GREEN SCHOOL DESIGN – PUERTO RICO

Sponsored by the International Institute of Tropical Forestry and Grupos Ambientales Interdisciplinarios Aliados

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By:

Michael Conte, Mechanical Engineering

Danielle Karcher, Biology and Biotechnology

Sarah Mavilia, Civil Engineering

John McGonagle, Civil Engineering

Kelly Winthrop, Mechanical Engineering

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Submitted to:

Magaly Figueroa and Katie Frecker
International Institute of Tropical Forestry

Colibrí Sanfiorenzo-Barnhard
Grupos Ambientales Interdisciplinarios Aliados

Prof. Stanley Selkow and Prof. Hugh Lauer
Worcester Polytechnic Institute

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ABSTRACT

In Puerto Rico, there is a lack of emphasis placed on the importance of environmental sustainability, particularly at schools. Our team's goal for the project was to research current conditions at the Sabana Llana Junior High School in San Juan, Puerto Rico and recommend a green infrastructure design. After we collected data about the school's current state, we investigated ways to improve the school buildings and surrounding outdoor area through means such as water catchment systems, solar panels, green roofs, cool roofs, high-efficiency plumbing and lighting, tree removal and planting, recycling systems, and composting. Through interviews, case studies, and cost-benefit analyses, we made recommendations to help the school become more environmentally sustainable.

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EXECUTIVE SUMMARY

In the world today, living green and protecting the planet's natural resources are becoming increasingly important. To be *green* means to be as resource efficient, energy efficient, non-polluting, aesthetically pleasing, and as self-sustaining as possible (Green Building, 2013). In this project, Worcester Polytechnic Institute students worked with the International Institute of Tropical Forestry (IITF) and members of the inner city Sabana Llana Junior High School of San Juan, Puerto Rico, to take steps towards making the school more green as well as improving its overall condition. The school has problems with flooding, garbage disposal, and garden quality, which led Grupos Ambientales Interdisciplinarios Aliados (GAIA) to work with the school to help it become more environmentally sustainable. To correct these issues, the goal of the project was to provide recommendations to create a green infrastructure design that benefits the Sabana Llana Junior High School, guide the school toward Leadership in Energy and Environmental Design (LEED) certification, and set an example for schools located throughout Puerto Rico and potentially beyond.

Our team conducted interviews with qualified experts in green building design. We also met with the Director and faculty of Sabana Llana Junior High School to better understand issues at the school and gather their ideas for improvement. A drawing activity with the students allowed us to bridge the language barrier so they could show us through pictures what they wanted implemented on the school grounds.

We evaluated the current condition of the school grounds and focused on:

- The current recycling and waste management practices
- The amount and types of toilets and faucets
- The trees causing major problems

- The types of permeable and impermeable surfaces and areas where flooding occurs
- The size of the buildings, parking lot, and basketball court

In addition to creating a green infrastructure design, our team made recommendations for improvements at Sabana Llana Junior High School. The school recently received a grant from Syracuse University to begin a recycling program. Additionally, we found that the school already uses water efficient toilets; therefore, replacing them with new models is unnecessary at this time. We also discovered that the school currently uses compact fluorescent light bulbs, which are energy efficient and therefore do not need replacing at this time. The school should look into adding cool roofs and solar panels to some of the school buildings to help reduce the school's energy consumption.

Twelve trees are causing serious damage to the buildings and plumbing on the school grounds and should be removed immediately. In compliance with a regulation of the Department of Natural and Environmental Resources, every living tree removed requires two new trees to be planted. Two of the twelve trees are dead, and therefore do not require trees to be planted in their place. The school should plant these trees in different areas to add shade and aesthetics to the school.

If the school switched the seating area and the parking lot spaces, the students could sit and eat outside in front of the cafeteria. This would add to the environment for the students and is in compliance with a law created by the legislature of the Department of Education that requires students to eat outside at least once a week.

Reconstructing the parking lot to be made of gravel and PolyPavement instead of asphalt would help the school reduce flooding issues. Also, a raised pathway made with

PolyPavement from the main building to the basketball court will alleviate the effects of flooding on the school grounds. Another way to improve the flooding issues is to install French drains at different locations on the school grounds. Creating rain gardens for the French drains to lead into will handle any rainwater left at the end of the French drains. Lastly, installing water catchment tanks onto the main building will reduce flooding issues and can be used to reduce the consumption of greywater.

If the school works towards implementing these recommendations, the overall condition and aesthetics of the school will greatly improve and they will be closer to becoming LEED certified. Furthermore, the school will reduce their environmental impact through these green aspects, which will also benefit the global community.

CHAPTER ONE: INTRODUCTION

In the world today, living green and protecting the planet's natural resources is becoming increasingly important. To be *green* means to be as resource efficient, energy efficient, non-polluting, aesthetically pleasing, and as self-sustaining as possible (Green Building, 2013). For example, the waste production in the United States is at an all-time high, nearly 220 million tons per year (How much do we waste?, 2011). Less than a third of solid waste in the United States is recycled each year but almost two-thirds of all waste production can be recycled (How much do we waste?, 2011).

The world's emissions of carbon dioxide and the waste of fresh, clean water can also be harmful to the environment. The average carbon dioxide emissions across the globe have increased from five billion metric tons per year in 1900 to over thirty billion metric tons per year in 2008. These emissions into the atmosphere have a negative effect on the climate, which can damage ecosystems and cause dangerous tropical storms (Global Greenhouse Gas Emissions Data, 2013). Furthermore, in developed countries around the world, most families use an average of 300 gallons of water each day (Water Use Today, 2013). This amount of water consumption per day threatens the ecosystems and habitats of surrounding wildlife. However, all of these problems have answers that can make our world one step closer to environmental sustainability.

One ideal scenario would be if countries around the world would use the resources found within their nations to sustain life while producing as little waste as possible. However, many countries around the world have a problem with waste management, reuse of fresh, clean water, carbon emissions, as well as a lack of knowledge about how to preserve the world's natural resources (Palmer, 2005).

Specifically, Puerto Rico needs to adopt more aspects of being environmentally friendly and apply them to everyday life on the island.

The island of Puerto Rico lacks an area where municipalities can properly discard their waste. Some of the problems are caused by landfills, which take up precious space on the island and also contaminate the soil the landfills surround (Youkana, Milano, and Bosman, 2004). According to the Solid Waste Authority of Puerto Rico, the island produces more than 4,000,000 tons of solid waste each year, yet recycles only 10 percent of this waste (Gabriel, 2011). In addition to this waste, the congestion of the human population in major cities is occupying space. The current population of Puerto Rico is nearly four million, with over one thousand people per square mile (Rivera, 2013). This population density is greater than every state except New Jersey (Resident Population Data, 2010). In addition, with a large number of students, the schools on the island lack the necessary resources to properly dispose of their waste. The faculty and staff need to be more conscious of the effects they have on the environment to set an example for the students.

For example, the inner city Sabana Llana Junior High School of San Juan, Puerto Rico is far from becoming self-sufficient and green, according to Colibrí Sanfiorenzo-Barnhard of Grupos Ambientales Interdisciplinarios Aliados (GAIA) (C. Sanfiorenzo-Barnhard, personal communication, September 9, 2013). GAIA, one sponsor of the project, is a non-profit organization with the goal of creating and teaching about the environment and what people can do to protect it (Verdes, 2013). GAIA manages the Urban Oasis School Program, which currently works with five other educational programs, including elementary schools, a vocational school, and a college program. This also includes the Sabana Llana Junior High School, which GAIA included because of its issues with flooding, garbage disposal, and garden quality (M. Varela, 2013). The director of the school approached GAIA showing interest in improving conditions of the school and surrounding area through a green infrastructure design (C. Sanfiorenzo-Barnhard, personal communication, September 9, 2013). GAIA then asked the International Institute of Tropical Forestry (IITF) and Worcester Polytechnic Institute (WPI) to form a team with the purpose of creating a design to help the school achieve their goal of self-sustainability. Further investigation of the problems with the school's waste and current state of school grounds was required in order for this school to become more environmentally friendly.

The goal of the project was for the WPI team to provide recommendations to create a green infrastructure design that benefits the Sabana Llana Junior High School, guide the school to Leadership in Energy and Environmental Design (LEED) certification, and set an example for schools located throughout Puerto Rico. With the information collected, we observed how much waste the school produces and developed new ways for the school to become self-reliant through infrastructure, recycling practices within the school, water and energy efficient methods, and education. We examined the school grounds to make recommendations for improvements to the school such as composting, implementing cool and green roofs, and installing a water catchment system. We made more recommendations using data collected at the school through interviews with sponsors, faculty, and students about their knowledge of environmental sustainability. Our team worked to achieve our overall goal of assisting the Sabana Llana Junior High School in becoming more environmentally sustainable.

CHAPTER TWO: BACKGROUND

This chapter includes a discussion of background material on how to create a more environmentally sustainable school, such as information on water catchment systems, green roofs, tree replacement, composting, efficient lighting and plumbing, alternative energy, and recycling. There are many other aspects of being green, but we narrowed our research in all aspects based on our sponsors' suggestions. We also considered the time of implementation, economic feasibility, as well as the social and technological conditions of the school. Our team reviewed the transformation of the Puerto Rican economy from 1950 to the present in order to understand the current economic situation and how it affects the type of funding a school project could possibly receive. Our team also researched the educational system of Puerto Rico, the Sabana Llana Junior High School's current environmental practices, and the environmental solutions to its problems, such as flooding, garbage disposal, energy and water usage, and garden quality. Next, we considered the LEED certification requirements, which are the foremost standard in the United States and Puerto Rico for green building design (LEED Rating Systems, 2013). Finally, we researched funding that could make a project of designing a green school possible.

PUERTO RICAN ECONOMY

The economic state of Puerto Rico has a great impact on the feasibility of the completion and installation of the green infrastructure design of the Sabana Llana Junior High School. In the last half century, the island's fiscal condition has been declining, affecting the financial state of Puerto Rican school systems (Collins, Bosworth, and Soto-

Class, 2006). Therefore, funding is an obstacle taken into account when making recommendations for the school.

Historical Background

Puerto Rico's economic history since the 1950s can be split into two distinct periods. Following World War II, the United States imposed Operation Bootstrap with the purpose of transforming the Puerto Rican economy from agricultural to industrial in a movement towards urbanization. In contrast to contemporary times, this was a period of growth and development for the island as Puerto Rico began its industrialization push and its incorporation into the emerging global economy. Residents felt a sense of progress as the program improved aspects of the community, including education, housing, drinking water, electrification, sewage systems, roads, and transportation facilities. However, by the 1970s, Operation Bootstrap failed to generate employment and two thirds of the population qualified for food stamps (Korrol, 2010). In the next five years, Puerto Rico experienced a downward cycle of economic issues that would leave them far behind the economic state of the mainland U.S. These economic problems have carried over into present-day Puerto Rico, thus making it difficult to receive funding for projects such as the design of a green infrastructure on the Sabana Llana Junior High School.

Current Economy

Today, the island of Puerto Rico suffers from a challenging economic situation, somewhat comparable to that of Detroit, Michigan (Connor, 2013). The income per capita is less than half that of the most impoverished state in the U.S. According to the 2006 report by Collins, Bosworth, and Soto-Class (2006), the living standards on the island are lower in 2006 than in 1970, in comparison to the United States average.

Through the assessment of three major aspects of the Puerto Rican economy, the authors show why the island has fallen below the living standards with respect to the U.S. since 1970. The commonwealth of Puerto Rico has a public debt of $65.2 billion, imposing limitations to aid in public programs (Rivera, 2013). Investigations of Puerto Rico's labor productivity show a decline in the working-age population and output per worker. This combination helps illustrate the reason for the severity of Puerto Rico's fiscal situation, more specifically in the divisions of labor supply and demand, trade, and entrepreneurship. This has had a major impact on the residents of Puerto Rico, and as a result, many have chosen to leave the island in order to seek better job opportunities and improve their livelihoods (Connor, 2013).

