current electric and natural gas rates, which are relatively variable. The advantage of the new system is the diversity of energy sources between electric and natural gas as compared to the existing system that depends solely upon electricity rates. Any future increases in electric rates would have a much more profound effect upon the on life cycle cost of the existing system when compared to the new centralized system with an absorption chiller heater.

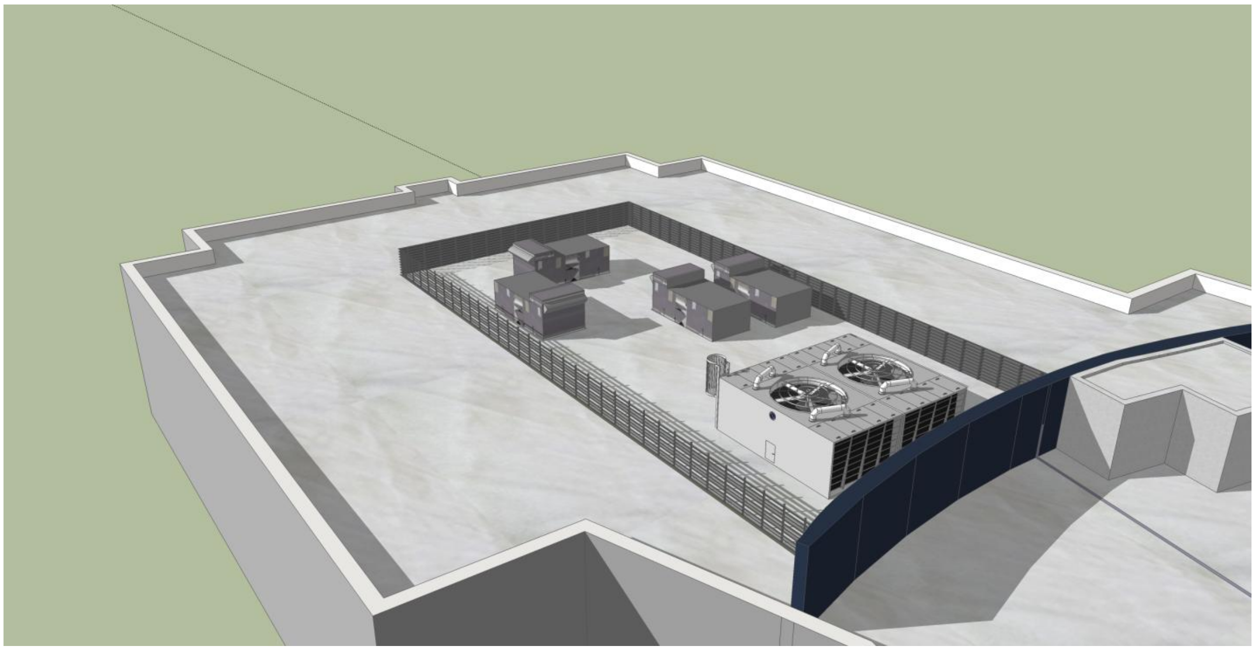

Figure 19 – Rendering of New Rooftop

Sustainability Study: Rainwater Capturing System

Sustainability Objectives

The objective of this design project is to create a system that captures rainfall that would normally be discharged into the storm water system and put it towards use in a building process that would be using potable water in addition to protecting the building structure from water damage. Due to the many possible applications of the captured rainwater (site irrigation, cooling tower makeup water, and toilet water systems) the decision was made that the harvested rainwater would be used for the toilet water systems in the building.

The decision was also made to provide a roofing system that is non-PVC and does not contribute to degradation of the environment during its disposal. The roofing type will have to be changed from PVC (Polyvinyl Chloride) to a TPO (Thermo Plastic Olefin) or EPDM (ethylene propylene diene M-class rubber).

Building Background

With all the current focus on energy efficiency of building envelopes and mechanical systems, the availability of clean, potable water has not been stressed enough as an important aspect sustainable design. HITT contracting Headquarters has 42,000 square feet of available flat roof that currently drains its rainwater to storm drain systems. NOAA rainfall data used for this analysis was approximated to be the same as data collected in Vienna, VA from 1971 to 2000 with the average annual rainfall for the site being 45.12 inches. See Figure 20 for a graph of monthly rainfall averages for Falls Church, Virginia as reported by NOAA.

