IMPLEMENTING RAINWATER HARVESTING SYSTEMS ON THE TEXAS A&M CAMPUS FOR IRRIGATION PURPOSES: A FEASIBILITY STUDY

A Senior Scholars Thesis

by

WILLIAM HALL SAOUR

Submitted to the Office of Undergraduate Research
Texas A&M University
in partial fulfillment for the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

April 2009

Major: Civil Engineering

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Approved by:

Research Advisor: Emily Zechman
Associate Dean for Undergraduate Research: Robert C. Webb

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ABSTRACT

Implementing Rainwater Harvesting Systems on the Texas A&M University Campus for Irrigation Purposes: A Feasibility Study. (April 2009)

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Increasing population and increasing urbanization threatens both the health and availability of water resources. The volume and timing of water that is readily available may not be sufficient to supply the demand for potable water in urban areas. Rainwater harvesting is a water conservation strategy that may help alleviate water scarcity and protect the environment. The benefits of collecting rainwater and utilizing it as irrigation water are both tangible and non-tangible. Through collecting and reusing rainwater, grey water may be utilized as a practical resource. Although grey water is not safe to drink, it is safe for other uses such as toilet water, cleaning water, and irrigation. By utilizing rainwater harvesting, a facility saves the cost of purchasing potable water from the local water supply, and the local water supply is not as stressed. In addition, the volume of runoff that flows into local rivers will be reduced, and as a result, the erosion of river banks will be lessened, and ecosystem health may be sustained. The use of rainwater harvesting contributes to the sustainability of building design, calculated using LEED points. This study investigates the water conservation, economic, LEED design, and stormwater benefits of rainwater harvesting for the Texas A&M Campus. With tangible

and non-tangible benefits, rainwater harvesting should prove to be a viable and appropriate solution to the conserving and sustaining of natural resources on Texas A&M University's campus.

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The author expresses thanks and appreciation to the Texas A&M Physical Plant, Engineering Design Services (TAMU PP/EDS), College Station, Texas, Gary Struzick of Klotz Associates, and Anthony Holder of Turner, Collie and Braden, both of Houston, Texas for their help and sharing of valuable storm water, rainfall, survey, and data base information. This additional information was gathered in a separate project funded by Texas A&M Utilities, College Station, Texas and managed by TAMU PP/EDS. I must mention Chris Matus of the Texas A&M University Campus Mapping Office and Frank Wurbs of Texas A&M Utilities Plant Office for allowing me to use their data to pursue this study.

NOMENCLATURE

LEED	Leadership in Energy and Environmental Design
USGBC	United States Green Building Council
RHS	Rainwater Harvesting System
TAMU	Texas A&M University

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CHAPTER I

INTRODUCTION

Traditional urban development increases the imperviousness of land, which alters the natural hydrologic processes. Urbanization results in an increase of total runoff volume, increased peak runoff flow, decreased time to concentration, and deteriorated water quality (Dietz et al. 2007). Best Management Practices (BMPs) are a set of techniques, measures, or structural controls that are used to prevent or reduce the degradation of runoff water quality and/or quantity (U.S. EPA 2004). BMPs for stormwater control are typically designed to reduce alterations in runoff volumes based on a peak flow value. Some BMPs includes bio-retention areas, green roofs, permeable pavements, and rainwater harvesting systems.

Rainwater harvesting is an ancient practice that has been increasingly receiving attention in the world, fueled by water shortages from droughts, pollution and population growth (Nolde 2007; Meera and Ahameed 2006). While originally used to collect water in depressions for irrigation, the practice of collecting rainfall from rooftops was later adapted for domestic water supply in rural areas and islands (Kahinda et al. 2007; Michaelides and Young 1983). Recently, environmental concerns have increased the appeal of green building practices, including rainwater harvesting systems, in urban areas. Rainwater harvesting is especially appealing as it combines the benefits of water

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This thesis follows the format and style of the *Journal of Water Resources Planning and Management*.

reuse with runoff reduction and groundwater recharge.

Rainwater harvesting systems (RHS) have been proposed to conserve rainwater and reuse it for landscaping. Although RHS have not been fully implemented in most residential areas, it has been accepted as a proper means to conserve water by cities and counties around Texas and may eventually appear in residential neighborhoods. In the eyes of the public, "Storing and reusing rainwater not only cuts down on utility bills and saves treated city water for drinking and bathing… it also helps reduce stormwater runoff into streets- recently listed by the U.S. Environmental protection agency as one of the major sources of water pollution in the country" (Sewell 2008). Thus, companies and neighborhoods that utilize RHS contribute to the conservation of local resources in a cost-effective approach.

The main Texas A&M University (TAMU) campus has become increasingly urbanized, resulting in areas of imperviousness that generate higher rates of runoff. This growth has proceeded unchecked, and significant growth and development are planned for the future. Both increased rates of runoff from previous development and the impact of anticipated development should be addressed through mitigation efforts. RHS may prove a useful strategy for the TAMU campus.

The objective of this research is to determine the feasibility of implementing rainwater harvesting systems on TAMU's existing buildings located in West Campus and using the collected water to irrigate the local landscape. Pumps may be necessary for irrigation purposes, and storage facilities, such as detention basins, must be considered to provide a convenient means of holding and distributing the water to the landscape. These issues will be investigated to determine a plan for the implementation of RHS on campus. This study will determine the efficiency of RHS in conserving potable water, reducing irrigation costs, reducing the amount runoff flowing into White Creek, and contributing to LEED points.

CHAPTER II

THE RAINWATER HARVESTING SYSTEM

The three components of a RHS are the catchment, the detention basin, and the conveyance system. The most important element in the RHS is the catchment, which is used to collect rainfall. Typical RHS use building roofs as catchments. The detention basin holds rainwater and must be sized and shaped for the amount of rainwater directed from the building. Detention basins are evaluated based on the capacity to store the necessary amount of water for irrigation. Fiberglass underground storage tanks will be used as the detention basins for the purpose of this study. With these two elements of the system determined, the conveyance systems can be situated. The conveyance system serves as a conduit to allow the collected rainwater to travel from one point to another. TAMU's RHS include three conveyance systems: (1) collection, (2) irrigation, and (3) wastewater.

The collection system carries the water from the catchment to the detention basin, which allows the water to be stored for future irrigation use. A First Flush System and filter should be applied in the collection system to eliminate any debris or waste that may flow into the system, as illustrated in Figure 2-1.

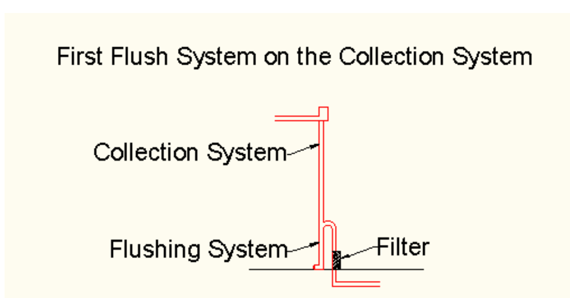

Figure 2-1. First Flush System on the collection system.

The irrigation system carries water from the detention basin to the irrigation system; this system allows the surrounding landscape to be properly irrigated. Pumps may be necessary for the irrigation system so the water will reach its specified destination at a specified flowrate. The wastewater system directs overflowing water to the storm sewer so that other parts of the system will not sustain damages. The elements of the RHS are shown in Figure 2-2.

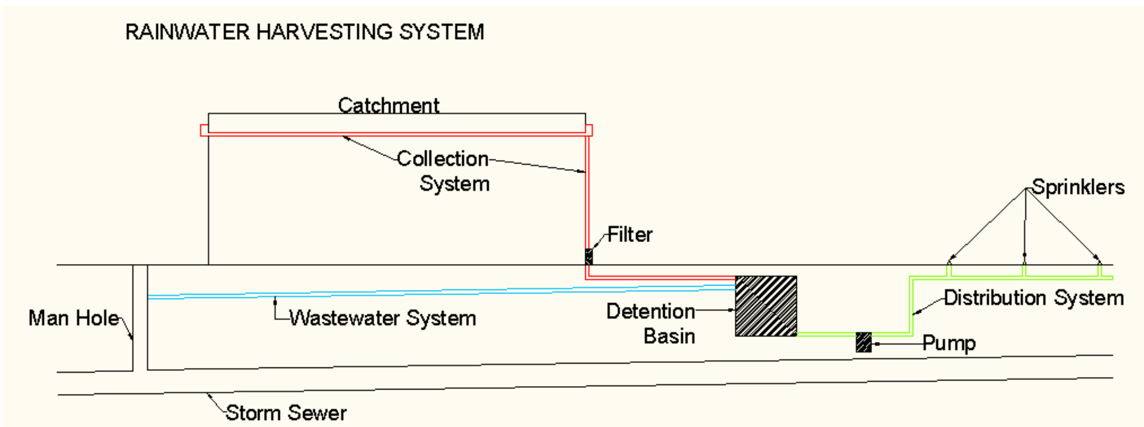

Figure 2-2. RHS with storage tank below ground.