With the fiscal state of the island in turmoil, Puerto Rico's Department of Education has a very austere budget. According to Colibrí Sanfiorenzo-Barnhard, Puerto Rico spends approximately $8,700 per student per year on average (C. Sanfiorenzo-Barnhard, personal communication, September 16, 2013). This is 21% less than the average spent on the U.S. public school student in 2012 (The Condition of Education 2012, 2012). This gap in funding creates obstacles in providing proper facilities and resources for students and limits available funds for supporting green efforts.

PUERTO RICAN SCHOOL SYSTEM

In order to design an environmentally sustainable school, it is necessary to understand how the school systems of the area function, how they are governed, and how they receive money for improvements. In addition, knowing the current state of environmental education in the Puerto Rican school system is useful to understand the depth of knowledge the students have about how they can influence the environment.

Department of Education of Puerto Rico

There are 1,473 public schools on the island, all under the central administration and management of the Department of Education of Puerto Rico and the Puerto Rico Education Council. According to an article in *Caribbean Business,* the Department of Education has a larger budget than any other government agency, consisting of $3.8 billion (A look at Puerto Rico's education system, 2013). While this budget seems like a lot of money, improving the quality of education has come second to meeting the requirements to qualify for federal funds (A look at Puerto Rico's education system, 2013). Because our project focused on improving the Sabana Llana Junior High School, it was important to know whether and how the Department of Education dedicates some of their money towards environmental improvements and changes in the curriculum.

Environmental Education

Although the overall state of the Puerto Rican education system is poor, there are ongoing attempts to improve the curriculum, especially in the areas of environmental education (A look at Puerto Rico's education system, 2013). These attempts emphasize the need for greater public awareness about environmental issues and teach the public how to assess and resolve them. The environmental movement in Puerto Rico is trying to partner with public schools to develop activities and knowledge relevant to ecological and environmental issues (Cintrón-Moscoso, 2010). By implementing environmental education programs in public schools, students can gain knowledge on how to be environmentally friendly while also learning basic science concepts that are relevant to the environment. These programs can benefit the environment and the learning process of students trying to understand science topics. Another goal of these programs is to initiate social change by pushing students towards a more fulfilling and well-rounded education and also by encouraging the surrounding communities to do more for the environment (Cintrón-Moscoso, 2010).

PROBLEMS AT THE SABANA LLANA JUNIOR HIGH SCHOOL

The Urban Oasis School Program of GAIA strives to incorporate green aspects, such as green spaces and the reduction of solid waste, into the structure and curriculum of Puerto Rican public schools (Programas, 2013). The program works with the Sabana Llana Junior High School because of its current poor conditions. Faculty and students at Sabana Llana Junior High School have shown much enthusiasm for this project and improving the state of their school (C. Sanfiorenzo-Barnhard, personal communication, September 16th, 2013). The health teacher of the school, Migdalia Varela, has been working at the school since 2000 and understands its structural and environmental issues, such as flooding, garbage, and gardening (Valera, 2013).

According to Colibrí Sanfiorenzo-Barnhard, the coordinator of the Urban Oasis School Program and liaison for GAIA, the Sabana Llana Junior High School suffers from a number of issues that lead to environmental concerns and unpleasant surroundings for the students, making it a great candidate for improvement. First, the location of the school is between two high-traffic roadways, which create air and noise pollution immediately around the campus. The space for the students to relax outside, two round cement sitting areas, is directly at the corner of these two roadways, making it an unwelcoming place for after-school activities. The large amount of rainfall in San Juan also poses a problem because it often floods the school grounds.

Additionally, the school faces a problem with tree roots interfering with plumbing and underground pipes. When the trees were saplings, the landscapers did not take into account how large the trees would grow and how they would affect the school buildings (C. Sanfiorenzo-Barnhard, personal communication, September 16th, 2013). Figure 1 displays the roots of one tree that are growing into the pipes outside a classroom building and are uplifting them, causing major damage.

Figure 1. Root Damage to Piping

Finally, the school has yet to establish an organized recycling program. Trash litters the school grounds because students do not have many readily accessible trash and recycling bins. However, some teachers have directed the students to pick up the trash off the ground and improve the cleanliness of the school. Taking all of these issues into consideration, it is clear that the Sabana Llana Junior High School can benefit immensely from the help of GAIA and the WPI team (C. Sanfiorenzo-Barnhard, personal communication, September 16th, 2013).

LEED CERTIFICATION

According to GAIA, achieving LEED certification may be useful in improving the school (C. Sanfiorenzo-Barnhard, personal communication, September 16th, 2013).

The LEED standard is aimed at reducing energy costs and pollution, as well as conserving resources such as energy, water, and recyclables. LEED buildings improve the environmental sustainability of not only themselves, but also help in the surrounding community by setting an example for other structures to follow (*LEED Rating Systems*, 2013). Being up to the standard of LEED would be beneficial because it would increase the environmental friendliness of the Sabana Llana Junior High School.

A point system is used in order to achieve different levels of LEED certification. Figure 2 outlines the criteria for receiving these points.

LEED 2009 for Schools New Construction and Major Renovations

Project Checklist

Project Name

Date

Y	?	N	Item	Title	Points
				Sustainable Sites	Possible Points: 24
Y			Prereq 1	Construction Activity Pollution Prevention	
Y			Prereq 2	Environmental Site Assessment	
			Credit 1	Site Selection	1
			Credit 2	Development Density and Community Connectivity	4
			Credit 3	Brownfield Redevelopment	1
			Credit 4.1	Alternative Transportation—Public Transportation Access	4
			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Roon	1
			Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Ve	2
			Credit 4.4	Alternative Transportation—Parking Capacity	2
			Credit 5.1	Site Development—Protect or Restore Habitat	1
			Credit 5.2	Site Development—Maximize Open Space	1
			Credit 6.1	Stormwater Design—Quantity Control	1
			Credit 6.2	Stormwater Design—Quality Control	1
			Credit 7.1	Heat Island Effect—Non-roof	1
			Credit 7.2	Heat Island Effect—Roof	1
			Credit 8	Light Pollution Reduction	1
			Credit 9	Site Master Plan	1
			Credit 10	Joint Use of Facilities	1
				Water Efficiency	Possible Points: 11
Y			Prereq 1	Water Use Reduction—20% Reduction	
			Credit 1	Water Efficient Landscaping	2 to 4
			Credit 2	Innovative Wastewater Technologies	2
			Credit 3	Water Use Reduction	2 to 4
			Credit 3	Process Water Use Reduction	1
				Energy and Atmosphere	Possible Points: 33
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
			Credit 1	Optimize Energy Performance	1 to 19
			Credit 2	On-Site Renewable Energy	1 to 7
			Credit 3	Enhanced Commissioning	2
			Credit 4	Enhanced Refrigerant Management	1
			Credit 5	Measurement and Verification	2
			Credit 6	Green Power	2
				Materials and Resources	Possible Points: 13
Y			Prereq 1	Storage and Collection of Recyclables	
			Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 2
			Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Element	1
			Credit 2	Construction Waste Management	1 to 2
				Materials and Resources, Continued	
			Credit 3	Materials Reuse	1 to 2
			Credit 4	Recycled Content	1 to 2
			Credit 5	Regional Materials	1 to 2
			Credit 6	Rapidly Renewable Materials	1
			Credit 7	Certified Wood	1
				Indoor Environmental Quality	Possible Points: 19
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
Y			Prereq 3	Minimum Acoustical Performance	
			Credit 1	Outdoor Air Delivery Monitoring	1
			Credit 2	Increased Ventilation	1
			Credit 3.1	Construction IAQ Management Plan—During Construction	1
			Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
			Credit 4	Low-Emitting Materials	1 to 4
			Credit 5	Indoor Chemical and Pollutant Source Control	1
			Credit 6.1	Controllability of Systems—Lighting	1
			Credit 6.2	Controllability of Systems—Thermal Comfort	1
			Credit 7.1	Thermal Comfort—Design	1
			Credit 7.2	Thermal Comfort—Verification	1
			Credit 8.1	Daylight and Views—Daylight	1 to 3
			Credit 8.2	Daylight and Views—Views	1
			Credit 9	Enhanced Acoustical Performance	1
			Credit 10	Mold Prevention	1
				Innovation and Design Process	Possible Points: 6
			Credit 1.1	Innovation in Design: Specific Title	1
			Credit 1.2	Innovation in Design: Specific Title	1
			Credit 1.3	Innovation in Design: Specific Title	1
			Credit 1.4	Innovation in Design: Specific Title	1
			Credit 2	LEED Accredited Professional	1
			Credit 3	The School as a Teaching Tool	1
				Regional Priority Credits	Possible Points: 4
			Credit 1.1	Regional Priority: Specific Credit	1
			Credit 1.2	Regional Priority: Specific Credit	1
			Credit 1.3	Regional Priority: Specific Credit	1
			Credit 1.4	Regional Priority: Specific Credit	1
				Total	Possible Points: 110

Certified 40 to 49 points Silver 50 to 59 points Gold 60 to 79 points Platinum 80 to 110

Figure 2. LEED Certification Table. Adapted from LEED for Schools. 2013

There are a total of 110 possible points that a building can earn towards becoming LEED certified. There are many different levels of LEED certification that can be achieved, such as the silver (50-59 points), gold (60-79 points), or platinum standards (80-110 points). However, only a minimum of 40 points is required for certification (LEED for Schools, 2013).

While most of the points are out of reach for the Sabana Llana Junior High School, the school can meet many attainable criteria by adding certain aspects to the campus. For example, it took the International Institute of Tropical Forestry in San Juan 5 years to become LEED certified at the silver level (Dr. A. Lugo, personal communication, October 28th, 2013).

EXTERIOR ENVIRONMENTAL SOLUTIONS

Several ideas that would lead a school to becoming more environmentally sustainable include implementing a water catchment tank, installing a green roof, planting new trees, installing permeable surfaces, and using ground waste for compost. However, because of the lack of funding and permission to construct, discussed in a later section, these ideas might not all become a reality in the short term for the Sabana Llana Junior High School.

Water Catchment System

One way to make a school and its campus more environmentally sustainable is to begin re-using water at the school by installing a water catchment system. Water catchments are installed near buildings with the purpose of collecting a surplus of rainwater. The collection of excess rainwater would reduce flooding on school grounds. This could be helpful at a school, such as Sabana Llana, as it experiences severe flooding when it rains, as shown in Figure 3. A tank, a filter, pumps, and gutters connected to the roof so water can drain into the tank are necessary to install a water catchment system.


Figure 3. Flooding of School Grounds

When rainwater is collected, schools can use the water in many different ways inside the building. Rainwater runoff is an important factor to consider because as water flows to drainage systems, it collects particulates and contamination from the school grounds and surrounding streets. This can be harmful to nearby water sources and affect the treatment process the water receives. However, performing constant water quality control tests can guarantee that the water contains no harmful toxins or pathogens that could be potentially dangerous to people (Franz, 2001). Yet this type of vigilant monitoring requires money and labor that may not be available.

For example, in Rincón, Puerto Rico, engineers have installed water catchment tanks in some buildings. Puerto Rico gets over 1550 mm per year of rainfall on the northern coast and over 910 mm on the southern coast. This amount of rainfall makes Puerto Rico an ideal place to install a water catchment tank (Average Weather and Climate in Puerto Rico, 2013). The water catchment system helps to provide water for plumbing and landscaping. These systems have proven to be effective ways to distribute water to different areas (Rainwater Harvesting Rincón, Puerto Rico, 2009). The success of this water catchment tank in Puerto Rico suggests that the Sabana Llana Junior High School could benefit from such a system.

