ADVANCING WATER SUSTAINABILITY IN CROZET: STRATEGIES FOR REDUCING WATER DEMAND

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Advancing Water Sustainability in Crozet: Strategies for Reducing Water Demand

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Prepared for Sustainable Waters

"On my honor as a student, I have neither given nor received unauthorized aid on this assignment."

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Table of Contents

List of Acronym and Abbreviations

ACSA	Albemarle County Service Authority
AWE	Alliance for Water Efficiency
AWWA	American Water Work Association
CCAC	Crozet Community Advisory Committee
CLWP	Comprehensive Local Water Planning
DSM	Demand-Side Management
ESA	Environmental Studies Academy
EPA	Environmental Protection Agency
FY	Fiscal Year
LADWP	Los Angeles Department of Water and Power
PUB	Public Utility Board
RWSA	Rivanna Water and Sewage Authority
SWAT	School Water Audit Program
VASWCD	Virginia Association of Soil and Water Conservation Districts
WAHS	Western Albemarle High School
WUMP	Water Use Mitigation Program

Glossary

Decreasing Block Rate – a rate structure under which the price of water per unit (block) decreases as the amount used increases.

Flat Rate/ Fixed Fee – rate structure under which all customers pay a set fee (monthly, quarterly, etc.) for water service that is not tied to the amount of water used.

Increasing Block Rate Structure – a rate structure in which the rate per unit of water increases as the volume of consumption increases.

Non-Revenue Water – water that has been produced and is lost before it reaches the customer.

Potable Water – water that is suitable for drinking.

Rate Structure – a set of fees and rates that a water system uses to charge its customers for water.

Rebate program – a planned, coordinated group of activities, procedures, etcetera, to return part of the original payment for a more water efficient appliance or fixture.

Rebound Effect – a reduction in expected gains from new technologies that increase the efficiency of water use, because of behavioral or other systemic responses.

Revenue – funds earned by the system through the sale of water or by other means.

Seasonal Rate – a rate that varies depending on the time of the year.

Uniform Rate – a rate structure under which customers pay a single charge per unit of water.

Water Conservation* – the preservation, control and development of water resources, both surface and groundwater, and prevention of pollution. It includes all of the policies, programs and practices designed to help one use less water.

Water Credit – water credits are earned when water conservation efforts achieve savings intended to offset the water consumption of a new service connection or development.

Water Offset – the projected demand of new water connections (or new development) being offset by on-site and off-site water conservation efforts.

Water Neutral Development – offsetting the projected water demand of new development with on-site and off-site water efficiency measures to neutralize the impact on overall service area demands.

Water Neutral Growth – offsetting the projected water demand of new development with on-site and off-site water efficiency measures.

Water Sustainability – the continual supply of clean water for human uses and for other living things.

Water Efficiency* – minimization of the amount of water used to accomplish a function, task or result.

***The terms "Efficiency" and "Conservation" are used interchangeably throughout this report.**

Executive Summary

Population growth in Crozet raises water demand for the town. The increased population is putting pressure on the water supply. With increasing demand and irregularity in climatic conditions, Crozet will need to address water scarcity some point in time. Sustainable water use is crucial to protect the watersheds and ecosystem and maintain economic health and vitality of the town. Promoting efficient water use behavior involves the implementation of several demand management tools that address basic factors determining the water consumption patterns.

This paper conducts literature review on the demand-side management policies. Four policy options -increasing block rate (status quo), water demand offset, water conservation education program, seasonal pricing – are analyzed under five criteria: reduction of water demand, cost, equity, implementation feasibility, and program sustainability.

It is recommended that the ACSA should initiate water demand offset program while continuing current conservation programs. Developing demand offset programs requires accurate data to project demand; the ACSA and RWSA should develop probabilistic models for water demand projection to advance water sustainability in Crozet.

Problem Statement

The town of Crozet is generally considered to have adequate water resources. Crozet has experienced a rapid population growth within last 20 years. A continually growing population poses a threat to its limited water resources. Warming climate and irregular precipitation could decrease the supply reliability. The rising demand for water, along with uncertain climatic conditions, poses negative consequences on the social, economic and environmental health of the Crozet community.

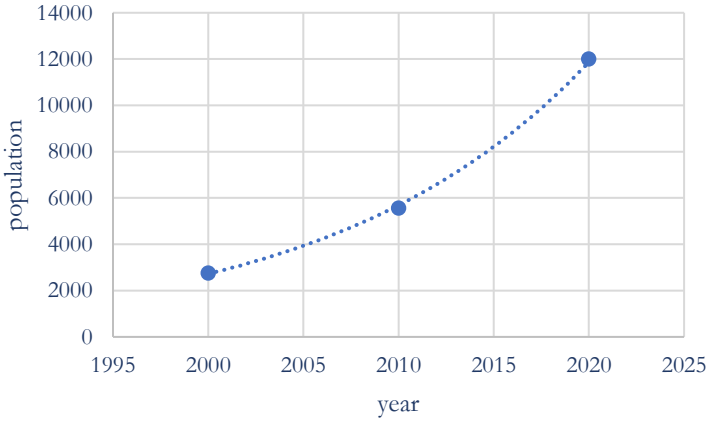
Background

Crozet is a part of the designated growth area in Albemarle County. Housing development in Crozet has increased significantly since 2000, and the population is growing rapidly. The Albemarle County Service Authority (ACSA), a wholesale buyer of the Rivanna Water and Sewer Authority (RWSA), distributes portable water to Crozet. The RWSA draws water from Beaver Creek and treats a maximum of 1 million gallons of water per day at the Crozet Water Treatment Plant. The RWSA expects that the town will need to process more than 1 million gallons per day around summer 2022 (Wrabel, 2017). The demand for water in this system will exceed this projection if a large commercial or industrial user locates in this area ("Water Supply Alternatives Supplemental Evaluation," 2004).

Population Growth

The population of Crozet was 2,753 in 2000, and it rose up to 5,565 in 2010 ("Crozet Master Plan," n.d.). The Crozet Master Plan estimates that the population of Crozet will reach 12,000 by 2020 (Marshall, 2009).

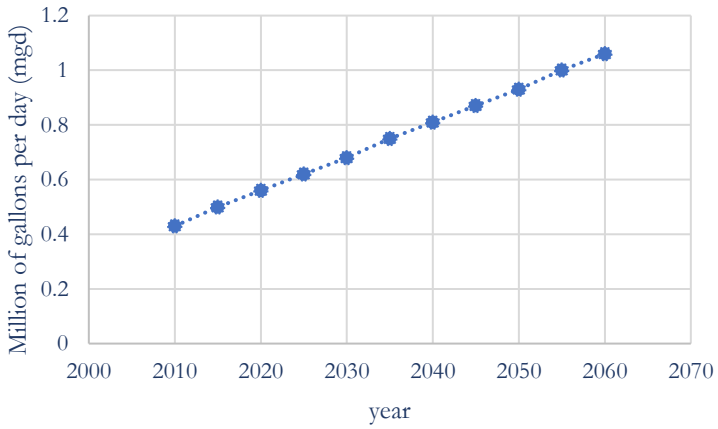
Figure 1: Population Growth in Crozet (2000-2020)



(Source: "Crozet Master Plan," n.d.; Marshall, 2009)

The survey on the people's opinion about the Crozet Master Plan, conducted by the Crozet Community Advisory Council (CCAC) and Albemarle County, shows that population growth and water supply are the two top concerns of the community (Marshall, 2009). A financial report from ACSA also states that the water consumption increases with the population growth in Crozet because water purchased for Crozet increased by 7.9 percent in 2018 ("Fiscal Year 2018: Annual Operating and Capital Improvement Budget," 2017). Besides the population growth, an increase in the number of businesses in town also raises water demand. The RWSA's Water Demand Analysis estimates that the demand of Crozet will change from 0.43 in 2010 to 0.56 MGD in 2020[1].

