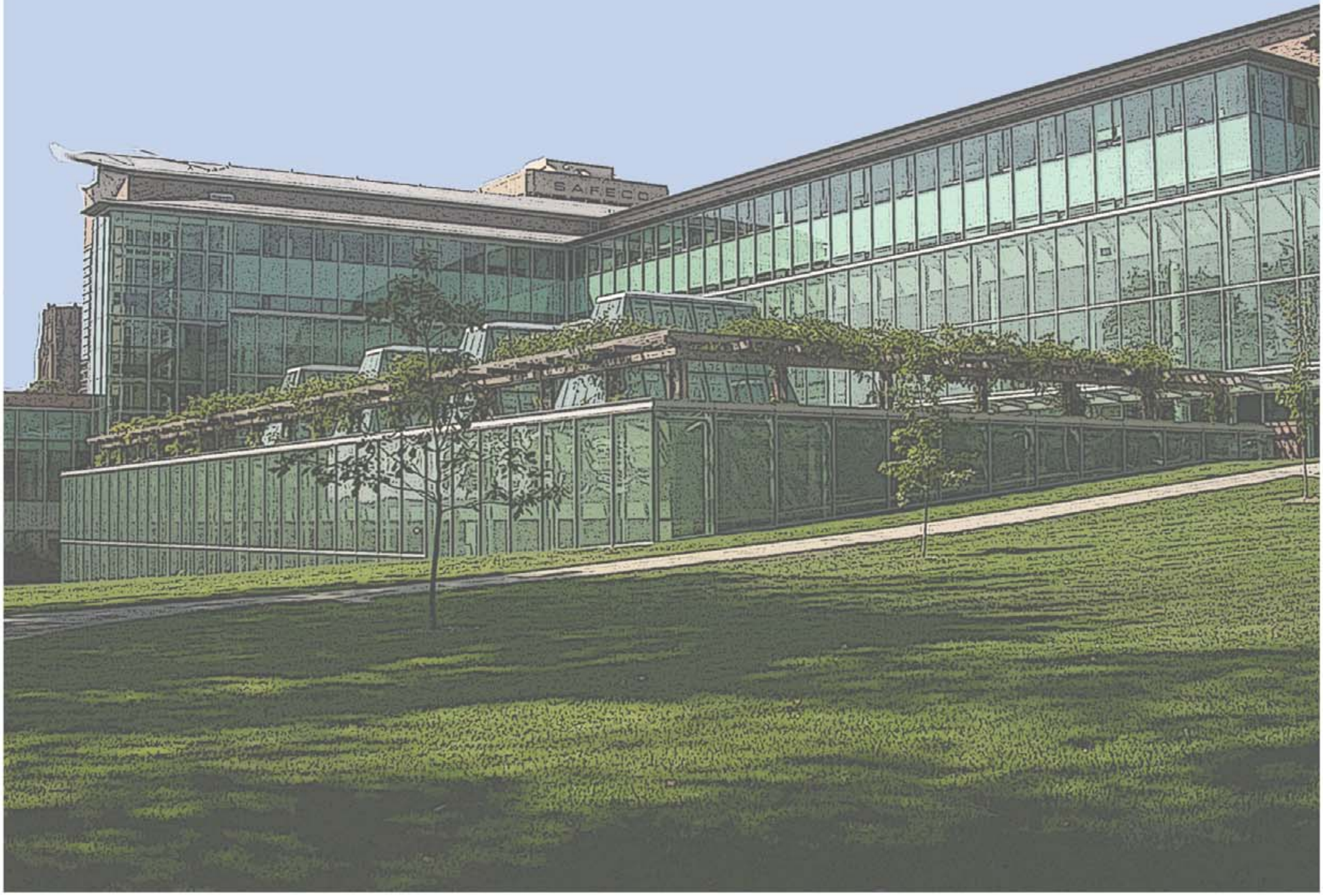
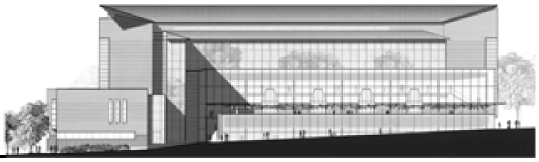
LEED Breadth

A Feasibility Study of Implementing a Rainwater Catchment System to Offset Cooling Tower Water Makeup





Introduction

With commercial buildings consuming approximately one-sixth of the world's potable water supply, it is important to investigate design considerations that will help to reduce a buildings dependency on the water supply. Due to the location of William H. Gates, in Seattle, Washington, and the region's notoriously rainy climate, making use of rainwater to supply the building's non-potable water demand lends itself well to such a system.

