ABSTRACT

Title of Document: ENGAGING CHILDREN IN HAITI: UTILIZING FOUND MATERIALS AND PROVEN TECHNIQUES TO GROW FOOD AND FILTER WATER

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The focus of this thesis is the design and implementation of a community health project at a new school campus for 600 students in St. Louis Du Norde, Haiti. The design harvests and filters rainwater to drinking water standards, grows nutritional vegetable crops on secure rooftops, creates social space, and recycles old tires, plastic bottles and rice sacks that otherwise pose a massive solid waste problem in Haiti. The processes are also taught to the students so they can take and use the planters at home. The materials for building the growing containers and the growing media are all free and made from local wastes (tires, plastic bottles, rice sacks, manure, soil etc.). They are easy to build and free to construct making them accessible to even to the poorest and neediest families in Haiti. The idea is to develop easily replicable and desirable solutions to the basic health needs.

ENGAGING CHILDREN IN HAITI: UTILIZING FOUND MATERIALS AND PROVEN TECHNIQUES TO GROW FOOD AND FILTER WATER

By

Harris Trobman

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Preface

Safe drinking water, sanitation, good hygiene and proper nutrition are fundamental to growth, self-worth, development, and more importantly survival. The failure to provide for these basic fundamental needs is widely acknowledged as a serious development failure of the 20th century. As a result, the poorest are left without access to sanitary water, sewage disposal, and trash collection. In developing countries, preventable water and sanitation related disease blights the lives of the poor. This presents a chronic public health challenge for developing countries with very limited resources.

This failure has left the most vulnerable populations exposed to poor health conditions causing illness and even death. Furthermore, the financial burden includes lost work days, missed educational opportunities, official and unofficial health care costs, and the draining of family resources. Lack of water and proper sanitation threatens and inhibits the learning and development abilities of millions of children around the globe (WHO/UNICEF, 2006).

The world has recently increased attention and efforts to remediate these development failures. However, efforts have proven difficult and unequal, resulting in vast coverage gaps between urban and rural populations. Far too much money has been spent on centralized, large-scale water systems that cannot be built or maintained with local expertise or resources. Despite technological advances, design has yet to remediate these social and environmental ills of poverty. Sustainable implementation of simple proven technologies with available resources would help alleviate these issues. (WHO/UNICEF, 2006).

Dedication

This thesis is dedicated to the enthusiastic children of Haiti who live in a constant daily struggle for basic needs. They endure so much, yet remain so positive. Visiting forever touched me.

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Dr. Ellis thank you for your tireless effort on the project. It was rewarding working with you. Traveling to Haiti is no easy task. You took such a strong interest and dedication in the work and made sure I learned and grew from the opportunity. Your flexible work style provided me confidence to explore lots of ideas. You imparted so much to me. I am obliged to you for your mentorship.

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Chapter 1: Global Need

Human Right

"The human right to water is included – implicitly or explicitly – in a number of international treaties and declarations. The Universal Declaration of Human Rights (UDHR) states that everyone has the right to "a standard of living adequate for [his or her] health and well-being," including food and housing (UNESCO, pg2, July, 2009.)" This cannot be achieved without a minimal basis of water, sanitation, and food. Worldwide the most vulnerable populations, in particular children in developing countries have struggled to achieve and maintain these basic human dignities. The Convention on the Rights of the Child unequivocally states that children have the right "to the enjoyment of the highest attainable standard of health (Article 24, UN-OHCHR, 1989.)" Furthermore, the Convention outlines that children are guaranteed the human rights of quality drinking water, sanitation, and nutrition (Article 24, UN-OHCHR, 1989.)

"The human right to water is indispensable for leading a life in human dignity and for the realization of other human rights: in particular the right to life, to an adequate standard of living, housing, food, and health" (UNESCO, pg1, July, 2009). In order to lift people out of poverty these basic rights of drinking water, sanitation, and nutrition must be attained at minimal levels.

Millennium Development Goals

The Millennium Development Goals (MDG) is an 8 goal agreement among the UN states which includes reducing poverty, hunger, disease, and environmental degradation (UN, 2014). The agreement stipulates 21 targets and 60 indicators for measurement (UN, 2014). These goals were agreed upon in September 2000, will be measured and reevaluated at the end of 2015. The UN has boasted that strong progress has been made on meeting the MDG goals (Table 1). However, progress has been uneven across different regions, urban and rural, and significantly rich and poor (UNICEF Statistics, 2014).

Table 1 Millennium Development Goals Progress (Author; adapted from UN Millennium Development Goals, 2014

Goal		1990	Recently	Target
Eradicate extreme poverty and hunger	Halve the proportion of people who suffer from hunger	36%	18%	18%
Achieve universal primary education	Ensure that children universally will be able to complete a full course of primary schooling	80%	88%	100%
Promote gender equality and empower women	Eliminate gender disparity in educational settings	91%	95%	100%
Reduce child mortality	Reduce by two-thirds, the under-five mortality rate	99%	53%	34%
Combat HIV/AIDS, malaria and other diseases	Halve the incidence of HIV/AIDS	3.4 million infections annually	2.3 million infections annually	1.7 million annually
Ensure environmental sustainability	Halve the proportion of people without sustainable access to basic sanitation	49%	64%	75%
	Halve the proportion of people without sustainable access to safe drinking water	76%	88%	

Drinking Water Challenge

Lack of access to safe drinking water is a pressing global issue. Often taken for granted in the developed world, access to water and sanitation is one of the most crises facing the world. Safe drinking water is a fundamental right, and an essential need to sustain life (UN, 2010.). Both the quantity and the quality of water pose a major threat to human health and the environment. A safe and adequate water supply is critical for the prevention of diseases. Studies have shown as a community improves its water supply, adequate sanitation and hygiene, health improves (WHO).

Safe Drinking Water Definition

The World Health Organization defines access to safe drinking water as "the proportion of people using improved drinking water sources: household connection; public standpipe; borehole; protected dug well; protected spring; rainwater (WHO)." Drinking water is used for basic necessities, including drinking, cooking, and personal hygiene (WHO). Without water, life would not be possible. Lack of access to safe drinking water and proper sanitation is the cause of waterborne diseases that lead to sickness and even death.

Uneven Achievement

In 2010, the world met the MDG goals on access to drinking water as measured by their proxy goals (UN, 2014). During this period, 2.3 million people gained access to safe drinking water. Despite these accomplishments, universal access to improved water sources remains a major problem (table 1). Issues and questions remain about the safety and reliability of the improved water sources (Data UNICEF, World Bank, UN, WHO). Contamination continues to occur during transportation and storage (WHO). Of the population that gained access, only 55% were from piped sources (UNICEF.) Even with the MDG having great progress, it is not enough. Globally an estimated 3.5 million people, mostly children, die annually from the effects of water related diseases (WHO).

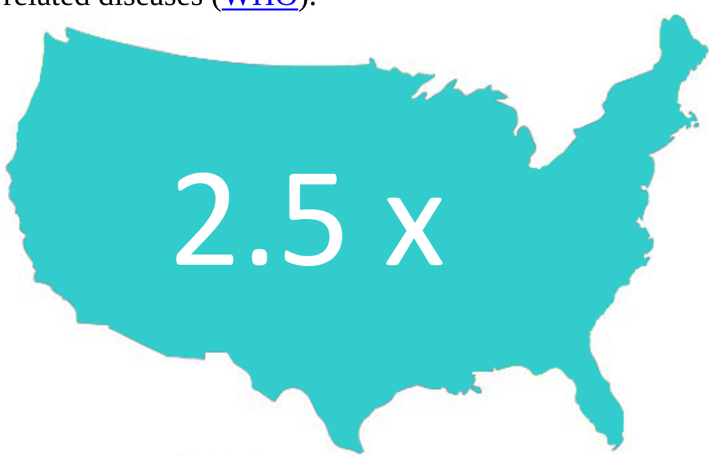

Figure 1 Population Without Access to Safe Drinking Water (Author; statistics from WHO and US CENSUS 2015)

Too many people lack the basic necessity of clean, safe water access. UNICEF estimates that globally 748 million or 1 in 9 people lack access to safe drinking water (WHO). Figure 1 displays this is roughly equivalent to the entire population of Europe (742 million) or two and half times the population of the United States (320 million). Limited resources and rapidly growing populations have made it difficult to achieve comprehensive water coverage. The right to safe drinking water refers to the overall affordability, access, taste, and sufficient supply (figure 2).

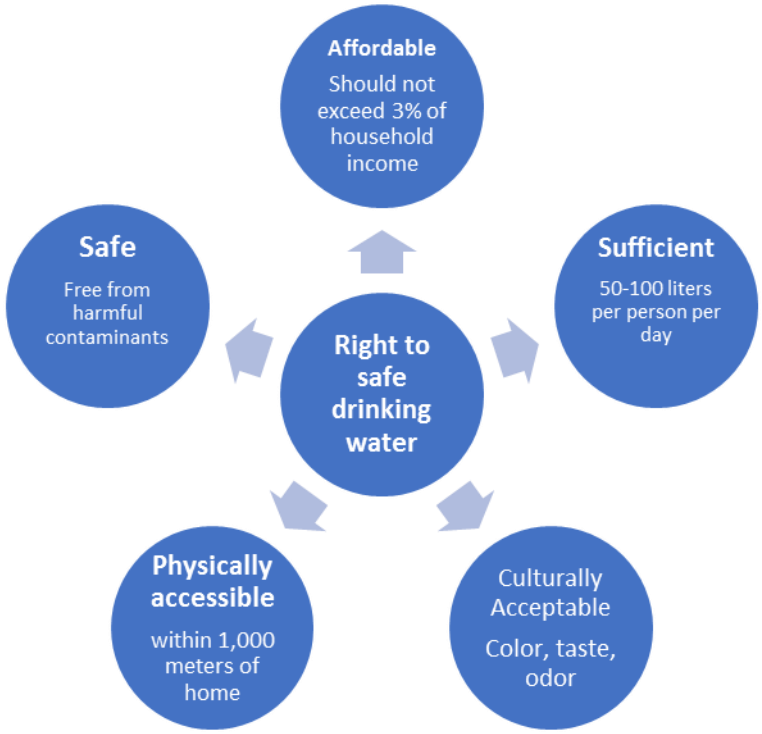

Figure 2 Rights of Safe Drinking Water (Author; adapted from UN, 2014)

A sharp gap exists geographically, economically, and socially in access to improved drinking water. Water issues are a huge burden for the poor. Research has shown people living in urban areas are much better off than the rural communities (WHO/UNICEF, 2014). "People living in low-income, informal or illegal settlements or on the outskirts of cities or small towns are less likely to have access to an improved water supply or better sanitation" (WHO/UNICEF, 2014). According to the

World Health Organization, 90 percent of the population without access to safe drinking water lives in a rural area, up from 84 percent in 2006 (WHO). The lack of drinking water in rural areas is challenging since distribution systems are difficult to extend cost effectively from urban areas, and increasingly so due to the lack of basic infrastructures such as road systems that would allow for a seamless integration.

Two thirds of the world population who do not have access to safe water comprises just 10 countries (UNICEF). Estimated losses for poor drinking water and lack of sanitation accounts for a 1.5 percent GDP loss or 260 billion annually in developing countries (UNICEF.) "Water safety is affected by geogenic contamination of groundwater, pollution from industry and wastewater, poor sanitation, weak infrastructure, unreliable services, and the need for collection, transportation and storage in the home" (UNICEF 2011.pg 10).

Water Resources on Earth

As one of the world's most precious resources, water continually presents issues across the world. Water right issues range from disputes over water contamination, water scarcity, unsustainable uses of groundwater, ecological degradation, and the threat of climate change. Some people often refer to water as liquid gold, due to its big value. 750 million people die annually due to the lack of quality fresh water (UNICEF).

Drinking water is both a problem of quality and quantity. About 71 percent of the earth is water; but 96 percent of this water is salt water, leaving only a tiny percentage (less than 3 percent) as fresh water (USGS). Water is a critical challenge facing both the short term and long term needs of people. It is not an either/or type of question. Source, quality, and quantity of water differ in areas due to geological and anthropogenic impacts (Koolwal van de Walle / Worldbank 2010.)

Health and Social impact

According to the World Health the combination of unsafe water, lack of sanitation, and insufficient hygiene account for an estimated 9.1 percent of the global burden of disease and 6.3 percent of all deaths Organization (Prüss-Üstün et al., 2008). Children and women are a particularly vulnerable population. 1 in 3 children in the developing world lack access to safe drinking water (UNICEF). A study by UNICEF found that in 60 developing countries, only 46 percent of schools had adequate water facilities (UNICEF). The majority (70 percent) of the burden of fetching water is endured by women and children, leaving less time for other socio-economic activities UNICEF.

Women and children spend collectively upwards of 140 million hours a day fetching water (watorg). Girls are twice as likely as boys to be responsible for collecting household water (UNICEF). On average, a woman and or child spends upwards of a few hours collecting water daily and up to 15 hours a week (UNICEF). This can be a major burden on educating young girls, such as arriving late or exhausted to school or even ultimately quitting school (UNICEF). The Koolwal van de Walle / Worldbank 2010 study found that in areas where a major gender gap exist, the ability to easily access water improves the attendance in school of both boys and girls. Studies have shown increases in school attendance with every hour of decrease in travel time for water (Koolwal van de Walle / Worldbank 2010).

Sanitation Burden

According to the WHO, improved sanitation is defined as "the proportion of people using improved sanitation facilities: public sewer connection; septic system connection; pour-flush latrine; simple pit latrine; ventilated improved pit latrine" (WHO). Since 1990, an estimated 1.1 billion people have gained access to basic sanitation. Despite this, uniform access remains remote (WHO; WHO/UNICEF, 2014). Improvements in sanitations have primarily benefited richer populations (UN NEWS, 2013). Similarly to drinking water access, sanitation is much worse in rural areas. Comparatively, 80 percent of urban dwellers and 47 percent of rural ones had access to basic sanitation (WHO/UNICEF, 2014).

"The vast majority of those without improved sanitation are poorer people living in rural areas. Progress on rural sanitation – where it has occurred – has primarily benefitted richer people, increasing inequalities," Dr. Maria Neira, WHO Director for Public Health, Environmental and Social Determinants of Health."