The placement of the detention basin or storage tank between the conveyance systems can be designed using several options. In Figure 2-2, the tank is placed underground. The advantages of placing the storage tank below ground consist of the tank's visual absence, safety, and the value of land; however, underground storage may not be appropriate for larger tanks and may cause maintenance problems as the tank is not easily accessible. Alternatively, the tank may be placed above ground as shown in Figure 2-3.

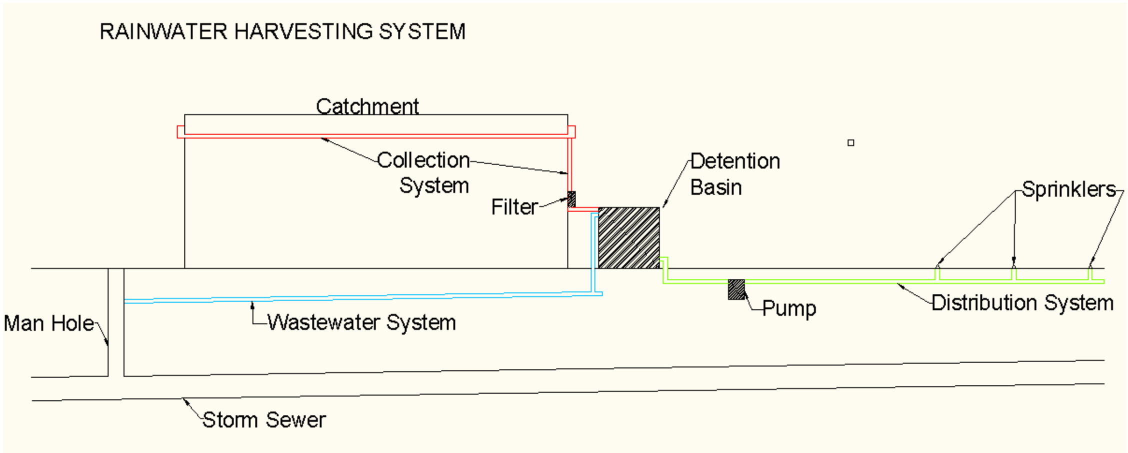

Figure 2-3. RHS with the detention basin or storage tank above ground.

The advantages to an above ground storage tank are more cost-effective installation and easy access for maintenance. Since the tank is above ground, the tank becomes an obstruction to its surroundings and may be damaged based on exposure to the elements or vandalism. For the TAMU case study, underground storage tanks will be designed.

In designing an RHS, multiple buildings may be connected to one tank, as illustrated in Figure 2-4. Since tanks have a limited number of sizes in order to be more economical,

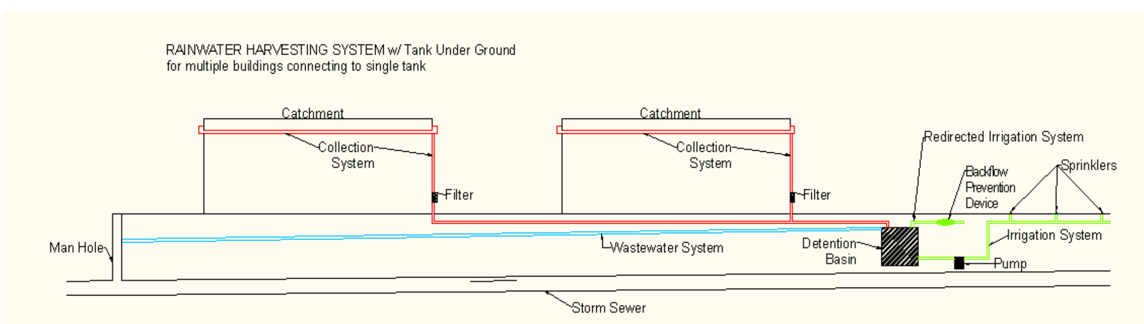

Figure 2-4. RHS with multiple buildings Attached to a single storage tank.

multiple buildings feed their collected water into the same tank. This method of adjoining buildings to the same storage tank is both efficient and cost effective, but it is only applicable to certain scenarios. Although both cases present problems and benefits, the RHS will have all the same elements and same objective. For the purpose of this study we will be using underground tanks due to the usage of land and the redirection of the irrigation systems, which will be explained in Chapter III.

CHAPTER III

RHS DESIGN FOR TAMU CAMPUS

A comprehensive RHS is designed here for a Watershed D on the West Campus of Texas A&M University. Watershed D encompasses 786 acres and contributes flow to White Creek, shown in Figure 3-1. Both Tributary D and White Creek have experienced erosion due to increased flow velocities.

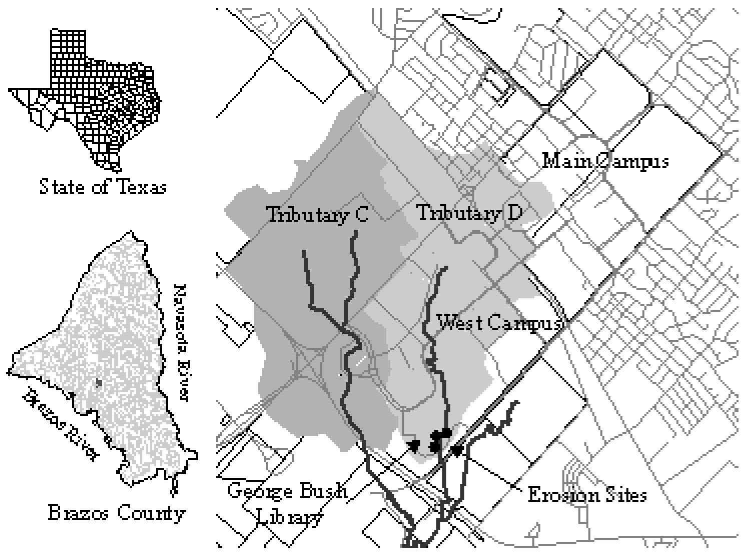

Figure 3-1. Location of Texas A&M University, West Campus Watersheds C and D, and the locations of erosion problems (AECOM).

In Watershed D, there are a total of 240 buildings with approximately 89 acres of roof area that can serve as catchments (Figure 3-2). One hundred thirteen buildings, with a total roof area of 60.5 acres, have been selected for installation of a RHS, based on building groupings, rooftop area, and proximity to landscaped areas.

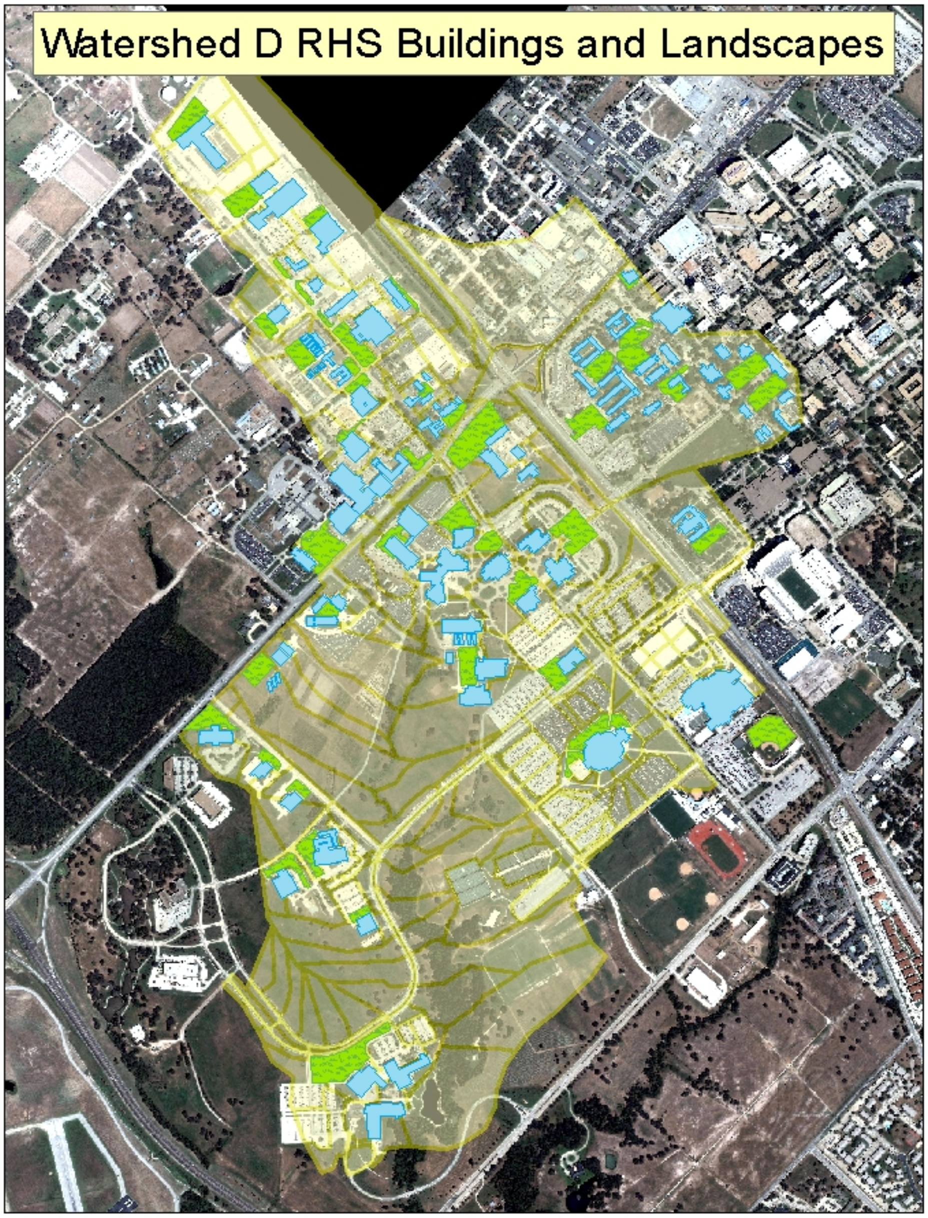

Figure 3-2. Location of buildings highligted in blue in Watershed D.

