

Duke University DELTA Smart House Project

Water Catchment and Purification

by

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ABSTRACT

Americans use about 3,700 billion gallons more than they return to the natural water system every year. The primary goal of the Water Catchment and Purification group is to help reduce the environmental footprint of the DELTA House through the reduction of water consumption and the use of alternative water sources to meet some of the house's water needs. Low-water fixtures have been researched to decrease the amount of water needed in the house; these include faucet aerators, low-flush toilets, low-flow showerheads and water efficient washing machines and dishwashers. These devices, combined with an increased awareness in water conservation and the implementation of a "smart" sprinkler system will be able to reduce water consumption in the house by more than 50%.

Rain water catchment and a gray water recycling system are being considered as options to reduce the amount of potable water used by the house. These are viable, financially sound, environmentally-friendly ways of reducing water consumption that can be used by anyone, from major companies to the average consumer. Furthermore, constructed wetlands have been explored as a natural way of treating some of the sewage generated by the house on-site. These methods for water conservation will allow for DELTA House to achieve the requirements set forth by the LEED Green Building Rating System pertaining to water management, and to benefit from the increased sustainability and savings possible from the implementation of water catchment and conservation techniques.

INTRODUCTION

The DELTA (Duke Engineering Living Technology Advancement) Smart House Project was started with the primary goal of creating a living environment that integrates technology pertaining to the three E's: Energy & Efficiency, Environment & Health, and Entertainment & Communications. To aid with the environment and health aspect, the Water Catchment and Purification team was developed. The principal role of this team is to conserve water through the design and construction of an advanced water catchment and recycling system. Possible other projects related to this field include a gray water recycling system, a UV purification system, natural waste water treatment, and water-efficient accessories for basic household appliances. In addition, the Water Catchment and Purification team anticipates close collaboration with the Smart Sprinkler System team in order to maximize efficient water use for the house.

The benefits of a household water catchment and purification system are numerous. First and foremost, the development and implementation of such a system directly works towards the DELTA Smart House's goal of being environmentally attentive. By acquiring the water needed for the house from a natural source (i.e. rainwater), and by recycling the water consumed (gray water), the DELTA house will be more environmentally friendly. As opposed to city water, rainwater is "naturally soft, contains almost no dissolved minerals of salt, and is free of chemical treatment" and is therefore suitable for anything from showering to cooking (Hsu). Gray water is any water that has been used in the home except water from toilets. This comprises about 60-80% of residential water use. This water can be reused for other purposes such as land irrigation; it has been shown that plants thrive on water that contains bits of compost. Therefore, by recycling the gray water being produced in the Smart House, the amount of "fresh" water being used can be greatly reduced. This system along with the rainwater catchment system circumvents the need to rely upon city water, thus making the home self-sufficient. This could be an advantageous quality in times of droughts and other occasions when public city water is scarce.

Moreover, one of the major environmental concerns facing society today is improper sewage removals that prove to be hazardous to both humans and the environment. The DELTA House by reducing water consumption and implementing a natural solution to sewage will be minimizing its impact on the environment.

GOALS

The goals of the Water Catchment and Purification team are as follow:

- To meet most of the water needs of the house by catching rainwater and reusing the gray water in the house
- To purify water to make it suitable for all household uses
- To reduce water consumption by implementing household devices aimed at conserving water
- To reduce amount of sewage generated by the house
- To meet LEED standards pertaining to water usage

LEED stands for Leadership in Energy and Environmental Design and refers to a set of standards developed by the U.S. Green Building Council to “promote buildings that are environmentally responsible, profitable, and healthy places to live and work” (Hunton). A building is awarded a certain number of points based upon its adherence to the guidelines outlined by LEED. The rating system places great emphasis on water management.

BACKGROUND INFORMATION

Statistics lend support to the notion that water catchment is not only a plausible idea, but also a highly practical and advantageous one. Each year, North Carolina receives approximately 45 inches of rainfall (Hsu). The average household consumes 63,408 gallons of water (EPCOR). How much, then, could a rainwater catchment system contribute to reducing water used within the house?

Naturally, the amount of rainwater that could be acquired through a water catchment system depends upon the area of the surface where the water will be collected. Assuming a 2,500 square foot roof, the yearly rainfall in North Carolina could yield approximately 51,000 gallons of water (EPCOR). This plan still leaves the house needing 12,408 gallons of water. To solve this problem, rather than finding another method of acquiring water, a more practical idea is to implement water-efficient devices aimed at reducing water consumption, and reduce the amount of freshwater needed for landscape irrigation by recycling the water that has been previously used in the house.

Several projects similar to the proposed one have already been undertaken. For example, in Oregon, one homeowner installed a rainwater harvesting and purification system in 1996. He reported that his system yielded 27,000 gallons of water per year with minimal maintenance. The household only used public water supply for their cooking and drinking needs. Last summer, he modified his system to include a commercially available roof washer to increase sanitation.

Gray water is being used for plant irrigation around the country. Gray water recycling has many benefits, in addition to decreasing the amount of fresh water used; it can also decrease the strain on septic tanks and wastewater treatment plants. Moreover, the water is purified by the soil and the plants therefore the possibility of the contamination of groundwater is greatly reduced.

Devices that reduce everyday water consumption are more common among American households. Many people own low-flow showerheads, faucet aerators, low-flush toilets, and water efficient dishwashers. These appliances can reduce water consumption by up to 70% in

some cases (Retrofitting). Compost toilets are somewhat more of a novel idea, but have the potential to make a dramatic difference in the amount of water consumed by the average household each year.

Over the past few years growing concern of contamination of lakes and other natural water resources due to improper waste disposal and chemical waste water treatment, has caused for communities and companies across the United States to resort to natural options for waste removal. For instance, constructed wetlands are being used to treat livestock wastewater and storm water runoff. The Adam Joseph Lewis Center for Environmental Studies at Oberlin College uses of a “Living Machine” that treats the black water that comes from the center’s toilets through the use of a natural plant network. This water is then pumped back to the toilets for flushing.

Given these statistics and the past implementation of some of these ideas, the plan of the Water Catchments and Purification team is as follows:

- Develop a catchment system to obtain rainwater
- Develop a gray water system to recycle water used in the house
- Devise a way to purify the water
- Implement appliances that reduce water consumption in the house
- Reduce amount of sewage generated in the house
- Devise a natural solution for sewage disposal
- Integrate water collection with output from fuel cell
- Monitor collection and consumption of water

Several potential problems that could be encountered while executing this plan have been identified. Legal issues pose a problem in regards to compost toilets. There are extensive regulations pertaining to the existence of compost toilets in North Carolina households. These regulations vary locally and must be carefully researched and considered before implementation of a compost toilet in the DELTA Smart House. Another potential problem is the possibility that not enough water will be harvested in the early stages of this project. The most practical solution in this case is to connect the house to the city water supply to be used as a last resort only.

TECHNICAL OVERVIEW

The following is an explanation of the different products being considered by the Water Purification and Catchment group:

- Water Catchment:
 - Tank Location: The tank used for the storage of the caught water can be located above or below ground. Both locations have advantages and disadvantages. It has been determined that having the tank above ground would make it easier for maintenance and overall implementation of the designed purification system. Furthermore, one great advantage to an above ground location is that one could potentially minimize the needs of a pump and could take advantage of the natural water pressure generated within the tank which would minimize the needs of a pump and how much power the pump must have. (Sustainable Building) Water gains one pound per square inch of pressure for every 2.31 feet of rise or lift. Plumbing fixture and appliances usually require 20 psi for proper operation, and standard municipal water supply pressures at 40 to 60 psi, therefore, the tank would have to be 92.4 ft above the highest plumbing fixture in the house to acquire the proper pressure.
 - Gutters: The purpose of gutters in the entire project is to transport the water from the roof to the tank and to facilitate the first stage of purification with the shield guards (these block leaves and insects from entering the tank). The gutters should be made from a durable material and the best option available is seamless aluminum or galvanized steel. These gutters should provide 1 square inch of downspout opening for every 100 square feet of roof area, to ensure efficient transport of the water from the roof to the tank. (Sustainable Building)
 - Roof Material: The goal of the Water Catchment and Purification group is to design a rainwater system that will catch enough water to meet all of the water needs of the Smart house, including water used for drinking. The materials being considered for the roof are:

metal, slate, clay, and cementitious. These materials will not cause further contamination of the water as it goes through the roof. (Sustainable Building)

- Pumps: If it is possible, depending on the location and design of the Smart House, it would be ideal to be able to use gravity to generate the water pressure needed to pump water through the house. If this is not possible the water will need to be pumped into a pressure vessel such as a pressure tank that will store some pressurized water to be used on demand. A small membrane pump that runs on solar energy can be used to pump the water from the storage tank into the pressure tank. A float switch in the tank will be used to determine when the water levels are too low and pumping of the water from the tank should be stopped and the entire house switched over to obtaining water from the city. This alternative would mainly be used during times of drought. In addition, some of the water will be used for potable purposes and will be directed to pass through an inline purification system before being pumped to the house.

