In addition, the sustainable use and availability of water resources are crucial for Sweden's industry, food production, agriculture, and drinking water supply(Chen et al., 2021; Vattenmyndigheten Södra Österjön, 2022). In order to maintain the country's current production levels, there is a need for incentives to promote efficient water use and planning (Vattenmyndigheten Södra Österjön, 2022).

2.3 Climate Change

Water supply is an important indirect concern related to climate change, and there is often a lack of understanding of the direct and indirect impacts of a changing climate on groundwater (Chen et al., 2021; Goderniaux et al., 2011). The conditions for ensuring safe drinking water supplies are particularly critical for domestic wells due to their vulnerability to changes, as they often depend on fast-reacting reservoirs that are highly sensitive to changes (Vikberg et al., 2015).

In Sweden, a rise in average temperatures, changes in precipitation patterns, and increasing sea levels are anticipated (SOU, 2015:51). However, climate models and trends project various regional changes in response to climate change (Schimanke et al., 2022). Northern Sweden is anticipated to experience a milder climate with increased precipitation and runoff, while central and southeastern regions are expected to become warmer with minimal changes in annual precipitation compared to the north (Chen et al., 2021; SMHI, 2023). Particularly during winter, significant alterations are expected, including shorter and milder periods of widespread cold, reduced snowfall, and more intense precipitation extremes (SMHI, 2023). Climate scenarios predict both heavy rainfall on short timescales and prolonged precipitation associated with low-pressure systems (SMHI, 2023). Average precipitation is projected to increase mainly during winter and spring, while summer precipitation is expected to decrease (Adler et al., 2022; SOU, 2015:51; Vattenmyndigheten Södra Österjön, 2022). The rise in average temperatures will also result in increased evaporation, more frequent heatwaves, extended dry periods, and prolonged vegetation seasons (Adler et al., 2022; Göteborgsregionen, 2020; SOU, 2015:51).

2.3.1 Effects on Domestic Wells

Groundwater Recharge

Changes in precipitation significantly affect groundwater dynamics, particularly recharge patterns controlled by the amount and timing of rainfall. Low winter precipitation is associated with reduced groundwater levels, emphasizing the need to consider temporal

precipitation distribution when studying groundwater responses to a changing climate (Stoll et al., 2011). Winter precipitation plays a crucial role in annual groundwater recharge, primarily concentrated between October and March. Winter precipitation is more effective at recharging groundwater, as less water is lost to evapotranspiration or plants. Therefore, droughts tend to be more severe when precipitation deficits occur during the winter months. In addition to the temporal distribution of precipitation, the total annual precipitation also has a major impact on groundwater. In particular, low annual precipitation occurring year after year is associated with groundwater droughts (Stoll et al., 2011) and may lead to water shortages (Göteborgsregionen, 2020). This is an especially important aspect for fast-reacting aquifers, often used by domestic wells, which are more vulnerable to changes in hydrological conditions such as drought or rainfall due to their shorter response time compared to slow-reacting reservoirs (Vikberg et al., 2015) (Drage, 2022). This vulnerability can have a significant impact on groundwater formation, making these aquifers extra sensitive to dry periods (Göteborgsregionen, 2020) and receding groundwater levels (Sundén et al., 2010). Domestic wells, which often are relying on fast-reacting and shallow aquifers, are frequently the first to experience water scarcity (Drage, 2022).

The impact of climate change on groundwater levels in Sweden has been analyzed by the Geological Survey of Sweden (SGU) using the UN's climate calculations. SGU's analysis of climate change and groundwater levels shows that most of the country is expected to experience an increase in average annual groundwater levels, except for the southern regions where levels are projected to decrease (SOU, 2015:51). However, lower groundwater levels can lead to reduced water availability and poorer water quality. The impact of this change will be most significant on small groundwater reservoirs, which are already at their lowest levels in summer and late summer when water availability is already at its lowest (Sundén et al., 2010). Domestic wells relying on this type of reservoir will be particularly affected. In addition, climate change is expected to alter the annual variation of minimum and maximum groundwater levels. Northern Sweden will be most affected, with reduced snow melt decreasing groundwater formation in the spring, while increased rainfall will prolong groundwater formation in the autumn (SOU, 2015:51).

Water Quality and Quantity

A changing climate poses significant challenges for drinking water supplies in Sweden, which may lead to a reduction in water quality and quantity in the short or long term (Adler et al., 2022; SOU, 2015:51; Vattenmyndigheten Södra Österjön, 2022). Impacts such as saltwater intrusion from rising sea levels and increased runoff of pollutants (e.g. road salt, agricultural fertilizers, pesticides, wastewater) and natural organic matter to water bodies or groundwater sources intended for drinking water may be critical for domestic wells by compromising the quality and quantity (Socialstyrelsen, 2008; SOU, 2015:51). Rising temperatures may lead to more frequent droughts and longer growing seasons (Göteborgsregionen, 2020), affecting the overall water supply and groundwater levels (Vikberg et al., 2015). It is important to note that the magnitude of changes will vary between regions, seasons and variables, and it is crucial to consider site-specific conditions such as soil properties, local climate and weather patterns, etc. in planning and management (Schimanke et al., 2022).

2.3.2 Effects on Public Health

Quality problems in domestic wells are common and can seem from various causes. A study conducted in the Nordic countries showed that drinking water from domestic drinking supplies generally is of poorer quality than water from municipal drinking water supplies. Over a five-year period, it was found that about 83% of registered waterborne disease outbreaks in the Nordic countries were associated with domestic wells (Gunnarsdottir et al., 2020). Climate change effects discussed above, poor well construction or location can lead to contamination of drinking water. Contaminants can originate from a variety of sources, including both natural sources, such as geological conditions, or saltwater intrusion (Maxe, 2007), and anthropogenic sources, such as polluted surface water from agricultural and wastewater activities, road salting (Drage, 2022; Göteborgsregionen, 2020). Infiltration of surface or runoff water into groundwater can introduce bacteria, viruses, and parasites, exacerbating water quality problems (EEA, 2018; Göteborgsregionen, 2020).

As a result, the Swedish Food Agency (SLV) recommends testing the water every three years or more frequently if the water is given to children or if there is suspicion that a change may have affected the water quality (Socialstyrelsen, 2008). Several studies find that a significant proportion of domestic wells, even worldwide, fail to meet drinking water quality guidelines. Barriers to low testing rates among well owners often include the cost of testing, lack of concern, inconvenience, or a lack of knowledge (Drage, 2022). Testing is crucial because water that appears to have no taste, smell, or discoloration may still have poor quality (Schulte-Herbrüggen et al., 2022). It is essential to test the water to identify contaminants and prevent prolonged consumption and exposure to harmful substances (Drage, 2022). If the quality of the raw water does not meet the desired standards, these issues have to be addressed. Failure to act can result in consumers suffering illnesses and chronic health problems due to the consumption of poor-quality drinking water (Schulte-Herbrüggen et al., 2022), highlighting the significant impact of domestic wells on public health (Drage, 2022; Gunnarsdottir et al., 2020). It should be noted, however, that not all domestic wells are used for drinking water and some rely on their wells for other water needs (Drage, 2022).

2.4 Control and Division of Responsibilities

Table 2.1 provides a schematic representation of the distribution of roles within the Swedish government hierarchy. However, it can be difficult to understand how these organisational responsibilities are allocated in practice. The purpose of this subsection is to provide clarity on some of the key roles involved in domestic water management in Sweden.

Actor/Authority	Responsibility	Legalisation/Goals
Well owner	- Primary responsibility of the well maintenance and water quality	
Municipality	- Ensure access to safe drinking water - Ensure health protection for individual facilities - Impose permit or notification requirements - Prevent water shortages and depletion of wells during low groundwater levels	Environmental Code (SFS, 1998:808) Environmental Code (SFS, 1998:808) Environmental Code (SFS, 1998:808)
County Administrative Board	- Responsible for overseeing water operations	Chapter 11 Environmental Code (SFS, 1998:808)
SLV	- Primary responsibility for drinking water issues - Provide advice and information - Recommendations	Not binding
SOS	- Supervisory authority for health protection - General advice on drinking water and health-based guidelines - Supervising health protection issues	Environmental Code (SFS, 1998:808) Not binding
BBR	- Works extensively with drinking water issues - Regulates domestic drinking water supplies through permits and measures	The Planning and Building Act (SFS, 2010:900)
SGU	- Ensures groundwater quality and coordinates sustainability efforts - Formulates and produces regulations	National Sustainability Goal "Groundwater of good quality"

Table 2.1: Highlights the key actors involved in domestic drinking water supply, their respective responsibilities, and the relevant laws or targets they are controlled by or can use.

2.4.1 Legalisation

In Sweden, a domestic well is classified according to two main criteria. Either if it serves less than 50 people on average, or if it produces less than 10 m^3 of water per day (Socialstyrelsen, 2008). Compliance with water safety regulations is generally lower for domestic drinking water supplies (Gunnarsdottir et al., 2020), which are instead guided by the National Board of Social Affairs and Health's (SOS) general guidelines on drinking water. Nevertheless, people who are supplied with domestic

drinking water have the right to the same level of health protection as those who utilize the municipal drinking water supply (Socialstyrelsen, 2008).

While there are structured legislation for municipal drinking water supply, such as the Public Water Services Act (LAV) (SFS, 2006:412) and regulations issued by SLV (Gunnarsdottir et al., 2020; Schulte-Herbrüggen et al., 2022), the Environmental Code (SFS, 1998:808) serves as the primary legislation governing domestic wells that falls under the classification described above. Domestic well owners receive recommendations from the SLV to conduct regular water quality tests. However, despite the SLV's recommendations, regular testing is not common, and the reporting of results is voluntary (Folkhälsomyndigheten & Karolinska Institutet, 2017; Schulte-Herbrüggen et al., 2022).

The Environmental Code (SFS, 1998:808) aims to promote sustainable development and protect people's health and the environment from inconvenience and damage (Socialstyrelsen, 2008), in line with Sweden's "Generationsmålet". The code considers it a health hazard if a residence lacks access to sufficient quantities and acceptable qualities of drinking water (Schulte-Herbrüggen et al., 2022), which is the case for many users of domestic wells (Folkhälsomyndigheten & Karolinska Institutet, 2017).

2.4.2 Management and Responsibilities

Municipalities ensure high-quality drinking water through continuous testing and control (SKR, 2022b; Socialstyrelsen, 2008). However, this responsibility mainly applies to general drinking water supply domestic drinking water supply (Göteborgsregionen, 2020). The responsibility for the maintenance of domestic wells lies with the well owner (Schulte-Herbrüggen et al., 2022), as the well owner is considered the operator responsible for ensuring the quality of the drinking water supplied (Socialstyrelsen, 2008). Municipalities, in accordance with the Environmental Code (SFS, 1998:808), are responsible for ensuring health protection for individual facilities and taking corrective measures if domestic well water is potentially unsafe (Socialstyrelsen, 2008). The practical supervision of domestic drinking water supplies is typically carried out by a supervisory authority, which communicates any concerns or necessary actions to the owner. If the well serves children or tenants, the supervisory authority has the authority to demand action from the owner (Schulte-Herbrüggen et al., 2022; Socialstyrelsen, 2008). Municipalities also have the authority to regulate domestic well construction and operation in problematic areas as stated in Chapter 9, section 10§ of the Environmental Code (Boman, 2004). Additionally, municipalities are obligated to prevent water shortages and well depletion during low groundwater levels (FN-förbundet, n.d.). Oversight of municipal drinking water facilities falls under the responsibility of environmental committees (SFS, 1998:808, 1998:900).

The county administrative boards have the responsibility of overseeing water operations within their respective counties, including small-scale water withdrawals like domestic wells, as stated in Chapter 11 of the Environmental Code (SFS, 1998:808) (Socialstyrelsen, 2008). These boards, in collaboration with water authorities, also conduct analyses and assessments to establish environmental quality standards for water and develop action programs. They play a crucial role in producing a knowledge base and formulating strategies for water management (Vattenmyndigheten Södra

Österjön, 2022).

SOS is a central supervisory authority responsible for health protection issues under the Environmental Code (SFS, 1998:808). While SLV has the primary responsibility for drinking water issues, SOS has jurisdiction outside of SLV's area of responsibility (Socialstyrelsen, 2008). For domestic drinking water supplies, SOS provide general advice on drinking water and health-based guidelines. These guidelines are linked to an assessment of the quality of water, which categorizes water as either serviceable, serviceable with remarks, or unserviceable (Socialstyrelsen, 2008). The guideline values were developed in collaboration with SLV to assist well-owners in complying with the Environmental Code (SFS, 1998:808), which is based on the EU's drinking water directive (Socialstyrelsen, 2008). SLV's main role is to provide advice and information, while the SOS is responsible for supervising health protection issues related to drinking water (Schulte-Herbrüggen et al., 2022).

The Swedish National Board of Housing (BBR), Building, and Planning is another agency that has a role in domestic drinking water management. The agency is responsible for community planning, urban and residential development, administration, and construction, and works extensively with drinking water issues (Socialstyrelsen, 2008). Additionally, the Planning and Building Act (SFS, 2010:900) regulates domestic drinking water supplies through building permits and other measures (Schulte-Herbrüggen et al., 2022). SGU is responsible for ensuring that the country's groundwater meets the environmental quality goal of "Groundwater of good quality". This mandate includes coordinating follow-up, reporting, and evaluation of efforts to achieve this goal. SGU also formulates environmental quality standards and produces a knowledge base and background information about groundwater, soil, and rock to support the development and indicators for achieving the overall goal (Schulte-Herbrüggen et al., 2022; Socialstyrelsen, 2008). This information is useful for all levels of government in Sweden that are involved with groundwater and domestic wells (Schulte-Herbrüggen et al., 2022). Recently, SGU introduced two new regulations that came into effect on March 1st, 2023. The first regulation pertains to "mapping, risk assessment, and classification of the status of groundwater", while the second regulation is focused on "environmental quality standards for groundwater". These regulations provide clarity on how the EU's water directive and groundwater directive should be implemented by water authorities and emphasize risk assessment. Additionally, the regulations specify threshold values for some new environmentally hazardous substances and introduce an effect-based approach for assessing measured PFAS levels (SGU, 2023).

2.4.3 Sustainability Planning and Protection

Drinking water supplies are generally considered of good quality and reliable, leading to limited public pressure to address water safety concerns unless contamination incidents occur (Gunnarsdottir et al., 2020). However, a notable difference between domestic and municipal drinking water production is the absence of wellhead and wellfield protection plans for domestic wells. This lack of strategic measures contributes to increased risks associated with water quality and quantity (Drage, 2022). Until recently, policymakers and stakeholders have not fully recognized the importance of water management and safety plans, resulting in insufficient attention being paid to addressing these issues in domestic water supplies (Gunnarsdottir et al., 2020). To

ensure sustainable planning for domestic wells and effectively adapt to a changing climate, it is crucial to prioritize the protection of drinking water and address water-related challenges in social development and urban planning. These measures should be of utmost importance on the political agenda (SKR, 2022b; Vattenmyndigheten Södra Österjön, 2022). In the pursuit of sustainability, proactive adaptation and preparedness measures are crucial to analyze climate change impacts and create resilient systems. Anticipating future events, risks, weather forecasts, and scenarios can provide valuable insights in mitigating the effects of climate-related factors on drinking water supplies (Brown, 2015; Rydell et al., 2010).

In Sweden, municipalities play a crucial role in local governance and spatial planning, including decision-making on climate change and adaptation strategies (Biesbroek et al., 2009; Storbjörk, 2010). However, a large number of municipalities are often tasked with monitoring water supply systems, but they often lack the capacity to fulfill this responsibility. This highlights the need for government institutions to provide support and guidance to these municipalities (Gunnarsdottir et al., 2020). Economic and geographical variations among municipalities may influence the prioritization of climate adaptation measures for domestic water sources (Biesbroek et al., 2009; Storbjörk, 2010). Municipal comprehensive plans and physical planning are influenced by elected parties and policies at national and local levels. To address water supply issues effectively, politicians need to take concrete steps and create an enabling environment for planners (Biesbroek et al., 2009). Political commitment plays a vital role in addressing climate adaptation challenges, as planning activities are politically driven. Therefore, political support and prioritization are crucial for advancing climate adaptation efforts within municipalities and ensuring sustainable water supply management (Galderisi and Ferrara, 2012; Hurlimann and March, 2012; Storbjörk, 2010). Clear leadership and top-down approaches are crucial for municipalities and regions to implement adaptation measures and minimise the impact of climate change on domestic water supplies (Biesbroek et al., 2009). Well-defined policies and objectives in physical planning help to ensure that the built environment is optimally developed, designed, used and maintained (Hurlimann and March, 2012; Storbjörk, 2010).

2.4.4 Challenges and Strategies

According to the Swedish National Board of Health and the Karolinska Institute, there is a worrying lack of awareness of water quality among well owners, with around half not following recommended testing practices. In addition, around 24% of domestic wells tested have water quality problems, making them unsuitable for use (Folkhälsomyndigheten & Karolinska Institutet, 2017). Changes in the physical environment can affect nearby wells, especially if they are in close proximity and share the same groundwater catchment area, leading to changes in groundwater conditions (Hjerne et al., 2021). In general, people are more likely to test their wells when they feel vulnerable to a significant threat and when the barriers and costs of testing are reasonable. Motivators for testing include visible changes in well water, property transactions, and the discovery of contaminated wells nearby (Drage, 2022). Given the increasing impact of climate change on groundwater, it is crucial for municipalities to identify areas sensitive to groundwater changes and ensure a sustainable long-term water supply (Socialstyrelsen, 2008). Hydrogeological assessments are essential for

assessing groundwater quality and quantity, predicting future problems and identifying mitigation measures to reduce associated risks (Drage, 2022). To ensure the sustainability of drinking water supplies, the implementation of climate adaptation measures, including water retention strategies, can help to alleviate water stress in scarcity prone areas and promote water conservation (Regeringskalnsliet, n.d.; Socialstyrelsen, 2008). This proactive approach is cost-effective compared to dealing with environmental problems later. Investing in improving water quality is an investment in achieving sustainability goals (SKR, 2022b; Vattenmyndigheten Södra Österjön, 2022).

Accurate data on domestic wells are essential for identifying areas vulnerable to groundwater contamination and other adverse impacts. These wells can also be valuable sources for regional groundwater research, providing extensive datasets to improve our understanding of hydrogeology, water balance, and quality changes over time (Drage, 2022). By analyzing and monitoring such data, future processes affecting groundwater resources can be identified and considered in impact studies (Stoll et al., 2011). This information can be used to identify and mark sensitive areas at risk in the Comprehensive Plan and is crucial for various purposes, including processing building permits, restoring water retention capacity, and addressing saltwater intrusion in coastal municipalities (Göteborgsregionen, 2020; Regeringskalnsliet, n.d.; Socialstyrelsen, 2008). In some areas prone to saltwater intrusion, it may not be suitable to have domestic water supplies or construct new wells due to potential impacts on groundwater quality and availability. Municipalities need to develop strategies to assist residents with domestic wells, including providing guidance on well construction and location (Göteborgsregionen, 2020). It is also vital to have information about the location and quantity of domestic wells to account for their water usage in water balance assessments. This is especially important for aquifers under strain or at risk of saltwater intrusion. Water shortages can arise when water demand exceeds supply, and domestic wells can have a substantial impact on groundwater extraction, depending on local circumstances (Drage, 2022).

3 Materials and Methods

3.1 Overview

In this chapter, Delimitation and Study Area, the methods applied to answer the aim and research questions presented in Section 1.2 are described. This study used a combination of an online survey and semi-structured interviews to explore adaptation strategies and efforts related to domestic drinking water supply, specifically in response to climate change impacts in different regions of the country. Using a qualitative method facilitated deeper understanding and establishing connections in a relatively unfamiliar topic area (Esaiasson, 2017).

Both the survey and interview data were collected in Swedish, the participant's native language. The interview guides, survey questions, and quotes are presented in Appendix A, B, C and E and are translated to English. This qualitative study focuses on capturing individuals' experiences and perceptions of reality.

3.2 Delimitation and Study Area

This study focuses on domestic wells in Sweden, where domestic wells form a significant but smaller part of the overall Swedish drinking water supply system. The study will assess the risks associated with domestic wells, with a particular focus on climate change and the sustainable utilization of water as a drinking water resource. Climate change is of utmost importance due to its increasing relevance and its impact on groundwater-dependent drinking water supplies (Butler et al., 2017; EEA, 2018).

Online surveys sent to all 290 municipalities in Sweden was the main method of the study. These surveys focused specifically on investigating and mapping the current work by Swedish municipalities. The inclusion of respondents from all parts of the country laid the groundwork for capturing geographical diversities. Municipalities are interesting survey participants due to their planning monopoly and influence on land use.

Semi-structured interviews was conducted with authorities operating in areas characterized by prevalent issues with their groundwater. The water district Södra Östersjön (Figure 3.1) was specifically targeted due to its experience of low groundwater levels in small reservoirs (Figure 3.2) which domestic wells are most reliant on. Consequently, for this research, interviews with municipalities and County Administrative Boards hold particular relevance as they allow for an exploration of the encountered problems with domestic wells and the approaches implemented to manage them. In a future impacted by climate change, issues related to water quality and quantity may be amplified. Valuable insights from experienced authorities can serve as guidance for drinking water supply management.

Figure 3.1: The image (Vattenmyndigheten Södra Österjön, 2022, p. 28) displays the boundaries of the Södra Östersjön Water District, with own modifications made to include the labeling of each water district's name.

