THE ROLE OF PERCEPTION ON WATER ALLOCATION AND CONSERVATION MANAGEMENT IN WESTERN NORTH CAROLINA

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by
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Abstract

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Western North Carolina (WNC) has traditionally given limited attention to conservation in water management primarily due to the fact that the area is a water rich region, with high annual rainfall and low population. Recent droughts and high population growth have put stresses on many water supply systems. In order to effectively deal with the new stresses on water supply, many new management practices were initiated, prompted by both state mandates and local pressure. Decision-makers are apt to make decisions based on perceptions, personal beliefs, and historical practice rather than on relevant data. Therefore, there is a need to understand the perceptions of decision-makers which influence management decisions. Results from eighty-five surveys and nine interviews are used to understand how decision-maker perceptions relate to active conservation policies. Water use, climate, and population data are also used to understand the effects of increased water management in the two case study towns of Boone and Hendersonville. Results indicate that while water management in WNC encompasses many aspects of sustainability, the region still has much room to improve to ensure that all current and future needs are met.

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Chapter 1: Introduction

Water management encompasses a variety of water issues from managing supply and demand, to examining ecology, equity, or economics along the way. In addition to the wide range of topics which can be included in water management, there are also a wide range of approaches. Not surprisingly, many of these approaches invoke the term 'sustainable' or are sustainability-oriented. Sustainable water resources management (SWRM) is one of these approaches to water management in which the systems are "designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental, and hydrological integrity" (Loucks 2000). This definition encompasses three main aspects, which make it appear complete: consideration for future generations, society's needs, and environmental concerns. Examination of other water management approaches provides additional insight. Water management, regardless of what you call it, inherently includes aspects of sustainable development by focusing on future needs and not using more than what is available (Tarlock 2011). Sustainable urban water management (SUWM) goes a little deeper into the philosophical side of water management compared to SWRM. SUWM is an integrated, adaptive, and participatory approach to water management (Brown and Farrelly 2009). This integrated approach is common among several other management practices as well, including integrated water resource planning (IWRP) and integrated water resources management (IWRM). IWRP focuses more on supply and demand within a climate change context. It does this through adaptive management, efficiency of use, and public engagement (Fane and Turner 2010). IWRM on the other hand stresses the importance of various

management entities (water policy makers, water resource managers, and scientists) working together to find a balance between society and ecosystem needs (Falkenmark 2004). Another use of sustainability in water management emphasizes efficiency of use as well as economic efficiency (Dalhuisen et al. 2003).

None of the definitions or explanations of water management options described above necessarily contradict with one another; rather they each focus on a different aspect of water management. This paper uses the term sustainable water management (SWM) to describe a more complete picture of SWRM as described above. SWM uses an adaptive, integrated, and participatory approach to provide water for social, economic and ecological needs now and in the future. This paper specifically addresses society's needs for and uses of the water supply, while keeping in mind the other aspects and philosophical approaches which are also important to SWM. This includes access and availability of water supply for human populations as well as efficient use and extraction of water.

Although the term sustainability is often a contested issue, it can be used in practices such as 'sustainable development' and can also be a useful way to evaluate water policy in the United States (Tarlock 2011). SWM aims to be a useful way to approach management by: highlighting unsustainable laws so they can be changed; supporting good practices with a positive label; and by being used as a standard to limit unsustainable uses. Academic research about sustainability and water management is abundant, much of it concerning how a successful system should look, barriers to sustainability, and the importance of attaining certain sustainability goals, which have been incorporated into this definition of SWM. Because much less is known about sustainability in real world applications, additional research is needed concerning the application and evaluation of existing systems.

Water supply management addresses indicators of sustainability, such as providing for public needs now and in the future, through public policy such as allocation or conservation

policies. This paper takes a non-traditional stance and views both allocation and conservation policies as supply-side management. Traditionally allocation and conservation policies have been studied from the perspective of demand-side management, rather than supply-side management (Larson, Gustafson, and Hirt 2009). However, in a recent survey, Western North Carolina decision-makers report the biggest benefit of conservation programs to be increasing the water supply. This indicates that decision-makers consider these types of programs as part of supply-side management and supports this non-traditional stance on supply versus demand-side management.

Statement of the Problem in Western North Carolina

Water management in Western North Carolina (WNC) has traditionally received little attention: a literature search using Google Scholar and Academic Search Complete returned no relevant sources concerning water supply management in North Carolina since 2000, out of 200+ returned citations. Results included papers concerning water quality or hydrologic processes in WNC, and two papers on water supply management in the piedmont of NC, but no papers on supply management in WNC. This is likely due to the fact that the area is a water rich region, with high annual rainfall and low population. However, there has been an increase in the frequency of droughts in WNC and the broader Southeast region. Droughts occurred in 2002-2003, 2007-2008, and 2010, temporarily reducing the available supply throughout the region. In addition, high population growth has been experienced throughout the region. For example, Watauga County experienced 20% growth between 2000 and 2010 (U.S. Census Bureau 2000; U.S. Census Bureau 2010). Increased population and a decrease in available water put stress on many water supply systems in WNC, particularly the towns of Boone and Hendersonville. In order to effectively deal with the new stresses on water supply, many new policies and management practices were initiated. These were prompted by both state mandates and local

pressure. Water management has generally not been well documented throughout the region or understood by those outside of the region and decision-making process. Therefore, there is a need to understand the drivers of these policies and what information is used by decision-makers when creating the policies.

Decision-makers are apt to make decisions and communicate based on perceptions and personal beliefs rather than scientific data (Caplan 1976; White, Corley, and White 2008; Cockerill 2013). In addition, it is important to know what water management policies are in WNC, because a comprehensive understanding of the management practices in the area does not exist at this time. Finally, it is important to understand the effects of these new water management policies and practices. These water management issues are not only important to understand in WNC, but are potentially relevant throughout Southern Appalachia and the Southeast.

Three research objectives aid in understanding policies in WNC, how they came about, and their associated effects. They are to: (1) understand the perceptions of decision-makers who influence decisions; (2) examine how these perceptions relate to active allocation and conservation policies; and (3) analyze the effects of the policies in relation to changes in residential demand. This study focuses on 22 counties in WNC as well as a case study of two medium-sized towns within the region: Hendersonville and Boone. Research objective (1) specifically focuses on decision-makers' concern for water and conservation as well as ideas about growth. These are divided among perceptions which are agreeable to goals of SWM and those that are contradictory to SWM. Research objective (2) examines active allocation policies which are tied to growth and conservation policies relating to education, rebates, and pricing. Research objective (3) uses interview data and monthly water use data from 2000 and 2010 to understand effects of conservation policies. While the first two research objectives examine these issues at two scales (WNC and the two case studies), the third research objective only

focuses on the two case study towns of Boone and Hendersonville. Each of these research objectives have been created and approached in a way that begins to outline what is happening in WNC in terms of SWM.

Study Area Justification

While there is an established body of research on water supply issues in arid regions such as the American Southwest (Hanak 2008; White, Corley, and White 2008; Larson et al. 2011), much less work is available on areas rich in water resources such as WNC. For this reason, this study provides a unique perspective to the existing literature. WNC receives between 40 and 50 inches of rain per year and because of this, water supply management has never been paid much attention in the area. Three substantial droughts between 2000 and 2010 brought many water supply issues to light and brought up concerns for future water supply issues in the area due to population growth and climatic trends. Global climate change (GCC) models have predicted a wide range of future scenarios in NC including both increases and decreases in precipitation (Cowell and Urban 2010). While it is uncertain how much drought frequency and intensity will increase, they are not expected to decrease (State Climate Office of NC 2012). This uncertainty could make management and planning for the future more difficult (Fane and Turner 2010). WNC is also unique in that it contains the headwaters for eight major watersheds, has a relatively low permanent population (the largest city has approximately 84,000 inhabitants), and experiences high tourism throughout the year. According to U.S. Census data for seasonally occupied homes, WNC has a relatively high number of second homes (20.5%) compared to the remainder of NC (13.7%).

This thesis also examines water supply management more in depth through case-studies in the towns of Boone and Hendersonville. In a survey of water management decision-makers conducted in the fall of 2011, the towns of Boone and Hendersonville had two of the

highest number of respondents. In addition, respondents had the opportunity to volunteer for further in-depth interviews. The higher response rate was assumed to be caused by recent issues in water supply management in the two towns, making it a salient issue. During recent droughts, water demand in Boone neared the maximum amount allowed by the state. In 2006, Boone reached 80%, the amount at which the state requires the process of obtaining a new supply be initiated (Town of Boone 2012). In the 2007-2008 drought, Hendersonville was listed as a Tier One drought-afflicted community by the state, meaning that they were within 100 days of running out of water, which may have helped to facilitate the acquisition of an emergency water intake on the French Broad River (Schulman 2008; NC Division of Water Resources 2013). Both of these issues have spurred on a wealth of new management practices within the two towns. In addition, the two towns have also experienced high growth rates between 2000 and 2010. Boone's population rose 27% to 17,122 in 2010 while Hendersonville grew by 26% to 13,137. This similarity makes the towns appropriate for comparison. Studying the larger WNC region will help explain if Boone and Hendersonville are truly representative of or unique to WNC.

This thesis provides a better understanding of how aspects of SWM may or may not be employed in WNC. First, it provides a general understanding of the types of water allocation and conservation policies in WNC, and provides an understanding of some of their effects in two of the towns. It also gives more insight into the relationship between policies and the perceptions of decision-makers. Finally, it gives more understanding into the relationship between water policy and growth. The results will be disseminated to both state and local decision-makers as well as interested non-profit organizations. This allows decision-makers to have a better understanding of what is happening throughout the region.

Chapter 2: Literature synthesis

Understanding the relationships between perceptions of decision-makers, water conservation and allocation policies, and effects on growth or water use is not a straightforward task. There is however, a broad base of knowledge and literature informing this research. Much of the research calls for new approaches in water policy as well as further research in relevant topics (Falkenmark 2004; Viviroli et al. 2011). As with many water related issues, there has been more research conducted in arid regions, such as the American Southwest, while there is a need for more research in areas such as the Southeast in order to reach a similar level of understanding. Scientific studies are not the only avenues necessary for research on water policy. While science is constantly influenced by social norms and politics, there are not enough studies on how decision-makers use the science, relate to water politics, and form water policy; particularly more research is needed in understanding why certain policies are chosen (Olmstead and Stavins 2009; Agnew 2011).

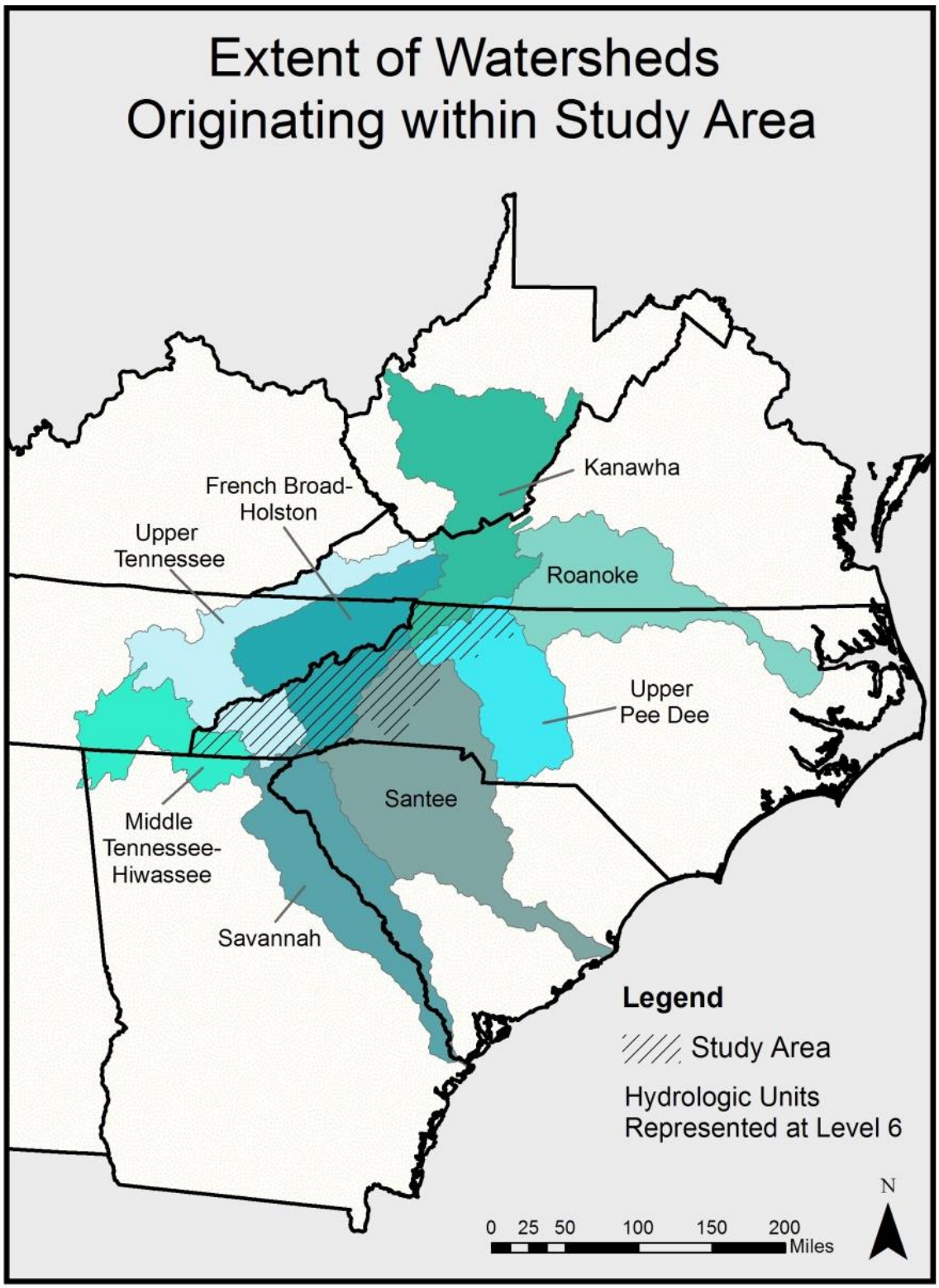
Hydrology of Western North Carolina

Water supply in Western North Carolina (WNC) comes from a combination of both groundwater and surface water. Surface water in the area is primarily characterized by small streams and rivers. There are few remaining potential dam sites due to the steep and complex topography of the area, therefore most of the surface water supply is taken directly from run of the river intakes (High Country Council of Governments 2010). The area is home to hundreds of miles of streams; however, stream flows are relatively low across the region. Like many