The LEED Breadth portion of the report looks at the feasibility of implementing a rainwater catchment system to help offset the cooling tower make up water requirements. This study will investigate the amount of water required to offset the cooling tower water makeup and the potential collectable rainfall per year. Additionally, the LEED Breadth will explore other requirements and equipment needed to implement such a system.

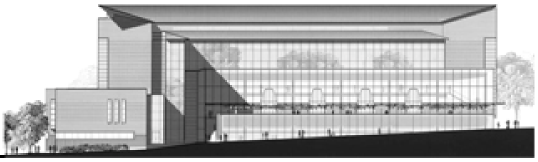
University of Washington's Commitment to Sustainability

In the University of Washington's 2004 Sustainability Report, the University states it's commitment to "environmentally sustainable principles that contribute to the long-term protection and enhancement of our environment, our economy, and the health of present and future generations." This commitment to sustainable building practices is evident in the university's declaration that all new buildings will be, at a minimum, LEED Silver-certified. Campus wide sustainability efforts have primarily focused on energy reductions and the use of renewable energy. Additionally, sustainable efforts focusing on water use and conservation have been made as well; however, are primarily concentrated toward reduction of water use in irrigation.

During the design and construction of William H. Gates Hall, which was opened in September 2003, the university had not yet adopted the LEED certified building initiative. While it is assumed that during the building's design process efforts were taken to incorporate energy efficient systems, there are no systems in the building that focus on utilizing natural resources and sustainable technologies. The architecture and systems design of the William H. Gates Hall is conducive to incorporating sustainable technologies and system in several areas, including daylighting integration and rainwater harvesting. This Breadth Study will focus on the potential of utilizing a rainwater catchment system to offset water usage in the building, specifically looking at the cooling tower makeup water requirements.

Cooling Towers

The current design of William H. Gates Hall utilizes two cooling towers for the building cooling system. The cooling towers, rated at 825 gallons per minute each, are located in a below grade pit on the north side of the building, adjacent to the chiller plant mechanical



room. Makeup water is supplied to the towers in 2" diameter pipes from the Seattle Public Utility.

Makeup Water

During the operation of the cooling towers there is a constant water loss from the cooling tower, which must be replaced in order for the system to run effectively. This replacement water is referred to as water makeup, and can be a significant source of water consumption in the building. The water lost from the cooling towers will be calculated as the result of three things: evaporation, drift and blow down. The sum of these three factors is the amount of water that must be constantly replenished to the system.

Evaporation:
Evaporation, which accounts for the greatest water loss from the cooling tower, is water evaporated from the circulating water into the atmosphere by the cooling process. This water amount is calculated according to the cooling capacity of the chillers.

275 tons * 12,000 Btu/hr = 3,300,000 Btu/hr

Heat vaporization of water = 2260 kJ/kg

3,300,00 Btu/hr * 1.055 kJ/Btu * 1/(2260 kJ/kg) = 1540.49 kg/hr

ρ_{water} at 1 atm, 90°F = 62.11 lb/ft3

62.11 lb/ft^3 * 0.4536 kg/lb * 1(7.481 gal/ft^3) = 3.766 kg/gal

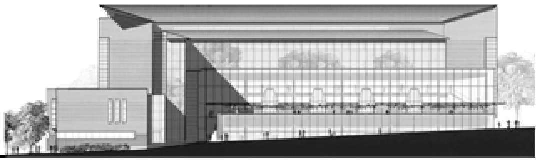
1540.49kg/hr * 1/(3.766 kg/gal) = 409 gal/hr

409 gal/hr * 1hr/60 min = 6.82 gpm

Evaporation = **6.82 gpm**

Drift:
Drift is water droplets that are carried out of the cooling tower with the exhaust air and is calculated as a small percentage of the cooling tower flow. According to the building specifications, drift is to be limited to 0.002% of the flow.