- Roof-top Garden: The Smart House will be designed to have a roof-top garden for aesthetic and conservation purposes. The membrane protecting the roof from roots and water will be used to collect the extra water not needed by the plants. This water will then be carried to the storage tank for further use.

- Driveway: The driveway and parking lot of the Smart House will be designed to be collection sites for rainwater that will later be used for irrigation.

- Water Purification:

- Filters: The rainwater may become contaminated by dirt, debris, and other materials from the roof surface. The best strategy is to reject the first wash of water over the roof. The first rainfall will clean away any contaminants and is achieved by using a "roof washer" such as a diversion valve that prevents water from going into the tank until a certain amount has passed through the valve. The water that is diverted from going into the storage tank will be stored in small rain barrels to be used later for other purposes. The first step of filtration will be to

filter and screen out the big contaminants before the water enters the tank and this will be achieved by using the gutter shield to keep bigger particles from being able to enter the tank. (Sustainable Building) Then when drinking water is needed, water will be pumped through the filtration system which will consist of 3 carbon filters and a UV filter.

Carbon filters were determined to be the most efficient in the purification of water from chemicals and other molecules. The filters that will be used are designed for the filtration of molecules of different sizes. Once water is pumped from the tank it will pass through the 20 micron carbon filter, then through the 5 micron carbon filter, and finally through the 1 micron carbon filter becoming cleaner and cleaner as it flows through the system. To ensure that the all harmful bacteria and chemicals have been filtered out from the water, the water will also be subjected to UV light energy at 200-280 nm in wavelength. The UV filter will be able to break down the bonds in molecules, and mutate the DNA of the bacteria and viruses. (UV Treatment)

- Roof-top Garden: It has been shown that plants and their soil can be effective filters of water, the roof-top garden will pre-filter some of the water that is caught from the roof when it rains.

- Gray Water Recycling:

- Sources and Uses: The water that has been used for everything except the kitchen faucet, the dishwasher, and the toilets will be recycled and reused for the flushing of toilets and lawn irrigation. This water is relatively clean and will undergo minimal filtration before its storage and use.

- Purification: The gray water after being used will be passed through a sand filter to filter out some solids that might be present in the water. The water will then be pumped through the constructed wetland and after treatment for a day will be pumped through a UV filter to ensure the proper removal of pathogens. After the filtration is complete the water will be

pumped into the water storage tank to be ready for use. Basic filtration of the gray water is needed to ensure that odors are eliminated and allow for safe and clean storage.

- Storage: The gray water after undergoing purification will be stored in a water tank that will be connected to the house pump. This pump will pump the water into the pressure tank to be ready for use.

- Water Conservation:

- Toilets: Low flow toilets have been around for sometime and these are known to reduce the consumption of water by about 20-40% in a regular household, using only 1.6 gal of water per flush. Another alternative to toilets is compost toilets which do not require any water and cut back expenses on sewage lines and septic systems, and can work with alternative sources of energy. However, a permit from the North Carolina Board of Health is required to be able to have waterless toilets in a house; therefore, low flush toilets present an alternative for reducing water consumption.

- Faucet Aerators and Low-Flow Showerheads: These devices can be used to reduce the amount of water that comes out from a faucet or a showerhead, and in general can cut down water usage by at least half. These systems work by restricting flow of water and thus cuts down on how much water can be used at a time (per hand wash/shower).

- Washing Machines/Dishwashers: An increasing awareness of the importance of the conservation of water has led companies to develop products that are water efficient. Washing machines and dishwashers account for a major percentage of water use in the average household, therefore, by using water efficient washing machines and dishwashers water consumption can be greatly reduced.

- Working with other groups: Sometimes water is wasted because of having to wait for it to reach the desire temperature. The Water Catchment and Purification group will be working

with other groups to make additions to the house such as an on demand water heater, which will in turn save water that would have otherwise been wasted.

- Sewage Reduction:

- Methods: By reducing water consumption already the amount of sewage being produced in the Smart House will be greatly reduced. Furthermore, by recycling water and catching rainwater the Smart House is further reducing its sewage.

- Constructed Wetland: Constructed wetlands can be made to be subsurface, free-water-surface, or hybrid. Because of the nature of the Smart House surface wetlands should not be considered because of the possibility of odors and attraction of insects such as mosquitoes. The constructed wetland would be used to purify the gray water from the house, and thus reduce the amount of sewage generated.

ENVIRONMENTAL CONCERNS

Water purification and catchment always causes rise to many environmental concerns, while in fact these methods prove to be better for the environment and in the long run better for everyone involved biologically and economically. Water catchment provides an alternative source of water and poses a solution to environmental concerns regarding contamination of the environment through water. Rain water closely compares to tap water that has been treated with various chemicals to ensure the elimination of bacteria and other harmful contents. A rainwater catchment system would make use of the North Carolina's rainy season and at the same time reduce the total water consumption in the city of Durham. The ultimate goal of the water catchment and purification team is to design a system which will meet all of the water needs of the DELTA Smart house. The rainwater will go through various steps of purification including UV filtration to ensure that all harmful contents are destroyed. UV filtration has been proven to be over 99.9% effective in getting rid of all bacteria present in the water. (UV Treatment)

Additional unease is caused to many by the idea of collecting the rainwater that has already touched the roof of the house which contains a mixture of everything present in the environment, good or bad. The concept of "first flush" was developed in order to literally rinse off the roof before water collection. This will ensure that bird droppings and other organic materials are not collected into the catchment tank. In addition, the roof of the house will be designed to be made of a sustainable and non-toxic long-lasting material that will not contaminate the caught water further. Several systems for purification will be used, starting with the idea of getting rid from bigger to smaller water contaminants. Therefore, the initial filtration system will be in the form of a shield guard over the gutters to keep out things such as leaves and twigs out of the caught water. After catchment and before use, the water will be submitted through a 20 micron size filter, followed by a 5 micron filter, a 1 micron filter and culminating in a UV filter designed to kill as much bacteria as possible so that the water will be safe for drinking.

Compost toilets also prove to be environmentally friendly efficient systems that help complete Mother Nature's never ending cycle. Instead of using septic tanks and costly sewage lines which pose a greater threat to the environment, Compost Toilets make use of microorganisms to break down the harmful contents of what is normally present in toilet water. Furthermore, these systems eliminate all worries caused due to drastic weather changes resulting in damage to water and sewage lines. The end product is harmless recyclable natural compost that can be disposed of in the garden. Compost toilet systems further provide the option of working with alternative sources of energy that are more environmentally desired such as wind turbines and solar power. Therefore compost toilets should not be considered an environmental concern.

In addition, the use of gray water can arise many concerns. Yet gray water has been proven to be beneficial to plants because of its organic content. Furthermore, to ensure that the use of gray water will not cause any harm, the water will be purified by the constructed wetlands and a UV filter. This water will only be used for toilet flushing and lawn irrigation. Additional concerns may also arise because of the constructed wetlands. This system will be very similar to a natural wetland and it is already in use in many communities in the United States. It is simply a network of plants that through their natural processes will purify the water.

DESIGN AND IMPLEMENTATION

Design Goals:

The goals of the Water Purification and Catchment group are the following:

- To meet the stated guidelines outlined in “*High Performance Guidelines: Triangle Region Public Facilities,*” and obtain as many points as possible for LEED Certification. (A maximum of 5 points in LEED and 197 points in the High Performance Guidelines are possible in the water aspect for the design of the DELTA Smart house Project).
- Water efficient landscaping (Limit or eliminate the use of potable water for landscape irrigation)
 - Use high efficiency irrigation technology, OR use captured rain or recycled site water to reduce potable water (including groundwater) consumption for irrigation by 50% over conventional means. (22 points)
 - Use only captured rain or recycled site water for an additional 50% reduction (100% total reduction) of potable water (including groundwater) for site irrigation needs, OR do not install permanent landscape irrigation systems and use drought tolerant plants. (27 points)
- Reduce generation of wastewater and potable water demand, while increasing local aquifer recharge.
 - Reduce the use of municipally provided potable water for building sewage conveyance by a minimum of 50%, OR treat 100% of wastewater on site to tertiary standards. (29 points)

- Maximize water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems. Reduce the burden on wells and aquifers by conserving potable water.
 - Employ strategies that in aggregate use 20% less water than the water use baseline calculated for the building (not including irrigation) after meeting Energy Policy Act of 1992 fixture performance requirements. (20 points)
 - Exceed the potable water use reduction by an additional 10% (30% total efficiency increase). (26 points)
 - Provide 50% of the building's potable water through treatment of recovered rainwater. (21 points)
 - Provide 75% of the building's potable water through treatment of recovered rainwater. (18 points)
 - Provide 100% of the building's potable water through treatment of recovered rainwater. (19 points)

- Learn whether the sustainable goals established during the design phase are actually achieved, thereby facilitating improvement over time in the performance of structure.
 - Produce a post-occupancy water quality management plan AND establish a post-occupancy monitoring schedule for all of the following: (15 points)
 1. Potable water use for landscape irrigation.
 2. Amount of captured rainwater or other recycled water used for irrigation per month/per year.
 3. Potable water used for wastewater treatment.
 4. Water use within the building.
 5. Annual and seasonal water use data, including peak demands.