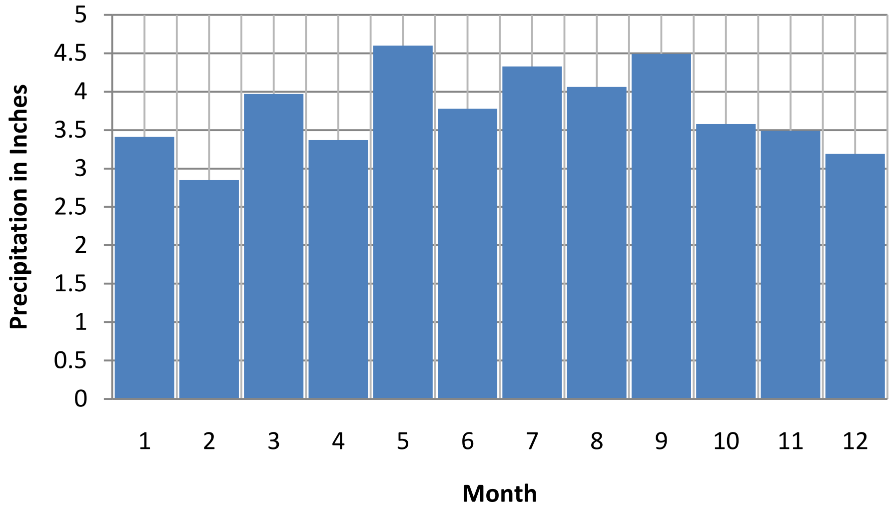

Figure 20 – Average Monthly Precipitation Totals in Inches from NOAA

Calculation

Toilet System Water Demand

The amount of water required per day by the toilet system was calculated as per the LEED NC v2.2 WE Credit 2 – Innovative Wastewater Technologies. The credit requires a 50% increase in performance over a baseline case that uses FTE (Full Time Equivalent) occupancy and usage rates. The typical occupant utilizes the restrooms three times per day, with the typical male having one water closet and two urinal usages. The FTE of the building was calculated to be approximately 200 by utilizing basic furniture and office space counting methods. For this calculation, it is assumed that half of the full time equivalent occupants are male and the other half female. See Tables 18 and 19 below for calculations involving the baseline and new design cases.

Table 18 – LEED Calculation: Baseline Case

Baseline Case				
Fixture Type	Daily Uses	Flowrate (GPF)	Occupants	Water Utilized (Gal/Day)
Water Closet (Male)	1	1.6	100.00	160.00
Water Closet (Female)	3	1.6	100.00	480.00
Urinal (Male)	2	1	100.00	200.00
				840.00

Table 19 – LEED Calculation: New Case without Rainwater Capturing

New Case without Rainwater Capturing				
Fixture Type	Daily Uses	Flowrate (GPF)	Occupants	Water Utilized (Gal/Day)
Low-Flow Water Closet (Male)	1	1.1	100.00	110.00
Low-Flow Water Closet (Female)	3	1.1	100.00	330.00
Waterless Urinal (Male)	2	0	100.00	0.00
Low-Flow Water Closet (Female)	0	0.8	100.00	0.00
				440.00

Since the new design case only reduces the usage to 440 gallons per day, this cannot be done by utilizing low-flow fixtures alone, supplemental rainwater is required to achieve the credit. This supplemental water will be provided by rainwater collected from the 42,000 square foot roof.

Tank Sizing Procedure

In order to size the rainwater storage tank, the monthly precipitation totals for the site, representative rainfall values for the Mid-Atlantic region and the usage rates of the toilet system calculated above must be used. Using the methods described in Baetz (2007), an equation can be derived that relates the required gallons per day of usage, the reliability of supply for that usage and the size of the tank required to provide that reliability.

The daily water demand found above to be 440 gallons per day. Utilizing the equations set forth in Baetz with the assumptions of 5% runoff and a first flush of 0.1 inches, the formula was put into EES (Engineering Equation Solver) and calculated for a range of reliabilities. A graph that displays the percentage of the time that the full 440 gallons would be able to be supplied to the toilet water system was produced by EES. See Figure 21 below for a graph of the tank size vs. reliability. The maximum reliability achievable would be approximately 35% of the year. This means that for 35% of the year, the toilet water can be entirely supplied by captured rainwater.

