Quantifying the Benefits of Greywater Systems

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Quantifying the Benefits of Greywater Systems

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To Ashley and George Wickstead

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SUMMARY

This thesis offers a decision support framework to establish the economic feasibility associated with considering the installation of a greywater system. Because of the potential dangers and lack of widespread knowledge of greywater systems, the study begins by providing an explanation of current greywater technology to include the history of the technology, an explanation of greywater as opposed to reclaimed water, the potential risks of greywater use, and the necessary components of a greywater system.

This decision support framework can be used with any scale of greywater system to be installed within any scale of facility. The example of an typical Atlanta, Georgia, USA multifamily rental development is used within the study to explain the framework by showing a working model. The need for water conservation in Georgia is shown and how greywater use dovetails with the need to lower overall usage. The legality of greywater use in Georgia along with the specific legal uses is also shown. The findings are then made State of Georgia and use specific to a multifamily development.

The decision support framework provided is a viable tool. The sample framework in chapter 5 shows that the implementation of a greywater unit in the sampled facility would save 5,060,739.6 gallons of potable water per year with a 10.49 year payback cycle as shown in Chapter 4.

CHAPTER 1

INTRODUCTION

Study and Methodology Overview

Thesis Statement

The two indicators of success in supporting the installation of a greywater system relate to net potable water saved and/or the lifecycle cost of the system. This study will provide a decision support framework to provide data for both of these two indicators.

Hypothesis

A decision support framework can be created to allow any reader to determine the financial feasibility and the potential net water savings associated with the installing a greywater system within a facility.

Research Method

This research gathered data to investigate the use of greywater and greywater systems and proposed and tested a financial analysis model to determine financial payback and water conserved.

Research Significance

Greywater technology is legal and underutilized technology that can have a significant impact on the amount of potable water used. This study combines existing research from the fields of international greywater use, federal studies, academia, and industry experts to give a holistic understanding of greywater combined with financial payback calculations and lifecycle costs. The framework provided can be modeled to study the potential use of greywater systems within other specific types of new construction, retrofits, and developments. This study is significant in that no existing literature or research found offers examples of a greywater study that introduces financial payback calculations and lifecycle costs.

Research Objective

The primary objective in the development of this decision support framework is to create a tool that can serve several purposes for several end users. The framework can be used within other research to quickly establish the fundamentals of a greywater system and determine water savings and lifecycle costs. It can also be used as a tool outside academia by the homeowner, builder, developer, planner, etc. to determine greywater unit feasibility regardless of the motivation whether it be financial, conservations, or a combination of both.

Background

Construction means and methods from US state to state, region to region, and from country to country, and continent to continent can live in very distinct silos. Business-as-usual, including time and cost restraints, typically prevent the idea of researching new or widely unused technology as a new solution or possible implementation. What may be common in one area is foreign to another. These restraints keep the technologies suppressed. One example is rainwater harvesting which is commonly used in Singapore, Tokyo Japan, Berlin Germany, Thailand, Indonesia, Gansu Province China, Africa, Dar es Salaam Tanzania, Botswana, Brazil, Bermuda, St. Thomas, US Virgin Islands, and the Island of Hawaii USA.

As an example, Bermuda has an average rainfall on 57.87" of rain a year which is the islands only source of fresh water. A unique feature of Bermuda roofs is the wedge-shaped limestone "glides" which have been laid to form sloping gutters, diverting rainwater into vertical leaders and then into storage tanks. Most systems use rainwater storage tanks under buildings with electric pumps to supply piped indoor water. Storage tanks have reinforced concrete floors and roofs, and the walls are constructed of mortar-filled concrete blocks with an interior mortar application approximately 1.5 cm thick. Rainwater utilization systems in Bermuda are regulated by a Public Health Act which requires that catchments be whitewashed by white latex paint; the paint must be free from metals that might leach into water supplies. Owners must also keep catchments, tanks, gutters, pipes, vents, and screens in good repair. Roofs are commonly repainted every two to three years and storage tanks must be cleaned at least once every six years.[1] This technology is well known to every layperson in Bermuda who many service their own rainwater collection unit the same way Americans may change the oil in their car.

The use of conservation techniques are typically not introduced to a region until the resource in question is either completely depleted, nearing depletion, or the cost of conservation implementation is lower than the historical source. This was the case with all of the locations mentioned in the U.N. study noted above. Greywater use faces the same constraints and is typically installed in the United States only when conservation outweighs financial as the driving motivation.

Problem Definition

It has been predicted that by 2020 a water shortage will be a serious worldwide problem[2]. The State of Georgia, specifically, is on the verge of a water crisis

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[1] United Nations Environmental Programme website (2010)
[2] UNESCO, United Nations Education, Science, and Cultural Organization website from The United Nations World Water Development Report 3 (2009) Water in a Changing World

based on the states ability to counter a long term drought with reserve water.[3] In Georgia it is regularly reported that water supply issues exist.[4] The culprit can be weather related, have to do with long ignored infrastructure, or a conflict with neighboring states. The final call to action could revolve around this third example, conflict with neighboring states.

Georgia's largest fresh water reservoir, Lake Lanier, supplies roughly 40% of Metro Atlanta's water supply.[5] The southeastern United Stated experienced a major drought between 2007 and 2008. A crisis began when the Army Corps of Engineers released more than 20 billion gallons of water from the lake for water starved multi-state municipalities downstream. The drought continued and left the Metro Atlanta area, at its lowest levels, with a three month supply of water. A federal judge recently declared withdrawals from the lake illegal. This accounts for 596,385,269 gallons per day that will have to be found elsewhere or reduced from total use with conservation efforts. [6]

Federal legislation has passed that require low flow plumbing fixtures and low use toilets that combined can save up to 35% of water usage. This law has few requirements to update existing fixtures; pertaining mostly to new construction.[7] More measures need to be implemented to bring a more significant and enduring difference and further fill the gap that may soon be created if the federal ruling stands. The use of greywater has the ability to reduce water usage an additional 26.7% if only used for toilet flushing.[8]

34% of the fresh water used in the United States is used for irrigation. This 34% is the second largest percentage only preceded by thermoelectric at 48% and the public

[3] Georgia's State Water Plan website (2009)
[4] Stooksbury, D.E., (2010)University of Georgia website
[5] Stockdake, C.B., Sauter, M.B. and McIntyre, D.A. (Oct 29, 2010) The Ten Biggest American Cities That Are Running Out Of Water
[6] The Economist (Sep 16, 2010) Chattahoochee blues, Are Georgia, Alabama, and Florida fighting over water or over growth?
[7] From the U.S. Environmental Protection Agency's WaterSense
[8] From the American Water Works Association website (2010)

supply at 11%. It should be noted that this 34% of water usage is used for agricultural irrigation. Reducing the amount of potable water for residential landscape irrigation should be a very high priority. Potable water for residential landscape irrigation is withdrawn from the 11% used for public supply.[9] A first step towards this goal would be to move the residential industry standard from conventional spray irrigation to drip and micro-spray irrigation. Drip irrigation was introduced to the market in the 1950's with the introduction of plastics. It provides a less expensive way to deliver water to the root zone of plants and is 100% efficient as opposed to conventional irrigation that rarely exceeds 70% efficiency while using much more total water volume.[10]

The need for a major demand side management and water conservation implementation is great. As stated in the Background, the time to research a new or underutilized technology is rarely explored. This is the stated problem. This research provides a tool to relatively quickly explore greywater use as a viable conservation/ cost saving option to offset the impending if not current need.

Methodology

The process of this research tested the preconceived notions of the author. The concept was to begin the research with an open mind. It was mentioned in the introduction that greywater technology was legal and underutilized technology. The intention of the research leading up to Chapter 4 was to establish why that was the case when the need for water conservation is so great and the use of greywater is seemingly obvious. This methodology proved very useful in clarifying that the main reason greywater technology has not become main-stream has to do with the very real and

[9] From the U.S. Geological Survey (2009) Water Use Trends
[10] From The Alliance from Water Efficiency

dramatic dangers associated with greywater use. While the intention of the research was to create a cost analysis framework; the byproduct was to offer a warning as to the tremendous importance of properly maintaining the system. The obvious nature of the technology is suppressed by the health risks and the costs associated with preventing them.