mountainous regions, WNC contains the headwaters for eight major watersheds (see Figure 1). Watauga County alone is home to the headwaters of the Watauga River (French Broad-Holston), New River (Kanawha), Yadkin River (Upper Pee-Dee), and the Catawba River (Santee). Since larger downstream communities often rely heavily on surface water originating in headwater areas, headwater communities must consider large downstream users when managing the water source in order to ensure reasonable water use does not harm other water users under the riparian law (Feldman and Elmendorf 2000).

While many may argue that more knowledge is needed, hydrologic processes have been studied and documented throughout the Southeast. O'Driscoll et al. (2010) summarizes a number of studies on hydrologic processes in the Southeast. Many studies have looked at the effects of growth on water supplies, including increased runoff during storm events and decreased water quality (O'Driscoll et al. 2010). While much is known about hydrologic conditions and processes in the Southeast, mountain environments are unique and more research is needed in this area (O'Driscoll et al. 2010; Viviroli et al. 2011). One issue in mountain environments is that the area is marked by small headwater streams, which can make a region more susceptible to water shortages during drought conditions (Beniston 2003; Vanham, Rauch, and Fleischhacker 2009). There have also been several severe droughts in recent years. The drought of 2002 set many records as it lasted from 1998 to 2002. During this time, more than 200 municipalities across NC put water restrictions in place. The drought was seen as an anomaly, yet the drought of 2007 was worse than the drought of 2002; in fact it was the worst since 1895. During the drought, the NC Division of Water Resources identified thirty municipalities which were at risk for running out of water. Several of these municipalities were located in WNC, including Boone and North Wilkesboro (High Country Council of Governments 2010). These recent droughts helped to remind both the decision-makers and the public that water is not an unlimited resource, even in the southeast.

Figure 1. Map of watersheds and study area.



Global climate change (GCC) is expected to have a large impact on precipitation, drought frequency, and temperature. All of this directly affects future water supply, and thus must be taken into consideration in understanding water issues (Fane and Turner 2010). Most municipalities do not have a great understanding of GCC impacts on local water supply, but those who incorporate this information into plans will have a lesser risk to problems of water scarcity (Fane and Turner 2010; Hamlet 2011). A large number of factors affect the climate of WNC, and the Southeast in general, which means that GCC models do not have high certainty in predicting future climate scenarios for the region (Seager, Tzanova, and Nakamura 2009). Many models show southern Appalachia to have an increase in years having extreme droughts similar to recent experiences (State Climate Office 2012). However, climate models have also shown that these recent droughts are not extreme or unusual for the region and they have not been caused by GCC (Seager, Tzanova, and Nakamura 2009). Either way, these recent droughts put large amounts of strain on surface water supplies, as well as a delayed effect on ground water supply systems (Cowell and Urban 2010). In the Alps, it has been shown that droughts can diminish ground water recharge and supply by 20 - 70% (Vanham, Rauch, and Fleischhacker 2009). The high stress experienced in the Southeast was likely not only caused by the recent extreme or unusual droughts, but also increased demand on the water supplies (Seager, Tzanova, and Nakamura 2009). More frequent or severe droughts due to GCC could create a water supply which is more vulnerable to increases in water demand.

Water Management

Water management can be a contentious realm of study: everyone uses water and everyone has their own opinions about the best way to use and manage it. However, there have been recurring topics throughout the history of water management including finding supply, controlling use, new problems in managing water supply, and new approaches to managing

supply and use. Finding water supplies is often a favored water management practice especially among politicians (Gleick 2002; Larson, Gustafson, and Hirt 2009). This practice of focusing on a centralized and large scale system of supplying water is often called the 'hard path' of water management (Gleick 2002). The 'soft path' in contrast places more emphasis on efficient use of water through policy and new technology. Gleick (2002) argues that the soft path will be the best path to follow in the long run, even if it requires more effort to begin. The soft path is also less expensive than hard path infrastructure (Lach, Ingram, and Rayner 2005). While others may not address the problem as the hard vs. soft path, there are many recommendations for a new approach to water management, including emphasis on ideas related to SWM, such as organizational changes (Lach, Ingram, and Rayner 2005; Brown and Farrelly 2009; Fane and Turner 2010; Tarlock 2011). Past approaches have used a top down approach, relying on supplying enough water, while new approaches would use a bottom-up method where consumers are responsible for efficient water use (Larson et al. 2011).

Stakhiv (1998) shows how water management focused on controlling water, while a better, new path would be to focus on uses. This new soft path is especially seen to be effective in addressing GCC issues. SWM has historically been more prominent and successful in state and local government rather than at the national level (Tarlock 2011); therefore it could be best to address water management at this local level. Unfortunately, policies are often created with little scientific understanding (Cockerill 2013) and much information must be inferred. As knowledge and experience are gained, policies are not always updated because it is a lengthy and complex process (Healy and Ascher 1995).

Water supply management policies have traditionally been disconnected from water demand, land use, development, and ecological needs. This traditional approach has caused a number of problems which are beginning to be addressed through the creation of new short-term management practices (Lach, Ingram, and Rayner 2005). One way to alleviate the

ecological and social problems is through employing SWM related practices. In order to do this, a variety of approaches have been suggested including adaptive management, integrative approaches, and treating water as a commodity. In general, the solutions are not technological in nature nor do they require a better understanding of hydrologic processes or ecological needs; many of the solutions address gaps in social organization, political processes, and paradigmatic shifts (Fane and Turner 2010).

Adaptive management addresses the issues inherent in thinking of the world as a static place, and allows for ways to address issues such as GCC (Stakhiv 1998; Brown and Farrelly 2009; Fane and Turner 2010). In addition, it has been recommended by many to use an integrative approach in management, by connecting water to land use, place, social issues, ecosystem needs, and politics to create a holistic solution (Carmon and Shamir 2010; Fane and Turner 2010; Mitchell 2005; Tarlock and Lucero 2002). In addition, the shift from thinking of water as a 'right' to thinking of water as a commodity with value is important in the appropriate management of water resources (Serageldin 1995; Stakhiv 1998; Tarlock and Lucero 2002; Hanak 2008; Fane and Turner 2010). Each of these approaches allows for policies to be specific to the geographic location and the related social and ecological needs. They also take into account the uncertainty in future water availability due to global climate change.

Water Consumption

Water supply is affected by a number of human and natural influences, including withdrawals for residential or commercial uses, impervious surfaces, and climatic processes. However the largest human influence on water quantity comes from withdrawals due to growth and increased population. It is not a new idea that growth negatively affects water supplies. Alberti and Waddell (2000) created a GIS model to examine the impacts of growth on water supplies as well as other ecological resources. The EPA has used these and other studies to

create a report which outlines how water policy and growth need to be linked to create a sustainable future (U.S. EPA 2009).

Many management practices view it as important to be able to accurately predict and understand individual water use. Understanding how specific variables influence water use is an important component in predicting water use. Many studies have attempted to do so in regions across the world using a wide variety of methods, these will be explained in subsequent paragraphs. Results have shown that public water use can vary greatly depending on the climate, population, income, lot size, and a host of other variables depending on the area, while the most influential factor in predicting demand is population changes due to growth (Arbués, Garcıa-Valiñas, and Martınez-Espiñeira 2003; Fox, McIntosh, and Jeffrey 2009; Polebitski and Palmer 2010).

The most common method of understanding how each variable affects water consumption is through statistical analysis. Specifically, multivariate regression models are used to determine the impact of each variable. To understand that population, income, or price of water can explain 20, 30 or 40% of water demand is quite important. Occasionally, studies used bivariate or univariate statistical methods as well (Fox, McIntosh, and Jeffrey 2009). The multivariate regressions provide some of the most comprehensive understanding of each variable for this problem. It is interesting to note however that results vary greatly depending on the context from which the studies are drawn. The largest indicator for water demand is the price and pricing structure of water (Arbués, Garcıa-Valiñas, and Martınez-Espiñeira 2003; House-Peters, Pratt, and Chang 2010; Polebitski and Palmer 2010; Rosenberg 2010). While increasing block pricing structures are associated with lower demand, no structure is effective in changing demand at low base prices (Arbués, Garcıa-Valiñas, and Martınez-Espiñeira 2003). It should also be noted that higher prices and certain pricing structures have shown to negatively affect areas with high poverty rates, such as Mauritius (Madhoo 2011), and can

disproportionately affect minorities in depopulating areas, such as in Michigan (Butts and Gasteyer 2011). However, this is not expected to be the case in this relatively affluent and growing Appalachian region of the US.

Because so much residential water demand is used for outdoor water use, price is not the only factor that is widely accepted. Climate changes, such as exceptionally dry or hot summers, increase water use substantially. However, this seasonal effect is much greater in arid regions rather than humid locations (House-Peters, Pratt, and Chang 2010). Lot size and housing density help to determine the area of lawn, and as such outdoor use (Arbués, Garcıa-Valiñas, and Martınez-Espiñeira 2003; Fox, McIntosh, and Jeffrey 2009; Polebitski and Palmer 2010). In addition, GIS can effectively be used in determining the percentage of green area (non-forested) in an area and then can be used to understand water demand as well for outdoor uses (House-Peters, Pratt, and Chang 2010).

The main disagreements in the literature surround the socioeconomic issues with water use. Educational attainment, lot size, home value, and income have all shown a strong effect on demand; while these are all closely related, the correlation values differ depending on other variables used and location. Educational attainment proved to have a larger *r* value than income (House-Peters, Pratt, and Chang 2010); however, income was found to a strong *r* value in other studies (Arbués, Garcıa-Valiñas, and Martınez-Espiñeira 2003; Rosenberg 2010).

It is important to note that while there is much agreement in current literature on accepted methods and variety of variables used in understanding demand, issues of scale have a large impact on the outcomes (Perveen and James 2011). It was shown that water resources in particular may appear to be more or less influenced by certain variables depending on the scale in which they are studied, therefore it is extremely important to understand the scale at which data is collected and analyzed (Perveen and James 2011). Fortunately, GIS can easily be used in order to address this issue. Census block or census tract levels may be appropriate for

understanding demand within a metropolitan area; however, various watershed scales may be more appropriate when understanding demand versus supply over a larger or more rural area (House-Peters, Pratt, and Chang 2010; Polebitski, Palmer, and Waddell 2011).

Understanding demand can aid policy studies, including understanding effectiveness of policy as well as influencing policy (Arbués, Garcıa-Valiñas, and Martınez-Espiñeira 2003; Jeffcoat, Baughman, and Thomas 2009). For example, Rosenberg (2010) created a water demand model which includes effects of various pricing structures on water use in order to better understand the effects of this type of policy. Understanding the effects of certain characteristics on water use may influence future policy, including building characteristics (Fox, McIntosh, and Jeffrey 2009). Policy can effect water use and understanding these effects can be helpful in decision-making, particularly in areas with active water management practices (Polebitski and Palmer 2010); this study was conducted in a water rich region, similar to WNC.