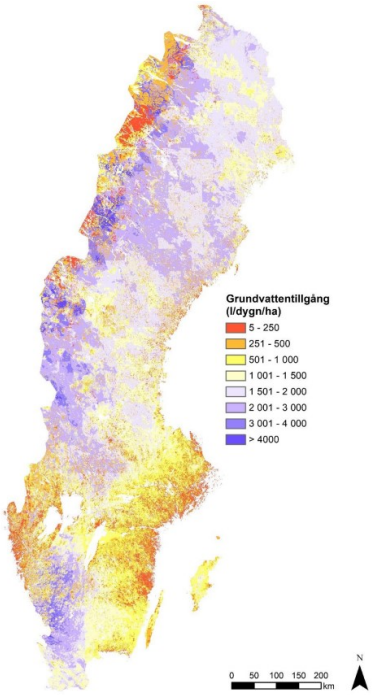

Figure 3.2: Estimated groundwater supply for small reservoirs in Sweden (Hjerne et al., 2021, p. 23).

3.3 Online Survey

The goal of the online survey was to gather information from as many of the 290 municipalities as possible. To ensure a high response rate, the questions were designed to be easy to understand and answer, without being too complex (Bryman, 2018), as the type of participants was yet uncertain. The survey aimed to reach the most knowledgeable person on the subject of domestic drinking water supply within the municipal office. Surveys have the advantage of reaching many people in a time-efficient way and providing a broad basis for the study (Bryman, 2018). The survey was published online using a service by SUNET (www.sunet.se) and was only accessible through a direct link that was generated to prevent public access. The survey consisted of total 36 questions. In total, the survey was out for 3 weeks (from 7/2 to 28/2).

3.3.1 Sampling of Participants for Survey

A list of all municipalities in Sweden was obtained from the Swedish Association of Local Authorities and Regions (SKR) (SKR, 2022a). An introductory email containing information about myself, the researcher, the subject of the study, the aim, and details about the survey was sent to the registration or administrative department of each municipality, allowing them to forward the survey to the most appropriate person or administration for participation in the survey. After this first contact, two reminder emails were sent out to recipients who lacked participation in the survey to increase the participation rate. The final participation in the survey is represented in Section 4.1.

3.4 Semi-Structured Interview

To investigate how municipalities and County Administrative Boards work with domestic drinking water supplies and the challenges they face semi-structured interviews, as described by Esaiasson (2017), were used. The interviews were carried out via Zoom.

An interview guide was created (see Appendix B, C) which consisted of specific themes and several predetermined questions, covering three topics: groundwater and domestic drinking water supply (water management), climate and climate adaptation, and co-ordination/collaboration. The use of semi-structured interviews allowed for follow-up questions during the conversation, resulting in more descriptive and detailed answers than in a static format such as an online survey. This method contributed to the results obtained and supplemented the survey responses (Bryman, 2018). The interview guide was designed to ensure consistency across interviews and to facilitate the comparison of responses between participants.

3.4.1 Sampling of Respondents for Interview

A total of 4 semi-structured interviews were conducted, including 2 with municipality actors and 2 from County Administrative Boards (in accordance with the information provided in Section 3.2) where each interview lasted about 45-60 min. The interviews followed a purposive snowball sampling method outlined by Bryman (2018). Initially, an email was sent to the customer service or relevant department contact person in

each municipality to identify experienced individuals knowledgeable about domestic well issues. Interview questions were shared beforehand to facilitate well-prepared and thoughtful responses and for the respondents to mentally prepare. Table 4.2 offers a summary of interview details, including participating municipalities and Country Administrative Boards.

3.4.2 Ethical Considerations

During the study, obtaining informed consent was crucial. Participants were asked for approval to record interviews for easier post-processing and assured that their identities would remain anonymous. All recorded interviews and transcribed documents were deleted after the study to ensure participant confidentiality (Esaiasson, 2017). To maintain privacy and avoid sensitive information disclosure, participants were provided with the study's topic and interview questions in advance. This allowed them to prepare mentally and prevented discussion of sensitive details. Considering the potential vulnerability of drinking water supply to sabotage or damage (Havs- och Vattenmyndigheten, 2020; Livsmedelsverket, 2019), certain information may have been withheld, although the collected data was deemed non-harmful to participants or their businesses if made public.

3.5 Thematic Analysis

To process the collected data from the online survey and semi-structured interviews a thematic analysis was used. Thematic analysis is a qualitative research method that aims to identify, code, and analyse overarching themes or trends within the data collected (Braun and Clarke, 2006). Coding involves using specific keywords or phrases to identify and highlight characteristics or attributes within a set of data. By utilizing coding techniques, large amounts of data can be efficiently organized (Bryman, 2018). The thematic analysis allows for systematic and qualitative analyses, regardless of how the individual data is structured. For this study, an inductive approach to thematic analysis, as developed by Braun and Clarke (2006), was chosen specifically. This approach allowed for an analytical process of the data without attempting to fit it into a predetermined framework of criteria. The approach of the inductive analysis process consists of six different phases or steps and was used and formed the template for this study, (1) familiarizing with the collected material, (2) creating working codes, (3) searching for themes, (4) Reviewing themes, (5) define and name the themes and (6) produce the final data. It entails when one performs theatrical analysis that you go through your material/data several times to get to know it, it reduces the risk of missing important information. This makes the method time-consuming while large amounts of data can be included in the analysis (Braun and Clarke, 2006). As thematic analysis can be quite tedious when analysing large amounts of data material, the thematic analysis was conducted using a digital program named NVivo. A qualitative data analysis software specifically designed to facilitate the analysis of qualitative data by helping to organize and sort textual data, identify patterns and themes in the data, and facilitate the management of large data sets as described above (Bryman, 2018).

3.5.1 Data Analysis Process

The analysis followed the described phases in Section 3.5 to extract relevant insights from the data material, focusing on the study's objectives and research questions related to domestic wells. The recorded interviews were transcribed, taking 5-8 hours per transcription, and imported into NVivo for categorization and grouping based on similarities by using keywords. For the survey data, comments from respondents were categorized and grouped similarly to the interview. The graphs were created using Microsoft Excel to process and summarize the survey answers using the Privot table. This approach effectively addressed the research questions and provided visual representations to fulfill the study's objectives.

The thematic analysis was carried out in several stages, and each stage is described below, providing an overview of how the analysis was carried out with the data collected.

In Phase 1, the raw data from the survey were organised in Microsoft Excel spreadsheets before being imported into the NVivo programme. Similarly, the interview material was imported directly into NVivo for analysis. The main aim of this phase was to become familiar with the data set and its structure.

Phase 2 consisted of thoroughly reading the data multiple times and applying coding to identify key terms related to quotes from both the survey and interviews. For instance, if a quote mentioned the absence of legislation or laws, it would be coded with the keyword "legislation" for easy retrieval and analysis.

Phases 3, 4, and 5 involved identifying recurring patterns in the data and creating distinct themes based on the coded keywords. The keywords were then reviewed and grouped to generate sub-themes, which were further organized into overarching themes that represented the individual comments. This process facilitated the quantification and analysis of the data.

In phase 6, the quantified data, together with the identified themes and sub-themes, were used to present the findings of the thematic analysis in the results chapter. These findings were then used to draw conclusions from the data collected. The results of the thematic analysis, including a table summarising the findings, can be found in Appendix D.

4 Results

The results obtained from the interviews were consistent with the responses obtained through the survey, providing valuable insights that may not have been apparent through the questionnaire alone. Therefore, results obtained from the survey and from the interviews are presented together and the structure is based on the themes that emerged through the thematic analysis (see Appendix D). The survey questions can be found in Appendix A, and the interview questions are listed in Appendix B and C. Due to space constraints, not all citations could be included in the text, and therefore, noteworthy citations have been listed in Appendix E.

4.1 General Information about Respondents

A total of 127 responses were received in the survey. However, it is important to note that these responses do not represent 127 municipalities (see Table 4.1). For instance, some municipalities submitted multiple responses, leading to duplicates where two different individuals from the same municipality provided separate answers. Furthermore, certain respondents answered the survey on behalf of multiple municipalities, possibly due to shared tasks and responsibilities over water-related questions.

General statistics	**Number**
Total number of municipalities included in the survey	290
Actual number of respondents	127
Actual amount of municipalities	143
Response rate (based on amount municipalities)	49%
Type of respondents	
Environmental Administration	44
Building- & Environment Administration	32
Department of Urban Planning & Development	15
Department of Environmental & Urban Planning	4
Environmental & Health Protection Department	9
Health Protection & Food Unit	8
Water & Wastewater Department	5
Environmental Association	4
Engineering Department	4
Other Departments	2
Total	127

Table 4.1: General statistics from the Online Survey February 2023.

The geographical distribution for the survey respondents are shown in Figure 4.1 over participated municipalities, non participants municipalities and the municipalities that declined to participate leading to a dropout. Some non-participating municipalities provided explanations via email, while others did not respond at all. To ensure an accurate representation of the response rate among municipalities, the data analysis process was adjusted accordingly, accounting for the actual number of participating municipalities.

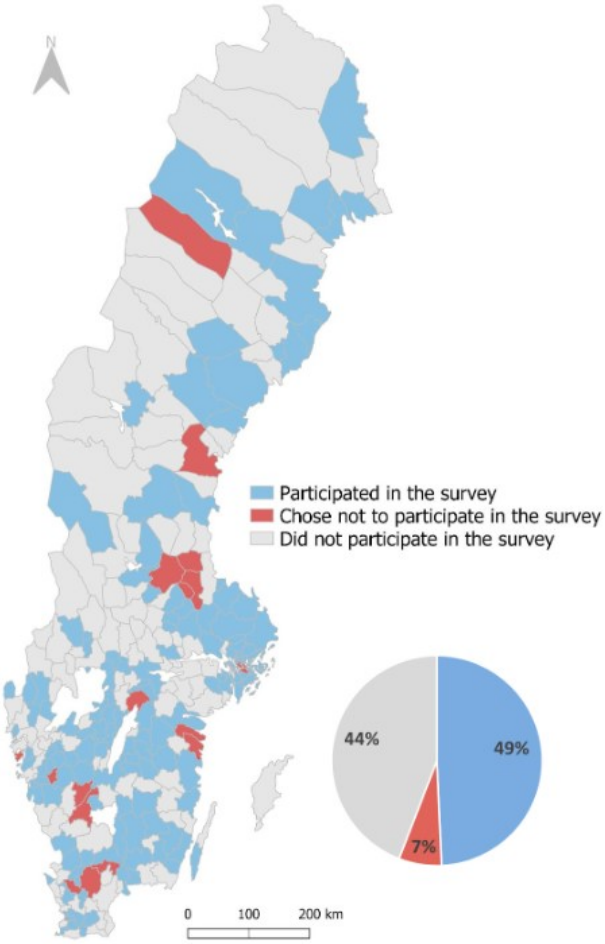

Figure 4.1: Geographical distribution of survey participation: blue indicates 143 municipalities, red indicates 19 municipalities who answered but did not participate, and gray indicates non-participating municipalities with no response or explanation. Spatial data from SKR (2022).

Table 4.2 presents the general statistics and information regarding the interviews conducted with both municipalities and County Administrative Boards. The respondents included a diverse mix of some actively engaged in domestic water supply issues while others were less involved in addressing this matter.

Interview	Municipality	Role	Department	Date
1	Torsås	Environmental inspector	The Building- & Environment Administration	28-Feb
2	Karlskrona	Environmental strategist	Department of Environmental- & Urban Planning	7-Mar
	County board			
3	Blekinge	Water manager	Planning & Environmental Protection	22-Feb
4	Kalmar	Water manager	Water department	7-Mar

Table 4.2: General statistics from the Online Survey February 2023.

Figure 4.2 shows the departments within the municipalities where the respondents

work, as well as how much they consider they work on the subject of domestic drinking water at present. The distribution in Figure 4.2 clearly shows that only a few of those who answered the survey often work with these questions. Most are only working 0-25% or not at all on these issues currently.

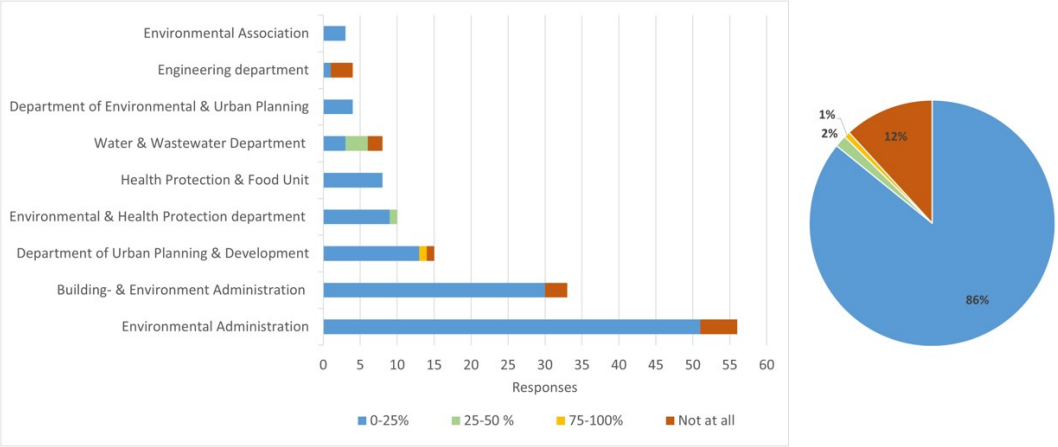

Figure 4.2: Respondents' answers to question 3 & 4 (see Appendix A) of which department the respondent works in and how much they appreciate working on the theme of domestic drinking water supply. Left: Proportion of each response category relative to the total number of responses. Right: Percentage breakdown

The distribution of population across the municipalities covered by the survey is illustrated in Figure 4.3. It is evident that the population varies across the country and is more concentrated in and around larger cities and their corresponding municipalities. According to the estimates provided by survey participants in Question 5, the number of wells reported by all municipalities that answered is approximately 275 393. It is important to mention that 21 out of the 127 respondents answered either 0 or 1 to the question, indicating their lack of estimate, uncertainty, or decision to skip the question.

It is important to note that many respondents answered that the exact number of wells is unknown, as a result of the absence of a registry or reporting mandate to track domestic wells. Municipalities do not actively collect this data, and most participants based their estimates on other parameters and records such as the number of private sewages, sludge discharges, information from SCB, and the "well archive" provided by SGU. Appendix E lists Quotes 2 and 3, which further explain how respondents approached this question.

"There is no register at all due to the lack of municipal supervisory responsibility. However, I estimate that there should be about as many domestic water sources as there are individual sewage systems. Even this number is to some extent an estimate, but it should be much closer to reality" - Svalöv Municipality, quote 1.

Figure 4.4 illustrates the geographical distribution of wells per capita and wells per square kilometer within each municipality, calculated based on the survey responses in question 5. When comparing Figure 4.3 with the calculated well numbers, it becomes evident that sparsely populated municipalities have a substantial number of households

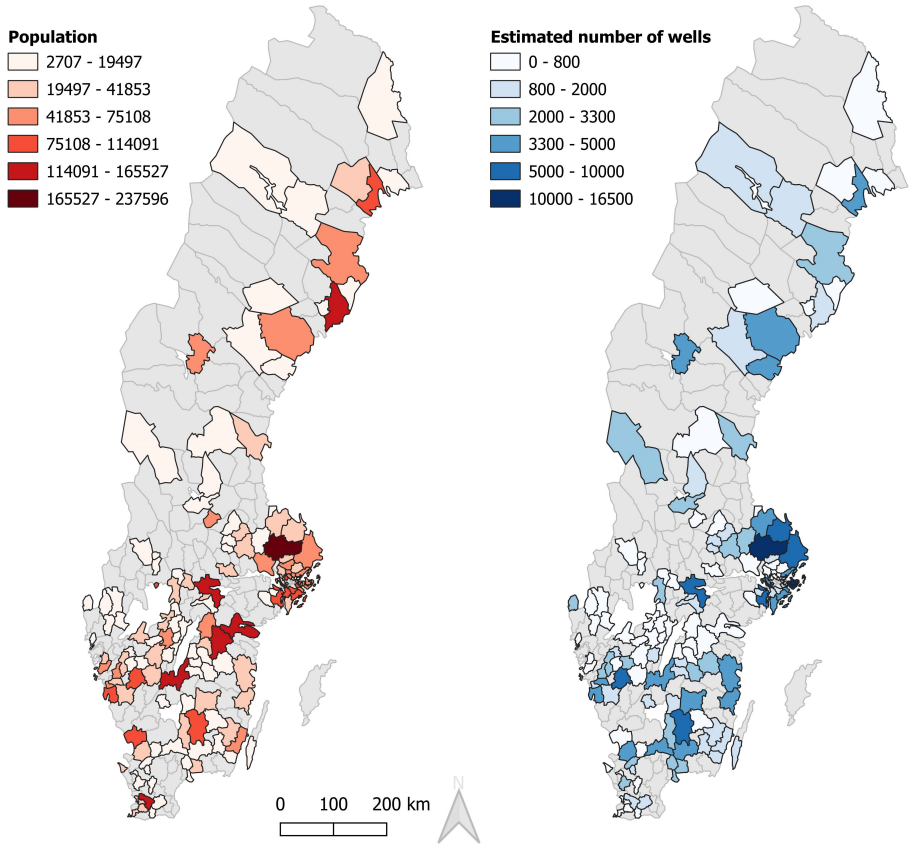

Figure 4.3: Map of the study area over estimated wells based on respondents' answers to question 4 (see Appendix A) of how much they appreciate working on the theme of domestic drinking water supply and latest population data from 2021 in each municipality (SCB, n.d.[a]). Spatial data provided by SKR (2022).

dependent on domestic wells compared to municipalities close to bigger cities.

4.2 Domestic Well Usage

Figure 4.5 shows that the number of private users of domestic wells is significantly higher than the number of wells used for agricultural or other industrial purposes.

In Figure 4.5 the level of knowledge varied among municipalities in accurately determining the distribution of domestic wells among private users, agriculture, and industry. The majority of respondents were unaware of the answer as this information is not typically collected by the municipalities themselves. Some responses suggested that very few industrial operations rely on domestic water supplies, and a few municipalities demonstrated better management practices by maintaining records of both agriculture and industry wells. Appendix E lists Quotes 4, 5, and 6, which further explain how respondents approached this question.

Figure 4.6 illustrates whether the estimated number of wells provided in question 5 accurately represents the true number or if there may be a significant under reporting of wells.

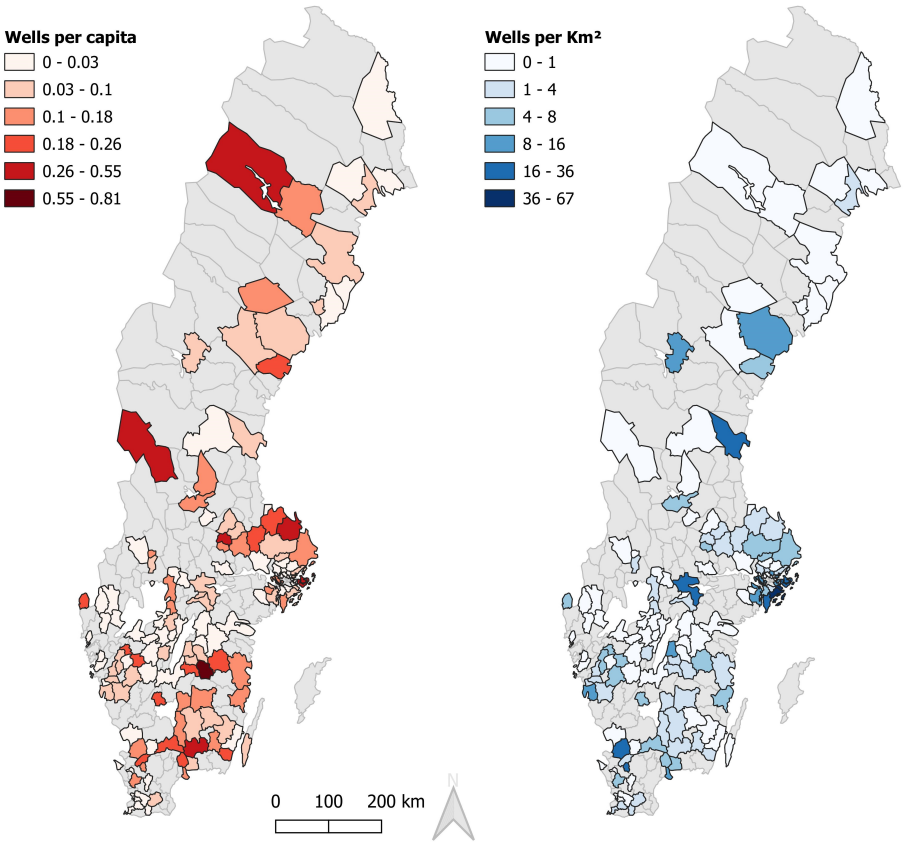

Figure 4.4: Estimated number of wells per capita and km² based on respondents' answers to question 4 (see Appendix A) of how much they appreciate working on the theme of domestic drinking water supply and latest land area information and latest population data (SCB, n.d.[a],[b]). Spatial data provided by SKR (2022).

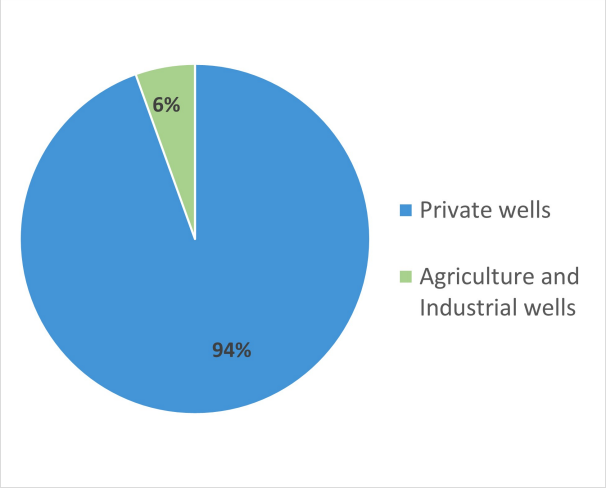

Figure 4.5: A percentage breakdown of respondents' answers to question 7 (see Appendix A) of how many of the estimated numbers of domestic wells installations are estimated to be agricultural/other industrial activities.