The physical methodology for this thesis consists of four primary tasks. The first task is to offer insight into the initial design of the research and how it evolved from a thesis statement to a thesis. This task is captured in Chapter 1. The next task is to offer a complete understanding of greywater from its history to its definition and use. The importance of this step was to use the research period as a testing ground to establish the factors needed for the framework and to create the most complete framework. This task is captured in Chapter 2. The third task is to create the actual decision support framework and to support its components and structure. This task is captured in Chapter 3. The fourth and final task is to use the framework to provide data associated with the water savings and lifecycle costs within a case study development. This task is captured in Chapter 4.

The methodology framework is based on interpretive analysis of data gathered from expert knowledge, quantitative methods, based on the analysis of collected regional data and information, along with appendices offering personal experiences of the author. These findings identify both a holistic understanding of greywater use while providing the necessary data and support to ultimately produce a viable decision support framework.

CHAPTER 2

ABOUT GREYWATER

Definition of Greywater

Because no scientifically set definition[11] currently exists for greywater, or spelling for that matter, this study represents the following to be the most thorough published definition to date. It is provided by the United States Green Building Council (USBGC).

"Graywater (also spelled greywater and gray water)

Defined by the Uniform Plumbing Code (UPC) in its Appendix G, titled "Gray water Systems for Single-Family Dwellings," as "untreated household wastewater which has not come into contact with toilet waste. Grey water includes used water from bathtubs, showers, bathroom wash basins, and water from clothes-washer and laundry tubs. It shall not include wastewater from kitchen sinks and dishwashers."

The international Plumbing Code (IPC) defines graywater in its Appendix C, titled "Greywater Recycling Systems," as "wastewater discharged from lavatories, bathtubs, showers, clothes washers, and laundry sinks."

Some states and local authorities allow kitchen sink wastewater to be included in greywater. Other differences with the UPC and IPC definitions can probably be found in state and local codes. Project teams should comply with graywater definitions as established by local authorities having jurisdiction in their areas."

Reclaimed water is differentiated from greywater in that it is a more refined product than domestic greywater having gone through a much more sophisticated

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[11] By scientifically set definition it is meant that a standard defined by total suspended solids, etc. as used to define reclaimed water and potable water does not exist for greywater

treatment process close to that of what is returned as potable water yet still not meeting tertiary standards.[12] Mike Hopkins, the Executive Director of Newton County Georgia's Water and Sewer Authority, stated that it is very difficult to differentiate a glass of reclaimed water from potable water. The same cannot be said for greywater. Reclaimed water is defined by the amount of suspended solids measured in the water. There is no similar scientifically measurable means to define greywater.

For the purposes of this thesis greywater will be defined as locally treated household wastewater which has not come into contact with toilet or food waste. Greywater includes used water from bathtubs, showers, bathroom and laundry sinks. It shall not include wastewater from toilets, urinals, kitchen sinks, bar sinks, dishwashers, or washing machines. Greywater, unlike reclaimed and potable water, has no threshold for suspended solids or comparably based level of purity or impurity.[13]

The History of Greywater Technology

The use of greywater on a large scale is a new concept. On a smaller scale it is known that ancient Roman's did make allowances in their water supply system for non-potable water to be reused.[14] As urban populations grow and water shortages become reality so does the concept of reusing water for non-potable purposes.

The move from the outhouse to the water closet and sewer system brought about the first inadvertent wastewater reclamation. It resulted in the mid 19th century London outbreak of cholera as drinking water was pulled from the same Thames River as sewage

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[12] As expressed by Anthony Andrade with the Southwest Florida Water Management Department
[13] See Appendix B
[14] From Monteleone (2007) A Review of Ancient Roman Water Supply Exploring Techniques of Pressure Reduction, p. 2

was being piped.[15] This also manifests itself as typhoid, e-coli, and other diseases even today. Current outbreaks are occurring now in Haiti and Southeast Asia. In rural areas throughout the world, reuse of water that has already been used for washing, cleaning, and bathing has always been a common practice. With the advent of piped water systems and wastewater collection networks, this practice diminished in prevalence, especially as communities grew denser and increasingly urbanized in the 20th century. Population explosion, especially in the arid regions of the world, has drained available water resources at an alarming rate. People have responded with water rationing and a call for water conservation while suppliers have responded with elevated water costs[16]

Greywater reuse is a rediscovery of an ancient practice, potentially dangerous to public health as noted above. A re-born surge in the desire for advancements in the technology has come about during every drought over the past 100 years.[17]

Reclaimed water vs. greywater has become a viable product with municipal uses of reclaimed non-potable water for irrigation purposes. The current industry standard is to distribute reclaimed water through purple pipe to distinguish it from potable water. Steve Sadler of Post Properties[18] noted that their multi-unit rental development in Tampa uses reclaimed water for irrigation. While reclaimed water use cuts potable water usage by 50% it does not cut expenses 50%. Municipal reclaimed water costs less than potable water but not significantly less according to Post's Sadler and confirmed by the Southwest Florida Water Management Department. The savings average 10%.[19]

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[15] From Higgins (1979) The 1832 Cholera Epidemic in East London, p. 1-3
[16] Concepts summarized from Rose (1991) Microbial Quality and Persistence of Enteric Pathogens in Greywater from Various Household Sources, p. 37-39
[17] From Diaper (2001) Small Scale Water Recycling Systems – Risk Assessment and Modeling, p. 83-90
[18] Sadler, S. (2010 Interview)
[19] Southwest Florida Water Management, (2010) Southwest Florida Water Management website

Anthony Andrade[20] with the Southwest Florida Water Management Department stressed that reclaimed water, as opposed to greywater, “is defined as domestic wastewater effluent that has received at least secondary treatment and disinfection at a wastewater treatment plant and is reused for irrigation, or other beneficial purposes.

The simplest reuse systems became popular in Georgia over the last drought which consisted of a bucket left on the floor of a shower. The collected water would be poured on landscaping, lawn, or planted pots.

Potential Risks of Greywater Use

Greywater is by definition, history, and content is to be treated with caution. While greywater offers possible solutions to many problems in our present and future it also presents many risks. At worst we have seen greywater mixed with potable water causing cholera epidemics in London in 1832, 1854, 1866 as well as several city states in India in 1817.[21] Many other isolated and epidemic events including a current outbreak of cholera in Haiti and Southeast Asia that have occurred after Earthquakes were experienced in each region. Each time hundreds, if not thousands, of lives are lost. The cause each time was and is waste water mixing with potable water. It is essential that the water is treated so that all organic content is rendered inert even if the intended use is only for irrigation and toilet water.[22] Beyond the risk of disease, the reservoir component of the greywater system should be maintained and treated to function properly.[23]

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[20] Andrade, A. (2010 Interview)
[21] Higgins (1979) The 1832 Cholera Epidemic in East London, p. 2
[22] Rose (1991) Microbial Quality and Persistence of Enteric Pathogens in Greywater from Various Household Sources, p. 39-42
[23] See Appendix D for the authors personal experience with greywater systems

Even though greywater excluded waste water, fecal coliform and other indicators in greywater samples show that precautions must be taken. Greywater advocates claim that no public health concern or outbreak has ever been traced to a greywater source since an explosion of greywater use occurred in California going back 60 years according to the California Greywater Policy Information Center in 2009.[24]

Although there are no near deaths or deaths from that California study performed by California Greywater Policy Information Center in 2009,[25] improper maintenance and user error can make for less than hygienic conditions.[26]

In Georgia there are few potential risks associated with greywater use from a legality standpoint. Effective June 1, 2010. Greywater can be legally used and is actually encouraged. Based on State Senate Bill 370 (10 SB 370/AP) By: Senators Tolleson of the 20th, Bulloch of the 11th, Cowsert of the 46th, Hooks of the 14th, Weber of the 40th and others, Section 2, Chapter 5 of Title 12 of the Official Code of Georgia Annotated, relating to water resources, is amended by inserting in lieu of reserved Code Section 12-5-4 a new Code Section 12-5-4 *"(7) Encourage the use of rain water and grey water, where appropriate, in lieu of potable water"*. Irrigation with greywater is allowed but only when used within a drip or soaker system. The use of greywater in a conventional spray system is forbidden.[27]

The Effects of Greywater Usage on Sewage Treatment Facilities

The amount of greywater taken "out of the loop" or "slowed in the loop" can eventually affect municipal sewage treatment facilities but only when used at a

[24] Oasis Design (2009) California Graywater Policy Information Center website
[25] Oasis Design (2009) California Graywater Policy Information Center website
[26] See Appendix D for the authors personal experience with greywater systems
[27] See Appendix C for all legislation related to greywater use in Georgia

tremendous scale. Water taken “out of the loop” refers to municipal water not returned as greywater to sewage treatment facilities. The City of Atlanta’s Building Department has expressed that this is why they would historically not permit a residential greywater unit. They had been directed by the water and sewer department that the lack of greywater would harm the city’s sewage treatment facilities.