Figure 2: Water Demand Projection in Crozet (2010-2060)



(Source: "Rivanna Water and Sewer Authority Regional Water Demand Forecasts," 2011)

Housing Development

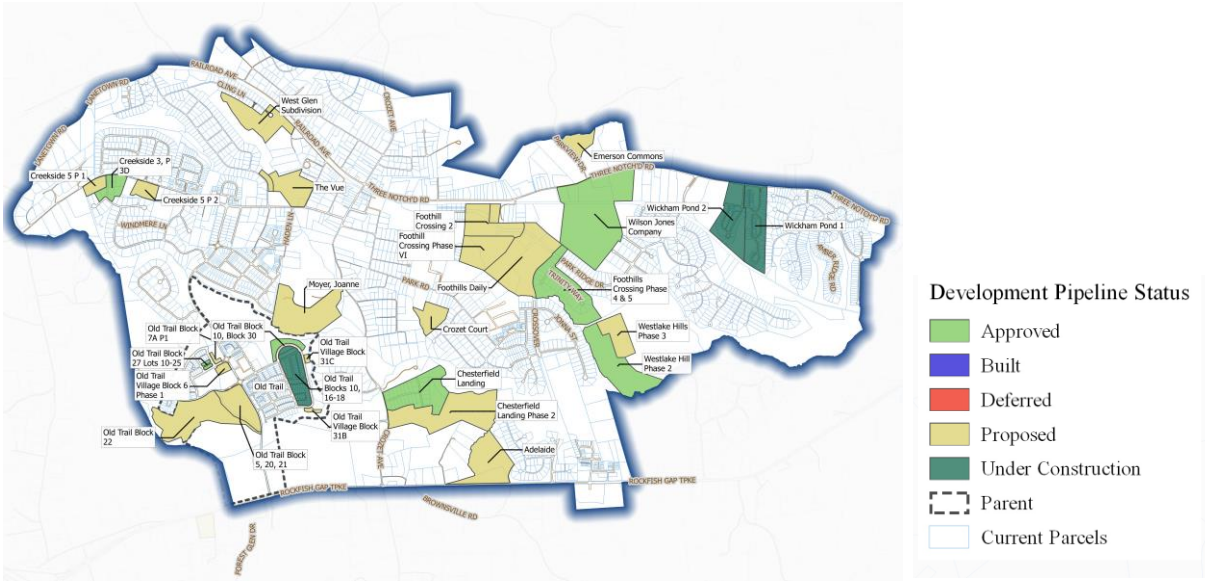
In Crozet, residences occupy most of the land areas. Commercial or mixed-use comprises 3 percent of the city ("Crozet Master Plan," 2010). As of 2017, there were 2,878 dwellings in Crozet ("Albemarle County Population/Housing Estimates," 2017). Among the residential units, there are 2,073 units of single-family households, 580 units of single-family townhouses or attached or duplets, 93 units of multi-family and single-family condos, and 132 units of mobile houses. Figure 3 shows the upcoming developments within the boundary of development area in Crozet. **The county staff estimate that 80 percent of this buildout development would occur by 2060** (Wrabel, 2017). **These new developments will add up additional demand for water in Crozet.**

[1] The RWSA underestimated the population growth rate. The actual demand will be larger than this projection.

Period Drought Conditions

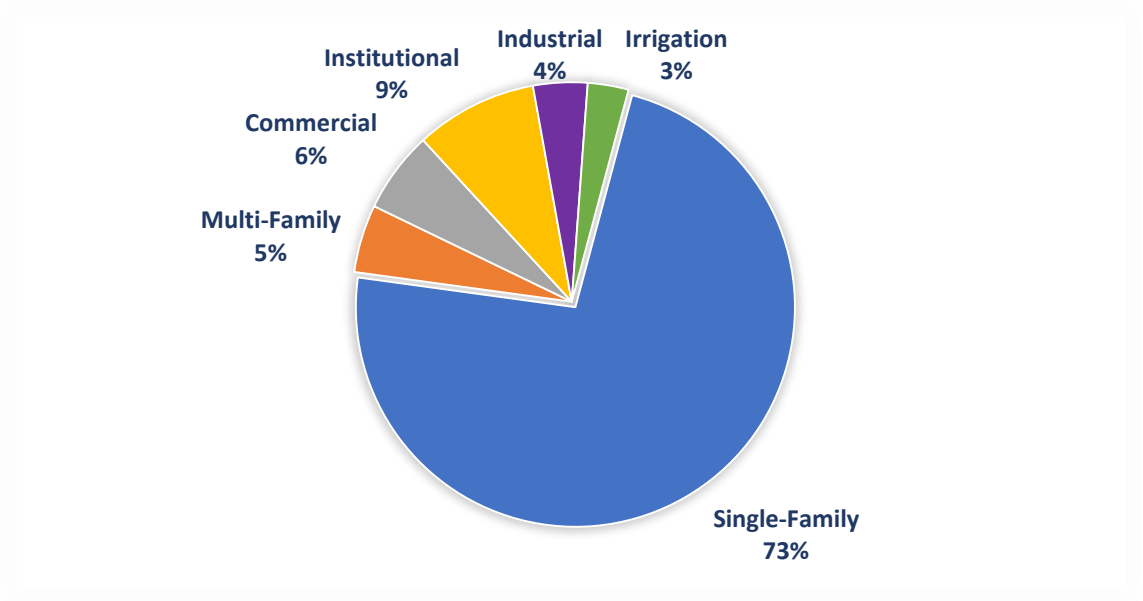
Crozet experienced a severe drought in 2002. During drought, water supply decreases while water demand increases by 5 percent due to high temperature (Ashoori, Dzombak & Small, 2017; Mcfarlane et al., 2012). The "Climate Change and Chesapeake Bay" Report warned that the future rainfall patterns are most likely to become irregular ("Rivanna Water and Sewer Authority Regional Water Demand Forecasts," 2011). The worst drought on the record is anticipated to exceed in the future due to economic growth and lifestyle changes (Zetland, 2011). Due to an uncertain climate conditions, the town of Crozet should prepare for drought resiliency by ensuring that the daily demand for water does not approach the safe-yield (1.8 mgd) to provide sufficient water for the residents during the drought. **The town of Crozet needs to adopt demand-side management policies to increase drought resilience.**

Figure 3: Crozet Development Pipeline Status



(Source: "Crozet Development Pipeline," 2017)

Figure 4: The Percentage of Total Water Use by Consumer Type in Crozet



(Source: "Rivanna Water and Sewer Authority Regional Water Demand Forecasts," 2011)

The Limitation of Supply-side Management Policies

Some legal challenges exist regarding the expansion of the Beaver Creek. The United States Soil Conversion Service (SCS) initially constructed the lake with the federal funds; any modification would require the approval from the governmental agency, and the replacement or repayment of some or all of the funds used to construct the lake (*Water Supply Alternatives Supplemental Evaluation*, 2004). Moreover, the increase in demand also requires the expansion of the wastewater treatment plants, which would cost a large sum of money. Water supply developments can have hydrologic alterations, which can cause ecological impairment in the Albemarle's ecosystem. **Therefore, supply-side management options will not be considered for more detailed analysis. Since the demand for water increase due to population growth is the root cause of this problem, I will consider demand-side management policies to address this issue.**

Promoting Water Efficiency through Demand-side Management Policies

Demand-side policy options are less costly than supply-side management policies. According to the Water Conservation Score Card from the Alliance for Water Efficiency (AWE), the current status of water efficiency policies in Virginia is "B-minus" ("The Water Efficiency and Conservation State Scorecard," 2012). The State of Virginia needs more commitment in water conservation. Besides enhancing drought resiliency, water conservation programs can eliminate, reduce, or postpone the need for capital projects, improve and extend the life of existing facilities, lower variable costs for water supply ("Water Conservation Plan Guidelines," 1998). Saving water can also save energy in

households because heating water consume large amount of energy in the building (Chwieduk, 2003). Water conservation helps reduce electricity bill and carbon footprint. Moreover, reducing water consumption can decrease the wastewater flow into the Chesapeake Bay drainage areas. **Efficient water uses benefits the environment, promote public health, and sustains economic growth by helping to maintaining aquatic ecosystems, protecting drinking water resources, and improving water quality.**

Table 1: Water Efficiency Scorecard of Virginia

Virginia	Water Efficiency Scorecard			Grade: B–
QUESTION		ANSWER	NOTABLE DETAILS	POINTS
1.	State agency in charge of drinking water conservation?	Department of Environmental Quality		1
2.	Water consumption regulation for toilets?	No		0
3.	Water consumption regulation for showerheads?	No		0
4.	Water consumption regulation for urinals?	No		0
5.	Water consumption regulation for clothes washers?	No		0
6.	Water consumption regulation for pre-rinse spray valves?	No		0
7.	Mandatory building or plumbing codes?	No		0
8.	Water loss regulation or policy?	Yes		1
9.	Conservation activities as part of water permitting process?	Yes		1
10.	Drought emergency plans required?	Yes		2
11.	Conservation planning required separate from drought plans?	Yes		2
12.	Authority to approve or reject conservation plans?	Yes		2
13.	How often are plans required?	5 or 10 Years		1.5
14.	Planning framework or methodology?	Yes		1
15.	Implementation of conservation measures required?	Yes		1
16.	State funding for urban water conservation programs?	Yes		1
17.	Technical assistance for urban water conservation programs?	Yes		2
18.	Does the state require volumetric billing?	No		0
19.	Percent of publicly supplied connections that are metered?	N/A		0
20.	ET microclimate information for urban landscapes?	No		0
EXTRA CREDIT			Extra credit awarded for Question 12	1
		TOTAL		16.5

(Source: "The Water Efficiency and Conservation State Scorecard," 2012)

Literature Review

This literature review examines the primary and secondary information on demand-side management policies from academic and grey literature and gives an overview of the range of possible demand-side management policies for water conservation and efficiency (Appendix A).

Demand-side management policies are more cost-effective than supply-side management policies. An Alliance for Water Efficiency (AWE) report states that investments in water efficiency could save 6.5 to 10 trillion gallons of water every year ("Transforming Water: Water Efficiency as Infrastructure Investment," 2017*)*. Increasing supply, such as building dams and reservoirs, can cost $4,000 per 1,000 gallons of capacity; meanwhile, water efficiency programs can cost between $ 0.46 to $ 250 per gallon saved ("Best Practices to Consider When Evaluating Water Conservation and Efficiency as an Alternative for Water Supply Expansion," 2016).