Role of Perception

Perceptions about the world around us influence the way we make decisions – both personal and professional. Perceptions about risk, value, urgency, conflict, and emotions all play important roles in decision-making (Shafir 2007). Early research on decision-making in the political and public policy world found that decisions are often based on soft knowledge or perception rather than scientific data. Caplan (1976) interviewed federal decision-makers representing a wide range of departments and found that even when given scientific facts the decision-makers would disregard the information if it conflicted with their individual perceptions of reality. Values, perceptions, and beliefs have also shown to have a large impact on ideas concerning sustainability (Lélé and Norgaard 1996). Because sustainability is inherently value laden, ideas about sustainability are not entirely derived from scientific information, making decision-making about sustainability more difficult and even more likely to

be based on perception (Lélé and Norgaard 1996). Negative reactions to 'sustainability' in general, due to green washing and political connections, have also shown to influence the perceptions of decision-makers (Tarlock 2011). Perceptions have also shown to be more influential in the decision-making process for local, rather than global decisions (Shafir 2007). Therefore it is important to understand perceptions of local decision-makers.

Perceptions about water are not only important to understand, but vary greatly depending on the geography of the area, climate, and condition of nearby water resources. Unfortunately, there is little research about perceptions of water in non-arid regions. Perceptions about water have been found to differ dramatically between urban and rural areas around the world. A study in Australia found that urban populations do not believe that they alone can make a difference in reducing demand and are less inclined to view water conservation as their personal responsibility compared to their rural counterparts (Graymore, Wallis, and O'Toole 2010). This may be attributed to the fact that rural communities (e.g., farmers) depend on water as a source of livelihood. The study also examined various drivers for reducing water consumption among urban and rural populations; saving money and concern for the environment were both found to be large drivers, while money was a much larger driver for rural individuals. Knowledge about how to reduce water consumption on an individual level is a barrier for both urban and rural, while cost and lack of ownership are also cited as reasons people do not conserve in cities (Graymore, Wallis, and O'Toole 2010).

Perceptions of public water consumers can be affected by not only personal or cultural values but also by local water policies and pricing (Larson et al. 2011). In Phoenix, AZ environmental concerns and water scarcity both played a role in how much water people used; greater concerns for the environment resulted in less water consumption by consumers (Larson et al. 2011). While findings of this study concerning water scarcity may not be relevant in non-arid regions, effects of income on water conservation perception and use may be

applicable. This would be true from an economic standpoint where water price can drive demand based on income. While higher prices can decrease demand, people with higher income have shown to be less concerned about higher water use or prices (Larson, Gustafson, and Hirt 2009).

More specifically, let's look at perceptions in decision-making concerning water management. Freeman (2000) argues that there are two types of knowledge used in water management: generalizable knowledge and location specific knowledge. The former is often based on scientific understanding, while the latter is based on perceptions and cultural influences. In order to have successful water management, the two must work together (Freeman 2000). A study of consumers, decision-makers, and scientists in Phoenix, AZ found very different perceptions about water management between the three groups. While all were concerned about drought and water shortages, each would place blame of shortages on different causes: consumers would blame other consumers for using too much water; scientists blamed weak regulations; and all three groups would blame nature, i.e., drought. By blaming drought, policy-makers are less likely to create conservation based policies which encourage water use behavior changes (Larson et al. 2009).

It is assumed that perceptions concerning water are different between arid and non-arid regions. One of these ways is that water is often seen as more of an infinite resource in non-arid regions; water needs to be controlled so human populations can use it (Routhe, Jones, and Feldman 2005). This is evident in a recent study regarding the perceptions involved in increasing water supply by installing a new dam in Tennessee. While policy-makers support increasing supply, the public was not in favor of the new supply due to perceptions about the environmental impacts of the project, the need for the project, and other impacts. These social perception issues slowed down the process but led to the conclusion that it is important for policy-makers to not only take into account the technical needs of a project but the values and

perceptions of the local residents. This study of public perceptions is one of few studies conducted in the Southeast. The other studies outlined above which address decision-maker perceptions are all based in the arid Southwest (Freeman 2000; Larson et al. 2009; Larson et al. 2011). It is therefore important to better understand the perceptions of decision-makers particularly in the Southeast to create a more complete picture of how geography may affect perceptions of water issues.

While literature is available concerning perceptions of decision-makers and SWM related practices, these have not been conducted in WNC. In addition, understanding how perceptions affect decision-making is not well documented. This paper will begin to provide an understanding of this in a region seldom studied and hopefully encourage additional related studies.

Chapter 3: Methodology

The methods used in this thesis include a mixed methods approach for both data collection and data analysis, including qualitative, quantitative, and GIS approaches. The combination of qualitative and quantitative data complements each other to allow for greater understanding of decision-maker perceptions surrounding water management in Western North Carolina (WNC). In addition a case study approach is used to gain a deeper understanding in two specific towns in WNC. This chapter will first outline the data collection methods used followed by the analysis methods used. The analysis section is divided into three sub-sections, one for each of the research objectives as outlined in Chapter 1.

Data Acquisition

The acquisition of data began in the fall of 2011 and ended in the spring of 2013. The first phase included a web-based survey of decision-makers, followed by in-depth interviews, and finally additional data were collected through a variety of public resources. Self-reported data collected through surveys and interviews were verified when possible during the last phase of data collection.

Web-Based Survey

A web-based survey was used to collect data about water management practices and perceptions surrounding water supply and growth in WNC. The survey was organized into five sections: general questions about respondents and their community, questions about

development and growth, water supply questions, water allocation questions, and questions regarding programs and regulations.

The Snap Survey web-based interface and software were used to create the survey and collect responses. The target audience included decision-makers of two Council of Governments (COG): Land of Sky and High Country, totaling 11 counties in WNC. Email addresses for elected officials, managers, utility personnel, and planners were collected through the COGs. A description of the project, a personal invitation to participate in the survey, and a survey link were e-mailed to 292 decision-makers in November of 2011. Two reminder emails were sent to people who had not yet completed the survey, and after 79 days, the survey was closed in January 2012. The survey returned 85 responses representing 22 counties and over 40 municipalities throughout WNC (see Figure 2). Many respondents indicated that they had forwarded the survey link to others or had been forwarded the link, which helps to explain the increased geographic area. Seventeen of the respondents were from outside of the original targeting study area. Assuming these 17 were the only people forwarded the survey, then the response rate is between 23% (based on the original list) and 28% (based on forwarded respondents).

The survey included 31 primary questions asked of every respondent, two of which had several parts (totaling eight). Six questions included a follow up, which was prompted based on responses to the original question. In total respondents were asked to answer up to 43 questions. Question format included open ended, ranking, multiple choice, and polar questions. Due to follow-up and multi-part questions, a total of 83 separate variables were collected and available for analysis.

In-depth Interviews

To supplement information collected from the survey, in-depth interviews were conducted: five in Hendersonville and four in Boone (see Table 1). Municipal utility personnel, elected officials, managers, and planners were interviewed. County planners were included to better understand the complex relationships involved in water provision to county residents as well as city residents. Seven of the interviews were conducted in person, while two of the interviews were conducted by phone. Three additional follow-up interviews were conducted by phone to include questions which were formed after the first three interviews were conducted. Initial interviews lasted between thirty minutes and one hour, while follow-up interviews lasted approximately fifteen minutes each. Notes were taken during each of the interviews by the author, summarizing interviewee responses.

Table 1. Interview Method by Interviewee Profession and Jurisdiction.

	Jurisdiction			
Profession	Boone	Watauga County	Hendersonville	Henderson County
Elected Official	In person	N/A	In person	N/A
Manager	N/A	N/A	In person	N/A
Planner	In person plus follow-up	In person plus follow-up	In person	By phone
Utility Personnel	In person	N/A	By phone plus follow-up	N/A

The interviews focused on the processes involved in water supply management, while getting at the underlying perceptions involved. The interviews were semi-structured in format, with a set of ten questions prepared for each interviewee (see Appendix B), but allowed for follow-up questions if needed, and questions were skipped if fully answered earlier in the interview. Because the questions focused on themes and perceptions rather than specific

answers to specific questions, questions were not only flexible in order but also in exact wording. Only some of the interviewees had completed the survey; for those who had not, relevant survey questions were added to the interview. The semi-structured interview format allowed for the interviewer to explore unknown topics and new ideas that the interviewees raised. These interview methods help to provide deeper insight and clarification surrounding processes and perceptions which shape decisions (Herbert 2000).

Additional Data

Because survey and interview data are self-supplied and therefore susceptible to reporting errors (Montello and Sutton 2006), additional data were collected to verify survey and interview data, supplement the survey and interview data, and provide information which was not feasible to collect through the survey or interview methods. While the survey and interviews asked about the presence of allocation or price-based policies and education or conservation programs in a community, many respondents were unsure. In addition, respondents from the same jurisdiction would provide conflicting answers. To verify the presence of particular policies, municipal websites and Local Water Supply Plans (LWSP) were examined for words or phrases common to water policies. Examples include: conservation, water saving tips, rebates, and rate structure.

Water use data for the case study towns was obtained from LWSP. Data was retrieved for the following years: 1997, 2002, and 2010. Monthly data was used which included maximum daily use for each month as well as average daily use for the month. The LWSP also provided information on population served. This demographic information was supplemented with U.S. Census population data of the case study areas for 2000 and 2010. Weather data used includes average monthly temperatures and monthly total precipitation for 2000 and 2010. This was obtained through the State Climate Office of North Carolina (http://www.nc-

climate.ncsu.edu/cronos). Climate Division Data was obtained for both the Northern Mountains region (for Boone) and the Southern Mountains region (for Hendersonville).

Analysis

Research Objective 1: Understanding Perceptions

In order to understand the perceptions of decision-makers in WNC surrounding water management, web-based survey data and follow-up interview data were used. The survey data were downloaded from Snap-Survey and imported into SPSS. Analysis of the survey and interview data was then conducted. Specifically, descriptive statistics of the survey data are provided as well as coding and analysis of the interviews. The survey and interview methods are similar to those used in other studies examining the perceptions of decision-makers in water resource management (Caplan 1976; White, Corley, and White 2008; Larson et al. 2009).

Not all survey questions were used in this section. Seven of the main questions directed at understanding perceptions were used and summarized (see Appendix A, questions A through G). In addition these seven questions were used to compare responses from the case study areas to the rest of the population. For this, the Mann-Whitney test of two independent samples was used. Results show which perceptions in the case study areas are representative of the region and which are unique to each of the case study areas.

Interview notes were taken by the author during the interview and included a summary of what was said. These notes were then analyzed through coding, where statements which were identified as perceptions or opinions were extracted and identified as being related to growth, drought, or the environment (see Table 2). In addition, statements relating to the effects of policies were identified and coded as such.

Interview data were then analyzed in order to understand perceptions in the case study areas. In order to understand perceptions, themes/ideas were identified from interview notes

using latent content analysis. Latent content analysis was used because summary notes were taken during the interviews rather than exact transcriptions of the interview (Hay 2000). Common, contradictory, and unique perceptions concerning water management, conservation, supply, and allocation were all identified and pulled out. In addition, perceptions were identified as being similar between the two areas or unique between the two areas. Specifically, coding was used in analyzing interview notes as outlined by Hay (2000) and Montello and Sutton (2006). For this research objective codes were given when comments or ideas included various perceptions about water supply and management, specifically: past/future changes in supply, growth, drought, environment, downstream communities, economics, infrastructure, and/or lifetime of the supply. Coded sections were then organized in a table to understand which respondents answered or provided information on each of the perceptions, as well as summary comments related to that perception from specific interviewees. Respondents could be identified as having a high concern for population growth decreasing water supply, low concern, or other type of perception concerning growth. For example, a note which was taken may read 'believe we have plenty of water for a long long time.' This would be coded as a perception related to future availability, and particularly coded as 'low concern' for future availability.

Research Objective 2: Influence of Perceptions on Policy Occurrence

In order to understand how perceptions influence active policies, survey data, interview data, and policy data were used. These policy data were a combination of reported policies as well as additional policies found through LWSP, and local government websites. Policies specifically addressed included active allocation policies which are tied to growth and conservation policies relating to education, rebates, and pricing.

Policy occurrence information was combined with survey data about perceptions to understand the relationship between certain perceptions and the occurrence of policies. Specific questions on perceptions were cross tabulated with the occurrence of water conservation, educational programs, and allocation policies. Any values of significance for multiple choice questions are from Pearson Chi-Square tests using crosstabs, as well as the Chi-square test for independence of categorical variables, while values of significance for ranking questions are from t-tests for comparing means of independent samples. To understand the relationships between perceptions and policies within the case study areas interview data were used. In this analysis coded responses related to perceptions of issues which may affect water supply or management were used. This included perceptions around: drought, population growth, regulations, future supply, the environment, infrastructure, downstream users, water availability, economics, and public concern.