Water is taken “out of the loop” when municipal water is used, gathered as greywater, and then reused for irrigation purposes. When this occurs the water cannot be treated and returned as potable water. Water is “slowed in the loop” when municipal water is used, gathered as greywater, and then reused for toilet water. The act of containing the water and looping it back as toilet water can have the net result of slowing the water’s return to municipal sewage treatment facilities.

Mike Hopkins[28], the Executive Director of Newton County Georgia’s Water and Sewer Facilities, discussed the effects greywater use would have on systems like the one he manages in Newton County Georgia. His said that the conversion rate is a very long period of time. He stressed that there would be no noticeable difference until an enormous amount of water was being used for greywater reuse, no less than 25% of total capacity.[29]

As is true with the potential for widespread use of any new technology, the concerns are addressed on a case by case basis and with caution. In legalizing the use of greywater without volume limitations; it can be assumed that The State of Georgia has agreed with Hopkins that greywater use would have no negative consequences to municipal sewage treatment facilities.

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[28] Hopkins, M. (2010 Interview)
[29] Summarized from a conversation with Newton County Georgia’s Mike Hopkins, See Appendix A

Greywater System Components

Greywater systems come in all shapes and sizes from an untreated bucket in a shower to commercial units housing thousands of gallons of greywater. Although diverse in form, the systems have evolved to have just a few major components as shown in Figure 1.

The first consideration is that waste water piping must be separated from greywater piping. This can be easily accomplished in new construction and from reasonable to very difficult to retrofit. As an example, in a typical second story residential home with basement the greywater system can be installed in the basement. Drain lines from first floor bathroom sinks and showers can be diverted from the sewer system and redirected to the greywater reservoir. The filtered and treated water can then be pumped to first floor toilets. Gathering second floor greywater and pumping to second story toilets would be much more invasive and expensive project. The first floor project can happen very easily without affecting the first floor living space.[30]

After the drain lines and sewer lines are separated, the greywater will go through some level of particulate filtration. This can be as simple as a residential sock with 3000 micron fibrous filter to as advanced as a multi-phased filtration system.

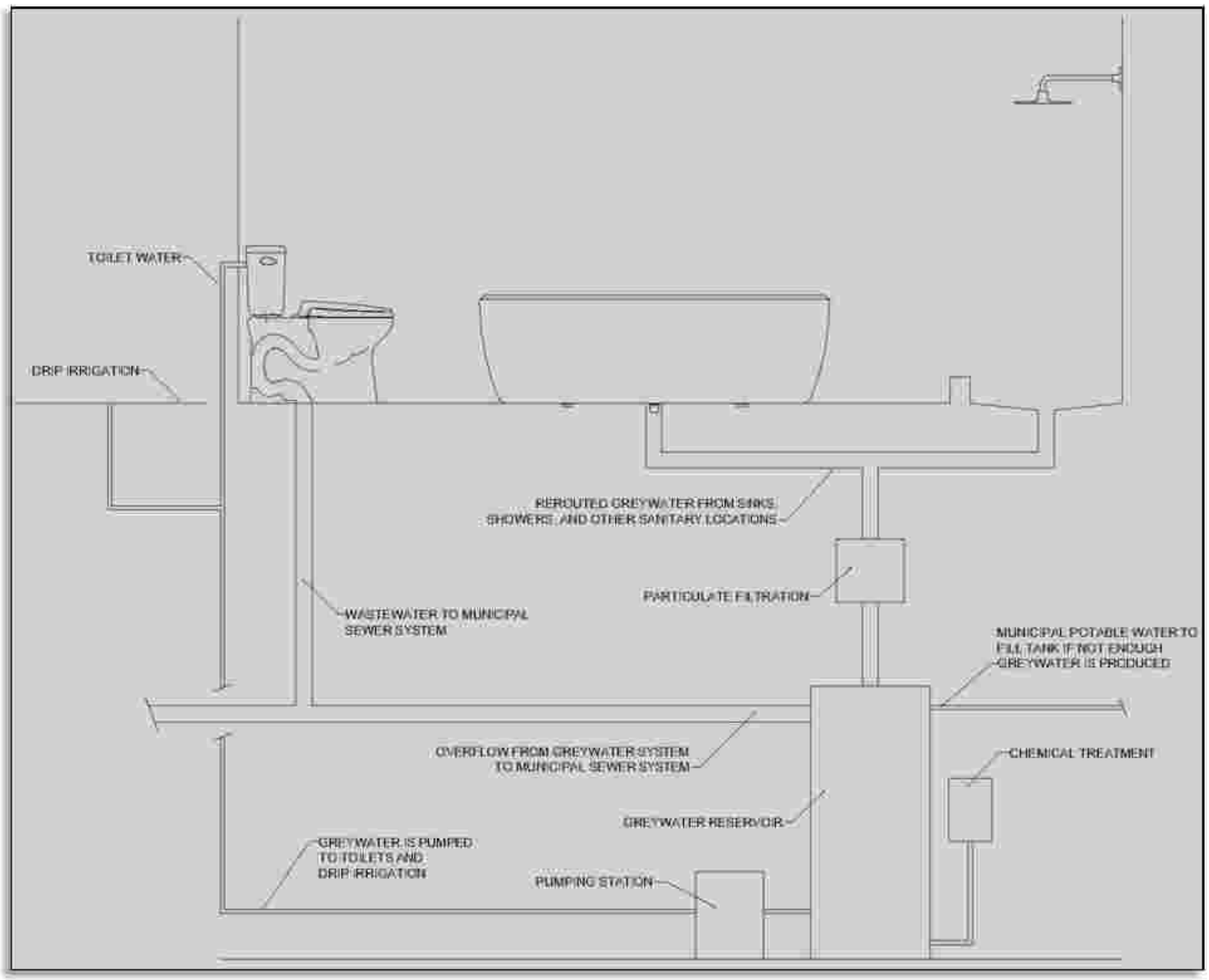
The water is emptied into a reservoir after particulate filtration has taken place. Residential units range from 1-5 gallon tanks to over 5000 gallon underground tanks. Some systems utilize septic tanks to hold greywater. Commercial systems start at 500 gallons up to thousands of gallons. Once tanked the water is chemically treated. Some commercial units are chemically treated prior to being tanked. Most are treated once tanked. The chemical treatment is typically done with a sodium hypochlorite product

[30] From Ludwig (2010) Builder's Greywater Guide, p. 9

concentrate like chlorine or household bleach. The chemical treatment accomplishes killing bacteria, viruses, parasites, algae, and molds. The greywater is now considered safe for reuse as toilet water and drip irrigation. The final component is a pump. This can range from a sump pump to a pumping station. [31]

Two capacities are critical for a greywater system to work properly as shown in Figure 2. The first is to connect a valved municipal potable water source to the system. This will guarantee that water will always be available when needed even when greywater production is insufficiently low. The second critical consideration is for an overflow to be installed at the greywater system's reservoir tank that would be connected to the municipal sewer system. This is necessary if more greywater is produced than is needed. This second scenario is more prevalent than the first in a properly sized system.[32]

[31] From Friedler, E. (2005) On-site Greywater Treatment and Reuse in Multi-Storey Buildings, p. 189-192
[32] From Rose (1991) Microbial Quality and Persistence of Enteric Pathogens in Greywater from Various Household Sources, 40-41



 [33]

Figure 1: Greywater Component Illustration

[33] Verified with information from Ludwig (2010) Builder's Greywater Guide, p. 9

CHAPTER 3

METHODOLOGY

There are ten factors that will need to be established to construct the framework. These ten factors have been establish through the body of this research and are meant to cover the vast majority of greywater system implementations. It is certainly conceivable that additional factors may be necessary when considering another specific case study. It is the responsibility of the reader to establish if the factors provided are suitable for their specific purposes. The first of the ten factors is to establish water usage per person per diem. When possible is would be important to establish this amount based on the specific building or the specific type of building. The second factor is to determine how many people will occupy the facility in question. The third factor is to determine how many units the greywater system would service. The forth factor to establish is the percentage of quantitative water used per each end use within the type of facility being considered. Examples of end-uses are toilet flushing, shower usage, etc. The fifth factor is to establish the amount of greywater produced per person per diem. When possible is would be important to establish this amount based on the specific building or the specific type of building. The sixth factor is to establish the amount of greywater produced per person per diem that will be left unused. This is the difference between the amount of greywater produced and that that can be used. The seventh factor to establish is the cost of water per gallon or specific quantitative measurement used with previous factors. The eighth factor is to establish the cost of an installed greywater system that has been designed for the type of building or the specific building. The ninth factor is to establish the per diem facility management costs of the specific greywater system. The tenth factor is to establish known or assumed component replacement costs along with the expected lifespan of each of those components.