Water demand management policies involve cost-reflective pricing, community education campaign, customer advisory services, regulation of water-efficient appliance, water offset policies, and water use restriction ("What is Water Demand Management," n.d.). The demand-side management policies consider factors which determine household's water usage. Personal factors (household income, household size, age composition, routines, values, belief, and norms) and contextual factors (water pricing, regulatory policies, technology, climatic variation, dwelling type and type of ownership) are correlated with the amount of water in households (Hoque, 2014).

The EPA Water Conservation Plan Guidelines identified water provider, residential and commercial water consumer, labor groups, business and commerce groups, industrial water consumer, civil right groups, environmental groups, education institutions and government agencies as stakeholders for water conservation (1998). Since the water uses from single-family households, multi-family households, and commercial buildings constitute around 84 percent in Crozet, residential and commercial water consumers are considered as stakeholders for consumer type for this policy analysis.

The followings are the best-management practices for demand-side management policies.

Cost-Reflective Pricing

Many water utilities use water rate as an economic incentive to promote water conservation for short-term water shortage problem (drought) to long-term water supply issues (climate change and population growth). Changing the pricing structure or rate is a common economic incentive to reduce or eliminate wasteful use of water within the households (Wichman, 2016). The responsiveness of demand to changes in price depends on household income, an initial level of

price, dwelling types and proportion of indoor and outdoor water uses. The EPA lists increasing block rate structure[2], water surcharges[3], and seasonal rates[4] as price structures that promote water conservation (*Pricing and Affordability of Water Services*, 2017).

Renwick and Archiband found that household demand is responsive to changes in water price (1998). Their research suggests that lower-income families were the most price sensitive of all and bore a significant share of the conservation burden than higher income families. Baerenklau, Schwabe, and Dinar investigated the effect of introducing increasing block rate structure on residential demand in the Eastern Municipal Water District households in Southern California (2013). The research suggests that the demand was reduced by 18 percent as a result of this change. Similarly, the city of Greensboro in North Caroline shifted from a decreasing block structure to a flat rate for non-residential consumers ("Pricing and Affordability of Water Services," 2017). The result shows that the total consumption by the top ten water consumers decreased by 31 percent by 2008. **Water authorities can use price-structures to reduce the demand for water, but they need to consider the impact on low-income families who are the most vulnerable to the cost-reflective pricing.**

Water Conservation Education Campaigns/ Programs

Many water consumers are unaware of the situation of their local water supply and demand. Water authorities, together with individuals and civil societies, can educate water consumers about water sustainability. Researchers found non-price management policies, such as water conservation education programs, to be successful in managing water efficiency; cultural, behavioral, and institutional aspects are more likely to be associated with household's water consumption pattern (Randolph & Troy, 2008). A study conducted by Maas et al. (2017) shows that environmental and social concerns are highly associated with household's conservation of water. Municipalities and government operate educational activities to inform the public regarding the sustainable use of water. Common education programs include municipal demonstration projects, workshops for homeowners and business owners, direct mails for residents or business about water conservation and efficiency tips, etc.

Many government agencies and utilities implement public awareness campaign to promote water conservation. In Singapore, population and economic growth along with drought and limited water supply incite concern over water security. Public campaigns played an important role in making people aware of water conservation. In 1972, Public Utility Board launched "Water is Precious Campaign" to promote water saving habits in large-scale customers (Hoque, 2014). During the

[2] a rate structure in which the rate per unit of water increases as the volume of consumption increases.
[3] an atypical charge designed to recover revenues for a specific purpose.
[4] a rate that varies depending on the time of the year.

drought in 1976, PUB displayed slogan posters "Don't wait till the last DROP – Save water now" in public places to make people conscious of the urgent need to save water.

Water conservation education programs also targets children and teenagers. According to the Residential End Uses of Water Study, children and teens are more likely to use water for showers and baths than adults; the presence of one or more teenagers in the household could increase the per capita water used for showers from a mean value of 9.64 gallons to 12.31 gallons per capita per day (Beal et al., 2011). In 2009, Water Champion Program in New Jersey targeted high school students as a future environmental steward to promote water conservation in their communities by engaging them in environmentally-oriented learning activities ("Water Conservation Education Program," n.d.). Arizona Project WET (APW) integrates science and mathematics into the School Water Audit Program (SWAT) and allows students to investigate and quantify their water use and let them decide to install water-efficient technologies for their school ("Arizona Project WET," n.d.). **These education programs may contribute water conservation in households; however, it is hard to quantify the effectiveness of these programs because most of the programs are implemented in conjunction with other demand management policies.**

Water Demand Offset Policies

Water offset refers to "the projected demand for new development being offset by on-site and off-site water conservation efforts" (Christiansen, 2015). Water offset policy options are targeted for the increase in water demand due to the new developments because it allows for the new growth while maintaining overall service area demand for water. This required new developments to pay for on-site and off-site efficiency measures based on the estimated water demand for new development to ensure that construction of new development does not result in an increase in overall water demand. Under this policy options, developers need to offset the projected water consumption for the development to receive a permit to construct.

The city government of Danvers, Massachusetts implemented a Water Use Mitigation Program (WUMP) in 2008 which collects fees from new developments to offset two times the estimated water uses of new construction (Christiansen, 2015). Residential building projects pay the fee based on the number of bedrooms, and commercial and industrial projects are charged per day. The collected fees are used to rebate for replacing inefficient fixtures for toilets, clothes washers, showerheads, faucets, and rain sensors for existing irrigation systems. The Cambria Community Service District in California mandates new construction projects to offset projected water use through plumbing retrofits to receive water service for that building (Christiansen, 2015). This program requires all new construction and other projects to install water and energy efficient faucets, showerheads, clothes washers, dishwashers, and toilets. **These cases show that implementing Water demand offset policies needs data on the number of homes with inefficient**

appliances and a proper method to estimate the projected water use to be sustainable and efficient.

Outdoor Water Use Efficiency Policies

Outdoor water use constitutes about 40 percent of all residential water use in the United States (Hoque, 2014). Most outdoor water uses are for lawn watering, filling up the swimming pool and car washing while indoor water uses include sanitation, bathing, and laundry, cooking and drinking. Indoor water use is more compulsory compared to outdoor water use. The usage of outdoor water is also correlated with the setting and household type, and single-family residents in rural areas are more likely use water for outdoor. Indoor water use, in contrast, is essential and have more elastic demand compared to the outdoor water uses (Zetland, 2011). Customers are more likely to cut down outdoor water use in response to higher water rates such as seasonal pricing.

Water Utilities also use mandatory restrictions to target non-discretionary water uses like outdoor water uses. In 1990s, Los Angeles Department of Power and Water (LADPW) adopted an Emergency Water Conservation Plan Ordinance, which has five phases of water conservation, to restrict water use during the drought (Hoque, 2014). Regardless of water availability, Phase 1 conservation measures, which include the prohibition of the installation of single-pass cooling system, using water to clean and the serving of water in restaurant without customer's request, are in effect permanently. If the customers of LADPW does not follow these restrictions, they received warning for the first violation, and will be fined up to the maximum of USD 300 for subsequent violations (Hoque, 2014). The voluntary and mandatory conservation programs can reduce the water use between 1 to 13 percent and 19 to 21 percent respectively (Hoque, 2014). While water restriction has high equity as it will be imposed on everyone in the county, seasonal pricing will be more put more conservation burden on low-income households (Zetland, 2011).

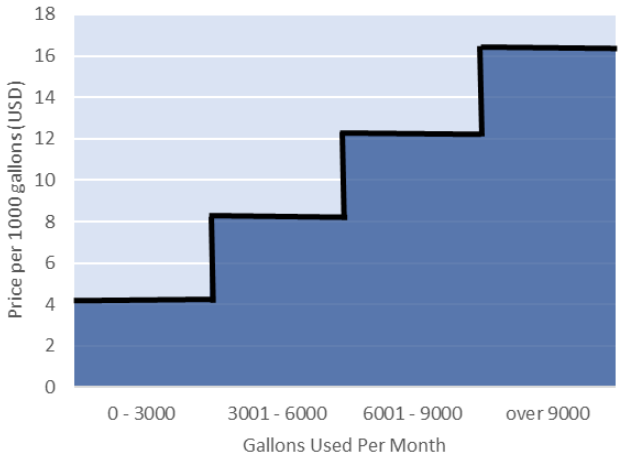
Policy Alternatives

The town of Crozet is committed to enhancing water sustainability to ensure water security for existing and future population and to preserve the habitats and ecosystem of the Albemarle County. The ACSA should consider following policy options to make the residents more conscious of their water use and to achieve reduction in demand for water.