A total of 43 RHS have been designed to store and release runoff from these 113 buildings. Since the average annual rainfall is 39 inches in College Station, the 113 buildings have the potential to collect about 60,850,000 gallons of water per year if 100% of the rainfall is collected over the entire year. Based on the potential amount of rainfall to be collected, this would save over $406,000.00 per year at $ 2.44 per 1,000 gallons (City of College Station 2008). The locations of the RHS can be found in the Appendix. Figure A-1 gives a general view of the watershed with the buildings underlined RHS number, while the landscape displays its circled RHS number. Figures A-2 through A-5 give a clearer view of RHS based their regional location in Watershed D.

To design the detention basin for the RHS, the amount of water needed for irrigation and the amount of rainwater collected for typical storms should be calculated. The area of the catchment ($Area_R$) is calculated as follows:

$$Area_R(ft^2) = Length(ft) * Width(ft) \qquad (1)$$

The amount of water that is supplied by rainfall (SUPPLY) and the water demand for the landscaped area that is near to the building (DEMAND) are calculated in gallons:

$$SUPPLY(gallons) = P(in) * Area_R(ft^2) * C * 0.623 \qquad (2)$$

$$DEMAND(gallons) = I(in) * Area_I(ft^2) * 0.623 \qquad (3)$$

where P is the amount of annual rainfall that falls in the specific location the RHS will be implemented. The parameter C is a runoff coefficient that relates rainfall to runoff, based on runoff coefficients used for the Rational Method, and is based on the material and inclination of the roof. The conversion factor 0.623 allows the supply to be calculated in gallons with the listed units for each variable. The amount of irrigation water the landscape requires per year to be properly watered is I, and $Area_I$ is the designated landscape that will be irrigated (Persyn, Porter, Silvy 2008).

The tanks that will be used are manufactured and priced by Darco, Inc. In Table 3.1, the listed sizes, diameters, length, and estimated prices are shown for different sized underground tanks.

Table 3.1. Darco, Inc. underground water tanks.

DARCO, INC. UNDERGROUND WATER TANKS			
Size of Tanks (gal)	Diameter of Tanks (ft)	Length (ft)	Price of Tanks ($)
10,000*	10		**12,676.00**
20,000	10	35	**27,589.00**
30,000*	12	48.53	**38,027.00**
40,000	12		**49,712.00**
50,000	12	60.42	**59,023.00**

It should be noted that these tanks include: "one of the 30"Dx24"T manway collar with riser to grade; one of the 6" PVC vent head-screened; two of the 8" diameter PVC pipe stubs each with flexible pipeline coupling (for inlet & overflow); one of the 4" flanged discharge nozzle with flexible pipeline coupling; shipping pads; heavy duty lifting lugs" (Eisenman 2009). Darco, Inc. has also stated, "freight and current fuel surcharge have been ESTIMATED and delivery to College Station, TX, is included in this quote" (Eisenman 2009). Please note the asterisk next to the 10,000 and 30,000 gallon tanks in Table 3.1; these tanks have not been estimated by Darco, Inc., yet these estimations are necessary to complete the feasibility study of RHS.

Two scenarios are compared for their efficiency in conserving water and meeting irrigation demands. Both scenarios have the potential to conserve millions of gallons of water. In RHS Scenario 1, the tanks are sized to store a 2-year 24-hour storm (2-year storm), which is the equivalent of 4.42 inches of rainfall. For RHS Scenario 2, the tanks are designed to collect 3 inches of rainfall for each storm. The maximum amount of storage achieved by each design is 60 million gallons per year, based on the assumption that all the rain that falls can be held in the RHS. This assumption, however, would only be true in years in which there were no rain events exceeding 4.42 inches for RHS Scenario 1, and 3 inches for RHS Scenario 2. A more in-depth analysis is necessary to predict the amount of water that would actually be stored using each system for a typical annual rain series. For the purpose of this study, it is assumed that RHS Scenario1 would be more likely to store the maximum amount of annual rain and RHS Scenario 2 would be less likely to reach this maximum. The total cost for the RHS tanks of RHS Scenario 1 and RHS Scenario 2 are $8,530,000 and $5,800,000, respectively. The return period, or the time it takes to recover the initial costs through water savings, is 20 years for RHS Scenario 1 and 14 years for RHS Scenario 2. The data supporting these values are listed in Table 3-2.

Table 3-2. RHS Water Conservation Savings and Cost.

RHS	Area (sft)	Supply (gal)	Demand (gal)	Supply/Demand	Savings per year ($)	Initial Cost ($) Scenario 1	Initial Cost ($) Scenario 2
1	53,456	1,233,891	1,523,322	81%	$ 3,737.73	$ 174,351.00	$ 128,004.00
2	152,960	3,530,646	4,645,587	76%	$ 11,385.56	$ 476,541.00	$ 348,976.00
3	90,089	2,079,458	4,621,018	45%	$ 11,385.56	$ 276,357.00	$ 189,745.00
4	115,496	2,665,891	4,518,460	59%	$ 11,106.59	$ 354,138.00	$ 236,092.00
5	42,189	973,820	2,631,945	37%	$ 6,503.79	$ 130,722.00	$ 99,424.00
6	77,488	1,788,599	8,129,995	22%	$ 20,093.54	$ 236,092.00	$ 175,478.00
6b	30,818	711,343	3,556,717	20%	$ 8,863.97	$ 59,023.00	$ 76,054.00
7	67,929	1,567,952	3,646,400	43%	$ 8,938.48	$ 226,437.00	$ 152,228.00
8	32,388	747,592	3,559,960	21%	$ 8,842.71	$ 99,424.00	$ 76,054.00
9	180,758	4,172,290	11,920,829	35%	$ 29,229.50	$ 558,796.00	$ 381,727.00
10	24,811	572,700	1,101,347	52%	$ 2,681.61	$ 86,612.00	$ 59,023.00
11	69,090	1,594,741	3,543,869	45%	$ 8,591.77	$ 228,162.00	$ 152,108.00
12	35,772	825,690	3,058,111	27%	$ 7,460.62	$ 118,046.00	$ 76,054.00
13	21,392	493,769	1,410,768	35%	$ 3,438.33	$ 76,054.00	$ 49,712.00
14	16,187	373,626	1,624,461	23%	$ 3,935.96	$ 49,712.00	$ 38,027.00
15	41,029	947,035	4,509,691	21%	$ 11,105.27	$ 84,375.00	$ 99,424.00
16	29,566	682,457	4,014,452	17%	$ 10,050.19	$ 25,352.00	$ 25,352.00
17	185,633	4,284,816	7,934,844	54%	$ 19,357.57	$ 548,238.00	$ 394,539.00
18	31,858	735,359	1,838,397	40%	$ 4,542.21	$ 112,100.00	$ 71,699.00
19	39,526	912,352	950,367	96%	$ 2,313.91	$ 118,046.00	$ 87,739.00
20	40,857	943,074	1,473,554	64%	$ 3,623.28	$ 118,046.00	$ 87,739.00
21	33,559	774,610	3,622,045	21%	$ 8,837.79	$ 93,206.00	$ 78,293.00
22	15,944	368,017	1,143,992	32%	$ 2,791.34	$ 49,712.00	$ 38,027.00
23	20,054	462,894	2,180,682	21%	$ 5,320.86	$ 59,023.00	$ 49,712.00
24	81,067	1,871,205	5,195,755	36%	$ 12,677.64	$ 266,189.00	$ 177,069.00
25	122,795	2,834,363	5,212,417	54%	$ 12,718.30	$ 381,727.00	$ 263,681.00
26	58,233	1,344,150	1,821,931	74%	$ 4,445.51	$ 177,069.00	$ 118,046.00
27	11,212	258,806	758,689	34%	$ 1,851.20	$ 38,027.00	$ 27,589.00
28	10,175	234,861	1,010,131	23%	$ 2,464.72	$ 38,027.00	$ 27,589.00
29	21,431	494,680	575,741	86%	$ 1,404.81	$ 59,023.00	$ 49,712.00
30	26,609	614,195	1,045,360	59%	$ 2,550.68	$ 12,676.00	$ 12,676.00
31	83,246	1,921,501	4,977,891	39%	$ 12,146.05	$ 263,681.00	$ 236,092.00
32	20,792	479,934	775,782	62%	$ 1,892.91	$ 80,530.00	$ 50,704.00
33	34,827	803,892	2,120,564	38%	$ 5,174.18	$ 108,735.00	$ 76,054.00
34	11,788	272,088	711,184	38%	$ 1,735.29	$ 38,027.00	$ 27,589.00
35	101,488	2,342,573	7,151,609	33%	$ 17,449.93	$ 326,069.00	$ 156,073.00
36	55,447	1,279,830	3,460,641	37%	$ 8,443.96	$ 196,849.00	$ 133,471.00
37	11,788	272,088	711,184	38%	$ 7,554.05	$ 175,478.00	$ 116,319.00
38	55,676	1,285,128	5,065,333	25%	$ 12,359.41	$ 189,401.00	$ 90,968.00
39	101,921	2,352,555	10,726,221	22%	$ 26,171.98	$ 337,017.00	$ 238,360.00
40	52,325	1,207,771	3,492,948	35%	$ 8,522.79	$ 193,123.00	$ 118,046.00
41	209,436	4,834,233	14,668,418	33%	$ 35,790.94	$ 649,253.00	$ 447,408.00
42	117,004	2,700,704	6,802,351	40%	$ 16,597.74	$ 366,814.00	$ 248,768.00
Total	**2,636,114**	**60,847,180**	**163,444,963**		**$ 406,090.24**	**$ 8,256,280.00**	**$ 5,787,444.00**