This statistic does not include days in which the captured rainwater provides a fraction of the toilet water.

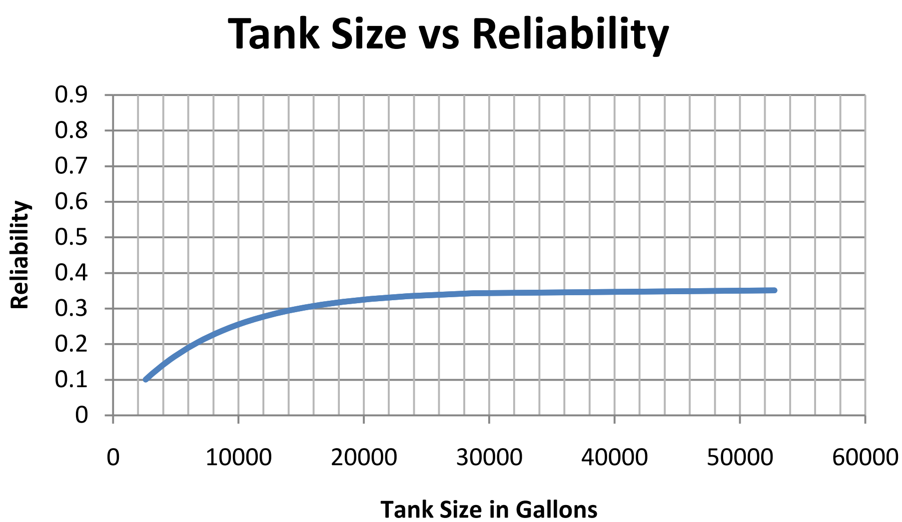

Figure 21 – Tank Size vs Reliability for a rate of 440 gallons/day

The maximum of 35% availability would be impractical because of the massive tank size greater than 40,000 gallons when compared to a tank of 15,000 gallons that would provide 30% availability. So a 10,750 gallon tank was selected because it is near the pivot point in the reliability graph of the tradeoff of availability to tank size. It was also chosen for economic reasons, the cost to upsize a 10,750 gallon tank and get 5% more availability throughout the year would have been in increase of $3700 or 43%. See Appendix D for further in depth calculations. Table 20 displays the LEED calculation with the additional rainwater incorporated.

This calculation is on the conservative side due to the fact that it only takes into account the days in which the rainwater capturing system provides all of the water to the toilet system and does not include days in which partial amounts are supplied

Table 20 – LEED Calculation: New Case with Rainwater Capturing

New Case with Rainwater Capturing				
Fixture Type	Daily Uses	Flowrate (GPF)	Occupants	Water Utilized (Gal/Day)
Low-Flow Water Closet (Male)	1	1.1	100.00	110.00
Low-Flow Water Closet (Female)	3	1.1	100.00	330.00
Waterless Urinal (Male)	2	0	100.00	0.00
Low-Flow Water Closet (Female)	0	0.8	100.00	0.00
Water From Capturing System	n/a	n/a	n/a	-110.00
				330.00

Equipment requirements

The existing roof of the structure of HITT Contracting Headquarters consists of a flat built up roof with rigid insulation and a 65 mill PVC (Polyvinyl-Chloride) fully adhered membrane. The roof drainage system is typical for this type of flat roof with penetrations for both regular roof drains and overflow drains used in the event of a failure of one or more of the regular drains. The regular storm drains guide the water to cellar level where it is connected with the building storm water rejection system. The overflow drains do not bring the water to together in the cellar, but release the water through downspouts along the building parameter.

The success of a rainwater capturing system depends upon the current roof drain system described above. A basic filtration system will have to be installed at the cellar level to separate the first flush debris from the rest of the harvested rainwater. A vortex filtration system was chosen to separate roof debris and dirt from being directed into the rainwater storage tank. See Figure 22 below for a diagram of the vortex filter.

TPO (Thermoplastic Polyolefin) Roofing was chosen to replace the existing PVC roofing as stated in the objectives for the rainwater system. The TPO roofing membrane will be fully adhered just as the existing PVC membrane was. TPO membranes are environmentally friendly and combine the advantages of both EPDM and PVC roofing materials.