Option 1: Continue the current policies

The ACSA adopts an increasing block rate structure for single-family residents; it charges a higher price at the larger consumption of water (Figure 5). The higher blocks serves as an incentive to conserve water and compensate for the first block's price. This pricing structure reduces the water utility bill for those using the least amounts of water. The ACSA implements uniform rate for multi-family and non-residential (Table 2). Figure 5 shows the ACSA's monthly water and sewer rates for FY 2018. Besides, the ACSA promotes water conservation through several initiatives, which include Toilet Rebate Program, Rain Barrel Rebate Program, 20 Percent Water Reduction Challenge, Toilet and Rain Barrel Rebate Contest, and Car Wash Certification Program (See Appendix B). The administration department of the ACSA also offers free water conservation toolkits – water saving showerheads, water saving faucet aerators, shower timers, water displacement bags, and toilet dye kits to check for leaks – to customers who ask for these materials. The webpage of the ACSA also provides daily water conservation tips and water use calculator.

Figure 5: Increasing Block Rate Structure for Single-Family Households



(Source: "Fiscal Year 2018: Annual Operating and Capital Improvement Budget," 2017)

Table 2: Water Pricing for Single-Family Residents and Multi-Family/ Non-Residential

Volume of Water Consumption (Gallons)	Charge per 1000 gallons
Single-Family Residents	
1 to 3000 gallons	$ 4.11
3001 to 6000 gallons	$8.22
6001 – 9000 gallons	$12.33
over 9000 gallons	$16.44
Multi-Family/ Non-Residential	
$7.93 per 1000 gallons	

(Source: "Fiscal Year 2018: Annual Operating and Capital Improvement Budget," 2017)

Option 2: Initiate Water Demand Offset Program

This option requires the ACSA to develop a water demand offset ordinance. Under this option, new developments that increase water demand have to offset such demand through conservation or new supply. This option will use a water demand offset ratio of 1:1, which requires 100 percent of the projected water demand to be neutralized. New developments will need to equip water and energy efficient faucets, showerheads, clothes washers, dishwashers, and toilets which meet the WaterSense or Energy Star specifications. Outdoor water efficiency measures such as sub metering for multi-family households, drip irrigation, the use of recycled water in common areas and outdoor facilities have to be installed based on the water demand. Since the town of Crozet has some old buildings with inefficient fixtures, off-site efficiency measures will be included in the ordinance besides on-site efficiency measures. Since the procedures for off-site efficiency measures may be burdensome for developers, there will an option, in which developers can pay a fee instead of performing off-site efficiency measures. If the developers choose to pay the fee, the AWSA will be responsible for implementing the efficiency measures and rebate for the replacement of inefficient fixtures.

Option 3: Develop Water Conservation Education Program

Under this policy option, the ACSA will form partnership with Western Albemarle High School (WAHS) & the Environmental Studies Academy to increase water conservation awareness among high school students. This goal of this option is to nurture water conservation practices in future society and to raise awareness in present society. The Environmental Studies Academy (ESA) is located in WAHS, and all the high school students can be trained along with ESA students to increase water conservation stewardship in high school. ESA students, who have more rigorous coursework and commitment to sustainability and conservation, can partner with non-ESA high school students to conduct water audit in school and take part in community awareness campaign. The curriculum for this program will be designed to encourage partnership between ESA students and non-ESA students and to motivate students to educate their neighbors about water

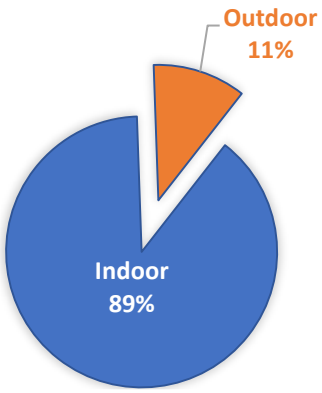
conservation. This program will schedule water conservation lesson with similar topics in coursework not to impede core courses; this program will allocate at least 25 hours of water conservation education and activities in a year.

High school students will be trained as agents for water conservation within the Crozet community. This would require ACSA to work with ESA teachers to integrate water conservation and sustainability curriculum for ESA students and other high school students. ACSA also needs to host water conservation workshops and preparatory training for teachers, organize in-class programs for high school students, arrange field trips to water facilities, offer water conservation field experience, and provide lesson plans and class materials (poster, student worksheets). This program can also partner with Virginia Association of Soil and Water Conservation Districts (VASWCD) Education Foundation to obtain financial and educational resources.

Option 4: Impose Seasonal Pricing

Under this option, ACSA will adopt a uniform rate[5] and impose seasonal pricing through increasing water rate by 20 percent during the time of the year when the water use is significantly higher (May-October). This policy option is designed to make people conscious of their outdoor water use and encourage water savings. During the summer months, people have increased outdoor water use as water consumption increases approximately 16 percent during the summer.[6]Single-family residences, which are predominant in Crozet, generally contain larger landscaped areas and require more water for outdoor application compared to other housing types. This policy option targets outdoor water users and imposes additional costs in summer when the peak demand is high, and availability is low.

Figure 6: Indoor Vs outdoor water use in Crozet



(Source: "Rivanna Water and Sewer Authority Regional Water Demand Forecasts," 2011)

[5] a rate structure under which customers pay a single charge per unit of water.
[6] this percentage is calculated by comparing winter water consumption and summer water consumption in the city of Charlottesville

Evaluative Criteria

I will evaluate the policy proposals presented in this paper on the basis of the following criteria:

1) Reduction in Water Demand
2) Cost
3) Equity
4) Implementation Feasibility
5) Program Sustainability

Reduction in Water Demand

The goal of this policy analysis is to reduce the water demand and promote water sustainability in Crozet. Reduction in water use is an essential criterion for sustainability and resilience of the Crozet community. This criterion will use the gallons of water reduced per day in 2038 compared to the baseline demand under uniform rate to analyze each option. The amount of water reduced daily in 2038 is used rather than the total amount of water saved within 20-year period because the RWSA used "million gallons per day (mgd)" to project the future demand for water. Reduction in water demand in 2038 can indicate the effectiveness of each policy alternatives in promoting efficient water use because the water demand reduction in 2038 results from the previous declines in water demand. The methodology for the analysis of each policy option under this criterion is included in Appendix C. (Weight: 40%)

Cost

All proposed policy options pose a cost to the ACSA, the Crozet community and other stakeholders. Although the policy options are not mutually exclusive, all these options cannot be implemented at the same time due to the limitation in the budget. I used cost data through literature review to evaluate the cost estimate of each alternative. Each option will be estimated for the 20-year time frame and compared with the rest of the options to determine the relative cost. I will score each policy option on a measure of 1 to 3 on the following scale:

1. High Cost
2. Medium Cost
3. Low Cost

(Weight: 20%)

Equity

New water efficiency policies have different level of impacts on residents, businesses, and industries. These policies also could have different consequences on different socioeconomic background.

Equity is an issue in this policy analysis because each policy option might not equally distribute the benefits water efficiency outcome in Crozet. A policy is regarded equitable if the projected outcome is likely to have a similar effect on the array of key stakeholders. I will score each policy option on a measure of 1 to 3 on the following scale:
1. Low Equity
2. Medium Equity
3. High Equity
(Weight: 10%)

Implementation Feasibility

I evaluate each policy option based on its implementation feasibility. This criterion measures the simplicity of policy and reveals the likelihood key stakeholders would support the proposal for water efficiency and accesses how logistically manageable it would be to implement the policy. This criterion will address the bureaucratic capabilities of the Albemarle County government and the Albemarle County Service Authority (ACSA) in implementing each alternative in Crozet. The ACSA will be managing water supply associated with each option. The Albemarle County government will handle development in each option. This criterion will consider how each option will be possible from the capacity and mission of these stakeholders, consistent with accepted practice and industry standards, local ordinances and state statutes, contractual obligations, etc. ("Case Studies of Sustainable Water and Wastewater Pricing," 2005).

I will rank each policy option on a measure of 1 to 3 based on the following scale:
1. Low Implementation Feasibility
2. Medium Implementation Feasibility
3. High Implementation Feasibility.
(Weight: 10%)

Program Sustainability

All policy options have different level of program sustainability. Although some programs are effective in the short-term, their effectiveness deteriorate as time passes. Since the demand reduction and water sustainability should have long-term effect, program sustainability is one of the important criteria for the analysis. I will score each policy option on a measure of 1 to 3 on the following scale:
1. Low Program Sustainability
2. Medium Program Sustainability
3. High Program Sustainability
(Weight: 20%)

Analysis

This section analyzes the proposed policy options under five criteria: reduction in water demand, cost, equity, implementation feasibility, and program sustainability. The methodology and calculation for reduction in water demand is shown in Appendix C.

Option 1: Continue Current Policies

Reduction in Water Demand: The current policy utilizes the increasing block rate structure to reduce the usage of water. By continuing this policy option, the average amount water saved in 2038 will be 0.172 million gallons per day.

Cost: Compared to other policy options, the cost for this policy is relatively low. The cost involved in this program are the administrative cost and the cost paid by households, which use more than the 5000 gallons of water.

Implementation Feasibility: Implementation feasibility is the highest for this option because the The ACSA has adopted this rate structure, and the residents of Crozet are already accustomed to this rate structure. Moreover, this policy option has more advantage in monitoring and enforcement compared to other policy options because water customers will have to comply with this pricing to receive water service.