Due to the significant uncertainty concerning the number of wells, the reported wells in question 5 may not be comprehensive. Several municipalities provided responses

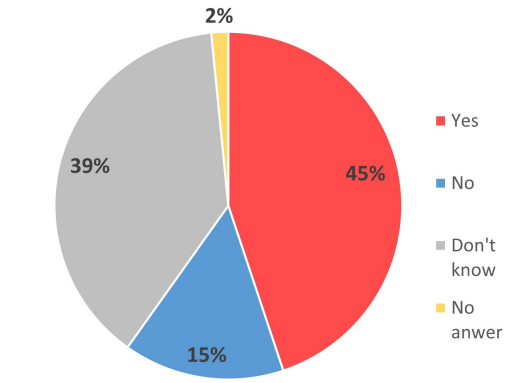

Figure 4.6: A percentage breakdown of respondents' answers to question 6 (see Appendix A) whether there is a large unrecorded number of wells.

such as "Yes," indicating a high level of uncertainty, or "Don't know." Appendix E lists Quotes 7 and 9 which further explain how respondents approached this question.

"There is no registry at all because there is no municipal supervisory responsibility. However, I estimate that there should be about as many private water sources as there are individual sewage systems. This figure is also to some extent an estimation, but it should be much closer to reality" - Örkelljunga Municipality, quote 8.

"[...] However, there is likely a big uncertainty between what is registered in SGU's well register and what is likely on site. This is because it is up to the property owners to register, which many likely do not do." - Uppsala Municipality, quote 10.

Municipalities that fall under the 15% who responded "No" (meaning that there is not a big uncertainty about the number of wells) and have a good understanding of the number of wells have typically conducted inspections of private sewage systems and maintained records of them. In addition, some municipalities have established a systematic process where well owners can send in water samples through the municipality, allowing for a more accurate estimate of the number of domestic wells.

"We have inspected all individual sewage treatment plants in the municipality and therefore have a pretty good idea of what the domestic drinking water supply looks like, since we always ask where the drinking water well is located during sewage inspections." - Herrljunga Municipality, quote 11.

"[...] but since Tidaholm municipality has offered owners of domestic wells to submit water samples, which the municipality forwards for analysis at a favorable price, and has been doing so since the mid-1990s, there are not so many wells that have not been sampled" - Tidaholm Municipality, quote 12.

During the interviews conducted with the Blekinge and Kalmar County Administrative Boards, it was revealed that industries often require water permits from the land and environmental court due to their significant water consumption. Additionally, these permits are often very old and outdated. However, the Kalmar County Administrative Board pointed out that agriculture or farms with extensive land areas often fall under

an exception in the Environmental Code.

"For industries that consume a lot of water, it's a different matter and they need something called a water permit, which is approved by the land and environmental court" - Blekinge County Administrative Board, Interview February 22, 2023.

"Definitely, they often have water permits, but the problem with them is that they are often very old and may not reflect the current situation when it comes to groundwater levels or water levels [...]" - Kalmar County Administrative Board, Interview March 7, 2023.

"[...] the exceptions in Chapter 11, Section 11 of the Environmental Code that we have raised, the question is whether it is reasonable to have several hundred animals for household needs. I understand if the legislation may come from a time when you had a cow on the farm and therefore did not need to apply for notification or permission. But when talking about several hundred animals in a herd and not having to have a water permit for it"- Kalmar County Administrative Board, Interview 7 March, 2023

4.3 Municipalities' Responsibility and Work Related to Domestic Wells Today

Several municipalities have emphasized that domestic drinking water issues are not their responsibility as there is no mandatory legislation that requires them to handle such issues. The municipalities' responsibility is only defined by the Public Water Services Act (LAV), which governs larger facilities that supply water to more people, and in some exceptional cases, the Environmental Code. Property owners are solely responsible for their domestic drinking water supply and the associated facilities. Appendix E lists Quotes 20 and 21 which further explain how respondents approached this question.

"It is not a municipal responsibility in individual cases. But according to the Environmental Code, the municipality has an overall responsibility for public health" - Sala & Hedby Municipalities, quote 18.

"Like I said, it's not something the municipality actively works with since the responsibility lies with the individual property owner to supply their property with drinking water outside the water and sewage area."- Skurup Municipality, quote 19.

"Since there is no requirement to report the excavation/drilling of private wells in the municipality, there is also no registry of such. [...] The municipality therefore has no registry of private wells/drinking water facilities except for those that must be checked against the requirements of the legislation (the drinking water regulations)" - Östersund Municipality, quote 22.

However, Torsås municipality pointed out that the municipality has a supervisory responsibility under the Environmental Code when renting out housing.

"In the Environmental Code, there is a provision in our supervision that if you rent out housing to others, among other things, you must ensure that there is good quality

and quantity of drinking water" - Torsås Municipality, Interview February 28, 2023.

Figure 4.7 shows whether municipalities are currently taking measures to ensure a reliable drinking water supply for individuals with domestic wells, as well as the extent to which those who answered "Yes" are actively addressing this issue. The municipalities in the northern water districts are currently not addressing these issues.

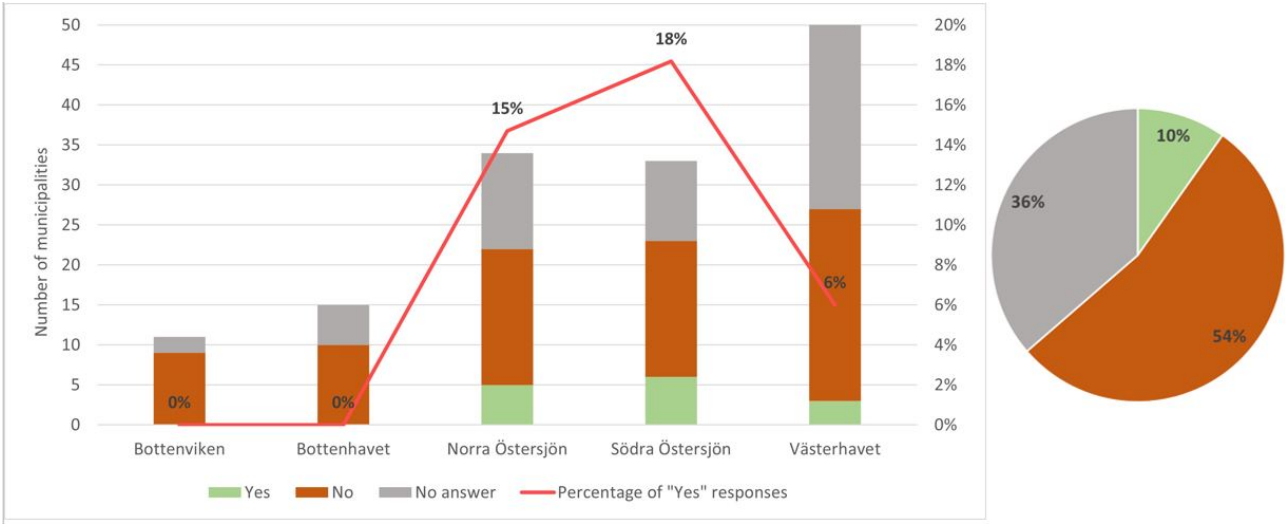

Figure 4.7: Respondents' answers to question 24 (see Appendix A) if the municipality work towards resilient drinking water extraction for people with domestic drinking water supply. Left: Proportion of each response category and water district relative to the total number of responses. The red line represents the number of "Yes" answers in relation to the total number of answers in each water district group. Right: Percentage breakdown.

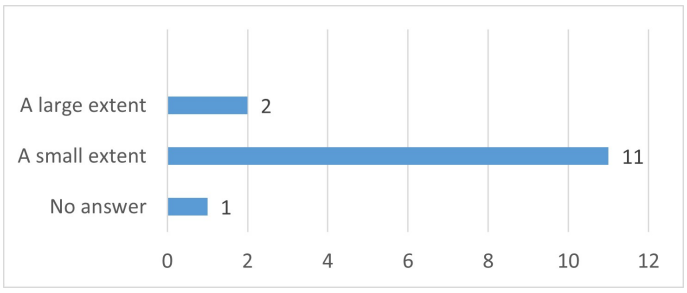

Figure 4.8: The respondents' answers to question 25 (see Appendix A) of those municipalities that worked with resilient water supply for domestic drinking water.

The findings in Figures 4.7 and 4.8 reveal that only a few municipalities are actively addressing domestic well issues. Some municipalities have implemented permit requirements for drilling new wells as a means to exert influence over sustainability aspects and are actively working towards connecting individuals to the municipal water supply network. Furthermore, measures such as increasing the capacity and regeneration of groundwater reservoirs or enhancing the efficiency of well usage are mentioned. Appendix E lists Quotes 58, 59 and 60 which further explain how respondents approached this question.

"Included in all our work - strategy/plan/building is to work towards future supply for both the municipal and in environmental work to protect private drinking water sources" - Sjöbo Municipality, quote 61.

"[...] YES: Regarding drilling of new wells, a permit requirement has been introduced, where the environmental office can influence sustainability aspects. When examining new individual sewage treatment plants, we always request chloride analyzes as an assessment tool. Through dialogue with the applicant, we try to make them understand how their drilling or sewage treatment plant installation can affect future drinking water extraction opportunities. NO: There are no preventive or supportive activities from the municipalities regarding domestic wells in general" - Vaxholm & Täby Municipalities, quote 62.

During the interviews with Karlskrona and Torsås municipalities, it became apparent that working on these issues can be seen as more of a voluntary task. Additionally, the extent of discussions necessary within Karlskrona municipality implied that there is currently limited work being carried out on these matters.

"Yes, but I was still thinking that we had to discuss these issues with different colleagues, which is because we actually don't work in this area. And that's also a good realization" - Karlskrona municipality, Interview on March 7, 2023.

"It feels a bit like a voluntary task when it comes to drinking water, but we actually work quite a lot with it and with statistics. So we have a lot of statistics on how it varies over time, etc." - Torsås municipality, interview February 28, 2023.

The municipalities that responded "No" or did not answer the question stated that they do not work on or have any knowledge about resilient drinking water for individuals with domestic wells. They mentioned that they work on resilient drinking water, but not specifically targeted towards domestic wells, rather mainly for the municipal Water- and Sewage network. Currently, it is not considered a primary responsibility of the municipalities to work on these issues. Instead, advice and general information are provided to the well owners on water conservation and measures that can be taken to protect water sources. However, some municipalities are requesting for more work to be done on these issues. Appendix E lists Quotes 63, 64and 65 which further explain how respondents approached this question.

"During 2023, the municipality will work on a Water Service Plan. It may lead to proposed measures" - Upplands-Bro municipality, quote 66.

"According to the municipality's VA plan, we are working on continuous expansion of the VA network to offer drinking water of good quality but also to reduce emissions of untreated wastewater" - Lysekil Municipality, quote 67.

Torsås municipality highlights that unclear legislation and ambiguous guidelines or general advice that can be challenging to interpret have played a role in contributing to this situation.

"It's a bit about the mandate and such. That there is no clear legislation, but it is largely about guidelines and general advice, and so on" - Torsås Municipality, Interview

on February 28 2023.

Figure 4.9, shows which municipal documents most frequently address or include domestic drinking water supplies. The results indicate some variation but that the majority of municipalities address domestic wells in both their Water- and Wastewater Plan and Comprehensive Plan.

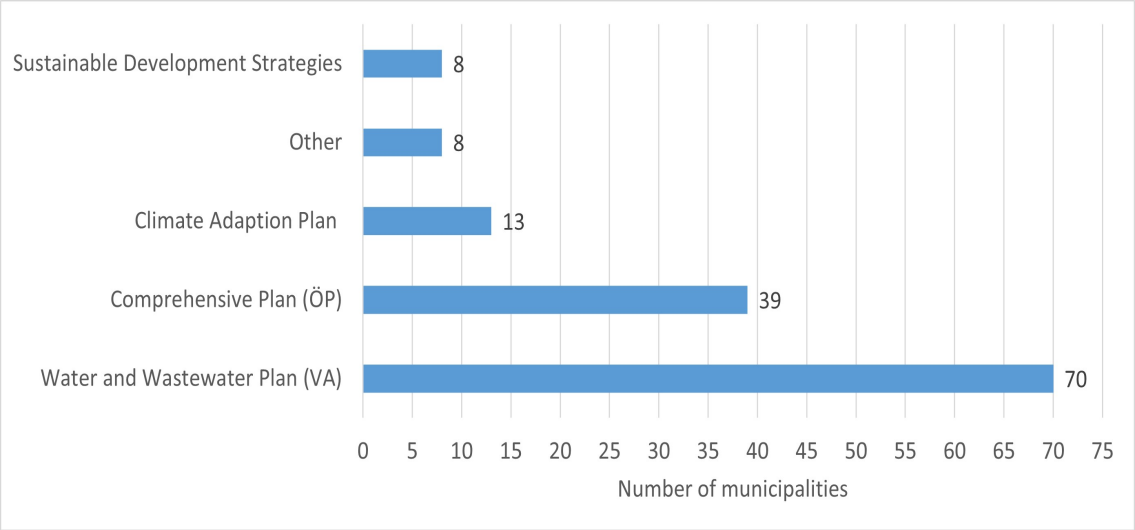

Figure 4.9: The participants' answers for question 27 (see Appendix A) of whether domestic drinking water supply today is included in the municipality's documents or work and where it is mentioned.

The "Other" category in Figure 4.9 represents municipalities that mentioned additional documents related to the subject. Although the documents often mention domestic drinking water supplies, some municipalities lack strategies on how to address them effectively. Appendix E lists Quotes 14, 15 and 17 which further explain how respondents approached this question.

"Botkyrka's Blue Values is a document that covers all types of water in the municipality and how we should work to ensure good water quality in the municipality" - Botkyrka Municipality, quote 13.

"Forms part of the VA plan, but there is also work underway to develop a water supply plan (which also compiles available knowledge regarding domestic water supply)" - Nybro Municipality, quote 16.

4.4 Domestic Well Vulnerabilities

In this section, challenges and factors identified by municipalities that affect the access and quality of domestic drinking water supplies and groundwater will be presented. These challenges include climate change, population growth, competition, pollution, location-specific conditions, or whether SLV's recommendations are followed to detect inconveniences.

4.4.1 Quality and Quantity issues

The municipalities were asked if they typically experience water shortages in terms of access and quality issues within the municipality. Figure 4.10 presents the responses regarding water shortages, and Figure 4.11 presents the responses regarding quality problems.

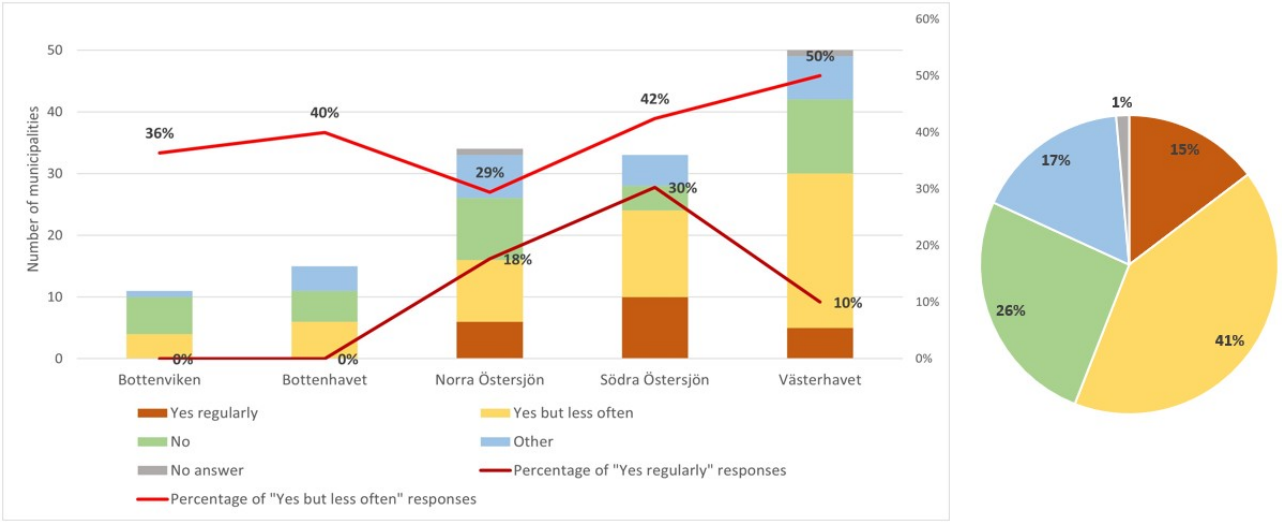

Figure 4.10: The participants' answers for question 8 (see Appendix A) of whether domestic drinking water supply is included in the municipality's documents or work today. Left: Proportion of each response category and water district relative to the total number of responses. The red lines represent the number of "Yes" and "Yes but less often" answers in relation to the total number of answers in each water district group. Right: Percentage breakdown.

Figure 4.10 presents the municipalities' experiences of water shortages and quantity problems for people with domestic wells. A significant percentage of municipalities reported that they usually experience water shortages, with 15% doing so regularly, especially in the southern water districts of the country. 41% of all responding municipalities experience water shortages, but less often. A considerable percentage of municipalities that do not experience any water shortage, and many did not know the answer to the question.

Figure 4.11 presents the municipalities' reported experience of quality problems related to domestic wells. The results show that over 64% of the municipalities experience such problems, and these are relatively evenly distributed across the different water districts. Only 17% of the municipalities report no water quality problems, while the rest either lack perception or insight into the quality of drinking water for individuals with domestic wells.

Municipalities frequently encounter water shortages, primarily in the summer months, and occasionally during dry periods in late autumn or early spring. Figure 4.12 identifies specific characteristics of locations within these municipalities where water shortages are regularly reported, including proximity to the coast and areas with shallow soil layers. Moreover, scarcity of water can worsen during periods of constraint and reduced groundwater formation, exacerbated by excessive withdrawals and increased

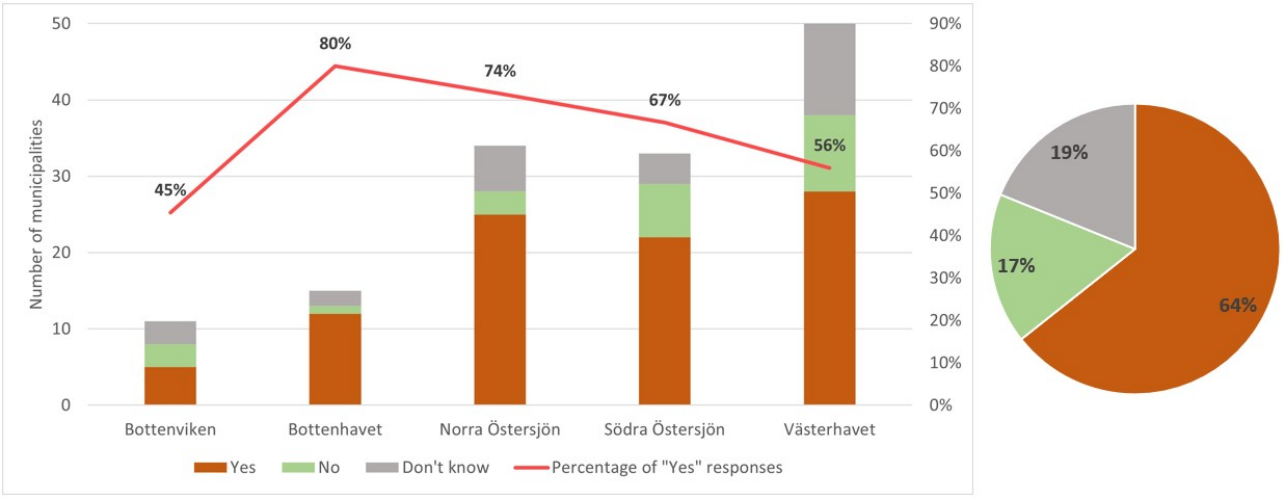

Figure 4.11: The participants' answers for question 11 (see Appendix A) of whether the municipalities experienced quality problems for domestic drinking water supplies. Left: Proportion of each response category and water district relative to the total number of responses. The red lines represent the number of "Yes" answers in relation to the total number of answers in each water district group. Right: Percentage breakdown.

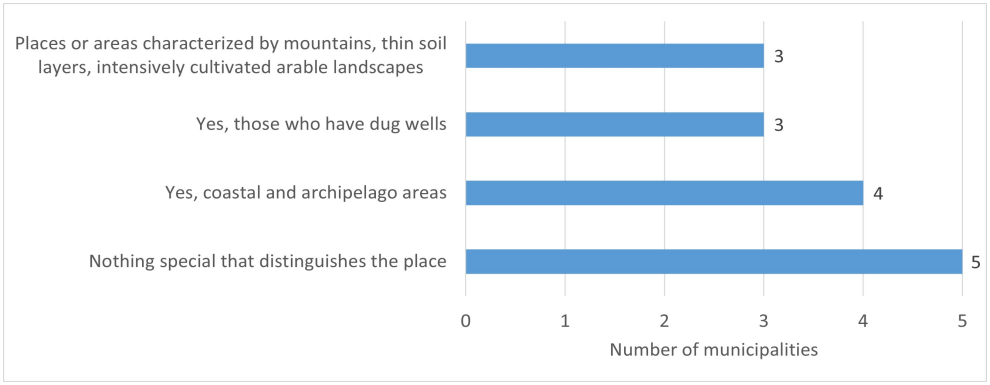

Figure 4.12: The participants' answers for question 9 (see Appendix A) and the most prevalent themes of whether there is anything that distinguishes a place that frequently experiences water shortages.

water consumption. Appendix E lists Quotes 24, 26, 27, 28, 29, 31 and 32 which further explain how respondents approached this question.

