A Case Study Analysis of Drought Management Strategies: Striving for Climate Resilience in Denver and Cape Town

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Abstract:

Climate change is shifting patterns in rainfall parameters. This may contribute to exacerbated droughts, which currently affect over half of the world's population. Some areas, such as Denver, USA and Cape Town, South Africa, have experienced drought conditions due to longstanding or extreme water shortages. This study investigates the strategies that water authorities use, or have used, in Denver and Cape Town to manage drought and develop a climate resilient urban system. These strategies are analyzed with a theoretical basis of systems thinking, where an integrated approach is suggested to create resilient, equitable, and sustainable cities. Qualitative Comparative Analysis was used to find how interventions by water authorities, climate resilience strategies, and public participation are used in policy documents. There are two different strategy combinations that contribute to successful drought management. Interventions alone are not enough for successful drought management. Climate resilience strategies were found to make a significant contribution in all successful drought management cases, while public participation was found to be contributing to successful drought management when combined with resilience strategies. The identification of these strategies allows for more efficient implementation of drought management in the future. Preparing for drought helps to create climate resilient urban areas. It is recommended that more cities are added to this analysis in the future to increase the breadth of the results and identify further strategy combinations that could be implemented to build climate resilience.

Keywords: Cape Town, climate change, Denver, drought, policy, qualitative comparative analysis, resilience, water management

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Abbreviations

fsQCA	Fuzzy-set Qualitative Comparative Analysis
INUS	Insufficient, Necessary, Unnecessary, Sufficient
IWRM	Integrated Water Resource Management
PRI	Proportional Reduction in Inconsistency
QCA	Qualitative Comparative Analysis
SYM	Symmetric Consistency

1. Introduction

Half of the world's population is exposed to the effects of a drought at some point every year (Caretta et al., 2022). While some regions are better adjusted to drought, the impacts of droughts can be exacerbated by anthropogenic activities and overconsumption. These exaggerated water shortages eventually lead to ecological issues in areas that may have previously had little experience with drought. For example, in the Netherlands, a country that has previously adapted to an overabundance of water, drought events have been increasing in recent summers (Wageningen University and Research, 2024). The shift in water management from dealing with too much, to also adapting to too little water, has come relatively suddenly. Climate change is also bringing other effects to the Netherlands, such as desertification of soil and a shorter growing period for native plants (Wageningen University and Research, 2024). This country, and many others, are newcomers to the effects of drought and have the unique opportunity to learn from regions that have historically dealt with extreme events such as droughts.

In semi-arid regions, the risk of drought is generally high (Carrão, 2016). Researching semi-arid regions presents a longer history of drought intervention than regions that are newly facing drought. There are many semi-arid regions throughout the world, so two extreme cases were selected for analysis for the purpose of this study. Using extreme cases can demonstrate the high and low qualities of drought management while simultaneously presenting a broad overview of the situation (Flyvbjerg, 2006). The selected cases are the metropolitan areas of Denver, Colorado, United States of America and Cape Town, Western Cape, South Africa. The capital of Colorado presents an extreme case, since the state, as well as others that rely on the Colorado River, have been experiencing a drought over the last 24 years (Bass et al., 2023). This continuous drought is classified as a megadrought as it has lasted over two decades. It will be investigated how the state is dealing with these conditions, while the capital of Denver's population grows. Cape Town was selected as the other case due to extreme drought conditions in 2018, which later became known as Day Zero. Forced rationing of water was narrowly avoided through the implementation of both supply and demand interventions which resulted in a near 50% decrease in water consumption (Enqvist & van Oysen, 2022).

The results of this study seek to contribute to the field of water management by investigating the implementation of policy strategies to cope with drought. The causes of institutional change are generally poorly understood in the context of environmental governance (Beunen & Patterson, 2019). Agrawal et al. (2022) have identified sectoral policies as part of this issue. By furthering research on drought management strategies, the possibilities for policy integration despite sectoral path dependency may be better understood. Contributing to the improvement of water management can help to cope with the path dependency of many regions and their failure to move forward with environmental policies under the growing threat of climate change (Beunen & Patterson, 2019). The time frame of policy implementation has been emphasized in global politics, but the process cannot be rushed. Including policies into current systems could reinforce existing inequalities. As an increase in water crises is expected, adjusting for inequality is crucial in water management

(Enqvist & van Oyen, 2022). The results of these analyses seek to identify drought management strategies that have been successful, which includes an investigation into whether they are equitable.

In order for regions to be prepared for drought, the successes and failures of others should be made clear. Learning these lessons in the position of their own context allows for regions to have a transparent view of policy (Stead, 2012). Borrowing and learning from the experiences and responses of regions that are exposed to similar conditions could assist in developing drought resilience as these events increase in frequency under climate change. It is expected that successful policy strategies will be singled out through the analysis. The clear identification of these elements allows for recommendations on which are necessary for successful drought management. This aims to address the gap between environmental policy and its integration into other policy sectors (Agrawal et al., 2022).

There is consensus between both theoretical literature and water management authorities that a gap exists regarding integrative water management (Ludwig et al., 2014). It is necessary to investigate planning approaches while acknowledging that there are many uncertainties in the future of water supply and demand levels. Through the analysis carried out here, a contribution can be made to discover successful policies under the uncertain, and often unpredictable conditions of climate change. In addition, the method of analysis seeks to analyze successful strategies for urban resilience. Resilience building can help to lower the vulnerability of populations to the effects of climate change. It is also envisioned that this study will contribute to the existing body of academic literature, by providing insight into the debate over the meaning of urban resilience. Urban populations, as well, are likely to become less vulnerable through the eventual implementation of efficient drought management strategies.

1.1 Research aim

The aim of this study is to investigate drought management policy in the two case study areas and present the findings of which strategies and strategy combinations contribute to success:

> *When analyzing the metropolitan areas of Denver and Cape Town, which drought management measures and implementation strategies can be viewed as successful and contribute to the creation of urban climate resilience?*

To comprehensively address this question, the research activities took place in different stages. A literature review was conducted to provide insight into environmental policy and the barriers to its implementation. The literature review additionally presented the term of climate resilience and the ambiguities surrounding it. Policy documents were next reviewed to form the first set of results, followed by a Qualitative Comparative Analysis (QCA) to identify successful strategies for urban drought management. These steps address the four secondary research questions:

1. *What are current barriers to effective drought management?*

2. *What strategies are taken by water authorities to address drought in urban settings while particularly following an approach with policy integration?*

3. *Which policy strategies are most effective in addressing drought and building urban climate resilience in the face of climate change?*

In addition to these research questions, an additional sub-question on the effect of crises to strategy effectiveness will be answered. Taking situations such as Day Zero into consideration, it is important to investigate how emergency responses contribute to developing long term solutions:

4. *How do crisis events impact the success of drought management strategies?*

The results of the first sub question present the issues that currently exist in the field of drought management. It is necessary to discover why drought management faces issues in implementation before attempting to fully explain the research problem. The results of the second sub question are presented in Chapter 4. This chapter addresses the histories of both cities and the current strategies in place. Exploring the urban contexts allows policymakers to identify similar situations where strategies are applicable. After the identification of these strategies, the QCA was run to find out which are most effective in order to answer the third sub question. The clear identification of strategies for successful drought management between the two areas contribute to the applicability of the research. It is likely that many cities that face drought can learn from these successful strategy combinations. The final sub question was addressed through the findings of the QCA in combination with the context of each city. Crises are likely to become more common as the climate changes. Understanding the effects of crises on drought management can allow for more robust measures to be put in place in advance.

1.2 Reading guide

This analysis of drought management policy and the discussion of its results are presented in the following five chapters. The theoretical framework of the research is first constructed in Chapter 2, with the section ending after the formation of a hypothesis. Chapter 3 follows with the methodology of the entire research process. This is then followed by introductions to the cases and reviews of the selected policy documents in Chapter 4. In Chapter 5, the calibration and findings of the QCA are presented. Following these results, Chapter 6 discusses the findings and concludes the research. Recommendations for future research and a reflection on the entire process and its limitations are also discussed in the final chapter. Appendices are present following the references, where documentation of the research process is recorded.

2. Literature review

This chapter presents the literature review, which discusses current academic literature regarding drought management and general environmental policy. Existing theories are examined and connected in order to understand the complex nature of issues that are affected by climate change. After the discussion of theories as the basis for this study, the chapter concludes with a conceptual framework to visualize the connections between them. Lastly, conclusions are drawn surrounding the theories, allowing for a testable hypothesis to be developed.

2.1 The importance of systems thinking

Climate change is a complex issue. Large amounts of research and attention must be given to the upcoming issues that are arising with a changing climate. This focus of research and attention, however, has proven difficult to procure due to the urgency of other issues. Short-term issues are often prioritized, while some groups dismiss the urgency of climate related issues in the first place. This debate over the prioritization of pressing societal issues arises from a plural set of world views within one urban area. Pluralism in environmental issues has been revealed through social fragmentation and a dispersion of power (Zuidema, 2016). Deciding on the solutions to climate change has proven difficult when even the causes cannot be agreed upon. To begin to understand the complexities surrounding the implementation of policies that are affected by climate change, a systems approach is necessary. Utilizing this approach recognizes the complexities of urban life and the variety of issues facing cities. Once recognized, it is possible to improve urban areas through collective actions (Loorbach, 2010; Rabe, 2007). This section will outline the relevant strengths of complex systems theory in the context of drought management.

Complex systems lie between a state of stability and a state of chaos. In these systems, it is possible to identify robust and predictable patterns, yet when the context changes, a new level of flexibility arises (de Roo, 2010). Complex systems theory seeks to bring a uniform identification to these patterns in ever-changing environments (Loorbach, 2010). In the context of drought management, Denver demonstrates this concept. An ongoing drought of twenty-four years has made drought the de facto state of the metropolitan area. Cities are able to adjust to long-term drought conditions, and even grow, despite the complications. Stability arises despite the default state of chaos (de Roo, 2010). Given the dynamic nature of drought events, the context of the problem can change at any point and the flexibility that is needed to deal with the complications of a water shortage must be found. Water shortages, for example, could suddenly become imminent despite the city being adjusted to less severe drought conditions. Meanwhile, the status quo that has been reached throughout the drought is not suitable for all parties. Persistent issues affect all parts of society, evoking unique reactions based on differing beliefs and needs (Loorbach, 2010). For example, homeowners with water-intensive lawns react differently to water restrictions than those who live in apartments without gardens. The life of a newly planted tree could be prioritized, by said homeowner, over the long-term issue of water scarcity for the entire city. The use of systems thinking seeks to recognize the complex interaction of contemporary wishes with persistent and changing future needs.

The established patterns within systems, when it is possible to single them out, can be researched to better prepare for the effects of climate change on water sources. These patterns, however, differ between and within differing urban contexts. Traditional rational policy making has fallen short of addressing persistent problems, as it is designed to deal with short- and medium-term issues (Loorbach, 2010). According to Rabe (2007) and Loorbach (2010), collaborative processes between society and the government are needed to begin to address the interrelated issues that occur in complex systems. Since the publishing of these papers, communicative processes in parts of governance have become more common. This study of drought management strategies now identifies public participation as one of the key explanatory factors for success in drought management. Without an understanding of how issues affect different segments of society, resilience cannot be achieved and repeated problems cannot be solved.

2.2 Building resilience in an urban context

In the literature on climate change, a variety of terms have been developed to address plans of action. Mitigation sought to stop the effects of a changing climate, while adaptation seeks to learn to deal with a changed world. Climate resilience, as a term with multiple dimensions, has grown to recent popularity as an appropriate measure (Wardekker, 2021). Resiliency originated from mechanical studies. In a mechanical context, resilience refers to the ability for something to recover from stress, such as a spring returning to its original shape. Returning to a state of equilibrium may be desirable for a physical process, but less so for complex social environments. Resilience has evolved to hold new meanings in social and environmental studies (Wardekker, 2021). For these fields, resilience building has become key to helping urban systems develop the capacity to recover from events connected to the changing climate.

The literature on resilience is diverse. Within the context of social and environmental resiliency, much is still up for debate. Some researchers recognize this as an opportunity, since it engages more people on the topic; others see the lack of definition for the term as something that contributes to overuse throughout research and policy (Wardekker, 2021; Moser et al., 2019). This debate over the usefulness of the term makes it appropriate to study further, as mentioned in Chapter 1. Moser et al. (2019) also distinguish interpretations of resilience. They found that distinguishing a certain interpretation helps to bridge gaps between different fields to further resilience building and manage complexities (Moser et al., 2019). For the purpose of this study, resilience is interpreted as a process. Researching the process of resilience looks at interventions made within urban settings. These interventions can include inclusivity and participative processes (Moser et al., 2019). It is possible that not all policymakers have the same idea of resilience while putting together policy documents. It is therefore necessary to understand if the inclusion of resilience building in policy contributes to successful outcomes in one aspect of climate change, that of drought management.

2.2.1 Framing resilience

Another way of interpreting resilience is by framing. In a complex system such as a city, many views exist on climate change and the extent to which policies planning for the future should affect life today. Wardekker (2021) presents four framings of resilience that focus on different goals (system resilience or community resilience) and timings (short- or long-term). As policy analysis is the focus of this study, the systems approaches are more relevant than the community framings. Participative processes are included, however, within systems framing. These systems framings are called Urban Shock-Proofing (short-term) and Resilience Planning (long-term) (Wardekker, 2021).

Short-term resilience focuses more on the recovery of a city after a disaster (equilibrium) than preparing for disasters (evolutionary) (Wardekker, 2021). Evolutionary resilience emerged as a challenger to traditional resilience thinking, acknowledging that the world changes and it is not possible to go back to how things were before a system shock (Davoudi, 2012). Evolutionary Resilience Planning is crucial to build cross-sectoral collaborations to prepare for a changed world. These collaborations promote climate change as a goal that should be included in all proceedings. In terms of drought management, this means that it should not just be water authorities focused on water conservation. Drought management needs to be included in everything from construction practices to elementary school education when following a Resilience Planning framing. To achieve this multi-disciplinarity across cities, central guidance can be recommended in the form of policy, as explained in the following section.

2.3 Environmental policy integration

Successful strategies for managing drought may be insufficient if improperly implemented. Agrawal et al. (2022) emphasize the importance of environmental policies being integrated throughout sectors in order for them to be most effective. The effects of climate change are already being felt, but the field of environmental policy still stands as a relatively singular issue, disconnected from other issues. Policymakers must balance the needs of all of their constituents when making decisions. Because of the diverse interests and needs of constituents, there is a lack of inclusion of issues that affect the future. Climate change will affect all sectors in the coming years, meaning that environmental goals need to be included in all sectors (Agrawal et al., 2022). Many different frameworks have been proposed to achieve this goal, one of which is environmental governance. Beyond a policy-based approach, governance includes private actors and community led projects to achieve a goal (Jordan et al., 2013). This approach widens the scope of environmental decision making, allowing individuals and communities to contribute innovative ideas to the policy realm as well as manage natural resources on a local level. Environmental governance has unfortunately been viewed as an ‘incomplete revolution’ and calls have been made to shift to ‘governing for sustainability’ (Agrawal et al., 2022, p. 616).

Governing for sustainability is vague, as sustainability has not been defined precisely in order to garner more support for the issue, similarly to resilience (Jordan, 2008). One common understanding of sustainability, tracing back to *Our Common Future*, emphasizes not overusing the resources of the next generation (Jordan, 2008; WCED, 1987). Governing for sustainability has a smaller focus on policy, yet still allows for nuance and exploration of different environmental developments. In following a governing for sustainability approach, environmental goals are to be included in all sectors. It demands a fundamental change of priorities in both policy and daily lives, centralizing sustainability as a main goal (Agrawal et al., 2022). Sustainability can also pertain to economic systems, garnering more support for this framework. In many fields, a business case for environmental policy is being made where companies are innovating for sustainable goals to remain competitive. Nevertheless, in the opinion of the author of this study, the idea of governing for sustainability calls for a radical change beyond individual actions that may be unrealistic considering the complexities of urban systems. Urban systems will need significant support to achieve governing for sustainability, as explained below.

Lafferty and Hovden (2003) proposed a framework to aid the transition to sustainable development through environmental policy integration. These authors also recognize that it will be necessary to break away from many regular patterns that exist in current political systems (Lafferty & Hovden, 2003). This framework proposes two overarching structures to be able to govern for sustainability. Horizontal environmental policy integration could act as the continuation of the current way of making environmental policy. As a separate branch or department, the horizontal element of integration lies in developing long-term sustainability goals, timelines, designation, and supervision (Lafferty & Hovden, 2003). This differs from current environmental policy administration through the configuration of government power. The horizontal branch would oversee vertical integration in every sector with this power configuration (Lafferty & Hovden, 2003). This requires all sectors to designate the environmental issues that they face, as well as a plan on how to solve these issues. Each sector would be required to be transparent about the environmental policies that they make (Lafferty & Hovden, 2003).

Despite it being over twenty years since the proposal of Lafferty and Hovden's 2003 framework, it is still not commonly used around the world, as shown by current policy integration attempts (Le Blanc, 2021). In 2021, the United Nations enforced the applicability and necessity of both horizontal and vertical integration following the exposure of poor sector coordination during the COVID-19 pandemic (Le Blanc, 2021). Sectors suffer or benefit in conjunction during crises, with a public health crisis exemplifying external ripple effects. This same proposal for policy integration is aimed for by 2030 in the Agenda for Sustainable Development (Le Blanc, 2021).

2.3.1 Integrated Water Resource Management

The field of water management has its own subsection of environmental policy integration: Integrated Water Resource Management (IWRM). The effects of insufficient water system infrastructure are felt across sectors (van de Meene, 2023). As an example, sewage system infiltration into ground water results in health issues in cities (Marcus, 2023). Economic decline is linked to this same issue, with lower levels of education in areas with inadequate infrastructure resulting partly from health issues caused by consuming contaminated water (Marcus, 2023). In terms of water quantity, insufficient household taps have effects beyond the water sector as well. Women and girls are more likely to have the responsibility of fetching water for a household (UNICEF & WHO, 2023). This results in lost time from work and education, as well as risk of injury (UNICEF & WHO, 2023). Water resources must be managed effectively through integration to prevent socioeconomic issues like these and promote equal opportunity across sectors (van de Meene, 2023).