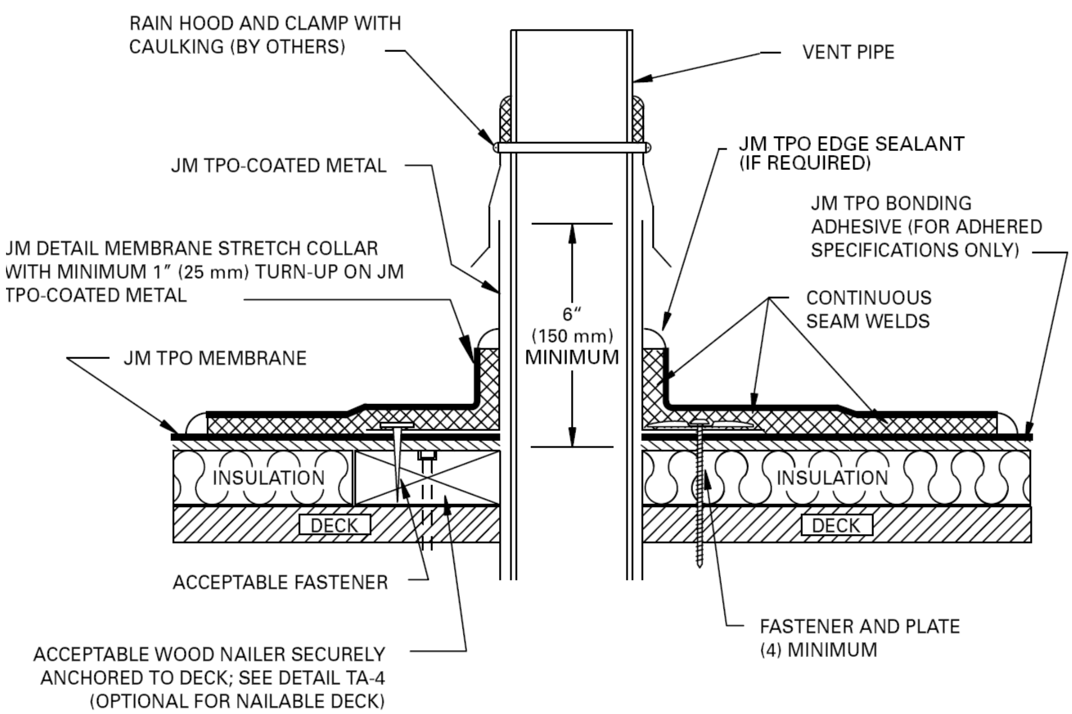

Figure 23– TPO Vent Penetration Detail

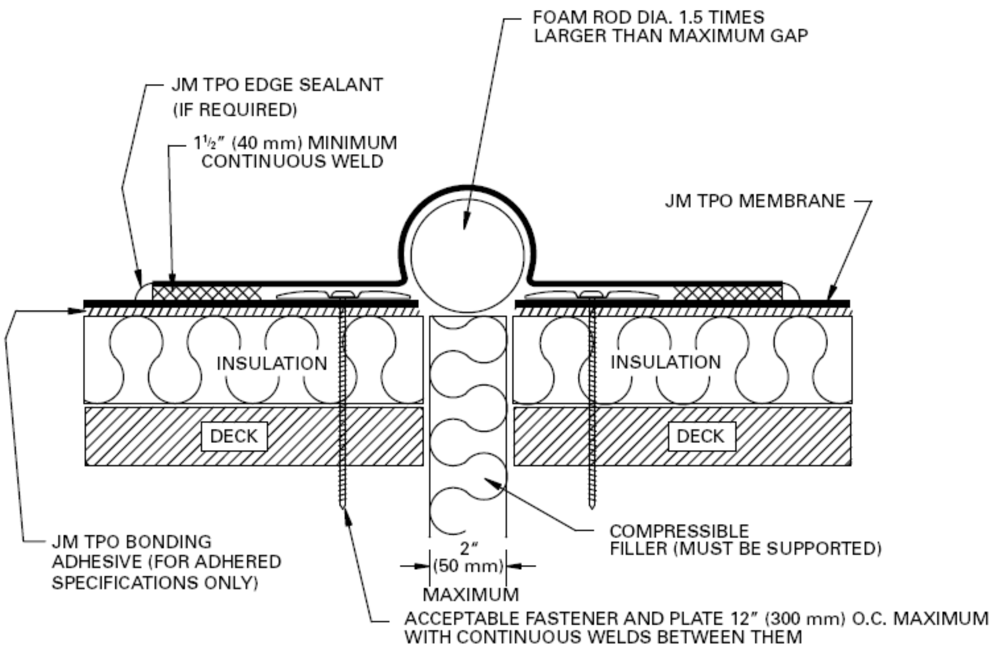

Figure 24 – TPO Expansion Joint Detail

Economic Analysis

This section includes the calculations involving the first cost of the rainwater system and roofing system along with the life cycle cost of the entire system. The life cycle cost analysis was performed with a simple interest rate of 6% over 20 years and concluded that the simple payback period for the system is 20 years. Maintenance for this system was assumed to be similar to that of the existing system for this analysis. Table 21 lists the water costs and first costs of the rainwater equipment require. Table 22 displays the first cost analysis of the new roofing system. The life cycle cost of the entire system is calculated in Table 23.

Table 21 – Rainwater System Economic Analysis

Economic Analysis - Rainwater System	
$3.03	per 1,000 gallons supplied
$5.91	per 1,000 gallons sewer
$47.60	Per month
160,600	Gallons supplied per Year Old
120,450	Gallons supplied per Year New
160,600	Gallons sewer per Year
$9,800	Filter First costs
$8,649	Storage Tank First Cost

$2,006.96	Cost per Year Old
$1,361.71	Cost per Year New
$645.25	Cost Savings per Year
40,150	Gallons of Water Savings per Year

Table 22 – Roofing System Economic Analysis

Economic Analysis - Roofing System	
$205.69	Cost per 100 ft^2 of TPO Roofing
$233.70	Cost per 100 ft^2 of PVC Roofing
42,000	Square feet of Roofing
$86,390	OPM Roofing First Cost
$98,154	PVC Roofing First Cost

Table 23 – Rainwater System Life Cycle Economic Analysis

Life Cycle Cost Comparison		
i=0.06	New with TPO	Old with PVC
Year 1	$1,362	$2,007
Year 2	$1,362	$2,007
Year 3	$1,362	$2,007
Year 4	$1,362	$2,007
Year 5	$1,362	$2,007
Year 6	$1,362	$2,007
Year 7	$1,362	$2,007
Year 8	$1,362	$2,007
Year 9	$1,362	$2,007
Year 10	$1,362	$2,007
Year 11	$1,362	$2,007
Year 12	$1,362	$2,007
Year 13	$1,362	$2,007
Year 14	$1,362	$2,007
Year 15	$1,362	$2,007
Year 16	$1,362	$2,007