Once the sizes of the tanks are completed, the conveyance system must be designed. Since the conveyance system consists of three parts: the collection system, wastewater system, and irrigation system, the system's pipes must be sized separately.

The collection system's pipes will encounter heavy flow from the catchment into the water tank; thus, the pipes must be large enough to handle this kind of flow. Since the inlets of the tanks are all 8 inches in diameter, the collection system's pipes will be sized at 8 inches in diameter. This will allow for all the potentially collected water from heavy rainfall to be directed to the water tanks at an efficient flow rate. The same will be for the wastewater system that leads to the storm sewer. Its stub is also 8 inches in diameter; thus, the wastewater system's pipe should be sized at 8 inches to send the overflowing water to the storm sewer at an appropriate flow rate. In order to correctly arrange the distribution system, the available options for integrating the irrigation systems must be studied.

There are a couple of options in determining how to distribute the collected rainwater to the landscape. One option is creating an entirely new irrigation system. The drawbacks to creating a new system are that the old system must still be available if there is not sufficient rainfall to irrigate the landscape. With a new irrigation system, there will be problems with the amount of available space for another system and the cost of designing and constructing an entirely new irrigation system. The other option is tying the collected rainwater into the existing irrigation system. This option is easy and economical, but the systems must be properly managed. It is understood that collected rain water is identified as grey water; therefore, it is not allowed to be redistributed in potable water pipe lines unless it has been properly treated to fit the standards of potable water (Wurbs 2008). TAMU's irrigation water comes from TAMU's local water supply, so the irrigation water is identified as potable. The collected grey water is not to be mixed with potable water in case of backflow. However, potable water is allowed to be mixed with grey water, so potable water can be pumped from the local water supply into the tanks of the RHS if extra water is necessary for irrigation. By rerouting the irrigation water pipes to flow into the RHS and inserting a backflow prevention device on the redirected irrigation water pipe, the current irrigation system is used rather than creating a new irrigation system. The RHS irrigation system leads from the water tank to the current irrigation system.

CHAPTER IV

HYDROLOGIC IMPACT

One benefit of installing a RHS is that the amount of runoff from the watershed will be reduced. The area considered in this study is located in TAMU's Watershed D, and the buildings that affect the amount of runoff are all located in this particular area as seen in Figure 3-2. Hydrologic modeling of the watershed is completed as part of this investigation to observe the effects of the RHS on the amount of runoff that leads into White Creek.

A hydrologic and hydraulic model of Watersheds C and D in West Campus for current conditions was developed by AECOM (AECOM 2008). Geographical, hydrologic, and meteorological information were incorporated within HEC-HMS (US Army Corps of Engineers 2008) for hydrologic simulation. Watershed D was divided into sub-watersheds, delineated corresponding to storm sewer manholes, culverts, channel junctions, buildings, and streets. Curve numbers for the watershed, specified in the Bryan-College Station Unified Design Guidelines (2007), are specified as 77 for landscaped areas. Streets, building roofs, and parking lots contribute to the percentage imperviousness for each sub-catchment. The Storm Water Management Model (SWMM) (U.S. EPA 2008) was used for hydraulic simulation. SWMM is a dynamic rainfall-runoff simulation model for both flow and water quality of a single storm event or a long-term continuous storm event. SWMM extracts the flow hydrograph information from HEC-HMS at sub-basins to route hydrographs through sewers, conduits, and open channels (AECOM 2008). The hydraulic model consists of a combination of links and nodes representing the storm water infrastructure, composed of box and circular storm sewers and open channels.

The curve number for a RHS is calculated using an approach for calculating the curve number for pervious pavements (Leming 2007). This method approximates the initial abstraction as the volume of water stored by the RHS, based on the storage capacity of the system. This initial abstraction is then used to calculate the curve number. This approach was modified to provide a more conservative estimate, by assuming that once the RHS is full, the runoff will mimic runoff from a conventional rooftop, with a curve number of 98. We conducted regression to identify the curve number that best approximates this behavior and found a curve number of 65 (Figure 4-1). We replaced rooftops in Watershed D with a curve number of 65.

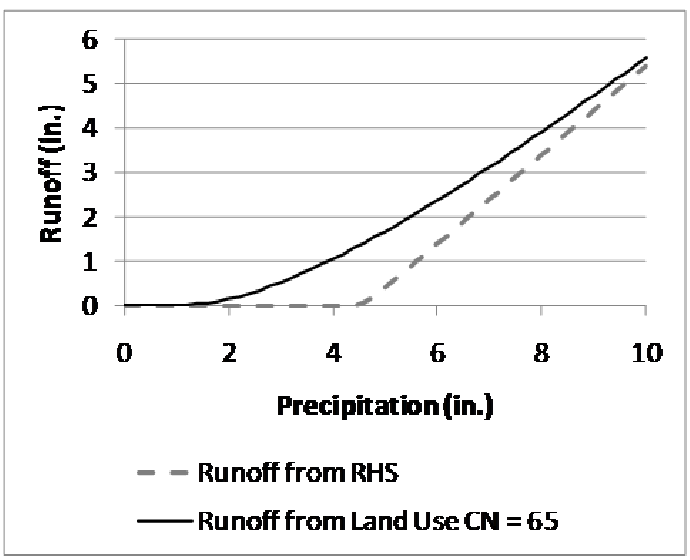

Figure 4-1. Representing RHS using a curve number of 65.

Using a curve number of 65 for RHS implementations, the composite curve number of the watershed is changed from 85.6 to 84.6. The land use information and corresponding curve numbers are shown in Table 4-1.

Table 4-1. Land use and curve number information for present conditions (no RHS) and for RHS design for RHS Scenario 1 (2-year storm)

Designs	Pervious Land Cover	Impervious Land Cover
Present (no RHS)	59% Land : CN - 77	41% Land : CN - 98
RHS for Scenario 1	59% Land : CN - 77 3% Land : CN - 65	38 % Land : CN - 98

The hydrologic model was changed to reflect the new curve numbers for each sub-basin based on the amount of roof area that was used to collect rainwater for an RHS.
Three rain events, including a 2-yr, 10-yr, and 100-yr 24-hr storms, were simulated under both current conditions (no RHS) and RHS Scenario 1 (Figures 4-2, 4-3, and 4-4). The peak flow for the 2-year storm is reduced slightly from 21.7 to 20.6 cubic meters per second. The implementation of RHS does not affect the discharge of runoff of Watershed D into White Creek significantly for the 10 year-storm and 100-year storm. The limited affect of the RHS on Watershed D’s curve number is due to the amount of undeveloped land in the watershed. RHS have a limited impact on managing stormwater for TAMU campus due to the small amount of area of roof compared to the total area of Watershed D.

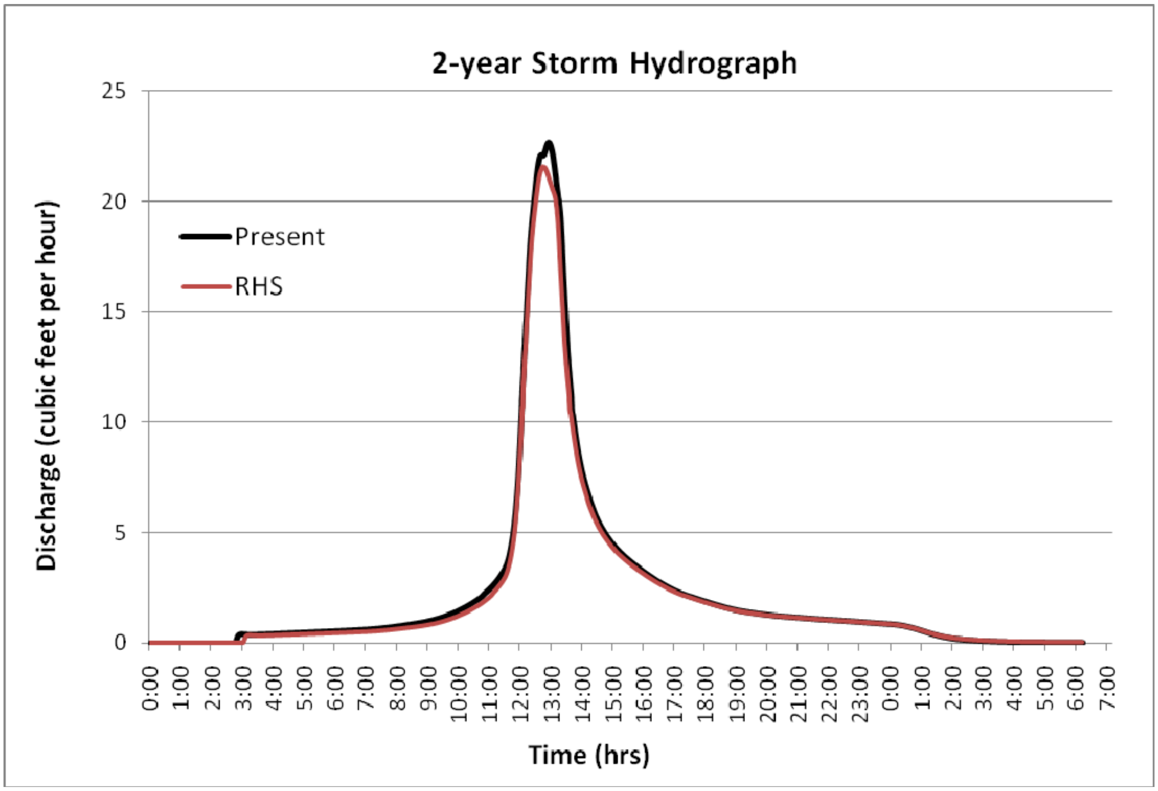

Figure 4-2. Hydrograph for present conditions and RHS Scenario 1 for a 2-yr 24-hr storm.

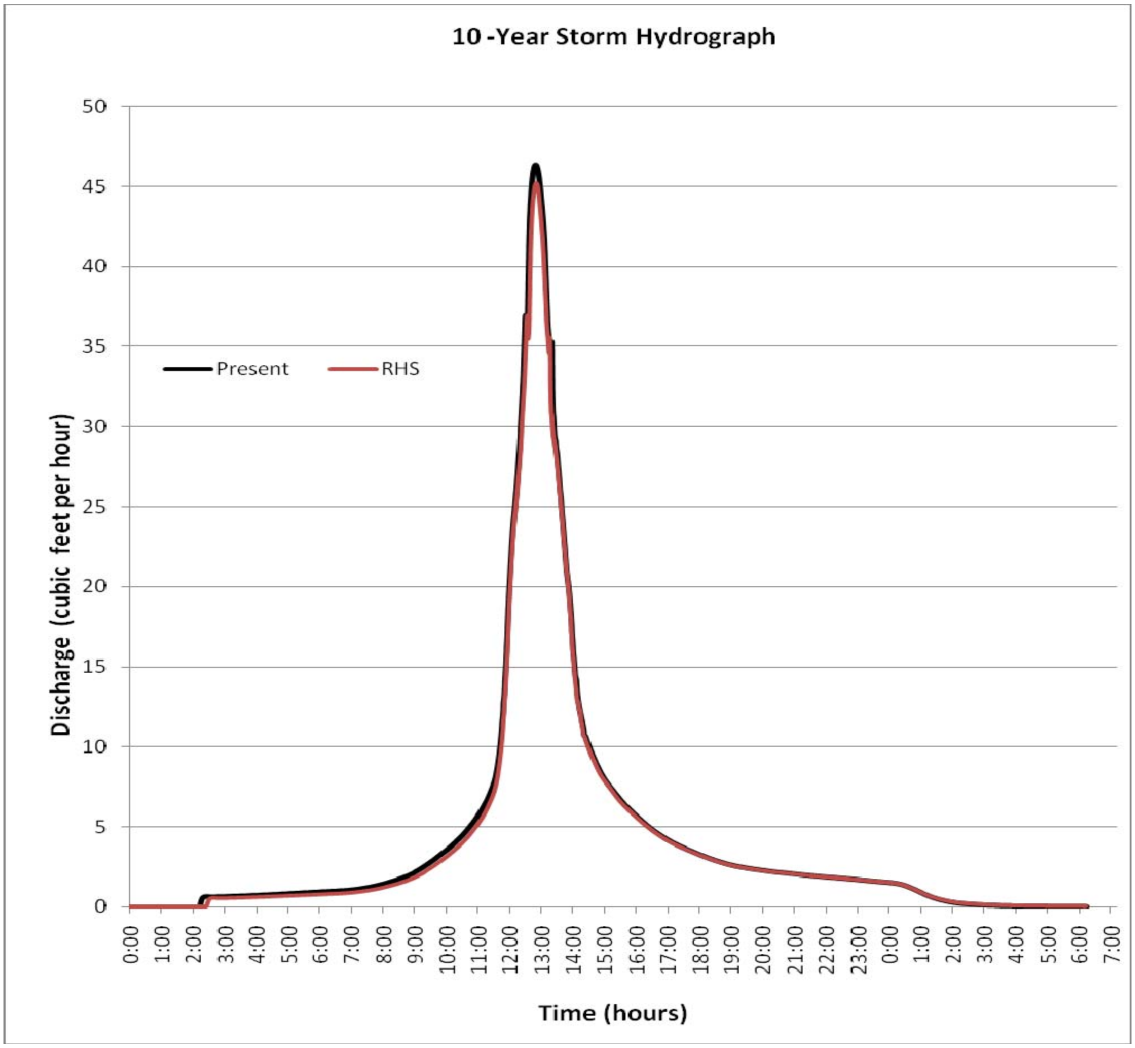

Figure 4-3. Hydrograph for present conditions and RHS Scenario 1 for a 10-yr 24-hr storm.

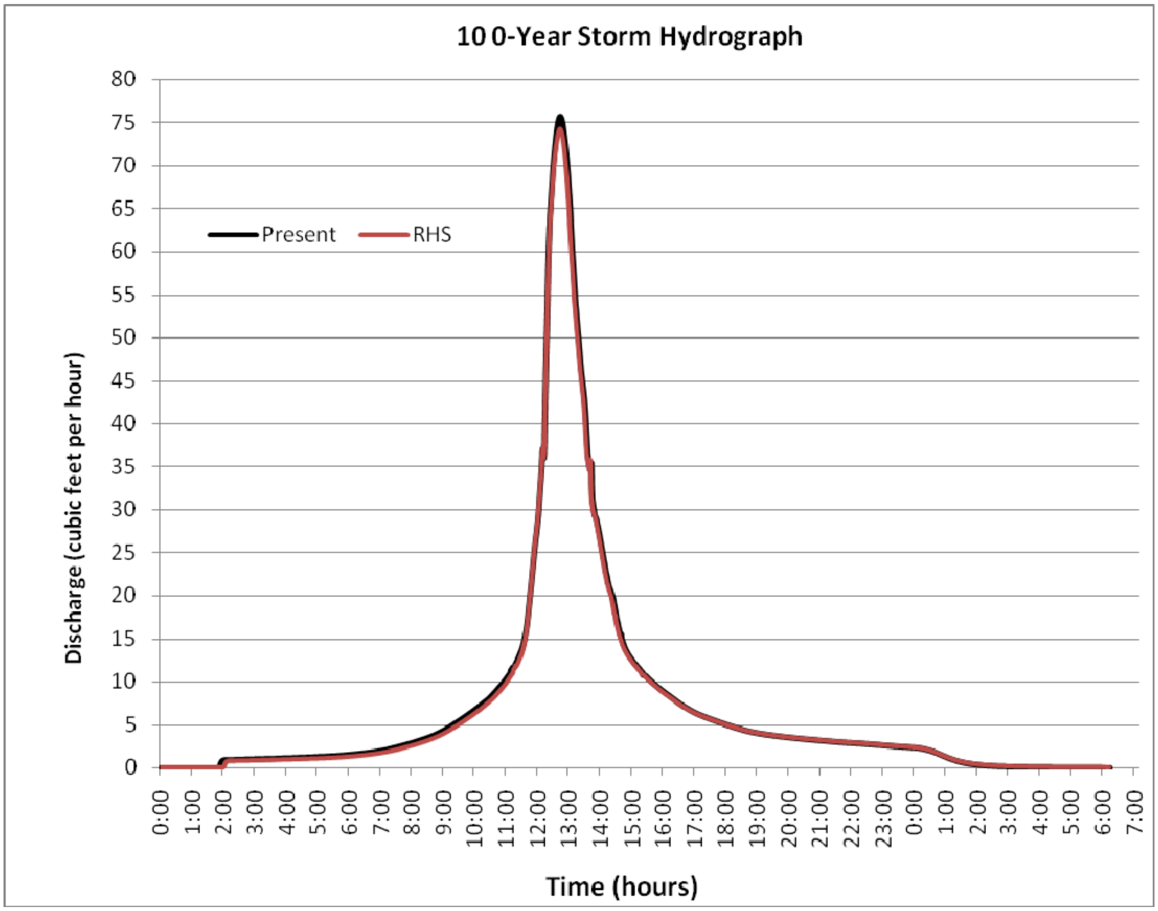

Figure 4-4. Hydrograph for present conditions and RHS Scenario 1 for a 100-yr 24-hr storm.