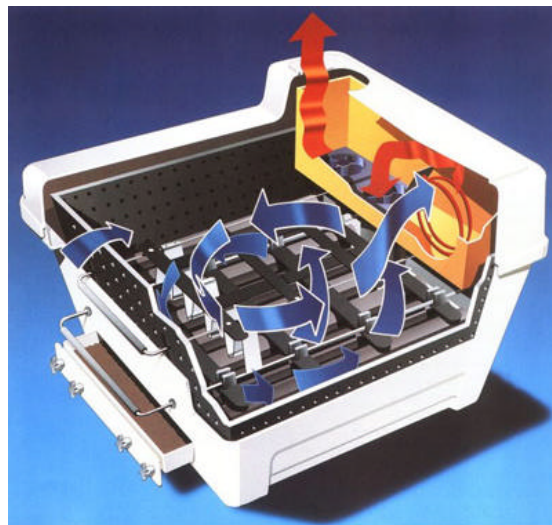
- Make use of already existing products and improve designs to minimize water consumption.

- Catch 100% of the water needed for the house.
- To use environmentally-friendly systems and materials.

Theories of Uncommon Devices:

- **Waterless Toilets (Compost Toilets):** Composting is the way that nature unites the cycles of all of its beings. In nature, organic wastes are broken down through a combination of biological and chemical processes. Biological agents like worms, insects, fungi, bacteria and other micro-organisms "chew up" the materials, which are further transformed by oxidation (exposure to air), reduction and hydrolysis (exposure to water). Compost toilets make use of the basic method used by nature with the goal of being as environmentally-friendly as possible.

Compost toilet systems make use of aerobic microbes and air to break down the harmful contents of toilet waste; which is then recycled into natural compost. These systems are odor-free, and do not make use of any chemicals. Odors are usually eliminated through the use of peat moss and a design which maintains a partial vacuum in the system which keeps odors from escaping.



The compost toilet design patented by Envirolet toilet systems, this design is supposed to improve aeration and evaporation as well as microbe activity.

- Tank: The water tank will serve as a container for storage of all water that has been caught. Rainwater will be directed there after enough water has washed the roof. The tank will be located in a dry place, preferably out of the sun to prevent algae growth. Ultimately a tank located on a hill would be optimal because its own pressure would be acquired by the height. The water levels in the tank will be measured and if water goes down to a particularly low level, the house will supplement its water needs with city water. (Sustainable Building)

- Constructed Wetland: There are three types of constructed wetlands: free-water-surface (FWS), subsurface flow (SF) and Hybrid. The free-water-surface wetlands usually consist of a standing body of water and resemble a pond. Subsurface wetlands are underground and all that is visible are the plants that are part of the system. The hybrid system is a more organized system that generally takes the concepts of the natural wetlands and puts the members of the systems into tanks where the purification of the water takes place in different steps. FWS wetlands generally require more land (~ 70%) than SF wetlands to achieve the same degree of purification but tend to usually be cheaper, the price of SF wetlands depends on the cost of land and of the substrate that you need (usually rock or gravel). Benefits of the SF and hybrid wetlands include that the factor of odor, mosquitoes, and weather would be eliminated. Sizing in general for SF systems is based on the BOD (Biochemical Oxygen Demand) level of the water and on the amount of water that will be flowing through the system.

For the needs of the house a system that is 1 cu. Ft. per gallon will probably be sufficient to achieve adequate purification levels. The location of the wetland should be so that the water can use gravity to flow through the system. The system should have as close to a 1:1 length to width ratio for optimal purification. The wetland would be useful for the removal of BOD, suspended solids, nitrogen, some metals, and pathogens to a certain degree. To increase pathogen removal the water from the system would be pumped through a UV filter.

The system is more effective the longer that water is stored within the system and the cleaner the water goes in. The BOD is the oxygen demand by the bacteria that break

down the waste in the water, if a constructed wetland were to be installed the BOD of the house's "waste" water should be lowered. This would be achieved by closely monitoring what is put down the drain. There are many household cleaners that are harmful to the environment and are also harmful to humans. To ensure the system's health only biodegradable products would need to be used in the home and a compost pile to dispose of all organic waste originating from the kitchen.

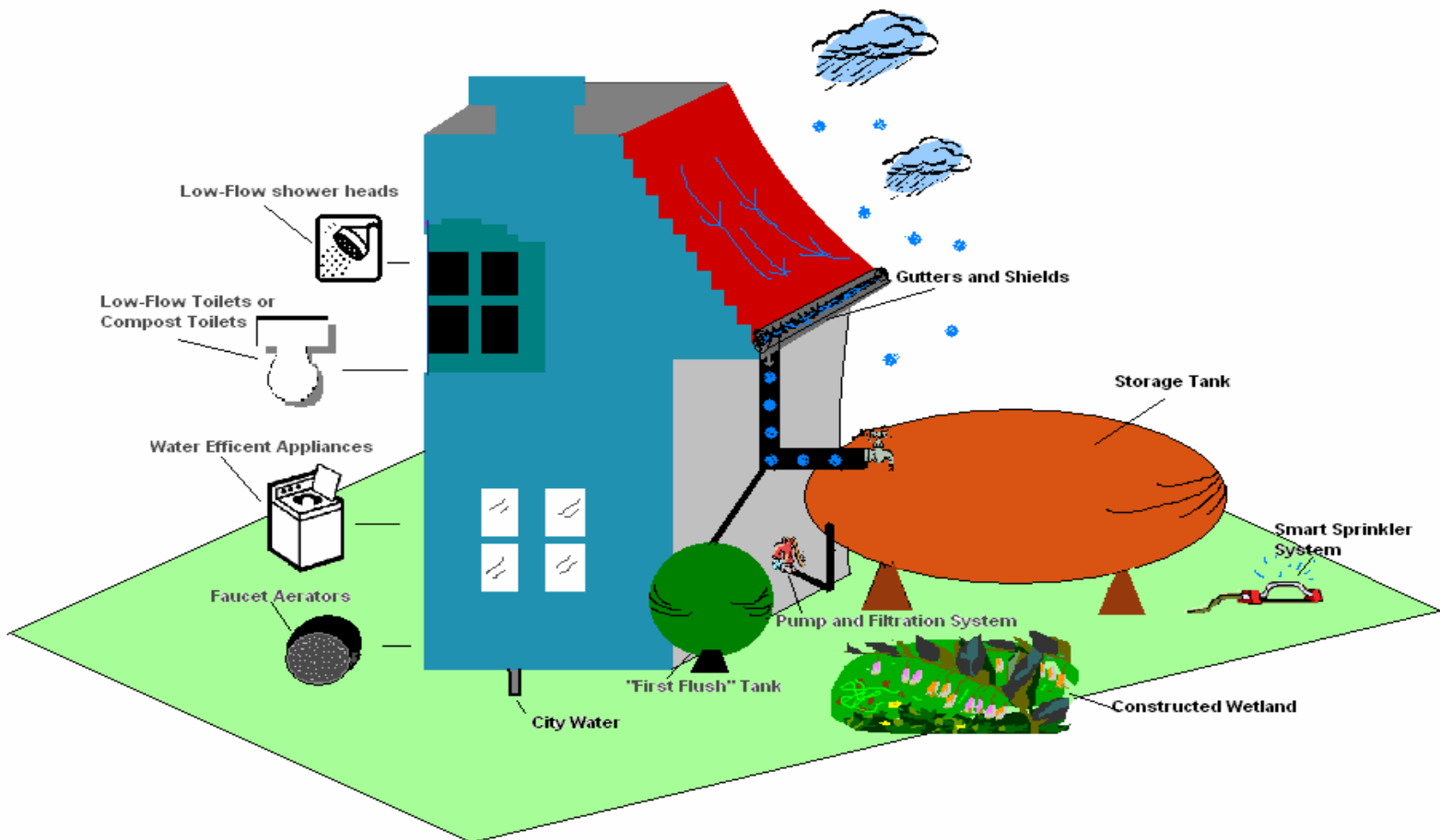
A constructed wetland would greatly reduce sewage costs and ensure an environmentally friendly way of recycling some of the resources being used by the house.