Year 17	$1,362	$2,007
Year 18	$1,362	$2,007
Year 19	$1,362	$2,007
Year 20	$1,362	$2,007
Net Present Worth	$15,619	$23,020
Initial Cost	$104,839	$98,154
Life Cycle Cost	$120,457	$121,174

Conclusions

Both of the objectives for the study were completed. The effective reduction in daily water usage provided by the rainwater capturing system drops the daily usage to a conservative 330 gallons per day, which is less than half of the 880 gallon per day baseline case. This reduction passes the LEED WE Credit 2 requirement of a 50% reduction in potable water usage through innovative technologies and achieves one LEED point.

Using methods described in “Sizing of Rainwater Storage Units for Green Building Applications” the total annual volume of rainwater that the roof could capture was calculated to be 1,033,529 gallons. It was also found that the reliability of enough rainwater being available for the usage of these systems was not anywhere near 100% as the annual usage is 3,212,000 gallons. As shown in the reliability graph in Figure 21 the maximum reliability for the amount of water required by the toilet water system when applied to the amount of rainwater collected throughout the year is 35%, but this would require a storage tank in excess of 40,000 gallons. The more reasonable tank size of 10,750 gallons was selected and has a reliability of 25%.

The rainwater system has a payback period of 20 years, which is not typically thought of as a very good payback length when compared to a typical 2-4 year payback. The goal of the analysis was to achieve LEED-NC v2.2 WE Credit 2 – Innovative Wastewater Technologies through the reduction of potable water usage and these requirements were more important than the economic effects in guiding the analysis.

Structural Impact Study

Structural Objectives

The roof structure will receive different loads and new loads with the implementation of the new centralized system. The goals of the structural impacts analysis are to: