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:

- Calculate the new structural design that takes into account the modified loading
- Calculate cost savings or increases of the new structural system compared to the existing system

Existing Design

The current roofing system is comprised of a 10" two way reinforced slab. The redesigned mechanical system requires additional mechanical equipment on the roof level along with a reduction in load of currently placed rooftop mechanical equipment. See Table 24 for a table describing the load changes from the existing to new design.

Table 24 – New & Existing Roofing Loads

Roofing Loads		
lbs or lb/ft^2	Existing	New
Live Load	15	15
Air handlers (each)	10000	8200
Cooling Towers (each)	n/a	8500

Structural Analysis

This report analyzes two of the changes to the roof loading, a typical change in air handler weight to a span and the addition of a cooling tower to a span. The two way slab structure was analyzed using the PCA Slab software. PCA Slab is a part of the PCA (Portland Cement Association) software suite and is specifically designed for analyzing concrete slab systems. The software analyzes one column line at a time, so two simple procedures were required to obtain slab thicknesses and the size and location of reinforcing steel; one that sizes the slab and steel in one direction and a second that sizes column line perpendicular to the first column line. These results are combined and are used in the design of the reinforced concrete.

Existing System Analysis

The existing system consists of the 10" slab noted in the existing design section along with the existing AHU loads acting on the members. Tables 25 and 26 below display the takeoff values for the existing design for both steel and concrete. Appendix E graphically describes the width and length moment, shear, deflection diagrams.

Table 25 – Existing Column Line Analysis: Length

Existing Length Results

Top Bars:	6120.1	lb	<=>	38.5	lb/ft	<=>	0.7855	lb/ft^2
Bottom Bars:	6821.2	lb	<=>	42.9	lb/ft	<=>	0.8755	lb/ft^2
Stirrups:	0	lb	<=>	0	lb/ft	<=>	0	lb/ft^2
Total Steel:	12941	lb	<=>	84	lb/ft	<=>	1.681	lb/ft^2
Concrete:	6472.9	ft^3	<=>	42	ft^3/ft	<=>	0.841	ft^3/ft^2

Table 26 – Existing Column Line Analysis: Width

Existing Width Results								
Top Bars:	3852.8	lb	<=>	27.92	lb/ft	<=>	0.931	lb/ft^2
Bottom Bars:	3264.6	lb	<=>	23.66	lb/ft	<=>	0.789	lb/ft^2
Stirrups:	0	lb	<=>	0	lb/ft	<=>	0	lb/ft^2
Total Steel:	7117.4	lb	<=>	51.57	lb/ft	<=>	1.719	lb/ft^2
Concrete:	4196.3	ft^3	<=>	30.41	ft^3/ft	<=>	1.014	ft^3/ft^2

Air Handler Analysis

The air handler analysis consists of the same 10" slab noted in the existing design section but includes the new AHU loads acting on the members. Slab depth did not have to be increased due to the new loading scheme. Tables 27 and 28 below display the takeoff values for the existing design for both steel and concrete. Appendix E graphically describes the width and length moment, shear, deflection diagrams for the air handler.

Table 27 – Air Handler Column Line Analysis: Length

New AHU Length Results								
Top Bars:	5860.3	lb	<=>	38.05	lb/ft	<=>	0.761	lb/ft^2
Bottom Bars:	6737.8	lb	<=>	43.75	lb/ft	<=>	0.875	lb/ft^2
Stirrups:	0	lb	<=>	0	lb/ft	<=>	0	lb/ft^2
Total Steel:	12598	lb	<=>	81.81	lb/ft	<=>	1.636	lb/ft^2
Concrete:	6472.9	ft^3	<=>	42.03	ft^3/ft	<=>	0.841	ft^3/ft^2

Table 28 – Air Handler Column Line Analysis: Width

New AHU Width Results								
Top Bars:	3930.5	lb	<=>	28.48	lb/ft	<=>	0.949	lb/ft^2

