# Conservation at College:

## A demand-side management approach to reduce student water consumption

Jake Reznick & Charlotte Arneson
*Carleton College, Environmental Studies Comprehensive Project*
*Northfield, MN, USA*

## Abstract

In this paper we design a financial incentive system for student water conservation and compare the effectiveness of that demand-side management approach against non-price, educational incentives. Students pay a flat, one-time water fee as part of their tuition and therefore have no direct incentives to conserve water. Research has shown that a combined structural, educational, and informational resource conservation strategy is more effective than any single method (Winkler and Winett 1982). While integrated conservation techniques have already been developed and evaluated for dormitory energy conservation, few resource conservation strategies exist specifically for water. We empirically examine how students respond to different financial and educational water conservation incentives in a six-week experimental study at Carleton College. The goal of this study is to help determine the most efficient method to foster sustainable student water consumption.

Using a concurrent embedded inquiry strategy, we find that our financial rebate was more effective at reducing overall water consumption. We also observe that education shifts student perceptions and may catalyze sustained behavior change. These findings suggest that the most efficient method to foster sustainable water consumption at American colleges is a price-based system supplemented with educational information.

## Acknowledgements

We would like to first thank Julie Thornton and the Department of Student Life, the students on CSA and Budget Committee, the Environmental Advisory Board, Steve Wisener, and the ENTS department for their financial support – without which this project would not have been possible. We would also like to thank the participants of our study (especially those who completed our survey), Professors Suh and Yiwen Chiu for granting us access to their water availability model, the staff at the Minnesota Department of Natural Resources and the Northfield Water Division, water guru David Zetland, and Don Smith in Campus Facilities. Thank you to Environmental Studies professors Aaron Swoboda, Kimberly Smith, and George Vrtis for their continual guidance and support. Finally, we would especially like to thank Martha Larson and our advisor Mark Kanazawa, without whom we would be lost.

## Table of Contents

# Conservation at College:
## A demand-side management approach to reduce student water consumption

## I. Introduction

Historically, the world's supply of freshwater has been sufficient to meet the needs of human growth and development. However, due to increasing demand from industrialization and population growth, water scarcity has replaced abundance. Competing demands for water threaten both economic development and social stability. In order to properly address this pending crisis, both bottom-up and top-down conservation approaches are needed. Institutions for managing water must value water at its full cost, while simultaneously, consumers must adjust their habits and curb demand for this precious resource.

American colleges and universities are uniquely positioned to lead society in finding sustainable water management solutions. Higher education institutions play this role by modeling conservation operations, expanding sustainability knowledge through research, and shaping the behavior and actions of future leaders through education. There have been a number of initiatives to address campus sustainability, including: the Campus Climate Challenge, Focus the Nation, and the American College and University Presidents' Climate Commitment (ACUPCC). While these programs demonstrate the power American colleges have for collective action, they focus predominantly on energy conservation while water remains a backburner issue.

In this study we design a financial incentive system for student water conservation and compares the effectiveness of that demand-side management approach against non-price, educational incentives. Using a concurrent embedded inquiry strategy, we examine how students respond to different financial rebates and educational water conservation incentives in a six-week experimental study at Carleton College. The goal of this study is to help determine the most efficient method to foster sustainable student water consumption.

## II. Background

The proposed model uses a currently relevant and innovative approach to water conservation. This section will provide a basis for understanding the mechanics and significance of our model.

### *Global Perspective, Local Action*

Increasing global water scarcity threatens both economic development and social stability. In a report from the United Nations Framework Convention on Climate Change (UNFCCC), almost half of the world's population "will be living in areas of high water stress by 2030" (UNFCC). These water issues are particularly relevant to the United States. Research on national water availability by the consulting firm Tetra Tech found that 70% of counties in the United States will face some risk of a water shortages by 2050 from climate change alone, and one third of counties will face "high" or "severe" risk[1] (TetraTech).

While the impact of water scarcity is predominantly local, even regional water crises have nationwide costs. For example, while the 2011 Texas drought led to $5.2 billion in state agricultural losses (making it the most costly on record), the impact to greater agribusiness cost an estimated $8.7 billion in total national financial losses

[1] *Tetra Tech composed a sustainability index using five criteria: "Extent of development of available renewable water, Sustainable groundwater use, Susceptibility to drought, Growth in water demand, and Increased need for storage." "The risk to water sustainability for counties meeting two of the criteria are classified as 'moderate,' those meeting three of the criteria are classified as 'high,' and those meeting four or more are classified as 'extreme.'" (TetraTech)*

(Guerrero 2011) (Jones, Amosson, and Mayfield 2011).

Direct losses aside, increasing demand for water has led to a number of costly inter-state legal battles over existing freshwater resources. An ongoing riparian rights battle between Alabama, Florida, and Georgia has already cost Georgia over $11 million in legal fees (AJC). Furthermore, should courts rule in favor of downstream Alabama and Florida, the economic cost to Georgia is estimated to be in the billions (Stephenson 2000). The future costs of water mismanagement are quickly rising. How communities will respond to approaching water shortages is the critical and unanswered question of the coming century.

This study focuses on water conservation methods at Carleton College in Northfield, MN. Seven times in the last decade, areas of southern Minnesota faced drought conditions considered "severe" by the National Oceanic and Atmospheric Association (NOAA) for periods longer than two weeks (US Department of Commerce). During these drough periods, electrical utilities had to draw water from distant well fields and ethanol and other agricultural processing facilities had to temporarily shut down production (Gordon 2005). Although Minnesota – known as the "land of 10,000 lakes" – is typically viewed as water rich, water scarcity has already had a demonstrated impact on state industry. Certainly the causes and severity of a shortage in Minnesota may differ from Texas or Georgia, however the solutions may also share similarities. We have designed our model from nationally available data, specifically to encourage adaptation to local characteristics.

### *Perceptions of Scarcity*

The price of water in the United States is so low, the average American pays more for soft drinks than for their entire water and wastewater bill each year (US EPA 2012).

Furthermore, the United States has the lowest burden for water fees as a percentage of household income among developed countries (US EPA 2012). According to economic theory, prices signal value to consumers and can help them manage their consumption appropriately. When the price of water is so low relative to income, consumers typically perceive water to be an inexhaustible resource. As a result, they will rarely actively consider conservation strategies outside of a severe drought or shortage that threatens their community (Winkler and Winett 1982).

The undervaluation of water, which has led to this false perception of abundance, is deeply rooted in antiquated pricing programs for both American farmers and municipalities. Among these issues are historic Bureau of Reclamation water subsidy programs, which encourage overuse and water-intensive crop selection (Kanazawa 1993). Other problems lie in the pricing methods used by US municipial supply agencies. These suppliers tend to set water prices low to cover the historical (fixed) costs of supply rather than future replacement costs (Hanemann 2005). Furthermore, after large capital infrastructure projects are built, supply capacity exceeds demand by such a large margin that prices are frequently set low to cover the short term operating cost rather than the long run marginal cost of supply. Once demand catches up to supply, utilities are often already fixed to these low price structures. In order to challenge this artificial perception of abundance, water must be priced in such a manner that utilities and other stakeholders can appropriately plan for the future costs associated with scarcity.

### *The Energy-Food-Climate-Water Nexus*

While the aforementioned cases from Georgia and Texas demonstrate the present challenge of water scarcity, increasing demand from industry, agricultural, and population growth will further test the limits of available freshwater resources. Agricultural irrigation already accounts for almost 35% of US water withdrawals (70% globally) and 90% of domestic consumptive water use[2] (Shiklomanov and Rodda 2004)(USDA 2004). While rising standards of living across the globe are projected to increase demand for US agriculture, farmers will have to compete with electric companies and municipal suppliers over limited water supply (Lawrence Berkeley National Laboratory)(Merson 2006). The energy industry alone uses 49% of total US water for thermoelectric power generation, and like agriculture, demand for electricity is projected to grow significantly in the next 20 years (Barber 2009). US government agencies expect electricity demand to grow 31% by 2035 and population to grow 48.8% by 2050 (US EIA 2011)(US Census Bureau Center for Economic Studies). In order to manage the pending conflict between electricity generation, agricultural production, and municipal demand, issues of water scarcity must be given immediate attention. However, increasing demand for water is not the only driver of future scarcity.

The projected impact of climate change on temperature and precipitation on global water supply will further complicate future water issues (Reeves). The effects of climate change on water resources vary regionally: while some states may experience an increase in freshwater availability, others may face more frequent droughts. However, one common prediction is that the intensity, frequency, and duration of precipitation events will increase in the future (Trenberth et al. 2003). This poses a particular challenge for future water resource management as extreme droughts and floods will occur more often with less predictability.

In order to adequately address rising stress on the water-energy-food-climate

[2] *Consumptive Use: "Amount of withdrawn water lost to the immediate water environment through evaporation, plant transpiration,*

‘nexus’, management approaches must account for this interlinked and multidimensional pressure. Thus, the demand-side management approach proposed in this study is structured to consider the projected impact of increasing industrial, agricultural, and population growth as well as local climate change effects on future water supply.

## III. Literature Review

The proposed model builds on a foundation of research in behavioral economics. The following section outlines existing research on water conservation incentives, how those studies were considered in our approach, and in which ways this paper contributes to the field.

### *Structural Approach*

Structural approaches are systematic and seek to soften conflicting group and individual interests in a given dilemma by providing direct incentives. According to economic theory, consumers generally will demand a smaller quantity of a good as the unit price of that good increases. Water utilities employ pricing structures to manage resource use through direct financial incentives. The more effective of these conservation structures operate by metering and charging residential or commercial consumers marginally, at a calculated, volumetric rate (Huffaker et al. 1998; Howe and Jr). Students at American colleges, however, pay for their water usage as an imbedded and flat cost in their tuition, therefore they have no direct financial incentives to conserve water. As a result, it is easy for students to operate under the assumption that water is a plentiful, inexhaustible resource. While some institutions have taken steps towards promoting water conservation, such as the instillation of low-flow showers and toilets, these are relatively passive conservation methods that do not directly influence consumer choice (Brandon and Lewis 1999). This study designs a structural approach for student water conservation with a rebate model. The proposed model provides students with a direct, marginal incentive to conserve water through conservation rebates.

### *Social-Psychological Approach*

The social-psychological approach seeks to motivate conservation behavior by altering the way consumers value and perceive a resource. The typical socio-psychological method involves the provision of information feedback to consumers (Thompson and Stoutemyer 1991). Other socio-psychological approaches relevant in this study are the effects of community cooperation and non-price educational incentives. Studies suggest that integrating structural price approaches and non-price methods can maximize the efficiency of resource conservation strategies (Winkler and Winett 1982)(McKenzie-Mohr 2000)(Lopez Garcia 2008).

The object of information feedback is to help consumers make educated decisions between cost and comfort. These factors are substitutable and together defined as "utility." For example, when the price of water is low, consumers may prefer to take longer showers. However, with daily feedback on the costs of their consumption, some consumers may realize they can maintain the same level of comfort with a shorter shower; thus saving money and maximizing their individual utility. The benefits of feedback for municipal consumer water conservation are well documented (Van Vugt and Samuelson 1999) (Kramer et al. 1986)(Winkler and Winett 1982). In response, more and more colleges are installing advanced monitoring systems for water (US EPA 2002)(Ridgeway and Nejad 2010)(Barry 2011). For example, at Carleton all water meters are currently being retrofit for electronic Siemens metering systems that will provide easily accessable, daily consumption information. In this paper we have included information feedback as a fixed component of our financial model.