As stated above, it is conceivable that additional factors may be required for other specific case studies. An example is than it was the nature of the rental development within with case study that called for the factor “number of units” to be considered. In another case study there may be two prices of source water to consider or fees associated with greywater use specific to a single municipality that were not exposed by this study.

Establishing per Person per Diem Amount of Water

Ranked worldwide, the United States far exceeds the average water usage per person of 243 liters or 64 gallons as shown in Table 1 from the United Nations Development Program. The United States uses over 150 gallons per person per day including all uses such as industrial, agriculture, and public use. [34] Gallons per person, shown later in this chapter, pertain only to domestic water and excludes all other uses. Other uses are excluded because are not affected by the installation of a greywater system.

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[34] From data collected from the U.N. Development Program and converted from liters to U.S. gallons

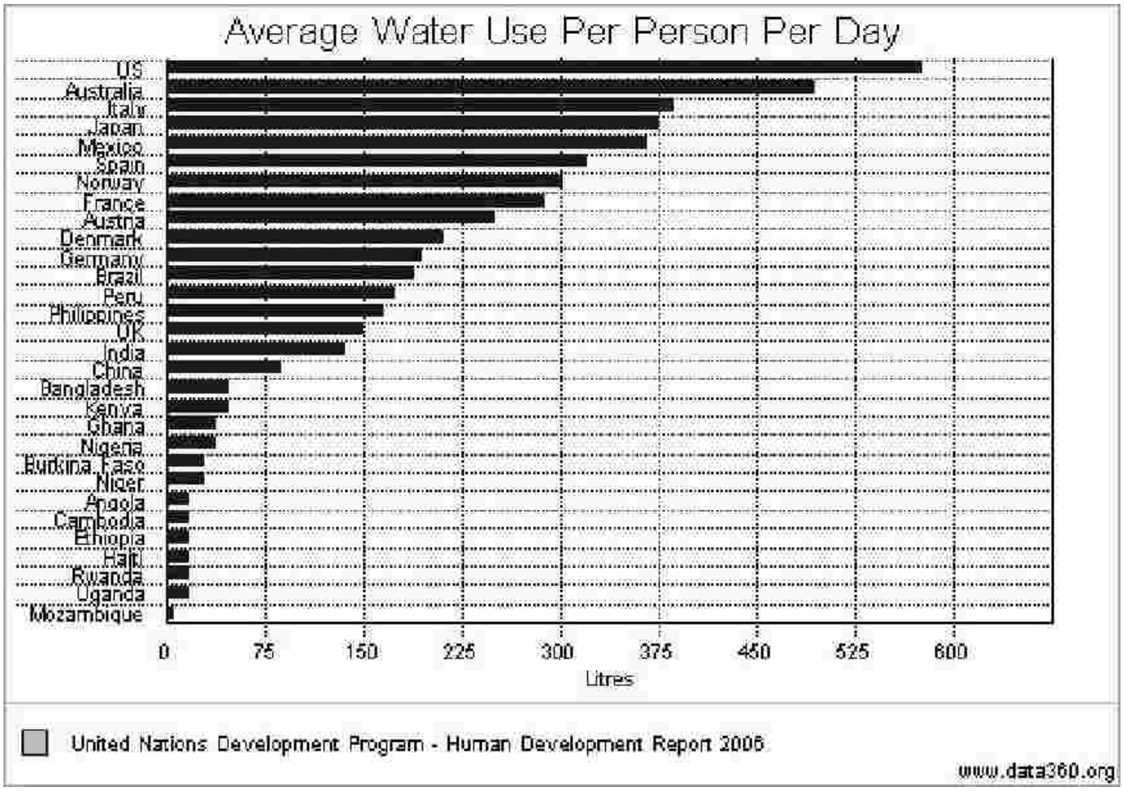

Table 1: Worldwide Water Usage per Person per Day

Georgia is a median water use state based on Figure 3 from the U.S.G.S.[35] More recent 2005 data from the U.S.G.S Georgia Water Science Center shows that the previous data is still accurate and that Georgia uses 5,471,047,000 gallons per day[36] which is, to keep things into perspective, about equal to the per diem water usage of Brazil. Brazil is 3,300,000 square miles and has a population of 193,671,945[37] as opposed to Georgia's 59,441 square miles and population of 9,685,744 in 2008.[38]

[35] From the U.S. Geological Survey
[36] U.S. Geological Survey (2010) Water Resources of Georgia website
[37] From Brazil's Official Population Clock
[38] From the U.S. Census Bureau

Total water withdrawals, 2000.

Figure 2: United States Water Usage by State

Figure 3 divides the average water usage of the state by the general population as does Table 1 to assess per country water usage.[39] This is an accurate portrayal of high level water usage but it does not express the amount of water that is within the control of individuals to conserve on a home to home or development to development basis. The public supply of water is only 11% of the total usage[40], see Figure 3.

Public supply refers to water withdrawn by public and private water suppliers that furnish water to at least 25 people or have a minimum of 15 connections. Public supply water may be delivered to users for domestic, commercial, industrial, or thermoelectric-

[39] From the U.S. Geological Survey
[40] From the American Water Works Association (2010) website

power purposes. Some public supply water may be delivered to other public suppliers or used in the processes of water and wastewater treatment. Public supply water is used for such public services as pools, parks, and public buildings; or be unaccounted for losses because of system leaks or such non-metered services as firefighting or the flushing of water lines. Some public suppliers treat saline water before it is distributed.[41] However, all public supply withdrawals in this study are considered fresh water. It is of this 11% that greywater can help replace. Greywater can also be used for some of the other purposes in the following categories in Figure 3 but are not the focus of this specific study.

After public use, domestic water, which is made up of individual wells, accounts for 1% of usage. Irrigation used for agriculture, not “the yard” or backyard garden, accounts for 34% of water usage. Livestock watering, aquaculture (fish farming), and mining each account for 1%. Industrial use accounts for 5% of usage and consists of water used in the manufacturing process. Thermoelectric power, as used in the cooling towers or nuclear power plants, accounts for 48% of water usage.[42] Yes, when you power a light fixture in your home, you are using water.

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[41] The U.S. Geological Survey website definition for Public Supply
[42] From the U.S. Geological Survey website