Effective water governance is necessary to support IWRM (van de Meene, 2023). IWRM has existed for many decades and has two general definitions surrounding the optimization of water system allocation. One definition takes a technical approach, assuming that planners and policymakers have definitive answers to water issues. The second definition focuses on the sociopolitical context of water issues from a systems approach (Ludwig et al., 2014). Both definitions provide usefulness to this research, as policy analysis was conducted with the framework of a systems approach in mind. This establishes that water governance must be integrated in order to create effective policies that address a wide range of issues.

Water policy should be developed through integrated, multilevel governance (van de Meene, 2023). Cape Town has previously been used as an example of the importance of multilevel water governance. A disconnect between water suppliers, policymakers, and residents was identified. Policymakers did not ensure the timely implementation of water supply augmentation despite reports indicating the need, leading to socioeconomic effects following the drought crisis several years ago (van de Meene, 2023). Partnerships and integrated approaches to water management became the response to ensure that complexities surrounding water supply are adequately addressed.

2.4 Barriers to effective drought management

Many barriers exist to the implementation of effective drought management, despite the multitude of approaches. One barrier to drought management starts at its definition, as droughts are highly contextual. In general, a drought is the widespread lack of water in a region for a temporary period. Whether the effects are agricultural, hydrological, meteorological, or socio-economic depends on the severity of the drought and how long it affects an area (Majerčáková, 2015). Types of droughts can be sequential, with low precipitation (meteorological drought) leading to deficits in groundwater and soil moisture (hydrological drought) which causes negative effects to agriculture and the local economy (agricultural drought) (Douville at al., 2021). Indicators exist to measure which type of drought a city is currently facing, but policymakers decide which to respond to. In Colorado, for example, the definition of drought used in Colorado focuses on consumption:

'A period of insufficient precipitation, snowpack and reservoir storage to provide adequate water to urban and rural areas' (Colorado State University, 2024).

This anthropogenic-centered definition may lack the implications of drought for the environment, specifically for large bodies of water. Cape Town has a similar definition, focusing on the imbalance of the hydrological systems, with emphasis on the impact on residents (Water & Sanitation, 2019). The author of this study suggests that the anthropogenic drought definitions of both cities indicate a greater need for integration. There is a need to form a consensus on a definition of drought, beyond residential consumption, to include vulnerable populations and sectors.

Another issue for current drought management is the incomplete application of urban resilience strategies. Despite goals that may aim for evolutionary processes, returning to equilibrium is dominant in practice (Laeni et al., 2019). When a city is faced by a drought crisis, the default response is to fix the problem in order to return to normal water levels. Returning to normal, however, neglects the longstanding issues that are not seen as urgent crises. Normative resilience may favor business as usual rather than capitalizing on windows of opportunity to promote new goals (Laeni et al., 2019). Equal access to high quality water is lacking all over the world, making evolutionary resilience necessary to fully address environmental justice issues, but this is still being worked towards.

Part of the reason that evolutionary resilience is yet to become common is due to path dependency. Beunen and Patterson (2016) identify path dependency as an obstacle to institutional change for environmental governance. Path dependence can develop due to a positive feedback loop increasing the rewards for following a path (Beunen & Patterson, 2016). As an example, informal networks develop in political processes. Breaking away from an established pathway can jeopardize an actor's status in this informal network. A possible way to disrupt path dependency occurs with external breaks (Lafferty & Hovden, 2003). A crisis can be a break from normality, presenting a window of opportunity to implement new policy structures (Huitema et al., 2011). Policymakers must be ready, however, to capitalize on a window of opportunity. A focus on returning to normal will once again prevail if the time after a crisis is not used for breaking away from current paths.

2.5 Conceptual model

A number of theories have been presented so far in this chapter. In order to relate these theories to each other, a conceptual model has been developed. Figure 1 aims to position the strategies studied in the case studies within the broader process of developing integrated environmental policy for drought management as climate change exacerbates local conditions.

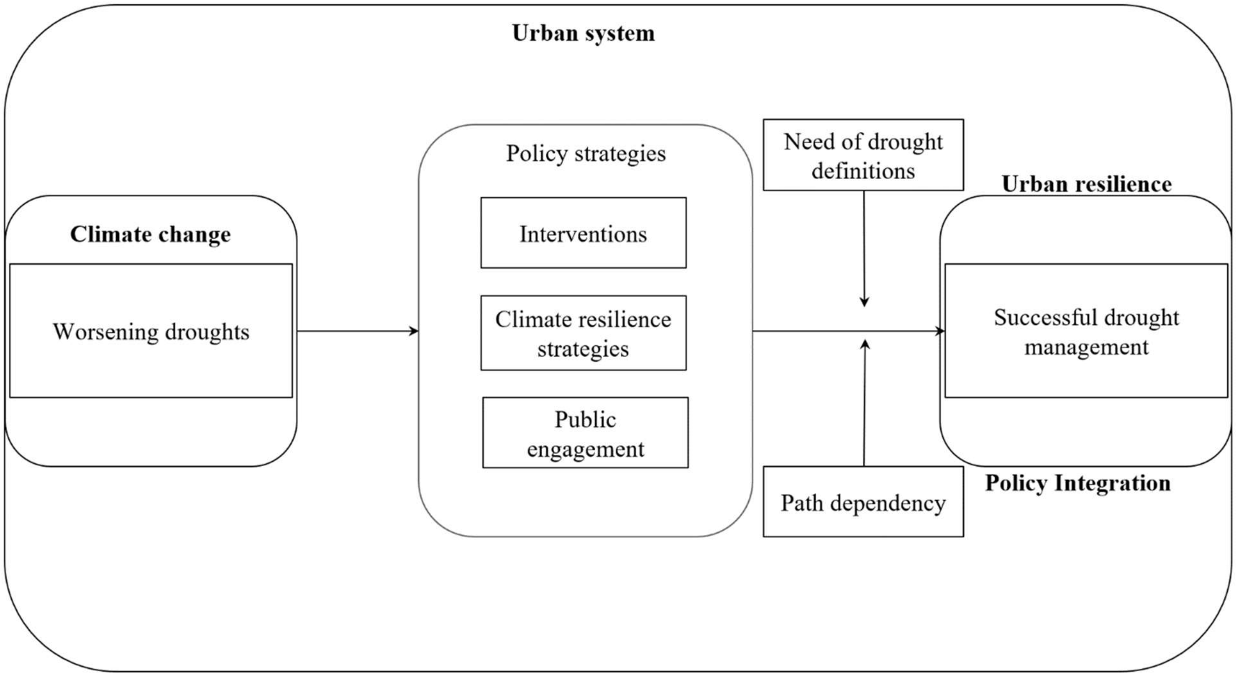

Figure 1: Conceptual model of drought management strategies in the context of environmental policy integration (Made by author, 2024)

In its entirety, Figure 1 represents a handful of the many factors inside of a robust system. The complexity of the interactions is simplified in this model, but still conveys the need for a systems thinking approach to complex urban systems. Climate change must influence policy, as climate change will have an increasing impact on all parts of life. Using policy to address the issues presented by climate change can be an effective way of building urban resilience. The first strategy of the model, interventions, are built on the mechanical definition of resilience (de Roo, 2006; Wardekker, 2021). Interventions are necessary for policy as they are the traditional approach to drought management, where water authorities seek to return to normal following drought through intervening in water infrastructure. The second strategy considers overall climate resilience strategies. These strategies are the innovative way forward in drought management, taking a Resilience Planning framing of the situation (Wardekker, 2021) and seeking to integrate sectors for a coordinated preparation for drought (Agrawal et al., 2022; Lafferty & Hovden, 2003; van de Meene, 2023). The final strategy of public engagement is necessary to enhance the effectiveness of drought management. Public engagement is needed to find equitable solutions to drought to build long-term resilience (Zuidema, 2016; Loorbach, 2010; Rabe, 2007; Jordan et al., 2013). Each of these strategies were built upon in the following chapters based on these theories. These strategies, however, may face difficulties in reaching their goal. Path dependency acts as one obstacle to resilience, as well as many types of droughts needing definitions. When defining drought, more representable impacts may be overemphasized, skewing the way in which urban resilience is achieved. If these obstacles are recognized and addressed, creating integrated drought management systems may be possible.

2.5.1 Hypothesis

From this conceptualization, it now becomes relevant to find out which policy strategies are most effective at managing drought successfully. It is expected that successful drought management will result from a combination of all of the policy strategies. The three strategies combined represent an integration of water management between authorities and the public while still protecting future interests. This level of collaboration and preparation for changes to current urban systems represents resilience. A lack of success is predicted to result from too much focus on interventions. Water authorities that have little focus on integration may be path dependent on a technical approach to drought management only, and deficient in other areas.

3. Methodology

This chapter presents the methods followed throughout the research process. The overall approach, which is a case study design, is first introduced. Next, the unit of analysis is specified. The following section then focuses on the protocol for analysis. This analysis is developed through the literature review described in Chapter 2. The last section of the chapter addresses the data management plan for the duration of the research and addresses the ethical considerations of the study.

3.1 Case study design

As mentioned in Chapter 1, the selected case studies have both experienced extreme drought conditions. Denver has relatively little public awareness about drought compared to Cape Town. This may be due to the fact that Denver's drought conditions have lasted over two decades, while Cape Town faced threats of imminent water shortages in a brief timespan. The difference in response due to the immediacy of the situation will be explained in further detail in Chapter 4. Both cities, however, address their drought situations in similar policy documents. For this study, a focus on policy was therefore chosen to limit the scope of the literature review to only government documents. This decision was made based on the theories of Chapter 2. These theories pointed to a lack of consensus and sectoral integration. Government decisions are enforced on all sectors, meaning that policy may be a way for cities to require the inclusion of more effective water management practices. Including actions taken by local initiatives and public-private partnerships exceeds the aims of this paper and is more suitable for in-depth qualitative research.

Denver, with a long-term drought, and Cape Town, where an immediate water crisis was faced, appeared as suitable cases for comparative research while also recognizing the different responses based on urgency. Policy has been published, and is available, in both cases to address the water management issues. The intention of studying extreme cases such as these is to examine underlying mechanisms in drought management (Flyvbjerg, 2006). These mechanisms include direct action from water authorities, the inclusion of cross-sector participation to reach climate goals, and shifting the design of policy to include more public opinions. With a broad understanding of these mechanisms, it is possible to draw conclusions on patterns of policy decision and implementation. These extreme cases were selected as being holistic in a multiple-case designed study (Yin, 2014). This means that separate contexts are analyzed (Denver and Cape Town metropolitan areas), but only one unit of analysis is selected (drought management strategies). The unit of analysis will be further defined in the following section.

This study is descriptive in analyzing existing policy. It is outside the scope of interest to prescribe future measures. A case study is appropriate for this aim, as they are designed to study contexts in depth (Yin, 2014). With a holistic understanding of each urban context, it is possible to make assumptions on which drought management measures could be applied to similar situations in the future.

Another trait of case studies is their capacity to use multiple data types collected with different methods (Yin, 2014). Use of mixed methods helps to strengthen case studies through answering the research aim in the most efficient way possible, rather than focusing on the methodology itself (Flyvbjerg, 2006). In this study, a mixed method analysis approach has been chosen to increase the validity. This method compiles qualitative data for quantitative analysis that is supported by a transparent, valid, and reliable research design. In addition, external validity of this study is constructed by presenting the results without extrapolation. The results of this study can be generalized to other cities experiencing drought. The successful strategies identified here may lead to success in other urban contexts as well.

3.2 Unit of analysis

The selected unit of analysis for the case studies are drought management strategies in the context of metropolitan areas. Both of the metropolitan areas of Denver and Cape Town include a variety of land uses, ranging from urban centers to agricultural hinterlands. It is crucial to have a unit of analysis that can address both population centers and rural agricultural land, as they are intensive water users. While land use is similar, Cape Town has more intensive water usage with a population density of 1,907 km^2 in 2021 versus 672.7 km^2 for Denver in 2020 (City of Cape Town, 2023; United States Census Bureau, 2021). In the context of this research, it is important to display the results of the analysis with the larger population and smaller metropolitan area size of Cape Town in mind. This has been achieved through comparing per capita consumption rates in the analysis. Due to this difference in size, strategies may be sightly stricter in Cape Town. Overall, the unit of analysis is comparable due to a similar administrative capacity for a mix of land uses.

With these contexts in mind, three drought management strategies have been selected based on the theory presented in the previous chapter. Interventions are the first strategy. This strategy represents traditional approaches to water management. These interventions can include actions such as supply augmentation, where water authorities focus on water supply issues as a technical way out of a drought. The second strategy is overall climate resilience strategy. This includes scenario planning and integration of sectors for building urban resilience. The final strategy chosen is public participation. Communicative action has been seen as a way to develop appropriate long-term goals for an urban area. Without the input and involvement of residents, water management may develop in unequitable or unsustainable ways.

3.3 Literature and policy reviews

The basis of this study was constructed through the literature review of Chapter 2. First, a theoretical literature review was conducted to set the scope of the study. Theories in drought management, as well as overall environmental policy, were the focus of this review. A snowball technique was used to explore the established bodies of literature on barriers to environmental policy implementation and the current state of drought management. These literature reviews serve as the initial phase of using multiple sources as a key principle of data collection (Yin, 2014). With multiple sources, the chain of evidence for the conclusion is started (Yin, 2014). This is necessary to ensure a transparent and repeatable research design.

A later review (Chapter 4) was then conducted on policy documents in order to establish current barriers and describe existing strategies as results for the first two sub-questions. First, the background of each context was researched to see what possible barriers may occur due to the historical circumstances of drought management in each city. The policy documents were next read in entirety and summarized (see Appendix II). The summaries were categorized based on the strategies presented in 3.1. The policies were purposefully selected with the reviewed theories in mind to give an accurate representation of the status of water management. Purposeful selection is necessary for this study to present the most recent developments in drought management for Denver and Cape Town. Due to this selection method, the results have 'limited generalization' (Gerrits & Verweij, 2018, p.113; Thomann & Maggetti, 2020, p.363). For this study, limited generalization means that the identified successful drought management strategies are only applicable in regions already effected by drought. It is therefore not possible to conclude if the strategies would immediately be successful in cities that are only preparing for a future drought and have not yet experienced one.

A total of ten policy documents were selected, with an equal number from each case study location for the purpose of the QCA (Gerrits & Verweij, 2018). The selected policies include a general water plan from each location. In addition, a drought emergency response plan was selected to address the fourth sub-question. The remaining six plans were chosen as they are the most recent developmental plans aimed at resilience building in water management. One exception to using the most recent report was made for Cape Town's Water Outlook (C2). The most current Outlook report is from 2023, but using 2022 allowed for the calibration of the outcome. The calibration required there to be a period of time between each policy document without overlap. This made it so that at least six months took place between all selected policies, so that the effects of each strategy set could be measured. This policy background and description presented the necessary elements for the QCA.

3.4 Qualitative Comparative Analysis

Policies for drought management are detailed and context dependent, but follow general trends towards the goal of reducing drought impact. QCA is suitable for policy analysis research as it is designed for cases that are rich in detail yet follow patterns (Gerrits & Verweij, 2018). In addition, QCA has been recommended for geographical research, as the importance of context for spatial issues can be addressed through this method (Cairns et al., 2017). Focusing on specific case studies allows for an in-depth presentation of the drought management strategies. QCA was therefore selected as the most viable option for this study.

Chapter 2 presented the first step of the research process, with a theoretical basis first being established through a literature review. The rest of the steps for the analysis are shown in the following two chapters, starting with the context of each case. Once a clear overview of the cases was made, the QCA was established through data calibration (see Section 5.1) and the comparison of the resulting truth tables (Gerrits & Verweij, 2018). This step was aided through software, in which Fuzzy Set Qualitative Comparative Analysis (fsQCA) was used (Ragin & Davey, 2023). The choice of fsQCA is made as this technique allows for classification of the drought management strategies on a scale from 0 to 1 (Pappas & Woodside, 2021). The selected conditions are 'fuzzy', in QCA terms, because the definition of success is defined by the author on a sliding scale. Interpretation of the tables and identification of patterns formed part of the last step for this study, presented in Chapters 5 and 6.

The policy documents introduced above in Chapter 3.3 were used for the QCA. These documents are typically referred to as cases in a QCA. In the ten policy documents, successful drought management was defined as the outcome of interest. This outcome is composed of the conditions: interventions, climate resilience strategies, and public engagement. These conditions are present in each of the policy documents from the two case studies. Conditions are considered as the explanatory factors for the outcome of interest in QCA (Gerrits & Verweij, 2018). These conditions were calibrated on scales from 0-1 on the basis of existing literature, following a theory-driven case study protocol.

Chapter 5 includes all steps of the QCA, from calibration to interpretation. The basis of condition selection and calibration is available in Appendix II to increase the replicability of this study.

3.4.1 Outcome calculations

The outcome of the QCA is the reduction of water usage following the policy documents' publications. The monthly water usage of Denver Water users (Denver Water, 2017-2024; Colorado Water Conservation Board, 2019) and the weekly water usage of residents of Cape Town (City of Cape Town, 2017-2024; Climate System Analysis Group, 2020) were first recorded in accordance with the dates of the policy documents. The Water Watch Reports from Denver span from November 2017 till May 2024. Denver Water also estimates the water usage for the entirety of the year, so June through December 2024 are included as well (Denver Water, 2017-2024). The weekly reports from Cape Town date from October 2017 until May 2024. In addition, January through December 2014 was recorded as a baseline year to compare the results to in the discussion. The year 2014 was selected as it was the most recent year prior to drought in Cape Town. There was no need for this baseline year in Denver, as it is in a continuous, less severe drought.

Following the collection of water usage values, it was necessary to normalize for population change. The yearly percentage of population change was first calculated (Colorado Department of Local Affairs, 2024; Denver Water, 2023; City of Cape Town Metropolitan Municipality, 2020; Western Cape Government, 2020). A scaling factor was next calculated by dividing the percentage of population change by the first year of a policy document. This scaling factor was multiplied by each monthly usage value to calculate the average water usage per policy period, normalized by population change.

Next, the projections for water usage were considered. The Colorado Water Plan (Colorado Water Conservation Board, 2023) has five planning scenarios for 2050. Three of these scenarios, ‘Weak Economy’, ‘Adaptive Innovation’, and ‘Hot Growth’ were selected according to similarities with Cape Town. Cape Town has three water usage projections for 2040: low, medium, and high (City of Cape Town, 2020). Calibration was possible through the comparison of water projections and current water usage following the publication of each policy document. Population projection dates were used to normalize these in the same method used for the years of the policies. The tables produced for these calculations can be found in Appendix III.