Our rebate model is designed to reward individual students for overall community conservation. Given the collective metering infrastructure on college campuses, we determined this was the most effective way to provide marginal, individualized incentives. However, this method does reward students who chose not to actively participate in conservation efforts (hereafter refered to as 'free riders'). While we cannot eliminate the presence of free riders, we have designed our model to minimize the effects of this negative externality.

Research by Corral-Verdugo et al. (2002) suggests another limitation to our community-centered conservation model; that the effect of perceived externalities on water consumption should be positive (the more people perceive that others waste water, the more they tend to increase their own consumption). Buckley (2004) proposes that this could be especially prevalent in residence halls, "where many students share restrooms and showers and would be more likely to witness excessive water use." Although we do not explicitly test the effect of community on conservation strategies, we acknowledge that community-centered conservation behavior is an implicit characteristic of our model. Furthermore, we believe that the benefits of community conservation may outweigh potential costs.

Kramer & Brewer (1984) and Messick et al. (1983) stress the relevance of social-psychological factors, such as interpersonal trust and group identity, in the management of a resource shortage. In addition, Geller et al. (1983) find that in times of relative scarcity, community identification was particularly instrumental in preventing overuse of communal resources. Therefore, the emphasis on water scarcity used in this model may further reduce the effect of these negative externalities.

The aforementioned research demonstrates that water usage monitoring and feedback encourages people to engage in conservation, particularly when it is collectively most desirable. This amounts to a "transformation of motivation," whereby individuals are no longer driven solely by their own immediate individual interests (Kelley and Stahelski 1970; Kelley and Thibaut 1978). Van Vugt and Samuelson (1999) suggest that community-based water monitoring may cause a transformation of motivation, where people forego their immediate outcomes and consider how their decisions affect society as a whole. In particular, they found that when consumers perceive a resource shortage and their consumption is measured, there is a greater collective concern with the costs of overconsumption (Van Vugt and Samuelson 1999). These results support "interdependence theory," which states that people will act in the best interest of their community when they perceive that their actions will have a direct effect on others (Kelley and Stahelski 1970; Kelley and Thibaut 1978). These transformations may be dictated, for example, by concerns with the welfare of the community as a whole or by the motivation to set a good example to other community members (Rusbult and Van Lange 1996).

Cooperation is a social value that is defined as "a preference for outcomes that increase or improve the gains of both self and others with whom one is interdependent" (McClintock 1972; McClintock 1978; McClintock and Keil 1983). Although the community consciousness at different colleges may vary, literature suggests this model is most effective when community values are high. Carleton College is a private undergraduate institution with a small population of 2000 students, no dormitories with more than 150 students, and explicitly declares in its mission statement that it "strives to be a collaborative community" (Carleton College). Therefore, we believe that the demonstrated benefits of this model will translate particularly well at schools with similar community-centered characteristics and values as Carleton.

### *Educational Approach*

In this paper we compare the relative effectiveness of two demand-side approaches to student water conservation: a financial incentive system and a non-price, educational incentive system.

Non-price incentives have some advantages over price-based incentives. For example, raising water prices is often politically challenging; therefore, non-price techniques may provide a less contentious management approach (Olmstead 2006). Furthermore, non-price incentives also are supported by advocates who claim “the use of price as an allocation mechanism is constrained by the fact that water is generally regarded as a basic necessity, even a right, not an economic good” (Berk et al. 1980).

Various non-price educational incentives have been proven effective at US colleges. A study conducted at Oberlin College found that when students’ electrical and water usage was monitored and the students were supplied with information on the environmental consequences of resource use and depletion, the students substantially decreased their consumption (Petersen et al. 2007). Similarly, a study at Virginia Polytechnic Institute and State University found a negative relationship between the provision of educational information on environmental issues (e.g. posters and pamphlets on climate change) and dormitory electricity and water consumption (Parece 2010). While non-price, educational incentives on college campuses have had a demonstrated negative effect on student water consumption, the comparative impact of added financial incentives for this population have never been measured before this study.

Literature comparing the effect of non-price and price demand-side water management strategies on municipal consumers find that financial approaches to water conservation are the more cost-effective option (Krause, Chermak, and Brookshire 2003). In particular, the relative gains from non-price methods are significantly lower as these management policies require significant monitoring and enforcement and violation is relatively easy (Olmstead 2006).

In this study we design a price-based demand management model for Carleton College students and compare the relative conservation effect of this model on student behavior with a non-price, educational approach. Our findings align with those for municipal populations; that financial incentives lead to a greater magnitude of water reduction than non-price, educational incentives.

## IV. Methodology

This section describes the data sources and analytical methods used to develop a mixed methods demand-side management approach to reduce student water consumption at Carleton College. We use a concurrent embedded inquiry strategy in this paper. Although we collect both qualitative and quantitative data simultaneously, our dominant analytical method is quantitative. We employ qualitative data from a survey to broaden our perspective and support our quantitative conclusions.

### *A Full Cost Rebate*

The goal of our financial model is to design a rebate system to incentivize sustainable student water consumption. The rebate sizes calculated in this model are set to the Full Cost (aka Social Cost) of water. Generally, Full Cost pricing is defined as an "attempt to represent the true market value of water to decision makers when designing and developing the built environment …(including) aesthetics, environmental sustainability, impact on ecosystem health," and other non-market indicators not included in present economic models (Hanemann 2005). For the purposes of this study, calculations for the Full Cost only consider externalities from future water quantity scarcity. The following procedure was developed to choose a meaningful rebate size for water quantity conservation in Northfield, MN.

In order to calculate regional water availability, this model uses a water balance calculation developed by Prof. Suh and his colleagues at the University of Minnesota (Suh, Yi-Wen, and Schmitt 2010). Water scarcity is calculated as a dimensionless index between 0 and 1, represented by the following equation:

(1) $$Water\ Scarcity\ Index\ [0,1] = \frac{Water\ Availability}{Consumption + Withdrawals}$$

The water stress index values of 0.1, 0.2, and 0.4 are thresholds for low, mid-high, and severe water stress, respectively (Oki and Kanae 2006)(Suh, Yi-Wen, and Schmitt 2010).

Water availability data were gathered from the USGS, NOAA, and US EIA and can be adopted for any of the lower 48 states. The measurement unit used by these sources is the watershed. The watershed selected in this study was the local Cannon River watershed, titled "Region 9" in (Suh, Yi-Wen, and Schmitt 2010).

In order to project future water scarcity, this model uses system dynamics modeling forecasts from the Suh paper (Suh, Yi-Wen, and Schmitt 2010). This framework incorporates the impacts of demographic change, climate change, biofuel development, and electric demand on available water resources. For a more detailed description of the methods and data used in these modules, as well as the specific dynamics of the growth scenario selected for this study, please refer to Appendix I.

For the purposes of this study, we define "sustainable" water use as consumption that does not exceed a "severe" water scarcity index of 0.4 or above. Based off climate change predictions and business as usual growth scenarios, the Cannon Valley watershed is predicted to have a water scarcity index of 0.833 in the year 2030 (see Appendix I). The target percent reduction in water use is then calculated from the quotient of estimated "sustainable" water consumption and business as usual water consumption for cannon valley in 2030. This ratio is then multiplied by the current baseline consumption trend to calculate the change in quantity, $\Delta Q_d$, for a given user (in our study, this baseline was individual dormitory usage).

The full cost of water is calculated using this quantity change ($\Delta Q_d$) with the following equation:

$$(2) \qquad Full\ Cost\ Water = P_i + \left(\frac{(\Delta Q_d)(P_i)}{(Q_d)(E_d)}\right)$$

Where $P_i$ is the current marginal cost of water and $E_d$ is the estimated price elasticity of demand for the target population. For the purposes of this study, $P_i$ was set to the 2010 residential water rate for Northfield, MN ($1.53/100 cubic feet) (City of Northfield).

Given that there is no substantial research on financial strategies for campus water conservation, we used two municipal price elasticity estimates for water demand, (*0.3*) and (*0.1*) (Allen et al.). These elasticities were used to set a low and high rebate size, (*0.3*) and (*0.1*) respectively. We hope the results of this study will help build a foundation for further research on water demand price elasticity for US college students.

Prices, demand for water, and the "sustainable" percentage reduction of water usage will vary regionally. This model is designed to accomodate those variations. For example, a college in arid Arizona will likely have a higher water stress index and more elastic demand for water, and thus a larger rebate size.

*Model Implementation:*
*A study of dormitory water usage at Carleton College*

The object of the study was to test the comparative impact of varying financial and educational incentives on student conservation behavior. During Carleton's Winter Term, from January 16, 2012 to February 26, 2012, we monitored the water usage of six campus dormitories at Carleton College in Northfield, MN. Each dorm was given a different treatment of educational programming (yes/no) and rebate (no/yes @ $E_d$ 0.3/yes @$E_d$ 0.1). These data are displayed in Table 1 below.

In order to evaluate the effect of these incentives on student behavior, we compiled a 12-year consumption baseline for each dorm. These data were compiled from handwritten and electronic monthly water meter readings collected by the campus facilities office beginning in 1999. Due to slight variations between records, these data were normalized using an approach described in Appendix II. Annual consumption data were then averaged to reflect per-capita usage. Population and demographic data were gathered from Winter Term records in the Campus Residential Life office. Individual dorm rebate size was calculated using the modeling approach described in Section IV above.

**Table 1.**
**Mixed Incentive Model Treatment by Dormitory**

| Dorm | Winter 2012 Population | Education Program | Rebate Program | Price Elasticity of Demand | Calculated Rebate ($/cu. Ft) |
|---|---|---|---|---|---|
| Musser* | 136 | Yes | No | n/a | - |
| Myers | 141 | Yes | Yes | 0.1 | $0.197 |
| Nourse | 105 | No | Yes | 0.3 | $0.073 |
| Evans | 106 | No | Yes | 0.1 | $0.152 |
| Watson | 153 | Yes | Yes | 0.3 | $0.081 |
| Davis* | 98 | No | No | n/a | - |

**Control Dorms*

The distribution of water consumption data for all dorms, except Davis and Musser, were normal. The distribution for Davis was heavily skewed to the left, signifying higher consumption in past years, while the distribution for Musser was skewed right, signifying higher consumption in more recent years. We believe that this is a result of variation that occurs between the dorms in unobserved ways.

On January 15, the evening before the study was implemented, students in the four study dormitories (Evans, Nourse, Watson, and Myers) were emailed a description of the project. Simultaneously, we asked the Resident Assistants (RAs) in those dorms to read a short project description during their weekly floor meeting to ensure that the information reached dormitory residents. We also asked the RAs to encourage their residents to work as a community to reduce water consumption.

Once the study was in effect, residents of dorms with financial incentives were sent email updates on a biweekly basis. The emails contained information regarding each dorm's respective water usage, how much water had been reduced compared to the historical average, and how much money each individual student had earned so far (a copy of the letter is printed in Appendix V).

After the study period was terminated, we compiled our data and performed a Multiple Linear Regression by running an Ordinary Least Squares with Fixed Effects Model (OLS with FE). The OLS with FE model was chosen to determine the relationship between the multiple variables present in our study and evaluate the independent treatments given to each dormitory. Given that our data displayed a normal distribution, we determined that OLS with FE would be suitable for analyzing our results. We constructed a model that captures as many of the effects of the included variables as possible (see Equation 3 below). To test for significance, we used the t ratio test.