Other Flooding Solutions

In addition to a water catchment system, raised pathways, watersheds, permeable surfaces, and French drains can help with general flooding situations. Raised pathways allow for easier movement in areas that are prone to problems with flooding because the water drains off the path and down the sloped sides. An example of a raised path is at the International Institute of Tropical Forestry (IITF) in San Juan, Puerto Rico. Around the entire perimeter of the building, the sidewalks are higher than the surrounding land, as shown in Figure 4 Because of the large amount of rainfall in Puerto Rico, the raised sidewalks allow for easy access to the

Figure 4. Raised Pathways and Watershed

building without having to worry about flooding problems. The water can drain off of the raised pathways and into the watershed. A watershed is an area where water can collect and drain more easily. The IITF has set up a watershed on its grounds that collects the water that drains from the raised pathways and distributes the water among the entire area rather than having the water accumulate in one place causing flooding, depicted in Figure 5.

Figure 5. Watershed

Asphalt and cement do not allow water to permeate the surface and drain into the soil. Instead, when it rains the water collects on the surface causing a large puddle of water depending on the slope of the ground. One way to combat this is to install permeable surfaces. These surfaces allow the water to penetrate the ground and absorb into the soil, which allows for better distribution of the water. There are several types of permeable surfaces including interlocking concrete pavers, concrete grid pavers, pervious (porous) pavements, and plastic reinforcing grids. However, permeable surfaces are more difficult to install than regular asphalt and concrete pavements and require continuous maintenance (Permeable Surfaces, 2008).

French drains allow water to be moved from flooded areas to water sheds or to storm drains on the nearby streets. They are highly effective ways to remove excess amounts of water that would otherwise just puddle. To install a French drain, a trench needs to be dug out at the lowest point of the grounds where the flooding occurs. Gravel then needs to be laid down in the trench with a perforated pipe resting on top of the gravel. The pipes need to connect throughout the trench so the water can easily move from one area out to the storm drain. More gravel is added on top allowing water to permeate through the gravel and the holes of the pipe. Since French drains have a low maintenance and installation cost, they can be useful in places such as the Sabana Llana Junior High School where funding is limited (French drains, 2013).

The slope of the school grounds causes major flooding in areas such as the basketball court and the parking lot in front of the cafeteria. Although the basketball court is covered with a roof, the court still receives copious amounts of water because it is one of the lowest points on the school grounds. In addition, when it rains, water collects in two large puddles outside the cafeteria because the parking lot is sloped and made out of asphalt. Water runs from the seating area closest to the street down to the area directly in front of the cafeteria. In both of these places, the water has no place to drain and stays there until it slowly evaporates; therefore permeable surfaces would help to alleviate these flooding issues.

Another way to reduce storm water runoff is to create a rain garden. A rain garden is an area of lower land intended to alleviate the issues created from excess water while adding to the aesthetics. Rain gardens are generally made up of trees and shrubs that absorb water and help remove pollutants through different ways such as absorption and sedimentation. Rain gardens also contain mulch to keep weeds at a minimum, retain moisture, and contribute to the appearance. There is not much maintenance that needs to be completed once a rain garden is implemented except for replacing mulch as it decomposes. Therefore, the cost of a rain garden is low, making it a great way to reduce flooding.

Green Roofs

Installing a green roof is another green aspect used to not only benefit the inside of a building but also improve the surrounding outside environment. There are different types of green roofs that vary based on their cost, maintenance, durability, and plant types used, shown in Table 1. Each type of green roof described can be used in any type of climate.

	Extensive Green Roof	**Semi-Intensive Green Roof**	**Intensive Green Roof**
Maintenance	Low	Periodically	High
Irrigation	No	Periodically	Regularly
Plant communities	Moss-Sedum-Herbs and Grasses	Grass-Herbs and Shrubs	Lawn or Perennials, Shrubs and Trees
System build-up height	60 - 200 mm	120 - 250 mm	150 - 400 mm on underground garages > 1000 mm
Weight	60 - 150 kg/m^2 13 -30 lb/sqft	120 - 200 kg/m^2 25 - 40 lb/sqft	180 - 500 kg/m^2 35 - 100 lb/sqft
Costs	Low	Middle	High
Use	Ecological protection layer	Designed Green Roof	Park like garden

Table 1. Types of Green Roofs

The first type is an *extensive green roof* that has the lowest cost and maintenance compared to the other three. This type is well suited for roofs with little load bearing capacities and for low growing plant communities because the mineral substrate layer is not deep (Green Roofs Types, 2013). After establishment of vegetation, the maintenance is limited to one or two inspections a year. There are three different types of extensive green roofs based on the types of plants used (Extensive Green Roofs, 2013).

The second type of green roof is a *semi-intensive green roof*. This roof is very similar to the extensive green roof except that it has a deeper mineral substrate layer which allows for more plant possibilities. The third type is an *intensive green roof* which can use many plant options such as bushes and trees. An intensive green roof is more like a garden because it can have walkways, benches, and even playgrounds. For this type of green roof, permanent fertilization and irrigation have to be ensured (Green Roof Types, 2013).

However, putting a green roof on school grounds can be expensive and sometimes impossible to achieve within a tight budget and modern safety codes. Also, when a building is not structurally capable of supporting a green roof, the building could possibly collapse.

Cool Roofs

If a green roof is not a feasible option, another green aspect that can be implemented to benefit the inside of the building as well as to the environment is a cool roof. A cool roof has a special paint containing a coating that is lightly colored and has certain beneficial properties including high solar reflectivity and high infrared emissivity. Solar reflectivity is the degree to which a roof reflects visible, infrared, and ultraviolet rays, while infrared emissivity expresses a roof's ability to emit its absorbed heat from the environment. By creating a cool roof, the amount of reflected infrared and ultraviolet rays would increase and heat would be dispersed at a faster rate (NYC CoolRoofs, 2013).

Implementing a cool roof can be beneficial in many ways. The main benefit is that the roof can reduce cooling costs of a building because it naturally lowers the amount of heat retained. Furthermore, this prolongs the life expectancy of cooling equipment used in a building since it performs less work to cool the building and it reduces the electrical power used by the equipment. This lowers air pollution and greenhouse gas emissions, as well, since there is a lower demand for power with a cool roof (EPA Cool Roofs, 2013).

Another benefit of cool roofs is that they are generally longer-lasting than conventional roofs because they expand and contract less often, creating less wear and tear on the roof. Additionally, they help reduce the Urban Heat Island Effect. This is the phenomenon in which the temperature of dense cities increases by up to five degrees due in part to the high concentration of dark material, such as conventional roofs and asphalt (EPA Cool Roofs, 2013). A disadvantage of a cool roof is that it can deflect heat gain in the winter, but this is not a problem in an area like Puerto Rico as it is hot throughout the year (Cool Roofs, 2013).

There are different ways to implement cool roofs depending on what type of roof already exists on a building. For example, cool asphalt shingles can be installed on a currently shingled roof while metal roofs can be painted with a cool coating. Tile roofs, usually made of clay, slate, or concrete, are sometimes naturally reflective enough to achieve cool roof standards but can also be transformed into cool roof tiles (Cool Roofs, 2013).

Tree Replacement

Another way to enhance the school grounds is by removing poorly located trees, that can also be considered hazardous due to their poor structural condition, and planting new ones. According to Colibrí Sanfiorenzo-Barnhard of GAIA, contractors improperly removed the trunks of older trees at the Sabana Llana School and the roots left behind are now damaging the plumbing of the cafeteria (C. Sanfiorenzo-Barnhard, personal communication, September 16th, 2013). Figure 6 depicts how some current trees and roots are growing into school buildings and are causing structural damage as well.

Figure 6. Branch Damage to Roof 3

The school community can fix the problems created by the trees by properly removing the roots of the old trees and assuring that there are no roots left in the ground. However, according to regulations of the Department of Natural and Environmental Resources (DNER), when one tree is removed two new trees at least six feet tall need to be planted in its place (Puerto DRNA, 2013). If the trees removed are already dead, new trees do not need to be planted in their place (R. Rodriguez, personal communication, December 11, 2013).

Also, students at the school spend most of their free time at the basketball court and enjoy sitting outside to watch basketball games. However, the sun is constantly beating down on them because the court is covered but the stands are not, as shown in Figure 7. New trees behind the stands could create shade that would protect the students from the sun while also allowing them to enjoy the basketball games (C. Sanfiorenzo-Barnhard, personal communication, September 16th, 2013).

Figure 7. Basketball Court and Stands

Planting new trees would also mitigate the carbon dioxide emissions that come from cars and trucks driving on nearby streets. Another major benefit of trees is that they absorb harmful greenhouse gases, such as carbon monoxide, and improve air quality by producing oxygen. Lastly, if the trees are strategically placed, roots can absorb a large amount of water, which can help reduce flooding and drainage problems that can occur on school grounds (Mundell, 2011).

Composting

An effective way to dispose of waste would be to turn food and garden waste into compost for the soil. There are several ways to use the waste already produced by the school to help give nutrients back to the soil. The simplest way to enrich the soil is to leave the clippings on the grass after mowing the lawn. The grass clippings decompose and return their leftover nutrients to the soil. Another way to create compost and get rid of organic waste is to buy a large bin to collect compostable waste and add earthworms. The earthworms will eat the food waste and create compost for planting. Additionally, using an aerated windrow composting system is an effective way to get rid of food waste and give nutrients back to the soil. The windrows allow for air to get in to the center of the waste pile and decompose it (Types of Composting, 2013). Another advantage is the reduction of economic and environmental costs associated with collecting, transporting, and disposing of compostable waste. All of these ideas require virtually no cost, so a school with little or no funds for green practices, such as Sabana Llana, could still have the possibility of implementing them.

However, some negative effects of composting are that the leachate liquid created from the compost can contaminate ground and soil water; therefore the school must collect the liquid so it does not reach the soil. Also, a lot of work is necessary because the school needs to rotate the waste periodically to create the compost.

In Chittenden County, Vermont, schools have put a composting system in place. The students and faculty are all involved in the upkeep of the composting system and have created an extensive plan for schools to follow. Composting bins that the school created have worked very well. However, sometimes plastics and other non-compostable objects end up in the compost bin and removal is necessary because they can take up to 450 years to decompose (Plastic Cutlery, 2013). It is imperative that the school constantly monitors and properly separates the food scraps so the process of decomposition works effectively (Composting at a School, 2007).

INTERIOR ENVIRONMENTAL SOLUTIONS

The inside of the school is just as important as the outside in helping create an environmentally friendly school. Efficient water usage, solar power, energy saving lighting, and effective recycling practices can aid in environmental sustainability inside a school. If implemented, these solutions could help make the Sabana Llana School green.

Water Usage

One important way a school can improve is by how it uses water. Water is becoming increasingly important as people rapidly exhaust supplies of fresh, clean water, and more pollution enters our water supplies. This is causing the price of water to rise dramatically as its supply decreases (Coto, 2013).

A school can reduce water consumption by installing low flow toilets and low flow faucets. Since the Federal Energy Policy Act of 1992, new toilets are designed to use at most 3.5 gallons per flush. Many have two different flush settings for solid or liquid waste, which further reduces the amount of water used (Environmental Protection Agency, 2012). The Seffner Florida High School did a study evaluating how much they could save by replacing their toilets with ones that only use 1.6 gallons per flush. By upgrading their toilets, they found that they could save 790,000 gallons of water per year. This would also allow them to spend $6,100 less a year on water bills, which would quickly cover the costs of retrofitting the toilets (School Case Study, 2013). Switching to more efficient faucet heads can also reduce how much water is released without reducing the pressure (Environmental Protection Agency, 2012).

Solar Energy

One aspect of making a school green is for it to generate a portion of its power. Energy costs continue to rise as fossil fuels become increasingly scarce. Solar energy is another natural resource that people around the world use. Appendix E shows that Puerto Rico does not produce any fossil fuels and therefore has to import the majority of its energy resources (Puerto Rico Territory Energy Profile, 2013). Fossil fuel consumption also emits dangerous greenhouse gasses into the atmosphere, causing unnatural and dangerous climate change. Solar energy is more effective than wind power because wind power requires a lot of money and space that a school may not have (Gevorkian, 2012). At the inner city Sabana Llana Junior High School, there is insufficient space for a wind turbine of any practical size. Solar panels on roofs of some of the buildings can generate electricity. While solar panels would require a substantial initial cost, they would pay for themselves in time with the energy they produce (Gevorkian, 2012).