Drift = 805 gpm * .00002 = **0.0165 gpm**



Blowdown:

While trying to maintain the amount of dissolved solids and other impurities at an acceptable level, a portion of the circulation water is released from the cooling tower. In William H. Gates Hall the water is maintained at 8 to 10 cycles of concentration. For the purpose of this calculation, the worst case scenario of 8 cycles will be used.

$$\text{Blowdown} = \frac{\text{Evaporation Losses}}{\text{Cycles} - 1}$$

$$\text{Blowdown} = \frac{6.82\text{ gpm}}{(8-1)} = \mathbf{0.98\ gpm}$$

Makeup Water:

The total makeup water required is the sum of evaporation, drift and blowdown.

Makeup Water = Evaporation + Drift + Blowdown

Makeup Water = 6.82 gpm + 0.0165 gpm + 0.98 gpm

Makeup Water = 7.82 gpm

The total makeup water required to the cooling towers is 7.82 gpm. A value of **8 gpm** will be used for the design of the system components.

Water Requirements

When operating at full capacity, the cooling towers require makeup water at a rate of 8 gpm. This value will vary depending on the cooling loads required and the outdoor air conditions, with less water required during cooler months when less building cooling is required. However, for the purpose of the feasibility study, the worst case scenario of the building operating at full cooling capacity year round will be assumed.

The following table outlines the monthly and yearly totals of the amount of water to be supplied to the cooling towers for makeup water. This table looks at both the makeup water amounts for one cooling tower, and also for the total building makeup water requirements with two cooling towers.

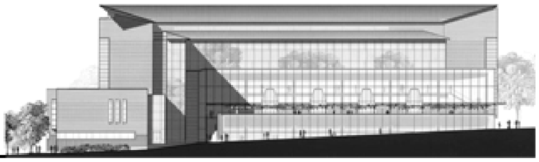


Table 6.1 – Cooling Tower Makeup Water Requirements

Month	Makeup Water Needed (GPM)	Days A Month	Makeup Water per Cooling Tower (Gallons)	Total Makeup Water (2 Cooling Towers)
January	8	31	357,120	714,240
February	8	28	322,560	645,120
March	8	31	357,120	714,240
April	8	30	345,600	691,200
May	8	31	357,120	714,240
June	8	30	345,600	691,200
July	8	31	357,120	714,240
August	8	31	357,120	714,240
September	8	30	345,600	691,200
October	8	31	357,120	714,240
November	8	30	345,600	691,200
December	8	31	357,120	714,240
		Total	**4,204,800**	**8,409,600**

With each cooling tower needing approximately 4.2 millions of water a year, William H. Gates Hall consumes approximately 8.4 millions of water each year on cooling tower water makeup. By developing a method to offset this water consumption, not only will the university incur lower water cost, but will also help to reduce the building's contribution to the depletion of fresh and potable water sources.

Rainwater Catchment

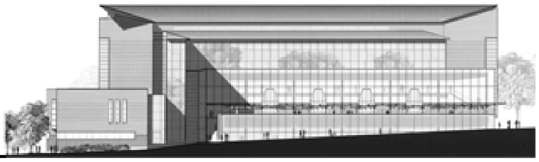
By implementing a rainwater catchment system, William H. Gates Hall can utilize rainwater to offset building water consumption. Due to the cooling towers high demand for water and the ability to use non-potable water, a rainwater catchment system is a good solution for this system. Additionally, Seattle's constant light rainfall makes this geographic area ideal for utilizing rain water catchment systems.

Collectible Rainfall

The rainwater catchment system will utilize a collectible roof area of approximately 48,500 square feet. Using monthly rainfall averages and the roof area of the building, the potential amount of water that can be caught monthly can be approximately by the equation:

*Roof Area Sent to Downspout (sq. ft) * Rainfall (in) * 0.6*

This equation is determined from the approximation that one inch of rain falling on a square foot of surface yields approximately 0.6 gallons of water. Monthly rainfall data is taken from



Seattle's monthly rain averages. Refer to Table 6.2 – Potential Monthly Rainwater Catchment below for monthly approximations of rainwater catchment.