(3) $$\text{Water Use} = \beta_0 + \beta_1\text{Education} + \beta_2\text{LowRebate} + \beta_3\text{HighRebate} + \beta_4\%\text{Male} + \beta_5\%\text{Freshmen} + \beta_6\text{Temperature} + \beta_7\text{Myers} + \beta_8\text{Watson} + \beta_9\text{Musser} + \beta_{10}\text{Nourse} + \beta_{11}\text{Evans}$$

There are multiple variables included in our model. Water consumption (cubic feet per capita) is the independent variable, $\beta_0$, against which all other variables were regressed. There are three explanatory variables related to our study. The first, Education, indicates the treatment where selected dorms were provided with educational information. LowRebate signifies the treatment where selected dorms were provided with a lower rebate price ($E_d = 0.3$), while HighRebate indicates the dorms that were provided with a higher rebate price ($E_d = 0.1$). We control for unobserved variation between dorms using our control dorm, Davis, as the constant in our Fixed Effects model. Due to the potential impact of demographic differences between dorms, we included dorm gender and class year in our regression model, respectively labeled %Male and %Freshmen. %Male indicates the proportion of each dorm's population that is a male, while %Freshmen refers to the proportion of each dorm's population that is a freshman student. We chose to isolate freshmen on the assumption that they were more likely to retain consumption habits from their homes, while sophomores and upperclassmen were more likely to have acclimated to campus norms. Finally, historical average temperature (Fahrenheit) was included as our model's last variable in order to test if water use behavior was linked to colder or warmer weather.

This project received a total of $4,600 in funding. Grants were solicited from various student organizations including: $1,000 from the Carleton Student Association

(CSA), $1,000 from the Environmental Advisory Board (EAB), $600 from the Division of Student Life, and $2,000 from the Environmental Studies Department.

### *Education Methodology*

Three dorms received the education treatment: Musser, Myers, and Nourse. Musser, serving as a control, received education but no rebate (Table 1). The educational information consisted of posters placed in the dorms and fliers put in residents' mailboxes (examples can be found in Appendix IV). The fliers and mailbox slips contained information about domestic and global water consumption and tips on how to cut back on water use. New educational material was distributed on a biweekly basis. Posters were put up on each floor of the dorms – one poster in the lounge, two posters in each bathroom, and one to two posters in entryways or other common spaces. We assume that the volume of traffic and the transfer of information between dorms would not be significant enough to contaminate our education variable. Results from our survey support this conclusion.

The purpose of the education treatment was to foster environmentally relevant behavior by encouraging students to consider the environmental and societal consequences of overusing water. Because studies have shown that students will respond to education when faced with a resource conservation problem (Petersen et al. 2007), we sought to harness that potential through the following approaches: (1) Posters and fliers with information on domestic and international water crises were posted in dorm hallways and bathrooms. (2) Examples of actions students could take to reduce their personal water consumption in the dorms. (3) Examples of other behavior students could take to reduce their water "footprint" (i.e. consuming fewer water consumptive goods).

We selected this information to give students a larger perspective on water consumption outside of their dormitories and to encourage students to think about water use in a context outside of their own realm of experience. Moreover, we used both national and global water information to engage as wide an audience as possible – part of the dorm population might have a stronger response to local water information, while another might respond to international issues. Many of the distributed educational materials used broad fact-based information in order to spark students' curiosity and inspire dialogue within the dorm communities. Ideally, this would lead students to actively seek out information on current events surrounding water and equip them to be future leaders in resource conservation. Examples of the educational materials we distributed are available in Appendix IV.

### *Survey Methodology*

At the end of our data collection period, we distributed a survey to all student participants. The survey was sent out via email and supported by the website Survey Monkey (http://www.surveymonkey.com). The survey was designed to receive feedback from the students on how effective they felt our reward incentives and educational information were at inspiring behavior change (e.g. Question 34: "*How likely is it that you will continue your water consumption habits as a result of this study now that it has ended?"*). The survey was also used to measure the level of information crossover between dorms with different treatments.

When we were developing the survey questions, each question and response option was formulated to evaluate students' perception of their water use, their attitudes towards water conservation, and how effective they believed our study was at inspiring a sustained behavior change. The questions for the survey were devised based on similar surveys found in primary and secondary literature (Parece 2010; Water Conservation School).

The survey contained four different categories of questions: (1) Multiple-choice questions with numerical responses, where the student was asked to quantify their water usage. (2) Questions where the student responded based on an ordinal rating scale (e.g. on a scale of 1-5, 1 signifying “low” and 5 signifying “extremely high”). (3) Multiple-choice questions that asked students to identify which actions that they took to actively conserve water. (4) The last question in our study gave students the option for free response. The survey in its entirety can be located in Appendix III.

The empirical data collected from the survey results contained a mix of quantitative and qualitative results. These data serve to complement the empirical results of our model and broaden our analytical perspective.

## V. Results

### *Regression Results*

The results for the model, shown in Table 2, indicate that both education and rebate incentives led to greater student water conservation behavior. All variables except for LowRebate are statistically significant. The multiple R-squared for the Fixed Effects model was 0.7471, indicating that the model explains 74.71% of the variance between variables.

In particular, the educational program had a high significant (at the 5% level) negative relationship with water use, while the high rebate size had a very high (at the 1% level) significant negative relationship. %Male and %Freshmen had very high significant negative relationships to water use. Temperature, on the other hand, had a very high significant positive relationship to water use. Variation between dorms was also very (at the 1% level) significant.

**Table 2.**
**Impact of Mixed Incentive Model Treatment on Water Consumption**

| Explanatory Variables | *Without Dorm Fixed Effects* | | *With Dorm Fixed Effects* | |
|---|---|---|---|---|
| | Change in Per Capita Water Use (cu. Ft) | Standard Error | Change in Per Capita Water Use (cu. Ft) | Standard Error |
| With Education | 0.2563 | (4.4044) | -4.9074** | (2.4434) |
| Low Rebate | 2.4342 | (4.8714) | -3.7397 | (2.7390) |
| High Rebate | -8.2922 | (4.9059) | -8.8173*** | (2.7403) |
| % Male | -0.7163*** | (0.1264) | -0.2848*** | (0.0769) |
| % Freshman | -0.0575 | (0.0386) | -0.1914*** | (0.0246) |
| Temperature | 0.1951 | (0.1428) | 0.2456*** | (0.0767) |
| Musser | – | – | 21.2821*** | (1.5516) |
| Myers | – | – | 34.3608*** | (1.5339) |
| Nourse | – | – | 28.3582*** | (1.5755) |
| Evans | – | – | 10.3562*** | (1.7615) |
| Watson | – | – | 39.2166*** | (1.5252) |
| Multiple R-Squared | 0.1083 | | 0.7471 | |

*Notes: *** Significant at the 1% level, ** Significant at the 5% level. n = 344.*

Our results indicate that in dorms provided with educational information, individual students lowered their water consumption by almost five cubic feet on average (Table 2). Furthermore, these findings indicate that our higher rebate size had a significant effect on reducing water use while our lower rebate size had no significant impact on student behavior. The high rebate led to a change in water use behavior by nearly nine cubic feet per student on average (Table 2).

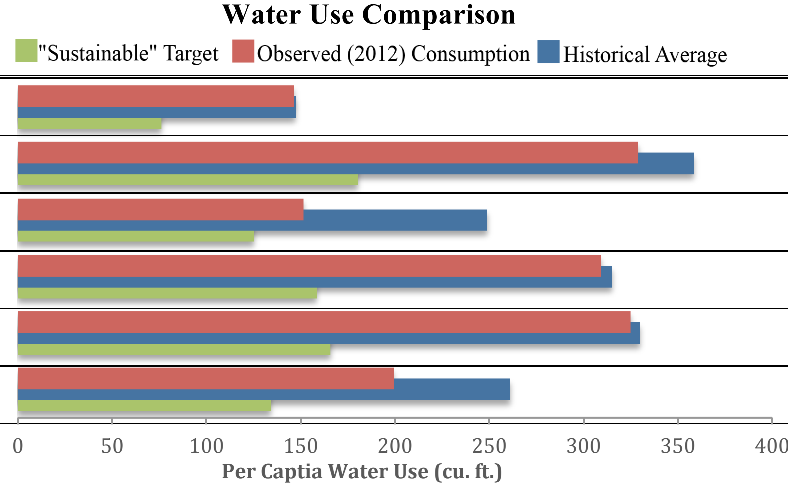
Our analyses of demographic and temperature variables all yielded significant results. We found that male students use significantly less water than female students. For every 10% more males in a given dorm, water use decreases by 2.8 cubic feet (Table 2). Furthermore, we found that for every 10% more freshmen than sophomores and upperclassmen living in a given dorm, there is a 1.9 cubic foot decrease in water consumption (Table 2). Finally, we find that for every degree (Fahrenheit) increase there is in temperature, there is a .25 cubic foot increase in water usage (Table 2).

The significant results for our dorm variables (Myers, Watson, Musser, Nourse, and Evans) indicate that they all independently use more water than Davis. This result was expected, as Davis is the only dorm that does not have its own washing machines; thus, uses significantly less water. Differences in water use range from 10 to 30 cubic feet per capita. This range is likely explained by structural (e.g. differences in water pressure) differences between each of the dorms.

At the end of our study, none of the dorms reduced their water consumption to the sustainable target level. However, many students reduced their monthly consumption by a noticeable margin from their dorm's historical average. Students living in dorms with financial incentives earned between $0.44 and $14.83 in rebate rewards by the end of the six-week study period. The final results of our study are available in Table 3.

**Table 3.**
**Final Results**

| Dorm | Water Use Comparison | Per Student Earnings |
|---|---|---|
| Davis | | – |
| Watson | | $2.42 |
| Evans | | $14.83 |
| Nourse | | $0.44 |
| Myers | | $1.01 |
| Musser | | – |



## *Survey Results*

Our survey was sent to all 739 students living in the six dorms we studied. In the five-day allotted response period, 386 students started the survey and 326 students completed the survey.

In response to questions 25 and 26, *"How often do you consider your water consumption?"* the change in answers for students in all dorms show a considerable behavior shift from low consideration of water consumption before the study towards more frequent consideration of water consumption after the study. Furthermore, there is a notable difference in the magnitude of this change between dorms given educational programming and those given no education (see Chart 1). In this case, education appears to have a stronger positive influence on frequency, indicating that these that students considered their water consumption more often.