"The places with a lot of exposed bedrock or clay. Places with close or direct connection to the sea, where the storage capacity is small and most of the rainfall during heavy showers runs straight into the sea. In these coastal areas and on the municipality's islands, the population increases during the summer when more visitors, friends, relatives, and family stay on the site for a few weeks/months" - Kungälv Municipality, quote 23.

"Domestic wells in certain areas. Problems with saltwater intrusion, problems with access, for example, at the end of summers in some years. More people are starting to desalinate seawater instead of using wells with quantity or quality issues" - Vaxholm and Täby Municipalities, quote 25.

"The issues we come in contact with are mainly bacteria from wastewater in small villages without municipal water and sewage systems. Pesticides occur in municipal wells and therefore likely in private wells as well. However, the testing frequency for private wells is low and we rarely get information about the drinking water status of private individuals" - Svalöv Municipality, quote 30.

The quantity and quality issues in Kalmar County are mainly due to its geographic location with a rain shadow and especially in combination with intensive agriculture. Karlskrona municipality highlights that water shortages can be mitigated by managing water usage, especially during the busy summer months.

"In Kalmar County, we have very limited water resources overall. It's a rain shadow, so we get about half as much water as the west coast has. [...] At the same time, we have very intensive agriculture, especially on Öland, which is perhaps one of the driest places in Sweden" - Kalmar County Administrative Board, Interview March 7, 2023.

"When it comes to quality, it's harder to say, but we have environmental monitoring that is ongoing, and we often discover pollutants. But not in such high concentrations that it affects usage areas, so to speak. Then, of course, we have the PFAS problems, where we don't have such good control over domestic wells today, I would say spontaneously" - Kalmar County Administrative Board, Interview March 7, 2023.

"The water quality is mostly good, it's more about how the water is used and we have watering bans in certain areas as always. The private individuals have limited knowledge about it, but it will be tough during the summer as for many others"- Karlskrona Municipality, Interview March 7, 2023.

The municipalities also state that it is difficult to estimate the water shortage in terms of quantity and mainly quality problems as there is no requirement for the property owners to notify the municipality if problems arise, even the test water results are not something the municipalities get notified of since they are directly sent to those affected. Appendix E lists Quotes 33 and 35 which further explain how respondents approached this question.

"Child water samples (for households with children under age of 5) can be ordered through the municipality, but we do not receive any feedback on these, they are only sent to those affected" - Lidköping Municipality, quote 34.

An interesting takeaway from the interview with the Kalmar County Board regarding the topic discussed above is that they expressed a desire to receive more reports from private well owners to gain a better understanding of the environmental conditions and water balance within the county and municipalities.

"From our or my perspective here at the county administrative board, I would really like to receive more information from private individuals, for example, to get an idea of the environmental condition. But we can't really request data that private individuals must pay for as some form of environmental monitoring" - Kalmar County Administrative Board, Interview March 7, 2023.

"[...] we would like to have better control over the water balance overall, so all infor-

mation and gathered information would be valuable to us when it comes to sustainable supply" - Kalmar County Board, Interview March 7, 2023.

4.4.2 Limited Sampling of Domestic Wells

Many municipalities suspect that few well owners regularly test their water, which increases the risk of consuming contaminants. Inspections of domestic wells have revealed that sampling usually occurs only through property exchanges or property sales, or after a well installation, and rarely happens thereafter unless there are obvious problems or changes of the water performance. Some municipalities have taken measures to increase sampling frequency and inform property owners about the SLV's recommendations, but few well owners seem to follow these recommendations. According to Figure 4.13, only one municipality reports that everyone with a domestic well probably tests their water regularly. In 39 of 143 municipalities, it is estimated that 0% of the well owners regularly test their water, the total number of wells in this category being about 26 681 wells. A total of 42 municipalities did not even respond to the question.

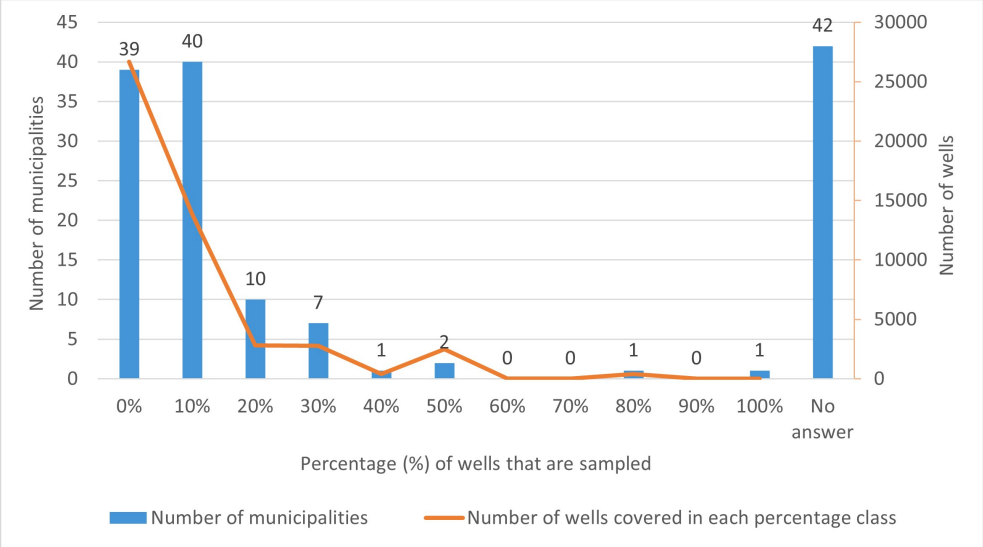

Figure 4.13: The proportion of each response category, answers to question 13 (see Appendix A), over how many well owners follow the recommendations from SLV's by testing the water every three years. The line represents the number of wells covered in each category based on the municipalities' estimation for question 5.

Around approx. 22 743 wells, accounting for roughly 8%, when summed up, are believed to follow the SLV's recommendations and regularly test their water every three years. In this calculation, the category "No answers" is considered as not conducting water sampling. This percentage is relatively small when compared to the total number of estimated wells for this study, as clearly illustrated in Figure 4.14.

The reasons for this can be attributed to a lack of knowledge, a tendency to rely on past experiences, and financial constraints among well owners. Many well owners have become accustomed to their water, even if it exhibits a slight colour and metallic taste. They often perceive their water as "good or tasty," which can contribute to a

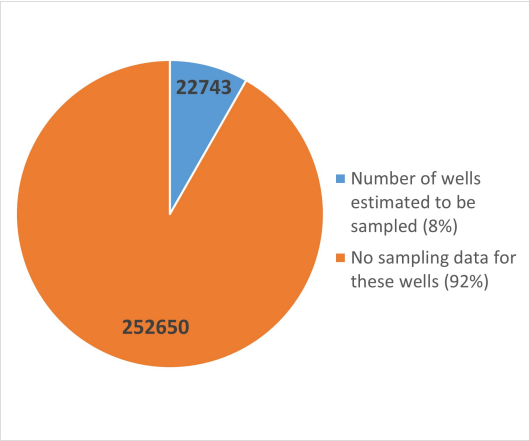

Figure 4.14: Distribution between the estimated number of wells to be sampled (blue) and those that may not be sampled or where the well owner may not be following the recommendations of the SLV (orange).

lack of motivation or perceived necessity to conduct regular testing. Appendix E lists Quotes 36, 38, 39, 40, 41 and 43 which further explain how respondents approached this question.

"Even if you as an domestic well owner may be aware of what is recommended, three years go by quickly and if you don't experience any obvious problems, it's easy to forget. Unfortunately, I think that the frequency of water sampling will decrease with the economic downturn we find ourselves in" - Österåker Municipality, quote 37.

"For most people, it is a non-issue as long as they have water in the tap and no one in the household gets sick" - Svalöv Municipality, quote 42.

"Examinations of the quality of drinking water in private wells are not done as often as recommended, probably due to lack of knowledge and relying on the safety of one's own water that has always been consumed. Sampling and maintenance needs are often discovered during sales/changes of ownership" - Enköping Municipality, quote 44.

4.4.3 Climate Change and Stresses on Groundwater

Regarding quantity and quality issues experienced over the last decade, there appears to be a geographic variation where several municipalities in the southern water districts in Sweden have encountered more significant problems, as shown in Figure 4.15. However, some municipalities have reported positive feedback or reduced problems due to factors such as climate change or the implementation of measures that have improved the situation. On the other hand, many municipalities have answered "No difference" or "Don't know," which may be partly due that many things can happen during a 10-year period.

Municipalities that have observed a change in the past decade have identified various factors that have contributed to the growing challenges. These factors include climate change, adverse environmental effects, urban development in coastal areas, and evolving lifestyles and convenience. Among these, the availability of groundwater emerges as the most prominent issue affecting individuals relying on domestic drinking water

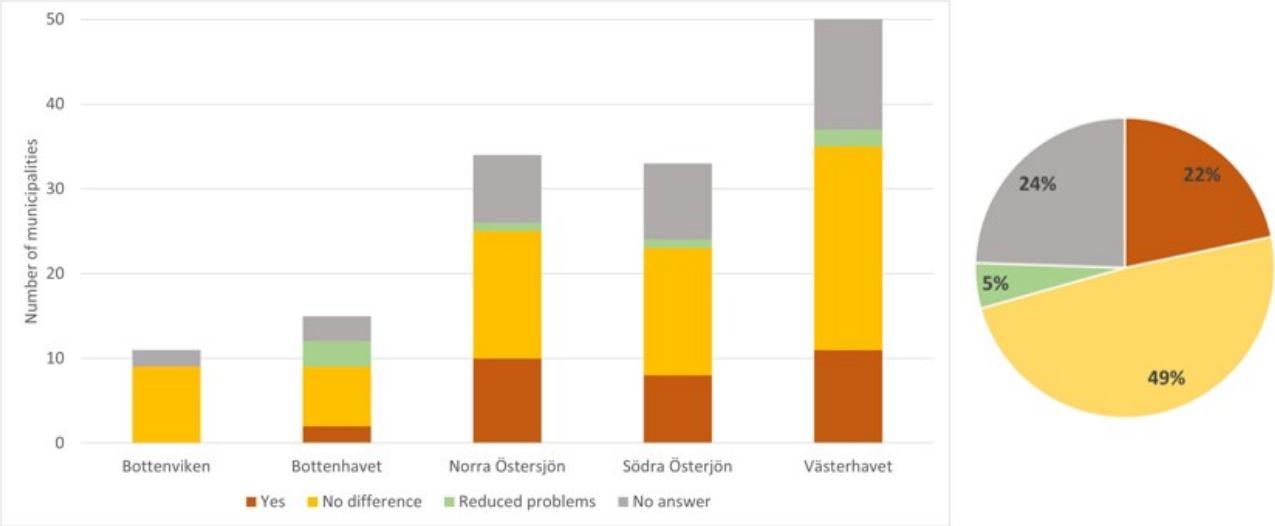

Figure 4.15: The participants' answers for question 16 (see Appendix A) if access and quality problems were perceived to be increasing/decreasing over the last 10 years. Left: Proportion of each response category and water district relative to the total number of responses. Right: Percentage breakdown.

sources. Appendix E lists Quotes 45, 46, 47, 48 and 49 which further explain how respondents approached this question.

"[...] Groundwater levels have decreased according to our experience in municipal wells. In smaller quarries, the levels vary more. [...]" - Nybro Municipality, quote 50.

"Possible causes may be increased water usage due to modern conveniences, people living more or less permanently on the islands, possibly less rainfall or more sustained heavy rainfall where infiltration is hindered" - Vaxholm & Täby Municipalities, quote 51.

"I personally feel it, but it's hard to say how the citizens feel about it based on how little we work with this. However, I see that the concern for water quality and availability is greater" - Ydre Municipality, quote 52.

Climate change has reinforced or further limited other factors that were highlighted in the interviews, such as population growth and development efforts in municipalities where it is already evident that the water supply will likely be insufficient. Related to this, Kalmar County recognizes the importance of having greater control over all water withdrawals and implementing new water permits to ensure water is used in the appropriate locations and distributed more fairly. The respondent also mentioned that some well owners may be hesitant to apply for new water permits, particularly in these circumstances.

"We do not know exactly what will happen in the future, but we know that dry periods during the summer will lead to significant challenges. These challenges may be due to both climate change and the need to develop our municipalities. In Karlskrona, for example, large development projects have been identified in the comprehensive plans, including increasing the population of Karlskrona from about 65,000 inhabitants to

perhaps 100,000, establishing or developing new industries, and developing the countryside. However, there is not enough water to supply so many people. It is also necessary to consider that there is enough water for everyone to use for various activities" - Blekinge County Administrative Board, Interview February 22, 2023.

"Many are perhaps a bit worried, like revising or updating their water permits, because they may not get the right to the water they need. But on the other hand, if everyone really updates and revises their water permits and licenses, we will overall have a better overview of everyone's withdrawals and a fairer use of the water in the end. Water is such a special resource, and it is needed by everyone and is the most valuable thing we have. So, it ties in with the fact that we need to have a better overview of water withdrawals, the right water for the right use and place, etc." - Kalmar County Administration, interview March 7, 2023.

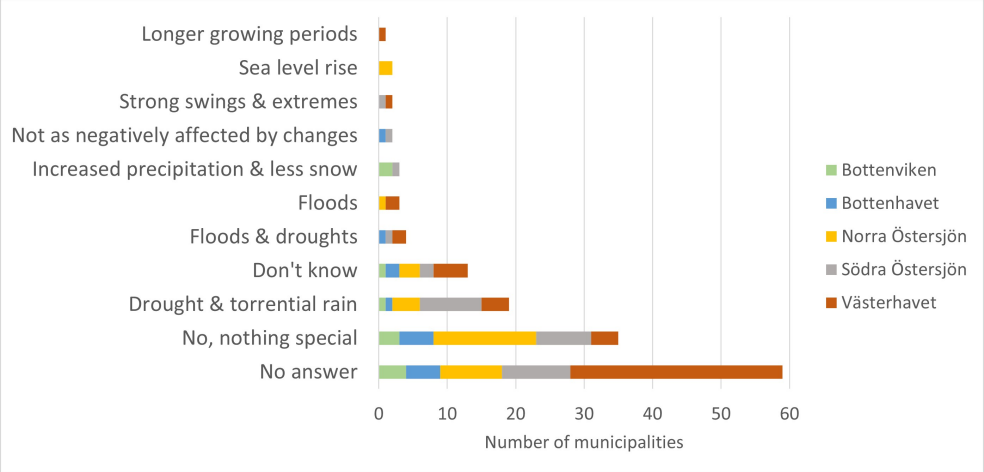

Figure 4.16: The participants' answers for question 23 (see Appendix A) and the most prevalent themes of which climate aspects stand out for their municipality divided the answers according to the water districts.

Figure 4.16 illustrates the most prevalent climate factors in the participating municipalities. As mentioned in question 16, these factors can have either positive or negative effects on individuals with domestic drinking water sources. Appendix E lists Quotes 53 and 54 which further explain how respondents approached this question.

"Uncertain access to water of good quality in coastal areas and densely populated vacation home areas where there is no communal water during winter, and more people want to settle or spend most of the year there. Better standard of houses and old zoning plans that are designed for a completely different use and utilization than in the 50s and 60s. Increased water usage also affects the individual sewage systems in these areas. Less snow in winter. More heavy rainfall" - Västervik Municipality, quote 55.

"Difficult to verify but possibly less snow, which reduces infiltration, and more intense rainfall, which also reduces infiltration. Worsened formation of fresh groundwater due to these parameters. Over time, there will be a rising sea level, which increases the risk of saltwater intrusion" - Vaxholm & Täby Municipality, quote 56.

"We are a municipality with a strong focus on green industries, and a municipality with relatively many and significant positive climate effects. [...]" - Ydre municipality,

quote 57.

The Kalmar County Administrative Board's standpoint on the impact of climate change agrees with the survey responses and emphasizes the importance of increasing redundancy and working with these issues.

"It is, above all, the rain shadow and that we seem to see that the drought is getting longer and longer, and the groundwater recharge is coming later and later in the year and it is becoming more and more often like that. And there are many people concerned about that outside the country and we too because we must work even more to ensure, as well as that there is a redundancy in the supply even in the future even more so with a changed climate. [...] And we kind of must work with today, because we already see what the situation is. I mean, what we experience now as extremes is like the new normal, really, and that's how we relate to it in the matter" - Kalmar County Administrative Board, Interview March 7, 2023.

4.5 Challenges of the Municipalities' Work with Domestic Wells

The current efforts of municipalities in addressing domestic drinking water supplies are uneven, with some municipalities being more active in this area than others, and some not addressing it at all. In this context, various examples of how to tackle domestic well issues within the municipality will be highlighted. However, there are specific challenges in dealing with these issues at the municipal level.

4.5.1 Managing Domestic Wells, Strategies and Obstacles

Figure 4.17 presents the results of the question regarding whether the municipalities have planned any measures to mitigate the risk of water shortages within their municipality (both private and municipal included). A considerable 32% of the participants did not provide an answer, while 25% stated that they were not entirely sure or that another department was better suited to answer the question. 16% responded with "No," indicating that they are not currently addressing these issues or do not see any risk of water shortages in their municipality. The remaining participants, the majority, stated that they have initiated measures to reduce the risk of water shortages.

The most common responses have been compiled for those who in some way indicate that measures are needed to reduce the risk of water shortages in Figure 4.18. And the most frequently mentioned measures included implementing common ground and permit requirements and expanding the municipal Water- and Sewage System. Appendix E lists Quotes 69, 70, 72 and 73 which further explain how respondents approached this question.

"Before a decision on a building permit application or planning areas is made, the water supply is always assessed in accordance with the Planning and Building Act. If the area is assessed to be at risk of water shortages, exploitation to such an extent is not allowed" - Kramfors Municipality, quote 68.

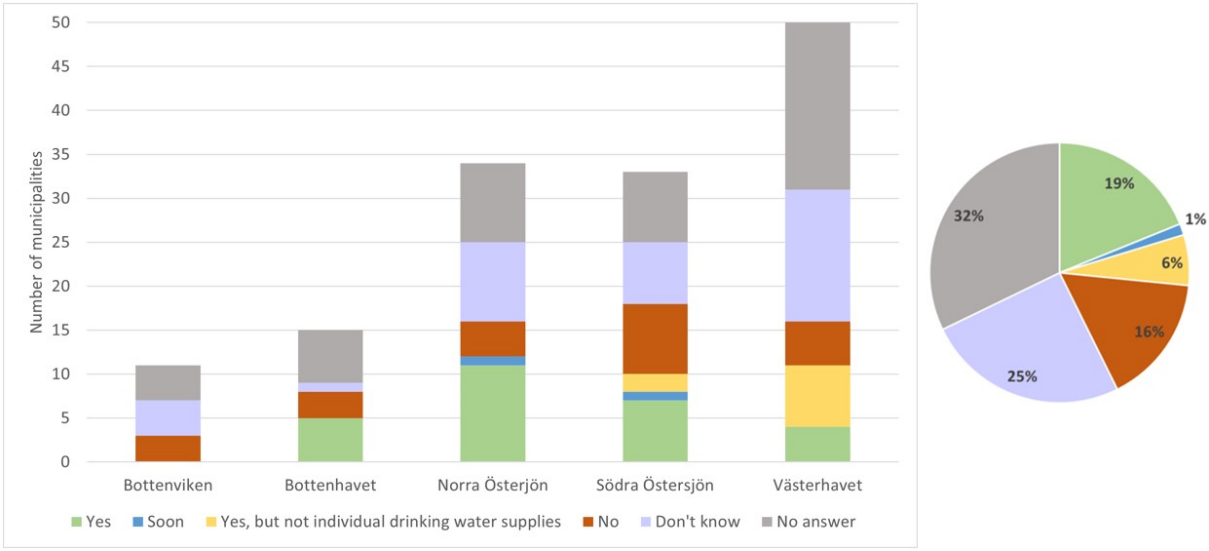

Figure 4.17: The participants' answers for question 26 (see Appendix A) and if there are any plans to implement measures to prevent future water scarcity in terms of water supply and quality. Left: Proportion of each response category and water district relative to the total number of responses. Right: Percentage breakdown.

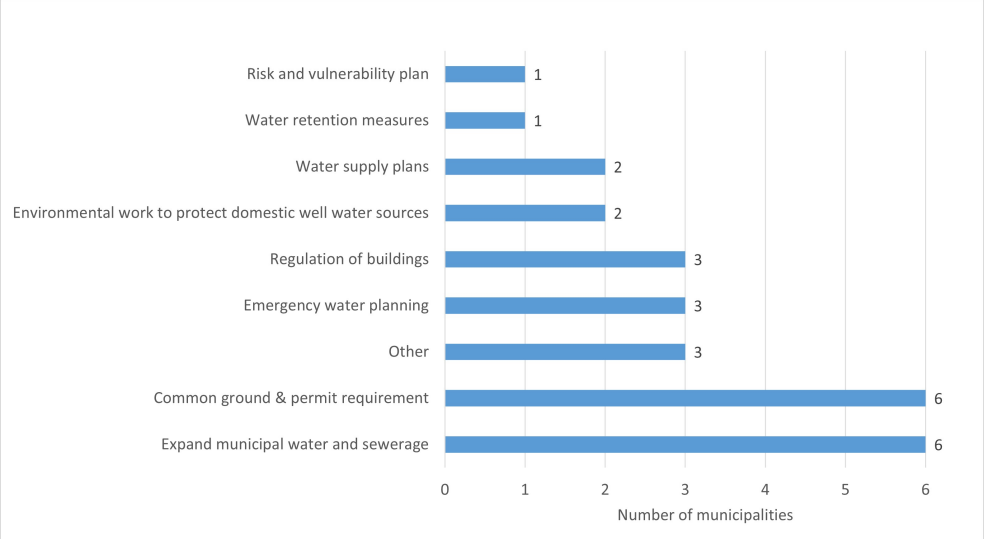

Figure 4.18: The participants' answers for question 26 (see Appendix A) and the most prevalent themes of the most common measures that municipalities are planning to implement to address future water shortages in terms of water availability and quality concerns.