Over 500 schools across the United States have added solar power to help them save on electricity (Carlton, 2012). The Scottsdale Unified Schools district outside of Phoenix, AZ installed solar panels on 19 of the district's 32 schools and signed contracts that enabled them to pay $0.07 per kilowatt-hour instead of $0.11 from the grid. This change allowed them to save an estimated five percent or $300,000 on their annual electricity bills. The savings permitted them to payback what they spent on the panels and installation. As a result, they had more money to pay teachers and faculty. The district then rehired six teachers who had been laid off with the money it saved (Carlton, 2012).

Even in northeastern states, like New York, where the sun is not as strong, solar energy has been an economical source of power. (Solar in New York, 2013). With Puerto Rico's proximity to the equator, solar panels are a strong potential electricity source. Also, since Puerto Rico currently pays $0.22 per kilowatt-hour, it has greater potential for saving money than Arizona by generating and conserving electricity (Energy Alert, 2013).

Energy Efficient Lighting

Many buildings, including schools, can also save on energy by improving the efficiency of their lighting. By switching to energy efficient bulbs, a school can save thousands of dollars' worth of power required to light the building over the bulbs' lifetimes. Figure 8 displays statistics on the different types of lighting from 2012.

	LED	CFL	Incandescent
Light bulb projected lifespan	50,000 hours	10,000 hours	1,200 hours
Watts per bulb (equiv. 60 watts)	10	14	60
Cost per bulb	$35.95	$3.95	$1.25
KWh of electricity used over 50,000 hours	300 500	700	3000
Cost of electricity (@ 0.10per KWh)	$50	$70	$300
Bulbs needed for 50k hours of use	1	5	42
Equivalent 50k hours bulb expense	$35.95	$19.75	$52.50
Total cost for 50k hours	$85.75	$89.75	$352.50
Energy Savings over 50,000 hours, assuming 25 bulbs per household:			
Total cost for 25 bulbs	$2143.75	$2243.75	$8812.50
Savings to household by switching from incandescents	$6668.75	$6568.75	0

Figure 8. Light Bulb Comparison. Adapted from Energy Efficient Lighting. 2012.

Although this table shows statistics for an average household, these data can also apply to schools even though they have different needs. The most viable type of lighting would be Light-Emitting Diode (LED) bulbs. Since they last much longer than other types of bulbs and use significantly less energy, LEDs cover their high initial cost over their lifespan. They give off less heat at three btu/hour compared with Compact Fluorescent Light (CFL) (30 btu/hour) and incandescent bulbs (85 btu/hour). Bulbs that give off less heat help keep classrooms cool. Also, LEDs do not have toxic chemicals, while CFLs contain five mg of mercury each. The lack of toxic chemicals in LEDs is beneficial because when the bulbs need replacing, they will not contaminate landfills (Energy Efficient Lighting, 2012).

The Springfield City School District in Springfield, Ohio, saved money and energy by converting to more efficient lighting. They used a combination of 28-Watt T-8 CFL bulbs in classrooms and hallways, and LEDs for exit signs and specialty lighting. The schools found that the longer CFL bulbs were more effective at covering large areas than using many LED bulbs, but LEDs were better for small areas. For the entire district, the project cost $332,400 and saved $104,240 per year on electricity. Therefore, the bulbs would pay for themselves over their lifetime (Fickes, 2010).

Recycling

A crucial step in becoming more environmentally friendly is the ability to reuse materials. This is especially important at a school because of the vast amount of different materials used on a daily basis and the fact that up to 80 percent of a school's waste is recyclable (School Recycling Made Easy, 2013). Many schools around the world have already taken the initiative towards being green through recycling and have reaped the benefits, as well as set a great example for other schools.

For instance, Robbie Lock, founder of GrowNYC's Recycling Champions Program, educates students about recycling through assemblies, presentations, and classroom activities. This program is dedicated to promoting recycling in schools in New York City (Aparicio, 2011). It is more likely that the students will be excited about recycling and carry on this practice if they learn about how they can make a difference by recycling and through environmental education in the curriculum.

One factor that can be less obvious when encouraging a school to recycle is the support of the school's administration and staff (Sloan, 2011). The custodial staff is particularly vital, as they are responsible for ensuring the waste from different bins remains separate before collection. If the staff is not enthusiastic about boosting the students' motivation to recycle in addition to recycling on their own, then the school will never realize its full potential of helping the community. With the employees and students agreeing that it is important to recycle, one school can make a substantial impact on improving the environment.

FUNDING

In order to ensure the project's completion, there needed to be a source of funding that pays for all intended materials and construction. The Environmental Protection Agency (EPA) is a US agency that has provided funding for many environmental projects in Puerto Rico. Our team researched other funding options as well to ensure that the project receives as much aid as possible.

Environmental Protection Agency Funding

Over the last two decades, Puerto Rican schools have received numerous grants from organizations such as the EPA (Profiles of Environmental Education Grants Awarded in Puerto Rico, 2013). Since 1992, the EPA has funded over 55 million dollars in environmental education grants for many projects throughout Puerto Rico (Ippolito, 2012). These projects range from developing web pages focusing on the local environment of junior high school students to studying the inhabitants of bioluminescent bays and how human activities may be threatening their sustainability (Profiles of Environmental Education Grants Awarded in Puerto Rico, 2013). All of these programs intend to help students, teachers, and community members understand their local environment and what they can do to change the environmental issues surrounding them.

Further Funding Options

Since the Puerto Rican Department of Education provides a very limited budget and because of the current economic situation the island faces, Colibrí Sanfiorenzo-Barnhard suggested that it would be preferable for funding to come from outside of Puerto Rico (C. Sanfiorenzo-Barnhard, personal communication, September 16, 2013). Furthermore, because GAIA is a non-profit organization, the proposed costs for all intended solutions to the problems that the school faces must be as cost effective as possible. A cost-benefit analysis can determine the estimated cost, a key part of the application process. A cost-benefit analysis is a technique used to analyze and compare the benefits versus the cost of a community or business. This systematic process is used to help judge the feasibility of a project or business.

CHAPTER THREE: METHODOLOGY

The main goal of this project was to create a feasible green design for a public school in Puerto Rico, particularly the Sabana Llana Junior High School in San Juan. Our objectives were as follows:

1. To examine the current conditions, such as waste management practices at the school, electricity and water usage, drainage, and landscape.
2. To identify ways to improve the infrastructure of the school through green aspects, as well as the feasibility of these improvements.
3. To create a list of future environmental improvements for the school based on our recommendations.

This chapter discusses the methodology to achieve the goal of this project. We analyzed the current conditions and practices at the school, the ways in which we wanted to see these improve, and the economic workability of our new green plan. To do this, we collected information using various methods including case studies, interviews, and a cost-benefit analysis.

Case Study

In Puerto Rico, we visited and performed a case study on the Sheraton Puerto Rico Hotel and Casino. We chose to study this building because it is located in San Juan and is LEED certified. We observed the infrastructure of the building as well as interviewed Ivan Alsina, the hotel's Head Engineer and Engineering Department Director, to learn about the energy efficient qualities of the hotel. Appendix A contains the interview questions and checklist used to examine aspects of the building that aided in the development of our project. By gathering this information, we further understood what is required when formulating a design for green infrastructure.

SCHOOL EVALUATION

Our team visited the Sabana Llana Junior High School to complete an evaluation of the current green aspects of the school, such as waste management and composting, water collection, trees on the grounds, current aesthetics, and recycling practices. In Appendix D, a checklist outlines exactly what our team examined upon visiting the school. Our observations allowed us to make recommendations for the school based on location, feasibility, and potential funding.

Waste Management and Composting

One objective was to determine the current waste management status of the school in order to evaluate areas for improvement. We assessed where the school members discard their waste and the companies used to remove the waste from the school. With intentions of creating a composting area, we analyzed how the school is separating their food waste and made recommendations for recyclable waste management.

Water Catchment

Our team determined if a water catchment system would be feasible on the school grounds because leading to reduced water consumption would help the school in becoming green and help mitigate puddles and large water run-offs. We determined the best locations to install water catchment systems. To determine their water consumption, we also analyzed the types of toilets and faucets the school uses by examining the current bathroom facilities. In order to determine how much water the toilets used, our team examined the brand of toilets and then researched online how many gallons per flush they use. Also, some toilets specified the gallons per flush directly on the fixture.

Other Flooding Solutions

Since the Sabana Llana Junior High School has problems with flooding, our team examined different ways to help combat this with aspects such as raised pathways, watersheds, permeable surfaces, and French drains. We investigated the best areas to implement these solutions. After focus groups with students and faculty, we found where flooding occurred on the school grounds and what they thought about different solutions to the problems. We documented where the impermeable surfaces are located by observing the current surfaces on the school grounds (Appendix H).

Our team interviewed Rosario Lecaroz, Professor and Landscape Architect at the University of Puerto Rico, and Carolyn Pabon, Head Engineer at the IITF, to further discuss permeable surfaces and methods to reduce flooding. Through these interviews, we gained information on several different types of permeable surfaces and the feasibility of implementing them.

Planting and Removing Trees

The branches and roots of some trees are creating problems for the school buildings, such as plumbing damages near the cafeteria. Many of these trees can also be considered hazardous, posing a safety concern for the students. Our team recommended which trees to remove based on the amount of destruction they have caused. We recorded where all trees are located on our sketch of the school to show where the problem trees are (Appendix G).

Our team met with Alejandro Perez, ISA Certified Arborist and owner of the company American Lawn, to investigate what trees needed removal based on the damage they are causing. He inspected every tree on the school grounds and gave us a quote on how much it would cost for the removal or maintenance of each tree.

Based on observations of the school, we determined the best areas to plant new trees so the students can enjoy shade. For example, the students enjoy watching the basketball games on the outdoor stands; however, the location provides no shade and often becomes very hot. The team considered the feasibility of planting new trees in this area as a way to create shade and also help the environment. Furthermore, through an interview with Ray Rodriguez of Para La Naturaleza, we determined the species of trees that would best complement the school grounds.

Solar Panels, Green Roofs, and Cool Roofs

We considered different locations to determine the feasibility of installing solar panels, green roofs, and cool roofs. By looking at the buildings, we determined if they are structurally sound enough to support solar panels or green roofs. Tall buildings with large roof areas that are unobstructed by trees would be more sensible for solar panels. We researched commonly available solar panel kits online to find their cost and how much energy they produce. Using these numbers, we calculated how long the return on investment for these panels would take. Our team also found and compared the costs for green roofs and cool roofs for the school after talking with arborists and Rosario Lecaroz. Through our research, we determined whether or not solar panels, green roofs, and cool roofs are effective improvements for the school.

Lighting System

Since sunlight does not produce a significant amount of lighting for the classrooms, we also examined the current lighting system to determine what types of bulbs they use. This allowed us to determine if more energy efficient models would benefit the school.

Recycling Practices at the School

Through interviews and our own observations, we assessed current recycling processes at Sabana Llana. By asking the students and faculty where they generated the most trash accumulation on school grounds, we determined the best locations for recycling bins to obtain maximum recyclables and trash separation. The students of the school helped us with this determination as part of a class. By learning the importance of recycling in school, it is more likely that the students will continue to recycle in the future.