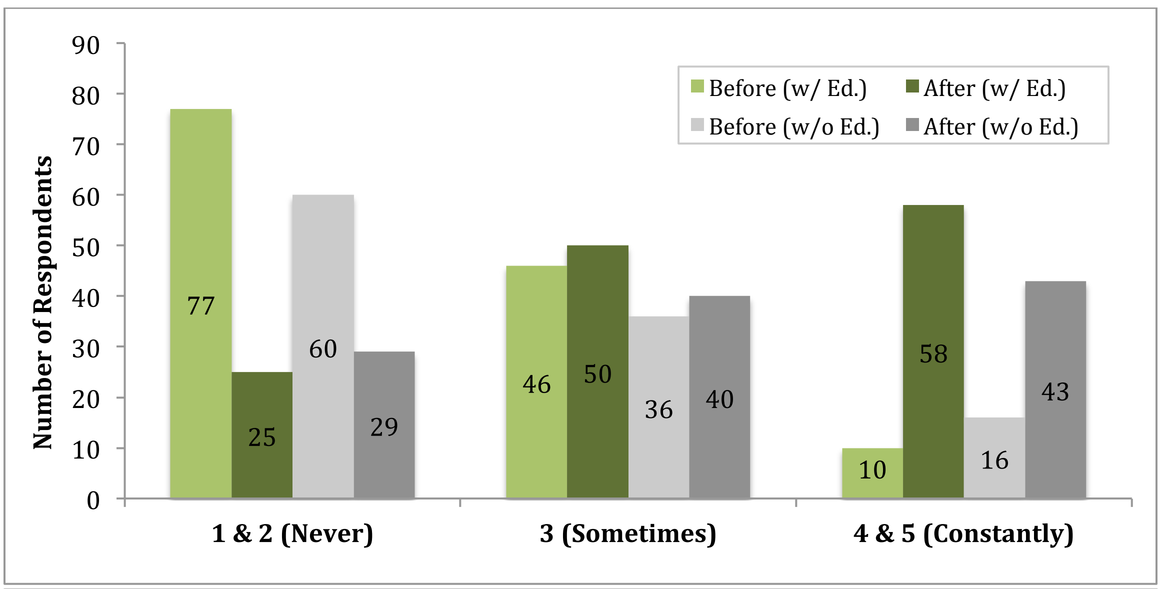



**Chart 1. (Questions 25 & 26) "How often do you consider your water consumption?"**
In this chart we compare how often respondents consider water consumption before and after the study. Respondents who received educational incentives (green bars) exhibit a greater relative shift in behavior towards more frequent consideration of water consumption (ordinal variables 4 & 5) than respondents who did not receive education (grey bars).

In question 33, students were asked: *"How have your habits changed outside of your dorm?"* For both groups (with and without educational incentives), approximately 40% of respondents marked "yes," they had changed their habits, while approximately 60% of respondents replied "no," they had not changed their habits. There was no significant difference between the responses of those who received education and those who did not.

For questions 27 and 28, *"How often do you worry about the state of the world's water supply?"* collected responses indicate that students given educational incentives increased their concern for the world's water supply by a larger magnitude after the study than did students without educational incentives (see Chart 2).

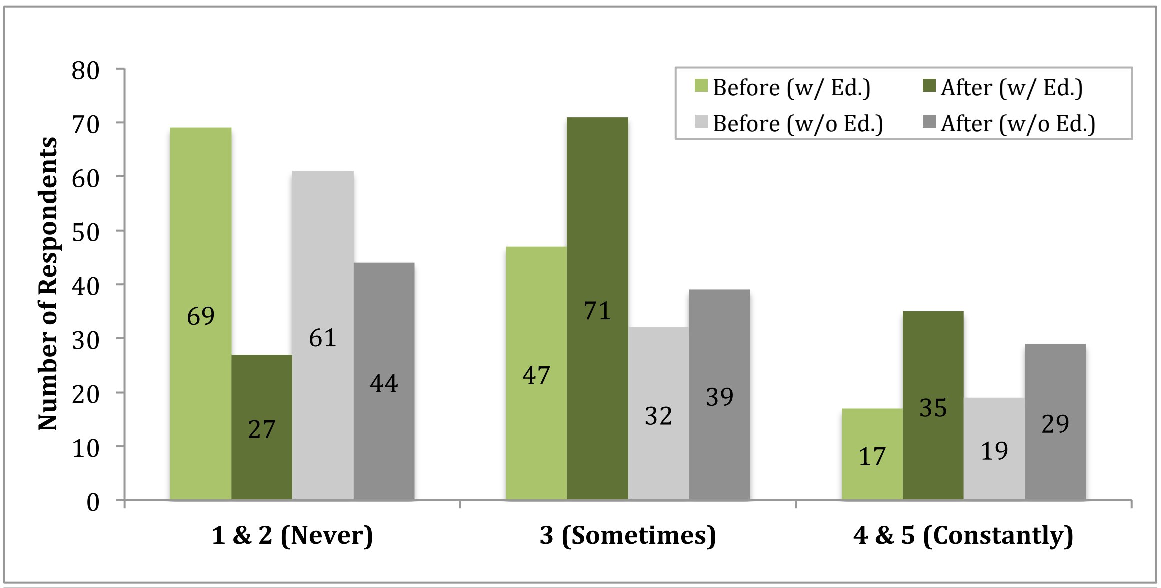



**Chart 2. (Questions 27 & 28) "How often do you worry about the state of the world's water supply?"**
In this chart we compare how often respondents worry about the state of the world's water supply before and after the study. Respondents who received educational incentives (green bars) exhibit a greater relative shift in behavior towards more frequent concern with the state of the world's water supply (ordinal variables 4 & 5) than respondents who did not receive education (grey bars).

Collected responses to questions 21 and 22, *"How scarce of a resource do you consider water to be?"* indicate that students' overall perception of water as a scarce resource increased during the study period. We observe a distinguishable relative increase in perception change for students given educational incentives compared to those who were not given educational incentives (see Chart 3).

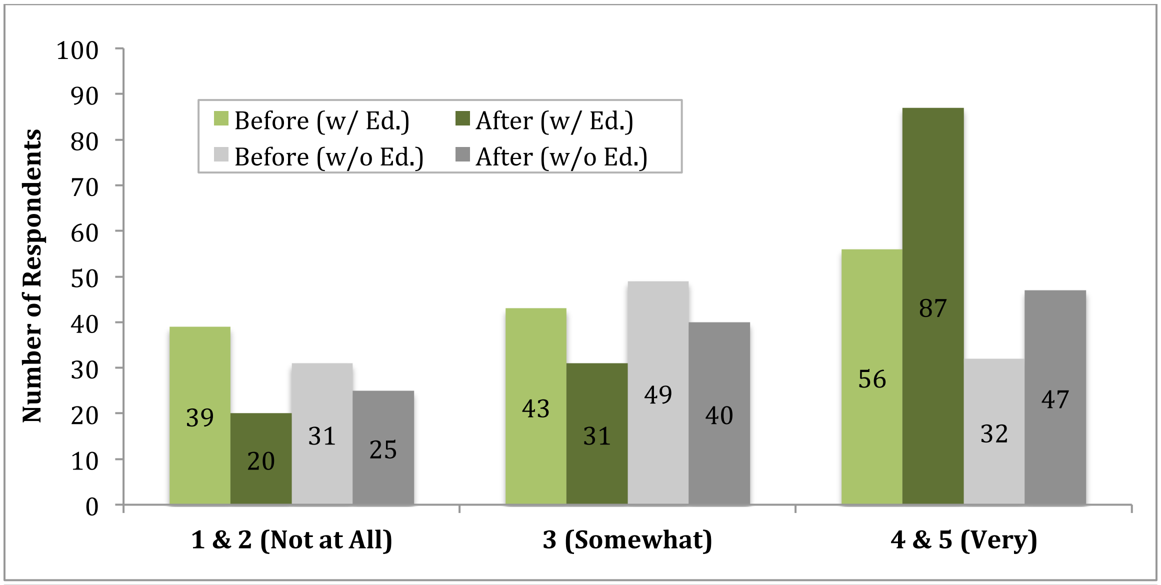



**Chart 3. (Questions 21 & 22) "How scarce of a resource do you consider water to be?"**
In this chart we compare respondents' relative shift in perception of water as a scarce resource before and after the study. Respondents who received educational incentives (green bars) exhibit a greater relative shift in behavior towards more frequent consideration of water consumption (ordinal variables 4 & 5) than respondents who did not receive education (grey bars).

When asked questions 23 and 24, *"How important do you consider water conservation programs to be?"* students in dorms with education show a slightly greater shift in perception from "not at all" important to "very" important than dorms without educational incentives (see Chart 4).

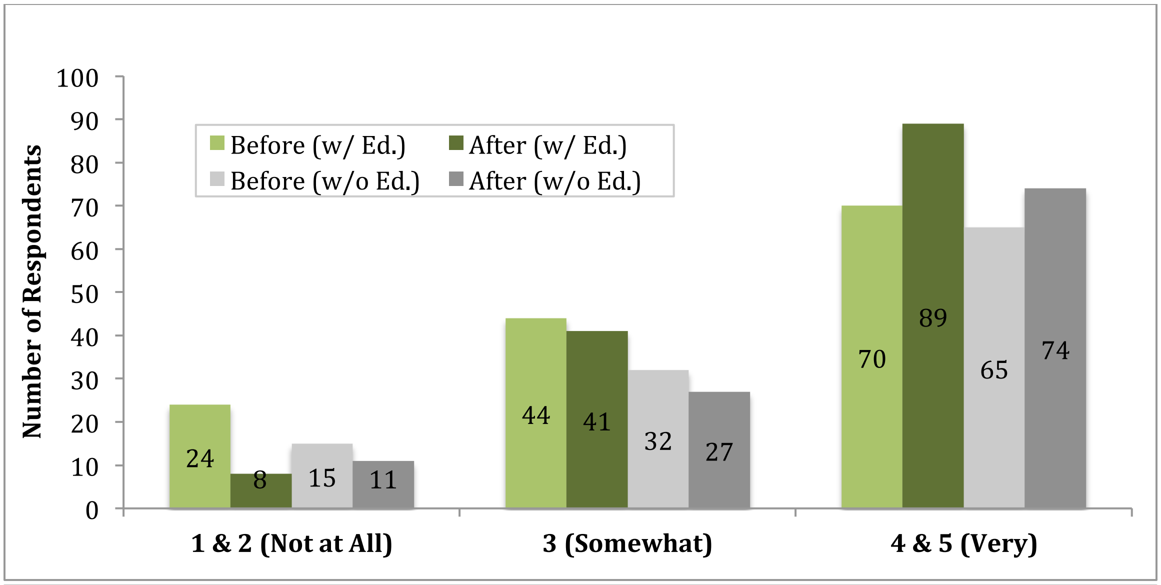



**Chart 4. (Questions 23 & 24) "How important do you consider water conservation programs to be?"**
In this chart we compare how important respondents consider water conservation programs to be before and after the study. More respondents who received educational incentives (green bars) placed higher value (ordinal variables 4 & 5)

In response to question 34, *"How likely is it that you will continue your habits as a result of this study?"* the majority of respondents indicated that they are "very" likely to continue their habits.

Questions 35 and 39 were included in the study to evaluate the level of information crossover between dorms. Of the 147 respondents who lived in dorms that did not receive educational information, only 9 students selected that they had heard about the study from *"posters in another dorm"* in response to question 35, *"From which of the following mediums did you hear about water conservation or this study? (Please check all that apply)."* Furthermore, only 12.2% of the total survey population responded "yes" to question 39, *"Did you hear about different monetary reward values for other dorms?"*

The free response answers to survey question 40, *"Please take a moment to provide us with some feedback on our study. Questions, comments, suggestions, other* *thoughts, etc."* are available online. Please follow the link below to access the anonymous responses: http://reznick-arneson-appendix.tumblr.com/freeresponse

## VI. Discussion

Our results indicate that both financial and educational incentives were effective in reducing student demand for water. However, the scale of this impact varies both quantitatively and qualitatively. These results highlight the importance of creating a system for price-based water conservation incentives at American colleges.