Research Objective 3: Effects of Water Management on Use

In order to understand changes in water use between 2000 and 2010, water use, temperature, precipitation, population, and policy occurrence data were used. These data were used in linear multivariate regressions: one for each of the case study towns. The regression variables were expected to explain how much influence new policies have had on changes in water use. These methods and choice of variables are similar to methods often used in residential water use studies (Arbués, Garcıa-Valiñas, and Martınez-Espiñeira 2003; House-Peters, Pratt, and Chang 2010; Polebitski and Palmer 2010).

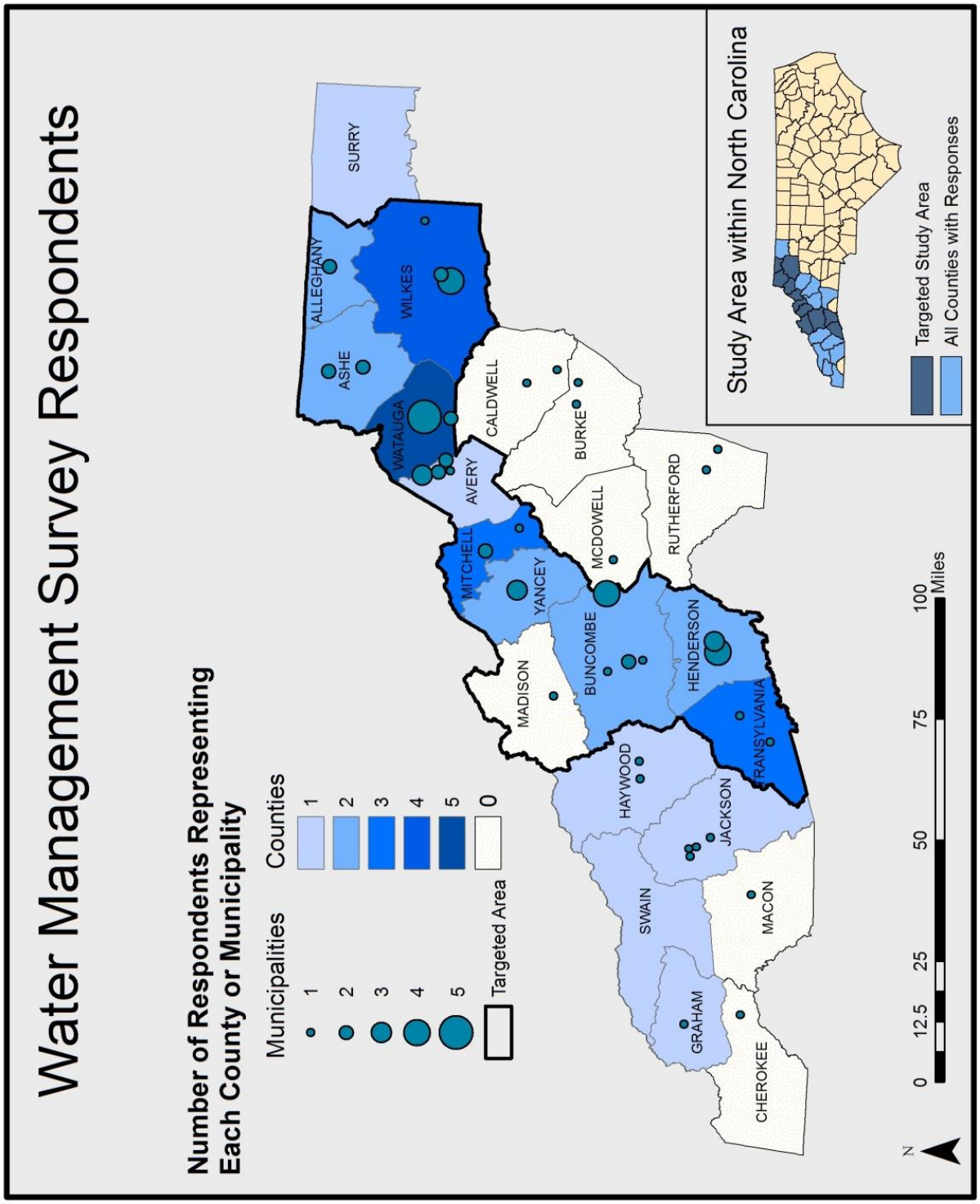
The effects of policies can also be understood more fully through interviews. Interview notes were analyzed in the same fashion as described above in Research Objective (RO) 1, except the codes and content being analyzed varied. For this RO, codes were given to ideas and sections which were related to the effects of policies. These were divided into the effects of

specific policies as well as general water management practices (see Table 2). Coded items were then organized in the same manner as explained in RO (1) above. During all interview notes analysis, critical reflexivity was employed as described by Hay (2000). There are inherent biases in interview analysis based on the researcher's position and own perceptions and every effort was made to eliminate these errors in analysis by being aware of the interviewer's position (relationship to the interviewee), personal beliefs about water management, and how these may affect what information was given by the interviewee and what was recorded or analyzed by the author.

Table 2. Codes used in Interview Analysis.

	Topics	**Relevant comments from each interviewee identified as one or both**	
Water supply management concerns	Growth Environment Drought Economics Infrastructure Regulations Public Past availability Current availability Future availability	Concern for (i.e., important in water management)	No or little concern for (i.e., not important in water management)
Effects of water supply management	Overall water management Rebate programs Educational programs Price & structure Allocation policy	Description / summary of policy	Effects of policy (including perceived, intended, expected, and observed)

Figure 2. Map of survey respondents.



Chapter 4: Results & Discussion

This chapter presents survey, interview, and regression model results. The results are integrated and organized to address each of the three research objectives. Discussion and analysis of the results is also provided in this chapter. In order to simplify the presentation of results, certain terminology will be used. Decision-makers who participated in interviews are referred to as 'interviewees.' Decision-makers who participated in the web-based survey are referred to as 'survey respondents' throughout the section and includes all respondents regardless of geographic location; 'case study respondents' refers to survey respondents who reported either Boone or Hendersonville as the community they represent. Several tables present the survey results; a total of 85 decision-makers responded to the survey. Case study respondents totaled eight; five were from Boone and three were from Hendersonville. Results from the entire survey population, or identified as WNC, are assumed to represent all 85 respondents, unless otherwise noted, while results presented as case study (CS), Boone, or Hendersonville are assumed to represent all eight, five, or three respondents respectively. For several questions, not everyone answered the question, and in these cases the number of respondents is identified.

Research Objective 1: Understanding Perceptions

Growth, Water Availability, and the Public

Survey respondents were asked a variety of questions aimed at understanding perceptions surrounding water. Because water and growth are closely linked in the minds of many decision-makers, an early set of questions aimed to understand what areas are expected

to have greater potential for growth. Respondents were asked to rank sources of growth between 1 and 7, with 1 as the most important potential growth area (see Table 3). While second homes were ranked 3rd, there was a large range of responses, from being ranked as highly important to not at all important. This is representative of the region, marked by high tourism in parts, as well as economically poor areas of Appalachia. While communities are less likely to expect growth from recreation, the majority say recreation is very important (53%) or somewhat important (33%) to their economy. Overall, the case study responses were quite similar to the entire decision-maker population. These communities in WNC expect to see the most economic growth from permanent residences, followed by small retail and second homes.

These results, concerning perceptions about growth, were confirmed in the interviews conducted in the two case study towns. Eight of the nine interviewees commented on growth and effects it has on water supply management. Five interviewees, including all Boone interviewees, expressed some type of concern for growth limiting future supply. All of the Boone interviewees mentioned population growth as a concern. Specifically, one Boone interviewee mentioned that population growth was happening faster than expected, likely due to increased enrollment at the university. Of the four interviewees in Hendersonville who discussed growth, all expressed that growth was down in the area and not likely to affect water management; several mentioned that the down economy is why growth is slow. However, it could be assumed that if growth picks up, there would be greater concern surrounding the water supply; one interviewee explained that a lack of water could be used to limit growth in other communities which are experiencing growth, unlike Hendersonville.

Respondents were asked about changes in available water over the past ten years and what they expect over the next ten years (see Table 4). Survey respondents were more likely to say that water has decreased rather than increased over the past ten years, but are equally divided about future availability. Responses from the case study respondents are similar to the

entire survey population; however, answers between Boone and Hendersonville are quite different. Interviews revealed that these responses are linked to the acquisition of water supplies. Two survey respondents from Hendersonville indicated that available water has increased over the past ten years, while no one from Boone chose this answer. Interviews revealed that a new water supply source was acquired during this time for Hendersonville, while the process was only started for Boone, but no intake had been acquired. The two case study respondents who expect to have more water available in the future were from Boone, where a new water supply intake is expected to occur over that time period.

In interviews, two people from Hendersonville and one from Boone mentioned drought as a reason that supply has decreased. Only one person from Boone directly mentioned that there is a constant finite supply of water available, but demand is what changes. The differences in perceptions concerning future availability is much greater between the two towns compared to past availability, which is interesting due to the fact that total survey responses were so evenly divided about the future. All four of Boone interviewees indicated concern for future water availability. One interviewee mentioned that there is concern for the future, especially if the new intake is not acquired and population continues to grow as expected. Another Boone interviewee believes that there could be future shortages if conservation efforts do not increase. All four Boone interviewees stressed the importance of providing enough water to meet future needs. All five interviewees from Hendersonville on the other hand expressed that there was enough supply to provide for the next ten years or more, and little to no concern for future supplies. Responses include phrases such as ‘we are blessed,’ ‘have abundant supply,’ ‘feel safe,’ ‘in great shape,’ and the ‘French Broad provides for all our future needs.’ One person did express concern for future supply due to drought and other expressed concern for future supply due to governance (DENR regulations) – both of which were factors perceived to have limited supply in the past. Based on survey responses, decision-makers may predict a variety of

scenarios for future supply; however, interviews show that the reasoning is based on past observations and perceptions from past experiences with the water supply.

Table 5 outlines the level of concern among decision-makers for a variety of factors to limit future water availability. Respondents are most likely to be concerned about the ability of drought to limit future supply, followed by state and federal regulations. Based on previous analysis, this would suggest that many of these decision-makers had perceived drought or regulations to reduce supply in the past. In general, case study respondents are more concerned compared to all survey respondents about each factor to limit water supply, with the exception of federal regulations; however, no major differences existed between the two towns. Respondents were also given the opportunity to provide other areas of concern; these included industrial, commercial, and institutional use, not acquiring new supplies, and water rights. Interviews confirmed survey responses. The most frequently mentioned concern, drought, was mentioned by seven interviewees. While concern for regulations was mentioned by five and growth by four, only one person expressed concern for tourism to limit supply. When explaining concern for drought, one person perceived droughts to be more frequent and expects this to continue. Two people expressed higher concern for drought because of geographic constraints, including being at the headwaters where flows are generally lower or less reliable and the lack of large reservoirs for storage.

Respondents believe that most people in their jurisdiction are somewhat concerned or not at all concerned about the future of the water supply. While the level of concern is higher in the case study areas, all of the 'very concerned' responses were from Boone (see the bottom of Table 5). Because decision-makers represent the needs and desires of the public, their perceptions of the public are especially important. Of the six interviewees who discussed concern and habits of the public, four (two from each town) expressed in some form a desire to increase conservation among the general public. Two mentioned that the public was 'wasteful'

in their use of water due to a lack of concern. However, three interviewees mentioned that concern among the general public has increased in the past ten years primarily through understanding the value of water and increasing conservation efforts.

Table 3. Potential sources of growth. Ranked from 1 to 7, with 1 as the most important.

Source of Growth	Mean	Mode	Std. Deviation
Permanent residences (n=80)	2.61	1 (39%)	1.811
Small retail businesses (n=78)	3.10	2 (28%)	1.632
Second homes (n=81)	3.46	1 (27%)	2.122
Recreation services (n=74)	4.11	5 (23%)	1.756
Institutions (n=76)	4.20	6 (21%)	1.804
Industry (n=76)	4.24	6 (21%)	2.084

Table 4. Perceived and expected changes in available water.

		WNC	Boone	Hendersonville
Change over past 10 years	**More water**	9 (11%)	0	2
	No change	30 (35%)	2	1
	Less water	26 (31%)	3	0
	Do not know	20 (24%)	0	0
Change over next 10 years	**More water**	22 (26%)	2	0
	No change	23 (27%)	0	3
	Less water	25 (30%)	3	0
	Do not know	15 (18%)	0	0

Table 5. Concern for factors to reduce available water.