3.5 Data management, positionality, and ethical considerations

All data within this study is publicly available. Policy information is always public in order for it to be properly implemented and addressed by the involved parties. Using completely public data contributes to the transparency of climate change research in the attempt to encourage interaction and awareness with the subject. The data management plan for this study is available in Appendix I, although comprehensive considerations on ethics were not required due to no personal data being used in the study.

As an ethical consideration, it is important to note the sensitivity of vulnerable communities in this research. Although this study acknowledges the impacts of lack of access to clean and sufficient water, it is not within the scope of the study to examine individual experiences under drought conditions. Nevertheless, the author remains sensitive to the interests of vulnerable communities and aims to highlight the needs for water equity in both cities. This study consider these water shortage impacts from a theoretical and policy level. In addition, the author is from Colorado with a supervisor who has worked in Western Cape. The personal insight of both parties is included through local knowledge of policy and literature sources, with an effort made to be aware of the cultural differences.

4. Results: Context of cases and current policy

The following chapter summarizes relevant background information for the two locations of the study. It is necessary to develop an understanding of both situations, including their climate and political processes, to answer the first two sub-questions. Developing a contextual background contributes to the depth of the cases for the QCA as well. In-depth analysis is an important benefit of QCA case studies, setting it apart from other methods. Current and historical climatic conditions are first presented for each case. This is followed by an explanation of the consequences of drought on both the physical and human environment. Next, the current state of drought management is outlined, including the political processes that surround it. This leads into the last section, the policy descriptions for the coming analysis of Chapter 5.

4.1 Denver's climate and water sources

Identifying the barriers to drought management requires knowledge of the current situation and resources available. One barrier to drought management is the topography of the state of Colorado, which greatly influences its climate. The Rocky Mountains run from the north to the south, separating mesas in the east from Denver on the plains of the west. Despite 90% of the state's population living to the east of the Rockies, 80% of precipitation falls to the west (Colorado Water Conservation Board, 2023). This precipitation is also low, at about 43 cm a year, and showing decreasing trends (McKee et al., 2000; Hicke et al., 2022). In addition to decreasing precipitation, annual streamflow, and snowpack are showing decreasing trends. This is visualized in Figure 2 below. As much as 80% of the surface water in the state is provided by snow melt (Colorado Water Center, 2024). Heavy dependence on snowmelt is concerning, as 'snow droughts' are starting to occur, characterized by a deficit of winter precipitation levels (Hicke et al., 2022, p. 1936). These factors alone require robust water management practices to ensure a reliable and sufficient water supply system for users.

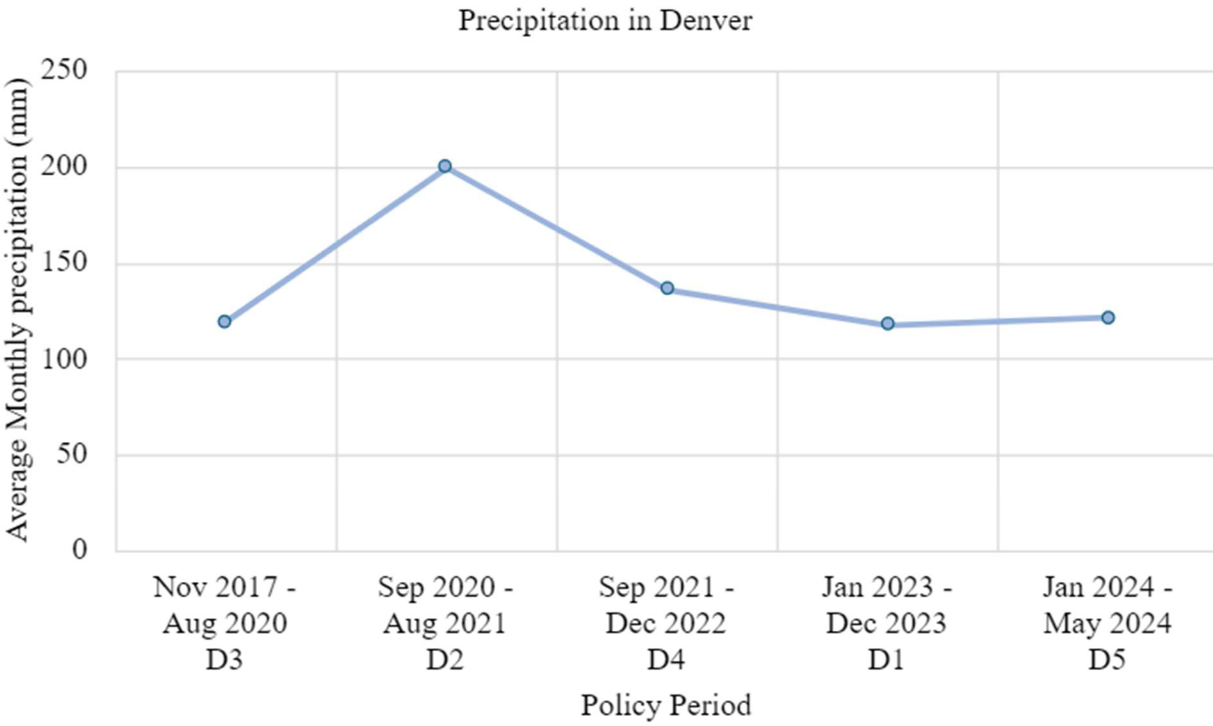

Figure 2: Precipitation levels in Denver since 2017 (Made by author, 2024, with data from National Oceanic and Atmospheric Administration, 2024)

In addition to these factors, the entire state is marked by extremes in precipitation patterns. This leads to a natural pattern of drought and flooding (Collins et al., 1991). These fluctuations can be difficult to prepare for, and as the climate changes, it will become even more difficult. Partly due to its dependence on highly variable precipitation, Denver experiences frequent, and often constant, droughts. As many as 33 weeks out of the year are spent in drought on average in the southeast of the state of Colorado (Colorado Department of Public Health & Environment, 2018a & 2018b; Colorado Environmental Public Health Tracking, 2016). The Denver metropolitan area fares better than the southeast, but still spends at least a month out of the year in drought on average.

Considering the case study from the context of the entire state is necessary due to the water supply system (see Figure 3). Denver Water, the water authority for Denver, stores water in 12 major reservoirs across more than 10,300 square kilometers (Adams, 2021). These reservoirs are needed to sustain Denver's population, as the Denver Basin Aquifer cannot sustain it alone. During a more severe period of drought in 2002, wells dried up on the western edge of the aquifer (Colorado Conservation Board, 2023). Denver Water has therefore planned to expand one of their reservoirs in the coming years (Adams, 2021).

Figure 3: Terrain map of area serviced by Denver Water and its supplying reservoirs (Made by author with data from: Denver Water, 2018; Denver Water, 2020a)

4.1.1 Consequences of drought in Denver

In the following sub-sections, the environmental and socioeconomic consequences of drought are described. This is intended to clarify the level of severity of drought in the study area, which influences which, when, and how responses are established.

4.1.1 Environmental consequences

Wildfires break out due to the dry climate. The severity of these fires is increasing (Colorado Division of Fire Prevention & Control, 2024). The three largest fires in the state's recorded history all occurred in 2020, burning nearly a quarter of a million hectares of land (Colorado Division of Fire Prevention & Control, 2024). The effects of these wildfires last long after the flames are extinguished. Burnt vegetation and topsoil significantly lower the ability of the soil to absorb water, even developing a layer that repels it (National Weather Service, 2024). Preventing wildfires through managing drought and replenishing groundwater supplies lowers the chance of fire breaking out and spreading. In combination with frequent heavy rainfall events, flash floods occur resulting in high volumes of run-off, erosion, and debris flows, leading to further environmental degradation.

According to the Soil Health Institute (2021), droughts can exacerbate the effects of flooding. When soil dries out too much, it forms a crust, becoming less permeable to water in the future (Soil Health Institute, 2021). Run-off accumulates faster in these dried out conditions and may lead to flooding. Since the start of the 2000 megadrought, there have been two major flood events. A storm front in 2006 caused significant damage in two instances of pluvial flooding from the heavy rainfall (Colorado Water Center, 2024). One of the major floods occurred in a burn area, resulting in a flash flood due to the lack of vegetation and poor soil quality (Colorado Water Center, 2024). In 2013, a storm caused areas to receive more than 600% of their normal monthly precipitation in one week. The resulting flooding was some of the worst in the state's recorded history (Colorado Water Center, 2024). There is very high confidence that heavy storms will increase in severity and frequency in Colorado over the next several decades (Hicke et al., 2022). In order to prevent increasing damage from flooding, drought management can slow the cycle of drying soil conditions leading to heavier flooding.

4.1.1.1 Socioeconomic consequences

Droughts affect the availability of water for all residents and many industries in Colorado, as well as millions of others downstream. Agriculture is the largest consumer of water in the state, using about 90% of the water, with 83% of this coming from surface water (Colorado Water Conservation Board, 2023). These irrigated crops contributed to about 13% of the whole state's Gross Domestic Product (GDP) in 2021. Tourism is another important industry for the state. In the same fiscal year, 5.2% of the GDP was made from water related recreation, such as skiing (Colorado Water Conservation Board, 2023). The limits of use for these industries during prolonged drought, and the implications for others downstream, are becoming more recognized (Colorado Water Conservation Board, 2023).

As well as industries, vulnerable communities in Denver are impacted by drought. These vulnerable communities experience the effects of drought disproportionately as well (Colorado Water Conservation Board, 2023). Homelessness is a problem for the city, where the average minimum wage is at $13 an hour while the wage needed to rent a two-bedroom apartment is $32 an hour (Estabrook, 2023). The increase in homelessness jumped up by 33% between 2022 and 2023. People experiencing homelessness are especially vulnerable to the effects of climate change due to insecure water access.

4.1.2 A brief history of water policy and infrastructure in Colorado

In the 1900s, there were four major droughts. These droughts lasted from 1930-1942, 1949-1957, 1958-1970, and 1976-1982 (Collins et al., 1991). Although historical droughts have extended over multiple years, the current drought has persisted since 2000, and is therefore the longest drought ever experienced in this area. Figure 4 below gives an overview of all statewide droughts since 1899 in Colorado, regardless of their level of severity. The depicted droughts all affected Denver, which is in the South Platte River Basin, but the figure is not comprehensive of all river basins throughout the state.

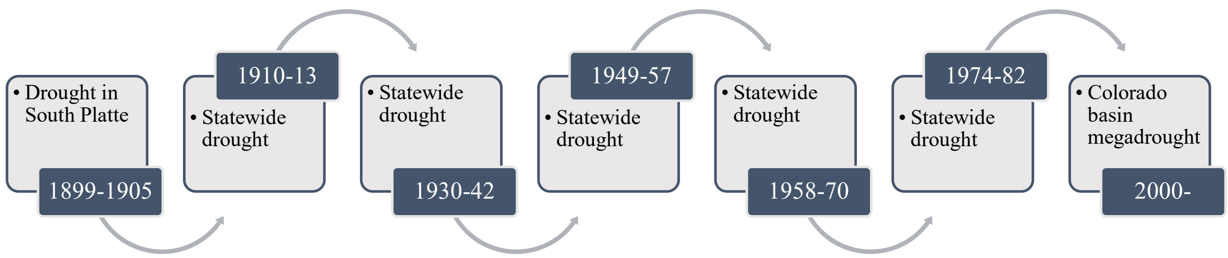

Figure 4: Timeline of drought in Colorado since 1899 (Made by author with data from: Collins et al., 1991; Colorado Water Center, 2024)

During the last major drought of the twentieth century (1976-1982), the Colorado Drought Response Plan was drafted (Collins et al., 1991). Since its implementation in 1981, the following principles have been applied in all new versions of the plan. The plan outlined the responsibilities of assessment and response in managing drought. The assessment team uses the Palmer Drought Index to call the response team into action. This index is standardized with values from -10, which is very dry, to 10, which is very wet. This is commonly used across the US to determine long-term drought periods (Dai, 2023). The plan outlines the responsibilities of the response teams to various levels of the state government, depending on the scale of the drought (Collins et al., 1991).

Under the federal government, drought action is delegated to the state and local levels (Stern et al., 2021). Other than financial aid, almost all drought action and response plans are taken on the state and local level (Stern et al., 2021). As water basins cover many administrative boundaries, the need for coordination has increased with prolonged drought. The selected policy documents therefore remain mostly at the local level of Denver Water, but include the state water plan for the context that the city works under. The contents of these policy documents are discussed in the following five sections.

4.1.3 Major drought policy in Colorado and Denver

This section presents the five policy documents relevant to Denver Water and overall state plans for drought management. These policies start with an overall goal for the state in D1, followed by emergency proceedings in D2. The next two policies present the steps towards managing drought and water supply. The last policy conveys the current situation of water management and gives projections for the near future.

D1: Colorado Water Plan (2023)

The statewide water plan presents a framework for adaptive planning to create projects that go beyond just meeting water needs. Projects falling under the theme of four main goals are advanced by the Colorado Water Conservation Board (2023). This is achieved through grants and loans for local level water-based projects. The interventions taken by the state level water authorities include reporting, modeling, mapping, and creating other tools to monitor water data. These are grouped into 'tools for action' of which water authorities take on 50 and recommend another 50 to lower levels of water authorities and the public (Colorado Water Conservation Board, 2023). The board focuses on strategies that have a low chance of being regretted, supporting across the sectors of conservation, education, multi-purpose storage, and land use planning. The board also proposes aquifer recovery through demonstrating ways to reuse water. At the level of water rights, the board seeks to propose alternatives for buying and drying practices that permanently erode arable land health (Colorado Water Conservation Board, 2023). Special attention is given to agriculture, as making it robust is one of the four goals for the board. The board also seeks out new economic opportunities in the water sector and aims to improve water use permit efficiency.

Resilient planning is another goal of the board. Through creating stakeholder partnerships and an equity task force, the water authorities aim to build resilience while acknowledging the risks it holds for some communities (Colorado Water Conservation Board, 2023). Projects should have multiple purposes, some with a focus on environmental justice. Encouragement is given to innovative practices in water management by reframing water shortages to water 'gaps'. A gap is meant to have a more positive framing to encourage people to innovate rather than foster fear about drought. Each water basin in the state has specific goals and challenges to closing their gaps, some of which focus on environmental health while others focus on socioeconomic conditions (Colorado Water Conservation Board, 2023). The public has a major role in meeting these goals and has so far been consulted through workshops and collaborative groups. By using the formulated action tools, 1800 local projects and plans are reaching higher levels of attention, allowing for project integration. Overall, D1 encourages the public to acknowledge the social value of water, promoting the Indigenous phrase of 'water is life' throughout the state (Colorado Water Conservation Board, 2023, p.3).

D2: Denver Water Shortage Response Implementation Plan (2020)

D2 presents a plan to cope with droughts. Indicators are used to signal when a water shortage is imminent within the city based on four levels of severity. Shortages are approached on a case-by-case basis, however, depending on which indicators are active (Denver Water, 2020b). Droughts can come in many forms, so this plan works to address the appropriate sectors that are affected. For this purpose, a response action chart shows actions and levels of water usage per sector. The chart includes interventions for Denver Water, such as forming water budgets, rationing, adjusting prices, and creating restrictions. Some measures are permanent following a drought in order to create resiliency. Some of the restrictions that have stayed in place since the 2002-2003 drought lowered water usage by 20% (Denver Water, 2020b). The plan has a limited role for the public. Media will be released throughout a drought to target domestic water usage. If water is overused, users may be fined or placed under a restriction after repeated violations (Denver Water, 2020b).

D3: Denver Water Efficiency Plan (2017)

This five-year efficiency plan moves away from economic goals towards urban resilience. Social marketing is employed as a tactic to encourage water users to become more efficient. Denver Water (2017) created efficiency benchmarks with a credit system to encourage households to decrease water usage. Rebates are offered as well as retrofitting in low-income areas of the city. Establishing benchmarks is the center of D3, also making them for public spaces and industries in the city. Denver Water encourages transparency in self-metering as well as promoting programs to encourage users to make their own areas more efficient (Denver Water, 2017). The overall aim of the plan is to change the city's goal from just conservation to overall efficiency, which includes the needs of water users. For their own part, Denver Water wants to integrate fighting the urban heat island effect with managing stormwater runoff areas to enhance parks and other public spaces (Denver Water, 2017). Resiliency is named as a goal to better prepare the city for a warming climate, drought, and fluctuations within the economy by having residents use 151 liters per day. This goal is said to make the city more liveable, while maintaining the health and safety of residents. Denver Water has defined efficiency together with residents in a working group to help facilitate the transition. Based on this definition, Denver Water (2017) informs users about their water usage compared to other users with targeted campaigning.

D4: Denver One Water Final Report (2021)

D4 is based on reaching five goals with a partnership of six entities under a theme of six different visions for the city. Together, the water authorities want to de-silo water administration to create a proactive system model for resource management (City and County of Denver et al., 2021). A framework has been created to identify, integrate, and implement projects that bring benefits to multiple stakeholders in the city. Projects include reuse of greywater, recycling water, rain capture, and restoring natural water systems. The water authorities then aim to strengthen connections and produce leadership and self-monitoring from water users. Institutionalized benchmarks are provided on how to create efficient green infrastructure and conserve water (City and County of Denver et al., 2021). These benchmarks aim to meet resilience goals through integrating water issues with energy and food supplies, as well as general climate mitigation and adaptation. An advisory group was formed to help reach stakeholders across many fields. The findings of this group were used to better engage with communities to encourage awareness about the issues and opportunities surrounding water usage. Creating supportive communities is one of the five goals of D4, and so far, water authorities have distributed surveys, given workshops, and encouraged water conservation among users (City and County of Denver et al., 2021). The plan, with 62% of residents supporting, has high goals for many communities to build resilience.

D5: Colorado Water Supply Outlook Report (2024)
Policy document D5 is largely technical in monitoring precipitation throughout the state. As Denver's water supply stems largely from the Rocky Mountains, the statewide report was chosen to include the high elevation watersheds. This report monitors snowpack, other precipitation types, streamflow, reservoir levels, and drought indicators (Natural Resources Conservation Service, 2024). Statistical normal values for the last 30 years are presented, but the uncertainties of how this will continue are highlighted. Explanations are offered on the figures throughout the report as well as transparency in forecasting (Natural Resources Conservation Service, 2024). The state's goals for resilience are not mentioned in this outlook report.