Student water demand was responsive to the price-based rebate system. However, significant responsiveness was limited to the high rebate size, which estimated student price elasticity of demand at (0.1). This finding suggests that for students living in dormitories at Carleton College in 2012, price elasticity for demand for water is approximately (0.1) and more inelastic than (0.3), the elasticity estimate used to calculate the low rebate size. In other words, price has a very low influence on student demand. This is the first known estimation of price elasticity of demand for students at an American residential college.

Results indicate that the non-price, educational incentive system reduced student water demand. However, the response to the educational system used in this study – determined by quantity of water reduced (4.9 cubic feet/student) – was approximately one-half the response to the high rebate system (8.8 cubic feet/student). These results suggest that the students had a stronger behavioral response to the price-based incentive system than the non-price incentive system. These findings are similar to existing research on the comparative effects of price and non-price demand side management structures for residential consumers (Olmstead 2006; 2007) (Krause Et Al. 2003).

Although our model was designed to reduce student consumption to "sustainable" levels (water scarcity index of 0.4 or below), neither financial nor educational conservation incentive programs successfully lowered consumption to target levels. A likely explanation for this result is the duration of our study. Since we only conducted the study for six weeks, our results only reflect short-term demand response. If we had run this model for the entire year, it is possible that we would have incentivized "sustainable" consumption behavior due to the differences between long-run and short-run price elasticity of demand for water. Demand for water is typically more elastic (more responsive to price) in the long-run since consumers become more aware and in control of their water consumption over time (Thomas and Syme). In the particular case of this study, there may also be a lag time in student adjustment to and awareness of the rebate system.

While our regression results find statistically significant relationships between selected variables, the results from our survey provide valuable insight into some of the non-quantified behavior changes embedded within these variables. In particular, the results of our survey reveal that while our price-based water conservation system had the strongest impact on student behavior, our non-price education program had a noticeably larger effect on student perceptions.

Results from questions 27 and 28 indicate that students who were given the education treatment came out of the study more concerned with the state of the world's water supply than students who only had financial conservation incentives. Constructing the water crisis within the framework of "global perspective, local action" is incredibly important. While water shortages around the world may have different causes and effects than local water issues, management solutions may share similarities. Therefore, the results of our survey suggest a potential benefit of education that may not translate into short-term behavioral change.

One of the major obstacles to implementing pricing systems that charge consumers for the "full cost" of water is the general consumer perception of water as an abundant resource. Results from questions 21 and 22 indicate that educational incentives raised student perception of water as a scarce resource by a noticeably greater degree than the increase in perception from students only given financial incentives. Furthermore, responses to questions 23 and 24 indicate that students given our educational program came out of the study with a greater perception that water conservation is important. These results have broad implications for American colleges and water utilities struggling to implement price-based water conservation programs, as they demonstrate that inclusion of educational incentives may foster greater acceptance of water management strategies.

While the direct impact of education on water use was not as large as the impact of the rebate program, educating students may help yield greater net conservation in the long term. In our survey results, we observe that education has a noticeably strong impact on student perception of water scarcity and importance. Over time, these perceptions may translate into instinctive behavior. The results of our survey suggest that education may have unseen benefits as an investment in future conservation behavior.

Although responses to question 33, *"Have your habits changed outside of the dorm?"* showed no difference between education treatments, given the short length of our study, the long-term effect of education likely did not translate to a behavior change outside of the dorms. However, for questions 25 and 26, *"How often do you consider your water consumption?"* the distinct relative increase in frequency during the study period for students given educational programming suggests that education may catalyze an earlier transition towards long-run student price elasticity of demand. Our results demonstrate that Carleton students given educational incentives are already considering their habits more frequently.

Reflecting on the results of this study and the model development process, there are some adjustments that could be made to our experimental design. As previously mentioned, it would be interesting to run this experiment for at least three to four months to test for increased behavioral response over time. In addition, now that we have a better picture of Carleton student price elasticity of demand for water, future steps would be to: (a) test this model on other US college campuses to determine how student price elasticity varies across different regions and college sizes and (b) to test more specific price elasticity estimates at Carleton. Many survey respondents wrote in the free response section that they considered the monetary incentive price negligible and some of these students lived in dorms with high rebate sizes, more money might have yielded a stronger response.

It is possible that there was some information crossover during our study. While each of our treatments were designed to be implemented independently of the others, results from questions 35 and 39 indicate that some respondents found out about the study by seeing posters in other dorms or heard that other dorms were given different monetary rewards. We do not believe this information crossover was great enough to introduce significant variation into our results.

Responses to the survey indicate that our study population was already fairly well informed about water issues. According to the responses to survey questions 16 and 17, over 20% of Carleton students hear about water conservation on a weekly basis and approximately 30% appear to be independently interested in water issues, respectively. If this study is conducted at a school with a less conservation-aware student body, our model may have a larger impact on water use reduction. Furthermore, some scholars suggest that while people typically have positive attitudes towards conservation practices, these perceptions are not demonstrated by actual behavior (Dolnicar and Hurlimann 2010). Testing this model and survey at a school with different levels of conservation-awareness may provide interesting insight on this hypothesis.

We used three control variables in our OLS with FE regression model, all of which had significant relationships to student water demand. We found that male students use less water than female students. One possible explanation for this result is supported by anecdotes from the free response survey question: that female students typically shave in the shower, and thus are not able to shorten all of their showers.

We also found that freshmen generally use less water than sophomores and upperclassmen. A possible explanation for this result could be that when students first come to Carleton, they are still accustomed to water use habits from their home. Students who come from places that are less water abundant than Minnesota – such as the southern United States or other water-scarce nations – would be more accustomed to conserving water. However, after spending a year at Carleton, these students may have acclimated to relatively more consumptive local norms.

Finally, we found that when it is warmer outside, students will use more water. Although this significant relationship merits further exploration, we suggest a possible explanation may be that during warmer days, students are more inclined to exercise, thus showering more often and soiling more laundry.

## VII. Conclusions

In this study we design a financial incentive system for student water conservation and evaluate the effectiveness of that demand side management system against non-price, educational incentives. We found that both financial rebates and educational programming motivated student conservation behavior, however these incentives had varying qualitative and quantitative effects. While our financial rebate was more effective at reducing overall water consumption, qualitative results from our survey suggest education shifts student perceptions and may catalyze sustained behavior change. These findings suggest that the most efficient method to foster sustainable water consumption at American colleges is a price-based system supplemented with educational information.

Not only do our results demonstrate an effective method for American colleges to manage student water demand on campus, but they also contribute to the larger goals of higher education institutions – in particular the goal of colleges to shape the long-term behavior and actions of future leaders. The effect of education on student perception indicates not only development of sustainable habits, but also a global perspective and local consciousness of water scarcity. By implementing water conservation program like the one in this study, colleges will not only serve their internal institutional objectives but also can lead greater society towards sustainable water management solutions.

## Bibliography


(NCDC), National Climatic Data Center. 2011. "Climate Data Online (CDO)." http://www.ncdc.noaa.gov/cdo-web/search;jsessionid=66BD167C3188CC87274A17A1F47C9380.lwf3.

AJC. "State Billed Millions for Lake Lanier Litigation | Ajc.com." http://www.ajc.com/news/state-billed-millions-for-102920.html.

Allen, Klaiber, Smith Kerry, Kaminsky Michael, and Strong Aaron. "Estimating the Price Elasticity of Demand for Water with Quasi Experimental Methods H. Allen Klaiber, V. Kerry Smith, Michael Kaminsky, and Aaron Strong*." http://www.google.com/url?sa=t&rct=j&q=water%20scarcity%20elasticity%20of%20demand&source=web&cd=6&ved=0CEMQFjAF&url=http%3A%2F%2Fageconsearch.umn.edu%2Fbitstream%2F61039%2F2%2F010260.pdf&ei=xRe_Ts3jGcSZ2QXuztWLCA&usg=AFQjCNFjorGWdayMVVXLthWcgTP-y616ZQ&cad=rja.

Barber, N. L. 2009. *Summary of Estimated Water Use in the United States in 2005: U.S. Geological Survey Fact Sheet 2009–3098*. http://pubs.usgs.gov/fs/2009/3098/.

Barry, Liz. 2011. "LC Initiative Cutting Campus Water, Energy Use." *The News & Advance*, February 3, sec. local. http://www2.newsadvance.com/news/2011/feb/03/lc-initiative-cutting-campus-water-energy-use-ar-819472/.

Berk, R A, T F Cooley, C J LaCivita, S Parker, K Sredl, and M Brewer. 1980. "Reducing Consumption in Periods of Acute Scarcity: The Case of Water." *Social Science Research* 9: 99–120.

Brandon, Gwendolyn, and Alan Lewis. 1999. "Reducing Household Consumption: a Qualitative and Quantitative Field Study." *Journal of Environmental Psychology* 19: 75–85.

Buckley, Ryan A. 2004. "Water Use Characteristics of College Students."

Carleton College Mission Statement. "Carleton College: Information & Resources for Visitors: Mission Statement." http://apps.carleton.edu/visitors/mission/.

City of Northfield. "Water and Sewer Rates from 1994 to 2011". c/o Lori Guggemos, Utility Billing Account Tech.

Corral-Verdugo, Victor, Martha Frías-Armenta, Faviola Pérez-Urias, Virginia Orduña-Cabrera, and Noelia Espinoza-Gallego. 2002. "Residential Water Consumption, Motivation for Conserving Water and the Continuing Tragedy of the Commons." *Environmental Management* 30 (4) (October): 527–535.

Dolnicar, Sara, and A Hurlimann. 2010. "Australians' Water Conservation Behaviours and Attitudes." *Australian Journal of Water Resources* 14 (1): 43–53.

Geller, E. Scott, Jeff B. Erickson, and Brenda A. Buttram. 1983. "Attempts to Promote Residential Water Conservation with Educational, Behavioral and Engineering Strategies." *Population and Environment* 6 (2) (July 1): 96–112.

Gordon, Greg. 2005. "Water Supply Can't Meet Thirst for New Industry." *Star Tribune*, December 26. http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&ved=0CEAQFjAD&url=http%3A%2F%2Fhomepage.mac.com%2Foscura%2Fctd%2Fdocs%2F122605watershortage.pdf&ei=x8pFT6bXK8Kfgwe-xNSrBA&usg=AFQjCNHe0i8R4UWbcayoiSjbXJXzPW_OyQ&sig2=iH637uPOq0T8wpJRXGO84A.

Guerrero, Bianca. 2011. *The Impact of Agricultural Drought Losses on the Texas Economy.* Texas AgriLife Extension Briefing Paper.

Hanemann, W. Michael. 2005. *The Economic Conception of Water*. CUDARE Working Paper Series. University of California at Berkeley, Department of Agricultural and Resource Economics and Policy. http://ideas.repec.org/p/are/cudare/1005.html.

Howe, Charles W., and F. P. Linaweaver Jr. "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure." *Water Resources Research* 3 (1): PP. 13–32. doi:196710.1029/WR003i001p00013.

Huffaker, R., N. Whittlesey, A. Michelsen, R. Taylor, and T. McGuckin. 1998. "Evaluating the Effectiveness of Conservation Water-Pricing Programs." *Journal of Agricultural and Resource Economics* 23 (1) (July 1): 12–19.