CHAPTER V

LEED POINTS

United States Green Building Council (USGBC) is an organization of engineers who address conservation problems in realistic and practical ways. In order to encourage engineers to use conservation tactics, USGBC has created Leadership in Energy and Environmental Design (LEED), which "is a benchmark for the design, construction and operation of high- performance green buildings" (Sewell 2008). Green buildings that are LEED certified help protect the environment while saving the owner money through both tangible and non-tangible benefits. Although the initial cost of constructing a LEED certified green building may not seem attractive, the cost benefits over time are much more lucrative. President Barack Obama supports USGBC's efforts in creating LEED certified green buildings by proposing "the expansion of federal grants to assist states and localities in building more efficient public buildings through the use of LEED" (USGBC November 2008). Through LEED, USGBC is investigating the implementation of cheap and environmentally friendly ways to reuse rainwater runoff from gutters in residential areas (USGBC 2006).

The purpose of USGBC's LEED points is to create a rating system that defines a green building based on a set of standards of sustainability. In reference to this, the USGBC states, "A sustainable building maximizes operational efficiency while minimizing environmental impacts" (USGBC September 2008). In order to accomplish the task of creating a sustainable building, the USGBC will rank the building based on LEED points to classify the building's level of sustainability. There are many creative ways to receive

LEED points, and rainwater harvesting is one of the applicable methods to obtain them. The accumulation of LEED points through the implementation of RHS on TAMU campus for irrigation purposes falls into 2 categories: SS-Credit 6: Stormwater Management and WE Credit 3.1-3.3: Water Efficient Landscaping. The requirements of the SS-Credit 6: Stormwater Management is listed below and will receive 1 LEED point for each building to which it is applied.

> During the performance period, implement a stormwater management plan that infiltrates, collects and reuses runoff or evapotranspirates runoff from at least 15% of the precipitation falling on the whole project site both for an average weather year and for the two-year, 24-hour storm. Implement an annual inspection program of all stormwater management facilities to confirm continued performance. Maintain documentation of inspection, including identification of areas of erosion, maintenance needs, and repairs. Perform all routine required maintenance, necessary repairs or stabilization within 60 days of inspection. (USGBC September 2008).

In theory, all of the buildings involved in this study should receive at least one point for this credit for the RHS Scenario 1. For RHS Scenario 2, however, no points would be awarded. The requirements to receive the WE Credit 3.1-3.3: Water Efficient Landscaping is listed below and allows up to 3 points per building.

> Reduce potable water or other natural surface or subsurface resource consumption for irrigation compared with conventional means of irrigation. If the building does not have separate water metering for irrigation systems, the water-use reduction achievements can be demonstrated through calculations. Points are earned according to the following schedule:
>
> - WE Credit 3.1 (1 point): 50% reduction in potable water or other natural surface or subsurface resource use for irrigation over conventional means of irrigation.
> - WE Credit 3.2 (2 points): 75% reduction in potable water or other natural surface or subsurface resource use for irrigation over conventional means of irrigation.
> - WE Credit 3.3 (3 points): 100% reduction in potable water or other natural surface or subsurface resource use for irrigation over conventional means of irrigation. (USGBC September 2008).

There are only a few buildings from this study that meet the criteria for this credit. For both scenarios, the buildings listed in RHS numbers 4, 10, 17, 20, 25, 26, 30, and 32 will receive one point, while the buildings listed in RHS numbers 1, 2, 19, and 29 will receive two points. Unfortunately, no buildings in this study will meet the criteria to receive three points from this credit alone, but all the credits for each RHS are listed in Table 5-1. Although there are not any points befitting the WE Credit 3.3, the total amount of points for the Water Efficient Landscaping category comes to 36. For RHS Scenario 1 and RHS Scenario 2, the total amount of LEED points received from both WE Credit 3.1-3.3 and WE Credit 3.1-3.3 credits comes to 149 and 36, respectively. With the LEED points found for the implementation of RHS to existing buildings on TAMU campus, other advantages should ensue such as possible tax reductions and benefits.

Table 5-1. RHS LEED points for Scenarios 1 and 2.

RHS	SS-Credit 6: Stormwater Management RHS Scenario 1	SS-Credit 6: Stormwater Management RHS Scenario 2	WE Credit 3.1-3.3: Water Efficient Landscaping RHS Scenario 1	WE Credit 3.1-3.3: Water Efficient Landscaping RHS Scenario 2
1	4	0	8	8
2	7	0	7	7
3	3	0	0	0
4	2	0	2	2
5	1	0	0	0
6	2	0	0	0
6b	1	0	0	0
7	4	0	0	0
8	1	0	0	0
9	3	0	0	0
10	1	0	1	1
11	1	0	0	0
12	1	0	0	0
13	1	0	0	0
14	1	0	0	0
15	1	0	0	0
16	5	0	0	0
17	4	0	4	4
18	2	0	0	0
19	1	0	2	2
20	1	0	1	1
21	13	0	0	0
22	1	0	0	0
23	1	0	0	0
24	1	0	0	0
25	2	0	2	2
26	1	0	1	1
27	1	0	0	0
28	1	0	0	0
29	1	0	2	2
30	2	0	2	2
31	1	0	0	0
32	4	0	4	4
33	3	0	0	0
34	1	0	0	0
35	5	0	0	0
36	8	0	0	0
37	4	0	0	0
38	5	0	0	0
39	8	0	0	0
40	1	0	0	0
41	1	0	0	0
42	1	0	0	0
	113	0	36	36

CHAPTER VI

CONCLUSION

The implementation of RHS on TAMU campus for irrigation purposes proves to have numerous beneficial aspects. Although it does not have a large hydrologic impact on the amount of runoff flowing from Watershed D into White Creek, the water conservation RHS produce is remarkable. RHS have the potential to save 60,850,000 gallons of water per year spent on irrigation alone. Even though this practice is expensive, the cost for storage tanks will be repaid from the savings on water payments in 20 years for RHS Scenario 1 and 14 years for RHS Scenario 2. Along with the tangible benefits of the RHS, the non-tangible benefits contribute to the overall reward of using the rainwater harvesting. The achievement of 149 LEED points for RHS Scenario 1 and 36 LEED points for RHS Scenario 2 contribute not only to the community, but also to the tax breaks TAMU will receive. RHS are a long term investment that demonstrates how effectively they conserve water and money on an annual basis. Water continues to be the most important resource and rainwater harvesting is the perfect solution to aid in the conservation of potable drinking water. The implementation of RHS for irrigation purposes prove to be a valuable practice that should be implemented on TAMU campus.