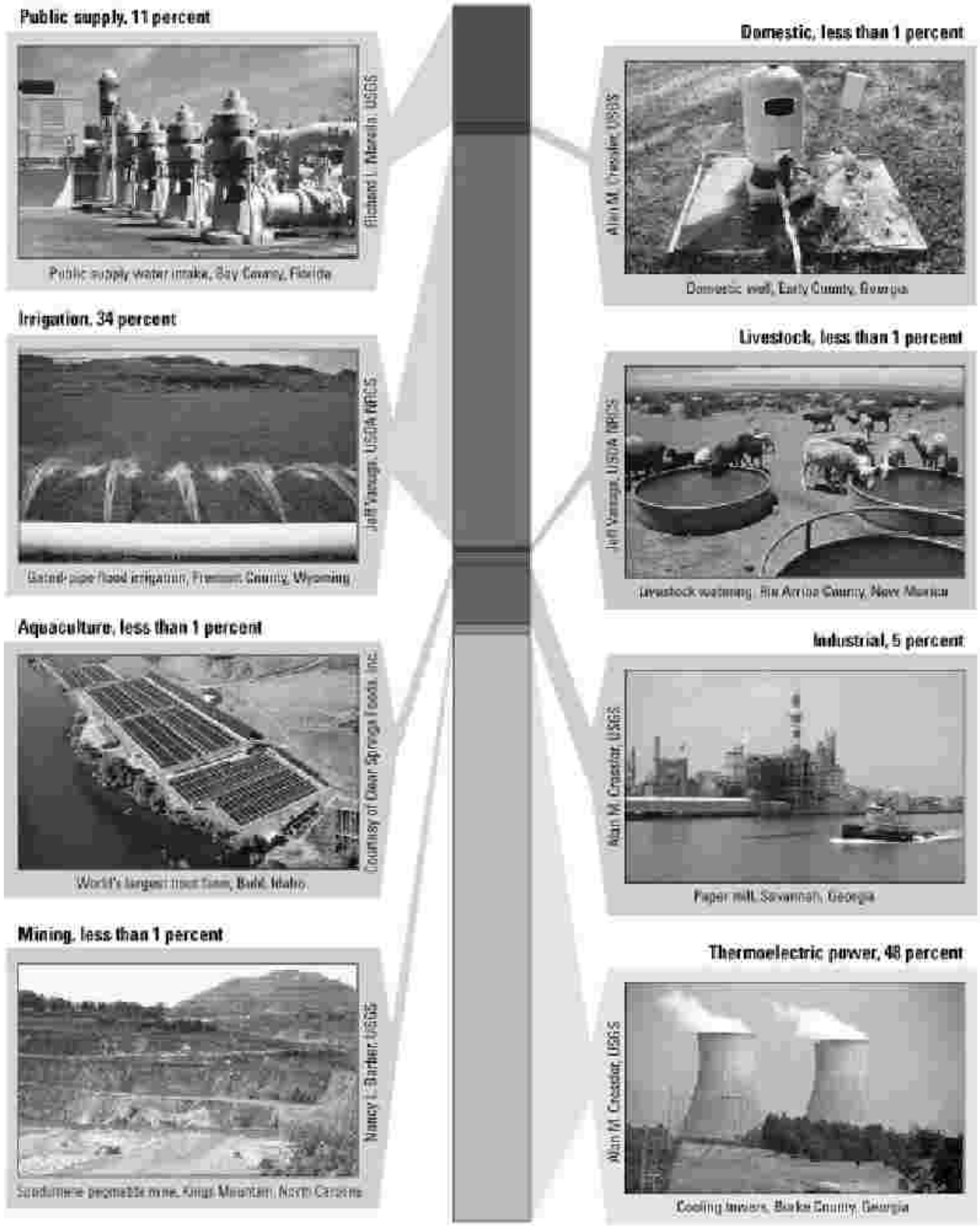

Figure 3: United States Water Usage by Category

The facility that will later be sampled is a typical multifamily rental development. Per person per diem statistics are, therefore, made specific to that type of development. After interviews with Steve Sadler[43] of Post Properties, Joe Wilber[44] and Dave Skelton[45] of Gables Residential, water usage per person per diem within multifamily rental developments has been averaged to 55 gallons per person per diem which is 11.3% lower than the average Georgian. In the interview cited above it was stated by one developer of multifamily rental developments that their properties averaged 62 gallons of water per person per day. The other developer stated that they averaged 48 gallons per person per day. The difference between the two developers was that one included laundry rooms within units and the other did not. For the sake of the case testing the framework, those two amounts have been averaged to 55 gallons per person per day. When using the framework in another case study it would be important to determine all end uses within the test case to best estimate per person water usage.

Establishing the Percentage of Quantitative Use per End Use

The average Georgian uses 62 gallons of water per diem[46] based on their share of the 11% for public use; however 55 is a more specific number for this study focusing on a multifamily facility as described in the previous paragraph. According to the American Water Works Association, of the 62 gallons represented above for the average Georgian, the percentage of use per "home" is as follows based on national averages. Note that Table 2 shows percentage used by the average existing home, not a home using new water conserving fixtures.

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[43] Sadler, S. (2010 Interview)
[44] Wilber, J. (2010 Interview)
[45] Skelton, D. (2010 Interview)
[46] U.S. Geological Survey (2010) Water Resources of Georgia

Daily indoor per capita water use based on the national average of 69.3 gallons per day

Use	**Gallons per Capita**	**Percentage of Total Daily Use**
Showers	11.6	16.8%
Clothes Washers	15.0	21.7%
Dishwashers	1.0	1.4%
Toilets	18.5	26.7%
Baths	1.2	1.7%
Leaks	9.5	13.7%
Faucets	10.9	15.7%
Other	1.6	2.2%

Table 2: Water Usage per Domestic Use

The following data is more relevant to this study because the developments in this study would conform to current code requiring water conserving fixtures represented in Table 3. Table 3 shows the net effect upgrading older equipment to new equipment can have on the percentages above. A total reduction of 35% or 24.1 gallons per person per day can be accomplished with new equipment. A comprehensive list of water saving fixtures can be found at http://www.epa.gov/WaterSense/products/index.html.[47]

The following percentages will be used to determine establish both greywater produced and the amount of greywater that can be used within the same facility.

[47] From the U.S. Environmental Protection Agency's WaterSense website

Daily indoor per capita water use based on the national average of 69.3 gallons per day.

Use	Gallons per Capita	Percentage of Total Daily Use
Showers	8.8	19.5%
Clothes Washers	10.0	22.1%
Toilets	8.2	18.0%
Dishwashers	0.7	1.5%
Baths	1.2	2.7%
Leaks	4.0	8.8%
Faucets	10.8	23.9%
Other	1.6	3.4%

Table 3: Water Usage per Domestic Use Using New Fixtures

The percentages above are national averages. The averages that will be used in the sample decision support framework will be as noted below in Table 4.

Establishing the Amount of Greywater Produced

The following table shows usage per use with the percentages for the lower use fixtures currently required in new construction which is most relevant to this study. Water use quantities below have been modified to reflect the amount established per person per diem of 55 gallons in a multifamily rental development.[48]

[48] 55 gallons per person per day as averaged between data received from Post's Sadler and Gables' Skelton as usage per person in an average residential multi-unit rental development, see Appendix A

Use	Gallons per Capita	% of Total Daily Use	Used as Greywater?
Showers	10.73	19.5%	yes
Clothes Washers	12.18	22.1%	no
Toilets	9.90	18.0%	no
Dishwashers	0.83	1.5%	no
Baths	1.49	2.7%	yes
Leaks	4.84	8.8%	no
Kitchen Faucets	4.38	8.0%	no
Bath Faucets	8.78	16.0%	yes
Other	1.87	3.4%	no
Total Greywater	21	38.2%	
Total Non-Greywater	27.29	49.6%	

Table 4: Water Usage per Person per Diem within sampled Multifamily Rental Development[49]

The percentage of greywater produced is determined by combining shower, tub, and bath faucet water, see Definition of Greywater. The quantity of greywater produced per person per diem in the decision support framework example will be 21 gallons.

[49] The original data referenced to the American Water Works Association has been recalculated to show usage specific to a multi-unit rental development. Greywater and blackwater have been separated as defined by this document. Faucet usage has been separated per use as defined by the Water Research Foundation.

Establishing the Number of Persons Inhabiting the Facility Serviced by the Greywater System

Water consumption and conserved have been based on a per person basis so it is important to determine how many people will be serviced by the greywater system. In the case of the sampled multifamily rental development the average persons per unit are 1.68.

Establishing the Number of Units Serviced by the Greywater System

A greywater system can be designed to service one or many individual buildings, homes, units, etc. The number of units serviced will need to be factored. The number of units serviced in the sample framework is 393. 393 is the average units associated with the typical multifamily rental development as sampled for this thesis and as tested in the framework in Chapter 4.[50]

Establishing the Amount of Greywater Produced that will be Left Unused

Based on data from Table 4, the amount of greywater the average unit produces is determined. Viable greywater can be collected from non-kitchen sinks, showers, and baths. The total percentage of water used for those items is 38.2%[51] after reducing the faucet number by the percentage used in the kitchen sink. Note that toilet water accounting for 18% of water usage[52] or 9.9 gallons meaning that potable water used as toilet water would be eliminated while leaving 11.1 gallons per person per day of

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[50] See Appendix A
[51] See Table 4
[52] From Table 4

greywater for irrigation purposes in the later example use of the decision support framework. This means that 100% of the greywater produced can be used. The amount left unused in the sample framework in chapter 4 is 0.

Establishing the Cost of Water

Water costs can vary from meter to meter depending on the rate being offered from the provider. Water cost used in the sample use of the framework is the average water cost in Georgia.

Georgia has one of the higher costs per gallon rates of water in the country. The average monthly Georgia water bill costs $21.00 for an average of 5000 gallons. This translates to $.0042 per gallon.[53] Michigan has one of the lowest rates at $.0005 per gallon[54] while California is another higher cost state at $.0031 per gallon.[55] The United States average is $.0015 per gallon.[56]

The water cost used in the sample use of the decision support framework will be $.0042 per gallon.