4.1.3.1 Summary of policies

These five policy documents present an overview of the approach to drought management in Denver. The first four policies consider the current situation and propose actions on how to proceed. The last policy gives the details of the water supply outlook, positioning the goals of the others in the context of today. Overall, Denver has many plans for creating resilience and seeks to reach their goals through interventions and public action. The following section presents the equivalent information for the case of Cape Town.

4.2 Cape Town's climate and water sources

Establishing the background of Cape Town's water management system allows for insights into the best ways for future strategy implementation. It is first necessary to show the physical situation of the city to acknowledge the initial barriers to water management. The City of Cape Town is situated in a natural harbor that has always been susceptible to highly variable weather (Ziervogel, 2018). The climate is considered to be Mediterranean, characterized by warm and dry summers that lead to cool and wet winters (Enqvist & Ziervogel, 2019). The presence of wet winters is what differentiates Denver and Cape Town's climates in the context of this research. It is a contributing factor to Denver's sustained droughts versus Cape Town's short-term droughts. On a smaller scale than Denver, mountains change the rainfall patterns for the metropolitan area. Microclimates surround Table Mountain, with rainfall averaging 40 cm per year in the Cape Flats compared to 100 cm a year on the slopes of the mountain (Enqvist & Ziervogel, 2019).

The highly variable rains are crucial to the city and its future plans for water management. Dams are replenished by rainfall in the winter months, which means that yearly patterns allow for dams to be just under 50% capacity before entering a drought preparation phase (City of Cape Town, 2024a). The city reached the water crisis after three years of drought with low levels of rainfall from 2015 to 2017, before dams started to recover in the winter of 2018 (Enqvist & Ziervogel, 2019). The water supply for the city, shown below in Figure 5, is planned to remain as the current six large rain-fed dams until at least 2045 (Water and Sanitation Directorate, 2023). It is expected that precipitation will decrease by up to 15% in the area by 2100. In addition, the known patterns are expected to shift, with an increase in the length of times without rain, though also an increase in the intensity of rainfall when it does rain (Ziervogel, 2018). These projections of unpredictable rain cycles, with an overall less amount of rainfall, make a case for urgent shifting of water supply from mostly relying on rain-fed dams.

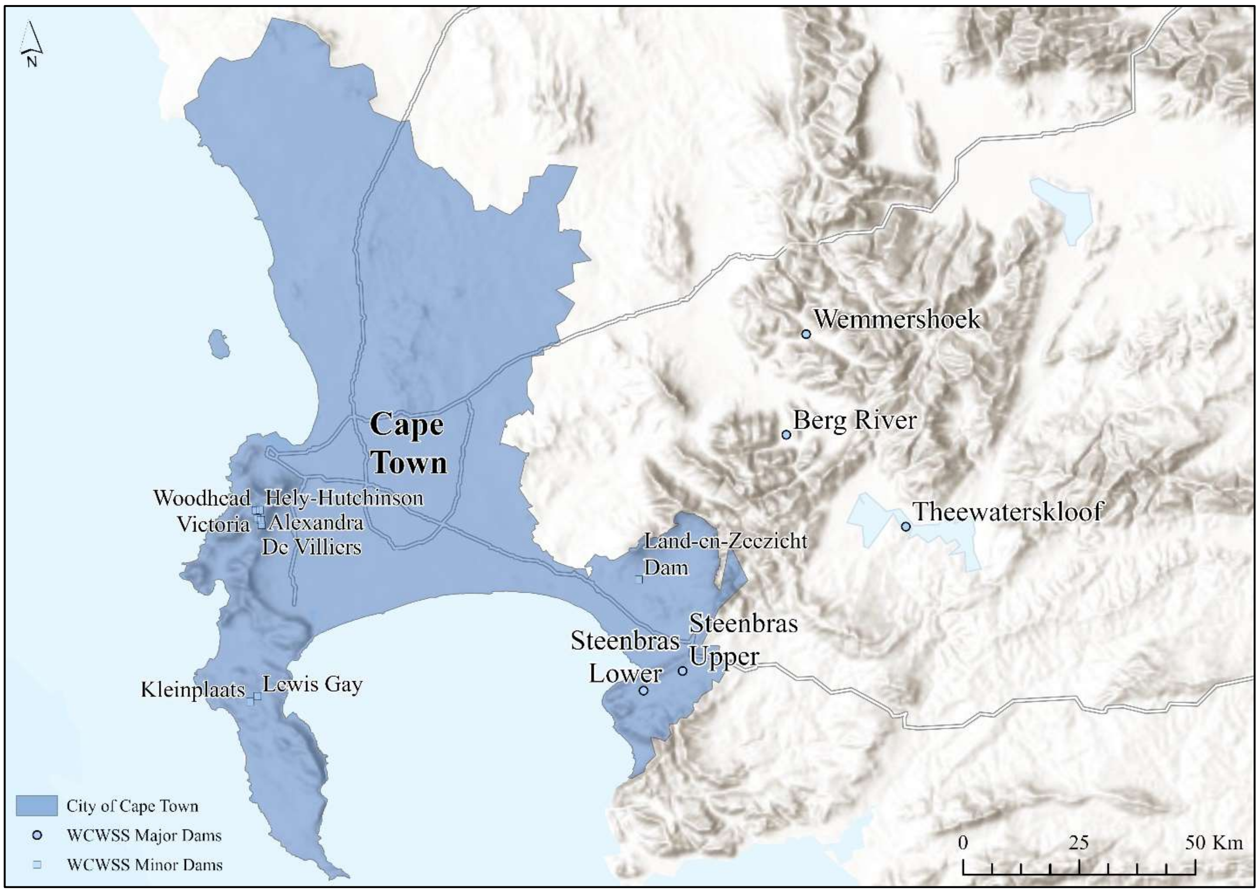

Figure 5: Terrain map of the City of Cape Town and the Western Cape Water Supply System dams (Made by author with data from: City of Cape Town Corporate GIS, 2020 Micheal Bauer Research GmbH, 2023)

4.2.1 Consequences of drought in Cape Town

The following subsections explore the various consequences of drought in Cape Town. Environmental consequences are followed by consequences on human systems.

4.2.1.1 Environmental consequences

During the dry season, wildfires are common in Cape Town. They become a major threat under a number of conditions, including if there is currently a drought (City of Cape Town, 2024b).

Wildfire season typically begins in January and lasts till March. So far, Cape Town has experienced a normal number of fires in 2024 (Global Forest Watch, 2024). These fires are exacerbated by highly flammable invasive plant species as well as drought (City of Cape Town et al., 2019). As mentioned above (section 4.1.1.1), fires can cause burn scars, contributing to the damage caused by flooding and erosion. Flooding is also a common issue for the City of Cape Town, occurring during the rainy winter season. Low-lying areas in the city experience a lack of infrastructure to cope with heavy rains, which contributes to the intensity of flooding when paired with high groundwater levels (Enqvist & Ziervogel, 2019). The impacts of flooding will be expanded on in the following sections.

4.2.1.2 Socioeconomic consequences

Drought impacts many lives in Cape Town. Tensions about water exist between industrial, agricultural, and domestic water use. Domestic concerns focus on some residents not having access to running water (City of Cape Town et al., 2019). This is exacerbated by high in-migration from inland areas, mainly due to the political situation (OECD, 2021). Each sector needs water with an increasing level of demand, but the amount available is limited and existing supplies are diminishing due to climate change, overconsumption, wastage, and pollution. One economic sector that is important for Cape Town is tourism. This sector felt a decline after the negative media surrounding Day Zero (OECD, 2021). The domestic sector is also heavily affected by drought. Several of the following policies presented in this section focus on domestic usage. As of 2016, 88% of Cape Town residents had access to water either in their housing or yard, with another 11.6% reporting access outside of their yard (OECD, 2021). If Cape Town had resorted to distributing water at points around the city, more residents would have felt the burden that those in informal settlements already feel. The average amount of water used in informal settlements is less than the basic amount needed (OECD, 2021). Carrying water results in time and money lost for those without access in or near their home. Had Day Zero occurred, this costly routine of carrying water would have had much more widespread effects.

Agriculture is another sector that is especially impacted by drought. The Western Cape Water Supply System allocates water for the province. About 64% of water is used by Cape Town, 7% is used by other urban areas, and the remaining 29% is used by agriculture in a year with no drought conditions (City of Cape Town, 2020). Drought has a heavy impact on this high-water usage sector. From 2013 till 2018, agricultural exports averaged 25% less than from the period of 2008-2013 in Western Cape (Agri SA, 2019). This loss of production cost around ZAR 5.9 billion (EUR 370 million) (OECD, 2021). The province produces 55-60% of the country's agricultural exports, making this an impact felt around the country (OECD, 2021) In addition, 215,000 employees are directly impacted by these droughts and lower levels of production, of which around 30,000 jobs were lost (Agri SA, 2019; OECD, 2021). Drought has a large socioeconomic impact on many residents of Cape Town.

4.2.2 A brief history of water policy and infrastructure in the Western Cape

The history of water supply infrastructure is crucial to account for in the current impacts of drought policy today. Apartheid rule led to the forced relocation of colored and black South Africans to low lying, flood-prone townships that are known as the Cape Flats (Enqvist & Ziervogel, 2019; OECD, 2021). Apartheid separation of water and sanitation services then led to inadequate levels of infrastructure being set up within these townships, partly due to a lower tax basis and overcrowding within many areas (Enqvist & Ziervogel, 2019). The apartheid history of water infrastructure still leaves its mark today. Despite the combination of all municipalities into one metropolitan area to assist in creating equitable public services, water management is lacking in informal settlements (Enqvist & Ziervogel, 2019). A combination of remaining debts from nonpayment protests in the last years of apartheid with a lack of funding to maintain infrastructure led to a water cut off for many following the 1998 Water Act (Enqvist & Ziervogel, 2019). This Act aimed to increase equity in water access through requiring water conservation, but some households would pass the maximum water usage simply through having leaky pipes. This is a widespread issue, with 57% of water infrastructure in need of renewal (OECD, 2021). Despite the encountered issues, the Water Act signified a shift in water policy towards conservation and an attempt at inclusion and community participation (Enqvist & Ziervogel, 2019). The legacy of this is visible in policy documents today.

4.2.3 Major drought policy in Western Cape and Cape Town

The five selected policy documents for Cape Town are summarized below, highlighting the major strategies for interventions and overall climate resilience. Themes of inclusion or design around participative processes are discussed in each as well. To gain an overview of current policy, the documents were selected from four themes: one overall policy aim for the city, one water outlook to lend estimations of water levels to the analysis, two broader resiliency plans, and one emergency response plan. Each policy document will be referred to by its code shown in the subsection heading throughout the report.

C1: Our Shared Water Future: Cape Town's Water Strategy (2020)

With a title aiming to build a sense of shared responsibility, C1 discusses a strategy for increasing water supplies and improving equitable access (City of Cape Town, 2020). The significant role of residents in preventing Day Zero is recognized, bringing attention as well to the effects of the prolonged drought on marginalized communities. Becoming better prepared for future droughts is proposed through augmenting water supplies. This is to be achieved through planning revisions to increase the amount of water that can be recycled, aquifer recharge, having alternative sources for non-drinking purposes, and upgrading the capacity and abilities of treatment plants. Desalination is planned for in times of extreme need. By 2030, the city wishes to increase the supply by over 300 million megaliters of water per day (City of Cape Town, 2020). This number was decided on through scenario planning, a part of the path towards becoming a climate resilient city. Overall resilience will also be built through clearing invasive species, slowing and storing more rainwater, increasing economic opportunities in the water sector, and increasing safety and sanitation in informal settlements (City of Cape Town, 2020). The city aims to increase the level of collaboration with residents to meet these goals in living labs, while also becoming more accountable and transparent in matters of water billing and providing education. Active engagement is key in this plan, requesting more residents upgrade to efficient household water systems (City of Cape Town, 2020).

C2: Cape Town Water Outlook (2022)

C2 shares a similar message to C1, emphasizing the combined effort of water management between residents and water authorities (City of Cape Town, 2022). Outlook reports are published periodically to show the progress on building water resilience, integrated management styles, and what the future may hold. There is concern in the report about pre-drought water consumption habits returning. The future is not clear, so the city emphasizes the need for a timely implementation of water augmentation projects (City of Cape Town, 2022). The water authorities themselves lay out many interventions to help achieve water resilience, including forming committees and having an independent advisory panel to improve transparency. In addition, there are plans made for augmenting supply through rain-fed dams, aquifer management, desalinization plant construction, and water reuse (City of Cape Town, 2022). This report also notes that the city is on target for meeting their augmentation goal stated in C1 of increasing supply by 300 million liters a day. Through sharing statistics regarding various water scenarios, residents can become better informed about their role in reducing consumption.

C3: Cape Town Resilience Strategy (2019)

C3 is developed in partnership between the City of Cape Town and the 100 Resilient Cities platform. Together, a strategy was developed for long term resilience through twenty different goals. Seventy-five actions were formulated to create a pathway towards meeting these goals (City of Cape Town et al., 2019). The city itself takes responsibility for many actions, ranging from partnering to include communications between heavy water users and the Department of Water and Sanitation, to reviving wetlands. The City of Cape Town also includes actions on performing informed aquifer recharge, collecting data on bore holes, monitoring for water vulnerabilities, clearing invasive species, building an eco-industrial park, and finding funding for all said projects. Through a set of protocols, the city aims to 'build back better' (City of Cape Town et al., 2019, p.105) rather than recover. This will be done through assessing the resiliency of neighborhoods through collaborative projects, addressing existing inequalities, and focusing on social cohesion goals. Water authorities are learning from the data gathered during the drought to develop robust and de-siloed infrastructure resilience (City of Cape Town et al., 2019). The public has a large role in this strategy, though it is acknowledged that they have already done so much during the drought. The sense of community and cohesion that was developed during the drought is the goal of the public (City of Cape Town et al., 2019). Interviews and workshops were conducted to find the best ways to achieve this social cohesion, of which the city plans to continue in order to address crime, poverty, and mental wellbeing.

C4: Critical Water Shortages Disaster Plan - Public Summary (2017)

This policy document, while being a disaster plan, follows the same line of reasoning as the others. C4 outlines the three phases of disaster response for a drought emergency in Cape Town (City of Cape Town, 2017). Interventions include defining water rationing and at what stages crucial decisions are made, such as injecting water into the sewage system to retain its functionality. To be prepared for the worst-case scenario, C4 takes a pessimistic approach with responsibilities for action spread across seven operational documents. The document has a limited level of detail for the public, but repeats the same message of working together with an additional note on emergency proceedings (City of Cape Town, 2017). The aim of this document is to minimize the impact of an emergency on daily proceedings, yet prepare the city for the worst.

C5: Water Services Development Plan - IDP Water Sector Input Report 2022-2027 (2023)

C5 stands in conjunction to C3 as concrete plans to achieve the goals that have been set. This development plan is a technical report, with acknowledgement of the large responsibility put on water users. The City of Cape Town has put forward goals of redesigning systems and replacing ageing infrastructure to improve efficiency (City of Cape Town, 2023). In addition, smart technologies will be invested in to help meet goals. There is a special focus put on stimulating a green economy and achieving certifications in the process. This plan outlines an increase in capacity for the City to improve metering and retrofitting actions. There are also steps to manage the entire network more effectively, which includes providing safe access to more water taps and toilets in informal settlements (City of Cape Town, 2023). The city aims to become water sensitive through these interventions, as well as addressing water losses at their sources. C5 acknowledges the difficulties in implementing these plans, but hopes to improve water sensitivity with a larger public works program. Inclusivity and trust are central in these plans, calling for user accountability, while also ensuring implementing a quality assurance of customer service (City of Cape Town, 2023). Many of the goals in this document require high levels of cooperation from water users and the city wishes to support this through accessible customer service.

4.2.3.1 Summary of policies

With a combined effort from the public and water authorities, Cape Town aims to build climate resilience and reduce its vulnerability to drought. These policies outline concrete actions as well as the promotion of community approaches to drought management. The city reflects on the impacts of the recent drought, but also highlights the importance of the collective action that developed during the crisis. As all analyzed policies were published during or after Day Zero, there is a focus on lessons learned from the crisis, indicating a lack of sufficient measures in some parts of policy beforehand.

5. Findings of the QCA

This chapter contains the procedure and outcomes of the Qualitative Comparative Analysis. First, the calibrations of the fuzzy sets are explained. Once defined, the analysis and its results are presented to determine which explanatory factors have had the greatest influence on the success of drought management in Denver and Cape Town.

5.1 Calibration

Calibration is necessary to define the degree to which cases belong within explanatory factors. Calibration is based on the information that has been reviewed thus far within the literature and policy reviews with a base of background knowledge of the situation (Gerrits & Verweij, 2018). Fuzzy-set calibration was performed after all policy documents were read in order to fully understand the contexts and content. Calibrating with an understanding of all policy documents allowed for sets to be tailored for this research. Each explanatory factor, as well as the outcome, have been defined on a scale of 0 to 1, with 0.5 as the crossover point. No cases are defined at the crossover point, as this is the most ambiguous ranking, where cases would belong neither to the set nor outside of it (Gerrits & Verweij, 2018). To increase the reliability of this study, all notes made while calibrating were included in Appendix II. The results of the calibration were summarized in Table 1 and explained in the following sections. Each policy document has been assigned a code for ease of reference in the following sections, as presented so far in Chapter 4. These codes are not chronological but are in the order that the documents were selected and analyzed. This shows the snowballing order of selection following the review of the overall water strategy (D1 and C1).

Table 1: Overview of policy documents and associated calibrations per explanatory factor (Made by author, 2024)

Code	**Policy**	**Year Published**	**Interventions**	**Climate Resilience Strategies**	**Role of the Public**	**Outcome**
D1	Colorado Water Plan	2023	0.25	1	0.8	0.8
D2	Denver Water Shortage Response Implementation Plan	2020	0.25	0.7	0	0.6
D3	Denver Water Efficiency Plan	2017	0.25	0.6	0	0.6
D4	Denver One Water Final Report	2021	0.75	0.6	1	0.6
D5	Colorado Water Supply Outlook Report	2024	0.25	0	0	0.6
C1	Cape Town Water Strategy	2020	1	1	1	1
C2	Cape Town Water Outlook	2022	1	0.8	0.6	1

C3	City of Cape Town Resilience Strategy	2019	1	1	0.8	1
C4	Critical Water Shortages Disaster Plan - Public Summary	2017	0.25	0.7	0	1
C5	City of Cape Town Water Services Development Plan 2022-2027	2023	0.75	0.6	0.6	1

5.1.1 Interventions

The first explanatory factor was the interventions taken by water authorities to manage drought. Calibration for this factor focused on the actions of the water authorities themselves, rather than plans for the future, or for others to make. This is a crucial part of drought management, as transitions towards sustainable practices require guidance (Culotta et al., 2016; Jordan, 2008). Each policy document was calibrated for its level of intervention as illustrated below in Figure 6. The reasoning for this calibration is presented afterwards.