Table 6.2 – Average Monthly Rainwater Catchment

Month	Monthly Rainfall (Inches)	Roof Surface Area (Sq. Ft.)	Monthly Catchment (Gallons)
January	5.4	48,500	157,140
February	4	48,500	116,400
March	3.8	48,500	110,580
April	2.5	48,500	72,750
May	1.8	48,500	52,380
June	1.6	48,500	46,560
July	0.9	48,500	26,190
August	1.2	48,500	34,920
September	1.9	48,500	55,290
October	3.3	48,500	96,030
November	5.7	48,500	165,870
December	6	48,500	174,600
		Total	**1,108,710**

Due to Seattle's typically dry summers and rainy winters, rainwater catchment amounts vary quite significantly between the summer and winter months. Potential monthly rainfall to be collected ranges from approximately 26,000 gallons to approximately 175,000 gallons.

Potential to Offset Cooling Tower Water Makeup

In a given year, the use of a rain water catchment system could provide William H. Gates Hall with approximately 1.1 million gallons of water. This water can help to offset approximately one eighth of the required cooling tower makeup water. However, due to the variation of rainfall and outdoor air conditions throughout the year, the actual amount of water that will be available and the amount of water that will be lost from the cooling towers will vary.

The following table outlines the potential monthly water savings by utilizing the water from a rain water catchment system.

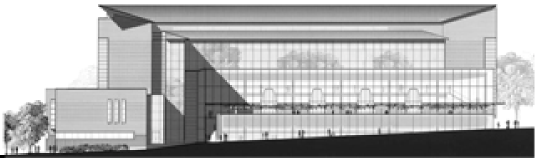


Table 6.3 – Potentially Monthly Water Savings

Month	Water Catchment (Gallons)	Makeup Water Required (Gallons)	Makeup Water Demand After Rainwater	Percentage of Water Use Offset
January	157,140	714,240	557,100	22.0%
February	116,400	645,120	528,720	18.0%
March	110,580	714,240	603,660	15.5%
April	72,750	691,200	618,450	10.5%
May	52,380	714,240	661,860	7.3%
June	46,560	691,200	644,640	6.7%
July	26,190	714,240	688,050	3.7%
August	34,920	714,240	679,320	4.9%
September	55,290	691,200	635,910	8.0%
October	96,030	714,240	618,210	13.4%
November	165,870	691,200	525,330	24.0%
December	174,600	714,240	539,640	24.4%

As noted above, these values assume the worst case scenario of the building operating at full cooling capacity year round. Therefore, the percentage of water offset may in actuality increase during fall and winter months, when lower cooling loads are required.

System Components

There are several components that need to be considered in implementing a rainwater catchment system, including water storage, required pumps, water filtration and treatment of the water. Each of these components is essential for the proper functioning of the system.