"We work extensively on remediation of contaminated land, as well as controlling the handling of contaminated elements in our operations" - Ydre Municipality, quote 71.

The Kalmar County Administrative Board emphasizes that while many people today are aware of the importance of conserving water and not wasting it, this alone may not be enough to overcome future water shortages or capacity issues. It is crucial to understand and manage water balances in order to determine how much water can be safely used.

"Sure, turn off the tap when you brush your teeth and take short showers and such, I mean most people already know that. So, I think we should focus a lot on the bigger picture as well, to achieve a generally smarter water use in all sectors. Because this water balance, ultimately, is a question of not taking out too much water compared to the input value" - Kalmar County Administrative Board, interview March 7, 2023.

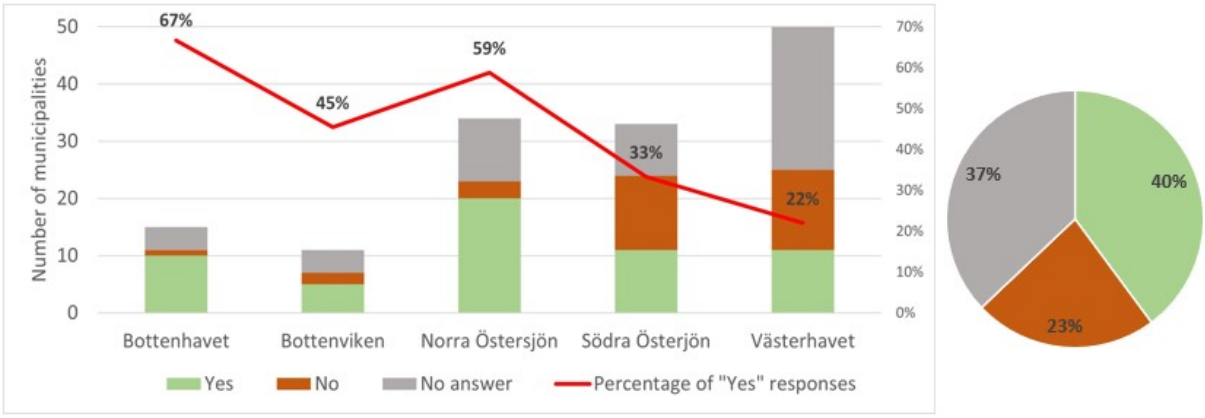

Figure 4.19: The participants' answers for question 28 (see Appendix A) if groundwater conditions are taken into account as a decisive aspect in new development strategies or planning permission procedures for new buildings. Left: Proportion of each response category and water district relative to the total number of responses. The red line represents the number of "Yes" answers in relation to the total number of answers in each water district group. Right: Percentage breakdown.

Figure 4.19, which is related to question 26 (see Figure 4.18), reveals that 40% of municipalities consider water supply issues when planning new developments. They do so to ensure an adequate water supply and to establish appropriate protective distances for wells to neighboring sewage systems. These municipalities emphasized that permitting construction in these areas often requires extensive documentation, data, and investigations, which can be resource-intensive and currently deficient. On the contrary, some municipalities have already incorporated this aspect into their Water- and Sewage Plans by conducting hydrological investigations. This proactive approach is vital to prevent future complications by avoiding development in areas outside the municipal Water- and Sewage network to avoid problems arising in the future. Appendix E lists Quotes 74, 75 and 78 which further explain how respondents approached this question.

"Domestic drinking water supply is always investigated and, in some cases, it may be a reason to say no to a development project" - Norrtälje Municipality, Quote 76.

"Previously, the municipality had bad experiences with allowing construction in areas outside the municipal water and sewage network. Therefore, it is reviewed more carefully nowadays" - Nykvarn Municipality, quote 77.

Those who have answered "No" in Figure 4.17, i.e. that they do not work or plan to introduce measures in the municipality, do so partly because it is not currently a priority in the municipality or that they have relatively small problems with water shortages, both in terms of availability and quality of water. Appendix E lists Quotes

79, 80 and 81 which further explain how respondents approached this question.

Figure 4.20 illustrates the challenges faced by municipalities when implementing measures to address water scarcity and managing private drinking water supplies.

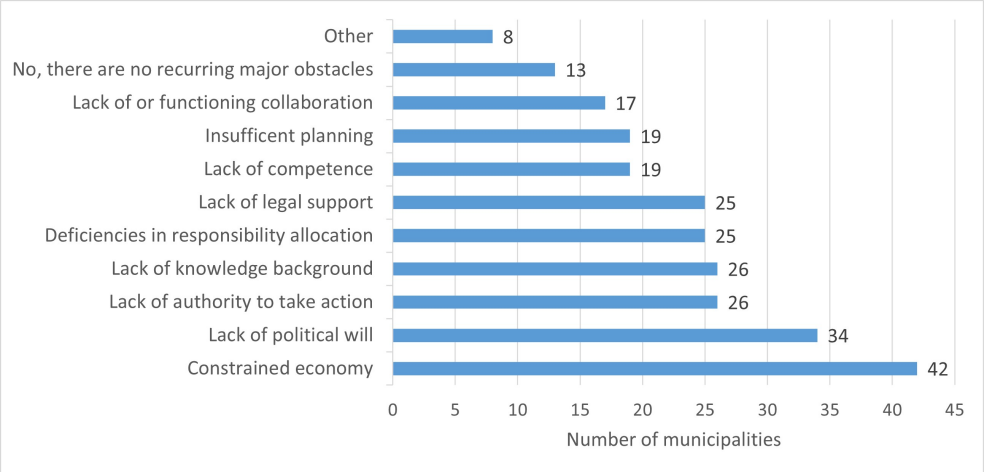

Figure 4.20: The participants' answers for question 30 (see Appendix A) of what the municipalities experience as the biggest obstacles to effectively taking action against water scarcity today.

The most significant obstacle is a lack of financial resources, followed by a lack of political will. Other obstacles are equally prevalent, with climate change identified as a major problem. Some municipalities also highlight unclear guidelines on what is expected of them and how to address issues related to private drinking water supplies, as this is primarily the responsibility of property owners. Appendix E lists Quotes 82, 83, 85, 87, 89 and 90 which further explain how respondents approached this question.

"Society as a whole doesn't seem to invest any money in domestic drinking water, it feels like there's no research, no work and no information from our county administrative board in Blekinge for the last 10 years (they had a good meeting about 10 years ago). We at the local environmental office hardly allocate any resources for this and neither does the rest of the municipality" - Karlshamn, Olofström & Sölvesborg Municipalities, quote 84.

"Lack of legal support to request information" - Nybro Municipality, quote 86.

"It's other issues that the politicians have chosen to focus on, and furthermore the resources are so limited and the organization so slimmed down that we officials rarely have time to work on anything other than what is regulated as mandatory requirements" - Ydre Municipality, quote 88.

County Administrations' interviews reveal divergent opinions on domestic wells, permits, and related challenges. The Blekinge county board emphasizes distinguishing between household and industrial/agricultural water use due to consumption variations. They argue that small water amounts should not require permits as their volume is insignificant. In contrast, the Kalmar County Administrative Board highlights the risks of inadequate domestic well management and obstacles. They attribute this to legislative exceptions benefiting large water users with domestic wells, impacting

water balance. Addressing withdrawals without permits and the legislative framework is deemed crucial.

"Households are a bit special in that they don't use very large amounts of water. And that's because it has been decided that they do not need to seek any special permits, whereas it is more for industries, agriculture, or even municipalities if they are to use any groundwater source for their water production, then they must have a water permit" - Blekinge County Administrative Board, Interview February 22, 2023.

"But also a big problem, so to speak, in our database or what we know, is that when it comes to private drinking water supply, a notification or a permit should be made according to Chapter 11, Section 11 of the Environmental Code. [...] You can talk about, for example, 400 animals/livestock that today get their drinking water from a private well without a water licence and without a permit, because it is considered an exception. So we have a lot of uncertainty about water abstraction and we don't have good control of water balances. We have a lot of water abstractions that we are not aware of and that do not have permits, but they may need a permit, but it is because the law is such that livestock herds are exempted from the general permit requirements" - Kalmar County Administrative Board, Interview March 7, 2023.

"[...] We need to have better control over extractions, including those that do not require a permit. Because we cannot control what we do not have, it is impossible for us to know how many extractions there are, etc., because they are not reported. The County Council does not have the resources to go around, inventory and map all the extractions that take place in the county. There are not enough resources and priorities for that at the moment. So we really only have these permit reports to rely on. There is quite a lot of uncertainty in them, so there is quite a lot of lack of knowledge and other things. [...] So it is a matter of reviewing these exemptions from notification and permitting requirements for water extraction. I mean, is it reasonable that large livestock herds are considered a domestic water need and therefore exempt from notification and permitting? There may be potential to develop legislation in this regard [...]" - Kalmar County Administrative Board, Interview March 7, 2023.

A significant challenge in ensuring water quality for domestic well owners is their lack of knowledge and commitment, as observed by many municipalities. It is crucial to continue disseminating information and ensuring well owners have the necessary knowledge and dedication to maintain their wells and ensure high-quality water. It should be emphasized that this responsibility lies with individuals and not with municipalities. Appendix E lists Quotes 92, 94, 95, 96, 97, 98 and 99 which further explain how respondents approached this question.

"They themselves must understand somewhere that water constitutes such a large and important part of daily life, so they seek information themselves. They receive advice from us when they call/visit, but we do not have any information projects" - Sollefteå Municipality, quote 91.

"Unfortunately, I don't even think that increased knowledge helps in some cases. [...] There are also some who believe that it is the municipality's responsibility to fix their problems if something happens, and it can be a 50-year-old well that no one has taken

care of" - Österåker Municipality, quote 93.

"What the control authority does is to try to inform the public about the importance of controlling their own water (both quantity and quality), suggestions on how the water can be tested, there have been sampling campaigns communicated through the municipality, we convey information from the National Food Agency, etc. The problem is reaching out with the information when there is no interest among individuals" - Östersund Municipality, quote 100.

Figure 4.21 lists some strategies within municipalities to increase the competence for well owners.

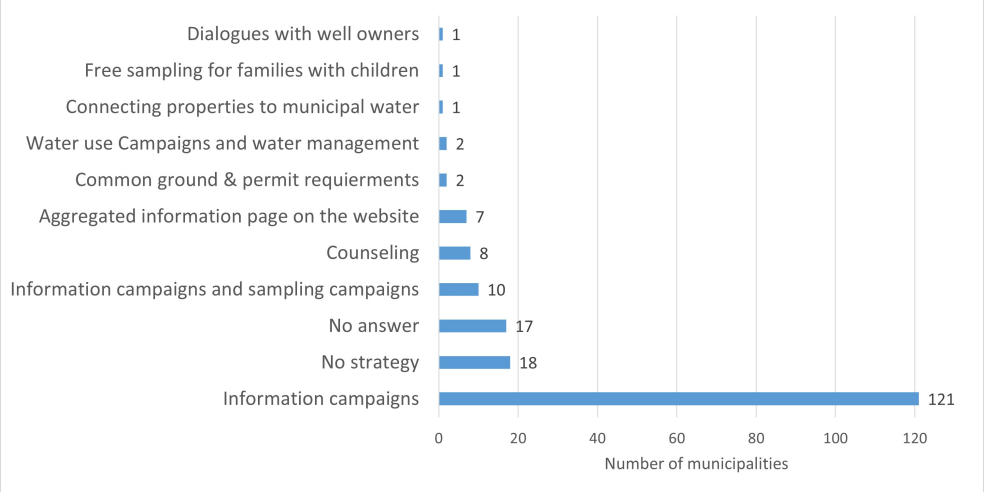

Figure 4.21: The participants' answers for question 22 (see Appendix A) of strategies or measures to increase competence and knowledge among the well owners.

Most municipalities work with information to varying extents, but they encounter problems and obstacles in implementing effective strategies. Out of the surveyed municipalities, 18 lack specific strategies to enhance domestic drinking water, while 17 did not provide a response to the question. Appendix E lists Quotes 101, 102, 105 and 107 which further explain how respondents approached this question.

"Important that everyone understands that they may need to save on the amount of water, especially at certain times of the year. It's about people adopting new behavioural patterns, which is not always the easiest thing" - Kungälv Municipality, quote 103.

"We inform several times a year in the media about the importance of testing your water. All pregnant women receive information via the maternity clinic that the municipality offers child testing to all permanent residents with children under 5 years of age. We talk to real estate agents about the importance of informing about the presence of a private well and what it entails. When selling a property, a current approved analysis report must be presented" - Laholm Municipality, quote 104.

"It is difficult to make an impact as long as the citizens perceive the water quality as good, that the water tastes good, and that they have enough water. If any municipal effort is to be made, money is needed. Something that could encourage more people to take samples is probably a campaign with a significant discount on the sampling costs"

- Örnsköldsvik Municipality, quote 106.

4.5.2 Governance

According to Figure 4.22, around 29% of municipalities expressed a desire for additional support from external actors regarding domestic drinking water supply. These municipalities are mainly situated in the Bottenviken, Norra Östersjön, and Södra Östersjön regions. Conversely, a similar number of municipalities consider the matter to be non-municipal and thus do not require support. Approximately 45% of municipalities either skipped the question or were unsure how to respond.

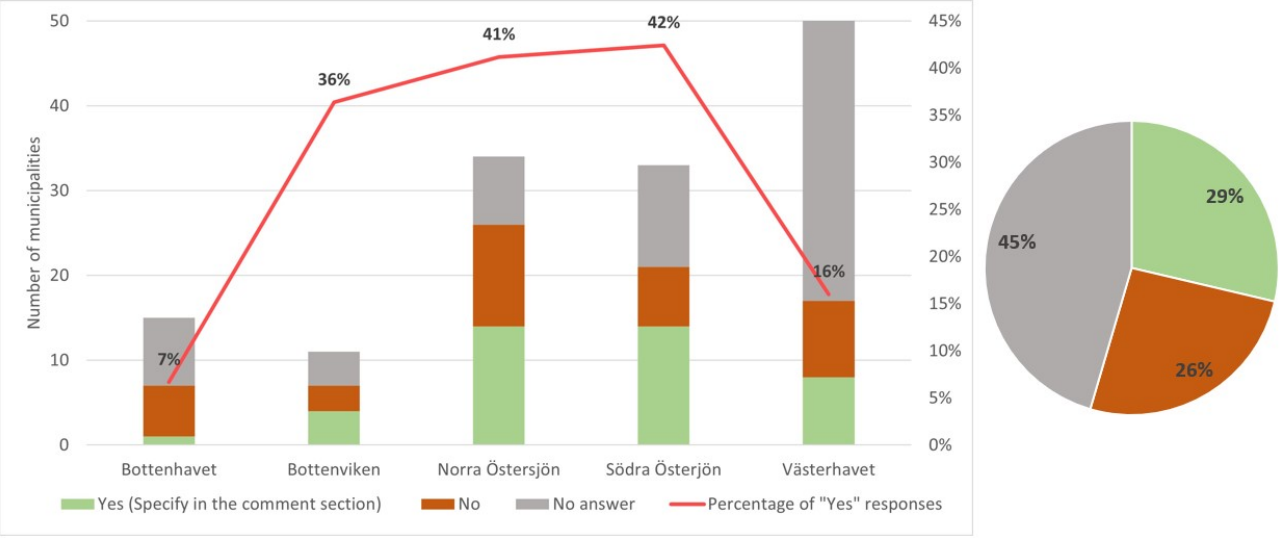

Figure 4.22: The participants' answers for question 31 (see Appendix A) where the municipalities would like more support from other actors/authorities. Left: Proportion of each response category and water district relative to the total number of responses. The red lines represent the number of "Yes" answers in relation to the total number of answers in each water district group. Right: Percentage breakdown.

Out of the 41 municipalities that expressed the need for more support request more efficient work with domestic drinking water supply at the municipal level and to increase public awareness of the subject. However, identifying the appropriate actors to provide the desired support is challenging as the responsibility is currently divided among many stakeholders. The issue has highlighted the need for improved cooperation between various actors and for support from government authorities in the form of advice, courses, and databases. There is a call for political interest and commitment to private wells, as well as for more legislation governing providers of filters and treatment plants. Well owners are also encouraged to take greater responsibility for improving their wells and water. Appendix E lists Quotes 108, 109, 110, 111, 112, 113 114, 116, 117, 118, 120, 121, 122 and 124 which further explain how respondents approached this question.

"Guidance is forthcoming from the National Board of Housing, Building and Planning regarding domestic wells in pre-consultation and permits. It is desirable to have more support regarding what type of planning basis is sufficient to assess whether the land is suitable for construction and when/if requirements should be placed on property owners

(applicants) to demonstrate the existence of water" - Södertälje Municipality, quote 115.

"The issue of individual VA advice for property owners should be introduced in the municipalities. This I have put forward, they have decided not to introduce it. There is no interest among civil servants or politicians" - Vaxholm & Täby Municipalities, quote 119.

"I believe it is important to raise the issue nationally that property owners have a great responsibility when they have their own well. Many are unaware. I have seen that the information on the National Food Agency's website for well owners on how to interpret test results has developed, which is good. But still, I think it is a big step for many individuals to know how to take a sample from their well. It also means a cost for them. Perhaps the cost of sampling should be subsidized so that it becomes cheap for individuals to do checks?" - Jönköping Municipality, quote 123.

The County Administrative Boards both mentioned that they are there to support the municipalities and act as a hub for cooperation. Kalmar County Council also mentioned that they would like to have more collected documents and information to be able to work further on the issue. In addition, such collected information and documentation could also be a sensitive issue to be aware of.

"Länsstyrelsen can act as some sort of hub for cooperation and try to drive and inspire it. So, we're trying to do that as much as possible. [...] we really need comprehensive data on water extraction and the information we have today is very fragmented. We have registered, for example, one called "11" which is based on the supervision of water extraction and is such a national plan. But it's not complete and it's not updated, and it's not actively used by all county administrative boards today, but it should preferably start doing so in the future. The register is a national database that is internal to the county administrative boards. But you also run into tricky confidentiality and information security issues. When you're going to start inventorying drinking water extractions because it's a sensitive task, especially today when we're working more with the conditions of heightened preparedness and war" - Kalmar County Administrative Board, Interview March 7, 2023.

"The County Administrative Board can offer support to municipalities that need help in the strategic work with routines and action plans. The support is designed based on the municipality's needs" - Blekinge County Administrative Board, Interview February 22, 2023.

In response to question 31 (see figure 4.22), many municipalities that are not seeking support or addressing the issue today claim that they are not responsible for domestic drinking water supplies. As a result, they do not feel the need to actively address the issue today. According to their understanding, the responsibility lies solely with the property owner. Appendix E lists Quotes 126, 127, and 128 which further explain how respondents approached this question.

"Difficult question to answer... It may not even be desirable for the municipalities to be responsible for each individual household's water supply. But if it were to become

part of the municipality's responsibility in the future, it would of course be good with support from e.g. The county board" - Herrljunga Municipality, quote 125

However, the Kalmar County Administrative Board emphasizes the significance of implementing preventive measures related to all types of water supply issues in response to a changing climate. This proactive approach seeks to prevent potential disasters and address conflicts of interest before they emerge, as water in today's Sweden is not infinite, but it can certainly vary from place to place.

"But traditionally, you may have seen water as an infinite resource, but right here we don't really have that and it is important to be able to prevent these conflicts of interest that arise, who has the right and who should have water when it comes to a location where very low flows and low groundwater levels. It is very important to deal with the issue before the conflicts of interest blossom. I think it is extremely, extremely important to touch on" - Kalmar County Administrative Board, Interview March 7, 2023

4.5.3 Preparedness in Case of a Crisis

Some municipalities have also mentioned crisis preparedness regarding domestic wells and their importance in case of political uncertainty, municipal water and sewage disruptions, and climate change. Figure 4.23 shows possible trends in municipalities regarding the extent to which residents consider their water supply.

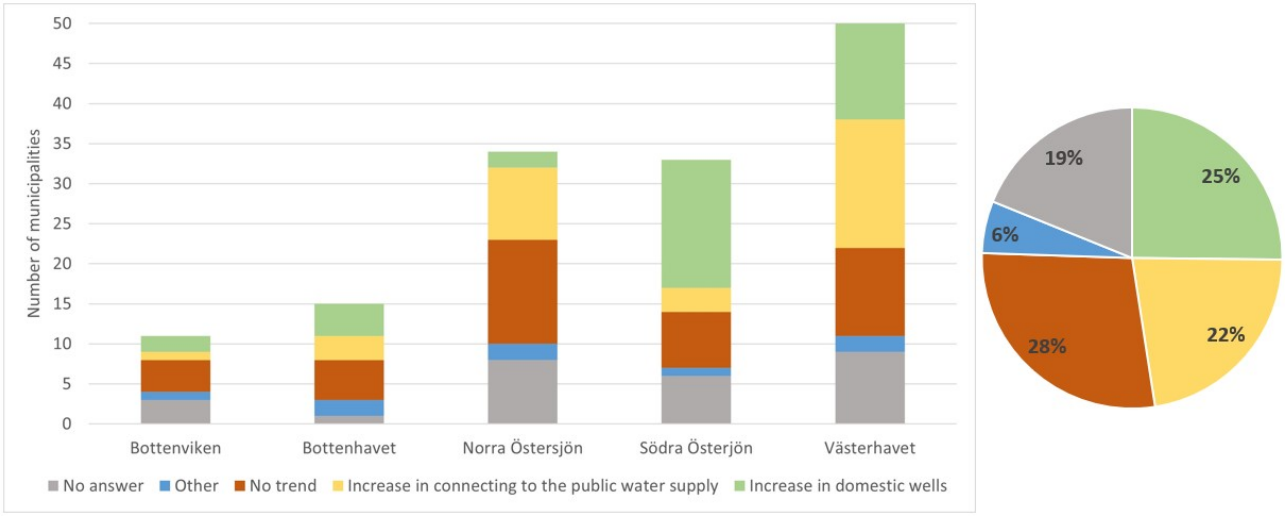

Figure 4.23: The participants' answers for question 32 (see Appendix A) if the municipalities see any trends regarding domestic water supply. Left: Proportion of each response category and water district relative to the total number of responses. Right: Percentage breakdown.