Establishing the Cost of an Installed Greywater Unit

Site specific greywater systems come in two forms within current building methods. The first type of system is a pre-fabricated system manufactured to perform the task of greywater reuse along with all the jobs as specified in Figure 1. The second type of greywater system is built on site with separate individual components meant to

[53] From the University of North Carolina 2010 Rates Dashboard: Georgia Water and Sewer
[54] From Michigan Advantage (2010) website
[55] From Welcome to California (2010) website
[56] From Rubin (2004) The Cost of Water and Wastewater Service in the United States, p. 20-21

perform specific tasks that together make up a complete greywater system.[57] The first system described above will be referred to as a "pre-fabricated" system. The second will be described as a "site-built" system.

The first unit priced is manufactured by BRAC Systems. BRAC is a Canadian based company that builds "pre-fabricated" systems.[58] Their product line ranges from small residential units to massive modular systems that would be suitable for the calculations for a multifamily rental development like an average 393 unit multifamily rental development used in the sample decision support framework.

The following pricing is for the BRAC Systems CGW-19800[59] with an additional tank making total capacity 15,226 gallons. The capacity is an important consideration. Too much capacity will allow the greywater to sit unused which increases maintenance concerns. Too little capacity may result in greywater not "sitting" long enough for the chemical treatment to be effective[60] or require the use of municipal water to supplement the tank. In the example use of the framework, 13,871.65 gallons of greywater would be produced per day which is slightly less than total capacity on a daily basis.

Brac System, materials, and shipping costs	**$80,000.00**
Labor and installation	**$30,000.00**
Additional 10,000 gallon capacity	**$35,000.00**
Total Installed Cost	**$145,000.00**

Table 5: "Pre-Fabricated" Greywater Unit Pricing[61]

[57] From Ludwig (2010) Builder's Greywater Guide, 27-33
[58] BRAC Systems: http://www.bracsystems.com/
[59] See http://www.bracsystems.com/products.php for more information
[60] From the City of Seattle Department of Planning & Development (2010) Technical Brief
[61] LaBelle, M. (2010 Interview)

The second unit priced is assembled by Highland Waterworks. Highland Waterworks is a Metro Atlanta based company specializing in rainwater reuse and greywater systems. Highland Waterworks assembles systems from separate components that would be suitable for my calculations for a multifamily rental development. This is an example of "site-built" system current local pricing.

1ea.	**30hp Berkley VFD pumping station with control system**	
1ea.	**15000 gallon fiberglass tank**	
1ea.	**Chlorine Injection system**	
1ea.	**4" Three way valve**	
Labor and installation		
Total Installed Cost		**$181,734.00**

Table 6: "Site-Built" Greywater Unit Pricing[62]

For the purposes of the example use of the framework given in this study; the cost of the "Pre-Fabricated" unit is used. It was decided that the prefabricated unit would be used in the test of the framework in Chapter 4 because it was significantly less expensive than the "Site-Built" system which adding no discernable benefit. The total cost used in the sample will be $145,000.00.

Establishing the Facility Management Costs Averaged per Diem

All greywater systems require monthly inspection and maintenance because of the potential risks associated with greywater. A maintenance contract could include the

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[62] Hester, J. (2010 Interview)

requirement that the management team return a monthly report of system findings along with photographs of system status to ensure that proper maintenance is taking place.[63] Facility management for onsite greywater systems will range based on the system installed. The information below is based on interviews with Mike LaBelle[64] , the "pre-fabricated" system installer, and Jim Hester[65], the "site-built" system installer. Typical facility management of all greywater systems will involve cleaning of the filtration system, maintaining chemical treatment levels, occasional tank cleaning, and occasional mechanical maintenance including the pump. Required maintenance will vary depending on the human behavior of the users at any given time. Examples of this would be the amount of hair collected, etc. Any greywater system should be monitored closely during the first 3 months of going online. This translates to weekly inspections of the filtration system and chemical reservoir.[66]

Facility management will be more expensive when there is no full time onsite facility manager or maintenance personnel. This is the case amongst the multifamily rental developers that were interviewed.[67] The numbers below are based on service contract with a local plumbing contractor familiar with the systems. Monthly maintenance would include cleaning the filters, maintaining chemical treatment levels, and pump and other system maintenance.

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[63] From Ludwig (2010) Builder's Greywater Guide, p. 22-23
[64] LaBelle, M. (2010 Interview)
[65] Hester, J. (2010 Interview)
[66] Diaper, C.; A. Dixon; D. Butler; A. Fewkes; S. A. Parsons; M. Strathern; T. Stephenson; J. Strutt (2001) Small scale water recycling systems, p. 83-85
[67] Information gathered from local developers, See Appendix A

Maintenance Costs per Year

(See Appendix A, interview with Terry Humphrey for more information)

Maintenance Costs	
Monthly Maintenance (including all associated expenses)	**$550.00**
Averaged Daily Facility Maintenance Costs ($550x12)/365:	**$18.0821**

Table 7: Per Diem Facility Management Costs[68]

The per diem facility maintenance costs associated with the sample decision support framework is $18.082.

Identifying Component Replacement Costs and Component Lifespan

Besides regular maintenance there could be component replacement costs associated with a greywater system. Components that will need replacement in the case of the sample given in the framework are filters and the pump. Yearly maintenance would include filter replacements. The costs of the filters are not included in the maintenance costs. The filter cost is $340.00 and is required on a yearly basis. The pump of the "Pre-Fabricated" unit was a warranty period of 15 years. The current cost of the pump is $7,500.00 installed. [69]

Per Diem Component Replacement Costs		
Pump Cost = $7500.00	**Pump Life = 15 year**	**(7500/15)/365 =$1.3698 per diem**
Filter Cost = $340.00	**Pump Life = 1 years**	**(340/1)/365 =$ .9315 per diem**
Total Per Diem Component Replacement Costs		**$2.3013**

Table 8: Per Diem Component Replacement Costs

[68] Humphrey, T. (2010 Interview)
[69] Humphrey, T. (2010 Interview)

Total per diem component replacement cost used in the sample division support framework will be $2.337.

Factor Establishment Summary

Once all ten factors have been collected then the decision support framework can be used to establish the feasibility of installing a greywater system within a facility regardless of the scale of the facility and regardless of the motivation whether it be financial, conservations, or a combination of both.

CHAPTER 4

THE DECISION SUPPORT FRAMEWORK

The following lists the ten necessary factors, less the individual end use percentages, along with the specific information gathered pertaining to an Atlanta, Georgia USA multifamily rental development. The individual end use percentages have been excluded because while they were critical in establishing factors D and E below, they have no additional value to the framework. The figures to the right of each factor will be later be used to test the framework.

The Factors for the Framework

Gallons of Water Usage per Person per Day	A	**55**
Persons per Facility/Home/Unit	B	**1.68**
Units Serviced by the Greywater System	C	**393**
Gallons of Greywater Produced per Person per Day	D	**21**
Gallons of Greywater Left Unused per person per Day	E	**0**
Per Gallon Cost of Water	F	**$0.0042**
Cost of the Installed Greywater System	G	**$145,000**
Per Diem Cost of Facility Management	H	**$18.0821**
Per Diem Cost of Replacement Components	I	**$2.3013**

Table 9: The Factors for the Framework

Formula for Establishing Lifecycle Cost

Lifecycle cost is established using the following formula:

[G/[((((D-E) B) C) F) - (H + I)]] / 365 = years to payback

Table 10: Formula for Establishing Lifecycle Cost

Formula for Establishing Total Water Conserved

Total water conserved is established using the following formula:

[((D - E) B) C] = total per diem water saved

[((D - E) B) C] 365 = total per year water saved

Table 11: Formula for Establishing Total Water Conserved

Test Case for Establishing Lifecycle Cost at a Typical Atlanta, Georgia, USA Multi-Family Rental Development

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[G/[((((D-E) B) C) F) - (H + I)]] / 365 = years to payback

[145000/[((((21 - 0) 1.68) 393) .0042) - (18.0821 + 2.3013)]] / 365 = years to payback

[145000/(58.233168 - 20.3834)] / 365

[145000/37.8497] / 365

3830.9418 / 365

10.495 years to payback

Test Case for Establishing Total Water Conserved at a Typical Atlanta, Georgia, USA Multi-Family Rental Development

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[((D - E) B) C] = total per diem water saved

[((21 - 0) 1.68) 393] = 13865.04 gallons per diem

[((D - E) B) C] 365 = total per year water saved

[((21 - 0) 1.68) 393] = 5,060,739.6

13,865.04 gallons per day

5,060,739.6 gallons per year

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTURE RESEARCH

Summary

The objectives of this research were: 1) To provide a holistic understanding of greywater and greywater technology; and 2) To provide a decision support framework to be used as a tool when consideration of the inclusion of a greywater system within a development or building regardless of the motivation whether it be financial related to cost savings or conservation; and 3) To provide an actual example of the framework being used to show sample results.