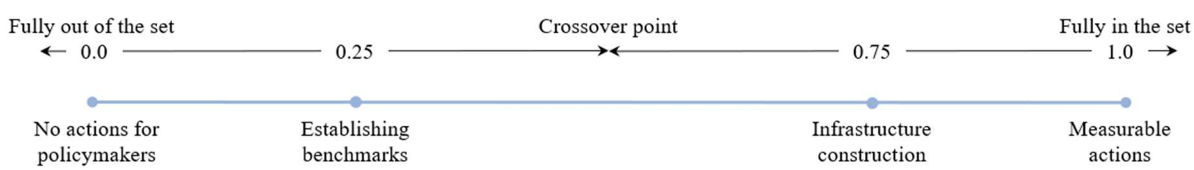

Figure 6: Calibration scale for drought management interventions (Made by author, 2024)

No actions

The null value of the calibration is defined by there being no actions for policymakers to take. None of the policy documents were set at this level, demonstrating a sufficient level of interventions in all ten.

Establishing benchmarks

Next on the scale is the 0.25 value, where benchmarks are established for policymakers within the policies. Making benchmarks is a sign that measurable goals in drought management were created. Without benchmarks, there is ambiguity in what water authorities actually need to achieve in order to be successful. Clear definition of goals and interventions is part of the process towards sectoral integration in the long term (Lafferty & Hovden, 2003). Interventions can clearly be called a success if they meet a benchmark. Policy D3 was ranked at 0.4, as there are no concrete interventions for Denver Water to take, but there is a definition of what efficient water use is for the city. D5 also falls at this mark, as monitoring levels are established and reported, yet no future interventions are ideated. C4 has this value due to limits and rationing levels being defined. A fourth policy document, D1, includes models and reports, but emphasizes that it only 'advances projects' and does not build any infrastructure itself (Colorado Water Conservation Board, 2023). Finally, D2 includes situation-specific benchmarks for water restrictions and when to respond with augmented sources but does not plan for the construction of new infrastructure to ease droughts.

Infrastructure construction

Following the crossover point is 0.75. At this point, policies include the construction of infrastructure to intervene in a drought. Building wastewater treatment or desalination plants are costly expenditures for water authorities, indicating that a strong level of action is being taken to prevent the worsening of drought conditions. Two policies (D4 and C5) outlined infrastructure construction. The policy for Denver, D4, focuses on de-siloing systems to create a more integrated water system for the city. This includes active restoration of green infrastructure to make room for rivers in times of flooding, which can help retain water throughout the city. For Cape Town, C5 includes building capacity throughout the city, slowing down rain for storage, funding of smart technologies in water management (like desalination, osmosis, and pressure management), retrofitting, and restoring existing infrastructure.

Measurable actions

Three policy documents achieved full belonging to the set. This means that each document includes all lower interventions and additionally states measurable actions for authorities to achieve. In the three policies that reach this level, measurable actions are set through the creation of new legal and legislative rulings on drought management, creating accountability for the planned interventions. Document C1 includes extensive monitoring, network changes, and creation of new water supplies, as well as cementing these steps for efficiency in planning by-law. In policy C2, a committee and Independent Advisory Panel are set up to oversee interventions in monitoring, project completion, and demand analysis. Lastly, C3 extends an advisory committee and partnership with the Water and Sanitation Department to ensure effective clearing of invasive species, aquifer recharge research, and wetland restoration.

5.1.2 Climate resilience strategies

Climate resilience strategies proposed by water authorities in both study areas are the second explanatory factor. Policies belonging to this set go far beyond planning for returning to normal after a water crisis event. Developing strategies to cope with droughts in the framing of city-wide climate resilience calls for an inclusion of collaboration, scenario planning, and environmental justice (Wardekker, 2021; Laeni et al., 2019). These themes are necessary to bring cities forward in improving in all spheres of life, rather than in a silo of water management (Davoudi, 2012). In Figure 7, these rankings are displayed with the explanation for the placement of each policy document following.

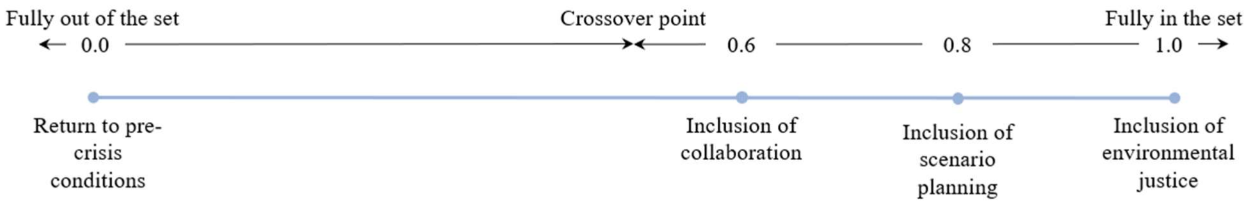

Figure 7: Climate Resilience Strategies calibration scale (Made by author, 2024)

Returning to normal

Policies that call for a to return to normal are ranked at 0. This ranking is based on the engineering definition of resilience, where systems return to equilibrium after a stressor (Davoudi, 2012). This definition is too simplistic for complex social systems like cities, especially in the aim of developing climate resilience. One report was given the score of 0. D5 is a technical report that does not explicitly mention resilience, despite resilience building being a goal for the entire state (Colorado Water Conservation Board, 2023).

Including collaboration

The value 0.6 lies beyond the crossover point, where collaboration is included in resilience building. A lack of communicative practice in developing climate resilience strategies can lead to the creation of stakeholder tension and impractical solutions (de Roo, 2006). Top-down control clashes with diverse views and experiences in democratic societies. The policies with this ranking (D3, D4, and C5), therefore, have a higher probability of being enacted through societal acceptance. Policy D3 outlines a comprehensive plan for integrated solutions in managing water and seeks to achieve this through a working group and encouraging users to manage their own usage. The following policy document, D4, goes beyond user collaboration to create a unified approach across different water authorities in the city. The aim is to create a unitary sense of stewardship of the resource with this agency collaboration. Lastly, C5 strives for resilience through creating a public works program and assuring quality service for water users.

Including scenario planning

With a higher level of belonging to the set, 0.8 is defined by the inclusion of scenario planning into the climate resilience strategies. Adaptive planning is included as a type of scenario planning for this analysis. The importance of plans being able to change is due to the high level of unpredictability and uncertainty in environmental and societal conditions (Haasnoot et al., 2013). Policy documents from each metropolitan area include this. In Denver, D2 proposes four stages of water use restrictions in the event of a drought. It should be noted that D2 has a low level of collaboration, relying on stakeholder education. The distinction between levels of collaboration is made in the last explanatory factor. D2's inclusion of collaboration, therefore, is enough to get it past the value of 0.6, but is lowered from 0.8 to 0.7 as the lack of feasibility of the scenario planning harms the score. For Cape Town, C4 follows suit, with three phases of drought management guiding the policy. Once again, however, this acts as advice for the public without any level of collaboration, lowering the score to 0.7. Document C2 fully earns the ranking of 0.8 by having a sufficient plan for collaboration and a scenario approach for managing future levels of demand.

Including environmental justice

Three policy documents earn the score of 1, where environmental justice is part of the resilience building strategy. Building resilience to climate change is a long-term goal. Within disadvantaged communities, there are many short-term goals that hold a higher, more immediate, priority. These communities, however, are also more prone to the vulnerabilities presented with a changing climate (Boltz et al., 2022). This means that a complete plan for building climate resilience must include measures to assist in protecting and improving the lives of vulnerable populations within the metropolitan areas. Policy D1 achieves this through the creation of a Water Equity Task Force for the inclusion of equity issues into water policy, on top of collaborative processes and adaptive planning. Document C1 includes scenario planning, increased collaboration, and a specific focus on improving water source access and quality in informal settlements. In C3, scenario planning and empowerment of stakeholders includes a specific focus on addressing existing inequalities throughout the city. Within this document, the focus of several goals falls on improving water management within informal settlements.

5.1.3 Role of the public

The last explanatory factor in this analysis is the role of the public within drought management. This fuzzy set has five values, with a basis formed by Arnstien's Ladder of Citizen Participation (1969). This 'ladder' explains the various forms of citizen power when involved in democratic processes (Arnstien, 1969). Coping with drought calls for public action as well as that of institutions, since household water usage can make a significant change as was demonstrated in preventing Day Zero in Cape Town. Figure 8 below shows the rankings of each policy document with the explanation following.

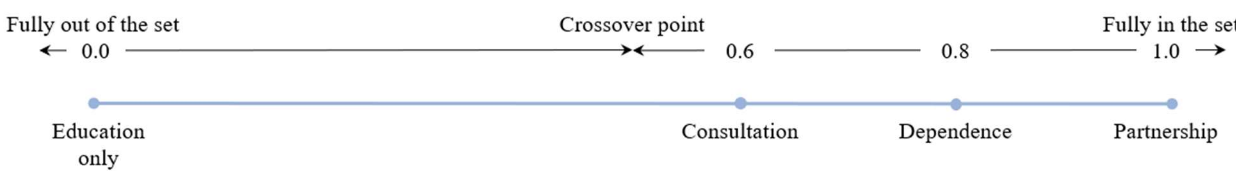

Figure 8: Scale of calibration for the role of the public in drought management (Made by author, 2024)

Education

The 0 value was set on the third rung of Arnstien's Ladder. This level was set because the lowest level of participation within the policy documents was informing the public. Within four of the documents (D2, D3, D5, C4), this level of public participation was identified. In the policies, D2 informed water users of rules and limits, D3 focused on targeted campaigning, D5 made no explicit reference to engaging the public, and C4 lacked operational details and stayed superficial in recommending that the public come together in order to best conserve water.

Consultation

The next value, 0.6, already falls above the crossover point with consultation of the public taking place. In Cape Town, C2 earns a value of 0.6 through stakeholder engagement and consultation with experts from different sectors. The other case with this value, C5, focuses on surveying and assuring quality in service to water users.

Dependence

Value 0.8 was decided on in addition to the rankings of the ladder of participation. This ranking signifies dependence on the public, placing responsibility of an issue that requires cross-sectoral collaboration and strong conservation on individuals. Blythe et al. (2018) identifies the risk of placing collective responsibility on individuals in the broad scope of transforming for sustainability. Every person has a different ability to act on climate change. Transferring responsibility for climate resilience to individuals can alienate and cause resistance when some feel powerless in the global scheme (Blythe et al., 2018). Policymakers, therefore, must take caution in not demanding too much from individuals when considering the need for drought resilience for the entire metropolitan area. Documents D1 and C3 would have initially been placed at the highest ranking on the scale, but were weakened by this demand placed on the public. D1 acted as a 'call to action', but additionally offered programs and outreach (Colorado Water Conservation Board, 2023, p.5). C3 planned workshops and gave technical education, yet called for the public to become resilient through local networks despite the large role users have already played in reducing water consumption.

Partnership

Lastly, full membership in the set was defined as partnership between water authorities and the public. D4 and C1 achieved partnership through extensive outreach programs, collaborative processes, and workshops where public input influences actions taken by authorities for water conservation.

5.1.4 Outcome: Sustainable water usage

Lastly, the outcome was calibrated based on the overall research aim. The outcome, indicating the success of a policy, can be defined as the reduction in water usage following the publishing of the documents. For a time period following the publication, the reduction in water usage for the cities was calculated (see Chapter 3.4.1). The average daily per capita water usage (in liters) was visualized as well, starting with Figure 9 for Denver.

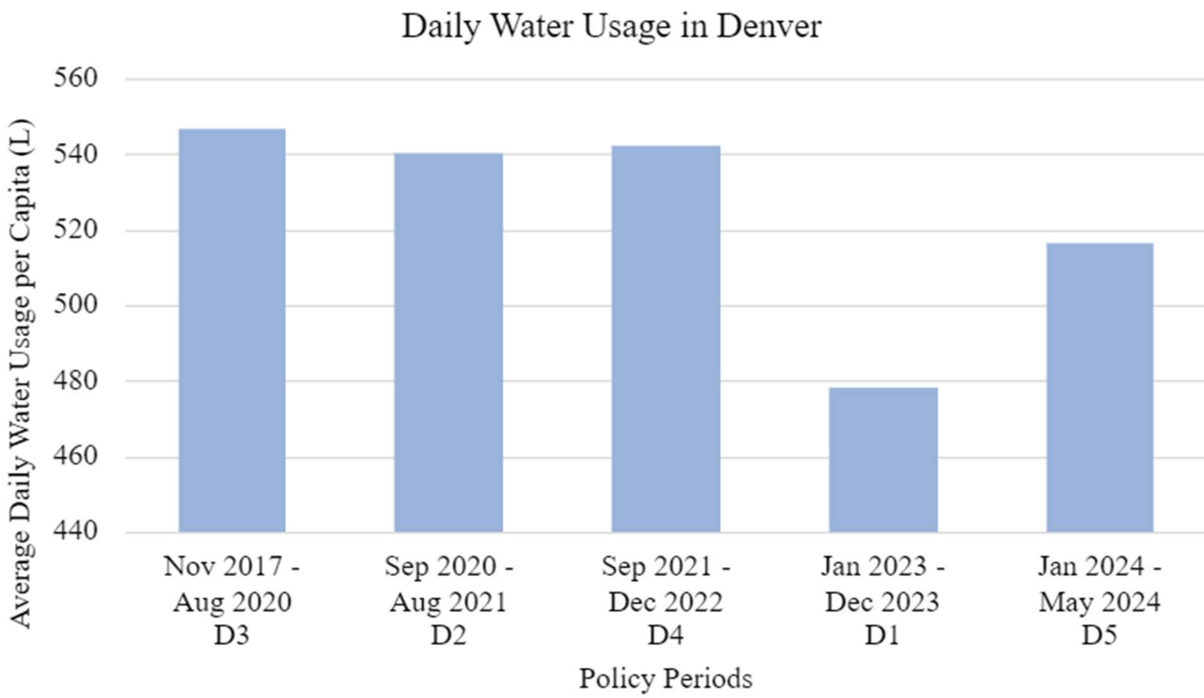

Figure 9: Chart of daily water usage from November 2017 until May 2024 (Made by author, 2024, with data from Denver Water, 2017-2024; Colorado Water Conservation Board, 2019)

This figure, as well as Figure 10 for Cape Town, is grouped by the policy period. This is the time between implementation of the policy before the next policy was published. For Cape Town, a baseline was also established for comparison to pre-drought conditions.

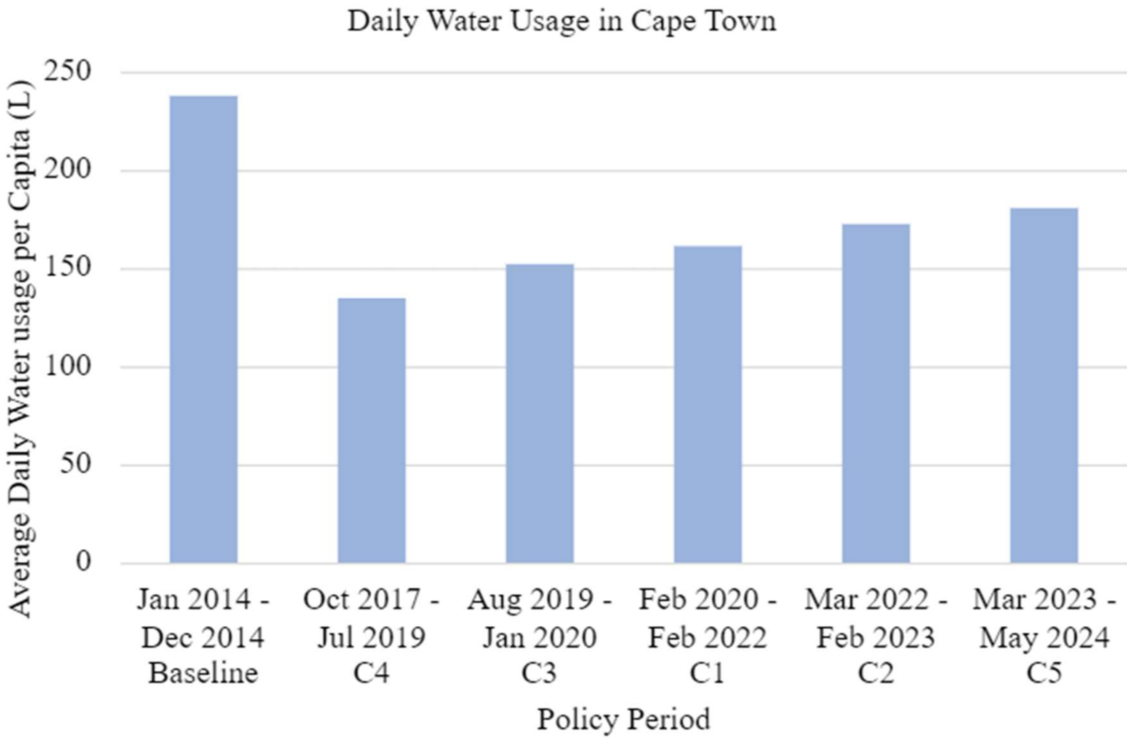

Figure 10: Chart of daily water usage from October 2017 until May 2024, with a baseline year of 2014 (Made by author, 2024, with data from City of Cape Town, 2017-2024; Climate System Analysis Group, 2020)

Drought management is a long-term goal, so the plans for each city until 2050 (Denver) and 2040 (Cape Town) were used to complete the outcome variable. Each city has several targets relating to water usage to maintain service functions and life as usual. These are projected to be achieved in the coming decades. The lowest, medium, and the highest projections were taken in this calibration.

If the reduction in water usage following the publication of a policy document does not meet any of the water need projections, the outcome of the score is 0, as seen below in Figure 11. None of the policy documents had an outcome of 0. A partial belonging to the outcome set is then defined at 0.6, if the low water projection is met. Policies D2, D3, D4, and D5 all are on track to meet the low projection, giving them this value. When both the low and medium projections are met, the outcome was defined as 0.8. D1 was the only case to meet the low and medium projections. Full belonging to the set at the value of 1 occurs when the reduction in water usage allows the city to reach the highest water need projection in 2040 or 2050. All five of Cape Town's policies had this outcome.