Moreover, half of the developing world lacks access to a simple latrine. This is considerably a troubling gap since more people have a mobile phone then basic sanitation (UN NEWS, 2013). As of 2013, six billion out of the world's seven billion people have a mobile phone. However, only 4.5 billion people have access to toilets or latrines (UN NEWS, 2013). The need for better sanitation is clear. Two and a half billion people worldwide or 64 percent of the world population lack basic sanitation. Additionally an estimated 1.1 billion of those practice open defecation. Asia alone accounts for half of the global population without access to basic sanitation of a toilet or latrine (WHO/UNICEF, 2014.)

Table 2 Water Pathogens (Author adapted from EPA, Pathogen Information, 2011)

Pathogens	Micro-organisms in water that cause sickness. They include a few types of bacteria, viruses, protozoa, and other organisms.
Coliform Bacteria	presence in drinking water usually results from problem with the pipes or treatment of the water
Fecal Coliform and E COLI	presence suggests that human/and or animal waste contaminated water
Cryptosporidium	parasite that enters lakes and rivers through sewage and animal waste
Giardia lamblia	parasite that enters lakes and rivers through sewage and animal waste

The lack of sanitation results in contamination of drinking water sources, increase spread of diseases, and major impacts to human health and the environment. Poor sanitation often contaminates drinking water leading to the transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, and typhoid (Table 2 and 3). (WHO/UNICEF, 2014). The areas where open defecation occurs are notably the countries with the corresponding higher mortality rates in children under 5, high rates of poverty and malnutrition, as well as significant gaps in rich and poor (UN NEWS, 2013). Sanitation is part of social norms and is often difficult to change without proper education.

Often overlooked, sanitation is critical, just like clean water, to maintaining health. Wastewater can be defined as the "liquid and fecal waste generated by a community." water. The two common types of waste water are black water containing feces and urine; and grey water used for basic bathing and cleaning. Although sanitation varies widely from region to region, waste water is commonly left untreated in developing countries; this poses contamination threats with drinkable water sources. Particularly, fecal coliform in the black water is a leading cause of water borne diseases. Traditionally in the United States, waste water will settle and any large solids will separate from the liquid.

Table 3 Diseases related to water and sanitation (Author; adapted from WHO & Bradley DJ (1998)

Group	Disease	Route leaving host	Route of infection
Water-borne diseases	Cholera Typhoid Infectious hepatitis Giardiasis Amoebiasis	Diarrhea Diarrhea/urine Diarrhea Diarrhea Diarrhea	Oral Oral Oral Oral Oral
Poor hygiene diseases	Bacillary dysentery Enteroviral diarrhea Paratyphoid fever Pinworm (Enterovirus) Amoebaisis Scabies Skin sepsis Lice and typhus Trachoma Conjunctivitis	Diarrhea Diarrhea Diarrhea Diarrhea Diarrhea Cutaneous cutaneous bite cutaneous cutaneous	Oral Oral Oral Oral Oral cutaneous cutaneous bite cutaneous cutaneous
Inadequate sanitation diseases	Ascariasis Trichuriasis Hookworm (Ancylostoma/Necator)	Diarrhea Diarrhea Diarrhea	Oral Oral Oral/percutaneous

Diseases with part of life cycle of parasite in water	Schistosomiasis	Urine/diarrhea	Percutaneous

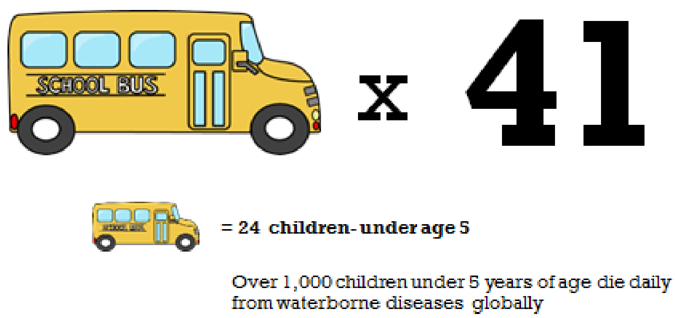

Figure 3 Children Under Aged 5 Waterborne Daily Deaths

Diarrheal Diseases

An estimated 1.6 million people die annually as a result of diarrheal diseases (WHO). Children in the developing world are the most vulnerable population, accounting for over half of all cases. According to UNICEF, waterborne illnesses are the second leading cause of deaths of children under the age of 5. Globally over 1,000 children die daily as a result of waterborne diseases, more than AIDS, malaria, and measles combined**.** Figure 3 shows this is equivalent to 41 school buses filled of children dying every day due bad water, poor hygiene, and lack of sanitation.

Nearly 90 percent of diarrheal cases in children are directly linked to waterborne diseases, sanitation, and hygiene. "Waterborne diseases are caused by a variety of microorganisms, biotoxins, and toxic contaminants, which lead to devastating illnesses such as cholera, schistosomiasis and other gastrointestinal problems" (NIH). As a whole, diarrheal diseases account for an estimated 4 percent of all deaths worldwide (WHO). Diarrhea is caused by infection spread through contaminated water by host bacteria, virus, or patristic organisms (WHO). Diarrheal diseases are caused by poor sanitation techniques in developing countries, with low access to safe drinking water.

Over 40 percent of diarrheal cases in school aged children result from infection at school, rather than home (Koopman 1978; Unicef). In the developing world, worms affect 400 million school children yearly (UNICEF). This affects children's performance in school as well as their physical health (UNICEF).

Bacteria

In 1866, scientist Ernst Haekel radically proposed a third classification kingdom known as Protista. Until this point, all living matter was considered either plant or animal. Protista comprised all microorganisms such as bacteria, protozoans, fungal and algae. While scientists continue to expand the classification kingdoms of living organisms, bacteria are distinct from other living organisms. Within the kingdom Prokaryote, bacteria unlike Eukaryotes (fungi, protozoa, higher plants, and animals), is uniquely singular, generally not complex, and not contained in a nucleus. (NESC; Jespersen, 2004.)

Malnutrition

Another burden associated with poverty is malnutrition, a major health, political and socioeconomic problem. Inadequate nutrition leads to poor health effects. According to the MDG, "Malnutrition erodes human capital, reduces resilience to shocks, and reduces productivity (impaired physical and mental capacity" (unsystem, 2004). The United Nations Food and Agriculture Organization estimates that 1 in 9 people, or 805 million people worldwide suffer from chronic malnourishment (WH, 2014). Simply, malnutrition indicates a lack of some or all nutritional elements necessary for human health (WH, 2014). Malnutrition can result from lack of food or not getting the proper foods, minerals, or vitamins (WFP, 2015). The underlying cause of lack of nutrition and proper food sources stems from economic and political operations that cause an unequal balance in resources (WH, 2014). Hunger results from a lack of resources or unequal distribution of resources. As of 2008, 1.35 million people lived on less the $1.25 a day (UN, 2014, WH, 2014).

Critical Period-Development Period

Malnutrition affects a child's performance at school as well as their future income status as an adult. The first two years of life are the most critical window for adequate nutrition. This period is critical to preventing irreversible damage to a child's physical and mental development as a result of malnutrition. 1 in 3 of all deaths in children under age 5 years old is a result of malnutrition or under nutrition (WFP, 2015.)

Types and Health Effects of Malnutrition

Malnutrition is the biggest contributor to disease in the world (WFP, 2015; unsystem, 2004).) As a whole, malnutrition affects the physical and mental development of people (WFP, 2015.) There are several different forms of malnutrition; each form is dependent on what nutrient is missing and for how long in the diet. The most basic is protein energy malnutrition. This results from a diet lacking in major macronutrients, such as carbohydrates, fats and proteins. The other type of malnutrition is micronutrient (vitamin and mineral deficiency) (WFP, 2015).

1 out of 3 people in developing countries are affected by vitamin and mineral deficiencies, according to the World Health Organization. The three most important vitamin deficiencies are vitamin A, iron, and Iodine (WH, 2014). People with these deficiencies have increased risks of chronic health problems, despite the fact that. These nutrients can be found in many common vegetables, fruits, and nuts (see table 4).

Table 4 Common Nutritional Deficiencies (Author)

Vitamin/Mineral	Health risks	Vegetable/Fruit/Nuts
Vitamin A	Leads to blindness, reduces resistance to diseases, and growth retardation	Dark leafy green; sweet potatoes; squash, mangoes, peppers; and carrots
Iron	Anemia; premature birth; low birth weight; physical and cognitive development	Sunflower seeds; dark leafy greens; nuts; and beans
Iodine	Stillbirths, mental health problems, and congenital abnormalities	Strawberries; potatoes; cranberries; beans; bananas; and seaweed

Eliminating malnutrition is a two part process: 1) stopping it and creating a sustained source of nutrition; 2) preventing it in places where it is likely to occur by providing a healthy environment and a food source that helps provide the nutrition needed. (WFP, 2015).

Chapter 2: Providing for Imperatives

What Can Be Done?

"Today millions of people on the planet, especially in the rapidly growing cities of the developing world, endure living conditions much worse than what Olmsted witnessed in Lower Manhattan. We confront as well — perhaps for the first time in history — the public health challenges of prosperity. We now identify diseases like cancer, heart failure, diabetes, emphysema and even obesity as "lifestyle diseases," resulting from individual and social behaviors, from personal choices and cultural patterns (Fischer, Places Journal 2010) " Tom Fischer, Dean of College of Design University Minnesota

At the same time, there is an immediate need for water, nutrition, and sanitation that can be addressed through simple and proven technologies. Far too much money has been spent on centralized, large-scale water systems that cannot be built or maintained with local expertise or resources. These result in of unused cisterns, latrines, and other technologically successful projects that are not being used. (Mihelcic, Fry). Good intentions often overlook the human or social impact of the implementation: including the maintenance, usability and the overall appropriateness of such technologies. These implementations must be better suited for the needs of the poorest and most vulnerable populations.

Turning away from the large "hard" engineering approaches, a "softer" approach would rely on smaller scale systems designed, built, and operated by local groups. This should involve collecting and analyzing environmental, cultural and social systems to make culturally appropriate and environmentally sustainable design decisions. This would rely on proven inexpensive, small-scale technologies to empower communities to create their own water and sanitation systems. Combining education and simple inexpensive technologies can help to ease existing barriers to progress in the developing world. Furthermore, the use of available resources can prove to help to reduce the implementation costs of these technologies while providing a way to make maintenance sustainable.

Repurposing Materials

One way to make things more affordable is through repurposing. When materials are repurposed it provides incentive as an inexpensive and poetic way of changing a cultural landscape [Linn, 2007, 199)]. Space is a social product, which rearranged through design can potentially provoke a new conceptualization [Linn, 2007]. Out of necessity, resourcefulness, and creativity this waste can become an inexpensive and scalable material for building [Linn, 2007, Denhart, 2009; Alejandro & Camila 2010].

"Bringing together resources from various sectors of a city and creatively using inexpensive salvaged materials ensures that commons projects are affordable and manageable for the people involved… community can be improved and large projects made feasible" (Karl Linn,2007,201).

Repurposing

Recently waste handling has become a pressing issue, but in other ages it was an integral part of society [Alejandro & Camila 2010]. This is a particularly steadfast issue in developing countries with shattered waste collection system. The theme of repurposing of waste materials is fundamental to the environmental movement; reutilizing the waste for architectural purposes can happen anywhere. For instance, it was a common architectural practice to re-use stones from great monumental constructions in Egypt, Greece, and Rome that had been destroyed by earthquakes or wars. The reuse of this stone involved much less effort than extracting new stone and transporting it from distant quarries [Alejandro & Camila 2010].

Moreover very little trace remains of the tons of iron used by the Romans in their buildings; as it was almost entirely re-used in the manufacturing of weapons. While in developing countries some of these building materials are often seen as an asset. This waste can include common packing Styrofoam containers as well as cardboard. All of these materials are composed of matter and can be reformed into something different. In these poor countries, industrialization, urbanization, and mass populations have created residues never before imagined. By repurposing the materials, new flow paths of the matter can be created [Alejandro and Camila 2010; Camillo and Hunter].

While the repurposing of a material is considered to be one of the most environmental acts it can also provide economic and social impact, as noted by Karl Linn. Waste can be a starting point for design manipulating it to function for a need. While, interventions can take varied forms it begins with either the deconstructing of a failed building or common consumer waste packaging. Ideally this could happen in close proximity to the project intervention site thus reducing the efforts of transporting the waste materials. This can be critical to the economic success of a project. [Linn, 2007]

Waste definition

For the purpose of this thesis waste will be referenced as defined by Webster dictionary as "material that is not wanted; the unusable remains or byproducts of something." Waste is a relative term since what may be classified as waste may change tomorrow. It is impacted by the flows of supply and demand. Also 'what is waste', may differ from one person to another. For instance, someone who composts probably would not see a banana peel as waste but rather an asset. The value placed on materials is temporal.

Improving Drinking Water

Water Source

The best way to improve water quality is through selecting a high source of water. Typically surface water is considered to be the least desirable source due to generally higher turbidity and microbes (NRC, 1997.) Alternatively, springs as well as rainwater harvesting are considered to be a few of the best sources of water quality. In many cases this is not always possible due to geographic, environmental, economic, and social constrains. Water filtration system is a primary option to help create safe drinking water by helping to remove microbes and/or turbidity in source water.

Quantity versus Quality

It is often more feasible to improve quality then quantity (Huisman, 1974. Huisman argues that in cities where Cholera outbreaks were prevalent, insufficient quantities of water were available, and people drank from unsafe, contaminated sources. When the options are limited it's important to select the "potentially" least unsafe source. Outside environmental sources such as birds and other wildlife, sewage disposal, etc. can also transmit infections to open water (Huisman, 1974).

Sustainable Access

Sustainable access to drinking water means that the source is less than 1 kilometer away from its place of use and that it is possible to reliably obtain at least 20 liters per member of a household per day, and that the water meets, at a minimum, WHO guidelines. UN MDG Figure 2 shows the parameters for sustainable access to drinking water. Table 5 displays sources for improved drinking water sources for sustainable access.

Table 5 Improved Drinking Water Sources (Author adapted from UN development Goals)

Source
Piped water into dwelling
Public tap or standpipe
Protected dug well
Protected spring
Rainwater

Filtration

Definition

"Filtration is the process of removing suspended solids from water by passing the water through a permeable fabric or porous bed of materials (pg1. NESC, 1996"). Water is naturally filtered as it moves through the layers of the earth. However, surface water such as lakes and streams are subject to "direct animal, human, and industrial contamination that can cause disease or illness in humans, so they must be filtered by a constructed treatment system (pg1. NESC, 1996).

Natural State of Water

During its cycle, water is constantly undergoing chemical and bacteriological changes. Streams and other sources filter the sediment and other particles from the water. At its chemical basis, it is a pure compound of hydrogen and oxygen evaporated from the surface of the ocean. It mixes with other gasses like carbon dioxide; as it moves to landfall it mixes further with dusts and vapors. At landfall, it picks up and absorbs particles, suspended solids, minerals, and microorganisms. These conditions are created both naturally through minerals from rocks or microorganisms from birds and anthropocentrically by non-point and point source pollution to the air and waterways. As the cycle continues, natural processes of "sunlight, aeration, biological oxidation, settlement, chemical reactions, and the action of predators" filter water and help change its biological and physical properties (Huisman, 1974.)

Humans extract water at any given point in this cycle to speed up the process in a confined space. "In its natural state, during its passage through the hydrological cycle, water is constantly changing in its chemical and bacteriological processes…polluting and purifying processes are continually at work (Huisman, 1974, pg12)."

Which Filter to use?

Given the impetus of modern technology it is possible to create clean water using any desired water quality, with almost any source (Huisman, 1974). However, site specificity determines the overall appropriateness of any technology, which should be chosen based on the correlation to the water needs of the community or household. Yet, this is extremely limited by economics and local resources. Often overlooked is the simplicity of the performance and maintenance of the filtration system (Huisman, 1974.). These methods include the drinking straw, electrolysis, reverse osmosis, and UV.

Scale

Scale is a pivotal factor in the uniform distribution of water coverage in both developing and developed nations alike. Water filtration systems for less than 500 people typically have more acute problems associated with them (NRC, 1997). Additionally, smaller communities in more remote areas similarly have more difficulty achieving water coverage (EPA, 1997, WHO/UNICEF, 2014).

United States Comparison

The United States is an example of an area with complete water coverage, relying heavily on small-scale water filter systems to create full coverage (NRC, 1997.) With increasing population and development, the number of small-scale water systems is growing expansively in the United States. In 1997, 20 percent of the U.S. population was served by approximately 54,000 systems, each serving 10,000 or fewer people, and more than two-thirds of these systems serve communities with populations of 500 or fewer (NRC, 1997). Furthermore, between 1963 and 1993, the number of water systems serving 500 or fewer people, increased from 5,000 to more than 35,000 (NRC, 1997).

Barriers for Small Scale Implementation

Critical social, economic, and geographic factors affect the ability of technology to be uniformly distributed. "The two major concerns regarding technologies for small systems are affordability and technical complexity: per household costs tend to be higher for the smaller system customers for most central treatment technologies, leading to many cases where small systems simply cannot afford to install a prescribed technology, and small systems often do not have access well-trained water system operators" (pg. 7 EPA, 1997). Small communities are near metropolitan areas where they are typically not connected to a major municipal supply. Furthermore, banks typically are less willing to supply loans for rural communities than to metropolitan ones because of the increased effort needed to monitor smaller loans relative to the profits they generate (NRC, 1997).

Large infrastructure costs and technological demands of large systems are a major barrier to improving drinking water in the developing world. One way to address this problem is through the use of decentralized and proven technologies for treating small communities or households. In 1997, the EPA published the Small System Compliance Technology List for the Surface Water Treatment Rule. This list identifies "feasible" technology that is available, affordable, and able to comply with national regulations (EPA, 1997). Points of Use (POU) and Point of Entry (POE) water systems are a recommended option due to the ability to the cost savings and easy maintenance (NRC, 1997). It also allows treating only a small quantity of water rather than large batches, reducing the need for huge storage facilities. This is particularly efficient for service for less than a dozen households (NRC, 1997). Three types of public water system use transient community, non-transient community, and community are presented in Table 6.

Appropriate Technologies for Small Scale Systems

Conventionally, the strategy of drinking water treatment systems has been driven by the need to remove microbial contaminants and turbidity. Microbial contaminants are the major worry because they can lead to sudden health problems. Turbidity is a concern not only because water-containing particles can have an objectionable taste and appearance but also because particles of fecal matter can harbor microorganisms (NRC, 1997). The NRC identifies the following technologies as appropriate and proven technologies for small-scale systems: rapid rate filtration, slow sand filtration, and diatomaceous earth filtration. The pros and cons of each system are illustrated in figure 4.

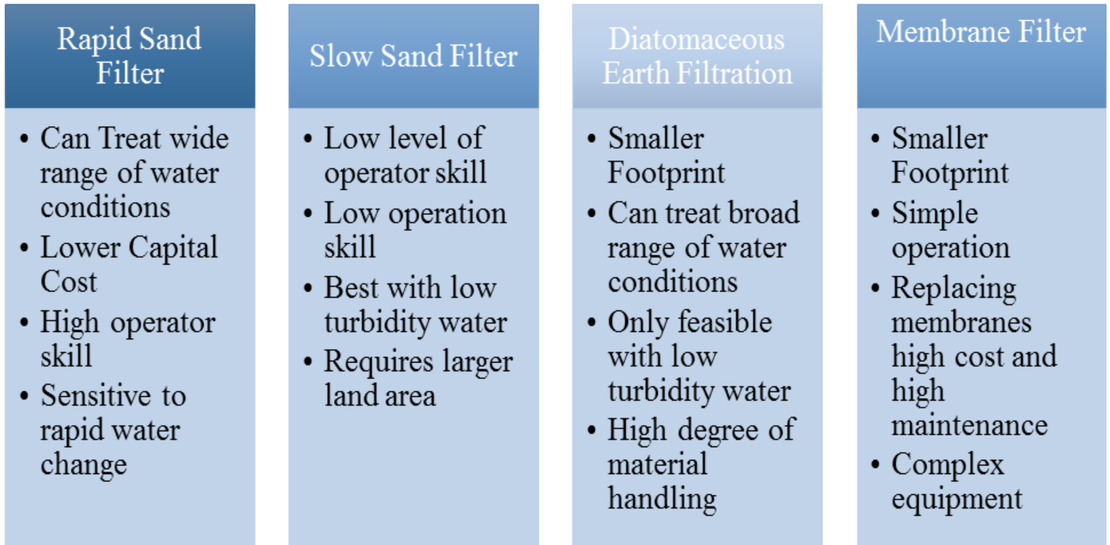

Figure 4: Decentralized Filtration Techniques Pros and Cons (Author adapted from NRC, 1997. & WADOH, 2003.)

Table 6: Water System Types (Author adapted from: pg. 14. NRC, 1997.)

System	Duration	Location
Community water systems	same population all year	Residential
Nontransient noncommunity water system	water to at least 25 of the same people for at least 6 months each year	Schools, factories, and with their own water supplies
Transient noncommunity water systems	transisitory populations for short period	Nonresidential areas: campsites, Gas stations, Motels, etc.

Slow Sand Filter

Overview

The slow sand filter is an established, simple, proven, low maintenance, and inexpensive mechanism to filter water. The slow sand filter has been used as an effective control of microbiological contaminant in water for variant scales of communities for over 200 years (Haig et all, 2011). It can achieve a high rate of filtration due to its naturally occurring biochemical processes in the filter including predation, scavenging, adsorption and bio-oxidation (Haig et all 2011; Huisman, 1974). While there has been increased pressure by new technologies, slow sand filters remain an appropriate choice for the developing world due to their easy use, maintenance and implementation (Huisman, 1974).

"No other single process can affect such an improvement in the physical, chemical and bacteriological quality of normal surface waters as that accomplished by biological treatment (Huisman, 1974)."

History

Slow sand filters are one of the earliest dated engineered forms of potable water. The first slow sand filter dates back to John Gibbs who created the filter for his bleachery in England, selling the excess water for a half penny a gallon (Haig et all 2011; Huisman, 1974; Baker 1949). Further advances were made before James Simpson first implemented the method for public water at the Chelsea water company in 1829 (Haig et all 2011; Huisman, 1974; Baker 1949). Even though bacteriological concerns were unknown, people could see the difference in the removal of turbidity and solids through the grains of sand (Huisman, 1974). As Cholera became wide spread slow sand filters became popular and mandatory throughout many major European cities.

As a result of rapid sand filters, chemical treatment, and other techniques that can adjust to a wider source of water qualities, the slow sand filters declined in popularity in the early 1900s (Haig et all 2011).

Recently a renewed interest for slow sand filters began to serve the gap of small to medium communities for both industrial and developing areas with minimal resources (Haig et all 2011; Huisman, 1974). Furthermore, the slow sand filter has been adapted for point of use household treatment, as well as other decentralized water treatment. One example is the commercially branded Biosand Filter by CAWST (Center for affordable Water and Sanitation Technology) (CAWST, 2015; EPA, 2015). Slow sand filters continue to provide superior water quality compared to other technological alternatives (Huisman, 1974).

Operation

Biological processes are important in slow sand filters, which filters form a filter skin containing microorganisms that trap and break down algae, bacteria, and other organic matter before the water reaches the filter medium itself (NESC, 1996.) Through this process, particulate impurities make contact with sand particles and remain there until the sand is cleaned. As the raw water percolates through the membrane, pathogens are detached by both mechanical (e.g. absorption, diffusion, screening and sedimentation) and other biological processes (See Table 9) Haig et all 2011; Huisman, 1974; CAWST, 2015.)

The influent of untreated water is introduced through the top surface and is filtered through the gravity percolation of a bed of sand (EPA, 2015). Biological activity created by a source of water 3cm on top of the upper portion (biological layer) of the sand eats many of the pathogens (Huisman, 1974). The sand removes and traps larger particles and pathogens from the raw water as they are unable to pass through the small grains of sand (Table 7.) Through gravitational processes, clean water is drained from the bottom of the sand (EPA, 2015).

Table 7 Transport Mechanisms (Author adapted from Huisman, 1974).

Transport Mechanisms	principal process in which particles are brought into contact with sand grains
Straining or screening	the interception and retention of particles too large to pass through the interstices between the grains of sand
Sedimentation	settling action within the pores, whereby particulate suspended matter is precipitated onto the grains
Inertial and centrifugal	forces act upon forces with specific gravity higher than that of the surrounding water, causing them to leave the flow lines and come in contact with sand grains
Diffusion	brings suspended particles in contact with containing surfaces
Electrostatic and electrokinetic attractive forces	holds particles that have been brought into contact with sand grains

Table 8 Attachment Mechanisms (Author adapted from Huisman, 1974)

Attachment Mechanisms	the main forces which hold particles in place once they have made contact with sand grains
Electrostatic attraction	the attraction between opposite electrical charges
Van der Waals force	mass attraction which only has a very minor effect in drawing particles from water
Adhesion	during the ripening process particles of organic origin will be arrested or deposited to the filter surface
Adsorption	a combination of the forces

Table 9 Purification Mechanisms (Adapted from Huisman, 1974)

Purification Mechanisms	purification processes, whereby the trapped impurities on and within the filter bed are broken down and made harmless
Microbiological	bacteria consume organic materials in the raw water and convert to food (dissimilation) and into cell material for their growth (assimilation)
Chemical Oxidation	addition of oxygen removal of hydrogen, or removal chemical
Other	biological forms of animal and/or vegetable life

Source: Huisman, 1974

Biolayer

The top 1-2 cm of the filter is called "schmutzdecke," which "removes suspended organic materials and microorganisms by biodegradation and other biological processes" (EPA, 1997, pg24). The layer is kept formed and kept active by predation, the feeding on incoming predators in the impurities from the incoming water source (CAWST, 2015).

It is critical that the use of the filter support this process. Slow sand filters are usually cleaned by scraping of the bio-film on the top sand layer. The top of the filter begins as a clean membrane and builds up over time. It takes several weeks for the filter to re-ripen from the passage of water. Water poured too fast into the filter can damage the membrane. A diffuser plate controls the flow and rate of incoming water onto the sand evenly so it does not disrupt the building and longevity of the bio-layer. (CAWST, 2015; Huisman, 1974)

As water moves through the filter past the schmutzdecke layer, microorganisms, other bacteriophages, and protozoa coat the sand particles with slime like biofilm. Impurities in the raw water become attached to the sticky sand particles by electrostatic and electrokinetic attractive forces (Table 8) (CAWST, 2015; Huisman, 1974)

Sand Size

Research has found that fine sand between .20mm-.35mm is optimal for removing pathogens. A fine tightly packed sand grain will prevent a pathogen as small as 1/7 the size of a sand particle from passing through the filter. This relationship of pore space to sand size is illustrated in Figure 5. Sand size has been found to be the most critical design factor for slow sand filters. Fine sand resulted in significantly better filter performance for removing bacteria, virus, and turbidity compared to coarse sand (Jenkins&CAWST 2011).Consider a pathogen similar to pasta entering a strainer; the strainer traps the pasta while allowing water to pass through. This process, known as mechanical trapping, does not allow the pathogen to pass through sand particles because they are literally too big. The flow rate of the water is a good indication of the relative pore size of the sand particles. Coarser, larger sand will move the water through the filter too fast reducing the filters effectiveness. Oppositely, smaller fine sand allows the physical and mechanical processes to take place. (Huisman, 1974.; CAWST, 2012).

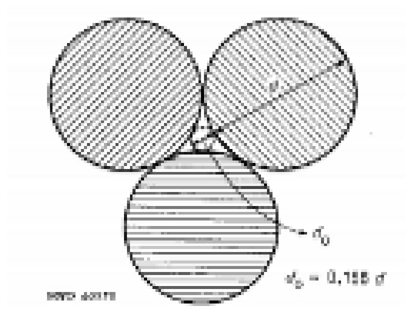

Figure 5: Relationship Between Grain Size and Pore Space (*Huisman, 1974)*

Effectiveness

A well-designed filter removes most turbidity and pathogens from reasonably turbid water in one single treatment process. It is best at removing larger impurities such as worms and turbidity. Like most filters, it cannot remove dissolved items such as salt, arsenic, and/or fluoride. Slow sand filters are proven as an effective remover of most turbidity, bacteria and most pathogens. Table 10 illustrates the effectiveness of the filter at removing impurities, turbidity, Helminths, Protozoa, Bacteria, and Viruses. Slow sand filters are still one of the most cost effective and efficient filtration technologies. The filter has been shown to remove up to 99 percent of bacteria and greatly reducing diarrheal effects (CAWST, 2015; Huisman, 1974)

Table 10 Slow Sand Filter Removal Rates (CAWST, 2015)

Impurity	Removal Percentage
Turbidity	Up to 95%
Helminths (worms)	Up to 100%
Protozoa	Up to 100%
Bacteria	Up to 98.5%
Virus	70-99%

Adaptability

Slow sand filters are an attractive filtration process because operation does not require electricity or chemical operations, and sand is readily accessible in the majority of the world. Additionally, sand filters can be scaled from the household level up to the community and even regional scale utilizing the appropriate tanks/cells for the sand. These include clay pots, 2-gallon buckets, 55 gallon drums, and trash cans. The slow sand filter has been proven to be effective point of use and community source for filtered water.

Sanitation

Improved sanitation refers to protecting water sources from excreta. It is long standing knowledge that bacterium in water from excreta causes illnesses. Improved sanitation definitions are shown in Table 11. Traditional pit latrines are a proven, effective, and accepted technology for black water sanitation. The standard parts of a latrine are illustrated in Figure 12. The traditional pit latrine is the most common latrine in developing countries. This is in large part due to the simplicity and overall ease of its design (Mihelic et al, 2009).

Table 11 Definitions (Author adapted from http://www.unicef.org/media/media_45481.html)

Definitions
An improved drinking-water source is one that by its construction is adequately protected from outside contamination, in particular from fecal matter
An improved sanitation facility is one that hygienically separates human excreta from human contact.
Open defecation refers to when people defecate in fields, forests, bushes, open bodies of water, beaches, and other open spaces

Table 12 Standard Latrine Components (Adapted from Mihelic et al, 2009)

Components of a standard latrine
Hole dug in ground
Slab covering the hole, constructed of logs or planks covered by compacted soils and/or concrete
An opening in the slab, which depending on culture may have a seat on top
An enclosing structure typically made of concrete

An Immense Problem

Despite centuries of technology people still lack basic needs such as safe drinking water, adequate nutrition, and proper sanitation. More people own cell phones then have access to toilets. Two and a half times the population of the United States lacks safe drinking water. With increased population growths expected over the next couple decades this is an enormous scale challenge effecting most of the developing world. Lots of resources have been spent on centralized systems that have not created uniform access. Large scale centralized infrastructure is costly to create and maintain. The developing world lacks the financial resources to gain such technologies.

Water, nutrition, and proper sanitation are basic human health needs. How do you even begin to address such a daunting challenge? With the lack of resources how do you provide for these basic health needs in a sustainable way? How do you make the techniques and technology accessible even to the poorest communities? How do you make widespread implementation of interventions aimed at remediating these developmental failures? In 2004, it was estimated that it would cost over 11 billion annually just to halve the population without access to safe drinking water and proper sanitation. In a negative world economy, with so many challenges everything cannot be afforded. How can we rethink infrastructure to better fit such an immense challenge. Moreover how can the skills of landscape architecture respond to such as huge challenge?

Chapter 3: Defining the Problem in Haiti

Background

Haiti is the poorest country in the Americas; its gross national income per capital is $660 US-over half less that of the second poorest country Nicaragua. Haiti has a population of over 10.5 million people. Over 2.5 million of the population lives in extreme poverty, less than the national extreme poverty line of $1.24 US a day and more than 6 million of the population lives on less than the national poverty line of 2.44$ US per a day (USAID, 2014; Worldbank, 2014). Figure 6 shows the informal work many Haitians take up such as selling shoes, food stands, and other items to make ends meet. In rural areas extreme poverty is estimated to be at 80% of the population (Worldbank, 2014; USAID, 2014). As a result, most Haitians lack clean drinking water, proper sanitation, and adequate nutrition. Deficiencies in these basic needs have largely contributed to severe health problems. It is estimated that 70% of the urban population lives in slums and is much worse in rural areas (WHO, 2011; WHO, 2015). Figure 7 displays slum housing that is built without any planning. These houses lack basic infrastructure and are also built on slopes that are vulnerable to landslides.

Figure 6: Street in Haiti (Author)

Figure 7: Informal Slum Housing (Author)

Living Amongst Waste

Currently, there is no collective waste system or facility in Haiti (Byrd,2014). Waste is strewn in the streets filling gutters, canals, and streams, ultimately ending up in ocean and rivers. Household waste, rubble, styrofoam, cardboard, plastic bottles, plastic bags, tires, and biomedical waste are commonly seen floating, burnt, or scattered through the streets degrading the character of the physical landscape (see figures 8-11). Culturally, it is common to burn waste in streets, oceans, canals, and rivers as seen in Figure 11 (Byrd, 2014). The waste problem is a chronic health and environmental problem facing Haiti.

Figure 8: Waste roundabout (Author)

Figure 9: Waste along sidewalk (Author)

Plastic water/soda bottles as a result of use and import by non-government aid organizations have exasperated the waste problem. With thousands of bottles used every day by foreign aid workers there is no solution or place to dispose of the empty plastic bottles. As a result, people generally place or throw their garbage onto the street reinforcing and worsening an already terrible environmental and human health problem. In 2013, the local Haitian government has banned the import of plastic bags and Styrofoam containers (Byrd, 2014; Guardian, 2013).

Figure 10: Waste pile on corner (Author)

Figure 11: Waste burning on beach (Author)

Drinking Water

Despite billions of dollars in aid funding poor access to drinking water remains a critical issue in Haiti. Waterborne diseases are the leading cause of death in children in Haiti (Worldbank Book, 2015). Access to water in rural areas is 47% compared to 75% in urban areas such as Port au Prince (WHO/UNICEF, 2014; Worldbank Book, 2015). Culturally Voodoo traditions reinforce beliefs that contaminated water is safe to drink. Figure 12 illustrates children getting water from a source which a livestock animal is bathing and defecating inside.

Figure 12: Children grabbing water out of pond while livestock defecates (Author)

Sanitation

The lack of sanitation is a major reason for widespread water diseases. One third of the population has access to improved sanitation facilities, however only 16% in rural areas (WHO/UNICEF, 2014; Worldbank Book, 2015). In 2010, Haiti faced one of the most devastating Cholera outbreaks resulting in the loss of over 8,500 lives and infected over 800,000 (Worldbank Book, 2015). It also is common for Haitians to bathe/wash in rivers and the ocean.

Nutrition

Half of Haiti is considered food insecure. “Chronically high levels of poverty, coupled with soil erosion, declining agricultural productivity, and high population growth, combine to make obtaining adequate food a daily struggle for many Haitians” (US AID, 2015). Street Markets displayed in Figure 13 typically import most of its products from the Dominican Republic. Prices are highly variable in the markets due to the lack of adequate supply. Common staples are rice, beans, and white sweet potato.

Figure 13: Street Market, Port au Prince, Haiti (Author)

Even with more than half of the population of Haiti working in Agriculture the majority of its food is imported. This causes vulnerability in the market place for local Haitians. The average Haitian consumes 1.58 meals per day. The burden of food insecurity is placed the highest burden in children. Chronic malnourishment in children can be upwards of 30 percent in certain geographic areas. One in five children remains stunted in Haiti as a result. The majority of women who are pregnant do not receive the recommended amounts of iron and other micronutrients during pregnancy. (US AID, 2015; PAHO, 2012)

Environmental Problems

Figure 14: Deforested Mountain and Valley (Author)

Haiti's landscape has been degraded over the course of centuries through poor management, planning, and practices. Deforestation is a major problem in Haiti due to the cutting and burning of trees for fuel (charcoal). Haiti is now only 2% forested, as seen in Figure 14. Due to the loss of tree roots, dramatic rates of soil erosion occur over much of the mountainous terrains of Haiti. Furthermore, Haiti is constantly vulnerable to floods, landslides, and pollution. A growing population has forced the development of settlements on unstable lands. Solid waste fills waterways such as streams, rivers, and oceans. This has devastated habitat for fish and other water dependent wildlife. Climate change makes Haiti much more vulnerable to increases of flooding and rising seas as a result of more frequent storms. (US AID, 2015)

Lack of Public Education

Figure 15: Haitian Boy (Author)

Figure 16: Haitian Teacher Conducting Lesson (Author)

Most (>80%) primary schools in Haiti are privately funded nongovernmental organizations, churches, communities, and for-profit operators, with minimal government oversight. Haitians typically receive an average of less than 5 years of total education and less than 30% attend secondary school. School expenses contribute to a large financial expense which many families cannot afford. The future for Haitian children is tough as a result (Figure 15). Culturally, teaching is not recognized as a high status job in Haiti and is often a last resort for college graduates. As a result teachers lack many basic qualification and/or training. (US AID, 2015; PAHO, 2012) Figure 16shows a teacher conducting a French lesson in a typical classroom. School is very prestigious and important in Haitian family culture.

Earthquake

The 2010 earthquake devastated the country with most of the damage in the capital Port au Prince where an estimated 30% of the population resides. Due to poor construction practices many of the buildings were unable to sustain the 7.0 magnitude earthquake assembling some twenty million cubic yards of boulders, dust, and rubble (Figure 17). As a result, this created a wave of movement of people from the urban Port au Prince to the northern rural areas. This has increased informal slum settlements where no infrastructure of water and sanitation are available. (Aquilino, 2010 & PAHO, 2012)

Figure 17: Concrete rubble (Author)

Global Health Impacts

According to the US Aid workers, "Haiti is hampered by some of the world's worst health indicators" (US AID, 2015). Due to limited funds, Haiti only has a few hospitals to serve a large population. Additionally, environmental issues, combined with lack of basic necessities of water and sanitation, predispose Haitians to health issues.

Geography

Haiti is located on the western third of the island of Hispaniola, bounded to the east by its only land boarder the Dominican Republic. To the south and west it is surrounded by the Caribbean and to the north by the Atlantic Ocean. Hispaniola is the name given to the island by Christopher Columbus. The name Haiti is from its land topography, indigenous Arawak place-name Ayti ("Mountainous Land"). Haiti is a small country approximately 28,000 square miles occupying the same footprint comparatively to Maryland. (Gelting et. all 2013; Hadden and Minson, 2010; WorldBank, 2015.)

Most of Haiti is mainly limestone with some small pockets of volcanic formations. Haiti's tropical climate is modified by the mountains and subject to periodic droughts and severe hurricanes. It is generally hot and humid in Haiti. November to January is considered Haiti's dry season, and February through May is its wet season. (Hadden and Minson, 2010; WorldBank, 2015)

Chapter 4: Concepts and Program

Design Challenge:

Haiti lacks publicly available sanitary infrastructure. As a result, citizens are left without access to sanitary water, sewage disposal, and trash collection. This presents a large scale, chronic public health challenge for a country with very limited resources. More specifically access to clean water and food are limited by the overall accessibilities including technical understanding, social acceptance, proximity access, and economic costs.

Site Selection and Analysis

An initial investigative trip took place in August of 2014. The purpose of the trip was to explore what kinds of projects were possible, specifically geared towards drinking water and agriculture. Several community oriented water and agriculture projects were discussed. However the priority project was selected as the New Covenant School/Church. The project was selected chiefly because the role of the site in the community. The school/church has been a part of the community for several years. This was critical to the decision to choose the site since people trust the New Covenant School and Church because it has helped enrich their lives by providing a place for the children to go to school.

Both Schools and churches' are traditionally rooted in the community. People care and value these sites. The School/Church has great potential to be a model/protype location for other schools, churches', and households. The planned expansion of the school onto a new site location posed an exciting opportunity to holistically plan the entire school/church campus. An additional factor was the vast need within the surrounding community for basic needs of food and clean water.

New Covenant School/Church

The New Covenant School was founded by a husband and wife. Living in Florida for around ten years, the couple returned to the husband's hometown of St. Louis Du Norde (Figure 20). During the visit, the wife, an elementary school teacher in Florida, was surprised at the children running around with nothing to do. Informed by the lack of public education in Haiti, the couple made it their mission to start a school and church for the children and people of the husband's hometown (Figure 19). The husband worked overtime as an electrician in south Florida to help pay for the school and church. At the same time, the wife worked to develop an extensive curriculum and applied for grants to build the school and church. .

The school and church has operated out of two houses for several years. The tight classrooms are displayed in Figure 18. With rapid expansion of the school currently upwards of 600 children, the couple has worked tirelessly to find a new appropriate site to construct a new campus to accommodate the growth.

Figure 18: Students in current classroom (Author)

Figure 19: Students (Author)

Figure 20: Context of the School (Author)

Location: St. Louis Du Norde

Saint Louis Du Norde is a peril urban town (Figures 22 and 25) of about 70,000 people. It is in the northern most part of Haiti surrounded by the Atlantic Ocean (Figure 23 and 26), making it vulnerable to hurricane winds and storms. It also is in close proximity to Haiti's historical island La Tortuga which locals of the island and Du Norde pay a local taxi service to cross between by sail boat (Figure 25). This could be a potential agriculture tourism activity. The town of St. Louis Du Norde is located physical distance closer to Cuba then to the capital of Haiti, Port au Prince (Figure 21).

The location of the school and church is in dangerous areas of the town. It is known for high rates of drug activity and crime. The church and school are a critical help in any potential revitalization of this area.

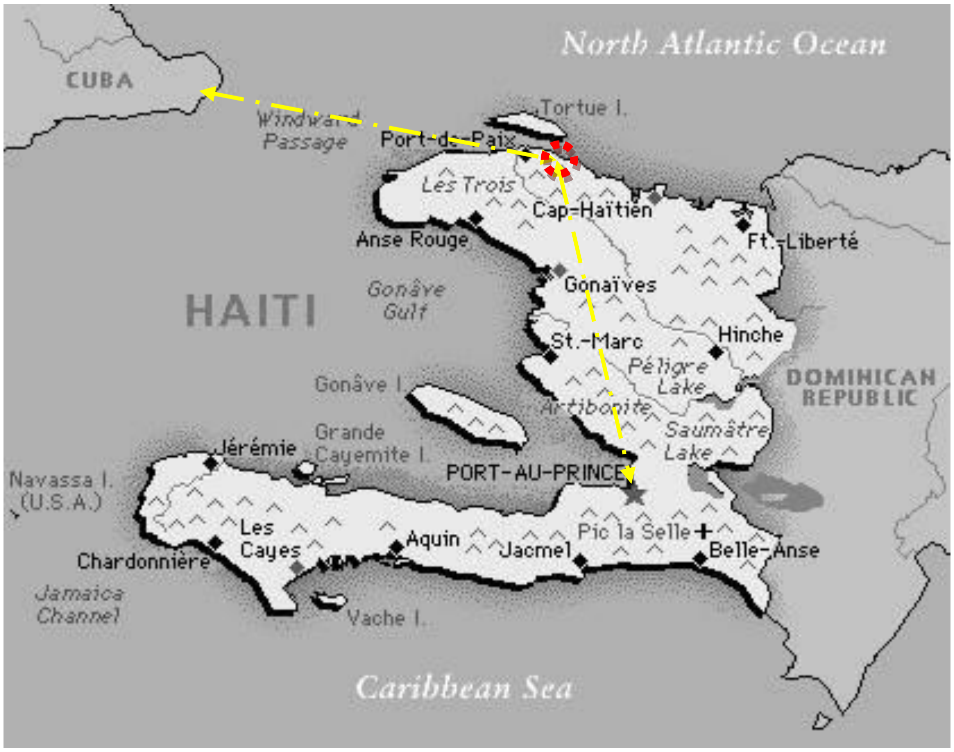

Figure 21: Sites Larger Context (Credit https://www.causes.com/causes/432384-support-relief-efforts-in-haiti)

Figure 22: Surrounding perri-urban context (Author)

Figure 23: Ocean Waterfront Condition (Author)

Figure 24: Main Street St. Louis Du Norde (Author)

Figure 25: Boat Taxi (Author)

Figure 26: Atlantic Ocean (Author)

Existing Conditions

Existing Site Layout

Figure 27 shows the existing condition of the site in August 2014. The site is approximately 1/8 acre. There is about 6% grade change between the road and the back of the site. Figure 32 shows an image of the sites slope character. It is located about 1 mile from the Atlantic Ocean. Two new mixed-use buildings will bound the site. The buildings will be for the school during the weekday and Church during nights and weekends. Initially the buildings will be constructed at one story for financial purposes.

In August of 2014, both buildings footprints and foundation were begun. The front school building was constructed partially as displayed in Figures 29-33. The distance between buildings is shown in Figure 28. The rear building is planned for construction during the summer (July/August) of 2015. Additionally, the latrine was fully constructed (Figures 38 and 39) and a hole was being dug for the rainwater cistern (Figures 36 and 37).

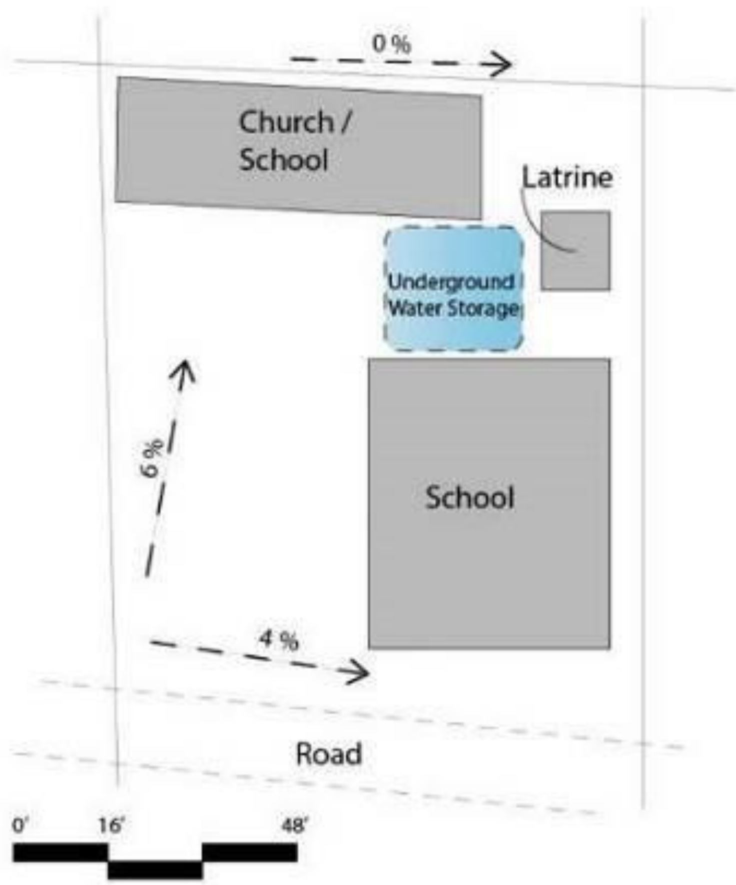

Figure 27: Existing Condition Map of site (Author)

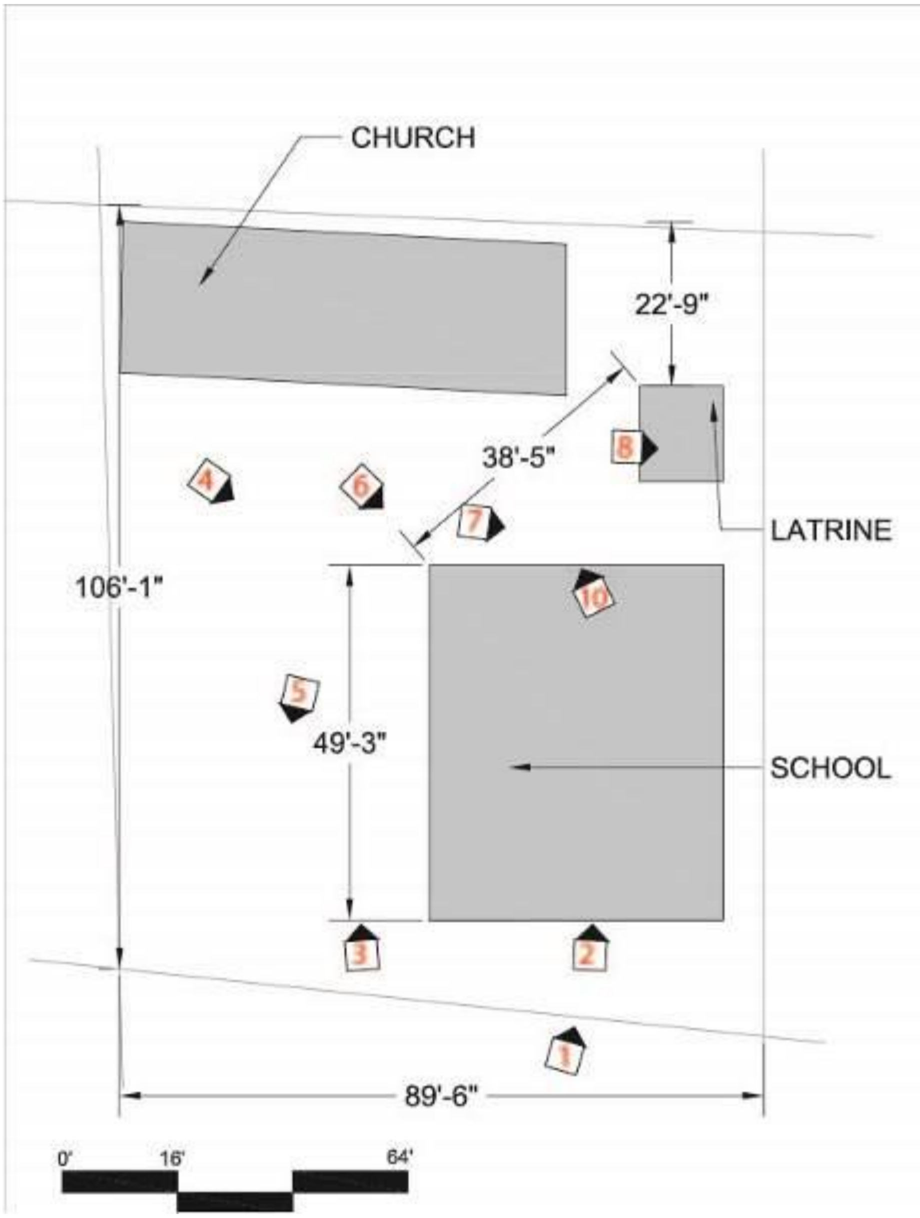

Figure 28: Context Map of Existing Condition Pictures (Author)

Existing Site Pictures

Front Building

Figure 29: Front School Building from road (Author)

Figure 30: Entrance to front building (Author)

Figure 31: Support Columns (Author)

Figure 32: Site slope from road (Author)

Figure 33: Facing towards front of building (Author)

Figure 34: Banana Trees on Site (Author)

Cistern

Figure 35: Soil Piles from Cistern Construction (Author)

Figure 36: Cistern Under Construction (Author)

Figure 37: Workers Dig *Cistern* (Author)

Latrine

Figure 38: Latrine Pit

Figure 39: Latrine Stall

Figure 40: Rear School/Church Building Foundation

Distance to Water Source

Figure 41: Map of Distance from Site Location to Water Source (Author)

The site is relatively close to a water source. However, quality of the water is a major issue.

Overall Concept

Recently in the United States, there has been a push for sustainable schools. These schools integrate sustainable technologies into the everyday classroom and school yard exercises, making children more aware of environmental ethics. Examples of these schools include the Sidwell Friends School, Willow School, and Brent Elementary School. The Sidwell Friends School decentralized constructed wetland and waste system (Figure 42) is integrated into the learning of the school. Students use the wetland to study biology and even perform dance recitals around the pond as displayed in Figure 43.

Figure 42: Diagram of Sidwell Friends School Stormwater and Wastewater Treatment System

Figure 43: Sidwell Friends School Biology Pond (Andropogon Associates, Ltd)

These schools use environmentally sustainable approaches such as stormwater management, wildlife habitat, and even constructed wetlands. Students are engaged in learning about these technologies through writing, learning, and hands on interaction with natural features. However these sustainable schools are very costly to implement for a school with very minimal means in Haiti.

How can these ideas of a sustainable school be translated into Haiti's culture? How can children be involved in creating, maintaining, and learning? How can the techniques be implemented with almost no cost? How can the techniques be learned about in basic classroom exercises? How can the sustainable techniques be combined with the goals of literacy, mathematics, and sciences? How can these technologies be replicated at the household scale?

Program

The project began as a brainstorming session identifying three intricate programs for the site: rainwater harvesting and filtration for drinking water standards; rooftop agriculture; and a playground space (Figure 44). These programs aim at reinforcing environmental stewardship and developing social interactions. This type of program is conventionally inaccessible to Haitian schools due to the high cost, technical barriers, and access to materials for such approaches. Drinking water, nutrition (rooftop agriculture), and play all fulfill basic human needs.

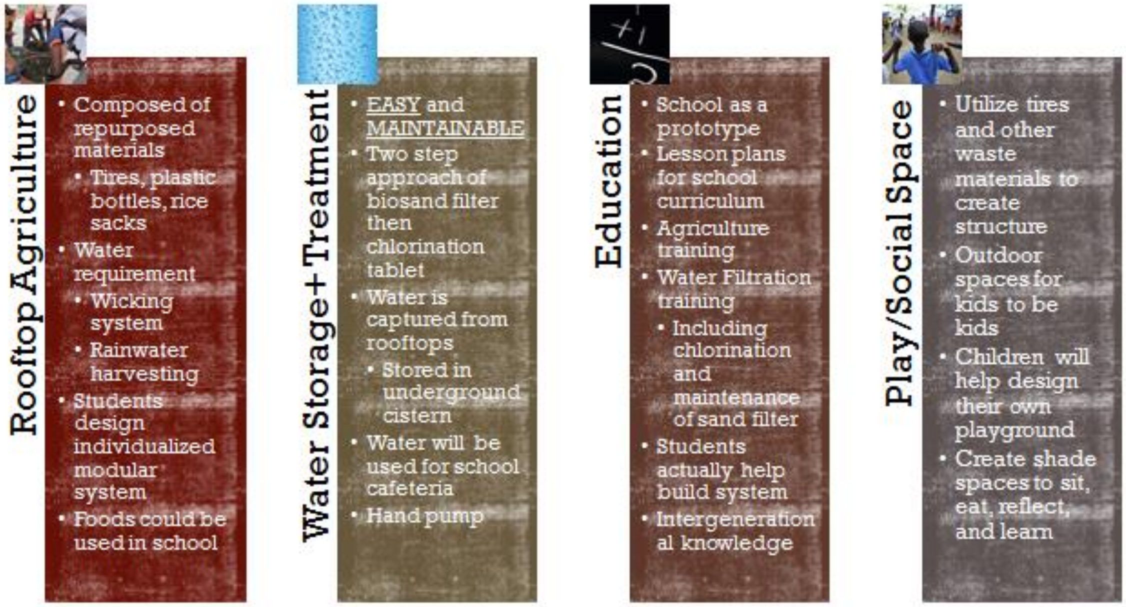

Figure 44: Proposed Program (Author)

Creating a System

System diagrams show how the entire program could work together and be realized. Figure 44 investigates the relationships on site. The primary applications are potable water through slow sand filter and rainwater harvesting and nutrition through sustainable gardening. Education and training are an opportunity created through the implementation of the sustainable gardening and potable water filter.

Improved community health is the desired outcome of the improved access to water and nutrition. Additionally, children are connected socially to the school through the gardening and a playground built out of repurposed/recycled materials. By helping to remove the waste from streets, it will have positive impacts on both the health of people and the environment. It will also help to create a positive aesthetic.

Overall, the stream is a closed loop system that will allow for the spread of the gardens and filtration system. Water is harvested from rain and then used for general purposes of drinking, cleaning, and watering of plants. Plants grow- beautifying campus, feeding the members of the church and school, and new seeds then can be replanted. Excess seeds can be sold or provided for future gardens. The waste from the plants and soils can be composted and used to create future gardens. Children are taught about the practices of the gardens and water filtration and can implement on their own homes. Through principles of environmentalism students are taught to be better stewards of the land of Haiti, gaining better understanding of the environmental problems facing Haiti. This will slowly help to create better community health.

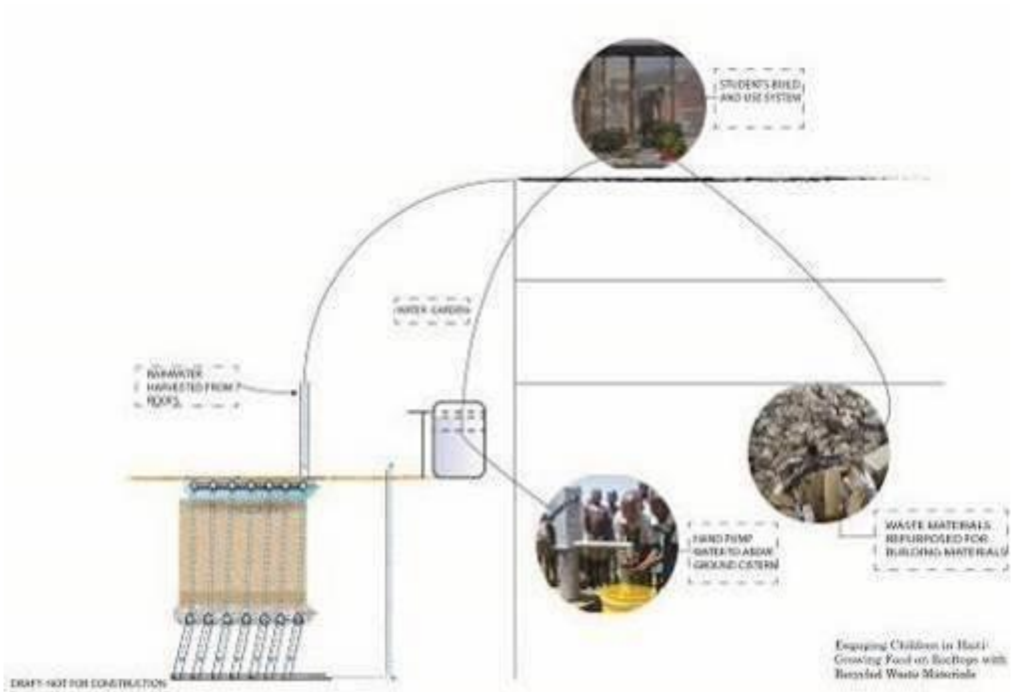

Figure 45: Integration of Systems into Students Learning (Author)

<u>*Making the design accessible:*</u>

The aim of the design is to make health design solutions available and replicable to even the poorest and most desperate people. Economically, the target is to design solutions that cost nearly nothing for materials. This is important to people who can barely afford two tablespoons of tomato paste (Figure 46) at the evening meal. This can be achieved through the repurposing and reusing of materials that are common and readily available at no cost. Socially, it is important that the techniques are easily understood. Collaborating with local school children, the design solutions should be easily understood and used by elementary age children. The children will be empowered through the customization of the different features of the design. For instance, painting a tire and being involved in the process makes the feel that it is theirs. Eventually the children can find and make their own health design solutions at their household. The children will spread the ideas, teaching their parents, family, friends, neighbors, and community. Haitians are able to do anything they must just be empowered to do so. Giving them the confidence to build simple and affordable techniques will ensure for widespread adoption. This design process logic is displayed in Figure 47.

Figure 46: Tablespoon of Tomato Paste (Picture Credit-Wikimedia)

Haitian children are especially remarkable and resilient people. While visiting Haiti, we observed one child about five years old who had a broken sandal. The child asked a local for a hammer type tool to fix his broken sandal. Within a couple minutes of receiving the tool the five year old was able to fix his sandal. Furthermore, by the time a Haitian child can walk, they are daily purchasing 5 gallon (41.7 pounds) buckets of water a few blocks away and bring it home to their family. We observed the children to be incredibly well behaved and eager to learn.

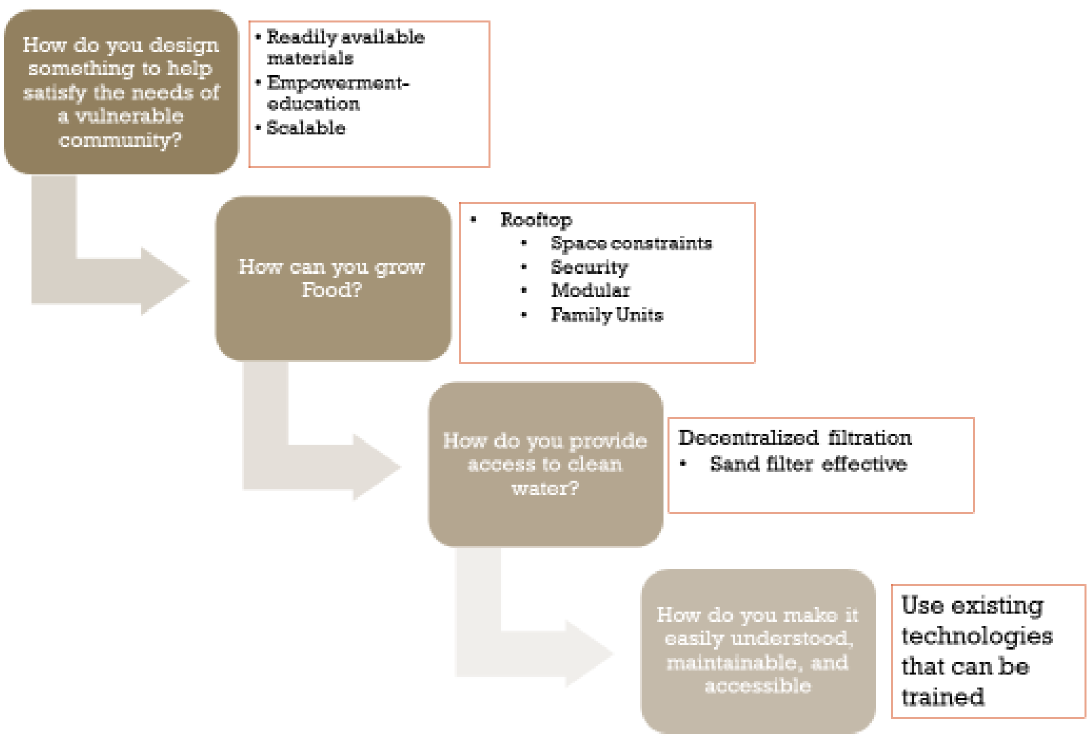

Figure 47: Diagram of Approach (Author)

In the developing world materials are the major commodity. Due to the poor economy and lack of job, people have a lot of time. Figure 48 shows how the design seeks to turn the waste into a function through labor.

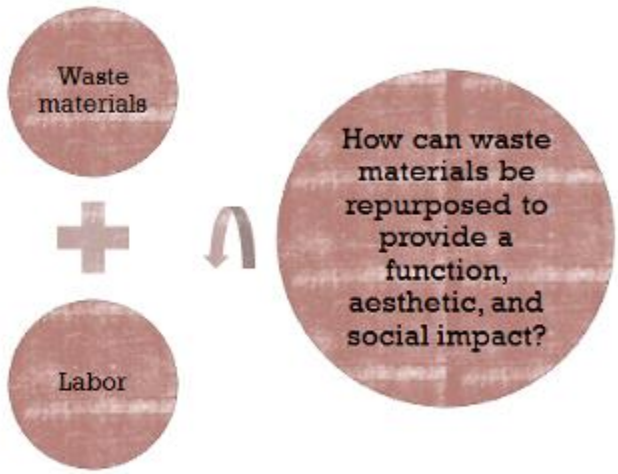

Figure 48: How can waste be repurposed to provide function (Author)

Identification of available resources and sustainable techniques

Using science that has already been proven to work an affordable, manageable, and sustainable technique that can provide access to nutrition and clean water. Figure 49 shows the general framework that was used to match materials with a proven technique that could be implemented. Different cultures have norms that may or may not be compatible with an outsider's design ideas. Different techniques were identified and investigated to find the one that best fit the culture. For instance, the biological slow sand filter was initially identified as a simple and easily understood technique. The filtration materials of sand and gravel could all be obtained from the river. Many slow sand filters require a concrete form making it inaccessible. We adapted the filter to a 55 gallon drum which is a very common repurposed material in Haiti. All the materials can be purchased or found in Haiti. This makes it sustainable and replicable. The sand filter is easily understood making it socially acceptable. Other considerations were included, such as the use of a 5 gallon bucket for use and the use of secondary treatments.

Figure 49: Intervention Process (Author)

Identification of available materials

During the initial visit a number of materials were identified as “waste” materials. These included plastic bottles, rice sacks, cardboard, and tires. Figure 50 shows an investigation of tires both in the waste stream and the informal use of the tires for seating.

Figure 50: Window Investigation of Tires (Author)

Program

Diagram 51 shows the initial layout resulting from the program. The layout is constrained by the small scale of the site and the initial placement of the underground storage.

The design seeks to be respectful of the children's need for play space. Placing the gardens on the rooftop helps achieve this goal. The primary focus of the design is potable water through biological filtration and sustainable green gardening. The secondary focus is on education and training. Improved community health is the desired outcome. A byproduct of the project is a playground built from recycled materials for the school.

Figure 51: Conceptual Bubble Plan (Author)

Health Benefit Goals

The project has long term health benefits for the community (potable water, sustainable gardening, education, and social space). The design aims to fulfill basic health needs for the members of the school and church.

Drinking Water

A biological filter system includes a cistern to provide drinking water for the children and adults during school and church. Rainwater is harvested from the two large rooftops into and underground storage cistern. Generally, the water will be stored in the cistern before it is filtered for potable use. Slow sand filters are a proven technique for removing contaminants from water. Providing water for the children can improve their performance in school.

Rooftop Gardening

The green roof is intended to provide fresh vegetables for the school kitchen and the church. The gardens grow foods that are local to recipes of the culture. Secondly, the gardens target the common micronutrient deficiencies such as Vitamin A. Due to space constrain vegetables must also provide a "big bang" for their space. Since grains are relatively inexpensive and require large quantities of land they do not make much sense to grow in the garden. However, crops such as tomatoes, okra, and onions can be costly in the market, require very little growing space, and are common to the Haitian diet.

Due to the intense sunlight, a shade structure must be created for plants to grow. It also reduces the required watering. While gardening will be taught conducted on the rooftops the practices can be applied on the ground as well. Placing the gardens on the rooftops secures them from potential vandalism. Tire gardens are a traditional and proven technique both in Haiti and in the developing world.

Playground Space

The playground space is intended to create social space for the children. Much research has suggested the need for recreational play for development in children. It is a basic need for cognitive development. A major factor in placing the garden on the rooftop is to dedicate space for the basic need of play. Tires are a flexible and strong material for building play structures. A tire can be used for climbing, sitting, and standing.

Play is a great contrast to the harsh daily life children endure in Haiti and other developing world. Play/sports can bring a community together.

Education, Training, and Oversight

Trained, paid community development staff from the Brethren church Agriculture and Medical team will oversee the project. They have extensive working experience with training members of the community to make sure the project is maintained and operating correctly. They will also be a constant connection for technical assistance between the design team and the school/church. Ideally, workshops can be arranged between the development team and the community.

The principles of these systems will be taught to students in the everyday school activities. This will include basic sustainable gardening practices including composting, wicking, seed harvesting, and planting seeds. Additionally, the students will learn to practice proper sanitation and hygiene.

Chapter 5: Water System Design

<u>Slow Sand Filter Options</u>

Several concepts were developed, modeled, and studied to compare for the site. These options were sent to stakeholders for feedback.

Other slow sand filters include CAWST's (Center for Affordable Water and Sanitation Technologies) Biosand filter technology. Their technology is geared to the individual household use. The filter also requires a concrete form to construct. This is problematic for a replicable application. Additionally, due to the poor quality of concrete in Haiti, the filters potentially crack over time.

Option A-Traditional Slow Sand Filter

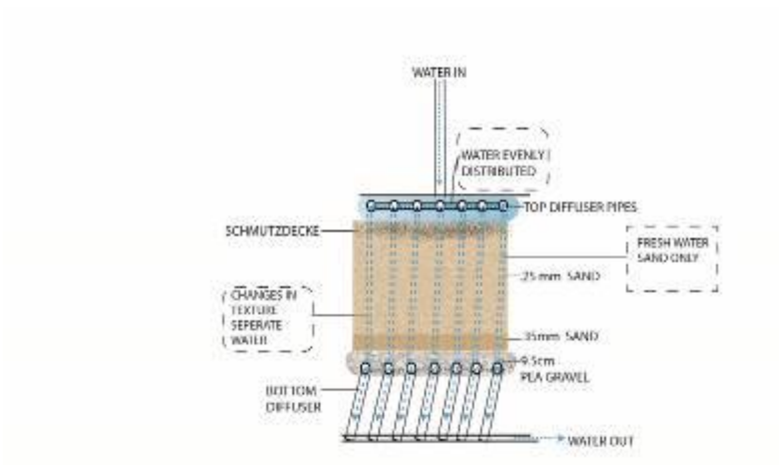

Figure 52: Traditional Slow Sand Filter (Author)

Option A is similar to a traditional slow sand filter. Figure 52 diagrams the layout of a slow sand filter. Sand is placed to fill almost the entire cistern with the exception of the bottom diffuser layer. The collector diffuser is located at the very bottom (about 18") of the cistern. Perforated pipes collect the clean water. As rainwater is collected the top perforated diffuser pipes distribute the water evenly across the surface of the schmutzdecke layer. As previously mentioned the schmutzdecke layer is the biological layer that eats the biological mass in the dirty water.

The large sand bed inside the cistern provides extensive filtering capacity. However, a large portion of water storage capacity is lost due to the sand grains. Since capturing rainwater is so important, this is not ideal. Also due to the lack of consistent rainfall, the schmutzdecke layer could potentially dry out and killing its biological capacity. During large rainfall the system could potentially be overwhelmed and put too much pressure on the pipes. This could be a potential maintenance problem. Additionally, the large amount of sand needed is problematic due to transportation and financial constraints.

Option B-Submerged Bucket

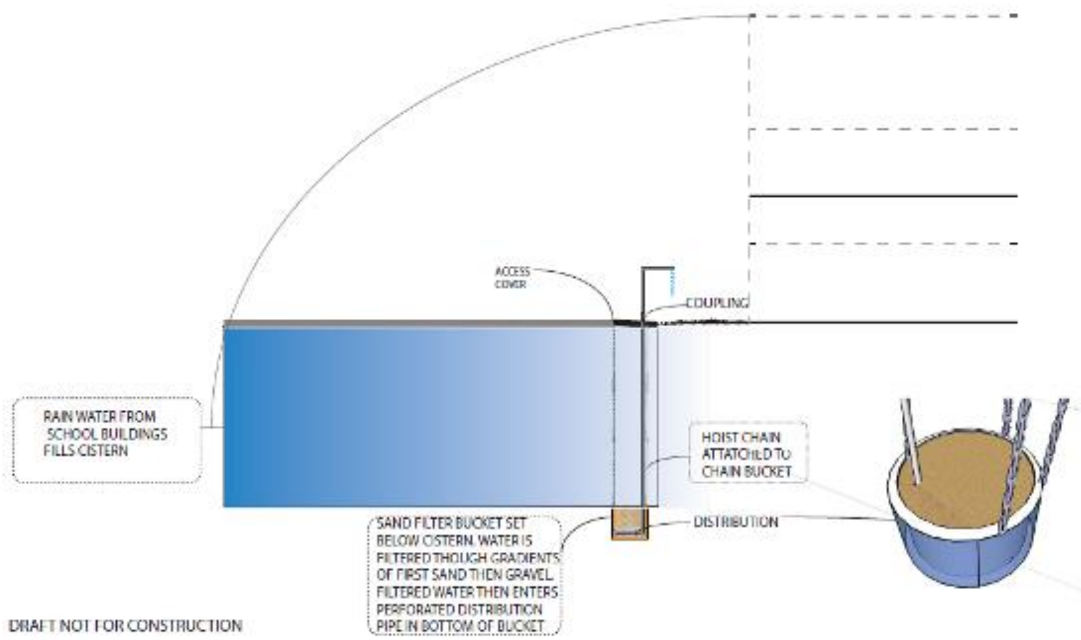

Figure 53: Conceptual Submerged Bucket Slow Sand Filter Layout (Author)

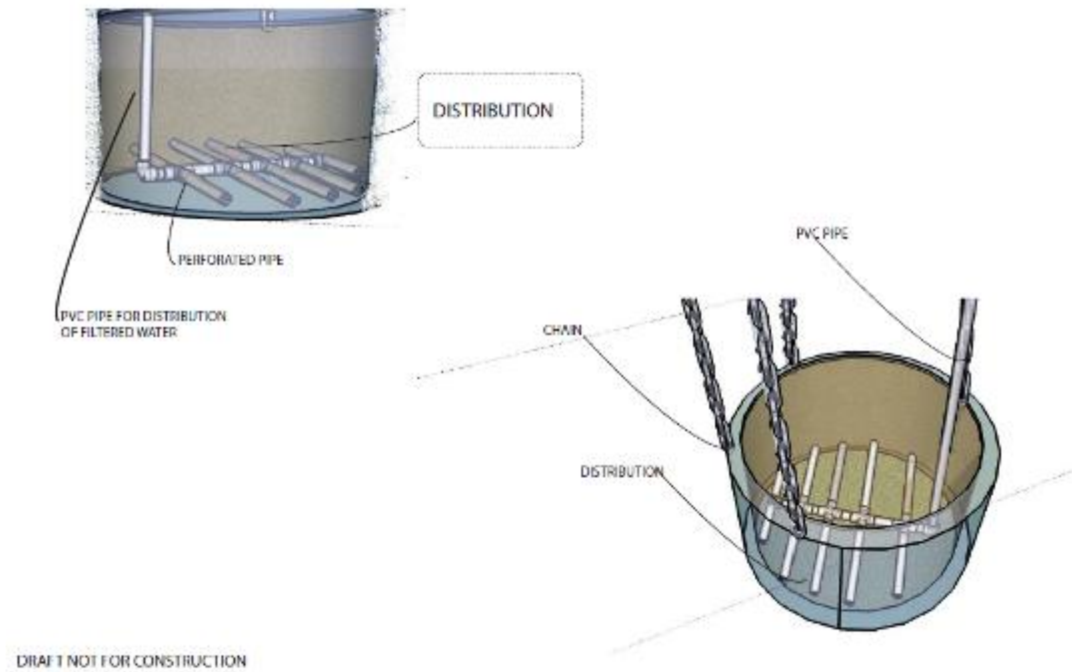

Figure 54: Submerged Bucket Technical Details (Author)

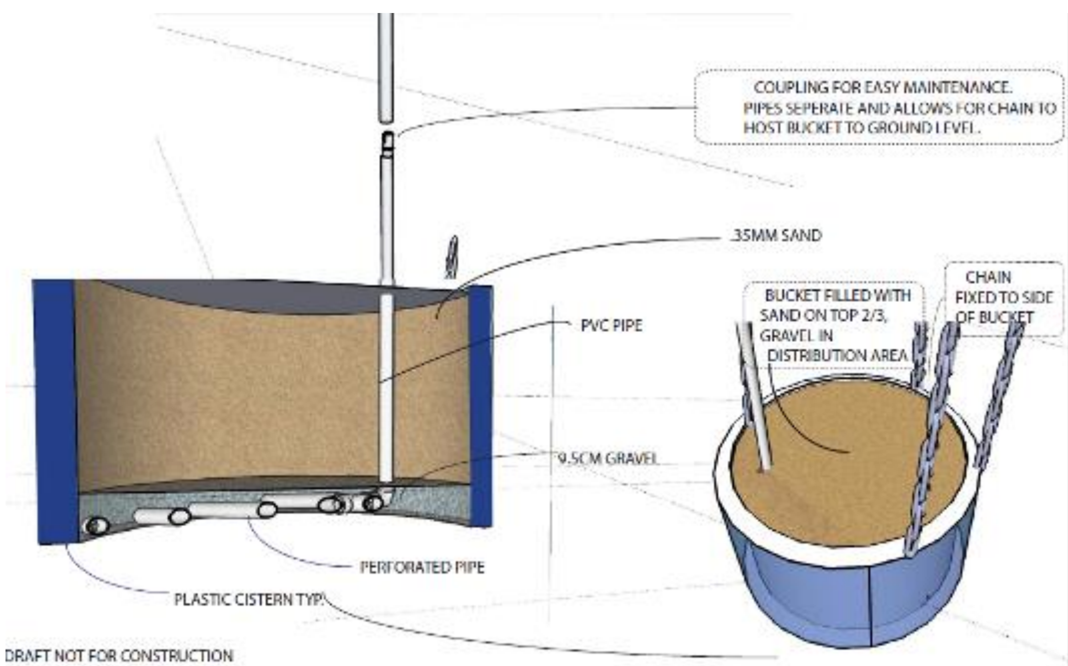

Figure 55: Submerged Slow Sand Filter Tension Detail (Author)

Option B is essentially a submerged bucket on a tension pulley system. The bucket is placed at the bottom of the cistern similarly to a drain. Figure 53 shows the entire system layout. The water would feed into the bucket filled with sand and a bottom diffuser pipe assembly illustrated in Figures 54 and 55. PVC pipe is inserted into the bucket with a coupling above ground for maintenance. The PVC pipe would provide filtered water above ground through head pressure. Pulley chains allow the bucket to be pulled to the top of the surface for cleaning.

This submerged slow sand filter has not been widely used. Several engineers were consulted, all approved of its technical potential to clean water. The stakeholders felt this was a bit "technical" with the bucket below ground. As a result, people may be less likely to use this. In Haiti a pulley is common due to the lack of technologies and machines. Locals are incredibly crafty at using tension. It does maximize water use. In theory, it is highly efficient at delivering clean water. Overall, there are a lot of moving parts which cause apprehension for its use and maintenance.

Option C-Repurposed 55 gallon Drums

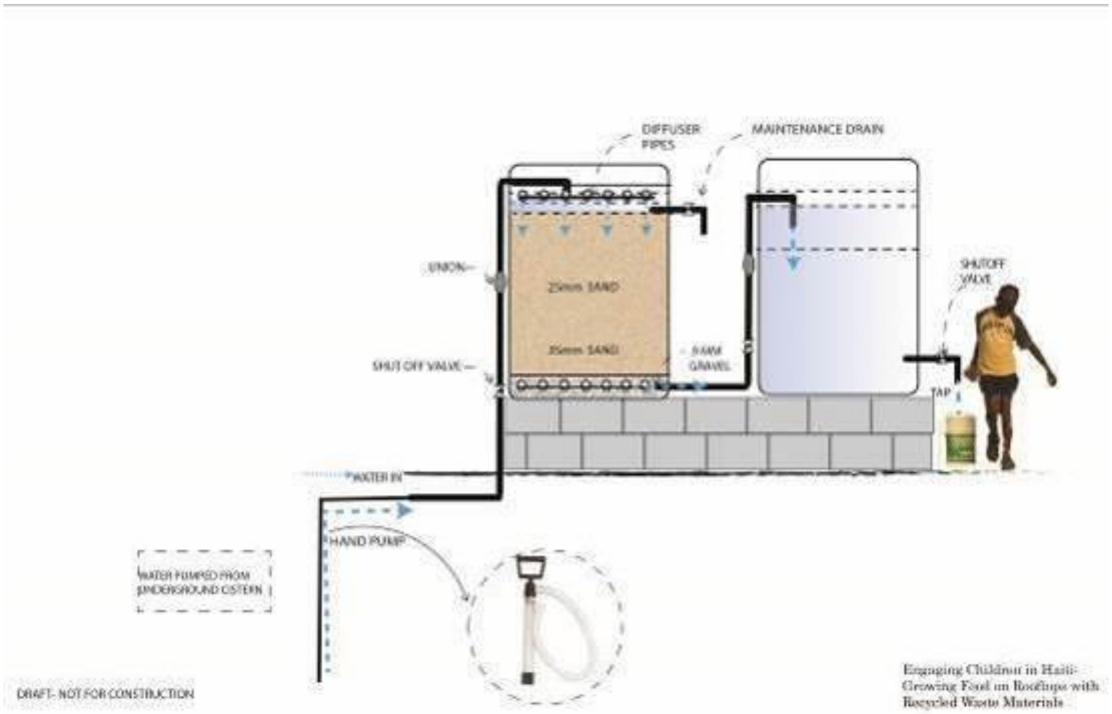

Figure 56: Fifty Five Gallon Drum Slow Sand Filter and Storage System (Author)

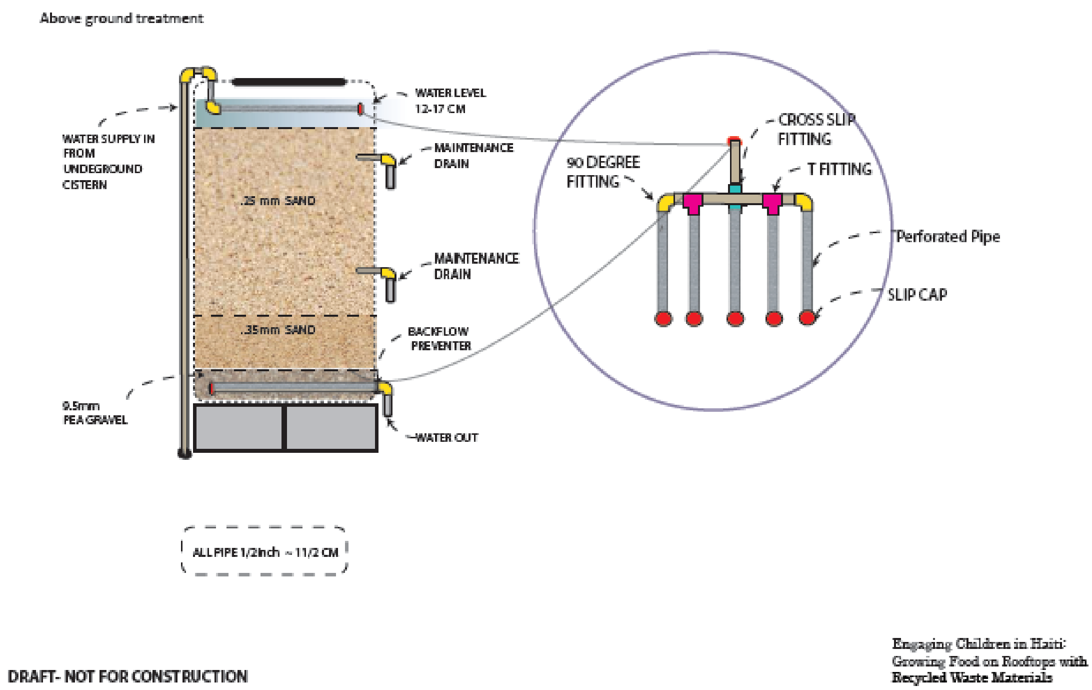

Figure 57: Slow Sand Filter Technical Detail of Diffuser and Underdrain (Author)

Option C

Figure 56 shows the layout of slow sand filter assembly in barrels. A 55 gallon drum is filled with a modified form of the traditional slow sand filter. Top and bottom diffusers control water in and out of the drum (Figure 57). Water is pumped into the barrel from a storage cistern. Gravel covers the bottom portion of the drum just above the collector pipe. The filtered water can be stored in other 55 gallon drums for demand use. It also allows for secondary treatment such as chlorination or bleaching.

This option was selected due to its simplicity and efficiency. 55 gallon drums are readily available and are easy to connect plumbing parts. It takes up minimal room and is highly flexible for arrangement. The entire cistern can be dedicated to storage of rainwater. Concrete blocks can be used to adjust the height of the drum so that a 5 gallon bucket can be used to obtain water from the storage tank. Maintenance is also considerably easier since the drum is accessible to observe changes in the schmutzdecke. It also creates exposure to the filter for children and adults to learn and engage.

Cistern Design

Sizing

The 1 year storm for the site was roughly estimated to be around 4 inches. This was fact checked by asking people in St. Louis Du Norde how often it rains 4”. The rooftop size of the school is 33’ x 49’. This is roughly 1600 square feet.