Equity: Low-income families usually spends a higher percentage of their bill on water compared to medium-income families and high-income families (Barrett, 2004). Low-income residents are more sensitive to water price changes than high income households. Thus, this block rate structure could unintendedly make some low-income households more sensible to changes in price. Although the first-block price serves to incentivize people to conserve water, low-income families will encounter financial burdensome when they need to use a significant amount of water for an emergency situation. As this option might make the poor-households more burdensome, equity is medium for this option.

Program Sustainability: The ACSA updates water rates annually to match inflation and income level. That makes the customers aware of the water schedule and use water more carefully. Sustainability is medium for this position. As the effectiveness of water conservation also depends on the motivation and characteristics of the customer, the price itself alone cannot actively enhance efficiency in the long run. Hence, sustainability is medium for this option.
The table below describes the summary of all the evaluative criteria.

Table 3: Analysis for Policy Option 1

Evaluative Criteria for Option 1				
Reduction in Water Demand (Million Gallons of water saved daily in 2038)	Cost	Implementation Feasibility	Equity	Program Sustainability
0.172 mgd	**Low**	**High**	**Medium**	**Medium**

Option 2: Initiate Water Offset Program

***Reduction in Water Demand*:** With this policy option, the number gallon saved per daily in 2018 will reach 0.85 mgd.

***Cost*:** The developers have to pay for the amount to reduce the water use of the new construction through water efficient appliances, and the developers will bear most of the cost of this policy option. The water supplier incurs the cost of developing the program, which includes law enforcement and hiring staffs. The RWSA and the ACSA will also bear administrative fees and processing fees to cover the cost of pre- and final-inspection. Although the developers incur the cost of the offset, increased housing fee or homeowner costs might be the negative tradeoff of this policy option. This offset program normally costs USD 8 million to save 0.9 million gallons per day (Christiansen, 2015). So, the cost is higher compared to other policy options.

***Implementation Feasibility*:** The RWSA can administer the water offset program which would require additional staff and administrative works. This program can have some legal issues on construction and off-site efficiency measures, and the development of the ordinance might face some opposition. One reason is that developers pay the offset fees, but the benefits of drought resilience and water sustainability would be experienced by the whole Crozet community. It can be implementable with current policy option. Hence, the implementation feasibility is medium for this option.

***Equity*:** This policy options can also provide a means of bringing conservation to low-income households that may not have the ability to implement such water efficiency measures. This program has a high equity because it would have a widespread, equitable impact on the majority of the residents.

***Program Sustainability*:** The installation of water efficient devices can promote water efficiency over time. Rebound effect occurred in some wasteful consumption practices can lower the expected saving. If the water price goes down due to an increase in efficiency, people will use more water. This policy option could facilitate economic growth, and create housing and jobs, and contribute the long-term water sustainability of Crozet. Sustainability is high for this option.

Table 4: Analysis for Policy Option 2

Evaluative Criteria for Option 2				
Reduction in Water Demand (Million Gallons of water saved daily in 2038)	Cost	Implementation Feasibility	Equity	Program Sustainability
0.85 Mgd	High	Medium	High	High

Option 3: Establish Water Education Program

***Reduction in Water Demand*:** Based on the estimation, this program will save around 0.019 million gallons per day.

***Cost*:** This program can cost around USD 100,000 which would be cheaper than water offset program; the cost can include curriculum fee, outreach, travel, appliances. The cost might be high initially for the development of curriculum, but it will cost less as the program is settled. The cost is medium for this option.

***Implementation Feasibility*:** The implementation feasibility is medium because it needs a lot of coordination and teacher development. It is also challenging to integrate water conservation curriculum with other high school courses, and some parents might object this program as they might think student might be able to learn other new skills instead of that program. This program can be implemented together with current policies. Therefore, implementation feasibility is medium for this option.

***Equity*:** Equity is high as water conservation benefit through this program will be shared by all households in Crozet.

***Program Sustainability*:** Although this program might promote socially responsible behaviors, it will be hard to sustain this program in the future as people might become less interested in this program over time. Thus, program sustainability is low for this option.

Table 5: Analysis for This Policy Option 3

Evaluative Criteria for Option 3				
Reduction in Water Demand (Million Gallons of water saved daily in 2038)	Cost	Implementation Feasibility	Equity	Program Sustainability
0.018 mgd	Medium	Medium	High	Low

Option 4: Seasonal Pricing

***Reduction in Water Demand*:** With this option, the town of Crozet could save 0.06 million gallons per day in 2038.

***Cost*:** The cost for this option is medium. The cost involved administration cost, operation cost, and the money collected from those who use water excessively during the summer. Moreover, increase in the price of water lower down outdoor eater use in Crozet. Lack of maintenance or turf and grass during the summer can decrease the property value in Crozet which is also the cost of this policy.

***Implementation Feasibility*:** Implementation Policy is medium. The ACSA set the same water price for the whole county. So, imposing seasonal price only to Crozet might require holding public meetings and approval to implement changes in the rate structure.

***Equity*:** Equity is medium because it might make low-income families use less water during the summer.

***Program Sustainability*:** Sustainability is low because the reduction in demand for water only occurs during the summer.

Table 6: Analysis for Policy Option 4

Evaluative Criteria for Option 4				
Reduction in Water Demand (Million Gallons of water saved daily in 2038)	**Cost**	**Implementation Feasibility**	**Equity**	**Program Sustainability**
0.06 mgd	**Medium**	**Medium**	**Medium**	**Low**

Outcome Matrix

Outcome Matrix				
Evaluative Criteria	Option 1: Present Trend	Option 2: Water Demand Offset	Option 3: Education Program	Option 4: Seasonal Pricing
Reduction in Water Demand (mgd)	0.172	0.85	0.018	0.06
Cost	Low	High	Medium	Low
Implementation Feasibility	High	Medium	Medium	Medium
Equity	Medium	High	High	Medium
Program Sustainability	Medium	High	Low	Low

Recommendation and Implementation

It is recommended that the ACSA continue the increasing block rate structure and initiate water offset program in Crozet. This mix of policy could achieve significant improvement in water sustainability in Crozet. Based on the outcome matrix, water offset program is the highest scoring option. The ACSA should continue the increasing block rate structure because it is already in place, and it is also compatible with the water demand offset program. Water offset program can increase the water equity in the region because it would allow low-income households to use highly water-efficient appliances and to promote water efficiency.

It is recommended that the ACSA reaches out to the Crozet community, and talks with the residents and CCAC regarding the need for water demand offset policies before implementing the program. AWE developed model ordinance template (Net Blue), and the ACSA should draft the ordinance together with the Albemarle County Government, CCAC, and the developers to create water demand offset approach that meets the needs of the local people. Demand offset programs require the accurate data for the water demand projection of the new development and the estimation of the water savings through on-site and off-site efficiency measures. The ACSA and RWSA should also perform sensitivity analysis to produce a range of water demand through the population growth, and water efficient appliances and fixtures. Developing probabilistic models for water demand projection is fundamental in implementing water demand offset program for Crozet.