Study Area		Not at all Concerned	Somewhat Concerned	Very Concerned
WNC	**Drought (n=84)**	4%	46%	50%
	State regulations (n=83)	20%	48%	31%
	Federal regulations (n=82)	18%	55%	27%
	General population growth (n=84)**	31%	57%	12%
	Housing development for residents (n=84)**	39%	49%	12%
	Second home development (n=83)	43%	47%	10%
	Tourism (n=82)	73%	50%	7%
	Concern among the public (n=84)*	35%	54%	12%
CS	**Drought**	--	13%	87%
	State regulations	13%	38%	50%
	Federal regulations	13%	75%	13%
	General population growth**	--	63%	38%
	Housing development for residents *	--	63%	38%
	Second home development	25%	63%	13%
	Tourism	13%	75%	13%
	Concern among the public *	--	50%	50%***

* $p \leq 0.01$

** $p \leq 0.05$

*** All four respondents were from Boone

Allocation Decisions

When making allocation decisions, survey respondents ranked the ability of infrastructure to support new connections as the most important aspect to consider. Seven of the interviewees expressed high priority for infrastructure considerations, while no one expressed infrastructure as low importance. Table 6 shows full survey results related to how perceptions influence allocation decisions. While overall, the case study area answers were similar to WNC; large differences exist between the two towns. The main difference is that Boone respondents ranked the ability to sustain the supply for a long time highly, while respondents in Hendersonville ranked it as a low priority, with over a two point difference. This was explained in the interviews, where in Hendersonville, all five interviewees believe there is enough water to provide for all future needs and one mentioned there is plenty of capacity to add new users. In Boone, all interviewees expressed concern about providing for

future needs, particularly if growth continues without the acquisition of a new supply. Case study respondents from Boone are also more likely to consider downstream users very important in water allocation decision, compared to all survey respondents (see Table 7). The study area lies within the headwaters for water supplies used throughout the southeast. One interviewee indicated that it is important to leave enough water so that larger downstream users have enough. However, two of the Boone interviewees perceived that acquiring a new water supply is easier for downstream communities.

Survey respondents were given the opportunity to provide additional influences on water allocation decisions; one respondent explained, that 'due to large supply, all requests for water are granted,' other responses pointed towards other people or entities with power, such as water authorities and elected officials. In Hendersonville, one interviewee expressed that allocation decisions are best made when based on infrastructure capacity or proximity. Most allocation decisions in Hendersonville are for extensions into the county, which two interviewees expressed to be a controversial issue in the area. As one interviewee explained, county residents feel that the city is controlling where growth happens, and city residents feel that they must pay for the high infrastructure cost of new extensions. Three interviewees explained how these are both perceptions of the public, but these issues have been addressed to ensure equity. In addition, a priority during allocation in Hendersonville, as explained by one, is to provide water to as many people as possible. Boone, on the other hand, does not extend or allocate water outside of the town's extraterritorial jurisdiction (ETJ). The ETJ is the area that is not yet included in the city limits, where the city has planning jurisdiction, and where growth and annexation is expected to occur in the future. Therefore, most allocation decisions are for new development or changes within town limits and are less controversial among the general public. Priorities in Boone for allocation were expressed by two interviewees to be to extend

the life of the water supply as long as possible, especially until a new intake is acquired. No plans were shared for what happens after an intake is acquired.

Table 6. Influences on allocation process. Ranked from 1 to 7, with 1 as the most important.

	WNC Mean Score	Boone Mean Score	Hend. Mean Score
Ability of infrastructure to support new use (n=70)	2.44	2.00	2.00
Potential for economic benefits to the community (n=69)	3.04	2.40	4.00
Potential for drought (n=75)	3.07	2.80	3.67
Compliance with state regulations (n=70)	3.44	3.60	4.67
Ability to sustain the supply for the long term (n=72)	3.44	2.20	4.67
Environmental concerns (n=71)	3.52	3.40	4.00

Table 7. Importance of downstream users in allocation decisions.

	Not at all Important	Somewhat Important	Very Important
WNC (n=80)	19 (24%)	37 (46%)	24 (30%)
Case study	0 (0%)	3 (37%)	5 (63%)
Boone	0	1	4
Hendersonville	0	2	1

Conservation Programs

Conservation programs can also be affected by perceived benefits. Survey participants were asked to rank a list of potential benefits from implementing a conservation program. Decision-makers see the greatest benefit of a conservation program to be lengthening the lifespan of the water supply, while improving environmental conditions and providing ecosystem services were ranked as the least beneficial (see Table 8). Case study responses were similar except for two differences: Boone survey respondents ranked environmental benefits over a full point higher than the entire study population; and Hendersonville respondents ranked reduced threat from drought over a full point lower than the entire study population.

Interviews did not reflect these results, however. While no one expressed a lack of concern for environmental issues, only five respondents expressed concern. One interviewee from each town self-declared as an environmentalist and mentioned negative environmental impacts from low flows. Comparatively, seven interviewees expressed concern for the future lifetime of the supply. Terms like 'future' and 'lifetime' mean different things to different people. In general, decision-makers in Boone plan further into the future compared to those in Hendersonville. Three Boone interviewees mentioned specific periods which are being planned for, such as 2040, 50 years out, or 20 years from now, while two interviewees from Hendersonville mentioned plans to upgrade intake 10 years from now. Threat from drought to reduce available supply is a greater concern among decision-makers in Boone, as explained previously. One interviewee explained that implementing conservation programs and updating drought plans provides the tools necessary to handle future droughts, thus reducing the threat.

Table 8. Benefits of conservation programs. Ranked from 1 to 6, with 1 as the most beneficial.

	WNC Mean Score	Case study Mean Score	Boone Mean Score	Hend. Mean Score
Lengthen lifespan of water supply (n=78)	2.10	2.00	1.80	2.33
Reduce threat from drought (n=75)	2.35	2.63	2.00	3.67
Reduce infrastructure needs (n=75)	2.72	2.75	2.60	3.00
Improve environmental conditions (n=76)	3.20	2.63	2.00	3.67
Provide ecosystem services (n=75)	4.09	3.50	3.20	4.00

Summary

WNC decision-makers have expressed a number of opinions and perceptions which could influence water management decisions. In general, the case study towns expressed similar perceptions as the entire survey population, but it appears that Hendersonville is more

representative of WNC, while Boone is unique in many aspects. While growth, primarily driven by permanent residences, is a concern for water management in the region, population growth is not the main concern for water supply, perhaps due to the fact that a slow economy can slow down growth. In fact, drought and regulations are bigger concerns for limiting supply. This is likely because many decision-makers have witnessed drought and regulations to limit supply, while low population throughout the region means that few stresses have been put on the water supply system due to population growth. Infrastructure and economic opportunity are both quite influential in water management decisions; however, environmental concerns are not perceived to be important. Boone is the exception for this. Mixed priority was expressed for considering the lifetime of the supply. Many aspects of SWM are not being met, in particular environmental needs are not being considered as equal to the needs of society in management decisions.

A main component of SWM is to make a water supply available for future uses and future generations. The lifetime of the water supply was of low concern to many decision-makers during allocation decisions, but was ranked as the most important benefit of a conservation program. This difference in ranking suggests a disconnect in water management perceptions in WNC. This disconnect in perceptions could lead to a disconnect in water management practices throughout the region. Both allocation and conservation are important components in SWM and contribute to water supply, availability, and use. The disconnect seen here suggest that perceptions influence various aspects of water management differently.

Research Objective 2: Influence of Perceptions on Policy Occurrence

There are many factors which may influence water management practices including availability of water, population, and policy. Because individual decision-makers have the

ability to determine and influence water management practices, the perceptions of individuals are also important to understand, although they are perhaps more difficult than understanding water availability or population. First, understanding the types of programs implemented is important. Survey respondents were asked if they had each of the following: an allocation policy, education programs, and/or conservation programs. In WNC, conservation programs are most prominent (62% reported having them), while education programs are least common (19% reported having them) (see Table 9). These results are all self-reported, and there are differences between respondents in the same jurisdiction. For example, when asked if there are educational programs in Hendersonville, two people responded 'no,' and one did not know. However, during interviews, I was told that there were educational programs – primarily passive in nature. It is assumed that this reporting error exists not only from case study respondents but exists throughout the entire survey population. During all analyses, original reported policy occurrence results were never altered. Therefore, where results indicate that a town has a specific policy, this is the perceived result of individual respondents, not necessarily the actual policy occurrence.

The web-based survey of 85 decision-makers revealed a number of interesting results for WNC. The four main issues related to SWM in WNC which were examined are concern for drought, environmental issues, future availability, and concern among the general public. Each of these appears to have a distinct influence on policy occurrence. Common themes of disconnections in water management appear and are discussed in subsequent sections of this thesis. Specific questions on perceptions (See appendix A) were cross tabulated with the occurrence of water conservation measures, educational programs, and allocation policies. In other words, data from Table 3 through Table 8 were cross tabulated with information from Table 9. First this was done for the entire survey population, then done for the case study areas. Any values of significance for multiple choice questions are from Pearson Chi-Square tests using

crosstabs, while values of significance for ranking questions are from t-tests for independent samples. When comparing WNC to the Case Study population, the Kruskal Wallis Test was applied.

Table 9. Water supply policy occurrence, percent of respondents.

Study Area		Have	Do not have	Do not know
WNC	**Allocation policy (n=84)**	50%	50%	--
	Education program (n=85)	19%	54%	27%
	Conservation measure (n=85)	62%	31%	7%
CS	**Allocation policy***	88%	13%	--
	Education program	50%	25%	25%
	Conservation measure*	100%	--	--

*$p \leq 0.05$

Drought

As determined through survey responses, one of the biggest concerns among decision-makers when managing water supply is drought (see Table 5). However, perceptions of drought have mixed influence on policy occurrence. Table 10 shows the concern for drought and occurrences of education and conservation programs. Greater concern for drought increases the chances of having conservation programs, but not education programs. Table 10 also shows how concern for drought has little to no effect on allocation policies. Similarly, when the potential for drought is more influential in allocation decisions, communities are more likely to report having conservation programs but are less likely to have specific allocation policies and little effect on educational programs. When asked about the benefit of conservation programs reducing threat from drought, 77% percent of respondents with a conservation program ranked this benefit as number one or two on a six point scale, while only 57% of respondents

without a conservation program ranked it first or second. Results were similar with education programs; however, this had no effect on having an allocation policy.

Three ranking questions were also aimed at understanding perceptions around concern for drought. Table 11 shows mean rankings by occurrence of various policies. Greater concern for drought in allocation or to reduce available water actually saw a slight decrease in allocation policies, but an increase in educational programs. While conservation programs saw both, concern for drought during allocation increases conservation programs; however, concern for drought to reduce available water shows a decrease in conservation programs.

Table 10. Policy occurrence and concern for drought to reduce water supply.

	Concern about drought	Have	Do not have	Do Not Know	All respondents
Education Programs*	**Not at all concerned**	0%	2%	9%	4%
	Somewhat concerned	67%	52%	22%	46%
	Very Concerned	33%	46%	70%	50%
Conservation Measures*	**Not at all concerned**	0%	12%	0%	4%
	Somewhat concerned	40%	58%	60%	46%
	Very Concerned	60%	31%	40%	50%
Allocation Policies	**Not at all concerned**	2%	5%	N/A	4%
	Somewhat concerned	48%	45%	N/A	46%
	Very Concerned	50%	50%	N/A	50%

* $p \leq 0.05$

Table 11. Policy occurrence and perceptions about drought.

	Policy Occurrence	Potential for drought to influence allocation decisions*+		Reduce threat from drought as benefit of conservation program++	
Allocation Policies**	**Have**	3.43	(n=40)	2.39	(n=38)
	Do not have	2.66	(n=35)	2.30	(n=37)
	Total	3.07	(n=75)	2.35	(n=75)
Education Programs	**Have**	2.92	(n=13)	1.77	(n=13)
	Do not have	3.07	(n=42)	2.30	(n=43)
	Do not know	3.15	(n=20)	2.84	(n=19)
	Total	3.07	(n=75)	2.35	(n=75)
Conservation Measures*	**Have**	2.51	(n=49)	1.98	(n=49)
	Do not have	4.10	(n=21)	2.71	(n=21)
	Do not know	4.20	(n=5)	4.40	(n=5)
	Total	3.07	(n=75)	2.35	(n=75)

* $p \leq 0.01$

** $p \leq 0.10$

+ Ranked from 1 to 7

++ Ranked from 1 to 6

Environment and Ecosystems

Sustainable water management as a whole, and conservation in particular, can both provide a framework for policy to address environmental needs, and SWM aims to in many cases. Because the environmental concerns were consistently ranked low in influencing water management, it is a way to see how aspects identified as 'not important' influence policy occurrence (see Table 6 and Table 8). Three ranking questions were asked pertaining to the influence of environmental concern, environmental conditions, and ecosystem services on water management. Mean ranks of those with or without conservation, education, and allocation programs indicates that while there are differences, there is little influence. Stronger environmental influence on allocation decisions effects the presence of allocation and conservation policies negatively but not educational programs (see Table 12). These results

indicate that decision-makers do not see the important SWM connection between human uses and ecological needs as important when managing water supply.

Table 12. Policy occurrence and perceptions about the environment.