The research was divided into five chapters. Chapter 1 described the intent of the research, provided the groundwork for the need for the framework, and described methodology that would be undertaken to create the research. Chapter 2 gave the holistic understanding of greywater with the intent to provide the reader with enough information to properly decide if the rewards of a greywater system would outweigh the risks. Chapter 3 established the factors of the framework while providing enough data to assist in finding data specific to their research or project while providing specific data for the sample framework in chapter 4. Chapter 4 provides the framework along with the results of the data gathered during the text of the thesis.

Conclusions

The research resulted in the conclusion that the hypothesis was correct in that a decision support framework could be created to allow any user the ability to determine the financial feasibility and the net water savings associated with the installing a greywater system within a facility.

Strengths, Weaknesses, and Recommendations of the Model

The strength of the model is that a complicated example of a large multifamily rental development was used as the test case. This example suggested the need to add the factor of total units within the development. If the example of a single-family home was offered then the idea of multiple units may not have been established. Another strength of the model is that is can be used for any scale of potential project or research.

Weaknesses of the model were exposed parallel to the strengths. While it was established that total units was necessary as a factor it also suggested that other factors may not have been discovered within this model. Another discovered weakness is that it could be said that this research simply used lifecycle cost analysis to establish greywater system feasibility. While it is true that lifecycle cost analysis is a large piece of this thesis; the function of this thesis as a tool to estimate lifecycle cost and water conserved is secondary to explaining the fundamentals associated with greywater use.

It is the recommendation of the model that cost and conservation come second to the users understanding that a commitment to system maintenance must be adopted before considering the technology. If the commitment can be made then greywater technology is an excellent demand side management tool.

Recommendations for Future Research

This study suggests several recommendations for future research. One recommendation is that with very little modification the decision support framework could be used to determine the feasibility of a rainwater reuse system. The sections specific to greywater reuse would be rewritten to offer background and component information for that specific technology. The same could be done with solar technology or any other conservation effort a researcher was considering using or studying. It is recommended that the framework within this thesis be used as a tool within any other conservation study to quickly establish feasibility.

APPENDIX A

INTERVIEWS

10/01/2010

Title: **Vice President, Strategic Business Services**
Entity: **Multi-unit rental developer**

1. **How many units are in your average Georgia development?**

    - *Our typical development is around 350 units.*

2. **What is the amount of water your average tenant uses per day?**

    - *Our Atlanta portfolio tends to average around 48 gallons per person per day. Typically apartment residents don't have their own washers and dryers so they use the common area laundry or simply take it to the cleaners. This tends to drive down water usage.*

3. **Do any of your properties utilize a greywater system?**

    - *We use municipal greywater at our Tampa property.*

4. **Can you speak to the facility management of the greywater usage at the Tampa property?**

    - *There's really no one down there that could address any questions about it. We simply have our irrigation system fed by the City's greywater service.*

5. **Your Tampa properties are on municipal greywater for irrigation? How does that affect your overall cost vs. your Atlanta properties?**

    - *We really don't save money by using greywater as we only use it for irrigation. Typically irrigation systems have their own meters and the local water supply only applies a water charge rather than water and sewer. However, irrigation water charges are usually about twice the normal water charge. So even though there is a slight savings in water costs, there's not a ton. The greywater system is not really any cheaper than regular water as they have the reclamation and distribution system to pay for. While it is "greener" it's not necessarily cheaper.*

6. **How many units does your company intend to develop in Georgia over the next 10 year?**

- *I would venture a guess at 8000 units within that time.*

7. Do you typically have on site facility management personnel?

- *Typically we do not.*

8. Describe your typical new development?

- *Our typical new developments are changing from what they were just a few years ago. Our newer developments are in a more urban setting and therefore have less grounds and need for landscaping. We are also paying more attention to xeroscape landscaping techniques that require less irrigation.*

9. What is the average number of tenants in a Post Property unit?

- *The average is 1.86 persons per unit. There are typically more studio and one bedroom apartments than there are two and three bedrooms. Here are the numbers we use on properties where we allocate water usage rather than sub-meter.*

10/03/2010

Title: **Senior Vice President, Investments**
Entity: **Multi-unit rental developer**

1. **How many units does your company intend to build in Georgia in the next 10 years?**

    - *We will build between 7000 and 10000 units in the next 10 years.*

The Senior Vice President, Investments then referred me to the Vice President, Investment Operations

10/06/2010

Title: **Vice President, Investment Operations**
Entity: **Multi-unit rental developer**

1. **What is the average unit number of inhabitants in one of your units?**

   - *The average # of inhabitants per unit it is closer to 1.5 for us due to the current trend with our unit mix, i.e. 60% 1BR vs. 40% 2BR.*

2. **Do you have any idea how much water is used on a per inhabitant basis?**

   - *Yes, 1,865 gallons per inhabitant per month or 62 gallons per inhabitant per day. Irrigation uses 5 to 8% of our total water usage. I have been told that our average inhabitant uses 8 gallons per day as toilet water.*

3. **Do you have any idea how much water is used on a per inhabitant basis?**

   - *Our average development has 435 units and 650 inhabitants (based on the 1.5 per unit ratio), water usage is 1,865 gals per inhabitant per month or 62 gals per inhabitant per day (based on 30 day month), Irrigation usage averages 5% - 6% per year (higher during the warm months & lower during the cool months)*

10/8/2010

Title: **Project Manager/Senior Water Conservation Analyst**
Conservation & Utility Outreach
Resource Projects Department
Entity: **Major regional water management district**

1. **May I use your graphic of reclaimed water usage?**

- *Please feel free to use the map of the reclaimed water infrastructure.*

2. **Your region use reclaimed water as opposed to greywater. Can you explain the difference?**

- *Greywater is water diverted directly from sinks/showers and used onsite (with minimal treatment) at a residential location. Greywater is not practiced very much in [our region] due to the expense, permitting and O&M involved. A simplified explanation of greywater is available at http://www.greywater.com/ (Greywater is washwater. That is, all wastewater excepting toilet wastes and food wastes derived from garbage grinders. There are significant distinctions between greywater and toilet wastewater (called "blackwater"). These distinctions tell us how these wastewaters should be treated /managed and why, in the interests of public health and environmental protection, they should not be mixed together)*

  Reclaimed water on the other hand is defined as domestic wastewater effluent that has received at least secondary treatment and disinfection at a wastewater treatment plant and is reused for irrigation, or other beneficial purposes. Reclaimed water is very prevalent in [our region] which is the national leader with more than 672 mgd reused representing more than 43% utilization of all wastewater treatment plant flows in [our region].

10/09/2010

Title: **President**
Entity: **Metro Atlanta plumbing company**

1. **After reviewing the information I sent you from Brac and Highland Waterworks. What would you charge me for a 1 year maintenance contract along with the more intense start-up period?**

   - *I would charge 1560.00 for the initial start up period of 3 months and then 300.00 per month to maintain the system. I'd charge an additional 180.00 a month for expense. A full year's contract for the first year would cost 6600.00. Following years would cost 3600.00 per year.*

2. **What other maintenance would you expect?**

   - *Valves should be inspected for clogs; overflow capability should be inspected and cleared occasionally. The ability for city water to fill the tanks if not enough greywater is produced is a big concern. The ability for city to fill the talks is built into each system. I'd expect no more than 1 filter changes a year at 340.00 each.*

3. **After reviewing the warranty information. How long would you expect components to last and how much would the cost be to replace in your experience?**

   - *The pump on each system is similar. With good maintenance it should last no less than 15-20 years. Replacing the unit will cost $5000.00-$7500.00 including all labor. The rest of the unit will be fine if monthly maintenance is performed.*

10/19/2010

Title: **Executive Director of a Water and Sewer Authority**
Entity: **Atlanta Suburban County**

1. **What effect would/ could greywater usage have on sewage treatment facilities?**

- *The conversation rate would be so long that it would be barely noticeable until it became a very large percentage. For example, The City of Atlanta has 2 million gallons of capacity for sewage treatment. You would have to get to 500,000 gallons of greywater usage before there would be a potential problem.*

2. **I know greywater has historically been illegal in Georgia. When did that change?**

- *With the passing of House Bill 370 in the Georgia General Assembly and signing by the Governor, domestic greywater use became legal in Georgia.*

3. **Has [your] County investigated providing municipal greywater like central Florida has been doing?**