Bottom Bars:	3295.9	lb	<=>	23.88	lb/ft	<=>	0.796	lb/ft^2
Stirrups:	0	lb	<=>	0	lb/ft	<=>	0	lb/ft^2
Total Steel:	7226.4	lb	<=>	52.37	lb/ft	<=>	1.746	lb/ft^2
Concrete:	4196.3	ft^3	<=>	30.41	ft^3/ft	<=>	1.014	ft^3/ft^2

Cooling Tower Analysis

The cooling tower analysis consists of the same 10" slab noted in the existing design section but includes the new cooling tower loads acting on the span. Slab depth did not have to be increased loading scheme. Tables 29 and 30 below display the takeoff values for the existing design for both steel and concrete. Appendix E graphically describes the width and length moment, shear, deflection diagrams for the cooling tower.

Table 29 – Cooling Tower Column Line Analysis: Length

New Cooling Tower Length Results								
Top Bars:	6245.6	lb	<=>	40.56	lb/ft	<=>	0.811	lb/ft^2
Bottom Bars:	6769.1	lb	<=>	43.95	lb/ft	<=>	0.879	lb/ft^2
Stirrups:	0	lb	<=>	0	lb/ft	<=>	0	lb/ft^2
Total Steel:	13014.6	lb	<=>	84.51	lb/ft	<=>	1.69	lb/ft^2
Concrete:	6472.9	ft^3	<=>	42.03	ft^3/ft	<=>	0.841	ft^3/ft^2

Table 30 – Cooling Tower Column Line Analysis: Width

New Cooling Tower Width Results								
Top Bars:	3952.3	lb	<=>	28.64	lb/ft	<=>	0.955	lb/ft^2
Bottom Bars:	3295.9	lb	<=>	23.88	lb/ft	<=>	0.796	lb/ft^2
Stirrups:	0	lb	<=>	0	lb/ft	<=>	0	lb/ft^2
Total Steel:	7248.2	lb	<=>	52.52	lb/ft	<=>	1.751	lb/ft^2
Concrete:	4196.3	ft^3	<=>	30.41	ft^3/ft	<=>	1.014	ft^3/ft^2

Economic Analysis

Table 31 displays the costs of the reinforcing steel and the total amounts of steel for each of the column line width and length cases combined: existing, new AHUs, and new cooling towers. The total amount of money saved was calculated to be $614.51 with a reduction of approximately 1232 pounds of steel. This calculation was performed on a solely material cost basis as the labor required to install the reinforcing steel is approximately the same, but the size of the members are slightly larger or smaller.

Table 31 – Structural Economic Analysis

Structural Economic Analysis				
	lbs	$/ton	$/lb	Cost
Existing Spans	20059	$998	$0.50	$10,009
New AHU Spans	19824	$998	$0.50	$9,892
New Cooling Tower Spans	20263	$999	$0.50	$10,121
Cost Differences				
	lbs Difference		Cost Difference	
7 New AHU Spans	-1640		-$818.41	
2 New Cooling Tower Spans	408		$203.90	
Total	-1232		**-$614.51**	

Structural Impact Conclusions

Both of the goals for the structural impact section were met; the new structural system was calculated and the costs associated with it were found with no requirement as to whether it was a reduction or increase in cost. This was decided in the objectives section because of the addition of weight of the new cooling towers along with the reduction in weight of the new air handlers. The changes saved approximately $614.51 in materials cost or 6% over the existing system.

Report Conclusions

The three primary sections of this report each achieved their stated goals. These goals included: improvements to energy efficiency of the system through the design of a centralized plant, water conservation and LEED, an assessment of the impacts of the new roof loads on the roof structure and redesign, and finally the overall educational experience from the research and calculations performed for this report.

The centralized plant redesign successfully reduced annual energy costs, while providing a payback period of 17 years. This is not the best of payback periods due to the high first cost of the new system but it should still be noted that the system does pay for itself over a reasonable