	Policy Occurrence	Environmental concerns' influence on allocation decisions[+]		Provide ecosystem services as benefit of conservation program[++]		Improve environmental conditions as benefit of conservation program[++]	
Education Programs	**Have**	3.77	(n=13)	4.14	(n=14)	3.14	(n=14)
	Do not have	3.59	(n=39)	3.95	(n=43)	3.35	(n=43)
	Do not know	3.21	(n=19)	4.39	(n=18)	2.89	(n=19)
	Total	3.52	(n=71)	4.09	(n=75)	3.20	(n=76)
Allocation Policies	**Have**	3.90*	(n=40)	4.08	(n=39)	3.36	(n=39)
	Do not have	3.03*	(n=31)	4.11	(n=36)	3.03	(n=37)
	Total	3.52	(n=71)	4.09	(n=75)	3.20	(n=76)
Conservation Measures	**Have**	3.77**	(n=47)	4.08	(n=49)	3.31	(n=49)
	Do not have	3.05**	(n=19)	4.19	(n=21)	3.14	(n=22)
	Do not know	3.00	(n=5)	3.80	(n=5)	2.40	(n=5)
	Total	3.52	(n=71)	4.09	(n=75)	3.20	(n=76)

* $p \leq 0.05$

** $p \leq 0.1$

[+] Ranked from 1 to 7

[++] Ranked from 1 to 6

Future Water Availability

Another main aspect of SWM is to keep water supply available for future uses and future generations. The lifetime of the water supply was of low concern to many decision-makers during allocation decisions, but the most important aspect of a conservation program (see Table 6 and Table 8), suggesting a disconnect in water management practices in WNC. Both allocation and conservation are important components in SWM and contribute to water supply, availability, and use. While education and conservation programs occur more frequently when

future supply issues are ranked higher, allocation policies follow an opposite trend, based on mean rankings as shown in Table 13.

Respondents were asked about changes in available water over the past ten years and what they expect over the next ten years. Respondents were more likely to say that water has decreased over the past ten years, but are evenly divided about the future availability (see Table 4). Many of these responses are linked to the acquisition of water supplies. For example, two of the three respondents from the City of Hendersonville, which acquired a new water supply source during this time, answered that available water has increased over the past ten years. On the other hand, two of the five respondents from the Town of Boone, where a new water supply intake is expected to occur in the next 10 years, expect to have more water available in the future. When decision-makers perceived that less water was available to their community over the last 10 years, they are significantly more likely to have water conservation measures. In addition, decision-makers who believe that there has been no change to the amount of water available in the past ten years are more likely not to have any conservation programs (see Table 14).

Table 13. Policy occurrence and perceptions about the lifetime of the supply.

Policy Occurrence		**Ability to sustain the supply for the long term influence on allocation decisions[+]**		**Lengthen lifespan of water supply as benefit of conservation program[++]**	
Education Programs	**Have**	3.31	(n=13)	1.79	(n=14)
	Do not have	3.44	(n=39)	2.07	(n=44)
	Do not know	3.55	(n=20)	2.40	(n=20)
	Total	3.44	(n=72)	2.10	(n=78)
Conservation Measures	**Have**	3.23	(n=47)	2.08	(n=51)
	Do not have	3.65	(n=20)	2.27	(n=22)
	Do not know	4.60	(n=5)	1.60	(n=5)
	Total	3.44	(n=72)	2.10	(n=78)
Allocation Policies	**Have**	3.58	(n=40)	2.18	(n=39)
	Do not have	3.28	(n=32)	2.03	(n=39)
	Total	3.44	(n=72)	2.10	(n=78)

[+] Ranked from 1 to 7

[++] Ranked from 1 to 6

Table 14. Conservation program occurrence and perceptions about changes in available water.

		Conservation program			Total
Change in available water		**Have**	**Do not have**	**Do Not Know**	
Over last 10 years *	**Do Not Know**	17%	27%	67%	24%
	Less Water	40%	15%	17%	31%
	No Change	32%	50%	0%	35%
	More Water	11%	8%	17%	11%
Over next 10 years	**Do Not Know**	11%	23%	50%	18%
	Less Water	32%	23%	33%	29%
	No Change	28%	27%	17%	27%
	More Water	28%	27%	0%	26%

* $p \leq 0.05$

Other Perceptions

Respondents believe that most people in their jurisdiction are somewhat concerned or not at all concerned about the future of the water supply (see Table 5). The prevalence of conservation programs also is associated with concern among community members. Respondents who believe there is a high level of concern among community members for the water supply are more likely to have conservation programs compared to respondents who believe most people are not concerned (see Table 15).

One more issue that can affect water management is ability of the infrastructure to provide water. Economic issues and regulations can also affect water management. Additional ranking questions were asked on these topics. Results showed that while some of these were ranked of very high importance (see Table 6 and Table 8), these had very little influence on whether or not respondents reported having or not having allocation, education, or conservation practices (see Table 16). The greatest trends (although not significant) were 1) greater emphasis on economic benefits meant less chance of allocation policies, and 2) greater

emphasis on infrastructure ability meant more allocation policies. Differences in mean ranks less than 0.5 were considered to have no effect.

Table 15. Conservation program occurrence and perceived concern of the public.

	Conservation Program			Total
Concern	**Have**	**Do not have**	**Do Not Know**	
Do Not Know	0	0	17	1
Not at all concerned	32	46	0	34
Somewhat concerned	55	46	67	53
Very Concerned	13	8	17	12

Table 16. Allocation policy occurrence and other perceptions.

Water Allocation Policy	**Economic benefits' influence on allocation decisions[+]**	**Ability of infrastructure influence on allocation decisions[+]**	**State regulations' influence on allocation decisions[+]**	**Reduce infrastructure needs as conservation benefit[++]**
Have	3.36 (n = 39)	2.18 (n = 40)	3.51 (n = 39)	2.77 (n = 39)
Do not have	2.63 (n = 30)	2.80 (n = 30)	3.35 (n = 31)	2.67 (n = 36)
Total	3.04 (n = 69)	2.44 (n = 70)	3.44 (n = 70)	2.72 (n = 75)

[+] Ranked from 1 to 7

[++] Ranked from 1 to 6

Research Objective 3: Effects of Water Management on Use

Regression Model Results

Several models were created to understand the effects of policies on water use between 2000 and 2010. Because adequate data were not available for 2000, data from 1997 and 2002 were both used. Factors used include: average monthly temperature; total monthly precipitation; estimated annual population served; monthly water use (average daily); maximum daily water use per month; number of residential and commercial connections, and policies in effect. Due to the way data had been collected by the utility departments, water use was calculated per capita served and per connection. Population data collected from the U.S.

Census is not necessarily the same as the population which is provided a water supply. For example, Hendersonville provides water to the residents of the city as well as thousands of residents outside of the city limits. Utility personnel calculate and report the population which water is provided to, this information is available on LWSPs and this figure was used rather than Census population data. The Boone figure for 2010 population served on the LWSP was assumed to be incorrect. Between 2002 and 2009, the population served increased by roughly 1,000 people, did not change between 2009 and 2010, but increased by over 2,000 people between 2010 and 2011. A more steady growth rate is assumed to have occurred, therefore, the average of 2009 and 2011 population served was used.

Average daily use for a given month (a) is dependent upon total monthly precipitation (p), average temperature for the month (t), active water management practices (m), and either annual population served (s) or number of connections (c) (see Table 17). Linear regressions were calculated for both the water use and the natural log of water use (see Table 18 and Table 19). Using the natural log showed a better fit for Boone, but not Hendersonville. Additional models were created to see if using population or number of connections was a better fit for understanding water use. To fit what is both expected and to match results from previous literature, it is assumed that population and temperature are positively correlated with use, while increased management practices and precipitation would see a decrease in use as seen in previous research (Arbués, Garcıa-Valiñas, and Martınez-Espiñeira 2003; House-Peters, Pratt, and Chang 2010; Polebitski and Palmer 2010). These patterns are seen in the Boone models, but not the Hendersonville models. In Hendersonville, increased management practices indicated an increase in use while increased population indicated a decrease in use. Because these values do not match up with what is expected through results seen in previous literature (Arbués, Garcıa-Valiñas, and Martınez-Espiñeira 2003; House-Peters, Pratt, and Chang 2010;

Polebitski and Palmer 2010), it is assumed that this model does not fit Hendersonville, but does fit Boone.

Coefficient values for precipitation and temperature in each of the Boone models were extremely low (see Table 18). This makes sense with what is expected. One interviewee from Boone explained that fluctuations in water use are not seen in summer with increased outdoor watering as is expected most places, but is seen in the fall when tourism increases. Using the numbers for population served proved to be more valuable than using number of connections. This could be due to the high number of student housing units which do not require individual connections. Using the number of connections may be more valuable where each unit is required to have its own meter. These results show that the major influences on water use are that an increase in population increases use, and an increase in water management has shown a decrease in use. However, water use has seen little change between 1997, 2002, and 2010.

Results for Hendersonville (see Table 19) do not reflect what is expected, however still offer some insight into water use. One interviewee in Hendersonville explained that peak water use occurs in the summer when outdoor use increases, another explained that even though tourism is an important part of the local economy, there was little concern for tourism to affect the water supply. Water use in Hendersonville is significantly affected by temperature. Coefficients for temperature and precipitation were larger and showed more of an effect on use in the Hendersonville models compared to the Boone models. Between 1997 and 2010, Hendersonville maintained water use (average water use in both years was 7.8 MGD), while experiencing population growth and expansion of the water system further into the county. This may be explained by a variety of factors as discovered through the interviews. A slow-down of the economy in the area could be one explanation; one interviewee explained that some large industrial water users had left. Another indicated that there was an effort to decrease leaks in the system during this time period. While interviewees in Boone expressed

similar experiences, they may not have occurred to the same degree. For example, if an extremely large leak had been fixed, this may explain a large portion of the decrease in water use. In addition, it is assumed that this large decrease in use explains why the regression model results are not as expected. Another interpretation is that indeed increased water management efforts showed an increase in use as the model explains.

Perceived Effects of Water Management

Further insight into the effects of policies can be found through the interviews. Interview notes were coded for perceptions related to the effects of water management practices, including: generic conservation policies, allocation policies, education programs, high efficiency technology (i.e., rebates), and pricing structure or increases (see Table 21). Interviewees in Boone explained that the intended effects of overall water management were to make the current supply last longer (expressed by two people) and meet the desires of the public (expressed by three people). In Hendersonville the overall effects of water management practices were intended to get people thinking about water conservation but not conservation itself (expressed by three people) and to provide water equitably to many people (expressed by two people). Clearly these are two different goals or intentions of water management between the two towns. Both towns focus on the public; however, in Boone the public is the driving force in water management, while in Hendersonville water management and ideas on conservation come from the decision-makers down to the public. Additionally, Boone interviewees expressed that reducing water consumption was a goal, while this was not the case for water management practices expressed by Hendersonville interviewees. These effects of overall water management help explain why the regression models show reduced water consumption due to increased management in Boone, but not Hendersonville. Described above were the effects of

general water management; however, individual policies were explained to have various effects.

Both towns have specific allocation processes, but they are quite different. For example, Hendersonville's water system provides to more people outside of the city limits than within. As explained by one decision-maker, because of the large capacity, the policy is less of an allocation policy and more based on planning for extensions of infrastructure. The intended effects of the allocation process were described as providing to as many people as possible, and improving the efficiency of the system in terms of the amount of infrastructure versus number of people served. It was brought up that other things are being done in Hendersonville to improve efficiency, including a water audit for the system and technological improvements. Often, the efficiency of the utility is the first step in conservation (Jernigan 2013), and therefore needed to meet SWM goals.

Boone, on the other hand, provides water mainly within the town limits, and to some areas of the ETJ. The intended effect of this allocation process was described by two decision-makers as extending the life of the current water supply, particularly until a new intake is acquired. It was assumed that the allocation process may not be needed after a new supply is acquired. Due to the fact that extra water allotments have been carried over from previous years, one interviewee believes that this process has been quite effective in achieving the desired goals: there is still water available to allocate without the town going dry before an intake is acquired. The fact that reduced water use was described as a goal of the allocation process in Boone, but not in Hendersonville, may explain why the regression models do not show reduced use due to increased water management.

During this time period, pricing and rate structures were altered in both towns, at least partially persuaded by the state government. Both towns originally had decreasing blocks, but have both changed the structure for residential customers to increasing blocks and have

increased base prices during this period. While one decision-maker in Hendersonville expressed that they would like to see more blocks with higher price increases, three explained that price increases are politically undesirable and unpopular among the public. However, this may be changing as two interviewees believe that customers are beginning to understand the value of water. An estimated bill for a customer within city limits using 0, 3,000, and 5,000 gallons a month are listed for 2010 prices (see Table 20). Based on these prices, a customer in Hendersonville would have paid only 33% of what the Boone customer paid at 0 gallons, 58% at 3,000 gallons, and 53% of what the Boone customer would have paid for 5,000 gallons. Price structures have shown to be effective in reducing consumption, but not at low prices (Rosenberg 2010). Perhaps, the Hendersonville base price is too low to effectively deter use.