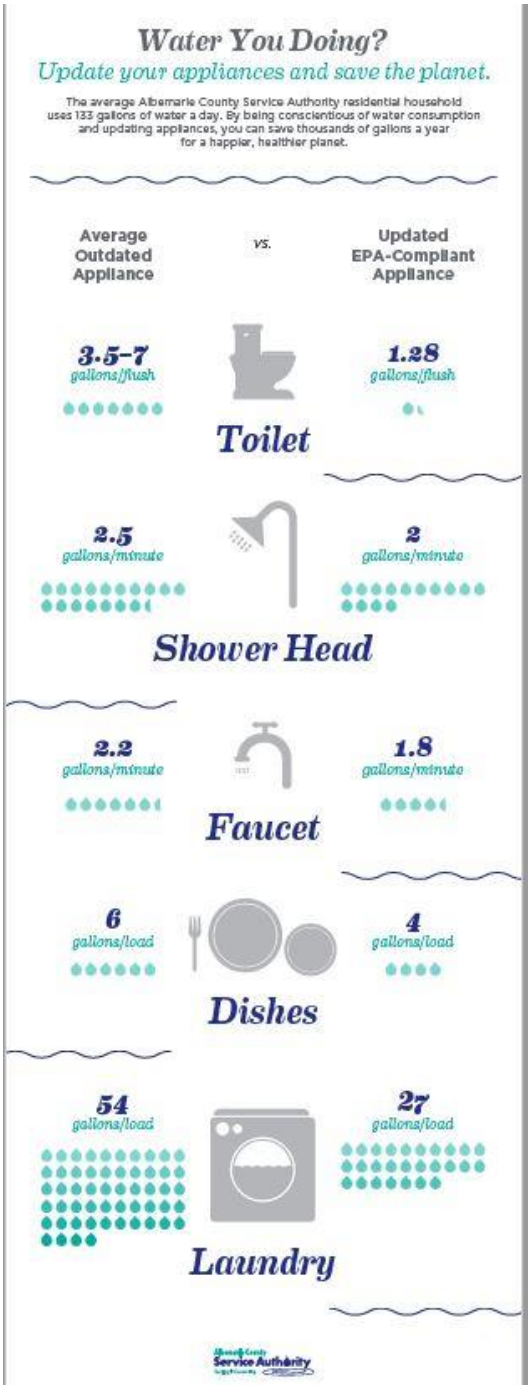
Appendices

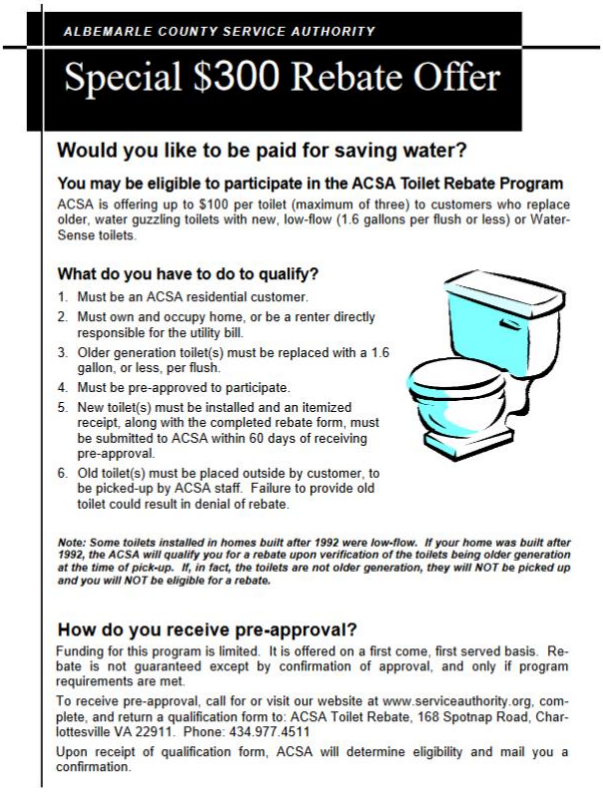
Appendix A: A range of policies that government can use to promote water conservation

Policy Matrix			
Using market	**Creating Market**	**Regulation**	**Engaging the Public**
Subsidy reduction Environmental taxes User fees Deposit-refund systems Targeted subsidies	Property Right/ decentralization Tradable permits/rights	Standards Bans Permits/Quotas	Public Participation Consultation Information disclosure Informal negotiation Community pressure NGO involvement

(Source: Brett, 2004)

Appendix B: Current Conservation Activities of the ACSA





(Source: "Conservation: Albemarle County Service Authority," n.d.)

ACSA Water Use Calculator Questions

GENERAL QUESTIONS	
1. Total number of people in your household. (Required)	
INDOOR WATER USE	
BATHROOM	
1. How many showers are taken each day in your household?	
2. What is the average length (in minutes) of each shower. *(Enter 6.3 if you are unsure).*	6.3
3. What is the flow rate (gallons per minute) of your showerhead? *(Enter 5 for standard showerhead; 2 for low flow).*	5
4. Total number of baths taken each week by members of your household.	
TOILETS	
1. Average number of times each person flushes a toilet in your house per day. *(Enter 4 if you are unsure).*	4
2. How many gallons does your toilet use per flush? *(Enter 5 if you have a standard toilet; 1.6 if you have a low volume toilet).*	5
FAUCETS	
1. How many times each day does each household member use faucets to shave brush teeth, wash hands and face?	
2. How many minutes does the water run during each use?	
WASHING DISHES	
1. How many times are dishes washed by hand each day?	
2. How many minutes does the water run during each wash?	
3. If you have a dishwasher, how many times is it used each week?	
4. The average dishwasher uses 15 gallons of water per load, change this number if yours is different.	15
LAUNDRY	
1. How many loads of laundry are done by members of your household each week.	
2. The average washing machine uses 55 gallons of water per load, change this number if yours is different.	55
OUTDOOR WATER USE	
LAWN WATERING & OTHER USES	
1. How many times is your lawn watered each week?	

2. How many minutes is the lawn watered per watering?	
3. Water is also used outdoors to wash cars, fill pools, rinse outdoor furniture and clean equipment. Estimate the average number of minutes water is used outdoors for purposes other than watering each week.	
Press the	

RESULTS			
PER CAPITA DAILY WATER USE IN YOUR HOUSEHOLD (gallons)			
INDOOR WATER USE		**OUTDOOR WATER USE**	
Bathroom		Lawn Watering	
Toilets		Other Outdoor Uses	
Faucets		**GENERAL WATER USE**	
Laundry			
Dishwasher			
Hand Washing Dishes			

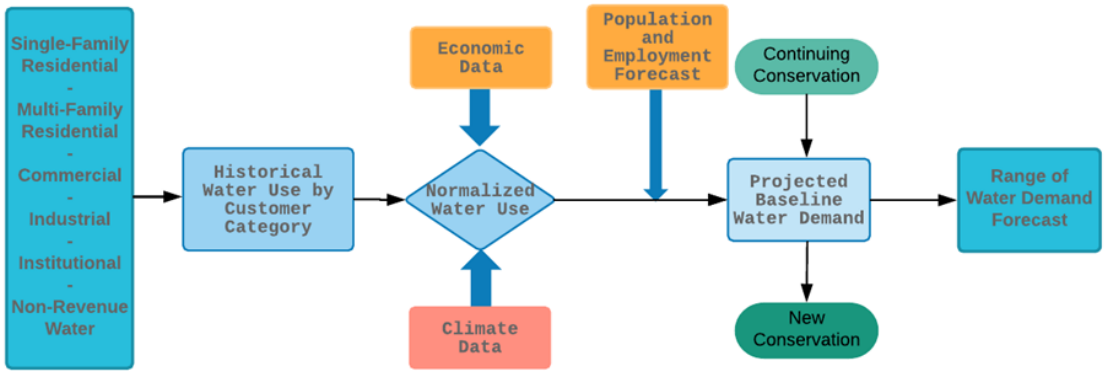
COMPARISON BETWEEN YOUR HOUSEHOLD AND THE Albemarle County Service Authority customer AVERAGE* HOUSEHOLD		
	Your House	**ACSA Average**
Interior per capita gallons per day		137
Exterior per capita gallons per day		40

	Total Per Capita Gallons of Water Used in the House		
	Per Day	**Per Month**	**Per Year**
Your Household			
Albemarle County Service Authority Customer Average			
Comments:			

(Source: "Conservation: Albemarle County Service Authority," n.d.)

Appendix C: Water Demand Reduction Analysis

The RWSA's Water Demand Projection Methodology



(Sources: *Rivanna Water and Sewer Authority Regional Water Demand Forecasts,* 2011)

Establishing the baseline to calculate effectiveness

Water utility managers use mathematical methods such as extrapolating historic trends, correlating demand with socioeconomic variables, or detailed simulation modeling to forecast future water demand of the certain region ("Water Rates: Water Demand Forecasting," n.d). The baseline for water demand is established using the RWSA Regional Water Demand Forecast report to calculate the effectiveness of each policy options in reducing water demand. The RWSA Regional Water Demand Forecast report underestimated the population growth; the RWSA projected the population of Crozet to be around 6,500 in 2017 but the actual population is 7,682. However, the methodology developed by RWSA considers most of the variables correlated with an increase in water demand. The goal is to reduce water demand in the long-run, so the 20-year time frame is chosen to analyze how much water will be saved daily in 2038 under each of these policy options.

Option 1: Continue the Current Policies

The AWSA adopts increasing block rate structure. The reduction in water demand under increasing block rate structure is calculated by assuming uniform rate structure as a baseline. The table below shows the assumption for this projection.

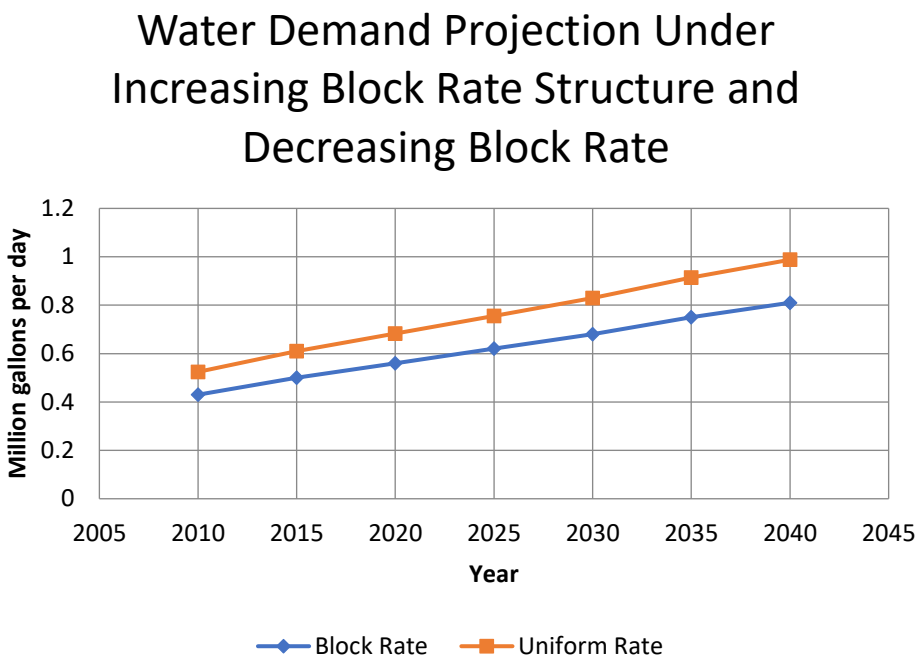
Assumption	Choice	Source
the effect of changing from uniform rate structure to block rate structure	18% decrease in Water demand	Baerenklau. Schwabe & Dinar, 2013

Since the demand for water is likely to be reduced by 18 percent when the ACSA changes from Uniform Rate to Increasing Block Rate -

$$\textbf{Water Demand under Uniform rate} = \frac{\textbf{Water Demand Under Increasing Block Rate}}{\mathbf{0.82}}$$

The following table shows the millions of gallons saved per day.