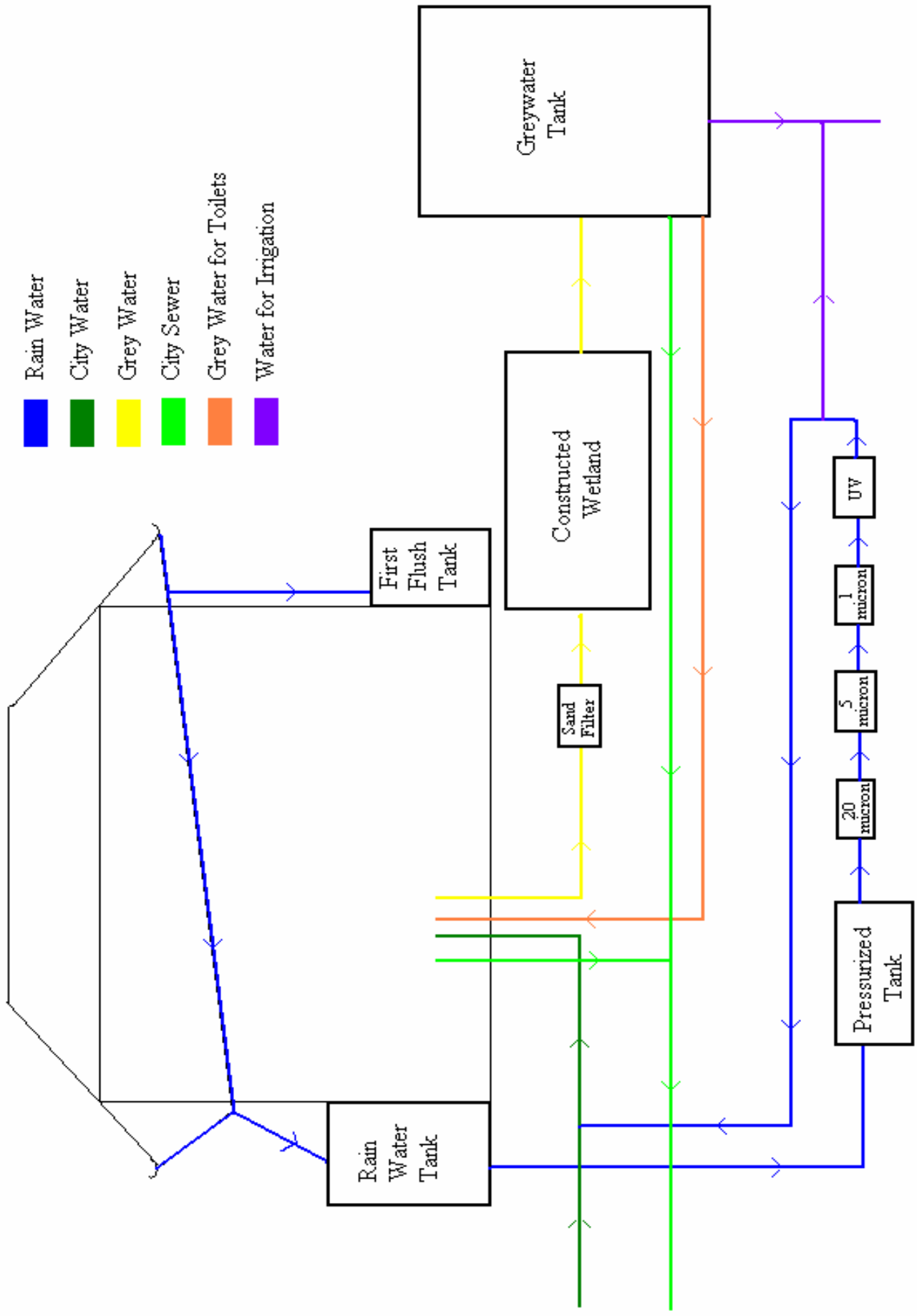
Steps of Purification:

1. Gutter Shield: The concept behind the gutter shield is to prevent leaves and insects from entering the tank and being mixed with the water going into storage.
2. The second step in purification will constitute of the water passing through filters that will filter out particles and organisms greater than 1 micron in size. The water will first go through the 20 micron filter, then the 5 micron filter and finally the 1 micron filter. One of the design goals is to devise a way of being able to have different degrees of filtration depending on what the water is needed for.
3. UV Filter: An Ultraviolet radiation filter is a commonly used water purification system in used today. UV light which makes up all light energy between 100 and 400 nm in wavelength can be used to breakup the DNA of different bacteria and viruses that are often present in water. The UV filter uses mainly the 200-280 nm wavelength, when the bacteria in the water is exposed to this energy their normal DNA replication is interrupted and organisms are killed or rendered inactive. (UV Treatment)

General Product Architecture:

The rainwater catchment system is being designed with the goal of being able to catch as much of the water needed by the Smart House as possible. Therefore, part of the project architecture includes the installation of water efficient systems and appliances throughout the house. The following are sketches of the basic goal of the Water Catchment and Purification team:





CALCULATIONS

City of Durham Water Costs:

Durham Water Costs (\$/ccf) (1ccf=748 Gallons)		
	Inside	Outside
Water	\$1.24	\$2.48
Sewer	\$1.99	\$3.98
Combined	\$3.23	\$6.46

Water Service Charge				
	Inside		Outside	
Water	\$2.19	\$4.38	\$4.38	\$8.76
Sewer	\$2.41	\$4.82	\$4.82	\$9.64
Combined	\$4.60	\$4.60	\$9.20	\$18.40
Approximate total water needed/year = 85,750 gal				
CCF's needed from city =			114.639	
Months of service =			12	
Total costs using only city water: (water + sewage + service fee)				
Water	\$ 142.15			
Sewage	\$ 228.13			
Service	\$ 26.28			
Total	\$ 396.56			

Possible System Components:

System Components	Price
2000 Gallon Polyethylene Vertical Water Storage Tank	\$866.95
40 Gallon Polyethylene Vertical Storage Tank (First Flush)	\$61.71

625 Gallon Polyethylene Vertical Storage Tank (Graywater)	\$285.34
Jacuzzi Shallow-well Pump	\$250
20 Micron Carbon Filter	\$28
5 Micron Carbon Filter	\$28
1 Micron Carbon Filter	\$28
PURA UV Filter	\$360
Pressure Tank	\$150
Water meter	\$50
Total	\$2,108.00

System Cost Analysis:

Approximate total water needed/year (gallons):	85,750
Total water catchment per year for a 2500 sq ft roof (gallons):	56,928
Graywater (gallons):	25725
Water needed from the city:	3,097
CCF's needed from the city:	4.14037433
Annual Costs:	
Water	\$ 5.13
Sewage	\$ 228.13
Service Fee	\$ 26.28
Total	\$ 259.55
Annual Savings:	
	\$ 137.01
System payback time (years)	15.3857383

CONTACTS ESTABLISHED

- **Professor Karl Linden:** Professor Linden is part of Duke's Civil Engineering Department. His research involves the development of physical and photo chemically based methods to evaluate UV dose from polychromatic UV systems. He will be helping the team with the purification needs for the house's water.
- **Professor Larry Bohs:** Professor Bohs is building a house that will make use of a rainwater collection system to meet all his irrigation needs. He will be giving the team advice on the rain catchment system.
- **Professor Ken Reckhow:** Professor Reckhow is part of the Duke Nicholas School Wetland Center and he is a professor of Water Resources. He will be providing general advice on water quality and management.
- **Warren-Wilson College:** Warren-Wilson College will be implementing a rainwater harvesting system in their new EcoDorm. The water collected will be used to flush the dorm's toilets. They are also installing compost toilets and solar water heaters.
- **bioMerieux:** This company located in Durham uses a gray water recycling and purification system to treat the water that they have used.
- **Companies Contacted:**
 - Carsten Ginsburj - Creative Energy Technologies
 - Miele, Inc.
 - Jacuzzi Leisure Products
 - Dan Sajw – McFarland Pump Co.
 - America Pacific Water Industries, Inc.
 - George Koch – Koch/Infinity
 - Puritec
 - Phil Dibetta – AM Conservation Group
 - Jeff Porter – USA Landlord
 - Glenn Nelson – Advanced Composting Systems
 - Al White – Bio-Sun Systems, Inc.
 - Peter Anderson – Biolet USA, Inc.
 - Brian Barry – Clivus Multrum
 - Joel Jacobsen – CTS Toilet
 - Ecotech Composting Toilets

- Norm Smith – Envirolet, Sancor Industries
- Pete Gillen – Equaris Corporation
- Restroom Solutions
- Mike Wilkinsen – Sun-Mar Corporation
- Toto USA, Inc.
- John Jacob – Highland Tank & Manufacturing Company
- Agri-Supply
- Norwesco, Inc.
- Wesley Lytle – American Tank Company
- Ed Roberts – Hydrotech
- Pureflow Ultraviolet
- Trojan Technologies
- Ozomax
- Ken Brumleve – Jenesco, Inc.