Interviewees in both towns intend the new rates and rate structure to be equitable for all users. However, all three of the Boone interviewees who commented on the pricing policy stated that reduced consumption was an intended effect. Two also stated than an intended effect of the price increase is to help raise money to pay for the new intake. Similar to Hendersonville, one interviewee wanted more blocks with higher increases. Another decision-maker believes that of all the water management practices, economic drivers of conservation (prices and pricing structures) have been the most effective in reducing water consumption. Two reported that the new pricing structure has been effective in reducing demand and two believe the public understands the value of water and the price increases, while another believes that future price increases will be unpopular among the public. Boone's more intensive pricing strategy may explain decreased use due to increased management practices.

Hendersonville's education program consists of tips in water bills and on the website. In addition, a staff member could be made available to do presentations for civic groups. One decision-maker explained that the town is interested in increasing educational efforts but does not know how to do it well. Also, one decision-maker explained that educating the public on

conservation issues was a responsibility of the city – the "right" thing to do. Only two of Hendersonville's interviewees mentioned the education program, likely because it is not an active component of water management in the town. Boone's education program is more organized, named 'Every Drop Counts,' and has a full time staff member dedicated to the City's conservation efforts. School and civic group presentations are more frequent as well as poster competitions for elementary students on conservation issues. Basic tips on the website, tips in water bills, and other promotional materials, have been a part of the program. Two interviewees mentioned that school aged children were the primary target because they are impressionable and it is good to get people started early. Both of these decision-makers also believe that this program has been effective in reducing demand.

Other conservation programs target homeowners. Low-flow technology, water reuse systems, or water reclamation are all ways to encourage reduced water consumption. Municipalities often give rebates for water efficient technology or provide this technology for free or reduced cost to customers. Hendersonville introduced a program during the past ten years which allowed customers to get a rebate on new purchases of high efficiency washing machines, irrigation equipment, and toilets. One interviewee explained that one of the intended goals of the program was to reduce water consumption. Two interviewees mentioned that the program did not receive much attention at first, but due to increased advertising, believes that it is picking up. The Boone program offers rebates only for toilet replacement, yet offers a limited number of rain barrels for free as well as a water conservation kits for customers which include low flow shower heads and other water saving devices. This program works closely with the education program under 'Every Drop Counts.' While no one specifically commented on the goals of the rebate/technology centered programs, one explained that reduced water use was due to the fact that many large users of water have switched their fixtures to new efficient technology. Another believes that businesses are also becoming aware of the benefits of water

conservation through efficient technology, evident through the use of these in new construction. This could be explained by a number of factors including a focus on education, increased prices, and emphasis on efficient technology. Again, while this program exists in both towns, it is more fully utilized by the residents of Boone.

Both towns use pricing, education, efficient technology, and allocation in water management, which is unique in WNC; however, the programs have manifested differently between the two towns. Conservation programs can only be as effective as they are designed or intended to be. While there are differences in each of the conservation programs between the two towns, there are also differences in the amount of organization of each program in the two towns. Hendersonville interviewees generally believed that programs have been helpful in getting people to think about water issues, but not effective in reducing consumption. Boone interviewees, in comparison, attribute reduction in use to the conservation and water management practices. The regression model results agree with these perceptions expressed by the decision-makers. Interestingly, per capita consumption has been reduced in both towns between 2000 and 2010.

In analyzing these practices based on SWM goals, the success of Boone water management practices in reducing consumption may be attributed to a few factors. First, the practices in Boone are integrated, in that each of the programs were created with the others in mind. For example, the efficient technology water kits also include educational materials and the educational campaigns discuss the benefits of the high-efficiency technology. Boone has more of a participatory approach: the public can serve on the water advisory board and the programs are directed towards engaging the public. The water advisory board is comprised of elected officials as well as members of the public and provides recommendations to town council for decisions regarding the water supply. Hendersonville, on the other hand, has no similar organization. Concern for future populations, economic efficiency of the system,

efficiency of use, and environmental needs can all be identified in Boone's water management. Each of these can be improved upon in order to reach ideal SWM. Some of these SWM aspects can also be identified in Hendersonville's water management practices, such as economic efficiency, and providing for the future; however, neither of these is as strongly identified in Hendersonville as they are in Boone.

Table 17. Table of variables used in regression analyses.

Variable	Description	Measurement Units
a	Average daily use each month	Million gallons
m	Active water management practices	1 = yes, 0 = no
p	Total monthly precipitation	Inches
t	Average monthly temperature	Fahrenheit
s	Population served	Annual estimate
c	Total connections	Residential and commercial connections

Table 18. Regression model results for Boone water use.

	Model 1 (Connections & Natural Log)	Model 2 (Population & Natural Log)	Model 3 (Population)	Model 4 (Connections)
R^2	0.361*	0.361*	0.354*	0.354*
m	-0.274	-1.882*	-1.875*	-0.279
p	-0.016	-0.016	-0.006	-0.006
t	0.006	0.006	0.007	0.007
s	---	2.110*	2.095*	---
c	0.718*	---	---	0.713*

* $p \leq 0.01$

Table 19. Regression model results for Hendersonville water use.

	Model 1 (Connections & Natural Log)	Model 2 (Population & Natural Log)	Model 3 (Population)	Model 4 (Connections)
R^2	0.641*	0.641*	0.640*	0.640*
m	1.085*	0.922*	0.886*	1.042*
p	-0.100	-0.110	-0.117	-0.117
t	0.712*	0.712*	0.716*	0.716*
s	---	-0.846*	-0.808*	---
c	-0.997*	---	---	-0.953*

* $p \leq 0.01$

Table 20. Pricing and rate structures in 2010.

	Number of Blocks	Gallons provided w/ base charge	First block max	Price difference outside city limits	Price for 0 gallons	Price for 3,000 gallons	Price for 5,000 gallons
Boone	4	2,000	4,999	200%	14.00	20.90	32.20
Hendersonville	2	0	40,000	160%	4.62	12.06	17.02

Source: UNC Environmental Finance Center 2010.

Units in gallons per month.

Table 21. Summary of perceived effects of water supply management.

	Summary of Perceptions	
Policy	**Boone**	**Hendersonville**
Overall water management	Increase lifetime of supply; Meet desires of public	Bring awareness to public; Provide equitably to many people
Rebate programs	Increased awareness of economic benefits of conservation	Reduced water consumption
Educational programs	Reduce demand; Educate children	Meets the city's moral responsibility to educate public
Price & structure	Provide water equitably; Reduce consumption	Provide water equitably; get public to understand value of water
Allocation policy	Extending lifetime of supply	Improve efficiency of system; Provide to as many people as possible

Potential Confounds

The methods and results described above were done in a manner to remain as unbiased as possible while providing a comprehensive understanding of SWM in WNC and how perceptions of decision-makers can affect this. Despite this, possible confounds do exist within

this study, including reliability of data and additional factors affecting water use and water management decisions.

Qualitative survey and interview methods are inherently subject to reporting errors (Montello and Sutton 2006). Reliability of the data is therefore dependent upon the survey respondents and interviewees who provide the data. Survey and interview questions were designed to promote an unbiased response as well as not to show the researcher's own biases. Some survey questions may have been unclear to certain respondents, as discovered through analysis of the data. For the ranking questions, some survey respondents assigned a unique value to each option, basically comparing each option to the others. Other survey respondents ranked each option independent of the other options, therefore the same value was assigned to more than one option. In addition, many respondents may not have been aware of the current water management practices in their community. As described earlier, of the three Hendersonville respondents, two responded that their community did not have any educational programs, while one did not know. Further investigation through interviews and government materials indicated that Hendersonville does have an educational program. Interviewees and respondents also have the tendency to over-report or under-report on certain topics in order to appear more in touch with public desires. For example, when asked about the importance of environmental concerns, many decision-makers may indicate that it is of relatively high importance if it is of high importance to the public, while a lack of environmental programs and an abundance of economic policies may indicate otherwise.

Data on water use and population served were obtained through LWSPs. These are often completed by the utility personnel in the particular jurisdiction and are often based on estimates. Utility departments often keep track of the number of connections, both metered and non-metered, which they serve, but to estimate the number of people using water from each

connection is more difficult and less reliable. To help alleviate this issue, regression models were made using both the number of connections and the number of people served.

A wide variety of issues can affect water use; however, the regression models used the most common variables which often have higher influence on water use. Every water supply system is unique and therefore needs to create independent water demand models to understand use and forecast future demand; however, working with and learning from nearby communities has shown to be effective in this process (Hanson 2013). Due to the unique nature of the region, and each of the two case study towns, the regression models may not have included important factors affecting water use, including demographics, housing characteristics, and seasonal populations (Vanham, Rauch, and Fleischhacker 2009; House-Peters, Pratt, and Chang 2010; Polebitski and Palmer 2010). For example, both towns, but Boone in particular, receives a high number of visitors throughout the year. These visitors could have a large impact on water use; including tourism data in the regression models may improve future results (Vanham, Rauch, and Fleischhacker 2009).

These models also did not look into the specifics of each of the water management practices involved. Previous research has shown that conservation, pricing, or educational programs all have a wide range of effects on reducing water use depending on the details, specific restrictions, and organizational capacity (Hanak 2008; Olmstead and Stavins 2009; Rosenberg 2010; Polebitski and Palmer 2011). While the specifics of each water management practice can affect water use, other management practices, such as the leak detection program in Hendersonville, have the ability to affect water use even more.

Chapter 5: Conclusion

Summary of Results

Interview and survey data collected from decision-makers provided great insight into the perceptions of decision-makers in WNC which influence decisions. In addition, regression models of water use were created for both Boone and Hendersonville based on a variety of data collected. While survey data provided information for the entire region, case studies in Hendersonville and Boone provided a deeper understanding in two towns. All of the data were analyzed to provide information on perceptions of decision-makers, how these perceptions relate to policy occurrence, and the effects of these policies within the study area. All of this was combined to provide an understanding of SWM in WNC.

Common trends in perceptions among decision-makers were identified; however, a wide variety of responses were received. While general perceptions are that there is an abundance of water in the region, supply side issues such as drought or water intakes are of the greatest concern for decision-makers in water management decisions. Decision-makers see it as less important to reduce consumption in order to increase supply. In general, economic concerns and infrastructure are very important to decision-makers, while environmental concerns are of the lowest concerns or importance in water management. Social concerns, such as providing for human uses now and in the future, are also of high importance to decision-makers in WNC.

When understanding how these perceptions relate to active water management policies, three trends emerged. First, conservation policies showed increase occurrence in

communities where social needs and concerns were important, such as the lifetime of the supply, and perceived public concerns, but where there was lower concern for the environment. Next, allocation policies experienced increased occurrence where there is strong concern for economic needs, such as infrastructure, as well as low concern for environmental and social needs. And finally, educational programs related to water supply occurred more frequently in areas where greater environmental concern among decision-makers was expressed. If a common explanation of sustainability is meeting the needs of the triple bottom line (environmental, social, and economic), a simple picture of how this relates to SWM in WNC can be created. As explained previously, this thesis views both conservation and allocation programs to be part of supply-side management rather than demand-side management, due to the fact that decision-makers perceive conservation programs to benefit the supply.

Conservation programs (occurring in 62% of respondent's communities) are designed to meet social needs, allocation programs (occurring in 50% of respondent's communities) are designed to meet economic needs, and educational programs (occurring in 19% of respondent's communities) are designed to address environmental needs. All three of these programs were found in the two case study towns, which indicates that social, economic, and environmental needs are each being addressed to some degree. The fact that educational programs occur less often than conservation or allocation programs indicates that this is one area for WNC to focus on in order to help promote sustainability for the future. Perhaps the region's environmental needs in terms of the water supply are being met; however, this would likely be due to something other than policy; if conditions change, these may not be met in the future. The same could be assumed for the region's social and economic needs to a lesser degree.

Regression models of water use and interview data collected on the effects of water management in the case study towns revealed that while both towns each had a variety of water management programs, the effects were not similar. Both towns have education

programs, allocation policies, conservation programs, increasing block rate structure, have increased water rates, offer rebates on efficient technology, and have updated their drought management plans. Each of these were implemented or increased in intensity (such as pricing) between 1997 and 2010. Increased water management between 1997 and 2010 was responsible for a decrease in water use in Boone, but an increase in water use in Hendersonville. This is partially explained through interviews, where intended effects of water management were explained. The main difference between the two towns is that Boone intended through each of the programs and policies for there to be a reduction in water use, and an increased lifetime of the current supply. However, in Hendersonville, decreased water use was not an intended effect of the water policies. The most common intended effects of the policies were explained to be to provide to as many people as possible in an efficient manner and getting people to think about water issues in the area. A perceived large water supply meant that policies did not necessarily have the goal to get customers to conserve water use. While regression model results for Boone show the increased water management to be effective in meeting the intended effects, the regression model results did not attempt to measure the effectiveness of the intended effects in Hendersonville.