Jones, DeDe, Steve Amosson, and Gid Mayfield. 2011. *State Drought Losses Have Significant Impact on Overall Economy*.

Texas A&M AgriLife Extension Economics Department.
Kanazawa, Mark. 1993. "Pricing Subsidies and Economic Efficiency: The U.S. Bureau of Reclamation." *Journal of Law & Economics* 36: 205.
Kelley, H H, and A J Stahelski. 1970. "Social Interaction Basis of Cooperators and Competitors' Beliefs About Others." *Journal of Personality and Social Psychology* 16: 66–91.
Kelley, H H, and J W Thibaut. 1978. *Interpersonal Relations: a Theory of Interdependence*. New York: John Wiley.
Krause, Kate, Janie M Chermak, and David S Brookshire. 2003. "The Demand for Water: Consumer Response to Scarcity" 23 (2): 167–91.
Lawrence Berkeley National Laboratory. "Agricultural Usage | Water Energy Technology Team." http://water-energy.lbl.gov/node/10.
Lopez Garcia, Claudia. 2008. "Pricing of Water Supply Services: Consumer Response to Price Structure." http://proquest.umi.com/pqdlink?Ver=1&Exp=10-18-2016&FMT=7&DID=1604358131&RQT=309&attempt=1&cfc=1.
McClintock, C G. 1972. "Social Motivation: a Set of Propositions." *Behavioral Science* 17: 438–454.
———. 1978. "Social Values: Their Definition, Measurement, and Development." *Journal of Research and Development in Education* 12: 121–137.
McClintock, C G, and L Keil. 1983. "Social Values: Their Definition, Their Development, and Their Impact Upon Human Decision Making in Settings of Outcome Interdependence." In *Small Groups and Social Interaction*. Vol. 2. New York: John Wiley & Sons.
McKenzie-Mohr, Doug. 2000. "Fostering Sustainable Behavior Through Community-based Social Marketing." *American Psychologist* 55 (5): 531–537. doi:10.1037/0003-066X.55.5.531.
Merson, John. 2006. *Energy Demands on Water Resources Report to Congress on the Interdependency of Energy and Water.* U.S. Department of Energy. http://www.sandia.gov/energy-water/congress_report.htm.
Oki, Taikan, and Shinjiro Kanae. 2006. "Global Hydrological Cycles and World Water Resources." *Science* 313 (5790): 1068 – 1072. doi:10.1126/science.1128845.
Olmstead, Sheila M. 2006. "Managing Water Demand: Price Vs. Non-price Conservation Programs." *Pioneer Institute for Public Policy Research*.
Parece, Tammy Erlene. 2010. "Managing Water and Electricity Consumption in University Residence Halls: a Study on Promoting Voluntary Resource Conservation by College Students": 1–106.
Reeves, Howard. *Water Availability and Use Pilot—A Multiscale Assessment in the U.S. Great Lakes Basin: U.S. Geological Survey Professional Paper 1778*. http://pubs.usgs.gov/pp/1778/.
Ridgeway, Peter, and Natalie Nejad. 2010. *SCHOOL SMART WATER METER PROGRAM 2010*. Case Study. Scoresby Secondary College.
Rusbult, C E, and P A M Van Lange. 1996. "Interdependence Processes." In *Social Psychology: Handbook of Basic Principles*, 564–596. New York: Guilford.
Santa Clara University & LLNL. "Santa Clara University & LLNL The World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project Phase 3 (CMIP3) Multi-model Dataset." http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/#Welcome.
Shiklomanov, I. A., and J. C. Rodda. 2004. *World Water Resources At The Beginning Of The Twenty-First Century*. Cambridge University Press.
Stephenson, Dustin. 2000. "The Tri-State Compact: Falling Waters and Fading Opportunities." *Journal of Land Use & Environmental Law* 16 (1): 83.
Suh, Sangwon, Chiu Yi-Wen, and Olabisi Laura Schmitt. 2010. *Future of Energy and Minnesota Water Resources | Minnesota's Legacy*. Report to Legislative Citizen's Commission on Minnesota Resources. Sain Paul, Minnesota. http://www.legacy.leg.mn/projects/future-energy-and-minnesota-water-resources.
TetraTech. *Evaluating Sustainability of Projected Water Demands Under Future Climate Change Scenarios*. http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCQQFjAA&url=http%3A%2F%2Frd.tetratech.com%2Fclimatechange%2Fprojects%2Fdoc%2FTetra_Tech_Climate_Report_2010_lowres.pdf&ei=5dJBT8qWLNDzggfDv9G

aCA&usg=AFQjCNEawWw1-R5Ctf-txXR5VfWnIusCrg&sig2=vyknWsNF1Luu4I5X3JvIzQ.
Thomas, John F., and Geoffrey J. Syme. “Estimating Residential Price Elasticity of Demand for Water: A Contingent Valuation Approach.” *Water Resources Research* 24 (11): PP. 1847–1857. doi:198810.1029/WR024i011p01847.
Thompson, Suzanne C., and Kirsten Stoutemyer. 1991. “Water Use as a Commons Dilemma.” *Environment and Behavior* 23 (3) (May 1): 314 –333. doi:10.1177/0013916591233004.
Trenberth, Kevin, Aiguo Dai, Roy Rasmussen, and David Parsons. 2003. “The Changing Character of Precipitation.” *Bulletin of the American Meteorological Society* 84 (9): 1205–1217.
US Census Bureau Center for Economic Studies, Phone 301-763-6460. “US Census Bureau Center for Economic Studies Annual Report Page.” http://www.census.gov/ces/publications/annualreport.html.
US Department of Commerce, NOAA. “Local Drought Page.” http://www.crh.noaa.gov/arx/?n=drought.
US EIA. 2011. *2011 Annual Energy Outlook*. U.S. Energy Information Administration. http://www.eia.gov/about/contact/forecasting.cfm#longterm.
———. “Electric Power Annual 2010 Data.” http://www.eia.gov/electricity/annual/.
US EPA. 2002. *Sub-Metering Energy Use in Colleges and Universities: Incentives and Challenges*. United States Environmental Protection Association. http://www.google.com/url?sa=t&rct=j&q=sub-metering%20energy%20use%20in%20colleges%20and%20universities%3A%20incentives%20and%20challenges&source=web&cd=1&ved=0CDcQFjAA&url=http%3A%2F%2Fwww.energystar.gov%2Fia%2Fbusiness%2Fhigher_ed%2FSubmeter_energy_use.pdf&ei=EfJeT4yJA4ONgwfS_f2HCA&usg=AFQjCNEMwJSQ9hFJDsKDWCr5sFm0FY_rqA&cad=rja.
———. 2012. “Water & Wastewater Pricing - Introduction.” *Water & Wastewater Pricing - Introduction | Sustainable Infrastructure | US EPA*. http://water.epa.gov/infrastructure/sustain/Water-and-Wastewater-Pricing-Introduction.cfm.
USDA. 2004. “Irrigation and Water Use: Glossary.” *ERS/USDA Breifing Room*. http://www.ers.usda.gov/Briefing/WaterUse/glossary.htm#consumptive.
Van Vugt, Mark, and Charles D Samuelson. 1999. “The Impact of Personal Metering in the Management of a Natural Resource Crisis: a Social Dilemma Analysis.” *Pers* 25 (6) (June): 735–750.
Winkler, Robin C., and Richard A. Winett. 1982. “Behavioral Interventions in Resource Conservation: A Systems Approach Based on Behavioral Economics.” *American Psychologist* 37 (4): 421–435. doi:10.1037/0003-066X.37.4.421.

## Appendix I – Suh et al. methodology

Biofuel data were collected from the US EIA Annual Energy Outlook (AEO) 2007. For the baseline case, business-as-usual (BAU) scenarios from the AEO 2007 report predicted a total ethanol demand of 41.2 $m^3$ by 2030. Suh et al assume Minnesota would produce 10% of the national ethanol pool, as was the case in 2007, and raised production predictions by 20% to create the extreme ethanol scenario.

Population estimates were developed from US Census population predictions up to the year 2035 by county. These data were selected for the business-as-usual scenario and raised by an additional 20% in the extreme scenario.

Electricity use predictions were derived from US EIA historical data and future predictions from their AEO 2006 report. (US EIA) The BAU scenario assumes that power demand per person would reach 17.3 MWh by 2030, and the extreme case assumes a 20% additional increase in power demand per person (20.76 MWh per person by 2030).

The climate change scenario was generated from data and models developed by the U.S. Bureau of Reclamation Technical Service Center, Santa Clara University, and the Lawrence Livermore National Laboratory.(Santa Clara University & LLNL) Among the various climate models available, the extreme scenario used in this study represents extreme energy usage (IPCC A2 emission scenario) while the BAU scenario was set to average NOAA climate patterns between the years 2000 to 2006. (NCDC 2011) (Suh, Yi-Wen, and Schmitt 2010)

For the formulas used in the “climate and water avaibility” and “water demand system dynamics modules,” please refer to (Suh, Yi-Wen, and Schmitt 2010) sections 4.2.1 and 4.2.2.

## Appendix II – Data Normalization Methods

In the year 2009, the original cubic feet meter heads were refit with meter heads that took readings in gallons. Unfortunately, these new heads were not pulse calibrated to the old cubic feet meters, resuling in a per-meter delta discrepency. To adjust for this multiplicative error, we generated a regression line from the original readings in cubic feet. We then fit the new gallon readings to each individual regression line by taking the mean of the gallon readings, fitting that mean to the linear slope, then adjusting for variation between transformed data. Since the error was a pulse problem, and thus multiplicative, we determined that this was a fair adjustment method.

Present readings are read electronically via output from a newly installed Siemens "Insight" System. These systems combine low and high flow readings into a single total flow reading. In order to normalize our data appropriately, we dissected this total flow reading with the mean ratio of high flow consumption to low flow consumption per dorm for all years in our baseline (1999-2011). Individual 2012 high flow and low flow readings were then delta adjusted from gallons to cubic feet in accordance with the linear normalization model discussed above.

According to campus facilities, the recorded observations often varied by either more than three days or less than three days from the recorded date. We used this information to adjust for potential outliers in our data set. We define an outlier as a data point outside 1.5 standard deviations from the annual historical mean of that particular dorm. We adjusted these outliers by three days towards the mean of the distribution (e.g. Watson 2002 consumption was 343 cubic feet per capita, an determined outlier. We multiplied this number by 30/33, assuming this reading was taken at the maximum three days from the recorded date, resulting in the large reading. We then replaced this transformed reading back into the database.)