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APPENDIX A

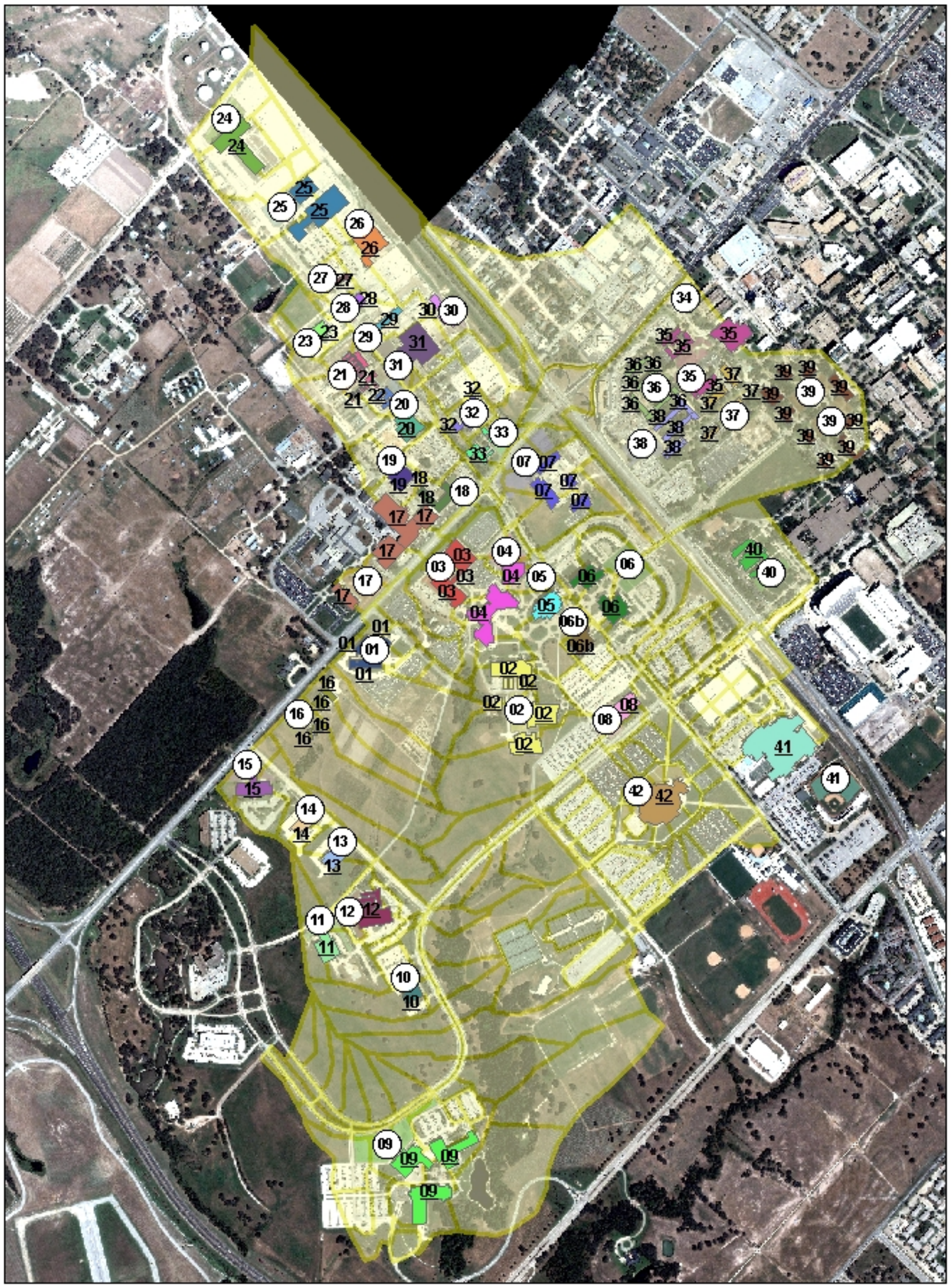

Figure A-1. Watershed D's RHS numbered by buildings and landscapes.

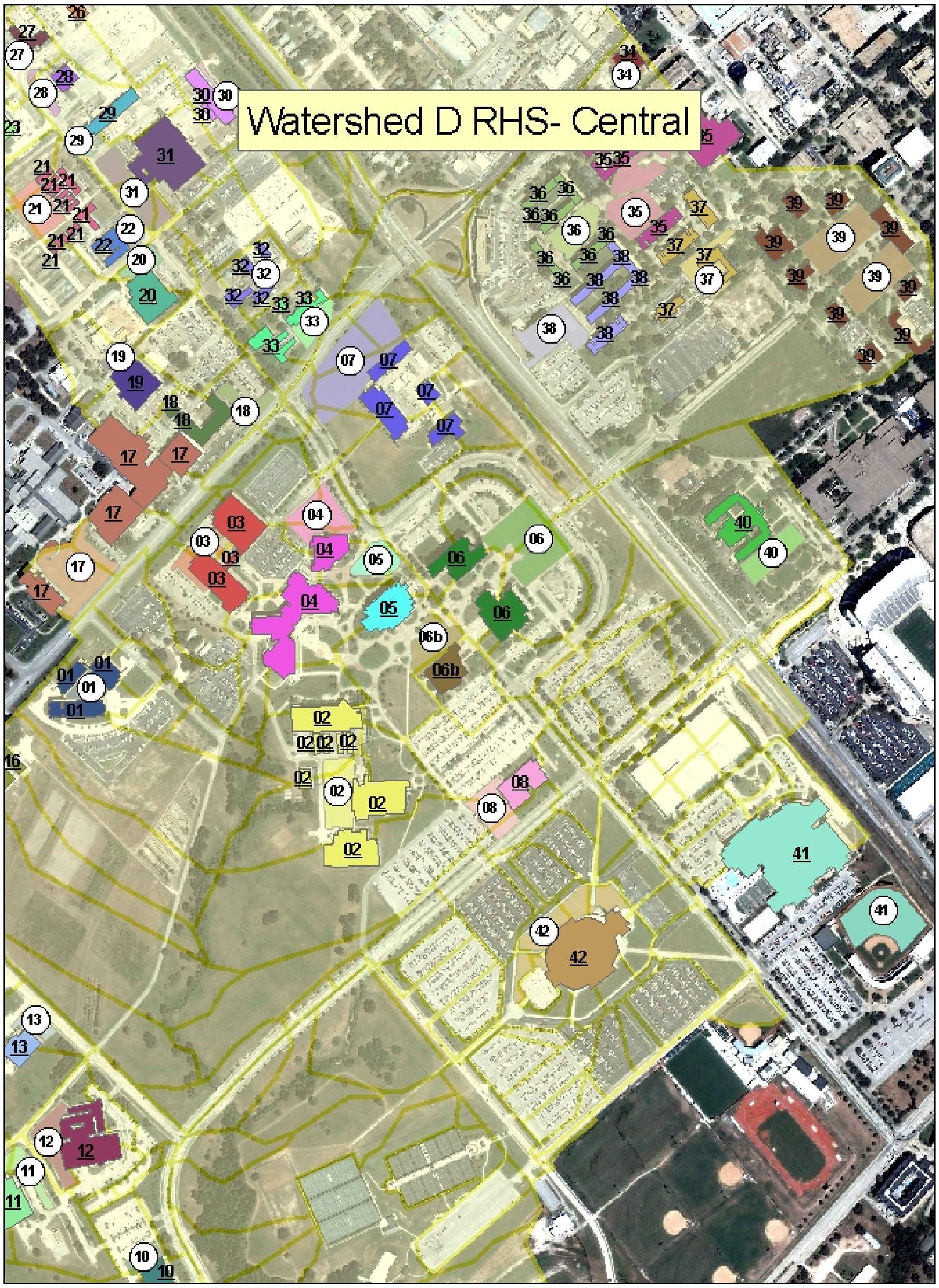

Figure A-2. Central Region of TAMU's Watershed D RHS.

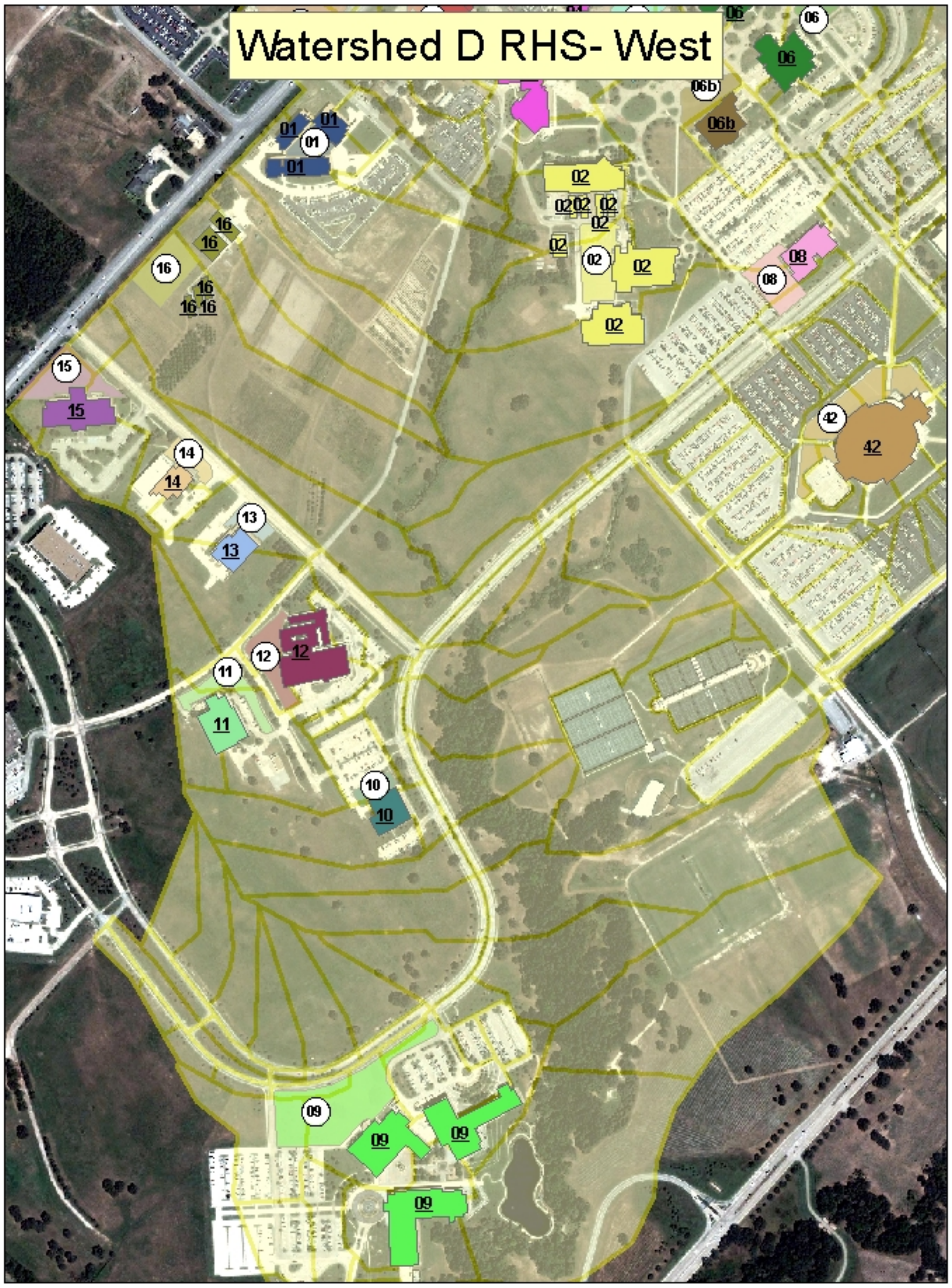

Figure A-3. West Region of TAMU’s Watershed D RHS.