HABITS AND OPINIONS ON THE ENVIRONMENT AT THE SCHOOL

In order to identify and understand the opinions of the students and faculty of the Sabana Llana Junior High School about the school's current environmental status, we conducted interviews and focus groups with faculty and administration. We met with teachers who wanted to speak to us because of their concerns with the school. We used classroom-sized focus groups and drawing activities with the students instead of interviews to alleviate intimidation that one-on-one interviews may cause. The drawing activities also allowed us to overcome the language barrier we faced with the children. Since our changes will affect students and faculty the most, their points of view were important to understanding how we can better incorporate their ideas into our design. We were also interested in the environmental habits, if any, that the students and faculty already had at the school. By observing the students and faculty at the school, we determined their everyday behavior and how they manage their waste.

Interviews and Focus Groups at the Sabana Llana Junior High School

Appendix C contains the questions used during our interviews with the staff and administration. These questions pertained to the environmental habits of the students and faculty and their opinions on the current and future environmental status of the school. We conducted a focus group with the faculty using Colibrí Sanfiorenzo-Barnhard as our translator. This was carried-out in a semi-standardized fashion, which allowed us to change the wording and format of the questions if necessary. For the students, we used classroom-sized focus groups and the questions asked are located in Appendix B. From these results, we compiled common interests and problems from the members of the school community. We used the responses from our interviews to help us make recommendations for how the school can become more environmentally sustainable.

COST-BENEFIT ANALYSIS

By performing a cost-benefit analysis for all solutions to the school's problems, our team investigated the most cost effective methods to retrofit the school. Through this procedure, we were able to analyze how much each solution cost and the amount needed. The cost-benefit analysis helped us estimate the savings over the lifetime use of the project. Through this, we provided recommendations for the most cost effective products.

Since GAIA is a non-profit organization and Puerto Rico's fiscal situation leaves little funding for the Department of Education, we researched some sources of funding from outside Puerto Rico. Grants would be the main source of funding because the school does not have the money to fund itself. Magaly Figueroa of IITF helped our team contact different grant sources. Some grants may cover the construction portion of the project whereas others may be for the materials needed. In order to fundraise and apply for funds, the school and GAIA needed a design of the green infrastructure. We developed a visual design of the school using sketches in order to aid in our redesign plan and to show the school our final recommendations.

CHAPTER FOUR: RESULTS & RECOMMENDATIONS

Our team has formulated results through interviews, case studies and an evaluation of the school, which helped us determine the most reasonable recommendations.

Sheraton Hotel Case Study

From Ivan Alsina, Director of Engineering at the Sheraton Puerto Rico Hotel and Casino, we learned that the investment of making a building more environmentally sustainable is expensive and time consuming. Most of the green aspects of this hotel are not applicable to the school because the hotel has more financial resources. Like many publicly funded facilities, the Sabana Llana Junior High School is not capable of reconstructing all of the buildings on the school grounds. However, some aspects such as recycling, water catchment, and cool roofs can possibly be implemented. The interview with Ivan Alsina further helped our team understand the realism of achieving LEED certification and the amount of work it entails.

Recommendation One

The school grounds have infrastructure concerns and flooding issues that our team believes should be the primary focus of the school. While LEED certification is a long-term target, we recommend steps in that direction to address the most immediate problems in these areas.

SCHOOL EVALUATION

Waste Management and Composting System

During a class discussion, the students helped us determine the six best locations for trash receptacles based on where the most trash accumulates on the school grounds. These six locations include:

1. The basketball courts
2. Fence at rear of school grounds
3. Sitting areas by the street
4. Side of health classroom
5. Near the vending machines
6. Behind the cafeteria near the technology classroom

While the school can begin to separate their recyclable waste, they need to find a company to pick up the waste. As suggested by our sponsor, we researched two recycling companies in Puerto Rico: Conwaste and Pronatura. Conwaste has a program in which they pick up solid and recyclable waste daily or weekly. The solid and recyclable waste are in separate containers, but the recyclables are single stream and they are separated at the plant (About Conwaste, 2013). Pronatura leave recycling bins on site and then collect the materials at a later time. This company would meet the needs and specifications of the site they are working with. (Pronatura, 2013).

If the school used Conwaste, they would receive an 8 cubic yard container for their recyclable waste. They would need to pay $125 for the company to pick up their waste once a week (C. Mulero, personal communication, December 10, 2013).

If the school used Pronatura, the cost would depend on the weight and type of materials recycled. For example, if the recycled material was mainly plastic, the school would pay $75 – $100 per month. However, Pronatura would pay the school if they recycle paper, cardboard, and aluminum (M. Figueroa, personal communication, December 9, 2013).

The school has a ground waste composting site consisting of leaves, grass, twigs, and dirt. This composting site does not receive any food waste because they separate their food waste in the cafeteria. According to Colibrí Sanfiorenzo-Barnhard, there is a law stating that it is illegal for a school to have a food composting site. Therefore, Don Edwin, a local farmer, comes to the school and takes the food waste to his pig farm for free. He comes to the school every day to pick up the 30-60 pounds of food waste the cafeteria produces. The material that cannot be composted such as plastic utensils, plastic milk pouches, and paper plates are separated by the school and then thrown away with the other waste.

Recommendation Two

As seen in Appendix I, our team recommends placing recycling bins next to every trash bin at the school, so that the students and faculty always have the option to recycle. The school should use Pronatura for their recyclable pick-up. The school has the possibility to gain money from Pronatura if the majority of the recyclables is paper, aluminum, and cardboard. Also, the cost to use Pronatura is $25-50 less than the cost to use Conwaste.

In Puerto Rico, public schools cannot have a food composting site because of a law created by the Department of Education. Therefore, the school should continue to work with Don Edwin to discard their food waste. The school should continue with their current ground waste composting site because it can help the school create its own soil while also cleaning up the fallen leaves, twigs, grass, and dirt.

Water Catchment

Our evaluation of the school showed that water constantly drips down in front of the main building and produces puddles. Also, there are spigots along the side of the building that drip water and create flooding along the pathway. Based on this information, we determined this building would be most ideal for a water catchment tank. It also has the largest rooftop of all the school's buildings, which we measured to have an area of 10,482.86 ft^2. In order to catch the water from the roof, the school would need approximately 562 feet of gutters. The average amount of rainfall per day on an average yearly basis for San Juan is 0.155 inches (Monthly Averages for San Juan, Puerto Rico, 2013). Using this amount, we found that 1,010.3 gallons of rain could fall on this roof on an average day.

Recommendation Three

Due to these factors, our team recommends installing two 1,500 gallon catchment tanks at the back and the side of the main building of the school (Appendix I). These tanks have diameters of only 6 feet and would cost around $2,300 each (Innovative Water Solutions, 2012). Although these tanks would not completely reduce the flooding problem, they would help manage the rainwater that comes off the roof of the main building. The school could also use the water collected in the tanks for domestic, non-potable purposes, such as toilet water.

Plumbing and Water Reduction

In order to fulfill the checklist items in Appendix D, our team found that there were 17 toilets and 10 faucets on the school grounds. There was no brand name on the faucets in the school, so they could not be identified. Therefore, we were unable to determine whether or not they were water efficient. We obtained the school's water bills from the Department of Education and found that the school used $339.10 in the month of October (E. Reyes Rodríguez, personal communication, December 16, 2013). This amount gave us an idea of what the school spends on an average month.

The three types of toilets we examined at the school were Zurn Aquaflush, Americana, and Sloan. These toilets use 1.1-1.6 gallons per flush, according to what was printed on the toilet. As seen in Figure 9 below, 1.6 gallons per flush saves more gallons per year than most toilets. Even though this figure is for a household, it can still be applied to a school setting.

TOTO High Efficiency Toilet Water Savings:
The average American flushes five times a day at home.
Assuming an average household of 3.2 people over 365 days:

Gallons per Flush	Total Gallons/Year	Gallons Saved/Year (using HET)
5.5 GPF toilet	32,120	24,665
3.5 GPF toilet	20,440	12,965
1.6 GPF toilet	9,344	1,869
1.28 GPF toilet	7,475	—

Figure 9. Toilet Water Savings

Recommendation Four

Through our research, we discovered the current toilet system already minimizes water consumption and no change is recommended. When the school decides it is necessary to replace them, we recommend that they install the newest model of water efficient toilets. We also recommend that the school installs the newest model of water efficient faucets when they decide to replace them.

Permeable Surfaces and Raised Pathways

We conducted an interview with Rosario Lecaroz, a landscape architect at the University of Puerto Rico in Carolina, to learn more about how to implement permeable surfaces at the school. She explained that the best option for the school would be to use PolyPavement as a permeable surface (R. Lecaroz, personal communication, November 18, 2013). PolyPavement is a liquid soil solidifier that can cover existing soil and other permeable surfaces to enhance the permeability of the ground (PolyPavement, 2013). For the parking lot of the school, the existing asphalt should be replaced with pebbles on the bottom layer and PolyPavement on top. To determine the cost of installing PolyPavement, we measured the school's parking lot. The school's parking lot occupies an area of 11,126.25 square feet. The PolyPavement costs $0.34 per square foot per inch of treatment depth (PolyPavement Costs, 2013). The cost for six inches depth would be approximately $22,697.55.

Carolyn Pabon, Head Engineer at the IITF, recommended using GravelPave as another option to create a permeable surface in the parking lot at the school. GravelPave consists of a connectable ring and grid system that covers the entire area of the parking lot. Once this is in place, gravel is added to the top of the grid system, making it permeable. However, GravelPave is expensive, costing nearly $40,000 for the 11,200 square foot parking lot (Vargas, A, personal communication, December 3, 2013).

We also found that raised pathways from each school building to the next and one from the main building to the basketball court are needed. Raised pathways would allow for a more reliable way to walk to the basketball court during flooding conditions because the students currently have to walk across dirt and grass.

Rosario Lecaroz recommended using PolyPavement on a raised pathway from the main building of the school to the basketball courts. She stated they could use crushed glass and concrete for the path with PolyPavement sprayed on top (R. Lecaroz, personal communication, November 18, 2013). This pathway would be 67.5 feet long by 7 feet wide, with a total area of 472.5 square feet. The PolyPavement costs approximately 12-18 cents per square foot of treatment (PolyPavement Costs, 2013). For our calculation of cost, we used the higher margin of 18 cents, making the cost $85.05 for a pathway. The cost of PolyPavement depends on the application method, weight, and level of traffic on the area (PolyPavement Costs, 2013). Due to this, the price for the parking lot would be significantly higher than that of the pathway.

Recommendation Five

Our team agrees with Rosario Lecaroz that the best solution for the school would be to use the PolyPavement. The cost is reasonable for the school, it is an effective way to reduce the flooding in the parking lot, and it can help create a raised permeable walkway to the basketball court.

In order to fix the parking lot, we recommend that they remove all of the asphalt and the cement seating areas by the main road. Then they should replace the asphalt and the seating area with gravel covered by PolyPavement. This would allow for water to drain through the PolyPavement and not flood the parking lot. A new seating area should be created in front of the cafeteria with cement picnic tables and grass covering the ground, instead of PolyPavement. Placing a seating area there would give the children more room to eat their food and keep them from sitting right next to the busy street. They can then move the parking spots taken up by the new seating area to where the old seating area was near the street to maintain the current number of parking spots. Lastly, we recommend planting trees around the seating area and along the back of the parking lot next to the road. These would separate the seating area from the parking lot and block off the major road from the school grounds. Appendix I contains the final design that combines the concepts described above.

French drains and Rain Gardens

Based on our evaluation, we determined that a watershed would not be ideal to construct at a school because of safety concerns. Since watersheds are essentially areas where water pools, they would not be safe at a school where children play. However, another flooding solution the school can use is a French drain. A French drain is an underground drainage system that allows rainwater to travel along pipes and reduce flooding in problem areas. To hand-dig, it would cost about $1,450 to install a French drain around the perimeter of the basketball court, which is about 340 feet. To rent a Do-It-Yourself Trenching tool, it would cost about $2,200-2,700. This would save time since you would not have to dig the trench yourself. It would cost about $3,400-11,800 to rent a backhoe and an operator. This machine is easier and more efficient than a trenching tool. Lastly, it would cost $8,750 to hire a professional. With a professional, there is less of a risk for mistakes to occur and it saves time and work (French drain Installation: DIY or Professional?, 2011).

When examining where the water from the French drains should empty, our team found that creating a rain garden at the end of each drain would help alleviate the pooling of water. Rosario Lecaroz stated that rain gardens absorb a large amount of water and are perfect for tropical climates, such as Puerto Rico. Because the pooling of water at the school is an issue, placing rain gardens on the grounds would decrease the flooding while also adding an aesthetic aspect. Depending on the size, the cost of rain gardens vary. According to The Three Rivers Rain Garden Alliance, a 5 by 5 foot, 4 inch deep rain garden would cost about $200.00. A 10 by 10 foot, 4 inch deep rain garden would cost about $500.00. We chose these measurements by observing the amount of open space available at the school and where the water tends to gather during rainfall.

Recommendation Six

A French drain is our recommendation for the flooding issues at the school because the installation is simple and there are multiple methods of installation. We recommend using the trenching tool because there is no digging required and the rest of installation is not as labor intensive. Additionally, the price for a professional to install a French drain is expensive. The school would be able to dig out their own trench with the tool and then install the pipe for much less of a cost.

Our team recommends putting French drains behind Building One and in between Buildings One and Two, because flooding was a major issue in these areas. The length of these French drains would be about 200 feet all together, which would cost about $1,552. We also recommend placing a French drain around the perimeter of the basketball court because this is another area where major flooding occurs. The cost for the French drain around the basketball court would be $2,200-2,700.

Additionally, we recommend installing three rain gardens on the school grounds. One 10 by 10 foot rain garden would be located at the end of the parking lot where the water naturally flows down and puddles. Our team recommends placing another 10 by 10 foot rain garden behind the basketball court. Lastly, the school should place a 5 by 5 foot rain garden at the end of Buildings One and Two because the French drain would carry the water directly to this area. The French drain would surround the perimeter and easily lead the water to this area. These three rain gardens would cost around $1,200 total. Appendix I contains the final design that combines the concepts described above.

Planting and Removing Trees

Alejandro Perez, owner of American Lawn, stated that 35 trees or stumps at the school need to be either pruned or removed. All of these trees and stumps are either causing or will cause damage to the school buildings and plumbing or are growing too large over rooftops. Additionally, there are safety concerns with some of the trees such as spikes on the branches and falling coconuts. Mr. Perez estimated that the total maintenance of these trees and stumps would cost $23,300. He stated that not all of the trees need to be removed, but every tree needs to be pruned eventually (Appendix F). Also, some of the trees on the school grounds require removal (Appendix F). Based on his quote, we calculated two different prices for tree and stump removal and pruning. When doing the calculations we used the highest number Mr. Perez suggested based on the cost per tree, machinery, and the number of days all the work would take him. Appendix F shows the total cost for removing all necessary trees, according to Señor Perez, and pruning the rest. Also included in the table is the cost for just removing the necessary trees.

Señor Ray Rodriguez of Para la Naturaleza helped us determine the best tree species that would work on the school grounds. These different species were recommended based upon the canopy of the trees and the overall size of the trees. The locations of the new trees can be seen in Appendix I and the list of the tree species are located in Appendix K.

Recommendation Seven

We recommend that the school only removes the 12 necessary trees that Señor Perez suggested, as denoted with an "X" in Appendix G. This would only cost the school $13,650 compared to the $23,300 it would cost to remove all the necessary trees and prune the rest. Based on the law from the Department of Natural and Environmental Resources, our team recommends planting 14 new trees in different locations on the school grounds and the other six trees around San Juan. Two of the twelve trees that need to be removed are already dead, so new trees do not need to be planted in their place. The location of these new trees will add to the aesthetics of the school while also providing privacy, better air quality and shade (Appendix I). According to Colibrí Sanfiorenzo-Barnhard, Para la Naturaleza would donate the new trees to the school at no cost; however, the school community has to plant the trees themselves. Appendix K displays the types of trees that will be planted and Appendix I shows where they will be located on the school grounds.

Solar Panels

A 10,000-Watt solar panel kit online from Home Depot costs $22,500. According to their website, this kit produces between 7,200 kWh and 16,800 kWh per year. At $0.22 per kWh in Puerto Rico, and taking into account how much energy these panels produce each year, a return on investment would fall between 6.1 and 14.2 years.

Recommendation Eight

Because the school could apply for a grant of up to 50 percent of the cost of solar panels from the Puerto Rican government, we believe it would be beneficial for the school to install solar panels (U.S Territory Incentives for Renewables and Efficiency, 2013). We recommend the school buy one solar panel kit and determine how effective it is before investing in more kits. These would work best on the main building of the school, since it is the least obstructed from the sun by trees and has the most roof area.

Green Roofs and Cool Roofs

Alejandro Perez said that his company, American Lawn, can implement green roofs on top of the buildings at the school (Appendix H). For each square meter, it would cost between $90 and $135 to install (A. Perez, personal communication, November, 20, 2013). With Buildings One, Two, and Five being approximately 191.1 square meters, it would cost between $17,199 and $25,798.50 to install green roofs on each building. Building Six is approximately 156.82 square meters, therefore it would cost between $14,113.80 and $21,170.70 to put a green roof on this building. Buildings Three and Four are 124.75 and 62.73 square meters respectively, thus it would cost between $11,227.5 and $16,841.25 for Building Three and $5,645.70 and $8,468.55 for Building Four. To install green roofs on Buildings Seven, it would cost between $87.650.1 and $131,475.15 based on the fact that the building is approximately 973.89 square meters.

Based on a quote from the Environmental Protection Agency, the cost of installation for a cool roof would range from $0.75 to $1.50 per square foot (U.S. Climate Protection Partnership Division, 2013). Buildings One, Two, and Five are approximately 2,052.75 square feet. This means it would cost between $1,539.56 and $3,079.13 to install a cool roof on each of these buildings. Buildings Three and Four are approximately 1,342.85 and 675.19 square feet respectively. It would cost between $1,007.14 and $2,014.28 for Building Three and between $506.39 and $1,012.79 for Building Four. Building Six is approximately 1,687.98 meaning it would cost between $1,265.98 and $2,531.97 for installation. Building Seven is 10,482.86 square feet and therefore it would cost between $7,862.15 and $15,724.29.

Recommendation Nine

Our team recommends installing cool roofs instead of green roofs on only Buildings One through Six (Appendix H) because the other buildings are not suitable for a cool roof and would cost too much based on their size. The total for this would cost $14,796.43, which is less than the $123,876.00 it would cost to install green roofs on these buildings. Also, installing cool roofs would help reduce the temperature of the buildings and would require no maintenance for the school members.

Lighting System

The school already uses CFL bulbs in every building for all lighting fixtures. Also, switching from CFLs to LEDs would not be feasible due to wiring at the school. We obtained the school's electricity bills from the Department of Education and found that the school uses $5,564 per month. This includes the cost for lighting, air conditioning, and any other electronic devices used at the school (E. Reyes Rodríguez, personal communication, December 16, 2013).

Recommendation Ten

Our team recommends that the school does not change the current lighting system. CFLs are energy efficient and are less expensive than LEDs. Installing LEDs would require a large amount of work and funds, which the school does not have. However, when the school does decide to replace the lighting system, they should switch to LEDs because they are more efficient than CFLs.

FUNDING

Current Grants

Through GAIA the school has already received two grants to begin making improvements. According to Colibrí Sanfiorenzo-Barnhard, the school has received a

$1,000 grant from Syracuse University to start a recycling program and improve the capacity of the buildings along with the infrastructure. A $700 grant from the Rural Education for Americans Project (REAP) Foundation was awarded to the school to create gardens and also improve the infrastructure and capacity of the buildings.

Solar Power Grants

We found two grants that the school could apply for that would help them pay for solar panels. One grant is the Puerto Rico – Green Energy Fund Tier II Incentive Program. This grant gives up to 50 percent of the estimated cost of installing solar panels. Another is the Puerto Rico – Green Energy Fund Tier I Incentive Program, which gives up to 40 percent of the cost (US Territories Incentives for Renewables and Efficiency, 2013).

DNER Grant

We also found a grant that the school could apply for through the Department of Natural and Environmental Resources (DNER). This grant could be used for any type of project that strives to benefit the environment and community. If the school were to receive this grant, they could put the money towards any of the green aspects this project recommends. Through our research and recommendations, we found that this entire project would cost about $83,897.03.The breakdown of the costs for this project are located in Appendix J.

CHAPTER FIVE: FUTURE CONSIDERATIONS

From working on this project, we have encountered many issues that should be mentioned if this project is to be continued in the future. There are other green aspects that should be focused on at the school and qualities of the structure of the Puerto Rican public school system that should be taken into consideration when looking into working on this project.

Future of this Project

After completing our recommendations, the school should consider several other green aspects that we were not able to assess due to time and resource constraints. They should research how to improve the air regulation inside the school buildings to reduce poor air quality and atmospheric contamination from air conditioning. This would involve examining the types of air conditioners they use, insulation and ventilation of rooms, and the indoor air quality.

Future improvements should also examine how to minimize the noise pollution of the school. Additionally, adding environmentally friendly transportation options could improve the school's environmental impact, such as encouraging students to walk or ride bicycles. The school should further assess and develop its methods of educating students on environmental issues to ensure that future generations continue environmentally friendly practices. A future IQP could potentially work on reviewing these aspects and eventually help the school work further in the direction of achieving LEED certification (LEED for Schools, 2013).

Realities of the Puerto Rican Public School System

In Puerto Rico, the entire public school system is centralized under a single school district. It is administered by the Puerto Rico Department of Education (PRDE) and fully funded by Puerto Rico's state government. This means that local communities have little say in the school curriculum and policies, and that many local initiatives common in other states cannot happen here.

The reality of the Puerto Rican public school system reflects the current socioeconomic status of the island, where the poverty rate is now 44.9% (Foxman, 2013). As a consequence of the high poverty rate, the public elementary and high schools are over-crowded with students (Gómez & Dávila). Families of the middle and upper classes can send their children to private K-12 schools, yet the large low-income population does not have the money to provide their children with these educational opportunities and must send them to public schools. This situation further exacerbates the divisions between the two classes and the current economic situation.

Since the public school system falls under one district for all of Puerto Rico, local school information and bills are sent to a central location in the Department of Education. Because of this, schools do not even see their bills and have little understanding of their monthly utility costs. Furthermore, schools are unaware of their consumption, and thus do not know how to gauge and reduce this usage, such as water, energy, and food.

In addition, it is difficult to retrieve this local information or communicate with an administrator specifically for the San Juan region. Furthermore, many of the Department of Education websites are not updated frequently, resulting in inaccurate contact information and resources.

Through major companies, schools can apply for different grants. However, the reality is that even though these grants are available, the application process makes it difficult for schools with limited resources to even consider them. Also, individual schools are less motivated to apply for grants and make changes because they do not receive the direct benefits these grants supply. For example, if a school were to receive a grant and install solar panels, they would not save any money from the reduced electricity consumption. Since the Department of Education pays the bills, they would be the ones to receive a credit from the electricity company that cannot even be applied to anything (C. Sanfiorenzo-Barnhard, personal communication, November 20, 2013).

Conclusions

We conclude that the recommendations we made for the Sabana Llana Junior High School are the best options for improving this inner-city school. If implemented, they will limit the school's environmental impact through reducing their waste production, flooding, carbon emissions, and water usage, while also making the school a more amiable place for teachers and students. We took into account the realities of Puerto Rico while deciding which green infrastructure design components would be feasible for the school. Since the total cost of the project is $83,897.03, we understand that outside funding from grants and the Department of Education would have to pay for most of these upgrades. Future research and fundraising would need to be continued to create a completely green infrastructure design for the school. Although it would probably take some time to complete these developments, the school and the environment should eventually appreciate their benefits. Finally, other schools in San Juan could use similar methods to ours to become more environmentally sustainable.

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APPENDICES

Appendix A: Sheraton Hotel Case Study Questions & Checklist and Answers

1. What types of environmentally friendly technologies and practices are present in the building?

- The Air Conditioning system manages indoor air quality efficiently
  - Fresh air intake
  - Uses little energy to cool building
  - 60-70% of energy reduction is from the AC units
  - Monitors PPMs (parts per million) of pollutants in fresh air
- Dimming system for lighting
  - Based on how much natural light is in the building, the system dims and brightens automatically throughout the day
- Lights are CFL bulbs
  - The hotel is in the process of converting to LEDs
- The hotel promotes alternate forms of transportation
  - Bike racks
    - Has lockers and showers for bike riders
  - Energy efficient cars receive optimal parking spots
  - Public transportation
  - Hope to have a train stop near hotel in the future
- Efficient water usage
  - 1.6L per flush toilets
  - Low water consumption faucets
  - Rain collection system
    - Drip system for landscaping
- Reflective and cool roofs
- Reflective windows
- Asphalt outside has a lower heat coefficient
- Paint with no VOC (volatile organic compounds)
- Furniture in guest rooms are made with recycled wood and fabrics
- Glue for carpets are low VOC and made with recycled material
- Sustainable Meeting practices
  - Recycled materials, reusable cups, recycling bins
- Company maintains a composting system
  - Food waste
- Phones in hotel are made from recyclable material
- All electric products are lead free
- Environmentally friendly chemical cleaning products

2. **What benefits have you seen from the green technologies?**
   The hotel improved the energy efficiency by 15-20%.
3. **How did you decide what improvements were feasible and which were not?**
   The hotel looked for the best environmental options, regardless of the cost.

Checklist

1. **How much energy do they save in comparison to buildings in the area that are not LEED certified?**
   15-20% of their energy
2. **How do they implement recycling?**
   - Where there is a trash receptacle, there are also recycling options.
   - Make a green choice program
     - Do your own room service for three days
     - Saves towels and cleaning supplies
     - Get a 5 dollar voucher each day
     - Receive cleaning service on the fourth day
3. **Are there solar panels placed on the roof or a garden?**
   - No solar panels
   - Cost too much money
   - Looked for return on investment within a year, not several years
4. **Did they apply for funds or did they have the money from within the building to make these changes?**
   They did not need outside funding.

Appendix B: Student Focus Group Drawing Activity

1. How can you make the environment at your school healthier?
2. What is one area of your school that you would like to be different?

Appendix C: Faculty Questions:

1. What grade and subject do you teach?
2. How long have you been teaching at the school?

Next, we would like to ask you specific questions about your school:

3. Do you teach about the environment in school?
4. In your opinion, what are some good qualities of your school?
5. Do you think your school could benefit from any improvements?

a. If so, what are the improvements?

6. Does your school have a recycling system?
7. Is there anything you have seen at other schools that you would like to see at your school?

Appendix D: Checklist for School

Inside:

1. **How many and what types of toilets do they currently have?**
   The school uses 17 toilets that are a mix of Sloan and Zurn Aquaflush toilets. These toilets use 1.1-1.6 gallons per flush.
2. **Are they using paper towels in the bathroom or hand dryers?**
   They use paper towels.
3. **How many and what types of faucets are they using?**
   They use 10 faucets that are a mix of ASME A112.19.2 and Glacier Bay.
4. **What kind of light bulbs are they using?**
   The school is using Compact Fluorescent Light Bulbs
5. **Ask if we can look at the current energy bills (water and lighting/energy)**
6. **Are they currently separating paper and plastic from the rest of the trash in classes?**
   Currently the school has a grant to start a recycling program but they currently do not separate paper and plastic from the rest of their trash.
7. **Is there a recycling option next to every garbage can?**
   No because the recycling system has not been implemented yet.
8. **Are there any signs that encourage students to recycle?**
   No because the recycling system has not been implemented yet.
9. **Where is the food waste being placed in the cafeteria and is it being seperated?**
   The food waste is separated from the rest of the garbage and picked up by a local pig farm company.

10. **Do they use trays and other reusable dishes and utensils during lunch or do they throw out their plates?**
    The school throws out their plates and utensils after separating them from the food waste.

Outside:

1. **Where is the majority of the flooding?**
2. **Are any of the roofs flat?**
   All of the roofs are flat except for the basketball court and theater.
3. **Is there a good spot to place a composting system?**
   The school currently has a composting system in place behind one of the classroom buildings.
4. **Is there room to place a water catchment tank?**
   Yes, but not for one large enough to catch the amount of water that the school receives from rainfall.
5. **What is the current condition of the sitting area for the students?**
   Many of the seats have cracks in the cement and do not provide much protection from the sun and rain. They are also not comfortable and they are located near the main road.
6. **Is there any noticeable environmental contamination?**
   Yes. There is trash on the ground throughout the campus. Some of the pipes are leaking greywater into the ground.
7. **How much rainfall does the school receive?**

Appendix E: Puerto Rico Fossil Fuel Export/Reserve/Import Table

Total Exports	Puerto Rico	United States	Period
Crude Oil Exports	0 thousand barrels/day	42 thousand barrels/day	2010
Total Petroleum Product Exports	0 thousand barrels/day	2,311 thousand barrels/day	2010
» Motor Gasoline Exports	0 thousand barrels/day	296 thousand barrels/day	2010
» Jet Fuel Exports	0 thousand barrels/day	84 thousand barrels/day	2010
» Kerosene Exports	0 thousand barrels/day	1 thousand barrels/day	2010
» Distillate Fuel Exports	0 thousand barrels/day	656 thousand barrels/day	2010
» Residual Fuel Exports	0 thousand barrels/day	405 thousand barrels/day	2010
» Liquefied Petroleum Gas Exports	0 thousand barrels/day	164 thousand barrels/day	2010
» Other Petroleum Products Exports	0 thousand barrels/day	705 thousand barrels/day	2010
Natural Gas Exports	0 billion cu ft	1,507 billion cu ft	2011
Coal Exports	0 thousand short tons	108,229 thousand short tons	2011

Reserves & Supply

Reserves	Puerto Rico	United States	Period
Crude Oil	0 billion barrels	23 billion barrels	2011
Natural Gas Reserves	0 billion cu ft	305 billion cu ft	2011
Recoverable Coal	--	260,551 million short tons	2008
Production	**Puerto Rico**	**United States**	**Period**
Total Energy	*	75 quadrillion Btu	2010
Crude Oil	0 thousand barrels/day	6,467 thousand barrels/day	2012
Natural Gas - Marketed	0 billion cu ft	24,036 billion cu ft	2011
Coal	0 thousand short tons	1,094,336 thousand short tons	2011

Total Imports	Puerto Rico	United States	Period
Crude Oil Imports	0 thousand barrels/day	9,213 thousand barrels/day	2010
Total Petroleum Product Imports	176 thousand barrels/day	2,580 thousand barrels/day	2010
» Motor Gasoline Imports	48 thousand barrels/day	134 thousand barrels/day	2010
» Jet Fuel Imports	10 thousand barrels/day	98 thousand barrels/day	2010
» Kerosene Imports	1 thousand barrels/day	2 thousand barrels/day	2010
» Distillate Fuel Imports	28 thousand barrels/day	228 thousand barrels/day	2010
» Residual Fuel Imports	60 thousand barrels/day	366 thousand barrels/day	2010
» Liquefied Petroleum Gas Imports	4 thousand barrels/day	179 thousand barrels/day	2010
» Other Petroleum Products Imports	26 thousand barrels/day	1,572 thousand barrels/day	2010
Natural Gas Imports	26 billion cu ft	3,469 billion cu ft	2011
Coal Imports	1,653 thousand short tons	14,505 thousand short tons	2011

Appendix F: Tree Removal Cost and Details

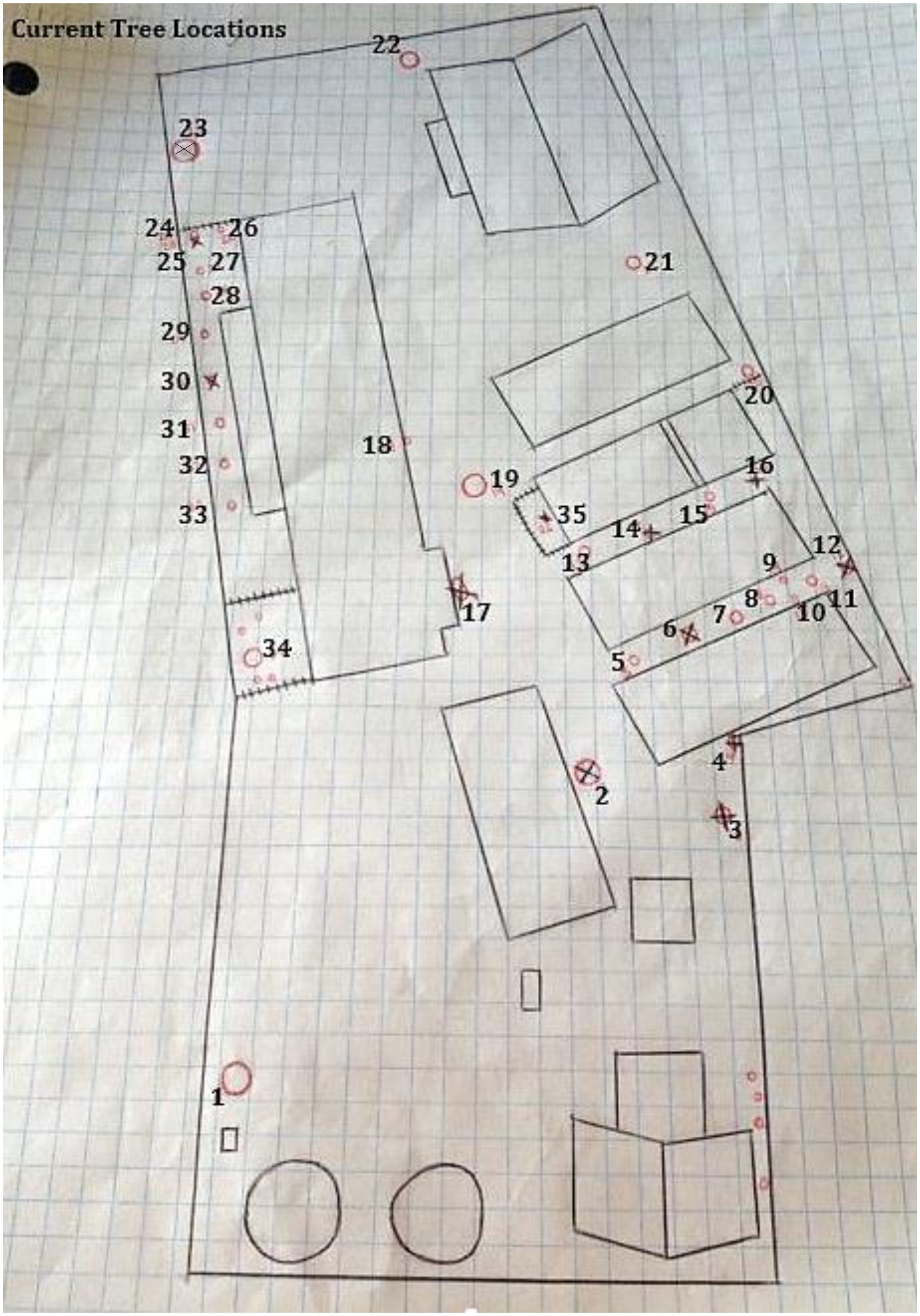
**Trees that require removal

Tree	Cost for Pruning/No root removal	Cost for Entire Tree Removal	Details/Notes
1	$2,000	$2,500	Partly hollow; water, fungus and termites inside; sprouting; root damage from cars
2**	2,200	N/A	Can only cut down to wall; nervous to work with due to damaged plumbing
3**	N/A	100	Currently small but falling coconuts may become a future safety concern
4**	N/A	100	Currently small but falling coconuts may become a future safety concern
5	200	N/A	Currently small but falling coconuts may become a future safety concern
6**	300	1,000	**Number 1 Priority for removal.** The internal fibers no longer connected to main growth of tree; Rotting from inside
7	200	N/A	Simple pruning
8	200	N/A	Simple pruning
9	200	N/A	Simple pruning
10	200	N/A	Simple pruning
11	200	N/A	Simple pruning
12**	N/A	350	Coconuts are a current safety concern; near students gardening site
13	600	1,400	For prune: leaning/diagonal branch and sprouts; Causing lots of roof maintenance from leaves and seeding
14**	N/A	1,200	Similar structural problems as Tree 13. Cannot be ripped out because it is growing into pipes. Chemical removal is required.
15	600	N/A	Make thinner at bottom; take lateral branches out; crown raising
16**	N/A	300	Hollow; infested with red ants
17**	N/A	1,000-2,000 (depending on complications)	Backhoe needed to take out tree if there is no piping underneath; The sideways growth creates very hard wood
18	0	0	Dead stump; removed on site via hands

19	500	N/A	Lateral prune of left side (due to regulations of roof overhanging); dead wood removal
20	200	N/A	Simple pruning
21	500	N/A	Roots are growing towards building; could be future issue
22	1,500	N/A	Crown raising; termites; take out entire right side (inverted corner)
23**	4,000	5,500	African species not native to Puerto Rico; pods have tons of seeds that will grow anywhere (as seen in tree 25); power line issues; areas of tree are sick/dead
24	150	N/A	Simple pruning
25**	N/A	500	Same species as Tree 23; needs to removed completely
26	100	N/A	Simple pruning
27	100	N/A	Simple pruning
28	100	N/A	Simple pruning
29	100	N/A	Simple pruning
30**	100	300	Simple pruning; only tree in row recommended to be taken out
31	100	N/A	Simple pruning
32	100	N/A	Simple pruning
33	100	N/A	Simple pruning
34	400	N/A	Crown Raising; get off electrical wires
35**	N/A	100	Interfering with electricity box

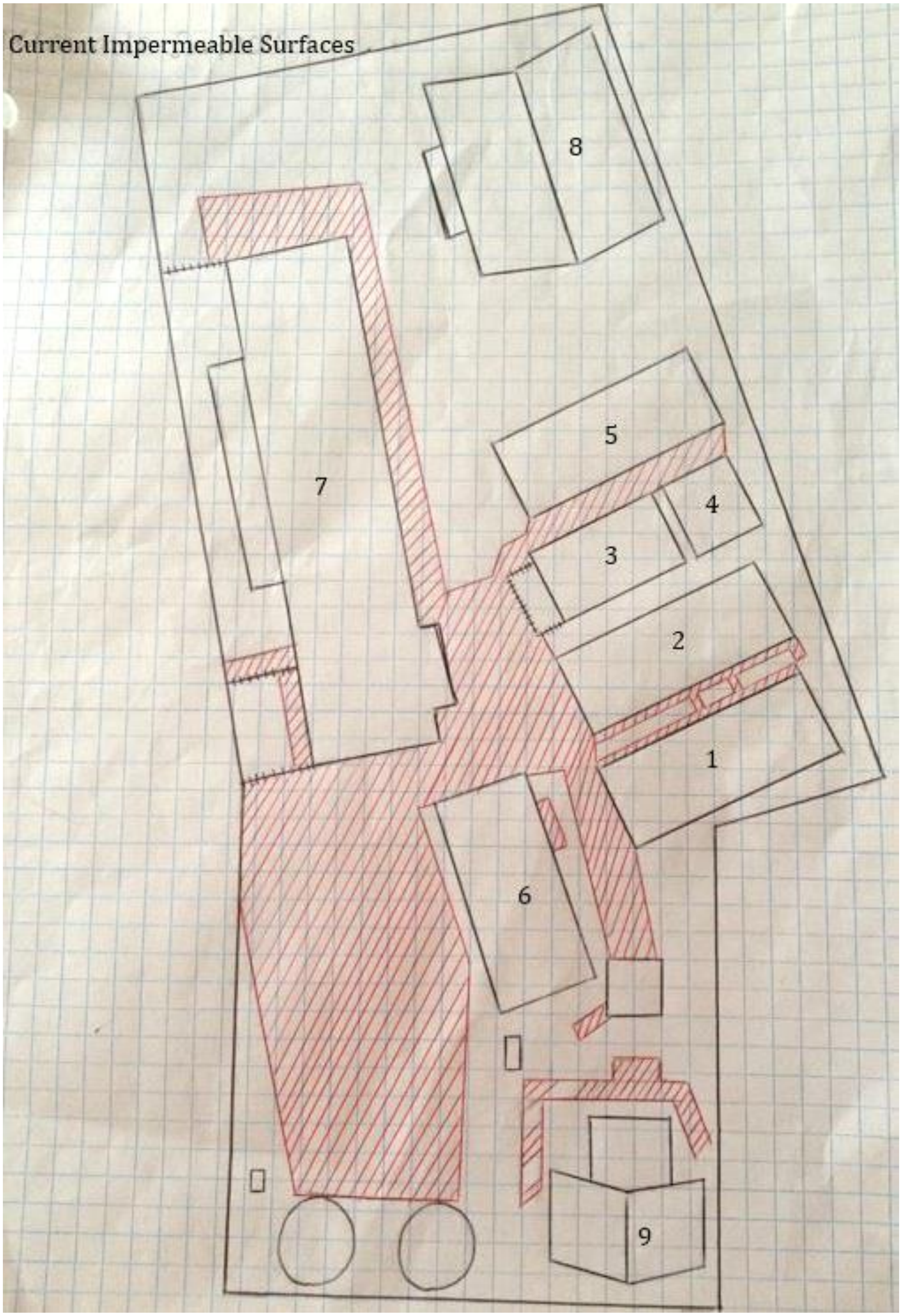
Cost for Removing all Necessary trees and Pruning all the other trees:	**Cost for only tree removal**	**Cost for Only Necessary Tree Removal (Trees with **)**
23,300 (This is the highest possible cost)	15,350	13,650

Appendix G: Current Tree Locations

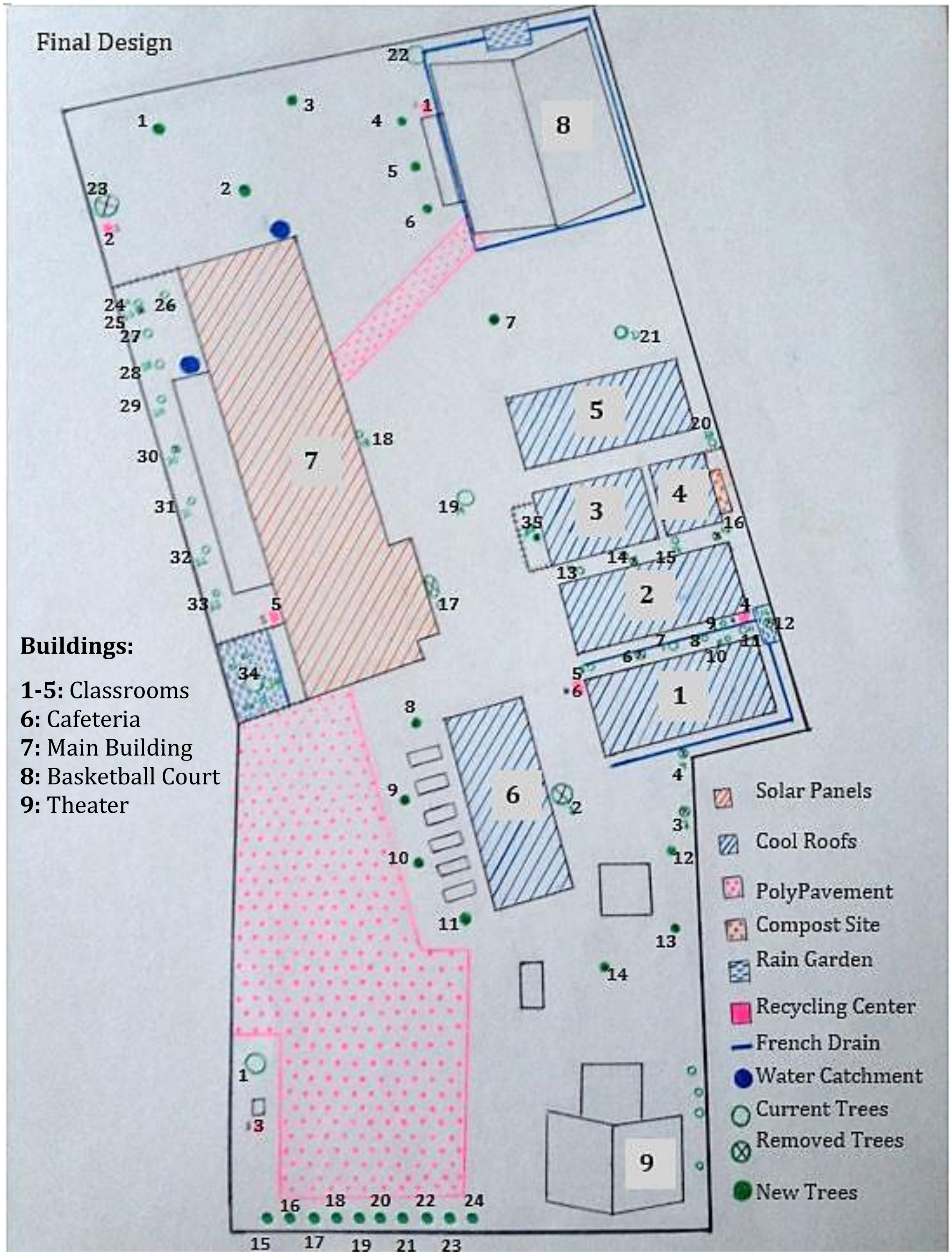


Numbers correspond to Table in Appendix F.

Appendix H: Impermeable Surfaces and Buildings



Appendix I: Final Design



Appendix J: Total Cost

Aspects	Price
Pronatura	$100.00
Water catchment tank	$4,600.00
Faucets and Toilets	$0.00
PolyPavement-Parking Lot	$22,697.55
PolyPavement-Walkway	$85.05
French drain-Basketball Court Perimeter	$2,716.00
Rain Gardens 5 by 5	$200.00
Rain Gardens 10 by 10	$1,000.00
French drain- Behind Building One and Two and Behind Building One	$1,552.00
Tree Removal	$13,650.00
Solar Panels	$22,500.00
Cool Roofs	$14,796.43
Lighting System	$0.00
Total	83,897.03

Appendix K: Tree Species

Tree Numbers	Scientific Name	Name	Distance from Another Tree	Area Of School
1,2 3 & 7	*Pimenta racemosa*	Malaguetta	15-20 feet	Open areas of school grounds
8,9,10 & 11	*Poitea florida*	Retama San Jose	Minimum of 12 feet	Cafeteria Seating Area
4 & 6	*Dendropanax laurifolius*	Cow Tree	25 feet	Near Bleachers
12,13 & 14	*Eugenia ligustrina*	Privet Stopper	12-15 feet	Area near cement block
1,2,3 & 7	*Tabebuia haemantha*	Maroon Oak	8-15 feet	Open areas of school grounds
5	*Citharexylum fruticosum*	Pendula	20-35 feet	Near bleachers
15-24	*Borrichia arborescens**	Tree seaside tansy	5 feet	Along fence near main street

*This plant is a shrub, not a tree, therefore does not count in the number of trees that need to be replanted.

Tree Numbers correspond to “New Trees” of Final Design in Appendix I.