TIMELINE

Summer 2003

Establish contacts

- Continue to meet professors who conduct research about water catchment and other relevant topics to gather ideas
- Contact companies that sell products of interest in order to obtain more information
- Possibly interview consumers who have water catchment systems in their homes
- Visit Warren-Wilson College in Ashville, NC.

Research acquisition of materials

- Water tanks
- UV filter
- Pump
- Gutters and shields
- Low-flush or compost toilets
- Low-flow showerheads
- Water-efficient appliances: washers, dishwashers, etc.
- Faucet aerators

Legal issues

- Research specific laws about water catchment tanks to insure adherence

Fall 2003

Modify plans for water catchment system based upon the design of the house.

Make decisions about which products to actually purchase, and from which companies.

Winter 2004

Purchase and/or construct materials, then test them to assure that they function properly.

Make any necessary changes to the water catchment system.

Spring 2004

Incorporate the design into the house.

CONCLUSION

The goals of the Water Catchment and Purification team may seem idealistic but can nevertheless be achieved through careful planning, research, and collaboration with other teams working on the DELTA Smart House project. The desired end result is for the house to have increased independence from public water and sewage systems as a result of its water catchment and purification system, and aided by the water-efficient appliances within the home.

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UV Treatment Technology Description

http://www.nemw.org/Balsurv2_UV.htm

APPENDIX A

Daily Rainwater:

Month	Day of Month	Julian Day	Normal Precipitation	Rainwater Collected (2500 sq. ft)	Rainwater Collected (3000 sq. ft.)
January	1	1	0.11	135.6	162.72
January	2	2	0.12	138	165.6
January	3	3	0.12	139.2	167.04
January	4	4	0.12	139.2	167.04
January	5	5	0.12	141.6	169.92
January	6	6	0.12	142.8	171.36
January	7	7	0.12	147.6	177.12
January	8	8	0.12	147.6	177.12
January	9	9	0.13	150	180
January	10	10	0.13	153.6	184.32
January	11	11	0.13	159.6	191.52

January	12	12	0.13	158.4	190.08
January	13	13	0.14	162	194.4
January	14	14	0.14	165.6	198.72
January	15	15	0.13	160.8	192.96
January	16	16	0.13	158.4	190.08
January	17	17	0.13	157.2	188.64
January	18	18	0.13	152.4	182.88
January	19	19	0.13	159.6	191.52
January	20	20	0.13	160.8	192.96
January	21	21	0.14	162	194.4
January	22	22	0.13	158.4	190.08
January	23	23	0.13	153.6	184.32
January	24	24	0.13	151.2	181.44

January	25	25	0.12	146.4	175.68
January	26	26	0.12	142.8	171.36
January	27	27	0.12	144	172.8
January	28	28	0.12	141.6	169.92
January	29	29	0.12	144	172.8
January	30	30	0.12	142.8	171.36
January	31	31	0.12	145.2	174.24
February	1	32	0.12	145.2	174.24
February	2	33	0.13	150	180
February	3	34	0.12	147.6	177.12
February	4	35	0.13	150	180
February	5	36	0.12	147.6	177.12
February	6	37	0.12	145.2	174.24

February	7	38	0.12	142.8	171.36
February	8	39	0.12	140.4	168.48
February	9	40	0.12	138	165.6
February	10	41	0.12	139.2	167.04
February	11	42	0.12	138	165.6
February	12	43	0.11	135.6	162.72
February	13	44	0.12	145.2	174.24
February	14	45	0.12	146.4	175.68
February	15	46	0.12	144	172.8
February	16	47	0.12	142.8	171.36
February	17	48	0.11	135.6	162.72
February	18	49	0.12	140.4	168.48
February	19	50	0.12	138	165.6

February	20	51	0.11	136.8	164.16
February	21	52	0.12	142.8	171.36
February	22	53	0.12	142.8	171.36
February	23	54	0.12	145.2	174.24
February	24	55	0.12	148.8	178.56
February	25	56	0.12	147.6	177.12
February	26	57	0.12	145.2	174.24
February	27	58	0.12	141.6	169.92
February	28	59	0.13	150	180
February	29	60	0.13	152.4	182.88
March	1	61	0.13	151.2	181.44
March	2	62	0.12	144	172.8
March	3	63	0.12	144	172.8

March	4	64	0.12	147.6	177.12
March	5	65	0.13	151.2	181.44
March	6	66	0.13	153.6	184.32
March	7	67	0.13	158.4	190.08
March	8	68	0.13	157.2	188.64
March	9	69	0.13	153.6	184.32
March	10	70	0.13	153.6	184.32
March	11	71	0.13	153.6	184.32
March	12	72	0.13	153.6	184.32
March	13	73	0.12	146.4	175.68
March	14	74	0.12	148.8	178.56
March	15	75	0.13	157.2	188.64
March	16	76	0.13	158.4	190.08

March	17	77	0.13	157.2	188.64
March	18	78	0.13	151.2	181.44
March	19	79	0.12	147.6	177.12
March	20	80	0.12	146.4	175.68
March	21	81	0.12	144	172.8
March	22	82	0.12	145.2	174.24
March	23	83	0.12	145.2	174.24
March	24	84	0.12	144	172.8
March	25	85	0.12	142.8	171.36
March	26	86	0.12	145.2	174.24
March	27	87	0.12	146.4	175.68
March	28	88	0.11	136.8	164.16
March	29	89	0.11	133.2	159.84

March	30	90	0.11	134.4	161.28
March	31	91	0.11	133.2	159.84
April	1	92	0.12	138	165.6
April	2	93	0.11	130.8	156.96
April	3	94	0.11	126	151.2
April	4	95	0.10	122.4	146.88
April	5	96	0.10	118.8	142.56
April	6	97	0.10	117.6	141.12
April	7	98	0.10	116.4	139.68
April	8	99	0.10	116.4	139.68
April	9	100	0.10	114	136.8
April	10	101	0.09	112.8	135.36
April	11	102	0.09	112.8	135.36

April	12	103	0.10	115.2	138.24
April	13	104	0.09	111.6	133.92
April	14	105	0.09	111.6	133.92
April	15	106	0.09	112.8	135.36
April	16	107	0.09	112.8	135.36
April	17	108	0.10	117.6	141.12
April	18	109	0.10	120	144
April	19	110	0.10	123.6	148.32
April	20	111	0.10	121.2	145.44
April	21	112	0.10	121.2	145.44
April	22	113	0.10	118.8	142.56
April	23	114	0.10	120	144
April	24	115	0.10	121.2	145.44

April	25	116	0.10	120	144
April	26	117	0.10	123.6	148.32
April	27	118	0.10	122.4	146.88
April	28	119	0.10	122.4	146.88
April	29	120	0.10	123.6	148.32
April	30	121	0.10	118.8	142.56
May	1	122	0.10	121.2	145.44
May	2	123	0.10	122.4	146.88
May	3	124	0.10	123.6	148.32
May	4	125	0.10	124.8	149.76
May	5	126	0.11	133.2	159.84
May	6	127	0.12	138	165.6
May	7	128	0.11	135.6	162.72

May	8	129	0.12	139.2	167.04
May	9	130	0.12	142.8	171.36
May	10	131	0.12	144	172.8
May	11	132	0.12	139.2	167.04
May	12	133	0.12	138	165.6
May	13	134	0.12	141.6	169.92
May	14	135	0.12	144	172.8
May	15	136	0.12	148.8	178.56
May	16	137	0.12	147.6	177.12
May	17	138	0.12	145.2	174.24
May	18	139	0.12	140.4	168.48
May	19	140	0.12	141.6	169.92
May	20	141	0.12	144	172.8

May	21	142	0.12	148.8	178.56
May	22	143	0.12	147.6	177.12
May	23	144	0.12	147.6	177.12
May	24	145	0.12	148.8	178.56
May	25	146	0.13	150	180
May	26	147	0.13	150	180
May	27	148	0.13	152.4	182.88
May	28	149	0.13	150	180
May	29	150	0.12	147.6	177.12
May	30	151	0.12	144	172.8
May	31	152	0.12	139.2	167.04
June	1	153	0.12	140.4	168.48
June	2	154	0.12	144	172.8

June	3	155	0.11	136.8	164.16
June	4	156	0.11	132	158.4
June	5	157	0.11	132	158.4
June	6	158	0.11	133.2	159.84
June	7	159	0.11	133.2	159.84
June	8	160	0.11	132	158.4
June	9	161	0.11	134.4	161.28
June	10	162	0.11	134.4	161.28
June	11	163	0.11	130.8	156.96
June	12	164	0.11	128.4	154.08
June	13	165	0.10	122.4	146.88
June	14	166	0.11	127.2	152.64
June	15	167	0.12	138	165.6

June	16	168	0.12	138	165.6
June	17	169	0.12	139.2	167.04
June	18	170	0.11	135.6	162.72
June	19	171	0.11	133.2	159.84
June	20	172	0.12	140.4	168.48
June	21	173	0.12	139.2	167.04
June	22	174	0.12	141.6	169.92
June	23	175	0.11	136.8	164.16
June	24	176	0.11	135.6	162.72
June	25	177	0.11	134.4	161.28
June	26	178	0.12	139.2	167.04
June	27	179	0.12	142.8	171.36
June	28	180	0.12	147.6	177.12

June	29	181	0.13	156	187.2
June	30	182	0.13	158.4	190.08
July	1	183	0.13	156	187.2
July	2	184	0.13	160.8	192.96
July	3	185	0.14	164.4	197.28
July	4	186	0.14	168	201.6
July	5	187	0.14	163.2	195.84
July	6	188	0.13	157.2	188.64
July	7	189	0.13	158.4	190.08
July	8	190	0.13	158.4	190.08
July	9	191	0.13	159.6	191.52
July	10	192	0.14	168	201.6
July	11	193	0.14	169.2	203.04

July	12	194	0.14	170.4	204.48
July	13	195	0.14	171.6	205.92
July	14	196	0.14	162	194.4
July	15	197	0.14	166.8	200.16
July	16	198	0.14	163.2	195.84
July	17	199	0.14	166.8	200.16
July	18	200	0.14	172.8	207.36
July	19	201	0.14	169.2	203.04
July	20	202	0.14	169.2	203.04
July	21	203	0.14	169.2	203.04
July	22	204	0.14	170.4	204.48
July	23	205	0.14	172.8	207.36
July	24	206	0.15	174	208.8

July	25	207	0.14	171.6	205.92
July	26	208	0.14	168	201.6
July	27	209	0.14	164.4	197.28
July	28	210	0.13	157.2	188.64
July	29	211	0.13	160.8	192.96
July	30	212	0.13	160.8	192.96
July	31	213	0.13	156	187.2
August	1	214	0.13	157.2	188.64
August	2	215	0.13	156	187.2
August	3	216	0.14	166.8	200.16
August	4	217	0.15	174	208.8
August	5	218	0.15	175.2	210.24
August	6	219	0.15	177.6	213.12

August	7	220	0.15	176.4	211.68
August	8	221	0.14	164.4	197.28
August	9	222	0.13	159.6	191.52
August	10	223	0.13	159.6	191.52
August	11	224	0.13	152.4	182.88
August	12	225	0.13	152.4	182.88
August	13	226	0.13	152.4	182.88
August	14	227	0.13	151.2	181.44
August	15	228	0.12	147.6	177.12
August	16	229	0.12	141.6	169.92
August	17	230	0.12	141.6	169.92
August	18	231	0.12	140.4	168.48
August	19	232	0.12	141.6	169.92

August	20	233	0.12	146.4	175.68
August	21	234	0.13	152.4	182.88
August	22	235	0.14	169.2	203.04
August	23	236	0.15	178.8	214.56
August	24	237	0.15	178.8	214.56
August	25	238	0.15	182.4	218.88
August	26	239	0.15	182.4	218.88
August	27	240	0.15	180	216
August	28	241	0.15	176.4	211.68
August	29	242	0.15	177.6	213.12
August	30	243	0.14	171.6	205.92
August	31	244	0.14	168	201.6
September	1	245	0.14	165.6	198.72

September	2	246	0.14	165.6	198.72
September	3	247	0.14	163.2	195.84
September	4	248	0.13	157.2	188.64
September	5	249	0.13	154.8	185.76
September	6	250	0.13	154.8	185.76
September	7	251	0.13	159.6	191.52
September	8	252	0.13	159.6	191.52
September	9	253	0.14	162	194.4
September	10	254	0.14	164.4	197.28
September	11	255	0.14	162	194.4
September	12	256	0.14	163.2	195.84
September	13	257	0.14	164.4	197.28
September	14	258	0.14	168	201.6

September	15	259	0.14	168	201.6
September	16	260	0.14	171.6	205.92
September	17	261	0.15	176.4	211.68
September	18	262	0.14	171.6	205.92
September	19	263	0.14	163.2	195.84
September	20	264	0.13	153.6	184.32
September	21	265	0.12	145.2	174.24
September	22	266	0.12	146.4	175.68
September	23	267	0.12	141.6	169.92
September	24	268	0.12	146.4	175.68
September	25	269	0.12	142.8	171.36
September	26	270	0.12	144	172.8
September	27	271	0.12	141.6	169.92

September	28	272	0.12	140.4	168.48
September	29	273	0.12	142.8	171.36
September	30	274	0.12	141.6	169.92
October	1	275	0.11	135.6	162.72
October	2	276	0.11	132	158.4
October	3	277	0.11	135.6	162.72
October	4	278	0.11	136.8	164.16
October	5	279	0.12	140.4	168.48
October	6	280	0.12	139.2	167.04
October	7	281	0.11	136.8	164.16
October	8	282	0.11	135.6	162.72
October	9	283	0.11	135.6	162.72
October	10	284	0.11	133.2	159.84

October	11	285	0.11	134.4	161.28
October	12	286	0.11	135.6	162.72
October	13	287	0.11	135.6	162.72
October	14	288	0.11	133.2	159.84
October	15	289	0.10	124.8	149.76
October	16	290	0.10	120	144
October	17	291	0.10	120	144
October	18	292	0.10	118.8	142.56
October	19	293	0.10	116.4	139.68
October	20	294	0.10	115.2	138.24
October	21	295	0.10	115.2	138.24
October	22	296	0.10	117.6	141.12
October	23	297	0.09	111.6	133.92

October	24	298	0.09	112.8	135.36
October	25	299	0.10	115.2	138.24
October	26	300	0.10	114	136.8
October	27	301	0.10	116.4	139.68
October	28	302	0.10	116.4	139.68
October	29	303	0.10	116.4	139.68
October	30	304	0.10	118.8	142.56
October	31	305	0.10	120	144
November	1	306	0.10	122.4	146.88
November	2	307	0.10	121.2	145.44
November	3	308	0.10	120	144
November	4	309	0.10	115.2	138.24
November	5	310	0.10	115.2	138.24

November	6	311	0.10	117.6	141.12
November	7	312	0.10	115.2	138.24
November	8	313	0.10	116.4	139.68
November	9	314	0.09	111.6	133.92
November	10	315	0.09	111.6	133.92
November	11	316	0.09	111.6	133.92
November	12	317	0.09	112.8	135.36
November	13	318	0.10	117.6	141.12
November	14	319	0.10	118.8	142.56
November	15	320	0.10	118.8	142.56
November	16	321	0.10	120	144
November	17	322	0.10	116.4	139.68
November	18	323	0.10	114	136.8

November	19	324	0.09	112.8	135.36
November	20	325	0.09	112.8	135.36
November	21	326	0.10	116.4	139.68
November	22	327	0.10	116.4	139.68
November	23	328	0.10	114	136.8
November	24	329	0.10	118.8	142.56
November	25	330	0.10	120	144
November	26	331	0.10	120	144
November	27	332	0.10	115.2	138.24
November	28	333	0.10	117.6	141.12
November	29	334	0.10	117.6	141.12
November	30	335	0.10	118.8	142.56
December	1	336	0.10	123.6	148.32