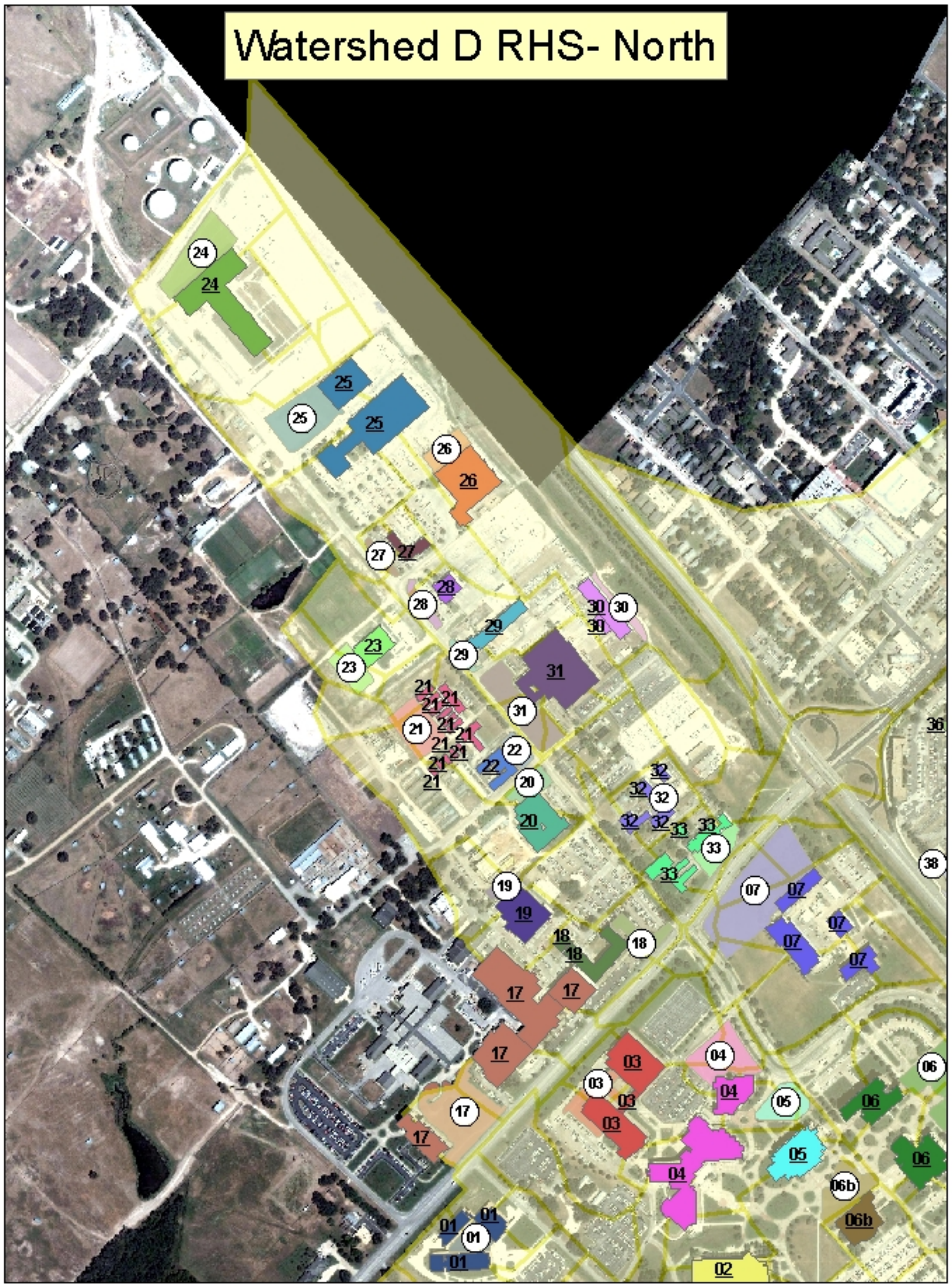

Figure A-4. North Region of TAMU's Watershed D RHS.

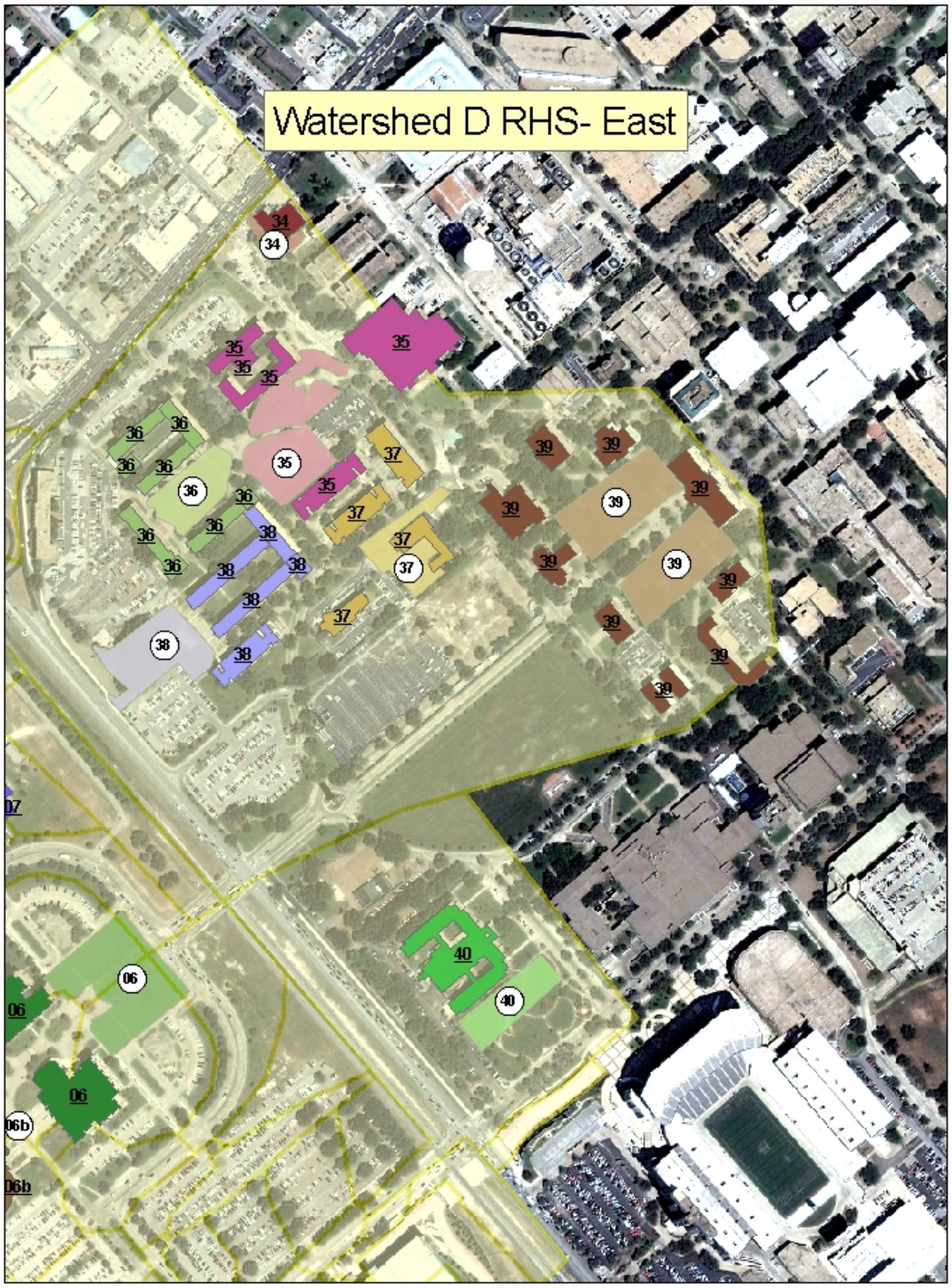

Figure A-5. East Region of TAMU's Watershed D RHS.

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