- *The Georgia Environmental Protection Division has required that [our] County create a study to investigate the potential to build a water reclamation facility as part of its new sewage treatment facility on the relatively undeveloped east side of [our] County. It is proving to be cost prohibitive. We would produce a lot of water so would need a customer base and storage facility. We have determined that a mile of pipe costs $140,000.00. The closest large potential client, a school, is 3-4 miles from the facility so the purple pipe alone would cost $490,000.00 and that's just to one client. There are no golf courses close to the potential facility either. They are usually great customers of reclaimed water. With greywater we keep hearing that "we'll use it, but we don't want to buy it".*

4. **Can you speak to the facility management of a reclaimed water facility?**

- *The Georgia Environmental Protection Division would make us get the water to an almost potable state to legally distribute it so the facility management costs are really the same as normal water treatment. There are no real savings.*

11/01/2010 (follow up interview)

Title: **Vice President, Strategic Business Services**
Entity: **Multi-unit rental developer**

1. **Would an 11 year financial payback be a reasonable investment for your company?**

    - *Yes, I'm thinking 11 years is a bit too long. It actually may be longer than that since we would only see a possible savings on irrigation as resident usage if billed back to them on sub meter basis. I'm thinking multifamily might actually fair better under a municipal graywater system rather than a property specific one.*

11/03/2010 (follow up interview)

Title: **Vice President, Investment Operations**
Entity: **Multi-unit rental developer**

1. **Would an 11 year financial payback be a reasonable investment for Post?**

   - *11 years would be too long for our company.*

2. **What time period would make sense?**

   - *We would have to consider using greywater when a 5-6 year payback was attainable. How many units per development were used in the study?*

3. **The average I used between you and your competitor was 393.**

   - *Future developments will be smaller than that. Maybe the cost would be less for a smaller development. Will you send me your system contacts?*

4. **Yes. (I sent the VP the installers contact information and all collected stats)**

APPENDIX B

GREYWATER DEFINITION BACKGROUND[70]

Having worked personally with greywater and greywater systems at the residential level for over 10 years I will offer some clarity and suggestions to go along with the provided USGBC definition. The simple goal of a greywater system is to collect the best of what would typically go down the drain. The purpose for the delineations of what water is reclaimed is to collect what can be reused while bringing the lowest potential for contamination, disease, or any other general harm. This is combined with general maintenance issues that go along with using anything other than potable water. This is why water that has been in contact with human waste, food, and/or other organics is excluded. This is why water from kitchen sinks is typically excluded. Kitchen sink water will usually experience some level of food waste contamination up to a high percentage of contamination in sinks that contain a garbage disposal.

The USGBC definition mentions that clothes washer water is an acceptable form of greywater. Depending on the intended use, system, maintenance plan, and facility management that is available it may be a good idea to forgo using laundry water for greywater use.

"Intended use" is mentioned because of the high phosphate content in most laundry detergents. High phosphate detergents can be harmful to groundwater, rivers, and streams if left to gather in high concentrations.[71] A maintenance plan and facility management is mentioned because laundry water contains high levels of lint and other

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[70] Appendix B, D, and E are the opinion and conjecture of the author having had over ten years experience with greywater systems and reuse
[71] from Duthie, J.R. (1972) Detergents: Nutrient considerations and assessment, p. 1-3

larger particulates.[72] Laundry water will require much more maintenance in terms of cleaning and replacing filter systems. This is unfortunate because laundry water is typically seen as the highest percentage of greywater produced in the average home at 22.1%[73] (see Chapter 4, Establishing the Calculations, Average Amounts of Greywater Produced.)

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[72] From Ludwig (2010) Builder's Greywater Guide, p. 19-20
[73] From the U.S. Geological Survey (2009) Water Use Trends

APPENDIX C

GREYWATER LEGALITY IN GEORGIA

Effective June 1, 2010

State Senate Bill 370 (10 SB 370/AP) By: Senators Tolleson of the 20th, Bulloch of the 11th, Cowsert of the 46th, Hooks of the 14th, Weber of the 40th and others, Section 2, Chapter 5 of Title 12 of the Official Code of Georgia Annotated, relating to water resources, is amended by inserting in lieu of reserved Code Section 12-5-4 a new Code Section 12-5-4

"(7) Encourage the use of rain water and grey water, where appropriate, in lieu of potable water".

And related to irrigation

Code Section 12-5-7, relating to local variances from state restrictions on outdoor watering, as follows "(4)(C) Reuse of gray water in compliance with Code Section 31-3-5.2 and applicable local board of health regulations adopted pursuant thereto; (D) Use of reclaimed waste water by a designated user from a system permitted by the Environmental Protection Division of the department to provide reclaimed waste water; (E) Irrigation of personal food gardens; (F) Irrigation of new and replanted plant, seed, or turf in landscapes, golf courses, or sports turf fields during installation and for a period of 30 days immediately following the date of installation; (G) Drip irrigation or irrigation using soaker hoses; (H) Handwatering with a hose with automatic cutoff or handheld container; (I) Use of water withdrawn from private water wells or surface water by an owner or operator of property if such well or surface water is on said *property; (J) Irrigation of horticultural crops held for sale, resale, or installation; (K) Irrigation of athletic fields, golf courses, or public turf grass recreational areas; (L) Installation, maintenance, or calibration of irrigation systems; or (M) Hydroseeding.*

Compliance with Code Section 31-3-5.2 is mentioned above which does not state any specific limitations to the use of greywater. The section delineates the legal guidelines for all irrigation not limited to irrigation with greywater. The major limitation related to greywater is that it can only be used in a drip system as opposed to a conventional spray system that could expose humans and animal life to the greywater.[74]

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[74] From the Georgia Environmental Protection Division website (2010) Senate Bill 370 and Georgia State Code Section 31-3-5.2

APPENDIX D

AUTHORS PERSONAL EXPERIENCE WITH RESIDENTIAL GREYWATER SYSTEMS[75]

Because of my professional familiarity with greywater systems I feel qualified to speak personally to the importance their proper maintenance. I have had two situations arise worth mentioning.

The first was a system that did not receive proper maintenance of the particulate filtration sock in addition to bleach tablets not being replaced as prescribed. The self contained unit required a blue dye disk as well as a bleach tablet in the reservoir of the system. This combination was to treat the water and kill organic compounds while the dye served as an indicator. The bleach tablet solved the problem of treating the water. The blue dye disk served as an indicator as to when to replace the bleach tablet. If the water was blue, the bleach tablet was still active. If the water was clear, the bleach tablet needed to be replaced. The failure to replace the bleach tablet caused the reservoir to become contaminated with heavy mold and required an extensive cleaning.

The second scenario was another self contained residential unit for a family consisting of one woman, one man, and three young boys. The woman called to have problem diagnosed that they were experiencing with what appeared to be toilets that were not flushing properly. Our finding was that, at least, the three boys were urinating in the shower. This meant that a high ratio of the reservoir was urine. The concentration was higher than the chemical treatment could eliminate. The result was that the graywater

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[75] Appendix B, D, and E are the opinion and conjecture of the author having had over ten years experience with greywater systems and reuse

returning to the toilets smelled of urine making the homeowner think the toilets were not flushing properly.

These are only two on infinite examples of how human behavior can upset the best planning.

APPENDIX E

AUTHORS EXPLAINATION OF SYSTEM PRICING METHODOLOGY[76]

Greywater reuse systems are newly legal to Georgia as of June 1, 2010. Because of this, competition levels are low. Companies that are entering the market thus far come mainly from companies familiar with rainwater reuse systems. Rainwater reuse companies are themselves, a small market. Adding greywater reuse to their résumé is a natural leap for these companies because of their basic interest in water conservation combined with a familiarity of greywater system basics which are the same for rainwater reuse. The significant difference between rainwater reuse and greywater reuse being the level of chemical treatment.

Because of this low level of competition, competent installers are few. The pricing obtained is from companies that are ahead of the curve with their understanding of the technology. I personally know of their competence and ability to correctly design, price, and install a systems suitable for use in this study.

The same is true for the plumbing company who provided the maintenance contract. Humphrey Plumbing is familiar with the components of the systems priced and would be a good choice to maintain a system installed in Georgia.

I made the decision in establishing the lifecycle costs relevant to this study to obtain actual, current, and local costs rather than using estimates based on vaguely similar systems installed outside of the region, scale, and timeline of this study.

[76] Appendix B, D, and E are the opinion and conjecture of the author having had over ten years experience with greywater systems and reuse

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