Water Storage

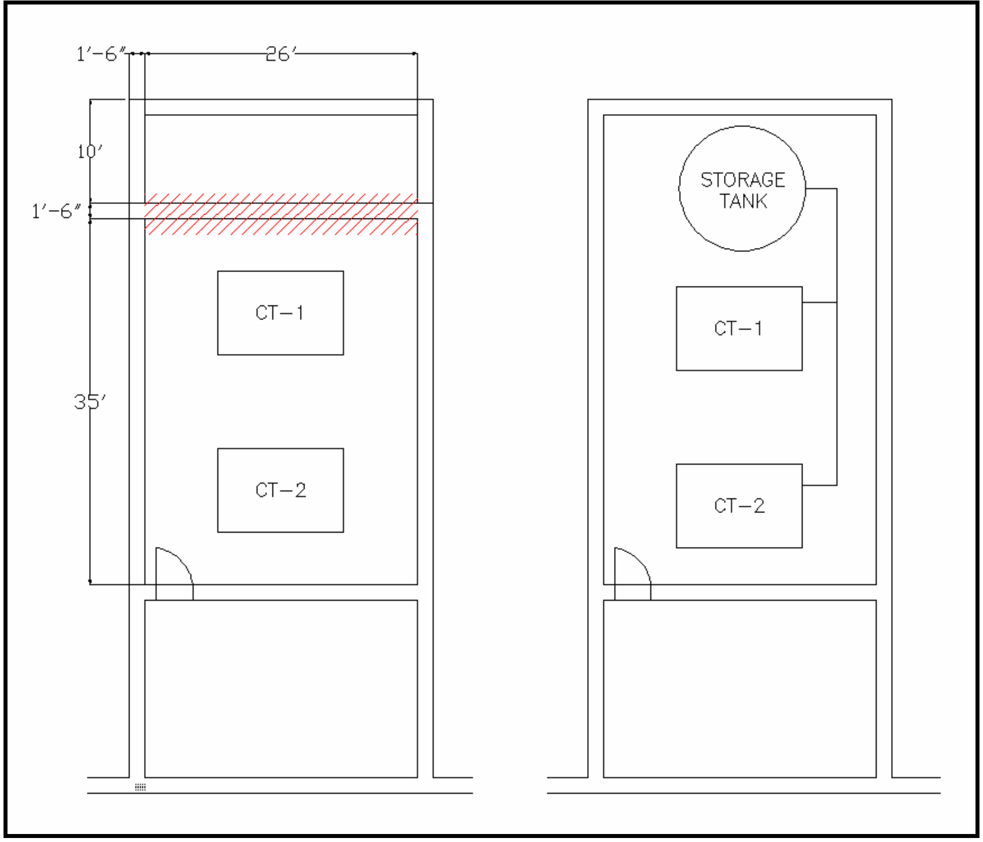
Upon collecting water from the roof it is essential to provide storage in order to retain the water for later use. Storage options are plentiful, as there are several types and materials of cisterns available. For the proposed rainwater catchment system for William H. Gates Hall, a fiberglass cistern will be used. Fiberglass tanks provide long durability and are easily maintained and repaired. Additionally, fiberglass cisterns are moveable, which will allow for the tank to be removed if need and not be a permanent fixture of the building. While fiberglass cisterns are slightly higher in initial cost as compared to some other types of storage tanks, their durability and dependability make them an attractive option.

The cistern for the rainwater catchment system in William H. Gates Hall will be 12 feet in diameter, 12 feet in height, with a capacity of 10,000 gallons. This size was chosen base on the expected storage needed, as well as the physical size of the tank and spatial limitations. When determining the appropriate capacity of the tank, average daily rainfalls were considered as well as record highs. An appropriate size between these two amounts was determined, both to ensure enough capacity for average rainfalls in addition to some spare capacity to take advantage of larger than average rainfalls.

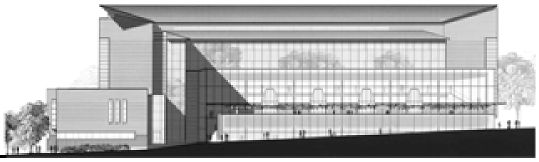
The cistern will be located below grade in the cooling tower pit. This will allow for the tank to be located as close as possible to the cooling towers to reduce the distance the water needs to be transported, as well as the required amount of piping. Additionally, by locating the cistern below grade, it is protected from direct sunlight and architecturally, there is no “eye sore.”

In order for the cistern to be located in the cooling tower pit, the pit will be extended ten feet at one end. This will allow for sufficient space for the cistern will still observing clearance requirements of the cooling towers. Refer to the following figure for storage tank location and cooling tower pit expansion.

Figure 6.1 – Cooling Tower Pit Layout and Modifications



Additionally, placing the cistern in this location raises question to possible structural concerns due to the extreme weight of the storage tank. An average cistern weighs approximately 8 pounds per gallon of water. A 10,000 gallon cistern filled to capacity the total weight would weigh 80,000 pounds, and over the 12 foot diameter will be approximately 710 lb/ft^2. The cistern is located on a 20 inch slab, which weighs 255 lb/ft^2 (150 lb/ft^3 for concrete * 20 in =



255 lb/ft^2), bringing the combined slab and system weight to total approximately 1,000 lb/ft^2, The cooling tower pit is located adjacent to, but outside of the building footprint, and incurs no other loads from additional stories. With an allowable bearing capacity of 10,000 lb/ft^2 and the bearing capacity for compacted fill of 4,000 lb/ft^2 the load of the system and slab are significantly below the allowable values, and therefore, there should not be any structural concerns regarding the weight of this addition.