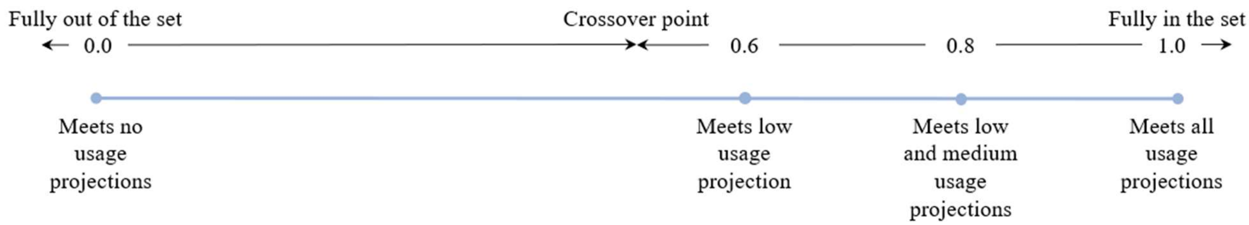

Figure 11: Outcome calibration for success of drought management policies (Made by author, 2024)

5.3 Results

Following calibration, it was possible to run the fsQCA software to produce a truth table. A truth table shows all possible logical combinations of factors (Gerrits & Verweij, 2018). Table 2 presents the final truth table for this analysis. The three factors have been represented by their first letters, for brevity (Interventions as I, Resilience as R, Public Engagement as P).

Table 2: Intermediate truth table (Made by author, 2024)

Factors			**Count**	**Outcome**		**Consistency**		
I	**R**	**P**	**N**	**O**	**Cases**	**Raw**	**PRI**	**SYM**
1	1	1	5 (50%)	1	D4 (0.6, 0.6), C1 (1, 1), C2 (0.6, 1), C3 (0.8, 1), C5 (0.6, 1)	1	1	1
0	1	1	1 (100%)	1	D1(0.75, 0.8)	1	1	1
0	1	0	3 (80%)	1	D2(0.7, 0.6), D3 (0.6, 0.6), C4 (0.7, 1)	0.959184	0.931035	1
0	0	0	1 (90%)	1	D5 (0.75, 0.6) *	0.925	0.833333	1

This truth table presents many findings, but interpretation is necessary for further description. Firstly, the consistency scores indicate that the factors are indeed consistent with the success of drought management. The raw consistency score is relevant to this analysis, and all QCA analysis. Raw consistency must be from 0.75 or higher, otherwise there is an indication of severe inconsistencies within the truth table (Gerrits & Verweij, 2018). With the lowest consistency value of 0.925, there was no need for recalibration during the analysis. The presence of two perfect consistency scores (1) indicates that the factors are sufficient for indicating the outcome (Gerrits & Verweij, 2018). The next consistency values, PRI, represent the Proportional Reduction in Inconsistency. PRI values are necessary to rule out negation of the outcome in fuzzy sets (Pappas & Woodside, 2021). These values should be close to 1 and similar to the raw consistency scores. As the threshold for PRI inconsistencies is at 0.5, these values are also consistent. The final consistency check is for Symmetric Consistency, or SYM, which is not necessary in this analysis.

After establishing that the factors are consistent with the outcome, further interpretation can be made about the solution formulas. Five cases (D4, C1, C2, C3, and C5) contain policy strategies that are fully belonging to the sets of each factor and contributing to successful drought management. The next fully consistent solution formula is only present in one case, D1. This case did not score for interventions, but did for the other two factors. As a small number of in-depth cases are used, there is no lower limit for case coverage (Gerrits & Verweij, 2018; Pappas & Woodside, 2021). The single case formula, D1, will therefore be considered more in the discussion section of the following chapter. It is not necessary to discard the solution formula even though there is only one case that it pertains to, unlike in a purely quantitative analysis (Gerrits & Verweij, 2018). There may be limited diversity, but this is a point for discussion.

The following formula solution is relevant for three cases. In D2, D3, and C4, Climate Resilience strategies account for successful drought management on their own. The consistency values indicate that this condition is enough to account for the success on its own. The final case and solution to be considered is D5. This solution presents a logical contradiction and is thus marked by an asterisk. Although the outcome of the policy was considered to be successful, none of the factors contributed enough. This case will be discussed further in the following chapter, as this is possibly due to the timespan of the policy period.

Completing interpretation and validation of the truth table allows for the final results of the analysis to be calculated. In Table 3 below, the output of the QCA is shown.

Table 3: Truth table analysis (Made by author, 2024)

Path	Minimal Configuration	Consistency	Raw Coverage	Unique Coverage	Cases
#1	~I*~P	0.869565	0.365854	0.310976	D2 (0.75, 0.6), D3 (0.75, 0.6), D5 (0.75, 0.6), C4 (0.75, 1)
#2	R*P	1	0.536585	0.481707	C1 (1, 1), D1 (0.8, 0.8), C3 (0.8 ,1), D4 (0.6, 0.6), C2 (0.6, 1), C5 (0.6 ,1)

Table 3 shows two solutions. These solutions have a high coverage of 0.847561 and consistency of 0.939189 together. The consistency cutoff was high as well, at 0.925. This value is the most important for the research, as it indicates that the theory behind the analysis is supported (Gerrits & Verweij, 2018). Raw coverage was rather low for both of the paths, indicating that several different combinations of the factors can lead to the same outcome in the end (Gerrits & Verweij, 2018). The unique coverage value for both is also lower, which is not uncommon. As the solutions together have a high coverage, these factor combinations show that the outcome is mostly covered by these paths.

As the last step of interpretation of the QCA, the configurations were investigated for necessity, sufficiency, and INUS. Both pathways are INUS, which means that the conditions are ‘Sufficient or Necessary to explain the outcome, and insufficient on their own but are necessary parts of solutions that can explain the result' (Pappas & Woodside, 2021, p.4). This complex statement simply points out the complexities of causation. None of the strategies are able to produce a successful outcome without the aid of another strategy, so both of the pathways are INUS. It is common to identify INUS conditions, because patterns are explored in the complexities of policy documents (Gerrits & Verweij, 2018). In the case of the second pathway, it is not possible for climate resilience strategies to produce the outcome without the condition of public engagement. This makes sense in the context of a city, as there are unique ties between policy implementation and public support. It is not possible to say, however, which of the strategies is necessary and which is only sufficient to create successful drought management, leading to an INUS identification signifying complex relationships of causation for strategies involving the public. These results will be explained with more theoretical and conceptual context in the following chapter.

6. Discussion and conclusion

The results of the QCA were presented in Chapter 5. This chapter now discusses these results in a broader context. These results were first placed into theory, with conclusions made afterwards. This chapter finalizes with recommendations on how to continue the line of research, as well as reflections and limitations on the process.

6.1 Discussion of results

After the presentation of the results in the last chapter, it is important to return context to the policy documents. Firstly, the pathways were explained. The pathway combination of ~I*~P + R*P resulted in successful drought management. The first pathway, which is not the conjunction of interventions and public engagement, essentially means that climate resilience strategies result in successful drought management. In addition to this, the second pathway indicates that the combination of climate resilience strategies and public engagement lead to successful drought management. Interventions alone are therefore not enough for successful drought management, while climate resilience strategies are present in all successful drought management policies. Public participation contributes to successful drought management, but only in combination with climate resilience strategies. Operationalizing these results again allows for connection to the broader body of theory on the subject.

The necessity of climate resilience strategies within policy documents for successful drought management points to an incorporation of systems thinking. A systems approach to water management calls for leaving behind silos of institutional policy. Systems thinking recognizes the complexity of an urban context and the interconnectedness of issues. Collaboration for resilience was classified in this analysis as the minimum requirement to have a policy belong to successful climate resilience strategies. With a level of collaboration, the pluralistic nature of environmental issues can be recognized and addressed within policy (Zuidema, 2016). The results of this analysis enforce the points made within systems theory. Urban settings, especially pertaining to environmental issues, hold too many views on what the correct way of addressing issues is to be met with a technical approach.

Resilience, as approached in this study, follows the most prominent framing in literature (Wardekker, 2021). Requiring the policy strategies to take an evolutionary approach, in order to be considered a climate resilience strategy, narrows the debate around the definition of resilience. The framing of Resilience Planning additionally includes scenario or adaptive planning (Wardekker, 2021). These two distinctions helped to define climate resilience strategies, which was later found to be the precondition for success in drought management.

Interventions by water authorities were found to be insignificant for overall long-term drought management. These interventions generally belong to the framing of resilience that just aims to return to business as usual (Wardekker, 2021). This is not to say that these interventions are not necessary, as actions such as supply augmentation and clear monitoring of the current situation are crucial. This alone, however, cannot solve issues surrounding droughts. Interventions and public engagement cannot be combined without a central strategy for resilience.

The importance of climate resilience strategies signifies support of the concept of governing for sustainability. The main aspect of governing for sustainability emphasizes de-siloing (Agrawal, 2022). As of now, it cannot be said that this de-siloing has been successfully implemented. There have been steps forwards, but it is far from the radical societal change of the theory. Many policies (D1, D3, D4, C1, C2, C3, and C5) include aspects of this de-siloing through collaboration and integration, but the fact that they still come from water authorities signify that the sectors are quite separate. It is possible that the water authorities are transitioning into becoming horizontal environmental policy integration facilitators, but it is too early to see if this will be supported by other integration measures.

6.1.1 Discussion of barriers to drought management measure implementation

The results from Cape Town's policy documents must additionally be reflected on in the context of the severe 2015-2018 drought. The crisis of an imminent need to shut off the city's water supply urged a previously unseen level of collaborative effort to reduce demand. It is not possible to say whether this drop in demand would have occurred without the threat of Day Zero, but it is very unlikely. This is a direct example of a window of opportunity allowing for radical change. Usage has increased since the end of the drought crisis, but not to pre-drought consumption levels (City of Cape Town, 2022). As found in the calculation of the QCA outcome, water usage is on track to meet the high consumption projections for 2040. Prior to the drought crisis in 2014, Cape Town was only on track to meet the medium consumption projections. For the purpose of this analysis, meeting both of these levels signifies successful drought management. Had the usage levels prior to the drought been projected to not meet the demands of 2040, it would have had a large impact on this methodology. Success from pre-drought and post-drought demand levels signifies that Cape Town's policy has had success despite the crisis.

6.1.2 Discussion of QCA case irregularities

Two of the policy documents were identified with results that require further discussion. Document D1 presents a single case formula in Table 2. The analysis identifies the combination of climate resilience strategies and public engagement as a possible formula for successful drought management. It is not possible to completely confirm that this is a successful combination, as it only occurs in one policy document. Considering that Pathway 1 is found to indicate that interventions are not necessary for success, it increases the likelihood that D1's formula is valid. It is only possible to confirm its validity through continuation of the study with a larger sample size.

The other case to further examine is D5. Despite all three factors leaning towards being outside of the set, the outcome was successful. Gerrits and Verweij (2018) offer several strategies for addressing logical contradictions. Their fifth strategy uses a qualitative approach to examine why this may have occurred. This strategy was used as the sample set is relatively small and Chapter 4 offers an in-depth summary of each policy document. First, it was confirmed that this policy is indeed within the range of appropriate case selection. This policy, and its counterpart C2 for Cape Town, address the current situation of the water supply. This insight is necessary to have a recent snapshot of the situation in both contexts. C2 exemplified that it is possible to present current readings in the context of overall drought management and resilience strategy. D5 is presented separately from the overall goals of the state to report and inform on drought status. The document does its best to provide readability aids, signifying that it is indeed meant to educate the public, but goes no further to connect the current water supply to future considerations (Natural Resources Conservation Service, 2024). This report was published on January 1, 2024, so it is entirely possible that the outcome examination period was too short until the end of May, 2024. Despite no higher-than-average precipitation (see Figure 2), reservoir levels are reported to be higher than normal throughout Colorado in D5. It is possible that the high levels removed the need for the report to connect to future drought management. In the long term, this can be considered short-sighted.

After reconsideration of D5, it was decided that re-running the QCA minimization without the case is useful for the discussion. The policy document was not entirely removed from the process, as it represents the complexities of drought policy. Removing the case from the analysis would be reductive, ignoring the realities of complex causation. It was decided, therefore, to leave D5 in the main results. For the purpose of this discussion, rerunning the QCA gave a pathway of ~I*R+R*P. The interpretation of the results is slightly changed in this pathway configuration. The second configuration is the same. The first configuration changes to only enforce that climate resilience strategies are necessary, rather than pointing to the combination of interventions and public engagement not being sufficient. Removing D5 makes the results more explicit, but overall has the same message on the importance of climate resilience strategies. This alternative configuration without D5 points toward the case being appropriate, but somewhat of an outlier. It is possible that another underlying factor is present in this case, that could be investigated during further research.

6.2 Conclusion

To conclude this research, the discussion of results is presented in the framing of the research questions.

The first sub question was designed to determine whether current barriers to effective drought management exist within the two study areas. This question was approached through the literature review and given context within the policies. The variety of definitions of drought were presented as the first barrier. Drought is not as straightforward as a lack of water. It is about who the lack of water effects and what the ripple effects are. The definition of drought in both cities focuses on human consumption (Colorado State University, 2024; Water & Sanitation, 2019). From an ecological perspective, the effects of drought could be much more severe in the long term for the environment than for urban residents. Drought management is attempting to de-silo and that could expand the scope of the definition of drought itself. To truly become sustainable in a sense that the environment will be resilient to drought as well, it is likely that much more action needs to be taken to cope with droughts. The environment has a demand for water that is not addressed in any of these policies beyond the water restrictions on lawn watering. This focused anthropogenic definition exemplifies the need for systems thinking in addressing environmental issues. It can be assumed that most cities face this issue, as urban centers are built for people. All cities aiming to increase their level of drought resilience should incorporate environmental needs into water planning through integrating sectors.

The lack of systems thinking in drought management was identified as another barrier (Beunen & Patterson, 2016; Lafferty & Hovden, 2003). Despite a call for intensive environmental policy integration for over twenty years, institutional silos are still an issue and drought management is still largely solely in the hands of water authorities, as demonstrated in all policies. Ideally, water authorities should be overseeing the implementation of sectoral drought management (van de Meene, 2023). It is a radical change to have every institution in charge of their own environmental issues. The oversight for this is not in place in either city as well. Cape Town presents a context where the city was able to collaborate on new levels during the crisis, but it is not quite governing for sustainability. The public had an increased role in drought management, but the public is not an institutional sector. This means that the path dependency of governing has yet to be broken in either city, therefore a window of opportunity is still necessary to find. These cities, and others facing drought, should harness political change as a window of opportunity. As the most predictable breaks to a path, drought management strategies may have a greater chance of integration, and thus more efficient implementation, when proposed during new political terms.

This second sub question, questioning which strategies are currently in place in cities, was addressed in Chapter 4. These strategies later became the factors of the QCA analysis. Interventions were the direct strategies taken by water authorities. These interventions included many direct actions, such as the monitoring and modeling of water supply and demand, creating programs and schemes for water adaptations, and augmenting supply. The strategies were considered to be fully belonging to the set of interventions when the water authorities set measurable benchmarks on their own actions, demonstrating accountability. The second set of strategies were overall climate resilience strategies. This set included actions that were planned for in the future or that were delegated to other actors. Resiliency was defined by the inclusion of plans to increase water equity and called for integrative, collaborative processes in drought management. The final strategies looked out how the public was engaged with all of these measures. In order to create a holistic and equitable water management plan, partnership is needed. These findings are specific to the urban contexts studied in this research. Other cities, however, should employ the same strategies to measure how effective their own drought management is. Based on the literature review, successful drought management requires certain levels of these strategies to be implemented. The first step of becoming more aware of drought management in cities could therefore be to measure their own policies using these strategies and the developed calibration scales (Figures 6, 7, 8, 11).

Following the identification of the current strategies, the third question sought to find out which are most effective in addressing drought and building urban climate resilience. This question was answered through the analysis of factors with the outcome of successful drought management in the QCA. Firstly, successful drought management was defined as the reduction of water usage following the implementation of a policy meeting future projections. In comparing the factors with these outcomes, the pathways ~I*~P + R*P were found. These pathways signify the importance of cities developing a long-term strategy for climate resilience. Without this strategy, interventions and public engagement are insufficient. The theories surrounding environmental policy integration and governing for sustainability are supported by this outcome. Inclusion of environmental issues in long term urban planning supports successful drought management. This will be necessary in these cities and many others in the coming years. Both Denver and Cape Town are expecting more sporadic and less predictable precipitation patterns, while precipitation is essential for a sustainable water supply. According to the findings of the QCA, all cities that look to build drought resilience should focus on creating a long-term strategy. These long-term strategies must include public engagement to reduce the vulnerabilities of disadvantaged communities.

The last sub question before addressing the entire research aim revolves around the effect of drought crises. Historical data from Denver is necessary in addressing this question. Following a severe drought period in the early 2000s, water usage decreased by 20% (Denver Water, 2020). The city had aimed for a 35% reduction. Several of the restrictions that went into place were employed permanently once the water crisis was past. Based on the projections of future water demand, this may be a necessary strategy for Denver. Over time, implementation of restrictions during less severe drought periods may be needed due to the consistency of the megadrought. Cities facing long-term drought could learn from this and begin by implementing light water restrictions that increase over time to increase public acceptance. These restrictions, in comparison to Cape Town's, are very limited.

Cape Town's water crisis pushed the city into extreme water saving measures. It is not possible to say yet if consumption will stay low, as it has risen since the end of the crisis. Regardless, the action taken during the period of crisis can be seen as exploitation of a window of opportunity. Breaking out of institutional patterns of path dependency often depends on a sudden shock to the system (Huitema et al., 2011). Limitations to the current way of water management were recognized during this shock period, and plans are still being implemented to increase the water supply as a response. In addition, the level of transparency with the public has increased as a result of the crisis. In order for users to reduce their water consumption, ideal levels of demand must be clearly communicated. All cities should work to increase their level of public engagement in order to build resilience to drought.

Both Denver and Cape Town have work to be done to become drought resistant, despite currently being on track for some of the water usage projections. As demonstrated in response to the first sub question, the whole system effects of drought are not yet addressed. While unfortunate, it appears that system shocks may be the way out of drought crises, according to the theory found. Policymakers should prepare for inevitable system shocks by developing scenario-based drought management. After a shock, policymakers would then be prepared to implement new policies for drought resilience.