The trend of an increasing number of drilled wells in municipalities can be attributed to various factors such as the unavailability of the public water network, cost-effectiveness, drinking water self-sufficiency and emergency preparedness through reserve water to ensure a reliable water supply. Appendix E lists Quotes 130, 131, and 132 which further explain how respondents approached this question.

"Increase in wanting to produce one's own drinking water. Many have old wells that

are no longer in use that they want to start up again as backup water" - Lomma Municipality, quote 129.

"More people want winter water in holiday home areas, especially after Corona when many people moved out. More people want to move from shared to their own facilities. Desalination plants (they seem to be outside all legislation)" - Västervik municipality, quote 133.

22% of the municipalities answered that they see a trend of more people wanting to be connected or connected to municipal water as well owners usually have problems with their water. Quote 134 also supports this view, listed in Appendix E.

"Most people who have problems with their drinking water want municipal sewage, then when the cost is presented for connection, a different assessment can take place" - Härryda Municipality, quote 135.

Where there is no clear trend, it can be difficult to assess the situation as there is no need to obtain permission to drill new wells. However, some property owners have taken steps to improve their drinking water security by improving the maintenance of their existing wells, keeping them as backup water sources even if they are connected to municipal water, or upgrading their systems to include desalination plants. Appendix E lists Quotes 136, 13,7, and 139 which further explain how respondents approached this question.

"However, I feel that the interest in taking care of one's wells may have increased somewhat recently. Works with supervision and licensing of small drains, and they're more and more have become aware of protecting their wells in recent months" - Jönköping Municipality, quote 138.

In addition, some municipalities consider private wells as a potential source of reserve or emergency water that could be utilized in a crisis, particularly considering external factors such as climate change that are becoming more evident. Appendix E lists Quotes 141 and 142 which further explain how respondents approached this question.

"[...] a water well that used to be used for the property before you got municipal drinking water and today is not used at all more than for watering the garden. However, these water sources can be good to have as a reserve water source in times of crisis if problems arise in a society that means that the municipal water cannot be delivered" - Kungsbacka Municipality, quote 140.

At present, the Municipality of Karlskrona does not prioritize issues related to domestic water supply and believes that the current level of work on domestic water supply is sufficient, as the Municipality's primary responsibility is for municipal water and wastewater. The municipality does, however, consider the link between domestic water supply and crisis preparedness to be an interesting issue.

"Difficult, but I thought it was very interesting what you said connected to preparedness. But as a municipality like that, I would probably say that it is rather at a fairly good level. The function of the municipality is, like the municipal, water and sewage" - Karlskrona Municipality, interview March 7, 2023

5 Discussion

This study aimed to improve our understanding of how municipalities deal with domestic wells and to recognize the requirements related to risk management and sustainability. To answer the research questions, this section of the discussion will interpret, discuss, and connect the study's findings to the relevant literature.

5.1 Discussion and Interpretation of the Result

5.1.1 Research Question 1

Are there geographical differences in the challenges experienced by municipalities related to the quantity and quality of water from domestic wells?

Municipalities across Sweden face varying challenges with domestic wells, with some regions more affected than others. While deficiencies in both quantity and quality of domestic drinking water supplies are reported by many municipalities, their responses differ. Water quantity emerges as a more concerning issue now and in the future than water quality, according to the findings in this study. Groundwater availability is identified as the primary concern for individuals relying on domestic water sources due to factors such as climate change, environmental pressures, coastal urban development, changing lifestyles, and population growth. These factors collectively increase the risk of water scarcity in relation to demand. Making water quantity a more stressing issue compared to quality concerns which are particularly discussed and shown in Section 4.4. Figure 4.7 illustrates that more municipalities in southern Sweden are taking action to address both domestic and municipal drinking water supplies, aiming to mitigate water shortage risks and enhance system resilience. This may be due to these municipalities experiencing regular problems from climate change, which negatively affects infiltration (Stoll et al., 2011), particularly in combination with over-abstraction and increased water use in areas with limited groundwater formation. As stated by the representative from Vaxholm and Täby municipalities (Quote 51), increased withdrawals due to modern comforts and a preference for living on islands can lead to saltwater intrusion or groundwater competition in these areas, particularly in southern coastal municipalities where population growth and population is higher, as shown in Figure 4.3. Many municipalities aim to develop the municipality by encouraging population growth, rural living development, and the development or establishment of industries. Blekinge County Board (Interview February 22, 2023) highlighted these three areas for Karlskrona municipality's new Comprehensive Plans where the current water supply cannot meet future development plans and goals. Furthermore, there is uncertainty about what will happen in the future regarding climate change, and trends such as dry periods that will pose significant challenges for the water supply, necessitating more planning and measures with new solutions to maintain municipalities' development projects and goals.

A strong connection regarding quality deficiencies is not that clear as for quantity

connections, as they appear to be more evenly distributed across water districts or influenced by local circumstances. The primary cause of declining quality appears to be pollutants that impact the water source, including bacteria, high levels of nitrates, or saltwater intrusion, as previously mentioned. Svalöv municipality has also observed that wells situated outside the municipal water and wastewater system encounter more significant challenges (Quote 30). This could explain the geographically dispersed quality issues, as well located outside the municipal system often have individual septic systems or are situated in rural areas near agricultural regions. This proximity to pollution sources, such as bacteria from sewage or agriculture, as well as pesticides, frequently leads to water contamination (Drage, 2022). Additionally, Herrljunga municipality has reported an increase in nitrate levels over the past decade (Quote 28), which may be linked to agricultural activities.

It is interesting to note that although many municipalities include domestic drinking water supply in their planning documents (see Figure 4.9), this does not necessarily translate into active efforts to improve it, as previous research has shown (Galderisi and Ferrara, 2012; Storbjörk, 2010). Tranås municipality emphasizes the importance of adhering to these plans and effectively managing the domestic drinking water supply so they just don't become plans (Quote 117). For instance, in the case of Essunga municipality, although domestic drinking water supply is included in its planning documents, there is no active plan to address it (Quote 14). Additionally, municipalities must adhere to and incorporate several regional plans and guidelines into their planning processes, which creates a question of prioritization. Since municipalities often lack the capacity to fulfill their responsibility of overseeing domestic water supply systems (Gunnarsdottir et al., 2020). Resources, commitment, and observation of domestic wells are often compromised, leading to a preference for the municipality rather than the domestic drinking water supplies (Göteborgsregionen, 2020). This underscores the need for government institutions to provide support and guidance to these municipalities (Gunnarsdottir et al., 2020). A common approach that municipalities have by dealing with domestic wells and related issues that emerged in this study is the continuous expansion of the Water- and Sewerage network as a way of providing good quality and quantity of drinking water, while at the same time reducing the discharge of wastewater (Quote 67). Once again, the focus is on the municipal water system, and this solution is not viable for people who live far from Water- and Sewerage infrastructure and therefore do not have access to good quality drinking water if significant problems arise (Göteborgsregionen, 2020).

5.1.2 Research Question 2

How are domestic wells currently regulated and managed by municipalities, and what measures are being taken to address problems associated with domestic wells?

Throughout the study, it became evident that the subject of domestic drinking water supply is characterized by a significant division of opinions, with varying perspectives on related issues and differing interpretations of the legislation. Three main groups can be distinguished.

The first group consists of municipalities that are currently not addressing this issue,

the majority of municipalities belong to this group. Arguments such as "no municipal responsibility," "perceived absence of problems," and "limited resources" have led to these municipalities not prioritizing domestic drinking water supply issues. In addition to providing guidance and easily accessible information, their primary responsibility is to comply with the LAV and ensure the municipal drinking water supply. However, some municipalities in this group have started recognizing an increasing need for greater control and management of domestic wells and would like to see more work done on this topic in the future.

The second group of municipalities is those who see a great need to work with these issues and request more tools and support to be able to work more efficiently and safely. Currently, they feel that the work with drinking water issues is more of a voluntary task for which they do not really have sufficient resources. Usually, municipalities in this group belong to those that have felt the consequences of climate change and have annual problems with low groundwater levels, private individuals with wells that are constantly seeping, or have extremely poor water quality values. Torsås municipality interprets the Environmental Code as meaning that they are responsible for issues surrounding domestic drinking water supplies and therefore use the law to work with these issues within the municipality. Under the Environmental Code, municipalities bear a supervisory responsibility for domestic drinking water supplies, particularly in relation to new developments, to guarantee adequate access to water of both high quality and quantity in potential development areas. This prerequisite is crucial for granting permission for new residential constructions on such sites. Torsås municipality is therefore actively working on these issues to ensure a safe drinking water supply within the municipality (Interview February 28, 2023). According to Sala and Hedby municipalities, the municipalities also have overall responsibility for public health according to the Environmental Code (Quote 18). This shows the importance for municipalities to also work with domestic drinking water supplies through information, sampling and the municipalities' water use to prevent problems from arising, which is often not the case today.

The last group is those who have not reflected on the question or where there has been great uncertainty about the given answers. This group has skipped or not provided answers to many of the questions or where you had to pass the survey questions around between colleagues to see if anyone knows the answers to how it is handled within the municipalities today. For example, Karlskrona municipality mentioned that they came to the realization that they are not actually working on this within the municipality and that it is a good insight to reflect on (Karlskrona Municipality, Interview March 7, 2023).

5.1.3 Research Question 3

Can municipalities contribute to ensuring a sustainable and safe drinking water supply for domestic well users and are there any measures that need to be taken?

How municipalities can influence domestic wells

This study emphasizes the crucial role of municipalities in promoting sustainable and safe drinking water supplies for individuals with private wells. Municipalities possess

a planning monopoly and have the authority to influence land use decisions, including those related to climate change and adaptation strategies. They have the power to impose permit or notification requirements for the construction and operation of domestic wells in areas of concern, safeguarding domestic water sources and public health, and ensuring a sustainable and reliable drinking water supply (Biesbroek et al., 2009; Boman, 2004; Hjerne et al., 2021; SKR, 2022b; Storbjörk, 2010). Based on previous literature, municipalities have significant support and opportunities to influence the domestic drinking water supply through the Environmental Code, as highlighted in section 2.4.2. However, this study suggests that many municipalities lack awareness or interest in addressing the issues faced by domestic wells. It appears more convenient for them to attribute liability to the physical well and expect the well owner to resolve any problems. Nevertheless, this study reveals that not all problems associated with domestic wells are solely local in nature. Larger influencing factors at different scales or in the surrounding environment can contribute to these issues, where private individuals or well owners have limited power to influence the situation. It is essential that municipal and other relevant authorities are involved and that the management of drinking water is brought within their remit in order to gain a full understanding of the situation and develop effective solutions.

Some municipalities in this study have already taken proactive measures to enhance conditions for those relying on domestic water sources. However, they face challenges stemming from inadequate support from other authorities and county administrative boards, which limits their effectiveness in fulfilling this role. It is important to acknowledge that while many municipalities may not currently encounter significant issues, the status of domestic wells remains uncertain, and unforeseen problems can arise. Without comprehensive knowledge of domestic wells, municipalities may lack awareness of potential issues and the extent of the problem, emphasizing the urgent need for increased attention and support. Achieving Sweden's environmental goals, as set by the Swedish Parliament and the UN's sustainability goals of ensuring good water quality, currently appears unlikely in the near future. This is due to factors such as increasing water shortages and poor-quality drinking water from domestic wells, lack of awareness and competence among well owners, and a lack of incentives and long-term strategies in the majority of municipalities studied (see Figure 4.21).

The limited oversight, data, and uncertainty surrounding domestic drinking water supplies, including the number of domestic wells, population reliance, water consumption, and adherence to sampling recommendations, present challenges for municipalities in establishing a resilient water supply and ensuring good water quality for all. This lack of information hinders municipalities' ability to form an opinion about the state of the environment and acquire a comprehensive overview of the prevailing water balance. In particular, the municipalities face difficulties accessing information on domestic drinking water supply processes, making it challenging to estimate water balance, assess the extent of water shortages, and address quality issues. One municipality mentioned that legal support for requesting such information from well owners had been helpful and facilitated the municipalities' work (Quote 86). This would reduce the risk of illness and disease, and ensure sufficient water supply for present and future needs. Survey results indicate that only approximately 8% of the estimated number of wells, or around 22 743 wells, comply with SLV's recommendations by testing their water every three years. This is concerning, and considering the large number of unknown wells,

the actual percentage is likely higher than suggested by this study. These findings highlight the numerous advantages and benefits of actively addressing issues related to domestic wells (Vattenmyndigheten Södra Österjön, 2022). It is crucial for authorities to register all water supplies to ensure the provision of safe water for everyone. Rather than solely focusing on expanding the Water- and Sewage infrastructure networks, municipalities should also prioritize protecting domestic drinking water sources. Aggregated data and information about domestic wells, like those available for the municipal drinking water supply system and those seeking water permits for industry and larger agriculture, is essential. Currently, the lack of knowledge regarding areas with poor groundwater quality and inadequate water supply hinders efforts to maintain control over water balances and achieve a sustainable water supply. Outdated water permits obtained by industry and agriculture also pose a potential problem as they may permit excessive water extraction, exceeding available resources. This situation could result in future complications (Kalmar County Administrative Board, Interview March 7, 2023). The concern is further intensified by the absence of accurate statistical data on the number of wells and total groundwater withdrawals, particularly for domestic wells and unpermitted agricultural water use. Given that significant water withdrawals can greatly impact groundwater supply (Drage, 2022).

Preventing a crisis and mitigating the effects of climate change is more manageable and cost-effective than dealing with it retrospectively, as indicated by previous research and literature (Vattenmyndigheten Södra Österjön, 2022). Such an approach can help municipalities avoid conflicts of interest when water shortages occur. Identifying and assessing areas of concern is crucial for ensuring water security in the face of climate change and other threats. These considerations should be actively integrated into national plans, comprehensive strategies, and particularly within municipalities. Initiating efforts to enhance and safeguard access to water, improve groundwater conditions in the region, and strengthen overall municipal water resources are critical steps. Some municipalities even consider domestic wells as part of their civil defense measures, even after connecting to the municipal Water- and Wastewater network. Well owners are instead encouraged to continue maintaining their wells on their properties to enhance water security in situations where the municipal supply may be compromised (Quote 140). The risk of not being able to maintain sustainability increases in the event of disruptions (Vattenmyndigheten Södra Österjön, 2022) and may potentially lead to vulnerabilities that can endanger socially significant activities and our national self-sufficiency in the future.

Enhancing governance for sustainable domestic well management

Previous literature and research emphasize the need for better support for a range of measures such as stronger governance, increased financial support, improved legislation, and increased awareness. These measures are essential to address the problems to ensure the safety and sustainability of domestic drinking water supplies (Biesbroek et al., 2009). The results of this study also highlight the need for clearer governance, higher authority, and political commitment to encourage action by municipalities and politicians to reduce risks, which was identified as a barrier to working with domestic wells (Figure 4.20). However, economic constraints remain a significant barrier as well as the lack of data available on domestic drinking water supplies.

In recognition of the importance of domestic drinking water issues, some municipalities are advocating for improved tools, legislation, and clearer guidelines to enable sustainable planning and water management (Quote 62). Currently, the absence of permit requirements for drilling new wells outside planned areas poses challenges for municipalities in regulating and minimizing risks related to water quality and quantity deficiencies. Municipalities must take greater responsibility for water safety, and the state should enhance its support for municipalities and county administrations to achieve national and global drinking water goals, ensuring favorable conditions for future water supply (SKR, 2022b).

Bridging the gap, unclear guidelines and responsibility

There noticeable divide between municipalities that actively address domestic wells and those that do not, is partly due to the lack of legislation in this field. Resulting in differing interpretations of municipalities' responsibilities towards individuals with domestic wells. The study's findings suggest that although many municipalities address domestic water-related issues in their municipal documents, they do not actively implement measures to improve domestic drinking water supplies or follow the legalisation highlighted in Section 2.4. The absence of clear guidelines creates uncertainty and reduces incentives to implement measures that mitigate the risks associated with water shortages and water quality problems for this group. Consequently, the well owner assumes full responsibility but are often lacking the same resources as municipalities.

In summary, to ensure a safe and sustainable domestic drinking water supply, it is necessary to establish new and well-defined legislation that minimizes interpretive variations and imposes binding regulations, thereby encouraging municipalities and agencies to prioritize domestic drinking water supply (Torsås Municipality, Interview 28 February 2023). It is also important to revisit the Environmental Code (SFS, 1998:808) to address exemptions for agricultural activities with significant water demands, as highlighted by the Kalmar County Administrative Board (Interview March 7, 2023). By making necessary improvements and gaining a clearer understanding of water balances, we need to review exemptions that currently allow large water users with domestic wells to bypass permit requirements or water assessments, potentially impacting the overall water balance. Many farms with intensive livestock operations and high water consumption are currently excepted from general permit requirements or water assessments due to exceptions in the Environmental Code. Adopting a holistic perspective is essential to achieve smarter water usage across all sectors and ensure that the total withdrawals do not exceed the water input value (Kalmar County Administrative Board, Interview March 7, 2023).

A geographical variation of municipalities that desire/require support

In general, it can be seen that the municipalities in the southern parts of Sweden are asking for more support. The reason for the geographical variation in those municipalities requesting support may be that they perceive a greater need for action on domestic wells as they are already experiencing problems compared to other parts of the country (as can be seen in Figure 4.21). Some municipalities have had negative experiences with domestic wells outside the municipal Water- and Sewage network and seek to implement changes to have a more substantial impact on new developments of

wells, which is an aspect they wish to further review and address (Quote 77). It is crucial to acknowledge that municipalities are significantly influenced by location-specific conditions and local variations (Schimanke et al., 2022), which in turn impact their level of prioritization and progress in addressing this issue. In this particular region of Sweden, lower rainfall and local challenges related to water demand already play a significant role.

To ensure the security of both municipal and individual drinking water, it is crucial for municipalities to have access to resources and information regarding water management, particularly considering climate change and its consequences on domestic water supplies. As municipalities hold a planning monopoly, they exert significant influence on land use within their jurisdiction. Therefore, conducting investigations to identify problem areas and to develop appropriate measures is vital, such as enhancing the water-holding capacity of the landscape to increase groundwater formation (Quote 60). This can have a profound impact on people's health and access to drinking water, especially given the anticipated variation in groundwater availability across the country in the future. Municipalities should have access to information and resources to effectively manage water supply. However, some municipalities have experienced a lack of investment and research from society, which leads to minimal work and information from some county boards (Quote 84). Unfortunately, this has hindered the implementation of reliable drinking water supply and climate adaptation measures by politicians at both the national and local levels. The experiences of municipalities like Vaxholm and Täby confirm this, where no preventive or supportive activities are in place for specific domestic wells (Quote 62) due to insufficient interest in domestic wells. The Kalmar County Board mentioned that water issues had not posed significant challenges in the past, with the resource being considered limitless. However, this mindset needs to change, and water issues must be elevated to the forefront of social debate and taken seriously. Climate change has turned extreme situations into the new norm, leading to recurrent water shortages and consistently low groundwater levels in numerous municipalities year after year. Planning is a politically driven activity that affects both municipal and private water management and supplies. Thus, it is necessary to address this matter to enhance redundancy, and better prepare for risks and conflicts related to the right to water during periods of low flows and groundwater levels (Kalmar County Administrative Board, Interview March 7, 2023).

5.2 Discussion of Methods and Study Design

5.2.1 Methodology Critique & Limits

Online Survey

Online surveys have certain limitations, such as the inability to ask follow-up questions or clarify doubts for respondents. During data processing, it was noticed that some questions, like question number 4 (See Appendix A), had limited options or were constructed wrong. It would have been preferable to have more options for this specific question since most respondents chose the range of 0-25% for working with domestic wells. This could have provided more detailed information. However, online surveys eliminate the interviewer effect, which is advantageous (Bryman, 2018). There are

also other potential issues, such as questions that do not fit well in a survey, duplicate responses, and concerns about anonymity and confidentiality that may discourage respondents from participating (Bryman, 2018).

Semi-structured Interview

While sending interview questions in advance carries the risk of receiving rehearsed or less spontaneous responses (as observed in one of the interviews), it was deemed necessary in this study to ensure higher-quality answers and assist respondents in understanding the purpose of the interview. This approach also helped getting in touch with the right person due to the challenges faced in reaching staff members with knowledge on the subject, as there is currently no legal responsibility in place. Even after securing interviews, participants encountered difficulties in answering the questions and allowed them to gather information from other colleagues within their organization to better address the questions.

Another factor that can affect the answers provided by respondents is the gap between academic values and the reality of working life. In some cases, academic concepts and terminology may be used that are not commonly used in practical work. Moreover, the issue of domestic wells can be challenging, as there may be gaps in knowledge within the research field and some professionals may not be fully aware of the problems or issues related to it. This relative newness of the subject matter can also make it difficult to formulate the right questions to obtain the necessary information from participants. As a result, it is essential to approach the subject matter with an open mind and adapt to the realities of the participants' experiences and knowledge levels.

5.2.2 Risk of Bias

The aim of the sampling for both the interviews and survey was to include a variety of municipalities or respondents who work with domestic wells to some extent. However, since a large number of municipalities were contacted for both the interview and survey for the snowball method, only those that were interested and able to participate were used in the study. This convenience sampling could create a sampling bias, where the respondents in the sample may have chosen to participate because they found the subject or questions important or were already working with these issues. This bias may be particularly relevant to the survey, as the sample may be biased towards those who consider domestic wells and water problems important or problematic, see (Bryman, 2018). This bias is further compounded by the fact that domestic well complications today are the responsibility of the well owner. It is also possible to argue that the municipalities in the southern parts of Sweden are slightly over-represented, which could affect the generalizability of the study. However, this could also be due to the fact that there are more municipalities in the south of Sweden compared to the northern parts. Moreover, the northern municipalities are typically larger in size.