## Appendix III – Survey Questions

**1. Are you 18 years of age or older?**

□ Yes □ No

**2. Do you agree to participate in this survey?**

□ Yes, I agree □ No, I do not agree

**3. Which dorm are you a resident of?**

□ Evans □ Watson □ Davis □ Musser □ Myers □ Nourse

**4. What year are you?**

□ Freshman □ Sophomore □ Junior □ Senior

**5. In the past month and a half, how have your shower habits changed?**

□ I shower more □ I shower less □ There has been no change

**6. A month and a half ago, how many times did you shower in a typical week?**

□ Less than 1 □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 □ More than 7

**7. On average, how long were your showers?**

□ Less than 5 minutes □ Approximately 5 minutes □ More than 5 minutes

**8. Currently, how many times do you shower in a typical week?**

□ Less than 1 □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 □ More than 7

**9. On average, how long are your showers?**

□ Less than 5 minutes □ Approximately 5 minutes □ More than 5 minutes

**10. A month and a half ago, did you leave the tap running while brushing your teeth, washing your hands, etc.?**

□ Yes □ No

**11. Currently, do you leave the tap running while brushing your teeth, washing your hands, etc.?**

□ Yes □ No

**12. A month and a half ago, about how many loads of laundry did you do a month at Carleton?**

□ Less than 1 □ 1 □ 2 □ 3 □ 4 □ 5 □ More than 5

**13. Did you only do full loads of laundry?**

□ Yes □ No

**14. Currently, about how many loads of laundry do you do in a month at Carleton?**

□ Less than 1 □ 1 □ 2 □ 3 □ 4 □ 5 □ More than 5

**15. Do you only do full loads of laundry?**

□ Yes □ No

**16. How often do you hear about water conservation in the media?**

□ Daily □ Weekly □ Monthly □ Bi-Monthly □ Never

**17. Do you actively seek out water conservation information?**

□ Yes □ Sometimes □ No

**18. How do you access water-saving tips and programs?**

□ Online □ Print Media □ Word of Mouth □ Other □ I do not access

**19. A month and a half ago, what techniques did you use to save water? (Select all that apply.)**

□ Turn off the tap while brushing teeth, washing hands, shaving, etc.
□ Washing only full loads of laundry
□ Take shorter showers (5 minutes or less)
□ Use low-flow appliances
□ Other

**20. Currently, what techniques do you use to save water? (Select all that apply.)**

□ Turn off the tap while brushing teeth, washing hands, shaving, etc.
□ Washing only full loads of laundry
□ Take shorter showers (5 minutes or less)
□ Use low-flow appliances
□ Other

**21. A month and a half ago, how scarce of a resource did you consider water to be?**

□ 1 (not at all) □ 2 □ 3 (scarce) □ 4 □ 5 (very)

**22. Currently, how scarce of a resource do you consider water to be?**

□ 1 (not at all) □ 2 □ 3 (scarce) □ 4 □ 5 (very)

**23. A month and a half ago, how important did you believe water conservation initiatives/programs to be?**

□ 1 (not at all) □ 2 □ 3 (important) □ 4 □ 5 (very)

**24. Currently, how important do you believe water conservation initiatives/programs to be?**

□ 1 (not at all) □ 2 □ 3 (important) □ 4 □ 5 (very)

**25. A month and a half ago, how often did you consider your water consumption?**

□ 1 (never) □ 2 □ 3 (often) □ 4 □ 5 (constantly)

**26. Currently, how often do you consider your water consumption?**

□ 1 (never) □ 2 □ 3 (often) □ 4 □ 5 (constantly)

**27. A month and a half ago, how often did you worry about the state of the world's water supply?**

□ 1 (never) □ 2 □ 3 (often) □ 4 □ 5 (constantly)

**28. Currently, how often do you worry about the state of the world's water supply?**

□ 1 (never) □ 2 □ 3 (often) □ 4 □ 5 (constantly)

**29. Were you aware that your residence hall was participating in a study on conserving water?**

□ Yes □ No

**30. How did you find out about the study? (Select all that apply.)**

□ Received an email
□ Saw the notices posted in my residence hall
□ Attended a meeting held in my residence hall
□ Saw posters in another dorm
□ From a friend
□ Other
□ I did not know about the study

**31. Did you actively participate in this study?**

□ Yes □ No □ I did not know about the study

**32. Please indicate which of the following actions you took. (Select all that apply.)**

□ Only washed full loads of laundry
□ Turned off the water while brushing my teeth, washing my hands, shaving, etc.
□ Took shorter showers

□ Other
□ Took no action
□ I did not know about the study

**33. After the study, did you change your habits outside of your dorm (e.g. turn off the tap in public campus spaces or other dorms)?**

□ Yes □ No □ I did not know about the study

**34. How likely is it that you will continue your water consumption habits as a result of this study now that it has ended?**

□ 1 (not at all) □ 2 □ 3 (likely) □ 4 □ 5 (very)
□ Not applicable (I did not know about the study)

**35. From which of the following mediums did you hear about water conservation or this study? (Please check all that apply.)**

□ Emails
□ Notices posted in my residence hall
□ Meetings held in my residence hall
□ Slips in my mailbox
□ Posters in another dorm
□ Friends/dorm mates
□ Other
□ I did not know about the study

**36. How influential were the feedback emails, informational posters, fliers, etc. on your decision to reduce your water consumption? (If you did not know about the study, please leave this question blank.)**

□ 1 (not at all) □ 2 □ 3 (influential) □ 4 □ 5 (very)

**37. Which among the following was the MOST influential in your decision to conserve water.**

□ Emails
□ Notices posted in my residence hall
□ Meetings held in my residence hall
□ Slips in my mailbox
□ Posters in another dorm
□ Friends/dorm mates
□ Other
□ I did not know about the study
□ None of the above affected my water consumption behavior

**38. How influential was the monetary reward on your decision to reduce your water consumption? (If you did not hear about a monetary reward, please do not answer this question.)**

□ 1 (not at all) □ 2 □ 3 (influential) □ 4 □ 5 (very)

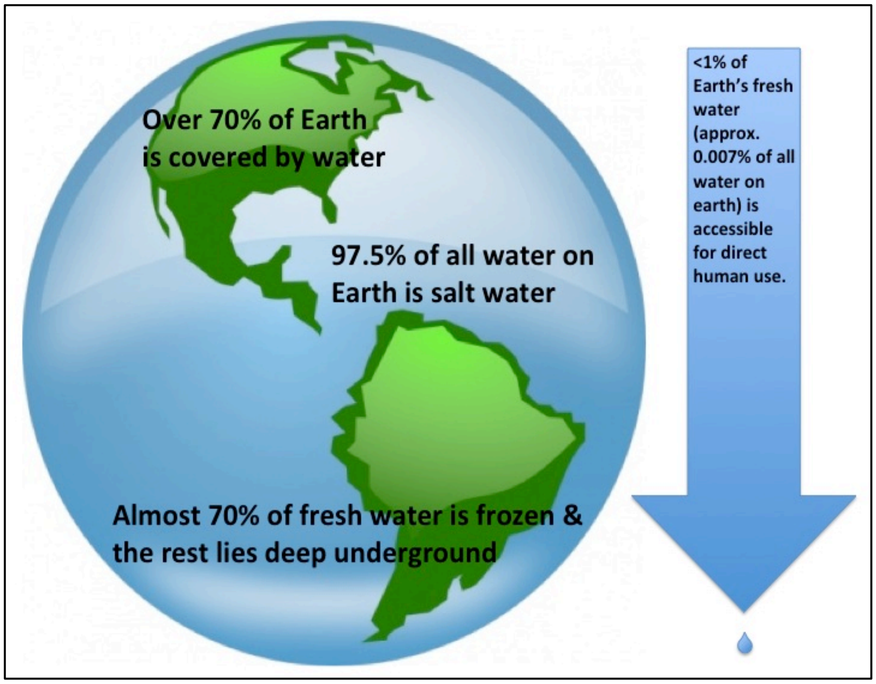
**39. Did you hear about different monetary reward values for other dorms?**

□ Yes □ No

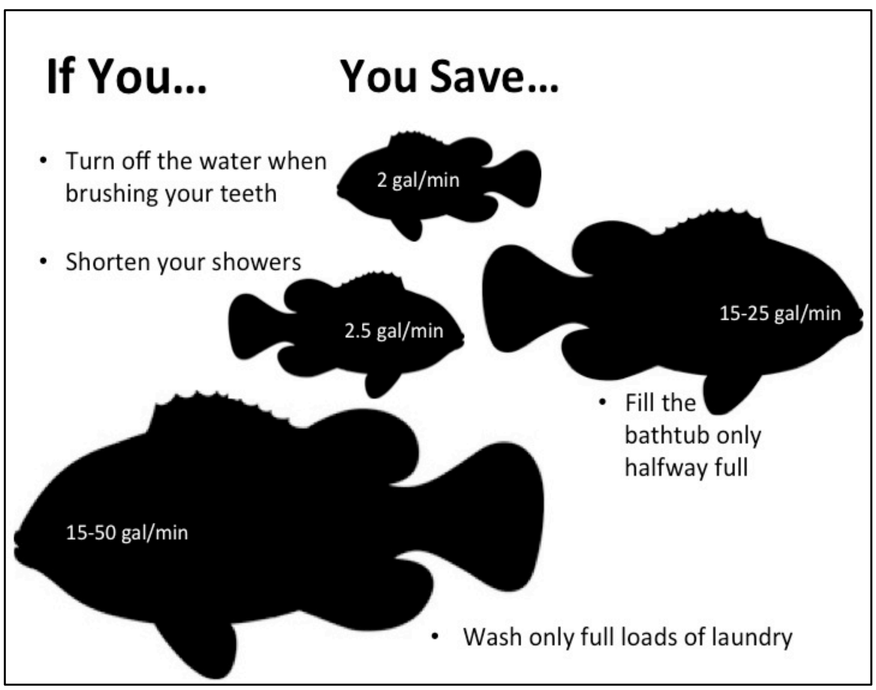
**40. Please take a moment to provide us with some feedback on our study. Questions, comments, suggestions, other thoughts, etc.**

# Appendix IV – Educational Materials

## *Posters*

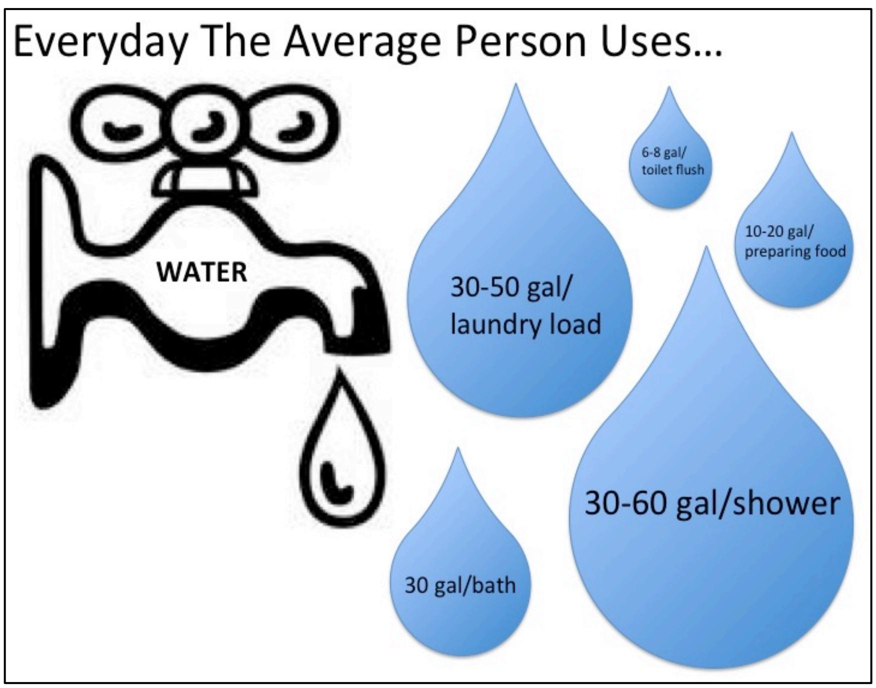



University of Michigan. *Global Change.* 2006. "Human Appropriation of the World's Fresh Water Supply." http://www.globalchange.umich.edu/globalchange2/current/lectures/freshwater_supply/freshwater.html