Building on the four sub questions, the overall research question becomes answerable:

> *When analyzing the metropolitan areas of Denver and Cape Town, which drought management measures and implementation strategies can be viewed as successful and contribute to the creation of urban climate resilience?*

Climate resilience strategies and public engagement lead to successful drought management in Denver and Cape Town as seen in the second path (Table 3). Public engagement is thus necessary to create resilience within these cities. Residents can be relied on to do their part, as demonstrated by the crisis in Cape Town, but it must be clear what their part is. Water authorities must incorporate the needs of residents into their long-term strategies as well for sufficient public engagement. This can be achieved partly through the definition found for urban climate resilience. Environmental policy integration is the key factor of urban climate resilience, which means that both cities have the capacity to improve their drought management programs through sectoral integration. Overall, it is necessary for these cities to collaborate both with citizens and between institutions to create drought resilient cities.

The conclusions of this study present opportunities for future research which are discussed below.

6.3 Recommendations

The findings of this research could be applied in the field of policy transfer. As mentioned in Chapter 1, places that are not used to drought could be dealing with increased drought conditions in the future due to changes in rainfall patterns and intensity. It would benefit cities to learn from others that have established drought management policies. Policy transfer is highly contextual and often needs a catalyst actor or event to stimulate the transfer, extending it beyond the scope of this research. In the future, suitable cities for policy transfer from either of these two unique contexts could be investigated.

Another recommendation for future research extends beyond policy to overall governance. Public participation was identified as a key factor in this research. Investigating the effects of these policies on the residents in Denver and Cape Town could produce insight into what factors of public participation are the most successful in drought management, or general environmental policy. Grassroot initiatives play a large role in many environmental shifts in urban areas, so it is possible that local measures to decrease water usage, for example, are developed in response to policy. It is also possible that grassroot initiatives inspire policy, leading to a supportive relationship between local governance and policy initiation. The relationship between top-down and bottom-up policy creation could produce insights to factors for successful climate resilience strategies.

In general, it is also recommended to continue the research with a larger sample size. As noted in the discussion, policy document D1 provided another formula for successful drought management, but that cannot be taken further due to only one document having this factor combination. Through continuation of the research, it can be investigated whether this formula is indeed contributing to successful drought management. Expanding the sample size to include the drought management strategies from other cities would also be useful. During the process of this research, the cities of Melbourne, Australia and Barcelona, Spain were found to be suitable contexts to investigate measures in, similar in context to Denver and Cape Town. Continuation of this study increases the number of contexts for which successful drought factors can be found in.

Outside of the field of planning, multidisciplinary research is needed to solidify a definition of drought. Each field has a specific definition that suits the needs best of those within it. This has had its benefits in the past, but it is time to make an integrated definition to increase climate resilience. All of the measures in these policies focus on the water needed for people. The agricultural definition of drought must be integrated into this, as those urban residents also need food. Climate change is likely to impact crop health in the coming decades, so drought cannot just be about the water used within a city. At the same time, urban centers already cause a number of environmental issues and neglect ecological health. Levels of water needed to sustain wetlands or forests need to be included as well. Climate change will affect all sectors of life, so an integrated perspective is needed now more than ever to prepare for the future as drought is inevitable.

Each of these possible studies should incorporate the following reflections to produce robust results in line with the line of research.

6.4 Reflection and limitations

During the research process, the research question developed and narrowed in focus in response to reading literature on the subject. Initially, the research was focused on finding out how to apply successful water management practices to other areas. The focus of this question was too broad for one paper, requiring identification of practices and then applying them to a new context. One of the secondary research questions from this topic ended up becoming the focus of the entire research.

The main research focus also lessened the emphasis on technical interventions throughout the process. Initially, the focus of a secondary research question would have revolved around the factor of technical interventions. This would have required a more technical analysis to be completed. The presence of technical interventions in policy, therefore, was included in order to discuss important strategies like desalinization.

It was additionally planned to have a spatial analysis element within the research. Due to narrowing the focus of the research, it became more appropriate to include maps for visualization purposes rather than analysis. Spatial analysis could have been utilized in assessing technical interventions, but this topical focus came to also be outside of the research scope.

A methodological reflection is relevant for the research process. Utilizing open data was an important step in increasing the accessibility of climate change research. Finding open data on water usage, despite being public data in both cities, was remarkably difficult. In the case of Denver, it was necessary to contact the water authority for access to the public records. While processed within three days (as required by the Colorado Open Records Act (Colorado Revised Statutes, 2017)), it is interesting to note that the public records are available only on request. Both cities publish weekly/monthly water usage reports. Neither city archives the sources in an accessible or reliable way. Denver overwrites the same website address with each monthly publication, making it difficult to compare usage values over time. Cape Town's water usage reports are easier to find, but the frequency of weekly reports makes compiling them over several years a difficult task, as they are made available in PDF format. Both cities should make a complete archive of their reports to increase accessibility to public water data. This could be an important step for water users to take to become mindful of their contribution to water use levels.

A limitation to this study is the scale of the research. QCA offers an in-depth approach to policy analysis, but only for a small number of cases. The analysis of the ten selected policies fit the aim of the research paper but could be expanded in order to increase societal relevance. Through the analysis of more policy documents, it would be possible to establish a historical perspective to drought management strategies in both contexts. Expanding the number of policies analyzed may point to possible unsuccessful strategies to avoid as well.

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8. Appendices

Appendix I: Data Management Plan

1. General	
1.1 Name & title of thesis	Bridgit Hebner An Analysis of Drought Management Strategies for Climate Resilience

2 Data collection – the creation of data	
2.1. Which data formats or which sources are used in the project? For example: - theoretical research, using literature and publicly available resources - Survey Data - Field Data - Interviews	Theoretical research will be conducted using literature and government policy documents. In addition, published climate models will be used for analysis.
2.2 Methods of data collection What method(s) do you use for the collection of data. (Tick all boxes that apply)	☐ Structured individual interviews ☐ Semi-structured individual interviews ☐ Structured group interviews ☐ Semi-structured group interviews ☐ Observations ☐ Survey(s) ☐ Experiment(s) in real life (interventions) ☒ Secondary analyses on existing data sets (if so: please also fill in 2.3) ☒ Public sources (e.g. University Library) ☐ Other (explain):

2.3. (If applicable): if you have selected 'Secondary analyses on existing datasets': who provides the data set?	☐ Data is supplied by the University of Groningen. ☒ Data have been supplied by an external party: Publicly available City of Cape Town and City of Denver

3 Storage, Sharing and Archiving	
3.1 Where will the (raw) data be stored *during* research? If you want to store research data, it is good practice to ask yourself some questions: ● How big is my dataset at the end of my research? ● Do I want to collaborate on the data? ● How confidential is my data? ● How do I make sure I do not lose my data?	☒ X-drive of UG network ☐ Y-drive of UG network ☐ (Shared) UG Google Drive ☐ Unishare ☒ Personal laptop or computer ☐ External devices (USB, harddisk, NAS) ☒ Other (explain): UG's ArcGIS Online environment
3.2 Where are you planning to store / archive the data after you have finished your research? Please explain where and for how long. Also explain who has access to these data NB do not use a personal UG network or google drive for archiving data!	☐ X-drive of UG network ☐ Y-drive of UG network ☐ (Shared) UG Google Drive ☐ Unishare ☐ In a repository (i.e. DataverseNL) ☒ Other (explain): UG's ArcGIS Online environment The retention period will be indefinite, as only public data has been used.
3.3 Sharing of data With whom will you be sharing data during your research?	☒ University of Groningen ☐ Universities or other parties in Europe ☐ Universities or other parties outside

	Europe ☐ I will not be sharing data

4. Personal data	
4.1 Collecting personal data Will you be collecting personal data? If you are conducting research with personal data you have to comply to the General Data Privacy Regulation (GDPR). Please fill in the questions found in the appendix 3 on personal data.	No
If the answer to 4.1 is 'no', please skip the section below and proceed to section 5	
4.2 What kinds of categories of people are involved? Have you determined whether these people are vulnerable in any way (see FAQ)? If so, your supervisor will need to agree.	My research project involves: ☐ Adults (not vulnerable) ≥ 18 years ☐ Minors < 16 years ☐ Minors < 18 years ☐ Patients ☐ (other) vulnerable persons, namely (please provide an explanation what makes these persons vulnerable)
4.3 Will participants be enlisted in the project without their knowledge and/or consent? (E.g., via covert observation of people in public places, or by using social media data.)	
4.4 Categories of personal data that are processed. Mention all types of data that you systematically collect and store. If you use	☐ Name and address details ☐ Telephone number ☐ Email address

particular kinds of software, then check what the software is doing as well. Of course, always ask yourself if you need all categories of data for your project.	☐ Nationality ☐ IP-addresses and/or device type ☐ Job information ☐ Location data ☐ Race or ethnicity ☐ Political opinions ☐ Physical or mental health ☐ Information about a person's sex life or sexual orientation ☐ Religious or philosophical beliefs ☐ Membership of a trade union ☐ Biometric information ☐ Genetic information ☐ Other (please explain below):
4.5 Technical/organisational measures Select which of the following security measures are used to protect personal data.	☐ Pseudonymisation ☐ Anonymisation ☐ File encryption ☐ Encryption of storage ☐ Encryption of transport device ☐ Restricted access rights ☐ VPN ☐ Regularly scheduled backups ☐ Physical locks (rooms, drawers/file cabinets) ☐ None of the above

	☐ Other (describe below):
4.6 Will any personal data be transferred to organisations within countries outside the European Economic Area (EU, Norway, Iceland and Liechtenstein)? If the research takes places in a country outside the EU/EEA, then please also indicate this.	
5 – Final comments	
Do you have any other information about the research data that was not addressed in this template that you think is useful to mention?	Only publicly available data will be used.

Appendix II: QCA condition selection notes

1. Colorado Water Plan 2023

Explanatory factors: see (Colorado Water Conservation Board, 2023)

- Interventions
    - Grants and loans for water projects on local levels (p.5)
    - Programs – agricultural support and climate adaptation (p.5)
    - ‘Does not build projects, it advances projects’ (p.5)
        - Funding, analysis, technical expertise
        - Promote diversity, collaboration, recognize rural-urban divide, support roundtables (p.5)
    - ‘Tools for Action’ (p.10)
        - 50 for self
    - Water reporting (p.16)
        - Agricultural focus
    - Modeling, mapping (p.16,48,49)
    - Tool for environment and recreation water usage (p.17)
    - Evaluate water conditions (p.23)
    - ‘low regret strategies’ (p.23)
    - Common framework for adaptive planning (p.24)
    - Support of (p.39)
        - Water conservation/reuse
        - Public education
        - Collaborative water agreements
        - Storage with many purposes

        - Land use planning
        - Funding
    - Drought contingency planning (p.58)
    - Aquifer storage and recovery, reservoir reallocation, reuse demonstrations (p.116)
    - Improve efficiency of water permits and protect watersheds (p.122)
    - Policy change (p.155-156)
    - Watershed planning (p.158)
        - Stream management and IWM
    - Data sharing (p.164,183)
    - Pipelines and water routing (p.166)
    - 'buy and dry' alternatives for periodic water right sharing (p.169)
    - Restoration of watersheds and streams (p.170)
        - Nature based solutions
        - Flow enhancement (p.171)
    - Share agreements (p.172,197)
    - 'Benchmark and institutionalize water saving communities' (p.182)
    - Water loss tracking (p.184)
    - Integrated land use planning (p.187)
    - Removal of intensive grasses, invasive species (p.188,206)
    - Research (p.190)
    - Build capacity (p.197)
    - Economic opportunities (agriculture) (p.200)
        - Aide (p.201)
        - Efficiency in farming
    - Interagency watershed planning (p.214)
    - Resiliency toolkit for localities (p.227)
- Climate resilience strategies
    - Multi-stakeholder partnerships (p.v)
    - Risk acknowledgment for resilience (p.2)
    - Visions and Actions
    - Water Equity Task Force (p.5)
    - 'Vibrant communities', 'robust agriculture', 'thriving watersheds', and 'resilient planning' (p.8)
    - Scenario planning approach (p.18)
    - Gap instead of water shortages (p.17)
    - Recognition of basin challenges (p. 120-121)
    - Formulation of specific basin goals (p.122)
    - Multi-purpose projects, not just meeting water needs (p.143)
    - Balanced mix of institutional, planning, and local tools (p.153)

  - Equity and environmental justice (p.160)
  - Forest health focus for watershed health (p.206)
  - River frameworks for health and guides (p.208-209)
  - River programs (p.213)
  - Build water security (p.216)
  - Roundtable projections (p.221)
  - Innovation (p.226)
- Role of the public
  - 'Get involved' (p.iv) 'call to action' (p.5) use plan to inform yourself (p.6)
    - Rely on 'robust stakeholder input' (p.iv)
    - Plan aimed to get residents to act (p.6)
  - Indigenous knowledge, 'water is life' (p.3)
  - Collective action across all levels (p.3)
  - Driven by innovation (p.5)
    - 1800 local projects/plans
  - Sector specific workshops for +1200 stakeholders (p.5)
    - Targeted interaction
  - Scoping stage (p.15)
  - 'Tools for Action' (p.10)
    - 50 for partners
  - Social value of water as highest impact on water future (p.19)
    - Emphasis on innovating out of crisis
  - Prior appropriation (water as commodity) v acequias (water as resource) (p.52)
  - Collaboration groups (p.157)
  - Storage, conservation, water wise, healthy lands, and integrated sectors (p.176-177)
  - 'Positive discussion space' (p.191)
  - Peer programs (p.196)
  - Outreach education and campaign (p.222)

Overall

Demanding of public, but provides good tools and help to get there, met past water conservation goals from last drought (p.4), and acknowledges challenges in achieving resiliency.

2. Water Shortage Response Implementation Plan 2020

Explanatory factors: see (Denver Water, 2020)

- Interventions
  - Indicators

        - Case by case measures depending on which indicators are active (p.5)
    - Response tools
        - Water budgets for large users (p.3)
        - Water use restrictions (p.7) – heavily outdoor
            - Minimize restrictions on water-based businesses (p.8)
            - Exemptions on trees and perennials (p.8)
        - Water rationing (p.7)
        - Water shortage pricing (p.9)
    - Response actions
        - Chart for water usage for various sectors (p.12-16)
    - Use of recycled water (p.10)
    - Water source augmentation (p.10)
    - Fixed-amount water contracts (p.18)
- Climate resilience strategies
    - Four stages/ scenario planning (p.7)
    - Public communication and media (p.18)
    - Permanent implementation of some restrictions from 2002-2003 drought (p.2)
- Role of the public
    - Rules on lawn watering (p.2)
    - Receiver of communication and education of water shortages (p.7)
        - Referred to as the customer throughout
        - May receive warnings and fines, or restrictions will be installed for repeated violations (p.9)

Overall

Water usage 20% less since 2003 (aimed for 35%) (p.2,22).

3. Denver Water Efficiency Plan 2017

Explanatory factors: see (Denver Water, 2017)

- Interventions
    - Efficiency benchmarks (from p.13 on)
    - Collaboration with customers to provide targeted information (p.8)
    - Free auditing for problem finding (p.14)
    - Rebates (p.14,18,35)
    - Retrofitting in low-income areas (p.14)

    - Landscape programs (p.18)
    - WaterSense Challenge program (p.22)
    - Efficiency Credits (p.22)
    - Water budget (p.28,32)
    - Develop benchmark for public spaces (p.31)
    - Sector specific benchmarks for industry (p.34)
    - Transparent self-metering (p.37)
- Climate resilience strategies
    - From conservation to water efficiency (p.1)
        - Balancing customer needs and water saving
    - Integrated plan to combat heat island and stormwater runoff, as well as enhance public spaces (p.2)
    - Working towards 40 gal per resident per day (p.2)
    - 5-year horizon – longer in another document (p.3)
    - Voluntary – higher use=higher cost (p.3)
    - Plan to make resilient to warming climate, drought, economic change (p.5)
- Role of the public
    - Customers lead through thought leadership (p.1)
        - Marketing and targeted communication (p.15,20)
    - Plan success on number of customers using water efficiently (p.2)
    - For health, safety, and liveability (p.2)
    - Water Efficiency Working Group (p.2)
        - Online and stakeholder group feedback seeking (p.2)
        - Efficiency defined together (p.6)
    - Targeted awareness towards inefficient consumers (p.5,6)
    - Inform consumers of what is efficient use, compare to others in area (p.7)
    - Community Based Social Marketing (p.50)

Overall

No interventions taken by Denver Water, just social marketing campaign for the public – but moving away from economic goals towards social resilience.

4. Denver One Water Final Report 2021

Explanatory factors: see (City and County of Denver et al., 2021)

- Interventions
    - Water recycling, greywater reuse, rainwater capture (p.9)
    - De-silo, follow resource management model, and create a proactive water system model (p.12)

    - Leadership, monitoring, connecting (p.22)
    - Strengthen communication and connections (p.27)
    - Identification and implementation of multi-benefit projects (p.33)
        - Framework for identifying
    - Proactive public private participation (p.39)
        - Pursue funding (p.39,45)
        - Policy for land and water usage
    - Implementation of projects (p.47)
        - Plan integration (p.51)
    - Green infrastructure (p.51)
        - Restoration of local systems, room for river
        - Integrated water knowledge into plans
    - Precise definitions and benchmarks for water conservation (p.51)
        - Uniform guidelines
    - Research on water reuse (p.51)
- Climate resilience strategies
    - Partnership of six entities (p.2)
    - Unified approach with standard, coordinated agency collaboration (p.8-9)
        - Institutionalized
    - Unified vision with conservation and stewardship (p.9)
    - 5 goals (p.11)
        - Collaboration, multi-benefit projects, community support, resilience, and integrated water management
    - 6 visions (p.13)
        - Equity, strong neighborhoods, accessibility, economic diversity, resilience, healthy
    - Advisory group (p.17)
        - NGO, roundtable, research, neighborhood organizations, engineering, and utilities
    - Water-energy and water-food integration (p.33)
    - Coordination of climate mitigation and adaptation (p.45)
- Role of the public
    - Stakeholder engagement and outreach to communities for awareness of water problems and opportunities (p.11)
    - 800 surveyed for community visions (p.15) – 62% support plan
        - High quality water, efficient management, reducing vulnerability to drought, enhance environment, affordable, lower flood risk, enhance recreation
    - Workshops, polling, social media, surveys (p.16)
    - Education on water cycle, conservation (p.39,51)

Overall

Visionary plan with strong goals and community engagement, but no defined benchmarks on what is to be achieved for a resilient future.