December	2	337	0.10	124.8	149.76
December	3	338	0.11	126	151.2
December	4	339	0.10	124.8	149.76
December	5	340	0.10	122.4	146.88
December	6	341	0.10	123.6	148.32
December	7	342	0.10	124.8	149.76
December	8	343	0.10	124.8	149.76
December	9	344	0.10	122.4	146.88
December	10	345	0.10	123.6	148.32
December	11	346	0.10	121.2	145.44
December	12	347	0.10	118.8	142.56
December	13	348	0.10	117.6	141.12
December	14	349	0.10	118.8	142.56

December	15	350	0.10	116.4	139.68
December	16	351	0.10	115.2	138.24
December	17	352	0.10	118.8	142.56
December	18	353	0.10	121.2	145.44
December	19	354	0.10	122.4	146.88
December	20	355	0.11	127.2	152.64
December	21	356	0.11	128.4	154.08
December	22	357	0.11	129.6	155.52
December	23	358	0.11	127.2	152.64
December	24	359	0.11	130.8	156.96
December	25	360	0.11	134.4	161.28
December	26	361	0.11	136.8	164.16
December	27	362	0.12	139.2	167.04

December	28	363	0.12	141.6	169.92
December	29	364	0.12	138	165.6
December	30	365	0.11	136.8	164.16
December	31	366	0.11	133.2	159.84

APPENDIX B

Estimated Water Overflowing to the Wetland:

Day	Rainwater	Water passing through tank	Overflow
1	135.6	252.4857143	0
2	138	507.3714286	7.371429
3	139.2	756.0857143	256.0857
4	139.2	756.0857143	256.0857
5	141.6	758.4857143	258.4857
6	142.8	759.6857143	259.6857
7	147.6	764.4857143	264.4857
8	147.6	764.4857143	264.4857
9	150	766.8857143	266.8857
10	153.6	770.4857143	270.4857
11	159.6	776.4857143	276.4857
12	158.4	775.2857143	275.2857
13	162	778.8857143	278.8857
14	165.6	782.4857143	282.4857
15	160.8	777.6857143	277.6857
16	158.4	775.2857143	275.2857
17	157.2	774.0857143	274.0857
18	152.4	769.2857143	269.2857
19	159.6	776.4857143	276.4857
20	160.8	777.6857143	277.6857
21	162	778.8857143	278.8857
22	158.4	775.2857143	275.2857
23	153.6	770.4857143	270.4857
24	151.2	768.0857143	268.0857
25	146.4	763.2857143	263.2857
26	142.8	759.6857143	259.6857
27	144	760.8857143	260.8857
28	141.6	758.4857143	258.4857

29	144	760.8857143	260.8857
30	142.8	759.6857143	259.6857
31	145.2	762.0857143	262.0857
32	145.2	762.0857143	262.0857
33	150	766.8857143	266.8857
34	147.6	764.4857143	264.4857
35	150	766.8857143	266.8857
36	147.6	764.4857143	264.4857
37	145.2	762.0857143	262.0857
38	142.8	759.6857143	259.6857
39	140.4	757.2857143	257.2857
40	138	754.8857143	254.8857
41	139.2	756.0857143	256.0857
42	138	754.8857143	254.8857
43	135.6	752.4857143	252.4857
44	145.2	762.0857143	262.0857
45	146.4	763.2857143	263.2857
46	144	760.8857143	260.8857
47	142.8	759.6857143	259.6857
48	135.6	752.4857143	252.4857
49	140.4	757.2857143	257.2857
50	138	754.8857143	254.8857
51	136.8	753.6857143	253.6857
52	142.8	759.6857143	259.6857
53	142.8	759.6857143	259.6857
54	145.2	762.0857143	262.0857
55	148.8	765.6857143	265.6857
56	147.6	764.4857143	264.4857
57	145.2	762.0857143	262.0857
58	141.6	758.4857143	258.4857
59	150	766.8857143	266.8857
60	152.4	769.2857143	269.2857
61	151.2	768.0857143	268.0857
62	144	760.8857143	260.8857
63	144	760.8857143	260.8857
64	147.6	764.4857143	264.4857
65	151.2	768.0857143	268.0857
66	153.6	770.4857143	270.4857
67	158.4	775.2857143	275.2857
68	157.2	774.0857143	274.0857
69	153.6	770.4857143	270.4857
70	153.6	770.4857143	270.4857
71	153.6	770.4857143	270.4857
72	153.6	770.4857143	270.4857
73	146.4	763.2857143	263.2857

74	148.8	765.6857143	265.6857
75	157.2	774.0857143	274.0857
76	158.4	775.2857143	275.2857
77	157.2	774.0857143	274.0857
78	151.2	768.0857143	268.0857
79	147.6	764.4857143	264.4857
80	146.4	763.2857143	263.2857
81	144	760.8857143	260.8857
82	145.2	762.0857143	262.0857
83	145.2	762.0857143	262.0857
84	144	760.8857143	260.8857
85	142.8	759.6857143	259.6857
86	145.2	762.0857143	262.0857
87	146.4	763.2857143	263.2857
88	136.8	753.6857143	253.6857
89	133.2	750.0857143	250.0857
90	134.4	751.2857143	251.2857
91	133.2	750.0857143	250.0857
92	138	754.8857143	254.8857
93	130.8	747.6857143	247.6857
94	126	742.8857143	242.8857
95	122.4	739.2857143	239.2857
96	118.8	735.6857143	235.6857
97	117.6	734.4857143	234.4857
98	116.4	733.2857143	233.2857
99	116.4	733.2857143	233.2857
100	114	730.8857143	230.8857
101	112.8	729.6857143	229.6857
102	112.8	729.6857143	229.6857
103	115.2	732.0857143	232.0857
104	111.6	728.4857143	228.4857
105	111.6	728.4857143	228.4857
106	112.8	729.6857143	229.6857
107	112.8	729.6857143	229.6857
108	117.6	734.4857143	234.4857
109	120	736.8857143	236.8857
110	123.6	740.4857143	240.4857
111	121.2	738.0857143	238.0857
112	121.2	738.0857143	238.0857
113	118.8	735.6857143	235.6857
114	120	736.8857143	236.8857
115	121.2	738.0857143	238.0857
116	120	736.8857143	236.8857
117	123.6	740.4857143	240.4857
118	122.4	739.2857143	239.2857

119	122.4	739.2857143	239.2857
120	123.6	740.4857143	240.4857
121	118.8	735.6857143	235.6857
122	121.2	738.0857143	238.0857
123	122.4	739.2857143	239.2857
124	123.6	740.4857143	240.4857
125	124.8	741.6857143	241.6857
126	133.2	750.0857143	250.0857
127	138	754.8857143	254.8857
128	135.6	752.4857143	252.4857
129	139.2	756.0857143	256.0857
130	142.8	759.6857143	259.6857
131	144	760.8857143	260.8857
132	139.2	756.0857143	256.0857
133	138	754.8857143	254.8857
134	141.6	758.4857143	258.4857
135	144	760.8857143	260.8857
136	148.8	765.6857143	265.6857
137	147.6	764.4857143	264.4857
138	145.2	762.0857143	262.0857
139	140.4	757.2857143	257.2857
140	141.6	758.4857143	258.4857
141	144	760.8857143	260.8857
142	148.8	765.6857143	265.6857
143	147.6	764.4857143	264.4857
144	147.6	764.4857143	264.4857
145	148.8	765.6857143	265.6857
146	150	766.8857143	266.8857
147	150	766.8857143	266.8857
148	152.4	769.2857143	269.2857
149	150	766.8857143	266.8857
150	147.6	764.4857143	264.4857
151	144	760.8857143	260.8857
152	139.2	756.0857143	256.0857
153	140.4	757.2857143	257.2857
154	144	760.8857143	260.8857
155	136.8	753.6857143	253.6857
156	132	748.8857143	248.8857
157	132	748.8857143	248.8857
158	133.2	750.0857143	250.0857
159	133.2	750.0857143	250.0857
160	132	748.8857143	248.8857
161	134.4	751.2857143	251.2857
162	134.4	751.2857143	251.2857
163	130.8	747.6857143	247.6857