Year	Water Demand Under Increasing Block Rate (mgd)	Water Demand Under Uniform Rate (mgd)	The amount of water saved (mgd)
2010	0.43	0.52	0.09
2015	0.5	0.61	0.11
2020	0.56	0.68	0.12
2025	0.62	0.76	0.14
2030	0.68	0.83	0.15
2035	0.75	0.91	0.16
2040	0.81	0.99	0.18



Since the increase in demand is in linear growth, the amount of water saved under increasing block rate structure between 2035 and 2040 is 0.02 mgd. As the duration is 5 years (2035 to 2040), annual increase is 0.004 mgd between 2035 and 2040. The reduction in water demand per day in 2038 is **0.172 mgd.**

Option 2: Water Demand Offset Policies

Assumption	Choice	Source
Water saved in new homes	94,627 gallons per year per new home	Christiansen, 2015
Water saved in old homes	12,904 gallons per year per household retrofit	Christiansen, 2015
Number of old homes with inefficient fixtures	2100[7]	"Rivanna Water and Sewer Authority Regional Water Demand Forecasts," 2011
Number of new homes built from 2018 to 2038	3000	Crozet Development Pipeline, 2017

$$Daily\ Saving\ in\ 2038 = 94{,}627 * \frac{3000}{365} + 12{,}904 * \frac{2100}{365}$$

The reduction in total demand per day under this option is 0.85 mgd.

Option 3: Water Conservation Education

Assumption	Choice	Source
Population Projection in Crozet	The data in the table below	"Rivanna Water and Sewer Authority Regional Water Demand Forecasts," 2011
The percentage of high school student in Crozet	14.80%	Derived from the current number of high school student and population
The percentage of high school student who live in Crozet	8%	US Census
The effectiveness of outreach	75%	Estimate
Reduction in water demand	16.7 gallons per day	Serna & Thompson, 2015
The lasting impact on households	20 household per year x 20 years	Estimate

[7] The report shows that Albemarle County has 61658. Since Crozet's population is 5 percent of the total population of the county, I assume that the old home in 2017 is 3000. In 2038, 70 percent of these home will be retrofitted.

I use the percentage of high school student in US population to project the number of high school students in Crozet over time. Students from nearby areas also come to Crozet attend WAHS, so the actual number of high school students is larger than estimated. Students from other nearby areas of Albemarle come to Western Albemarle High School, so the actual number of high school students who live in Crozet will be smaller than the actual number of high school students. Currently, there are 1,041 high school students. I assume that 8 percent of the population in Crozet are high school students, who live in single-family homes in Crozet. Among these available students, 75 percent of them follow water conservation practices.

Year	Population	Total High School Population (projected actual high school students)	Students from Albemarle (8% of population)	Effectiveness (75%)
2015	6366	942	526	395
2020	7170	1061	592	444
2025	7973	1180	659	494
2030	8777	1299	725	544
2035	9581	1418	792	594
2040	10385	1537	858	644

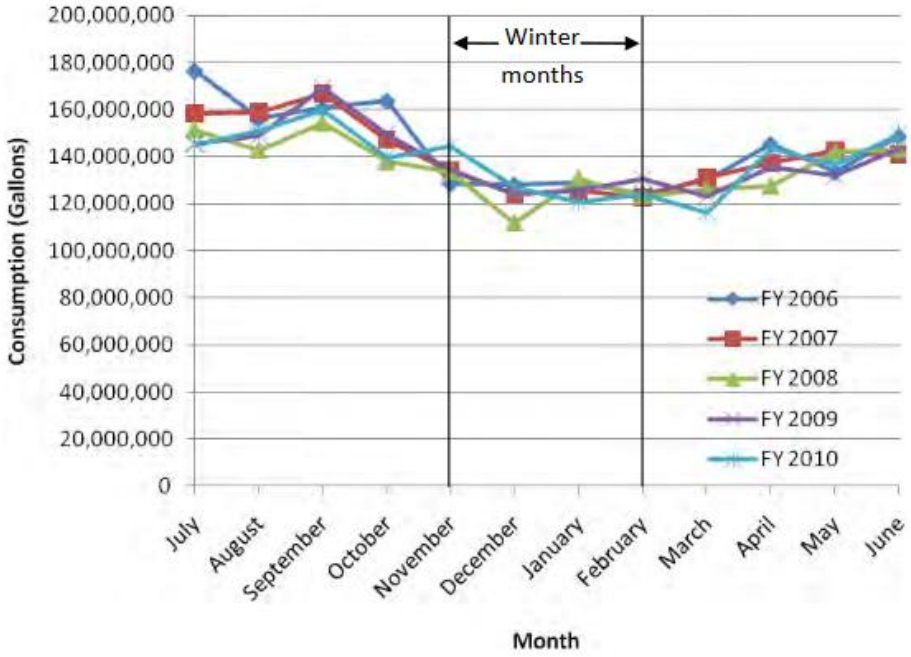
Based on this projection, the number of high school students in 2038 will be 624, which is also the number of households. I also assume that the program makes some people remain conserving water even after high school. I assume this number is 25 households per year, so after 20 years, there are approximately 500 households practicing water conservation. Since Serma and Thompson (2015) suggests that water conservation education could reduce an average of 16.7 gallons per household per day, the total gallons of water reduced will be

$$(624 + 500)* 16.7 = \textbf{0.018 million gallons of water per day}$$

Option 4: Seasonal Pricing

Assumption	Choice	Source
Reduction in demand in response to price	10 percent increase in the marginal price reduce demand by 3 percent	Olmstead & Stavins, 2006

Since the seasonal price will only be imposed during the summer months, water demand reduction will only take place during the summer. There is no data for monthly consumption in Crozet. There is a water demand data for Charlottesville from 2006 to 2010. I assume that the percentage change in water use for winter months and water use for summer months will be constant and applicable to the different locations in Albemarle County. I used the consumption pattern of Charlottesville to estimate how much water consumption increases during the summer months in Crozet.



Month	2006	2007	2008	2009	2010	Average
November	130,000,000	130,000,000	130,000,000	135,000,000	145,000,000	134,000,000
December	130,000,000	125,000,000	110,000,000	125,000,000	130,000,000	124,000,000
January	130,000,000	125,000,000	130,000,000	122,000,000	120,000,000	125,400,000
February	120,000,000	125,000,000	120,000,000	130,000,000	125,000,000	124,000,000
March	130,000,000	130,000,000	130,000,000	125,000,000	115,000,000	126,000,000
April	145,000,000	135,000,000	125,000,000	135,000,000	145,000,000	137,000,000
May	135,000,000	140,000,000	140,000,000	130,000,000	135,000,000	136,000,000
June	145,000,000	140,000,000	140,000,000	140,000,000	145,000,000	142,000,000
July	176,000,000	160,000,000	150,000,000	142,000,000	145,000,000	154,600,000
August	158,000,000	160,000,000	140,000,000	150,000,000	150,000,000	151,600,000
September	160,000,000	168,000,000	155,000,000	168,000,000	160,000,000	162,200,000
October	162,000,000	145,000,000	137,000,000	145,000,000	140,000,000	145,800,000

Using the average of demand during winter and summer, I calculated the change in demand:

Summer Use Average	**148,700,000**
Winter Use Average	128,400,000
Percentage increase	0.16
	16 percent increase in summer

Using the fact that demand increases 16 percent increase in summer, I calculated how much water can be saved using seasonal pricing. The results show that 0.06 million gallons of water will be saved daily in 2038.

Year	Water Demand under Uniform Rate for the whole year average	Water Demand under Uniform Rate for Summer	Water Demand Uniform rate for summer with seasonal pricing	Water saved
2010	0.49	0.57	0.53	0.03
2015	0.57	0.66	0.62	0.04
2020	0.64	0.74	0.69	0.04
2025	0.70	0.82	0.77	0.05
2030	0.77	0.90	0.84	0.05
2035	0.85	0.99	0.93	0.06
2040	0.92	1.07	1.00	0.06

References

2009 WaterSense Single-Family New Home Specification Supporting Statement. (2009, December 09). Retrieved May 1, 2018, from https://www.epa.gov/sites/production/files/2017-02/documents/ws-specification-home-final-suppstatement-v1.0.pdf

Albemarle County Population/Housing Estimates. (2017, May). The Albemarle County Community Development Department, Division of Information Services.