5. Colorado Water Supply Outlook Report (2024)

Explanatory factors: see (Natural Resources Conservation Service, 2024)

- Interventions
  - Snowpack monitoring (p.1)
  - Drought monitoring (p.3)
  - Precipitation monitoring (p.5)
  - Reservoir storage levels (p.6)
  - Streamflow (p.7)
- Climate resilience strategies
  - Including of 30-year statistical normal (p.37)
  - Uncertainties highlighted (p.39)
- Role of the public
  - Explanations on graph reading (p.38,40)
  - Transparency on forecast creation (p.39)

Overall

No explicit reference to resilience or public engagement. It is a highly technical report with some assistance on making it accessible.

6. Cape Town Water Strategy Feb 2020

Explanatory factors: see (City of Cape Town, 2020)

- Interventions
  - Water pricing, but free for those who cannot afford tariffs (p.5,21,62)
  - Water efficiency and recycling though by-law and planning revisions (p.5)
  - Water network management to cut losses, write off debts for leak repairs (p.5,21)
  - Develop new water supplies (p.5)
  - Water sensitivity through stormwater management, aquifer recharge, recycling by new regulation and new infrastructure (p.5,37)
  - Desalination plants (p.7)
  - Water control devices, pressure management zones, water leak finding, and night-flow monitoring (p.22)
  - Alternative water for non-drinking functions (p.22)

    - Clearing alien vegetation (p.35)
    - Upgrading capacity and performance of wastewater treatment (p.50)
- Climate resilience strategies
    - ‘Number one water-saving city’, but want to prepare for climate change, explicit goal of water resilient city (p.1)
    - Aim of robust strategy, uncertain future, increase supply by 300 mil L per day for 10 years (p.3,25)
    - Reduce likelihood of severe restrictions through regular light restrictions (p.7)
    - Working with nature to enhance water resilience (p.11)
    - Slow, store, repurpose rainwater, diverse water sources (p.11,30)
    - Connect new economic opportunities to water (p.11)
    - Connection of safety and sanitation in informal settlements (p.14)
    - Scenario planning for high/low demand with incremental/step changes in water availability with annual reviews (p.28-29,34)
    - Adaptability and scalability of water sources (p.32)
    - 3 restriction levels (p.40)
    - Path to water sensitive city by 2040 (p.50)
    - Plans in sectors of transition, development, and resilience with monitoring (p.66)
    - Learn by doing and monitor results (p.82)
- Role of the public
    - Slogan of combined effort
    - Combined effort between city and citizens (p.1)
    - Collaboration, trust, transparency and accountability (p.4,57)
    - Active citizenship, improved engagement from government (p.5)
    - Replacing water intensive plants, installing more efficient household systems (p.18)
    - Water awareness and education (p.22)
    - Better complaint management and response (p.55)
    - Improvement of water bills (p.56)
    - Improved arrangements for users with governance (p.57)
    - Agreements for providing own water (p.63)
    - Collaborative labs and data (p.88)

Overall

Diverse plans, scenarios, and public role.

7. Cape Town Water Outlook March 2022

Explanatory factors: see (City of Cape Town, 2022)

- Interventions
  - Publication of report (p.1)
  - Decision Support System for improved management (p.16)
  - Assessment for understanding of demand curve (p.2)
  - Publication of weekly dashboards (p.3)
  - Water demand study (p.4)
  - Water data analysis (p.5)
  - Water demand prediction (p.5)
  - Supply augmentation (dams, groundwater, desalination, reuse) (p.6)
  - Timing and planning of projects (p.7)
  - Improvements to monitoring, analysis, and decision making processes (p.16)
  - Modeling (p.16)
  - Digital twin, AI, machine learning, infographic creation of data, and predictive tools to streamline management (p.17)
- Climate resilience strategies
  - Collaboration for resilient and sustainable water (p.1)
  - Transparency and accountability in water (p.1)
  - Investigates future water demands (p.1)
  - Scenario approach water demands (p.4)
  - Updates to Strategy and New Water Program (p.6)
    - Supply augmentation for future resilience (p.6)
  - Multiphase projects (delayed) (p.7)
    - Updated transparency
  - On track for capacity increase (p.8)
  - Invasive plant clearing (p.9)
  - Multi partnered projects w/ committees (p.10)
  - Schemes and desalination (p.11)
  - Importance of retaining institutional knowledge (p.16)
  - Projections of demand, related to program implementation (p.18)
  - Risk acknowledgment, lack of buffer period on projects (p.18)
- Role of the public
  - Report established to inform public
  - Part of new relationship with water (p.1)
  - Audience of this outlook report (p.1)
  - Returning to pre-drought demand levels (p.4)
  - Collaborative motto (all pages)
  - Stakeholder engagement (p.15)
  - Demonstration plant (p.15)

Overall

Informative on water levels, on track for 2030 goals. No longer a buffer period, therefore imperative to achieve on time completion of current projects.

8. City of Cape Town Resilience Strategy 2019

Explanatory factors: see (City of Cape Town et al., 2019)

- Interventions
  - 75 actions (p.4)
  - Integrated approach (p.8)
  - River rejuvenation for natural wetlands (p.64)
  - Extend Water Resilience Advisory Committee (p.69)
  - Partnering solutions – large water users in communication with Water and Sanitation (p.69)
  - Partners for funding in Greater Cape Town Water Fund (p.70)
  - Clear invasive vegetation near catchments (p.70)
  - Aquifer recharge (p.71)
    - Including scrutiny in processes and research
  - Green economy research and training, sustainable supply chains, and make eco-industrial parks (p.79-81)
  - Business forum on resilience, especially for resource use, create a societal connection (p.90-91)
    - Promote tourism that was hit by drought (p.92)
  - Develop scenarios to prepare businesses for climate events (p.94)
  - 'Build back better' protocols for public infrastructure after a crisis (p.105)
    - Simulations of events (p.106)
    - Resilience assessments for neighborhoods (p.108)
  - Emergency information app with contact and vulnerabilities (p.110)
  - Bore hole data collection (p.111)
  - Plan for emergency funds (p.116)
  - Invest in community engagement (p.128)
  - Monitor outcomes (p.135)
    - Spread common understanding of water resilience, repeat and open assessments across all stakeholders (p.136)
    - Develop vulnerability indices (p.137)
- Climate resilience strategies
  - 20 goals (p.5)
  - Address existing inequalities (p.7)
  - Become connected, create jobs, be ready for shock, and collaborate (p.6-7)

- Commitment to working together with a common goal, not direction towards how it should be accomplished, but a process (p.8)
- Exchange of resilience ideas with 100RC network (p.18)
- Water Resilience CoLab (p.19)
- Supporting economic opportunities, promotes cohesive communities, ensuring social justice, empowering stakeholders (p.22,85)
- Social cohesion goals – Pillar 1
  - Focus on woman and girls in disaster resilience (p.109)
- Mobility goals - Pillar 2
- Spatial plans (p.66,68)
- Focus on informal settlements (p.73-76)
- Drought as learning opportunity (p.118)
  - Use data available (p.130)
- De-siloed projects for infrastructure resilience (p.121)
  - Include in early-stage planning (p.122)
  - Integrated, adaptive risk management for times of pressure (p. 124-127)
- Scenario planning and open source tool for helping affected after events (p.132,133)

- Role of the public
  - Acknowledgment of role of the public in reducing water consumption so far (p.3)
  - Adress crime, poverty, and mental health issues (p.6)
  - Building resilience together – current lack of social cohesion – but could come together during crisis (p.8)
  - 11000 interviews with those in informal settlements, workshops later to confirm strategy choices (p.20)
  - Create network of support with neighbors, volunteer, make emergency plans, organize community events, and learn a new skill (p.25)
  - Public education on aquifers
  - Inclusive participation for empowering residents (p.128)

Overall

Policy language that demands a lot of the public, but overall very thorough and includes plenty of actions (interventions) as well as goals (resilience) to aide in this.

9. Critical Water Shortages Disaster Plan – Public Summary 2017

Explanatory factors: see (City of Cape Town, 2017)

- Interventions
    - Water rationing (p.1)
        - Predefined limits (p.5)
        - Supply limitation and pressure management (p.5)
        - Outages at some times (p.5)
        - Water management devices (p.5)
        - Water collection sites (p.6)
        - Critical services exempt until phase 3
    - Water injection into sewage system (p.6)
    - Reduction of critical service in a disaster scenario (p.7)
- Climate resilience strategies
    - 3 phases/ scenario planning
    - Pessimistic approach (p.3)
    - Seven departments (p.3)
    - Minimizing impact of daily life (p.3)
    - Coordinated processes in response (p.4)
- Role of the public
    - Limited operational details for public (p.1)
    - Call for action for the public to act together in conserving (p.7)
    - Store 5L of water for emergency use (p.5)

Overall

Reduction in water usage by nearly 50%. Also noted in (Enqvist & van Oysen, 2023).

10. City of Cape Town Water Services Development Plan 2022-2027 (2023)

Explanatory factors: see (City of Cape Town, 2023)

- Interventions
    - Restructuring for goal achievement (p.8),
    - Value water, build capacity, design for adaptation, live with water, work with nature, when it rains, slow (down), store and repurpose (water), stimulate the green economy (p.10)
    - Improving water in informal settlements, network management (p.13)
        - Provision of taps and toilets in informal settlements (p.23)
    - Maintain/replace ageing infrastructure (p.27)
    - Promotion of densification (p.27)
    - Smart technologies

        - Desalination, drilling, metering, pipeline construction, refurbishment, pressure management, osmosis technologies, expanded database, wastewater plant updates (p.30)
    - Water schemes (p.34)
    - Wastewater treatment (p.36)
    - Reallocation of dam supplies for bulk water (p.40)
    - New infrastructure to increase capacity and maintenance of old (p.45,75)
    - Fines against pollution (p.49)
    - Blue and Green Drop certification (p.52)
    - Metering and retrofitting (p.56)
    - Increasing staff capacity (p.63)
    - Comprehensive water loss reduction (p.80)
    - Addressing water losses (p.80)
- Climate resilience strategies
    - Maintain, grow infrastructure, and become water sensitive (p.8,70)
    - Safe access, wise use, sufficient and reliable water with a diverse set of sources, shared benefits > overall water sensitivity (p.10)
    - Balanced water work supplies in case of issues (p.45)
    - Recognition of challenges to plan implementation (p.54-55)
    - Emphasis on informal settlements (p.68)
    - Public works for job creation (p.69)
    - Emphasis on water quality (p.77)
- Role of the public
    - Inclusivity and trust, work together and across boundaries (p.10)
    - Accountability, trust, and accessibility, customer-oriented (p.13)
    - Electronic billing (p.30)
    - Customer Service Charter, plus quality assurance (p.62)
    - Surveying (p.65)
    - Raise awareness of reporting leaks and blockages (p.80)
    - Lack of systematic feedback loop and reporting (p.87)

Overall

Technical report, acknowledgement of heavy challenges especially pertaining to customers.

Appendix III: QCA Outcome Calculations

In this Appendix, each policy period is first presented. This is followed by the population per year and population projections per city. Lastly, the projected demands are shown.

Denver:

D3	Avg daily gal per capita
Nov-17	140.08
Dec-17	140.08
Jan-18	145.89
Feb-18	145.89
Mar-18	145.89
Apr-18	145.89
May-18	145.89
Jun-18	145.89
Jul-18	145.89
Aug-18	145.89
Sep-18	145.89
Oct-18	145.89
Nov-18	145.89
Dec-18	145.89
Jan-19	139.76
Feb-19	139.76
Mar-19	139.76
Apr-19	139.76
May-19	139.76
Jun-19	139.76
Jul-19	139.76
Aug-19	139.76
Sep-19	139.76
Oct-19	139.76
Nov-19	139.76
Dec-19	139.76
Jan-20	150.26
Feb-20	150.26
Mar-20	150.26
Apr-20	150.26
May-20	150.26
Jun-20	150.26
Jul-20	150.26
Aug-20	150.26
Avg	144.41

D2	Avg daily gal per capita
Sep-20	150.26
Oct-20	150.26
Nov-20	150.26
Dec-20	150.26
Jan-21	138.88
Feb-21	138.88
Mar-21	138.88
Apr-21	138.88
May-21	138.88
Jun-21	138.88
Jul-21	138.88
Aug-21	138.88
Avg	142.67

D4	Avg daily gal per capita
Sep-21	138.88
Oct-21	138.88
Nov-21	138.88
Dec-21	138.88
Jan-22	144.62
Feb-22	144.62
Mar-22	144.62
Apr-22	144.62
May-22	144.62
Jun-22	144.62
Jul-22	144.62
Aug-22	144.62
Sep-22	144.62
Oct-22	144.62
Nov-22	144.62
Dec-22	144.62
Avg	143.185

D1	Avg daily gal per capita
Jan-23	126.27

Feb-23	126.27
Mar-23	126.27
Apr-23	126.27
May-23	126.27
Jun-23	126.27
Jul-23	126.27
Aug-23	126.27
Sep-23	126.27
Oct-23	126.27
Nov-23	126.27
Dec-23	126.27
Avg	126.269

D5	**Avg daily gal per capita**
Jan-24	136.4187
Feb-24	136.4187
Mar-24	136.4187
Apr-24	136.4187
May-24	136.4187
Jun-24	136.4187
Jul-24	136.4187
Aug-24	136.4187
Sep-24	136.4187
Oct-24	136.4187
Nov-24	136.4187
Dec-24	136.4187
Avg	136.42

Yellow = Projected consumption

	Average daily gallons per capita	Population	
2016	143.86	1,238,000	
2017	140.08	1,248,000	1.008078
2018	145.89	1,261,000	1.010417
2019	139.76	1,270,000	1.007137

2020	150.26	1,277,000	1.005512
2021	138.88	1,287,000	1.007831
2022	144.62	1,295,000	1.006216
2023	126.27	1304753.52	
2024	136.42	1314580.51	

	Projected Demand	Projected Population
Weak Economy	516897797.5	3817098.851
Adaptive Innovation	523146993.6	4161583.781
Hot Growth	639203493.9	4317748.543
Adjusted		
Weak Economy	135.4164033	
Adaptive Innovation	125.7086295	
Hot Growth	148.0409263	

Cape Town:

Null(ML)	ML/day	**L/capita**
Jan-14	1061.00	268.4591
Feb-14	1163.00	294.2676
Mar-14	1064.00	269.2182
Apr-14	964.00	243.9157
May-14	878.00	222.1556
Jun-14	741.00	187.4912
Jul-14	730.00	184.708
Aug-14	755.00	191.0336
Sep-14	809.00	204.6969
Oct-14	917.00	232.0236
Nov-14	1002.00	253.5306
Dec-14	1168.00	295.5327
Avg	937.67	237.25

C4	ML/day	**L/capita**
Oct-17	643	152.3695
Nov-17	645	152.8435
Dec-17	660	156.398
Jan-18	638	148.1145

Feb-18	571	132.5602
Mar-18	571	132.5602
Apr-18	555	128.8457
May-18	563	130.7029
Jun-18	556	129.0779
Jul-18	527	122.3454
Aug-18	540	125.3634
Sep-18	515.5	119.6756
Oct-18	564.5	131.0512
Nov-18	560.5	130.1225
Dec-18	559.5	129.8904
Jan-19	592.75	134.944
Feb-19	622.75	141.7738
Mar-19	593.25	135.0579
Apr-19	599	136.3669
May-19	585.75	133.3504
Jun-19	549	124.984
Jul-19	559	127.2606
Avg	580.48	134.35

C3	ML/day	**L/capita**
Aug-19	566.3333	128.9301
Sep-19	629	143.1966
Oct-19	678	154.3518
Nov-19	689	156.8561
Dec-19	748	170.2879
Jan-20	733	159.3899
Avg	673.89	152.17

C1	ML/day	**L/capita**
Feb-20	783	170.2624
Mar-20	817	177.6556
Apr-20	706	153.5188

May-20	719	156.3456
Jun-20	622.13	135.2814
Jul-20	666.5	144.9296
Aug-20	643.33	139.8913
Sep-20	654.5	142.3202
Oct-20	696.5	151.453
Nov-20	731.4	159.042
Dec-20	734	159.6074
Jan-21	780.5	166.5416
Feb-21	801.5	171.0225
Mar-21	785.75	167.6618
Apr-21	786.4	167.8005
May-21	753	160.6737
Jun-21	724.2	154.5284
Jul-21	726.25	154.9658
Aug-21	735.4	156.9182
Sep-21	734.75	156.7795
Oct-21	725	154.6991
Nov-21	788.6	168.2699
Dec-21	845.75	180.4645
Jan-22	891	186.5382
Feb-22	910.25	190.5684
Avg	750.47	161.11

C2	ML/day	**L/capita**
Mar-22	899.75	**188.3701**
Apr-22	830.25	**173.8197**
May-22	756.2	**158.3167**
Jun-22	734	**153.669**
Jul-22	725.6	**151.9104**
Aug-22	766.4	**160.4522**
Sep-22	788.5	**165.079**
Oct-22	852.25	**178.4256**
Nov-22	913.4	**191.2278**
Dec-22	718.6	**150.4449**
Jan-23	941.2	**193.3621**

Feb-23	978.25	**200.9738**
Avg	825.37	**172.17**
C5	ML/day	**L/capita**
Mar-23	880.25	180.8404
Apr-23	857	176.0639
May-23	823.8	169.2432
Jun-23	794	163.121
Jul-23	789.25	162.1452
Aug-23	808.2	166.0383
Sep-23	789.75	162.2479
Oct-23	868	178.3238
Nov-23	949.5	195.0673
Dec-23	974.6	200.2239
Jan-24	1005.4	202.7032
Feb-24	975	196.5742
Mar-24	938.5	189.2152
Apr-24	893	180.0418
May-24	897	180.8482
Avg	882.88	180.18

Year	Population
2014	3952185.00
2016	4131452.00
2017	4220004.00
2018	4307478.00
2019	4392562.00
2020	4598785
2021	4686518
2022	4776501
2023	4867551
2024	4959960
2040	5800000

2040 Water demand	Mil Kl/year	ML/year	ML day	L/day/capita
Low	462	462000	1265.753	218.2333
Medium	500	500000	1369.863	236.1833
High	571	571000	1564.384	269.7213