In the case of the online survey, high non-response rates are a common problem associated with this method in many countries, and they can be attributed to various reasons. During the survey, several reasons for non-response were identified, including time constraints, personnel shortages, frequent survey requests, lack of involvement in domestic well-related issues, or the absence of domestic wells in the municipality,

as reported by 19 municipalities Bryman, 2018. To address this issue, it was emphasized that "an answer is better than no answer," and even if the municipality does not work with domestic well issues. Providing an answer, saying "Don't know!" would still contribute to the result. This approach helps to increase the response rate, highlight both sides of the issue within municipalities, and avoid the over-representation of those who are knowledgeable or interested in the topic. Reminder emails were also sent to non-responding municipalities on two occasions, explaining the importance of their participation. This approach is established and effective in increasing response rates (Bryman, 2018; Esaiasson, 2017).

The sampling process for the study encountered challenges, particularly in identifying staff members with the most expertise on the subject. To address this, more persuasive explanations were provided to emphasize the importance of including municipalities that do not typically handle domestic wells, ensuring a comprehensive understanding of the topic. By sending reminder emails that highlighted the value of diverse perspectives, additional survey respondents were recruited. Although a few participants dropped out, the collected data exhibited good quality, as the survey questions generated high-quality comments that enhanced the study's validity and realism (Esaiasson, 2017). And despite difficulties in securing interview participants, it was deemed less significant compared to the alternative of having no samples at all. In the end, four interviews were conducted with participants who possessed varying levels of experience in addressing domestic well issues.

5.2.3 Challenges and Insights for the Sample

Insights gained after the submission deadline for the survey and some already scheduled interviews revealed that it would have been preferable to either conduct more interviews or to skip interviews with municipalities and instead, contact experts on domestic wells from SGU or SLV, for instance. This would have provided a more diverse range of perspectives and a broader understanding of the study's subject on domestic wells, as well as gain insight into how the issue is handled across different levels. However, since there was an expectation of low participation in the survey due to the extensive surveys and the lack of legal responsibility as of today, contacting municipalities for further interviews seemed like a reasonable option at the initial stage of the study. Nevertheless, the sample size is still considered sufficient to provide the information that was required to answer the study's questions. And the municipality interviews did come with some extra interesting information that did not get covered by the survey. Had there been more time, involving more individuals from the authorities who work with or are familiar with the subject of domestic wells would have been beneficial as it would have contributed to a more in-depth understanding. However, due to the limited amount of time, it was decided to not contact more individuals for the interviews, as the response to the survey was better than expected.

5.3 Further Research

Domestic wells are an understudied area with significant knowledge gaps, especially in municipal planning and their susceptibility to various factors. An area of interest for future research would be investigating health risks associated with domestic wells.

The study revealed that many respondents reported highly poor drinking water quality and irregular testing among domestic well users, making it crucial to determine the number of individuals who may potentially suffer from health issues due to consuming contaminated water. The societal costs of such health risks can be significant, and research on this topic can contribute to advancing sustainable drinking water supply for domestic wells and raising national awareness. Additionally, a potential study could explore the capacity of domestic wells to contribute to civil defense and ensure sustainable and safe drinking water security, which was only briefly touched upon in this study. By involving politicians in the research, the role they play concerning domestic wells and national drinking water security can be examined, ultimately promoting sustainable development. In conclusion, the subject of domestic wells offers numerous opportunities for further research. It would be interesting to see additional studies exploring this field, providing insights into promoting sustainable and safe drinking water supply for domestic wells and enhancing overall water security.

6 Conclusions

Domestic wells deserve more attention from authorities and agencies, and people dependent on domestic wells have the right to the same level of health protection as the municipal drinking water system. This study highlights the need for increased focus on individual drinking water supply and domestic wells due to their significant impact on society, human health, and the water balance, particularly in light of changing conditions caused by climate change. The major findings of the study conclusions are:

- Municipalities lack a systematic approach to addressing domestic drinking water concerns, as they do not consider them as their specific responsibility, it is more of a voluntary undertaking.
- The management by municipalities of domestic drinking water varies regionally and is influenced by the historically experienced water issues.
- There is a lack of information on the status and quality of the domestic drinking water supply. Significant uncertainty and insufficient statistical data regarding individual wells can pose severe problems.
- In many cases, well owners lack the competence, knowledge, interest, and resources to maintain their wells often leading to potential risks to water safety.
- A large proportion of the wells reported in this study are rarely tested (about 8 % are believed to follow the SLV's recommendations for testing drinking water) and a large proportion of the wells are believed not to meet drinking water quality standards by the municipalities, which can pose a threat to the health of domestic well users.
- Municipalities need support in the form of better tools, legalization, national guidelines, and better data on domestic wells to overcome the challenges posed by a changing climate to better manage domestic drinking water supplies and achieve a safe and resilient drinking water system.
- By enhancing the engagement of municipalities in the management of domestic well drinking water supply and revising water permits for significant water users, a more public understanding of the overall water budget and water balances in terms of water access can be attained.

Efforts are therefore needed to improve the current state of Sweden's domestic drinking water supply. At present, Sweden and its municipalities are far from meeting the environmental targets set by the Swedish Parliament and the UN's sustainability goals, especially with regard to ensuring good water quality and a resilient national drinking water supply. This challenge is compounded by the looming threat of climate change, which will bring new and changing conditions.

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Appendix A

Questions included in the February 2023 online survey

Link to the survey questions and responses (containing no contact information):

https://sunet.artologik.net/gu/rapport_enkät_enskild_vatten_anonym

Brief information about the respondent

1. Which municipality do you work for?
2. What is the role of the respondent within the municipality?
3. Which department do you work in?
4. How much would you like to work on the topic of domestic wells/domestic drinking water supply?
   (a) 75-100 % of my time
   (b) 50-75 % of my time
   (c) 25-50 % of my time
   (d) 0-25 % of my time
   (e) Not at all

Questions about domestic drinking water supply in your municipality. These questions are about the challenges you feel regarding water supply and water quality in domestic wells. But also how this is usually addressed in your municipality. For some questions, you can click on several answer options and feel free to leave comments.

5. How many domestic wells/domestic drinking water facilities do you estimate to be in the municipality? Enter the number.
6. Is there a large unrecorded number of wells/domestic drinking water supplies that may not be included in the above estimate?
   (a) Yes
   (b) No
   (c) Don't know, specify in the comments section

7. How many of the estimated numbers of domestic wells/domestic drinking water installations are estimated to be agricultural/other industrial activities? Answer in percent (%).

8. Have you experienced a water shortage affecting domestic drinking water supplies in your municipality?

   (a) Yes regularly

   (b) Yes but more rarely

   (c) No

   (d) Other, specify in the comments section

9. If you answered "Yes regularly" to question 8, are there certain locations that are exposed more often, what characterises the location?

10. If you answered "Yes regularly" to question 8, in which months is the situation usually strained?

11. Have you experienced quality problems for domestic drinking water supplies in your municipality?

    (a) Yes

    (b) No

    (c) Don't know, specify in the comments section

12. Briefly comment on question 11, regardless of the answer.

13. How many of those who have a private drinking water supply estimate that they follow the Swedish Food Agency's recommendations to test their water every three years? Answer in percent (%).

14. What is the estimated distribution of water quality remarks among those who have tested their water?

    (a) % "tjänligt vatten2

    (b) % "tjänligt med anmärkning"

    (c) % "otjänligt"

    (d) Don't know

15. If you have experienced water shortages/quality problems, how do you work and deal with them?

    (a) Not at all (responsibility of the well owner or owners' association)

    (b) Through information and counselling

    (c) By drilling new wells

    (d) Connecting well owners to municipal water supply

    (e) Tankers/ water kiosks/ tapping points to collect drinking water.

    (f) Sampling campaigns

(g) Other, specify in the comments section

16. Are problems with access and quality perceived to be increasing/decreasing over the last 10 years?

    (a) Yes increasing

    (b) No difference

    (c) No decreasing

17. If you answered "Yes" to question 16, have studies been carried out on the quality and quantity of groundwater in the municipality in favour of domestic drinking water supply?

    (a) Yes large scale

    (b) Yes small scale

    (c) No

18. What are the most common questions you receive regarding domestic drinking water supply?
    Often, Sometimes, Rarely, Never & Don't know

    (a) Help with water shortages

    (b) Help in interpreting the analysis results

    (c) High metal levels in drinking water

    (d) High levels of salt in drinking water

    (e) Contaminated drinking water

    (f) Problems with smell, colour or taste

    (g) Problems with microbiological growth or bacterial levels

    (h) Competing water use among neighbours

    (i) Impact from surrounding neighbours/area

19. **Is there a perceived lack of expertise and knowledge within the municipality to strengthen domestic drinking water supplies?**

    (a) Yes

    (b) No

    (c) Other, specify in the comments section

20. If you answered "Yes" to question 19, what is the strategy for increasing knowledge within the municipality?

21. Is there a perceived lack of skills and knowledge among well owners to maintain good quality drinking water supplies?

    (a) Yes

    (b) No

    (c) Other, specify in the comments section

22. If you answered "Yes" to question 21, what is the strategy to increase knowledge among well owners or what do you think is necessary?

Climate change and domestic drinking water supplies

23. Is there any aspect of the changing climate that you think stands out for your municipality? What are these?

24. In relation to question 23, does the municipality work towards resilient drinking water extraction for people/activities with domestic drinking water supply?

    (a) Yes

    (b) No

25. If 'Yes' in question 24, to what extent?

    (a) Small extent

    (b) Large extent

Planning and cooperation of domestic drinking water supplies

26. Do you plan to implement measures to prevent future water scarcity in terms of water supply and quality? If so, which ones?

27. Is domestic drinking water supply included in the municipality's documents or work today?

    (a) The comprehensive plan

    (b) The water and wastewater management plan

    (c) Climate Adaptation Plans

    (d) Sustainability Strategies

    (e) Other, specify in the comments section

28. In new development strategies or planning permission procedures for new buildings, are groundwater conditions taken into account as a decisive aspect if municipal water supply does not cover a certain area if an area is to be developed or not?

    (a) Yes (specify in the comment section)

    (b) No

29. Do you feel that there are clear guidelines from higher authorities on how to plan for domestic drinking water?

    (a) Yes

    (b) No

30. What (if any) is the main obstacle to effective action on water scarcity today?
    (a) Limited economy
    (b) Lack of division of responsibilities
    (c) Lack of ability to carry out measures
    (d) Lack of competence
    (e) Lack of political will
    (f) Lack of or absence of cooperation
    (g) Insufficient knowledge background
    (h) Insufficient legal support
    (i) Insufficient planning
    (j) No there are no major recurring obstacles
    (k) Other, specify in the comments section
31. Would you have liked support from other actors/authorities?
    (a) Yes (specify in the comment section)
    (b) No
32. Are there any trends around domestic water supply?
    (a) An increase of drilled wells
    (b) More people feel they want to connect to municipal water services
    (c) No trend
    (d) Other, specify in the comments section

Contact details If you would like to be informed of the results of the survey and/or would be willing to be interviewed briefly, please leave your contact details below.

33. Use of contact information
    (a) I want to be informed about the results of the survey
    (b) I would be willing to be interviewed
    (c) I am willing to answer a few short follow-up questions by email or phone.
    (d) I wish to remain anonymous and do not provide any contact details
34. Your name:
35. Your email address:
36. Your phone number:

Appendix B

Interview guide county administration

Time aspect: the interview takes about 45-60 minutes

General questions (3)
Your name

Job title and background (education and previous experience)

In which contexts do you usually come into contact or work with domestic drinking water supply?

Groundwater and domestic drinking water supply (Water management) (10)
What is the role of the County Administrative Board in relation to the domestic drinking water supply? (responsibilities and issues related to domestic wells)

How many inhabitants are currently supplied by domestic drinking water supplies within the county's borders?

Is there an increased need to monitor domestic wells and their quality and quantity today compared to before?

What is the current situation regarding groundwater in the county? Is it good or are there problems with quantity (quantity) or quality in certain areas/municipalities?

What is the current groundwater capacity, is it sufficient for all water use? (for agriculture, industry, private households, etc.).

How do you work with domestic drinking water supply in the county today to ensure a good supply and good quality drinking water? Does anything need to be changed/improved?

What are the difficulties or challenges in working towards sustainable water management of domestic drinking water supplies?

Is there a lack of further legislation or guidance on domestic drinking water supply to facilitate the management and control of long-term sustainable drinking water management?

Is there good competence among those who make decisions on issues related to domestic drinking water management? (e.g. within the municipalities or at your county administrative board).

Climate and climate adaptation (4)
Is there any aspect of climate change you think stands out for your county? What is/are these? (e.g. increased precipitation, heat waves)

How does the county administrative board relate to changes in the climate today?

In relation to climate change, does the county administrative board work towards resilient drinking water extraction for people/activities with domestic drinking water supply? How and to what extent?

With a changing climate, more extreme events and political uncertainty, the need for measures against drinking water security increases. Have you experienced any difference in terms of domestic wells and how residents reason about their management of these crises to ensure drinking water security now and in the future?

Coordination/ Collaboration (3)
Does the county administrative board currently work together with other actors to strengthen the drinking water supply (for municipal & domestic drinking water supply), if so, how?

What is the communication behind water management with domestic drinking water supplies?

How do you feel at the county administrative board that issues of domestic drinking water supply are prioritized in terms of politics and in the municipalities, but also at your office? (national-local)

Concluding questions
Is there anything you think we haven't talked about that is still important to bring up that concerns domestic drinking water management and achieving a sustainable drinking water supply?

- What is your opinion on the domestic drinking water supply? Do you think it is an important topic that should be addressed or, on the contrary, not important?

Appendix C

Interview guide municipalities

Time aspect: the interview takes about 45-60 minutes.

General questions (3)
Your name

Job title and background (education and previous experience)

In which contexts do you usually come into contact or work with domestic drinking water supply?

Groundwater and domestic drinking water supply (Water management) (10)
How many inhabitants are currently supplied by domestic drinking water supply in the municipality?

Is there any understanding of the share of agriculture and industry in the domestic drinking water supply quota?

Is there an increased need to have more control over domestic wells and their quality and quantity today compared to before?

What is the current situation regarding groundwater in the municipality? Is it good or are there problems with quantity (quantity) or quality?

What is the current groundwater capacity, is it sufficient for all water use in the municipality or is there a high risk of water shortage? (for agriculture, industries, private households, etc.).

How do you work with the domestic drinking water supply in the municipality today to ensure good supply and good quality drinking water? Does anything need to be changed/improved?

What are the difficulties or challenges in working towards sustainable water management of domestic drinking water supplies?

Is there a lack of additional legislation or governance around domestic drinking water supply to facilitate the management and control of long-term sustainable drinking water management?

Is there good competence among those who make decisions on issues related to domestic drinking water management? (e.g. for politicians, building permit officers, etc.)

Climate and climate change adaptation (4)
Is there any aspect of climate change that you think stands out for your municipality? What are they? (e.g. increased precipitation, heat waves).

How does the municipality relate to changes in the climate today?

In relation to climate change, how does the municipality work towards resilient drinking water extraction for people/organizations with domestic drinking water supplies?

With a changing climate, more extreme events, and political uncertainty, the need for measures against drinking water security increases. Have you experienced any difference in terms of domestic wells and how residents reason about their management of these crises to ensure drinking water security now and in the future?

Coordination/ Collaboration (3)
Does the municipality currently work together with other actors to strengthen the drinking water supply within the municipality (for the municipal & domestic drinking water supply), if so, how?

What is the communication behind water management for domestic drinking water supply?

How do you feel that issues of domestic drinking water supply are prioritized in the municipality in terms of politics (national-local)?

Final questions
Is there anything you think we haven't talked about that is still important to address regarding domestic drinking water management and achieving a sustainable drinking water supply?

- What is your opinion on the domestic drinking water supply? Do you think it is an important topic that should be addressed or, on the contrary, not important?

Appendix D

Thematic analysis

Themes	Sub-Themes	Code words
Distribution of responsibilities	The role of the property owner	The question of liability
	The role of the municipality	Many actors involved
	Unclear division of responsibilities	Should it be a municipal issue
Interest in individual drinking water supply	Strengthening drinking water supply in emergencies	Emergency wells
		Strategies for strengthened drinking water supply
	Priority and interest of municipalities	Desired focus on individual drinking water issues
		Low priority and interest
		Fall between the cracks
	Trends to strengthen drinking water safety	More people are connecting to the public water supply
		More are drilling wells
		Increased concern about water safety
Municipalities' work today	No problem with individual wells	Few well owners looking for help
		Strategies for strengthened drinking water supply
		No water shortage in the municipality
	Planning documents	Planning document
		Production of knowledge materils
		Identification of risk areas
		Rural development
	Climate adaption work	Water retention measures
		Implementation of desalination facility
	Urban planning	Public- and permit duty
		Building permit and advance notice
		Physical planning

Themes	Sub-Themes	Code words
		Expansion of municipal water and sewage
	Strategies for individual drinking	Water sampling campaigns
		Behavioral change in water use
	Climate adaption work	Water retention measures
		Implementation of desalination facility
	Urban planning	Public- and permit duty
		Building permit and advance notice
		Physical planning
		Expansion of municipal water and sewage
	Urban planning	Public- and permit duty
		Building permit and advance notice
		Physical planning
		Expansion of municipal water and sewage
	Strategies for individual drinking	Water sampling campaigns
		Behavioral change in water use
	Available municipal service for individual drinking water supply	Advice and information
		Reduced prices for water samples
		Free children's water tests
Knowledge dissemination	Lack of competence and understanding among well owners	Unengaged/uninterested well owners
		Short memory
	Knowledge dissemination	Participate in more training courses/ conferences
		Enlighten well owners
		Expansion of municipal water and sewage
Governance	Legislation	Environmental Code
		Swedish Water and Sewage Services Act
		Legislation is missing
	Guidelines	Governance and guidelines are missing
		Reduced prices for water samples
		Free children's water tests

Themes	Sub-Themes	Code words
	Guidelines	Governance and guidelines are missing
		Reduced prices for water samples
		Free children's water tests
	The value of collaboration	Inter-municipal work Cooperation
		Collaboration
		Free children's water tests
Challenges for municipalities' to work with domestic wells	Administrative challenges	Staff turnover
		Actionable
		No specific job positions have been appointed
	Poor knowledge base	Few records and statistics
		Municipalities do not get access to the results of water sample analyses
		Lack of insight in individual drinking water supply
		Little knowledge base and data
	No supervisory responsibility at present	No permit required
		No supervisory responsibility
	More support and guidelines	Municipal support (the political interest)
		Guidance and guidelines
	Lack of resources	Funds/money
		Time
Domestic Well Vulnerabilities	Population growth and competition	Population growth
		Water competition
		Increased water extraction
	Contamination	Well constructions
		Environmental impact
	Climate change	Climate impact on quality
		Climate impact on quantity
	The SLV's recommendations	Quality marks
		Low sampling frequency
	Site-specific conditions	Saltwater intrusion
		Relic water
		Thin soil layers
		Distance between properties

Appendix E

Result citations

Quote 1
"Completely missing records as there is no municipal enforcement responsibility. However, I estimate that there should be about as many domestic water sources as domestic sewers. This figure is also to some extent an estimate, but should be much closer to reality"- Svalöv municipality

Quote 2
"I cannot make an estimate of the number of domestic drinking water installations. We have a figure from SCB (2020) on the number of single-family house properties that have domestic water all year round: 3683. When it comes to e.g. agriculture or other, I have no figure"- Alingsås municipality

Quote 3
"We really have no idea, but in the municipality, there are about 2200 domestic sewers that have a sludge separator that is emptied by the municipality's sludge emptying contractor. We can assume that these also have domestic drinking water. We also know that there are holiday homes that do not have sludge emptying (no sewage system/have an outhouse/simple sewage system for BDT water)"- Kinda municipality

Quote 4
"Good question, don't know"- Kungälv municipality

Quote 5
"No idea. But most industrial operations do not have domestic wells" - Hudiksvall municipality

Quote 6
"We have about 70 properties in the municipality that have horses, farm animals or are engaged in plant cultivation. Most have their own water. There are also a few industries, including a cement factory with its own well, but it is unclear how many. I, therefore, estimate the number to be about 5%"- Nykvarn municipality

Quote 7
"Impossible to know, there are probably many wells that are not included in the well register SGU"- Arjeplog municipality

Quote 8
"There is no register as there is no municipal supervisory responsibility. However, I estimate that there should be about as many domestic water sources as domestic sewers. This figure is also partly an estimate, but should be much closer to reality"- Örkelljunga municipality

Quote 9
"However, quite a few properties have both an old dug well, which is no longer used, and a newer drilled well that is used. Therefore, there could be quite a few more than 1500"- Huddinge municipality

Quote 10
"[...] However, there is probably a dark figure between what is registered in SGU's well register and what is probably on site. This is because it is up to property owners to register, which many probably do not do"- Uppsala municipality

Quote 11
"We have inspected all domestic sewage facilities in the municipality and therefore have a pretty good idea of what the domestic drinking water supply looks like, as we always ask where the drinking water well is located during the sewage inspections."- Herrljunga municipality

Quote 12
"[...] but since Tidaholm municipality has offered owners of domestic wells to submit water samples, which the municipality forwards for analysis at a favourable price, and has done so since the mid-1990s, there are not many wells that have not been sampled"- Tidaholm municipality

Quote 13
"Botkyrka's Blue Values is a document that addresses all types of water in the municipality and how we will work to ensure good water quality in the municipality"- Botkyrka municipality

Quote 14
"It is mentioned in the water plan, but no direct plan to actively work with it"- Essunga municipality

Quote 15
"We are working on a new comprehensive plan so it is an issue we will include"- Gnosjö municipality

Quote 16
"Part of the VA plan, but work is also underway to develop a water supply plan (this also compiles available knowledge regarding the domestic water supply)"-Nybro municipality

Quote 17
"Included with regard to the environmental objective Groundwater of Good Quality, but mainly with regard to safeguarding the existing resources and a description of the status of the groundwater supply being good at present"- Örkeljunga municipality

Quote 18
"It is not a municipal responsibility in the domestic case. But according to the Environmental Code, the municipality has an overall responsibility for public health"- Sala & Hedby municipalities

Quote 19
"As I said, it is not something the municipality works actively with as the responsibility lies with the domestic property owner to provide their property with drinking water outside the VA area"- Skurup municipality

Quote 20
"Again, not the municipality's responsibility to collect data on this"- Sunne municipality

Quote 21
"We have no control over domestic wells as long as they are not commercial or produce more than 10 m3 or to more than 50 people/day"- Kalmar municipality

Quote 22
"Since there is no requirement to notify the digging/drilling of domestic wells in the municipality, there is no register of such wells [...]. [...] The municipality thus has no register of domestic wells/drinking water facilities except for those to be checked against the requirements of the legislation (drinking water regulations)"- Östersund municipality

Quote 23
"A lot of bare rock or clay. Locations with close or direct access to the sea. Where the storage capacity is small and most of the rainwater during heavy downpours runs straight into the sea. In these coastal areas and on the municipality's islands, the population increases in the summer when more visitors, friends, relatives, and family stay for a few weeks/months in the area"- Kungälv municipality

Quote 24
"Places or areas characterized by mountains, thin layers of soil, intensively cultivated arable landscapes"- Mörbylånga municipality

Quote 25
"domestic wells in some areas. Problems with saltwater intrusion, problems with access, e.g. at the end of summers in some years. More people inform that they are starting to desalinate seawater instead of using wells with the quantity or quality deficiencies"- Vaxholm and Täby municipalities.