164	128.4	745.2857143	245.2857
165	122.4	739.2857143	239.2857
166	127.2	744.0857143	244.0857
167	138	754.8857143	254.8857
168	138	754.8857143	254.8857
169	139.2	756.0857143	256.0857
170	135.6	752.4857143	252.4857
171	133.2	750.0857143	250.0857
172	140.4	757.2857143	257.2857
173	139.2	756.0857143	256.0857
174	141.6	758.4857143	258.4857
175	136.8	753.6857143	253.6857
176	135.6	752.4857143	252.4857
177	134.4	751.2857143	251.2857
178	139.2	756.0857143	256.0857
179	142.8	759.6857143	259.6857
180	147.6	764.4857143	264.4857
181	156	772.8857143	272.8857
182	158.4	775.2857143	275.2857
183	156	772.8857143	272.8857
184	160.8	777.6857143	277.6857
185	164.4	781.2857143	281.2857
186	168	784.8857143	284.8857
187	163.2	780.0857143	280.0857
188	157.2	774.0857143	274.0857
189	158.4	775.2857143	275.2857
190	158.4	775.2857143	275.2857
191	159.6	776.4857143	276.4857
192	168	784.8857143	284.8857
193	169.2	786.0857143	286.0857
194	170.4	787.2857143	287.2857
195	171.6	788.4857143	288.4857
196	162	778.8857143	278.8857
197	166.8	783.6857143	283.6857
198	163.2	780.0857143	280.0857
199	166.8	783.6857143	283.6857
200	172.8	789.6857143	289.6857
201	169.2	786.0857143	286.0857
202	169.2	786.0857143	286.0857
203	169.2	786.0857143	286.0857
204	170.4	787.2857143	287.2857
205	172.8	789.6857143	289.6857
206	174	790.8857143	290.8857
207	171.6	788.4857143	288.4857
208	168	784.8857143	284.8857

209	164.4	781.2857143	281.2857
210	157.2	774.0857143	274.0857
211	160.8	777.6857143	277.6857
212	160.8	777.6857143	277.6857
213	156	772.8857143	272.8857
214	157.2	774.0857143	274.0857
215	156	772.8857143	272.8857
216	166.8	783.6857143	283.6857
217	174	790.8857143	290.8857
218	175.2	792.0857143	292.0857
219	177.6	794.4857143	294.4857
220	176.4	793.2857143	293.2857
221	164.4	781.2857143	281.2857
222	159.6	776.4857143	276.4857
223	159.6	776.4857143	276.4857
224	152.4	769.2857143	269.2857
225	152.4	769.2857143	269.2857
226	152.4	769.2857143	269.2857
227	151.2	768.0857143	268.0857
228	147.6	764.4857143	264.4857
229	141.6	758.4857143	258.4857
230	141.6	758.4857143	258.4857
231	140.4	757.2857143	257.2857
232	141.6	758.4857143	258.4857
233	146.4	763.2857143	263.2857
234	152.4	769.2857143	269.2857
235	169.2	786.0857143	286.0857
236	178.8	795.6857143	295.6857
237	178.8	795.6857143	295.6857
238	182.4	799.2857143	299.2857
239	182.4	799.2857143	299.2857
240	180	796.8857143	296.8857
241	176.4	793.2857143	293.2857
242	177.6	794.4857143	294.4857
243	171.6	788.4857143	288.4857
244	168	784.8857143	284.8857
245	165.6	782.4857143	282.4857
246	165.6	782.4857143	282.4857
247	163.2	780.0857143	280.0857
248	157.2	774.0857143	274.0857
249	154.8	771.6857143	271.6857
250	154.8	771.6857143	271.6857
251	159.6	776.4857143	276.4857
252	159.6	776.4857143	276.4857
253	162	778.8857143	278.8857

254	164.4	781.2857143	281.2857
255	162	778.8857143	278.8857
256	163.2	780.0857143	280.0857
257	164.4	781.2857143	281.2857
258	168	784.8857143	284.8857
259	168	784.8857143	284.8857
260	171.6	788.4857143	288.4857
261	176.4	793.2857143	293.2857
262	171.6	788.4857143	288.4857
263	163.2	780.0857143	280.0857
264	153.6	770.4857143	270.4857
265	145.2	762.0857143	262.0857
266	146.4	763.2857143	263.2857
267	141.6	758.4857143	258.4857
268	146.4	763.2857143	263.2857
269	142.8	759.6857143	259.6857
270	144	760.8857143	260.8857
271	141.6	758.4857143	258.4857
272	140.4	757.2857143	257.2857
273	142.8	759.6857143	259.6857
274	141.6	758.4857143	258.4857
275	135.6	752.4857143	252.4857
276	132	748.8857143	248.8857
277	135.6	752.4857143	252.4857
278	136.8	753.6857143	253.6857
279	140.4	757.2857143	257.2857
280	139.2	756.0857143	256.0857
281	136.8	753.6857143	253.6857
282	135.6	752.4857143	252.4857
283	135.6	752.4857143	252.4857
284	133.2	750.0857143	250.0857
285	134.4	751.2857143	251.2857
286	135.6	752.4857143	252.4857
287	135.6	752.4857143	252.4857
288	133.2	750.0857143	250.0857
289	124.8	741.6857143	241.6857
290	120	736.8857143	236.8857
291	120	736.8857143	236.8857
292	118.8	735.6857143	235.6857
293	116.4	733.2857143	233.2857
294	115.2	732.0857143	232.0857
295	115.2	732.0857143	232.0857
296	117.6	734.4857143	234.4857
297	111.6	728.4857143	228.4857
298	112.8	729.6857143	229.6857

299	115.2	732.0857143	232.0857
300	114	730.8857143	230.8857
301	116.4	733.2857143	233.2857
302	116.4	733.2857143	233.2857
303	116.4	733.2857143	233.2857
304	118.8	735.6857143	235.6857
305	120	736.8857143	236.8857
306	122.4	739.2857143	239.2857
307	121.2	738.0857143	238.0857
308	120	736.8857143	236.8857
309	115.2	732.0857143	232.0857
310	115.2	732.0857143	232.0857
311	117.6	734.4857143	234.4857
312	115.2	732.0857143	232.0857
313	116.4	733.2857143	233.2857
314	111.6	728.4857143	228.4857
315	111.6	728.4857143	228.4857
316	111.6	728.4857143	228.4857
317	112.8	729.6857143	229.6857
318	117.6	734.4857143	234.4857
319	118.8	735.6857143	235.6857
320	118.8	735.6857143	235.6857
321	120	736.8857143	236.8857
322	116.4	733.2857143	233.2857
323	114	730.8857143	230.8857
324	112.8	729.6857143	229.6857
325	112.8	729.6857143	229.6857
326	116.4	733.2857143	233.2857
327	116.4	733.2857143	233.2857
328	114	730.8857143	230.8857
329	118.8	735.6857143	235.6857
330	120	736.8857143	236.8857
331	120	736.8857143	236.8857
332	115.2	732.0857143	232.0857
333	117.6	734.4857143	234.4857
334	117.6	734.4857143	234.4857
335	118.8	735.6857143	235.6857
336	123.6	740.4857143	240.4857
337	124.8	741.6857143	241.6857
338	126	742.8857143	242.8857
339	124.8	741.6857143	241.6857
340	122.4	739.2857143	239.2857
341	123.6	740.4857143	240.4857
342	124.8	741.6857143	241.6857
343	124.8	741.6857143	241.6857

344	122.4	739.2857143	239.2857
345	123.6	740.4857143	240.4857
346	121.2	738.0857143	238.0857
347	118.8	735.6857143	235.6857
348	117.6	734.4857143	234.4857
349	118.8	735.6857143	235.6857
350	116.4	733.2857143	233.2857
351	115.2	732.0857143	232.0857
352	118.8	735.6857143	235.6857
353	121.2	738.0857143	238.0857
354	122.4	739.2857143	239.2857
355	127.2	744.0857143	244.0857
356	128.4	745.2857143	245.2857
357	129.6	746.4857143	246.4857
358	127.2	744.0857143	244.0857
359	130.8	747.6857143	247.6857
360	134.4	751.2857143	251.2857
361	136.8	753.6857143	253.6857
362	139.2	756.0857143	256.0857
363	141.6	758.4857143	258.4857
364	138	754.8857143	254.8857
365	136.8	753.6857143	253.6857
366	133.2	750.0857143	250.0857

APPENDIX C

Water Survey Results – DELTA Summer Interns:

Taking a shower (for how long and how many times?)	1438.5	1438.5
Taking a bath	0	0
Washing face or hands	193	863.625
Brushing teeth (water running)	74	
Brushing teeth (water turned off)	21.75	
Shaving	46	
Getting a drink	21.875	
Cooking a meal	117	
Washing dishes by hand	390	
Flushing the toilet	372.8	372.8
Running a dishwasher	60	60
Doing a load of laundry	162.5	162.5
Watering lawn	300	300
Washing car	110	110
Total per week	3307.425	
Total per day	472.4892857	
Total per year	115759.875	

Water Use (DELTA Project Summer Interns)