Arizona Project WET. (n.d.). Retrieved March 02, 2018, from https://arizonawet.arizona.edu/programs/school_water_audit

Ashoori, N., Dzombak, D. A., & Small, M. J. (2017). Identifying water price and population criteria for meeting future urban water demand targets. *Journal of Hydrology, 555*, 547-556. doi:10.1016/j.jhydrol.2017.10.047

Barrett, G. (2004). Water Conservation: The Role Of Price And Regulation In Residential Water Consumption. *Economic Papers: A Journal of Applied Economics and Policy, 23*(3), 271-285. doi:10.1111/j.1759-3441.2004.tb00371.x

Baerenklau, K. A., Schwabe, K. A. & Dinar, A. (2013, September). Do Increasing Block Rate Water Budgets Reduce Residential Water Demand? A Case Study in Southern California. Retrieved April 21, 2018, from www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=8600

Beal, C., Stewart, R.A., Huang, T.T., Rey, E. (2011). SEQ residential end use study. Journal of the Australian Water Association, 38 (1), 80-84.

Best Practices to Consider When Evaluating Water Conservation and Efficiency as an Alternative for Water Supply Expansion (Rep.). (2016, December). Retrieved March 03, 2018, from EPA website: https://www.epa.gov/sites/production/files/2016-12/documents/wc_best_practices_to_avoid_supply_expansion_2016_508.pdf

Brennan, D., Tapsuwan, S., & Ingram, G. (2007). The welfare costs of urban outdoor water restrictions. *The Australian Journal of Agricultural and Resource Economics, 51*(3), 243-261. doi:10.1111/j.1467-8489.2007.00395.x

Case Studies of Sustainable Water and Wastewater Pricing. (2005, December). Retrieved April 09, 2018, from

https://www.financingsustainablewater.org/sites/www.financingsustainablewater.org/files/resource_pdfs/EPA-Smallsystems-Fullcost-Pricing-Case-Studies-2005.pdf

Christiansen, B. (2015). Water Offset Policies for Water-Neutral Community Growth: A Literature Review & Case Study Compilation. Retrieved April 26, 2016, from *www.allianceforwaterefficiency.org/water-offset-report-Jan-2015.aspx*

Christiansen, B. (2016, April). Improving Water Conservation & Efficiency in Six Great Lakes Communities. Retrieved April 10, 2018, from http://www.glc.org/wp-content/uploads/2016/10/AWE-FinalReport-April-2016.pdf

Chwieduk, D. (2003). Towards sustainable-energy buildings. *Applied Energy, 76*(1-3), 211-217. doi:10.1016/s0306-2619(03)00059-x

Conservation: Albemarle County Service Authority. (n.d.). Retrieved May 2, 2018, from http://www.serviceauthority.org/conserve.html

Crozet Development Pipeline. (2017, September). County of Albemarle.

Crozet Master Plan. (n.d.). Retrieved March 3, 2018, from http://www.downtowncrozetinitiative.com/crozet-master-plan-1/

Crozet Master Plan (Rep.). (2010, October 13). Retrieved http://www.albemarle.org/department.asp?department=cdd&relpage=435

Fiscal Year 2018: Annual Operating and Capital Improvement Budget (Rep.). (2017, April 20). Retrieved March 3, 2018, from Albemarle County Service Authority website: http://www.serviceauthority.org/Finance/BudgetFY2018.pdf

Green, D. (2010). Water Conservation for Small-and Medium-Sized Utilities. American Water World Association /Colorado.

Harder, J. (2014). Demand Offsets: Water Neutral Development in California. Retrieved April 2, 2018, from http://www.mcgeorge.edu/Documents/Conferences/harderPresentation2.pdf

Hoque, S. F. (2014). *Water conservation in urban households: Role of prices, policies and technologies*. London: IWA-Publ

Maas, A., Goemans, C., Manning, D., Kroll, S., Arabi, M., & Rodriguez-Mcgoffin, M. (2017). Evaluating the effect of conservation motivations on residential water demand. *Journal of Environmental Management, 196*, 394-401. doi:10.1016/j.jenvman.2017.03.008

Marshall, M. (2009, August 06). Michael Marshall. Retrieved May 2, 2018, from https://www.crozetgazette.com/2009/08/06/population-concern-tops-survey-results/

Mayer, P., W. DeOreo, T. Chesnutt and L. Summers (2008). Water budgets and rate structures: Innovative management tools. Journal of the American Water Works Association 100(5): 117-31.

Mcfarlane, D., Stone, R., Martens, S., Thomas, J., Silberstein, R., Ali, R., & Hodgson, G. (2012). Climate change impacts on water yields and demands in south-western Australia. *Journal of Hydrology, 475*, 488-498. doi:10.1016/j.jhydrol.2012.05.038

Olmstead, S., & Stavins, R. (2006). Managing Water Demand: Price vs. Non-Price Conservation Programs. *Pioneer Institute for Public Policy Research*. Retrieved April 25, 2018, from https://ebcne-web-content.s3.amazonaws.com/fileadmin/misc/WaterPrice.pdf

Pricing and Affordability of Water Services. (2017, March 20). Retrieved March 03, 2018, from https://www.epa.gov/sustainable-water-infrastructure/pricing-and-affordability-water-services#resources

Randolph, B., & Troy, P. (2008). Attitudes to conservation and water consumption. *Environmental Science & Policy, 11*(5), 441-455. doi:10.1016/j.envsci.2008.03.003

Renwick, M. E., & Archibald, S. O. (1998). Demand Side Management Policies for Residential Water Use: Who Bears the Conservation Burden? *Land Economics, 74*(3), 343. doi:10.2307/3147117

Rivanna Water and Sewer Authority Regional Water Demand Forecasts. (2011, August 24). Retrieved April 25, 2018, from http://www.cvillepedia.org/mediawiki/images/20110824-AECOM-forecast.pdf

Serna, V. F., & Thompson, R. (2015, August 21). *Effects of a water conservation education program on water use in single-family homes in Dallas, Texas* (Doctoral dissertation, UNIVERSITY OF NORTH TEXAS, 2014) [Abstract]. Retrieved May 3, 2018, from https://digital.library.unt.edu/ark:/67531/metadc699967/

Transforming Water: Water Efficiency as Infrastructure Investment (Rep.). (2017, December). Retrieved March 3, 2018, from Albemarle County Service Authority website: http://www.serviceauthority.org/Finance/BudgetFY2018.pdf

The Water Efficiency and Conservation State Scorecard (Rep.). (2012, September). Retrieved March 3, 2018, from Alliance for Water Efficiency website: www.allianceforwaterefficiency.org/AWE-State-Scorecard.aspx

Water conservation plan guidelines. (1998). Retrieved April 4, 2018, from https://www.epa.gov/watersense/water-conservation-plan-guidelines

Water Champions - A Program to Promote Water Conservation in Our Schools Background. (n.d.). Retrieved March 2, 2018, from http://njwatersavers.rutgers.edu/For%20Educators_WaterChampions.html/

Water Conservation Education Program. (n.d.). Retrieved March 2, 2018, from http://www.sustainablejersey.com/actions-certification/actions/?type=1336777436&tx_sjcert_action%5BactionObject%5D=71&tx_sjcert_action%5Baction%5D=getPDF&tx_sjcert_action%5Bcontroller%5D=Action&cHash=7c68d6c4dfea2ff1a18a0a2a0e63e5a9

Water Demand Offset (WDO) Program. (2014, June 16). Retrieved April 5, 2018, from https://www.soquelcreekwater.org/conserving-water/water-demand-offset-program

Water Offset Policies for Water-Neutral Community Growth (Rep.). (2015, January). Retrieved March 3, 2018, from Alliance for Water Efficiency website: www.allianceforwaterefficiency.org/water-offset-report-Jan-2015.aspx

Water Rates: Water Demand Forecasting. (n.d.). Retrieved March 29, 2018, from http://pacinst.org/wp-content/uploads/2013/01/water_rates_water_demand_forecasting.pdf

Water Supply Alternatives Supplemental Evaluation (Rep.). (2004, July). Retrieved March 3, 2018, from Rivanna Water and Sewer Authority website: http://files.cvilletomorrow.org/docs/water/200407-watersupplyalternatives.pdf

What is Water Demand Management?. (n.d.). Retrieved March 23, 2018, from http://www.pacificwater.org/pages.cfm/water-services/water-demand-management/what-water-demand-management/

Wichman, C. J. (2016, September 14). Water Conservation Policies: Prices versus Restrictions. Retrieved from http://www.rff.org/research/publications/water-conservation-policies-prices-versus-restrictions

Wrabel, A. (2017, July 02). RWSA preparing for increasing water needs in Crozet area. Retrieved April 7, 2018, from http://www.dailyprogress.com/realestate/articles/rwsa-preparing-for-increasing-water-needs-in-crozet-area/article_2e5200f0-5ebf-11e7-8935-0f972e1acd21.html

Zetland, D. (2011). *The end of abundance: Economic solutions to water scarcity*. Amsterdam: Aguanomics Press.