Quote 26
"Areas with a lot of bare rock or thin soil cover. Holiday home areas with an increasing proportion of year-round residents"- Nacka municipality

Quote 27
"We offer water samples through the municipality and get test results from there and most wells have minor problems but some get more, salt water is a bigger problem in some parts"- Essunga municipality

Quote 28
"We see more often problems with high nitrate levels now compared to 10 years ago. Iron and manganese are also common problems. Also sometimes too low fluoride levels"- Herrljunga municipality

Quote 29
"Practically all drinking water wells have quality problems, many people think they have good water but have not tested for a long time"- Luleå municipality

Quote 30
"The problems we come into contact with are mainly bacteria from wastewater in small villages without municipal water supply. Pesticides occur in municipal wells and therefore probably also in domestic wells. However, the test frequency on domestic wells is low and we rarely learn about the drinking water status of private domestics"- Svalöv Municipality

Quote 31
"There are problems, but there is certainly a large number of unrecorded cases"- Mölndal municipality

Quote 32
"In occasional, very hot, dry, low rainfall summers, domestic wells have dried up and some well owners have then contacted the municipality to try to get help with water."- Lund municipality

Quote 33
"The municipality only has supervisory responsibility for larger domestic facilities, and therefore lacks information about smaller facilities"- Borlänge municipality

Quote 34
"Child water samples can be ordered through the municipality, but we do not receive feedback on these and they are only sent to those concerned"- Lidköping municipality

Quote 35
"The municipality does not have insight into private property owners' sampling of their drinking water"- Svedala municipality

Quote 36
"Can not say with any certainty as we do not get that information. Estimated very low test frequency, however, close to 0%, based on what usually appears during inspections of sewers or contact with brokers / new property owners. Standard seems to be a test when moving in (if at all) and then nothing new"- Perstorp municipality

Quote 37
"Even if you as a domestic well owner may be aware of what is recommended, three years pass quickly and if you do not experience any obvious problems, it is easy to forget. Unfortunately, I think that the sampling frequency will decrease with the recession we have ended up in"- Österåker municipality

Quote 38
"We only receive results from child water samples, with a selected number of parameters that the municipality pays for to households with small children. There, the most common is that they are serviceable with a remark, usually some elemental parameter"- Skövde, Karlsborg, Falköping, Hjo & Tibro municipalities.

Quote 39
"Practically all drinking water wells have quality problems, many believe they have good water but have not tested for a long time [...] No one knows, but my experience is that practically almost all have serviceable with the remark, or they already have filters for problems, unfit is not so common, but sometimes occurs, especially high iron levels"- Luleå municipality

Quote 40
"The experience is that it is a vanishingly small part that even regularly analyses its water at larger intervals"- Nybro municipality

Quote 41
"We have no such statistics. We do not regularly receive copies of such protocols as far as I know. There are probably quite a few who sample their water more than once"- Umeå municipality

Quote 42
"For most people, it is a non-issue as long as they have water in the tap and no one in the household gets sick"- Svalöv municipality

Quote 43
"There is a small minority who care enough about their well water, by analyzing it every three years etc. People get used to the water they have, it can be a bit colored and taste metallic, but they always have "very good water""- Borås municipality

Quote 44
"Investigations of the drinking water quality in private water are not done as often as recommended, probably due to ignorance and leaning on the security that it is your own water that you have always drunk. Sampling and maintenance needs are often revealed during sales/change of ownership"- Enköping municipality

Quote 45
"I have only worked for 6 years but I feel the difference"- Essunga municipality

Quote 46
"We think we see a trend that problems with high nitrate levels are increasing. Otherwise unchanged"- Herrljunga municipality

Quote 47
"As there is construction in several coastal areas where the water supply is limited, there is now more often a risk of water shortage in these areas than before (although only a few areas) when there was lower consumption in these areas. However, these areas will be prioritised for the operational area for water connection"- Hudiksvall municipality

Quote 48
"Partly due to climate change I think"- Kungälv municipality

Quote 49
"Mainly the supply! Water shortage clearly more common in the last 10 years"- Kungs-

backa municipality

Quote 50
" [...] Groundwater levels have decreased according to our experience in municipal wells. In smaller wells, the levels vary more. [...]"- Nybro Municipality

Quote 51
"Possible causes may be increased withdrawals due to modern conveniences, people living more or less permanently on the islands, possibly less rain or more persistent heavy rain where infiltration is more difficult"- Vaxholm & Täby municipalities

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Quote 56
"Difficult to verify but possibly there is less snow which reduces infiltration and heavier rain which reduces infiltration. Impaired formation of fresh groundwater due to these parameters. In the long term, the sea level will rise, which increases the risk of saltwater intrusion"- Vaxholm & Täby municipality

Quote 57
"We are a municipality with a large focus on green industries and a municipality with relatively many and large positive climate effects. [...]"- Ydre municipality

Quote 58
"In the work with the VA plan, it is investigated to expand municipal VA to areas with difficulties regarding domestic VA, water shortage during the drought had been taken into account there"- Alingsås municipality

Quote 59

"The municipality is working to develop a water supply plan that also includes domestic drinking water sources"- Kalmar municipality

Quote 60
"Information on delaying measures and water saving and that the municipality has its own projects underway"- Nybro municipality

Quote 61
"Included in all our work - strategy/plan/build to work for future supply for both the municipality and in the environmental work to protect domestic drinking water sources"- Sjöbo municipality

Quote 62
"[...] YES: with regard to the drilling of new wells, a permit requirement has been introduced, where the environmental office can influence sustainability aspects. when assessing new domestic sewage facilities, we always include chloride analyses as a basis for assessment. through dialogue with applicants, we try to make them understand that how they carry out drilling or sewage construction can affect future drinking water availability. NO: There are no preventive or supportive activities on the part of the municipalities regarding domestic wells"- Vaxholm & Täby municipalities.

Quote 63
"This is currently not a primary municipal responsibility"- Lund municipality

Quote 64
"We have several smaller waterworks for municipal drinking water production, and are working to increase the pace of maintenance of the network. But within domestic water supply, we do not work specifically with it, except to enable increased connection rates"- Ydre municipality

Quote 65
"We would have to do this"- Östhammar municipality

Quote 66
"In 2023, the municipality will work on a water service plan. This work may result in measures being proposed"- Upplands-Bro municipality

Quote 67
"According to the municipality's VA plan, we work with continuous expansion of the VA collective's network to offer drinking water of good quality but also to reduce emissions of untreated wastewater"- Lysekil municipality

Quote 68
"Before deciding on building permit applications or planning areas, the water supply is always assessed according to the Planning and Building Act. If the area is deemed to be at risk of water shortage, exploitation to such an extent is not permitted"- Kramfors municipality

Quote 69
"Introduce a notification/permit requirement for drilling for water in areas where we

see that groundwater availability is critical (coasts, areas with high development pressure and high competition for water and islands). NB only a proposal at present that needs to be adopted by the politicians in order to be introduced"- Norrtälje municipality

Quote 70
"A few years ago we had a project to inventory and control domestic sewers. In connection with this, we have collaborated with the technical and property administration to prioritize which areas need to be connected to municipal water and sewage"- Lidingö municipality

Quote 71
"We work a lot with remediation of contaminated land, as well as controlling the organization's handling of contaminated elements"- Ydre municipality

Quote 72
"We are in the process of developing a water supply plan in the municipality where problem areas will be highlighted and what measures will be implemented"- Emmaboda municipality

Quote 73
"Not for domestic drinking water sources. The municipality reviews the municipal water sources and has produced a risk and vulnerability analysis for the largest water source in the municipality"- Strömstad municipality

Quote 74
"Yes, since you also have to build a domestic sewer, you also have to make sure that you have a sufficient safety distance to your own and your neighbor's water source"- Gnosjö municipality

Quote 75
"Water supply is included as an issue to be considered in new plans"- Lidingö municipality

Quote 76
"domestic drinking water supply is always investigated and in some cases it can be a reason to say no to an exploitation"- Norrtälje municipality

Quote 77
"The municipality has previously had bad experiences of allowing development in areas that are outside the municipal water network. Therefore, it is reviewed more carefully nowadays"- Nykvarn municipality

Quote 78
"Yes, groundwater conditions are an important part of preliminary approvals and building permits where domestic water supply is relevant"- Östhammar municipality

Quote 79
"No, Tidaholm's inhabitants, whether they have municipal or private water, are so spoilt when it comes to good access to good water, that it is not the time for it, at least not yet"- Tidaholm municipality

Quote 80
"No, at present there is no such municipal planning"- Lund municipality

Quote 81
"Not directly, drinking water availability is good in our area"- Leksand municipality

Quote 82
"Limited finances and human resources"- Borås municipality

Quote 83
"The big problem is climate change"- Forshaga & Munkfors municipalities

Quote 84
"Society, in general, does not invest any money in this with domestic drinking water, it feels like. No research. No work and info from our county administrative board in Blekinge in the last 10 years (they had a good meeting about 10 years ago). We at the local environmental office hardly allocate any resources at all for this and not the municipality in general either"- Karlshamn, Olofström & Sölvesborg municipalities.

Quote 85
"The municipality's water supply network is managed by Nacka Vatten och Avfall AB, whose responsibility is within the operational area. Outside the operational area, it is the domestic property owner who is responsible for their water supply. Through special orders, temporary tapping points have been set up during the summer"- Nacka Municipality

Quote 86
"Lack of legal support to request information"- Nybro municipality

Quote 87
"Miljö- och byggnadsnämnden claims that we do not have supervision of domestic water sources outside areas for authorization or notification obligation"- Västervik municipality

Quote 88
"There are other issues that the politicians have chosen to focus on, and in addition, the resources are so limited and the organization so slim that we administrators rarely have time to work on anything other than what is regulated as a requirement"- Ydre municipality

Quote 89
"But there is a lack of data from SGU and it is considered too costly to require a hydrological or geohydrological from private domestics"- Arjeplog municipality

Quote 90
"The information has been missing to a large extent. Discussions are ongoing about how to handle this in both the Va plan and the ÖP"- Knivstad municipality

Quote 91
"They must somehow understand that water is such a large and important part of daily

life that they themselves seek information. They get advice from us when they call/visit but we have no info projects"- Sollefteå municipality

Quote 92
"Continued information, they are receptive to the information when there is a problem"- Rättvik municipality

Quote 93
"Unfortunately, I don't even think that increased knowledge helps in some cases. [...] There are also some people who think that it is the municipality's responsibility to fix their problems if something happens, and it may be a 50-year-old well that no one has taken care of"- Österåker municipality

Quote 94
"For most people, it is a non-issue as long as they have water in the tap and no one in the household gets sick"- Svalö municipality, ID 176

Quote 95
"It is likely that there may be a need for increased knowledge. We are therefore planning an information initiative for domestic drinking water facilities, even if the responsibility for the water there lies with the domestic"- Kristinehamn municipality

Quote 96
"Domestic well owners are probably not always aware of low levels until it stops running in the tap. You could have avoided a sinking well if you saved water. [...]"- Vetlanda municipality

Quote 97
"Knowledge is generally available, but many people are uncertain about the division of responsibilities. The municipality provides information via targeted mailings and information on the website"- Upplands-Bro municipality

Quote 98
"In case of problems, they are in great need of help. Often they do not even know that their water should be tested"- Vaxholm & Täby municipalities

Quote 99
"Many of those who have bought a house, and may not have grown up there, do not even know whether they have a drilled or dug well, or that they should report the well to the well archive. Even worse is the knowledge of the property owner's responsibility for the quality and availability of drinking water in the community"- Ydre municipality

Quote 100
"What the control authority does is to try to inform the public about the importance of having control over their own water (both quantity and quality), suggestions on how the water can be sampled, there have been sampling campaigns mediated via the municipality, we mediate information from the Swedish National Food Agency, etc. The problem is to reach out with the information when the interest is not among the domestics"- Östersund municipality

Quote 101
"Not sure if there is any strategy, but the municipality tries to have good information on the website and to provide information during, for example, sewerage inspections, as they often talk about drinking water wells at the same time"- Botkyrka municipality

Quote 102
"It is the well owner's responsibility, but in the case of campaigns, for example from the Swedish National Food Agency or from the municipality's procured laboratories, the municipality participates provided that there are resources"- Höganäs municipality

Quote 103
"It is important that everyone understands that you may need to save on the amount of water, especially at certain times of the year. It is about people acquiring new behavioral patterns, which is not always the easiest thing to do"- Kungälv municipality

Quote 104
"We inform several times a year in the media. The importance of testing your water. Everyone who is pregnant receives information via the BVC that the municipality offers child tests to all permanent residents who have children under the age of 5. We talk to estate agents about the importance of informing people that they have their own well and what that means. That you present an approved analysis response that is taken in the present time when selling" - Laholm municipality

Quote 105
"We receive water analyses in connection with applications for private sewage systems, prior approvals, and building permits, so it is possible to have a dialogue with the property owners or refer them to the development center for water here in the municipality We have also developed a proposal to introduce a permit/notification obligation in areas with high development pressure and along coasts and small islands. As I wrote, it is only a proposal so far, but the hope is that it will enable us to regulate the location of drinking water sources in order to minimize the risk of water sources being contaminated by, for example, domestic sewage plants"- Norrtälje municipality

Quote 106
It is difficult to achieve this as long as citizens perceive the water quality as good, that the water tastes good, and that they have enough water. If any municipal action is to be taken, money is needed. Something that could encourage more people to take samples is probably a campaign with a substantial discount on the cost of sampling"- Örnsjöldsvik municipality

Quote 107
"There is a strategy, our website will be updated in the spring of 2023 and there we will have information about our own water wells, but knowledge among well owners is low. They call here and think that it is we who should take samples and take responsibility for the well and water quality [...]"- Vårgårda municipality

Quote 108
"As an environmental inspector specializing in food control, my obvious go-to is the Swedish Food Agency and the Public Health Agency. And if you look at the issue

with a climate eye, I would have hoped that the Swedish Environmental Protection Agency/SGU would be able to assist with something"- Boden municipality

Quote 109
"Cooperation is always most effective, both within and between different kinds of organizations"- Enköping municipality

Quote 110
"Yes, that the county administrative board and the central authorities had organized courses, research, etc. in the area. That consumer tests of filters and purification plants had been organized so that consumers can be confident when buying water purification plants"- Karlshamn, Olofström & Sölvesborg municipalities.

Quote 111
"I would have liked to participate in any collaborative group that discusses drinking water issues"- Kungälv municipality

Quote 112
"The National Food Agency has guidance for drinking water quality. But there are no clear guidelines or legislation for the use of water and resource management"- Lidingö municipality

Quote 113
"Don't know which central authority or authorities could provide support, responsibility is fragmented"- Lund municipality

Quote 114
"Of course, we have different challenges and opportunities, for example in inland municipalities and coastal municipalities in the west and east. But not all municipalities need to reinvent the wheel... We are grateful for the data produced by SGU and SMHI. When it comes to qualitative aspects of the domestic water supply, we usually only get answers to standard parameters in the sampling kits. We know little about, for example, heavy metals and pesticides in general"- Nybro Municipality

Quote 115
"Guidance is on the way from the Swedish National Board of Housing, Building and Planning regarding drinking water supply in preliminary decisions and permits. It is desirable to have more support on the type of planning documentation that is sufficient to assess whether the land is suitable for development and when/if requirements should be placed on the property owner (applicant) to show that there is water"- Södertälje municipality

Quote 116
"Well, there is certainly plenty of good water in the municipality - but if you look out into the world around us, you realize that things can change. So a little more focus on drinking water would probably not be wrong"- Tidaholm municipality

Quote 117
"There is already some support, as both the county administrative board and the Swedish Agency for Marine and Water Management are working on it, such as regional water

supply plans and guidelines for planning. However, more can be done and it is important that it is not just planned, but that work is continued based on what has emerged in the planning"- Tranås municipality

Quote 118
"SGU- when drilling. Livsmedelsverket in case of problems with water, analyses and measures"- Västervik municipality

Quote 119
"The question of domestic VA counseling for property owners should be introduced in the municipalities. I have expressed this, and they have decided not to introduce it. There is no interest among officials or politicians"- Vaxholm & Täby municipalities

Quote 120
"Society rarely raises this issue regarding domestic wells and maintenance"- Vetlanda municipality

Quote 121
"Politicians and sea and water authorities. But above all, this is an issue where domestic well owners need to take responsibility and work together for an improvement"- Ydre municipality

Quote 122
"We would have liked someone to work with these issues at the municipal level"- Växjö municipality

Quote 123
"I think it is important to raise the issue nationally that property owners themselves have a great responsibility when they have their own well. Many people don't realize this. I have seen that the information on the Swedish Food Agency's website for well owners on how to interpret test results has been developed, which is good. But I still think it is a big step for many domestics to know how to take samples from their well. It also means a cost for them. Perhaps the cost of sampling should be subsidized so that it becomes cheap for private domestics to carry out checks?"- Jönköping Municipality

Quote 124
"Better central information campaigns from central authorities are needed"- Karlshamn, Olofström & Sölvesborg municipalities

Quote 125
"Difficult question to answer... It may not even be desirable for municipalities to be responsible for the water supply of each domestic household. But if it were to become part of the municipality's responsibility in the future, it would of course be good to have support from e.g. the County Administrative Board"- Herrljunga Municipality

Quote 126
"If it is not designated a municipal issue, I see no need for support from other actors"- Sunne municipality

Quote 127

"At present, it is usually only raised when people contact us with problems. Otherwise, it is mainly an issue that is taken up indirectly in other planning and supervision work to protect existing drinking water wells in terms of both access and quality. In order to put more focus than that, a direct assignment to the country's municipalities is probably required"- Perstorp Municipality

Quote 128
"No strategy exists. It will have to be a political decision whether we should focus on this, but as a small municipality, the focus is on securing the municipal supply first"- Sunne municipality

Quote 129
"Increase in the desire to produce their own drinking water. Many people have old wells that are no longer used that they want to start up again as reserve water"- Lomma municipality

Quote 130
"[...] Connection is also a cost issue for property owners. In municipalities with low property values, it is probably still common not to want to connect"- Nybro municipality

Quote 131
"After 2018, many have drilled deeply"- Skövde, Karlsborg, falköping, Hjo & Tibro municipalities

Quote 132
"Don't know, but there are more people who have contacted us about drilling wells and wondering if a permit is required for it"- Strömstad municipality

Quote 133
"More people want winter water in holiday home areas, especially after Corona when many people moved out. More people want to go from shared to private facilities. Desalination plants (they seem to be outside all legislation)"- Västervik municipality

Quote 134
"Many have waited a long time for municipal water supply"- Nacka municipality

Quote 135
"Most people who have problems with their drinking water want municipal sewage, then when the cost is presented for connection, a different judgment can be made"- Härryda municipality

Quote 136
"Difficult to know as private property owners do not need permission from the municipality to build a drinking water well"- Arvidsjaur municipality

Quote 137
"In practice, we have not seen any change, but we get requests to connect to municipal water even if you are outside the water supply area. Sometimes we also get questions about how to take care of your well to be able to use it as emergency water if necessary

when the household mainly has municipal drinking water"- Skurup municipality

Quote 138
"However, I feel that the interest in taking care of their wells may have increased somewhat recently. I work with supervision and licensing of small sewers, and more and more people have become aware of protecting their wells in recent months"- Jönköping municipality

Quote 139
"More people getting desalination plants instead of drilling wells, very common on the archipelago islands especially"- Värmdö municipality

Quote 140
"[...] a water source that used to be used for the property before municipal drinking water was provided and today is not used at all except for watering the garden. These water sources can, however, be good to have as a reserve water source in times of crisis if problems in society arise that mean that the municipal water cannot be delivered"- Kungsbacka municipality

Quote 141
"[...] the issue of preparedness is increasingly high on the agenda"- Ekerö municipality

Quote 142
"Tidaholm municipality also insists on keeping and taking care of their well despite being connected to the water supply as a backup to further strengthen drinking water security in the municipality as you never know when the wells can be used again"- Tidaholm municipality