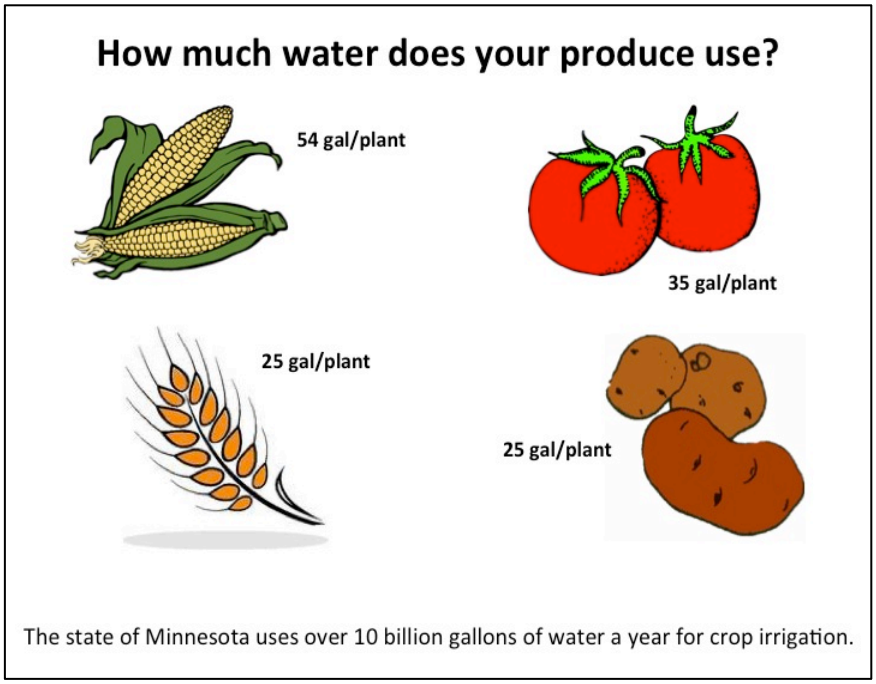



San Diego County Water Authority. 2007. "The 20-Gallon Challenge." *http://www.20gallonchallenge.com/residenttips.html*

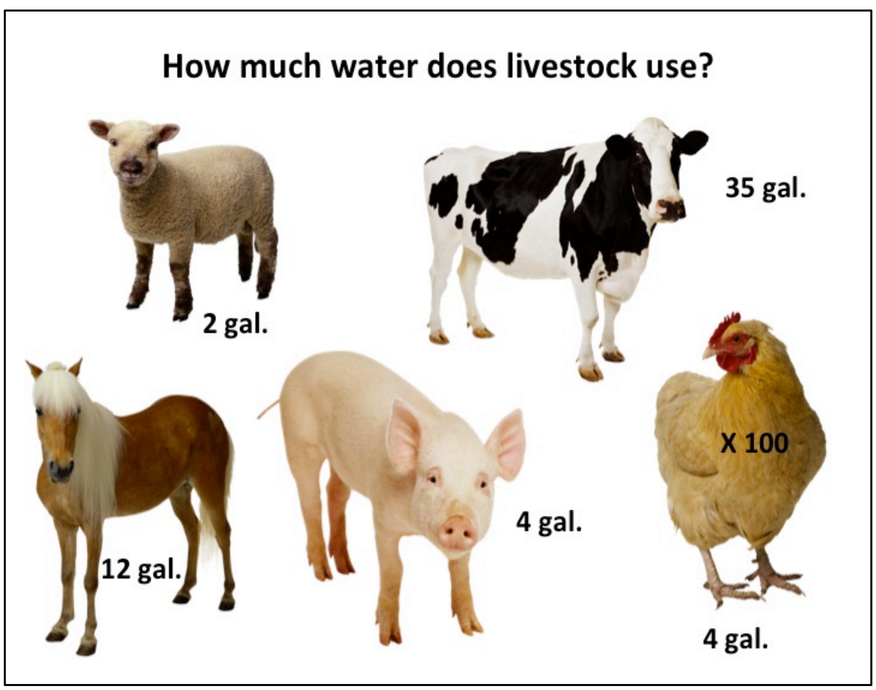

(INA), International Networks Archive. "Glass Half Empty: The Coming Water Wars." *http://visual.ly/glass-half-empty-coming-water-wars*



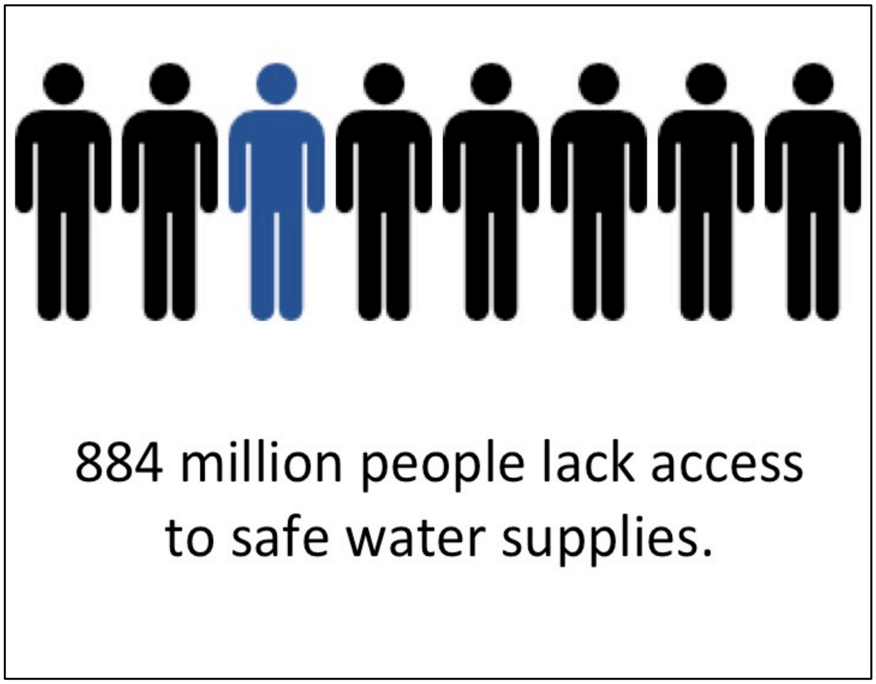

UXL Science Fact Finder. 1998. "How Much Water Does An Average Person Use Each Day?" *http://www.enotes.com/science/q-and-a/how-much-water-does-an-average-person-use-each-day-288217*
University of Minnesota. *Extension: Our World of Water.* 255. "Water Use and Conservation." *http://www.extension.umn.edu/distribution/youthdevelopment/components/0328-05.html*



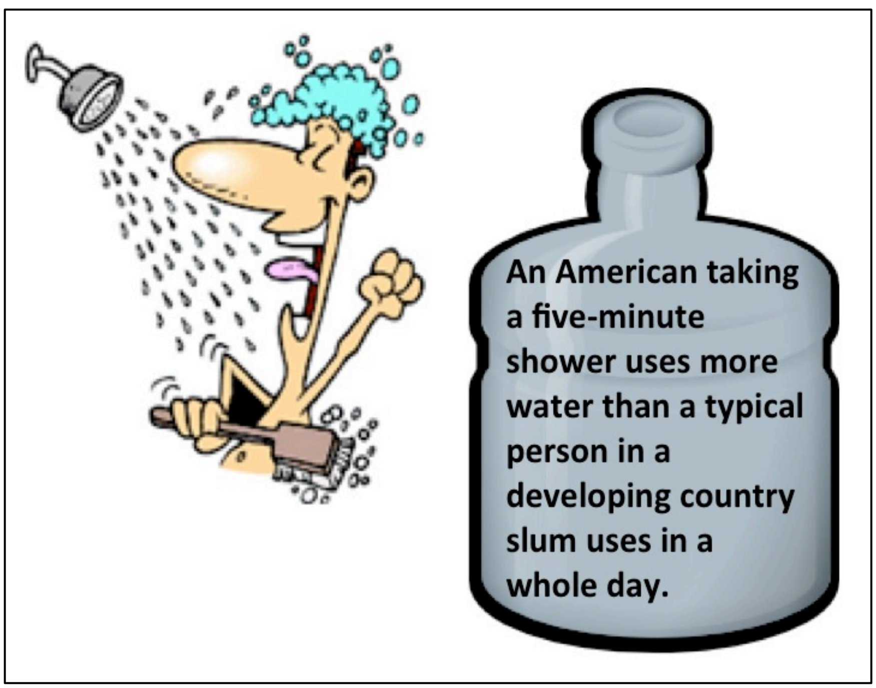

University of Minnesota. *Extension: Our World of Water.* 255. "Water Use and Conservation."
http://www.extension.umn.edu/distribution/youthdevelopment/components/0328-05.html




University of Minnesota. *Extension: Our World of Water.* 255. "Water Use and Conservation."
http://www.extension.umn.edu/distribution/youthdevelopment/components/0328-05.html




Water.org. *The Crisis.* “Water Facts: Water.” *http://water.org/water-crisis/water-facts/water/*




*Blue Planet Network. The Facts. 2010. “The Facts About The Global Drinking Water Crisis.” http://blueplanetnetwork.org/water/facts*


Conserve Water!
Reducing your shower time by a few minutes can save gallons of water!


Save a drop, earn a buck!
Remember to reduce water waste in your dorm – and receive cash as a reward!

*Mailbox Flier*

## EVERY DROP COUNTS!

### *Water Saving Tips*

- **Take shorter showers.**
  - **Every minute you shave off your shower saves 2.5 gal/min.**
- **Turn off the water when brushing your teeth or shaving.**
  - **When you don't leave the tap running, you save 2 gal/min.**
- **Wash only full loads of laundry.**
  - **Inefficient laundry practices can waste anywhere from 15-50 gal/min. of water.**
- **Don't leave the sink running when doing the dishes.**
- **Taking showers saves more water than taking baths.**
- **When washing your hands, don't turn the tap to the highest pressure setting.**
- **Encourage your friends and floor mates to conserve water!**

*San Diego County Water Authority. 2007. "The 20-Gallon Challenge."* http://www.20gallonchallenge.com/residenttips.html

## Appendix V – Student Rebate "Bill" Example

---

February 20th, 2012

Dear Evans Hall Resident,

This is your updated water conservation rebate report:

- We have conducted our study for 5 weeks to date.
- During the study period, your dorm has conserved 79 cubic feet of water / student less than in previous years.
- At your individual water conservation rate of 15.2 cents per cubic foot, you have earned $12.04

Our study will continue until the end of winter term, so there is still time to earn money! Remember, for every gallon of water your dorm saves, you and your dorm mates will *individually* receive an equal payment. Conserve a lot - earn a lot!

You can conserve water in in your dorm by:

- Taking shorter showers.
- Turning off the tap when brushing your teeth.
- Washing fewer loads of laundry.
- Working as a community to reduce water waste!

We're really excited to pay you for environmentally sustainable behavior! Thank you for participating! Please feel free to contact us if you have any questions or concerns.

Sincerely,

Jake Reznick
reznickj@carleton.edu
917-583-5841

Charlotte Arneson
arnesonc@carleton.edu
612-599-6405

---