The different goals in water management between the two towns may explain why the regression model seems to fit Boone more predictably than Hendersonville. This shows that while it is important to have water management practices, the effects can change based on decision-maker perceptions and intended effects of each program. In addition, Boone water management was shown to be more integrated and participatory in nature compared to Hendersonville's management. Both towns showed interest in economic efficiency, and supported efficient technology usage.

All of these results can help to explain how SWM is occurring in the towns of Boone and Hendersonville, and WNC in general. Comparing case study survey results to the entire survey

population shows that the case study towns employ more active water management practices and are generally more concerned about water management issues as a whole. However, the relative importance of each of the issues and perceptions from decision-makers in the case study are representative of the entire survey population. In addition, interviews revealed that water management in the case study is primarily reactive rather than proactive. Therefore it is assumed that in general, communities in WNC are meeting the goals of SWM less than the case study towns are. As a reminder, SWM aims to meet social, environmental, and economic needs now and in the future. Integrated, adaptive, and participatory approaches are also necessary. All of this should be achieved through valuing water appropriately and employing efficient use and extraction of water. Social, economic, and environmental needs are being met, to various degrees through conservation, allocation, and educational programs respectively in the two case study towns. Interviews revealed that integrated, adaptive, participatory approaches are being employed in Boone, and adaptive approaches are being employed in Hendersonville. Efficient technology is being utilized by customers in both towns through rebate programs, while Hendersonville also has a strong focus on efficiency of the entire system. Finally, water is being valued as a commodity and a finite resource (through increasing block rate structures); however, this has been, and continues to be a gradual process within the towns. An ideal pricing policy has not been identified in either town.

Overall, Boone has met, to some degree, each of the main SWM goals, and Hendersonville has met all but two of them (see Table 22). None of the goals has been met to a perfect level, and each could be improved upon; however, elements of SWM do exist within the case study. It is assumed that many of these elements also appear throughout WNC, but likely to a lesser extent than in the two case study towns. Water management in the case study towns was found to be primarily reactive rather than proactive. The case study towns were representative of WNC on many perception issues, but unique in that the water supply was a

more salient issue and had more active water management in place. Therefore it is assumed that the rest of WNC is likely to be more reactive in water management than proactive. For cases where this is true, more experiences with water supply issues will increase water management efforts throughout the region and potentially SWM.

Table 22. Attainment of SWM goals in Boone and Hendersonville.

SWM Indicator	Boone	Hendersonville
Social Needs	✓	✓
Economic Needs	✓	✓
Environmental Needs	✓	✓
Integrative Approach	✓	X
Adaptive Approach	✓	✓
Participatory Approach	✓	X
Valuing Water Appropriately	✓	✓
Efficient Use and Extraction	✓	✓

✓ Indicates that the SWM indicator is being met to some degree.

X Indicates that the SWM indicator is not being met.

Implications

Each of the findings in this research may be relevant to local, regional, and global water issues. Water is necessary for life and at any given place and time is also a finite resource. It is not spatially or temporally distributed evenly throughout the world and because of this society manages water in order to control this distribution. Water management is receiving increased attention in non-arid regions of the world, such as the American Southeast. Water shortages, due to recent droughts and population growth, spurred on a number of new policies and management practices in WNC. Because policy decisions are often based off of perceptions, personal beliefs, and other pressures, rather than scientific data or information, there is a need to understand the perceptions of decision-makers. This research helps to understand these perceptions in WNC and how these perceptions affect water management practices. In addition, SWM provides the framework for ensuring adequate management of water resources to

provide for all needs, now and in the future. This research also provides an insight into how SWM is occurring in WNC.

The perceptions of decision-makers in WNC are generalizable to the remainder of southern Appalachia, a cultural region marked by high precipitation, low population, and high tourism. These perceptions could possibly be generalizable to other areas with similar characteristics. By understanding the perceptions of decision-makers which influence decisions, it is also possible to determine the issues which are not influencing decisions, in this case, environmental issues. Communities in WNC may become more aware of these perceptions, and if either the public or the decision-makers are dissatisfied with the amount of influence certain perceptions have, more effort can be made to change this. Without this knowledge, it would be more difficult to even identify areas which needed change.

This study also begins to outline which water management practices occur in WNC and the frequency of these. This data could be compared with management practices in urban environments throughout NC, including Raleigh or Charlotte, in order to understand urban versus rural approaches to water management. This research also made connections among these policy occurrences, perceptions, and the three primary needs of sustainability (social, economic, and environmental). This allows a greater understanding of which perceptions influence specific policies. For example, if a community has a specific allocation policy and no other policies it can be assumed that economic needs are being addressed and are perceived to be important to the decision-makers in that community. Communities in WNC could then realize that in order to combat the inherent biases, extra effort is needed in addressing the social and environmental needs.

The regression model and interview data examining the effects of water management on use also provide insight into several aspects of water management in WNC. First, it provides Boone and Hendersonville with an idea of how water use changed between 1997 and 2010,

when water management practices increased. It also provides these two towns with a demand forecast model to help estimate water use in the future. This is an important step in water management which can easily be overlooked (Hanson 2013). The regression models also verify that many factors can affect water use in an area, not just population, climate, and policies. The interview data concerning the effects of water management show that merely having a conservation policy does not mean that reduced consumption will be an effect, especially if the decision-makers intended the policy to have other effects.

This research also provides a baseline framework for understanding SWM in WNC. By understanding what is currently happening in the region, future comparisons could identify areas which have improved. This may also highlight areas of SWM which would be beneficial to focus on in WNC communities as well as similar communities throughout southern Appalachia. All of this research begins to fill in an area of study which has not traditionally been focused on in non-arid regions, including WNC.

While water resource issues do not stop at political boundaries, survey results show that communication between decision-makers does stop there; the survey shows that most decision-makers communicate with neighboring communities concerning water supply less than five times per year, and most of those were less than one time per year. Dissemination of this research aims to facilitate communication and provide an exchange of knowledge within the study area. These results not only benefit WNC but are also generalizable to Southern Appalachia. While many policies change at political boundaries, water supply issues are likely similar throughout Southern Appalachian. The entire region receives high annual rainfall and has a low population, likely resulting in similar perception of water supply issues and local water policies. This research may benefit local decision-making and research in the area at a time when future water supply management is facing uncertainties due to GCC, population growth, and SWM practices.

Future research

Several lessons have been learned during the course of this research and numerous new ideas have been sparked as well. Iterations of portions of this research could be done in order to achieve even deeper understanding of water management in WNC. Additionally, by varying the geographic range of study, comparisons could then be made between regions in order to give a broader understanding of how these perceptions vary due to geography. Future research may also aim to determine a way to rank or rate water management practices on how they meet SWM goals.

Future studies building upon this research should first work to identify more comprehensive understanding of what affects water use in WNC communities. It is expected that tourism data would be beneficial to include in future regression models, particularly for Boone. Results from Hendersonville also indicate that other factors are affecting water use, and this could be examined through the efficiency of the entire utility. For example, if a large leak is detected or major upgrades to the system occur, this should be included in the regression models. This research used data from 1997, 2002, and 2010; annual data could help to provide a more accurate model; however, this data was not readily available. Specific dates of when each water management policy or program was initiated or updated could also improve understanding of how different policies affect use. This information was also unavailable, often undocumented, or a range of dates was provided to the researcher by the interviewees.

This research aimed to get an understanding of the types and numbers of active water management policies. Future needs are in assessing the quality of these policies. The difficult comparison of water management practices between Boone and Hendersonville showed that this type of research would benefit from a specific way to measure individual policies against a standard measurement for aspects of SWM.

Finally, this research would benefit from being repeated across various geographic areas. For example, a study across the entire state of NC would allow comparisons between rural and urban areas, coastal, piedmont, and mountain regions, or primary political affiliation in a region. A study could also be conducted which compared two regions, one in the arid southwest and one in the water-rich southeast. This would provide information on how perceptions change due to perceived and real water availability.

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Appendix A: Survey Questions Used In This Thesis

A: Please rank from 1 to 7, with 1 as the most important and 7 as the least important, the following in terms of their potential to be a source of growth for your community

___Permanent residences
___Second homes
___Small retail businesses
___ Industry
___ Institutional (e.g. government, museum, education)
___Recreation services (e.g. fishing guides, hotels, restaurants)
___Other _____

B: Has the amount of water available (e.g. well level, river level) to your community/jurisdiction changed in the past 10 years?

___Yes, more water ___Yes, less water ___No change ___Do not know

B: Do you anticipate that the amount of water available (e.g. well level, river level) to your community/jurisdiction will change in the next 10 years?

___Yes, more water ___Yes, less water ___No ___Do not know

C: In your community/jurisdiction which of the following reflects the level of concern among the general public over the future of your water supply?

___Most people not concerned
___Some people concerned
___Most people concerned

D: How concerned are you about the potential for each of the following to restrict/reduce the amount of water available (water supply) to your community/jurisdiction?

Drought:
___Not at all concerned ___Somewhat concerned ___Very concerned

State regulations:
___Not at all concerned ___Somewhat concerned ___Very concerned

Federal regulations:
___Not at all concerned ___Somewhat concerned ___Very concerned

General population growth:
___Not at all concerned ___Somewhat concerned ___Very concerned

Housing development for full time residents:
___Not at all concerned ___Somewhat concerned ___Very concerned

Second home development:
___Not at all concerned ___Somewhat concerned ___Very concerned

Tourism:

___Not at all concerned ___Somewhat concerned ___Very concerned
Other source of concern? _____

E: Please rank from 1 to 7, with 1 as the most important and 7 as the least important, the following in terms of their influence on your community's/jurisdiction's decision-making process for allocating water to new users.

___Potential for drought
___Environmental concerns
___Potential for economic benefits to the community
___Ability of infrastructure to support new use
___Ability to sustain the supply for the long term (>50 years)
___Compliance with state regulations
___ Other _____

F: When making water allocation decisions in your community/jurisdiction, how important are considerations of downstream uses?

___Not at all important ___Somewhat important ___Very important

G: In other communities it has been demonstrated that in addition to saving water, conservation programs offer economic and other benefits. From your perspective, please rank from 1 to 6, with 1 being the most beneficial to 6 being the least beneficial, these potential benefits from implementing a conservation program.

___Reduce infrastructure needs
___Improve environmental conditions
___Lengthen lifespan of water supply
___Provide ecosystem services
___Reduce threat from drought
___Other _____

H: Does your community/jurisdiction have a specific policy/ordnance that guides water allocation decisions?

Yes No

I: Has your community/jurisdiction implemented any public/school education campaigns/programs related to the water supply?

___Yes ___No ___Do not know
If yes: When? What was the focus? Who was the target audience?

J: Has your community/jurisdiction implemented any water conservation measures?

___Yes ___No ___Do not know
If yes, please list:

Appendix B: Interview Questions

1. How is water supply relevant to your job – what do you have to consider/think about regarding water?

2. What is the process for making water management decisions in your community? Key players? Citizen involvement? Downstream users? County? Data used?

3. We conducted a survey. Do you think that the amount of water has changed in the last 10 years? Do you expect it to change over the next 10 years? What is the basis/evidence for saying water supply decreasing/increasing?

4. What have been impacts (economic/social/job duties) of changing water supply?

5. If your current drinking water source were threatened (e.g. drought, poor quality) what would be (or what has been) the approach for managing this?

6. There were several droughts in the southeast between 2000 and 2010. How did these droughts affect your community? Impacts, new policies, etc.?

7. What might prompt your community to develop management measures beyond state compliance?

8. What is the political feasibility/desirability of raising water rates in your community? Implementing education programs, other conservation programs, allocation restrictions?

9. How successful have current programs been in meeting desired goals (reduced consumption, population control)?

10. In the survey we asked a question asking 'how concerned are you about the potential for each of the following to reduce water supply? Drought, state and federal regulations, general population growth, housing development for full time residents, second home development, and tourism. Please discuss your concern for each of these. Why are you most concerned about *drought etc.* to reduce available water supply?

Vita

Robin Hale was born in Raleigh, North Carolina, where she lived until attending college. She attended the University of Denver in Denver, Colorado, receiving a Bachelor of Arts degree in 2006. She majored in music and minored in sociology. After several years of traveling, volunteering, and working, she decided to attend graduate school in geography and planning. She received her Master of Arts in Geography from Appalachian State University in May 2013.

Robin was awarded one of approximately twenty Graduate Research Associate and Mentoring (GRAM) Program positions to provide research, financial, and professional guidance and support throughout her graduate studies. She is a member of Gamma Theta Upsilon International Honor Society in Geography. Her research interests lay at the intersection of human and environment interaction, and how policy influences this relationship. She plans to work several years in the field before pursuing a doctoral degree.