First-Flush Diverters

A first-flush diverter is needed in order to prevent the first flow of water from the roof surface, which can pick up the dust, leaves, insects, and airborne residues that have collected on the room, from being deposited in the storage tank. This allows the system to rid itself of the small contaminants that have accumulated on the roof and been picked up by the rainfall.

Pump

Another consideration that needs to be taken into consideration for the rainwater catchment system is whether there is a need for a pump. If the pressure in the system is great enough, gravity will allow water to flow from the cistern into to cooling tower. Since both the cooling tower and storage tank will be located on the same surface at the same height, there is a possibility that a gravity system could be an option. The following calculations use the relationship between the kinematic pressure and static pressure to determine whether or not a pump is needed by finding the minimum height at which water in the cistern must be maintained in order for gravity to control the system.

$$8\text{ gpm} * .003785\text{ m}^3/\text{gal} * 1\text{ min}/60\text{ sec} = 5.05\text{ E }-10\text{ m}^3/\text{s} = V_{dot}$$

$$V_{dot} = VA \rightarrow V = V_{dot}/A$$

Assume that pipe size is 2” diameter

$$A = \pi r^{2 =} \pi * (1\text{ in})^2 = 3.14\text{ in}^2$$

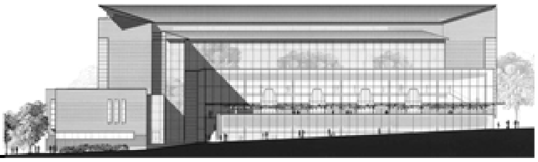
$$3.14\text{ in}^2 * .000645\text{ m}^2/\text{in}^2 = .00203\text{ m}^2$$

$$V = (5.05\text{ E }-10\text{ m}^3/\text{s})/ .00203\text{ m}^2 = 0.249\text{ m/s}$$

$$\rho g h = \tfrac{1}{2}\rho V^2$$

$$\cancel{\rho} g h = \tfrac{1}{2}\cancel{\rho} V^2$$

$$h = (\tfrac{1}{2} * V^{2)}/ g$$



$$h = (\tfrac{1}{2} * (0.249\ \text{m/s})^2)/9.81\ \text{m/s}^2$$

$$h = .00316\ \text{m}$$

$$h = .00316\ \text{m} * 3.28\ \text{ft/m} = \mathit{0.01\ ft}$$

In order for gravity to run the system, the height of water in the cistern cannot fall below 0.01 feet. At all times, there will be greater than 0.01 feet of water in the tank, and therefore, no pump is needed for this system.

Filtration & Water Treatment

Filtration is required in order to remove unwanted particles and objects from the water. Leaf guards should be used on the roof at the roof drains to prevent leaves, twigs and insects from entering the pipes and the system. Additionally, filtering to remove smaller particles should occur before the water enters the cistern.

While the water from this catchment system is being used for non-potable sources, it is still necessary to chemically treat the water. This treatment helps to limit the growth of mineral and microbial deposits that can reduce the heat transfer efficiency of the cooling tower.

Additional Water Supply

While the rainwater catchment system helps to offset the water demands of the cooling towers, a traditional water supply is still needed in order to reach the makeup water requirements. A water supply line will connect into the cistern and controlled with a float valve to maintain appropriate water levels in the tank at all times.

Conclusion

In order to implement a rainwater catchment system for William H. Gates Hall there are several system components that must be included and many areas of coordination and integration that need to be considered. By using a rainwater catchment system in this situation, cooling tower water makeup can be offset by approximately 1 million gallons a year, with the potential for more of an impact during the rainy, cool months than the dry, warm months. In addition, implementing a system can be done with minimal effects to other systems, with exceptions of the cooling tower pit expansion. Overall, the system is a feasible option for William H. Gates Hall and would be recommended depending on the life cycle cost, which are addressed in the Construction Management Breadth portion of this report.