1600’^{2} x 4”/12”= 528’^{3} of possible water to harvest for the school rooftop.

Conversion to gallons

528’^{3} x 7.48 cubic feet per gallon = 3949.49 gallons

With the eventual church rooftop there will be 2 rooftops. There will be approximately 7900 gallons for a 1 year storm. The cistern size was based off of this quick calculation.

Liner

Due to the close proximity of the cistern to the latrine, a polypropylene liner was recommended for this project. With better planning a liner would not be needed. The liner is 45 ml NSF certified for potable water consumption. Geomembrane underlayment was also specked.

Conceptual Water Flow

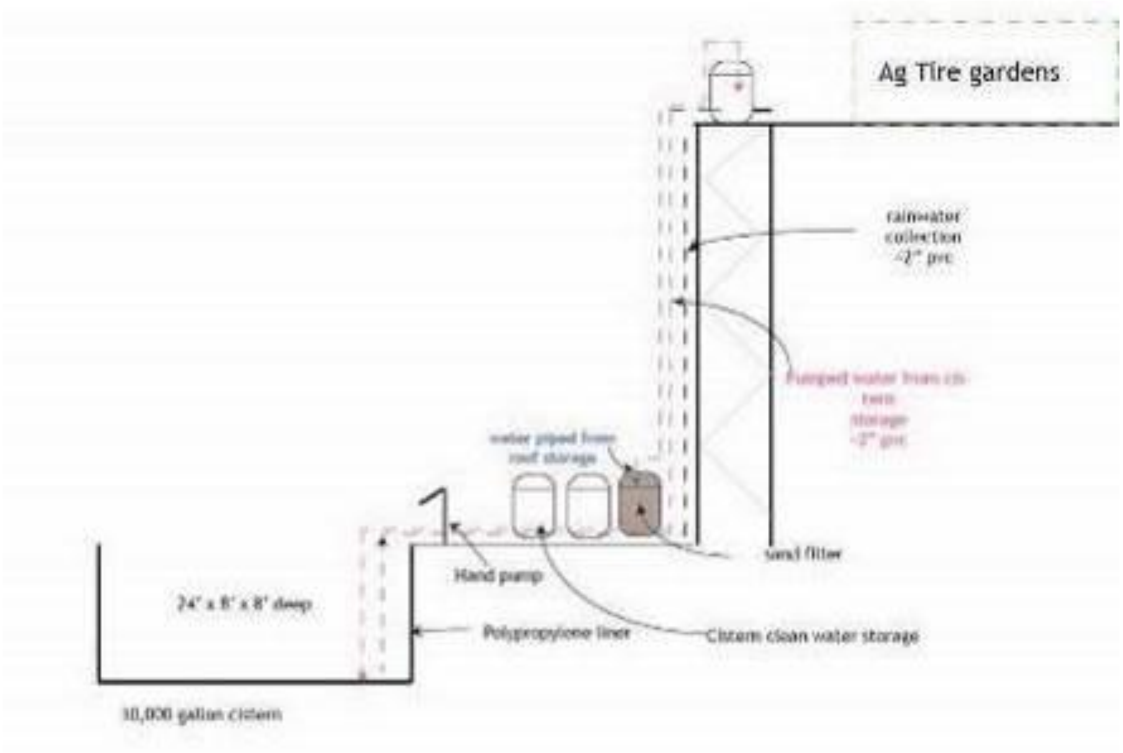

Figure 58: Water Flow Diagram (Author)

Figure 58 shows the capturing of rainwater and movement to filter water to drinking water standards. The system utilizes the cistern, a pump barrel, and a couple storage barrels for clean water.

Cistern

Water is directed from the rooftop through drain pipes into the underground cistern. This holds water until needed.

Pump- Barrel

Water is pumped up to the rooftop to a 55 gallon barrel through hand pump or electrical pump. This barrel provides pressure to keep the filter wet. The filter uses a float valve similar to a toilet to maintain water level. This barrel also serves as a way to access water for the gardens.

Storage Barrel

After water is filtered pressure pushes the water into 55 gallon storage barrels. A control valve provides flexibility. For instance, one barrel can potentially be filling, another barrel could be in use, and a third barrel could be chlorinating.

Secondary Treatment

Chlorination

Slow sand filters are very effective at removing contaminants from the water. However, small percentages of contaminants can remain. As water sits in storage barrels it can grow bacteria. By providing a small dosage of chlorination, it will shock the water. A drinking water specialist recommended "2 teaspoons of 54% hydrochloride powdered shock in 16 ounces of water. Then one teaspoon of that solution in 5 gallons of water is the equivalent of 8 drops per gallon which is about the mixture that they use in most municipal water systems." Chlorination is extremely cheap and long lasting.

Table 13: Chlorination Solution Amounts (Author)

Hydrochloride Powder (dry measurement)	Solution (liquid measurement)	Gallons of water treated (liquid measurement)
.02 teaspoons	1 teaspoon	5 gallons
.25 teaspoons	11 teaspoons	55 gallons
2 teaspoons	96 teaspoons	480 gallons of water
33 teaspoons	1600 teaspoons	8,000 gallons

Water Testing

There is a large need to develop simple, cheap, quick, and effective presence/absent bacteria tests. Cost and effectiveness are principal to any test. Through extensive research a few tests were identified that were reasonably inexpensive ranging from 1 – $15 US per test. All of the tests did not require a machine incubator.

Ultimately the PathoScreen TM Medium Presence/Absence Powder Pillows was our selected choice. The pathoscreen test is about 1.50$ US per test. This is important for applications in the developing world.

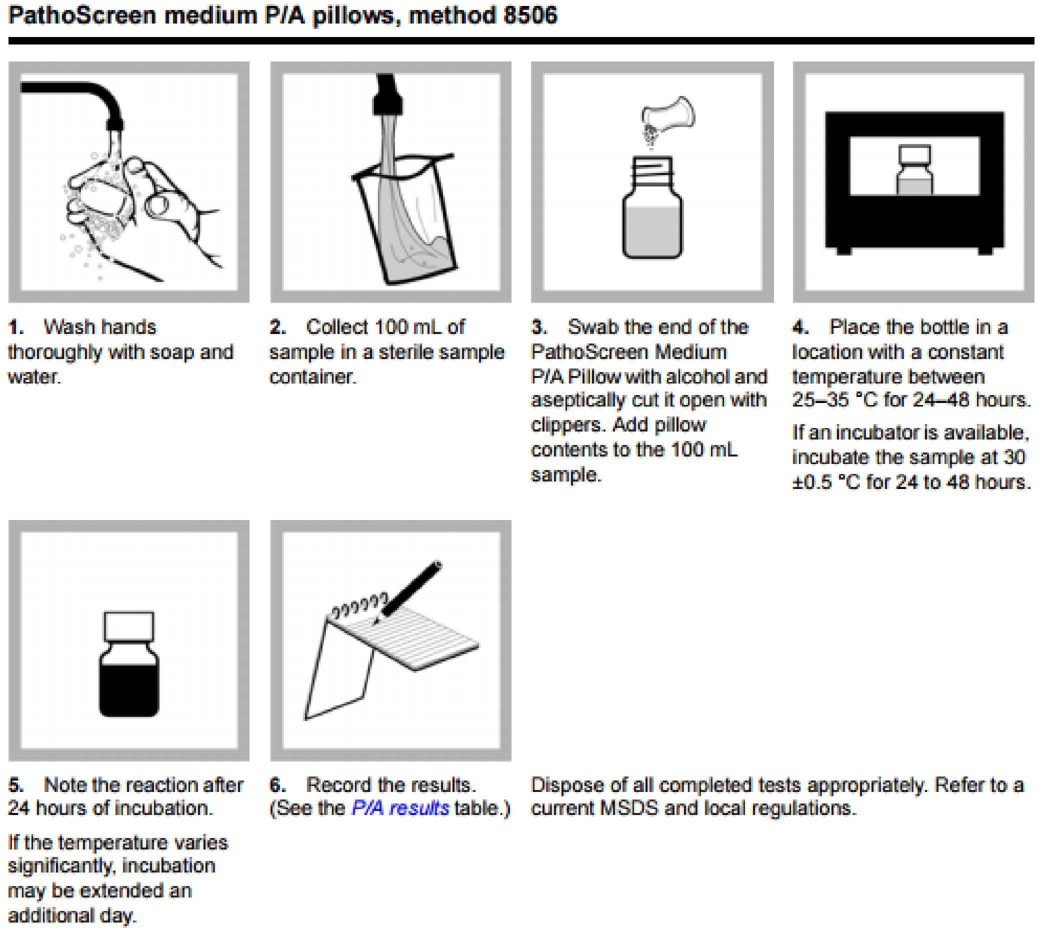

Figure 59: Water Testing Procedure (Pathoscreen)

A 100ml sample is collected in either a sterile bag or bottle. The bottle is then placed in a constant temperature between 25-35c for 24-48 hours. This is easy in a subtropical region such as Haiti. Once the powder medium is poured in the sample turns yellow. If a change is observed to black it indicates that there are bacteria in the water. A chlorinated sample that shows a reaction indicated a need for more chlorine.

Chapter 6: Site Design

Planning and Organization

Extensive planning, coordination, and collaboration happened before traveling to Haiti for the implementation.

Funding

Several grants were obtained for implementation of this project and other water related project. The funding covered the travel expenses and building costs associated with the project. $6,000 US was dedicated to the New Covenant School site.

Materials

All materials for the project were local from Haiti with the exception of a polypropylene liner which unfortunately needed to be imported. Better planning would reduce the need for a liner. Local materials make the project available to anyone in Haiti. All paid materials help support the economy of Haiti.

Parents and local community members of the church collected waste items:

- 70 tires (Figure 60)
- 200 Plastic bottles
- 50 rice sack bags
- Cardboard
- School Children were paid $1 in exchange for a sack for manure

Figure 60: Tires Collected by Community (Author)

Seeds and plant Cuttings

Seeds and plant cuttings were acquired from a supplier in Florida. Finding good seeds in Haiti is very difficult.

Volunteers and Paid Labor

Local volunteers including school children, parents, and local members of the church were recruited as volunteer labor. Three Pennsylvania Dutch farmers who are members of the Brethren Church in the states volunteered to travel to Haiti to help implement the project. The volunteers from the state have significant experience in mission trips and are skilled with building. The volunteer labors were combined with some local paid help. This helped to support the local economy and provide needed jobs for some of the members of the church. They included masons, welders, and carpenters.

Plans

The plans for the site are meant to be flexible guide. There is no fine grading for sites during construction in Haiti. With lack of machines and organization, soil is moved without plans. A lot can change so it is difficult to plan exactly how things were going to change. The technical details such as the water system and the tire gardens for the rooftop were planned before travel. The play components of the design are meant to be a collaborative component for the students. The design components of music play structure and a climbing structure are all meant to be place holders for a final on-site design.

The section (Figure 61) and plan (Figure 62) express the use of tires as a building component for social spaces. Additionally, it is envisioned that a shade structure built out of localized leaf materials and bamboo would cover the tire gardens on the rooftop. It is proposed that the students paint the tires. The sand filter system is walled in against the school building wall. Bougainvillea is proposed to be planted in a few tire gardens on the front edge to provide some aesthetic interest.

Proposed Section

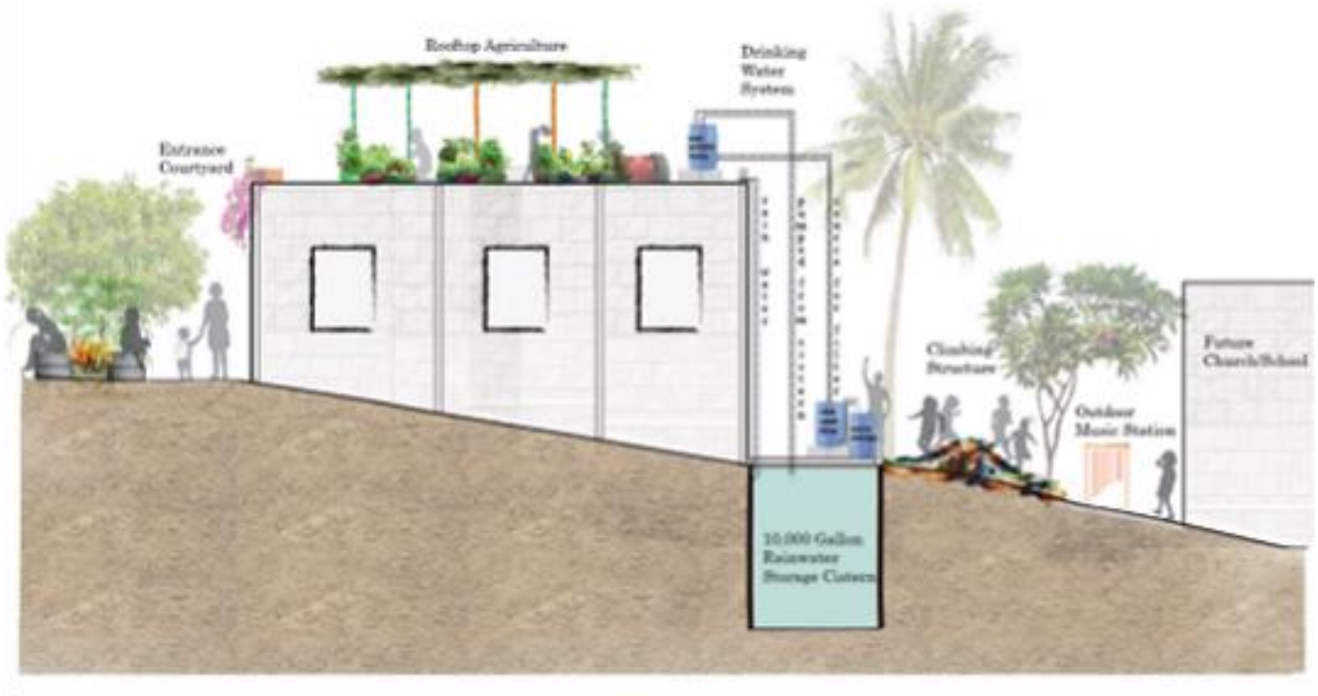

Figure 61: Proposed Section New Covenant School- Haiti (Author)

Proposed Plan

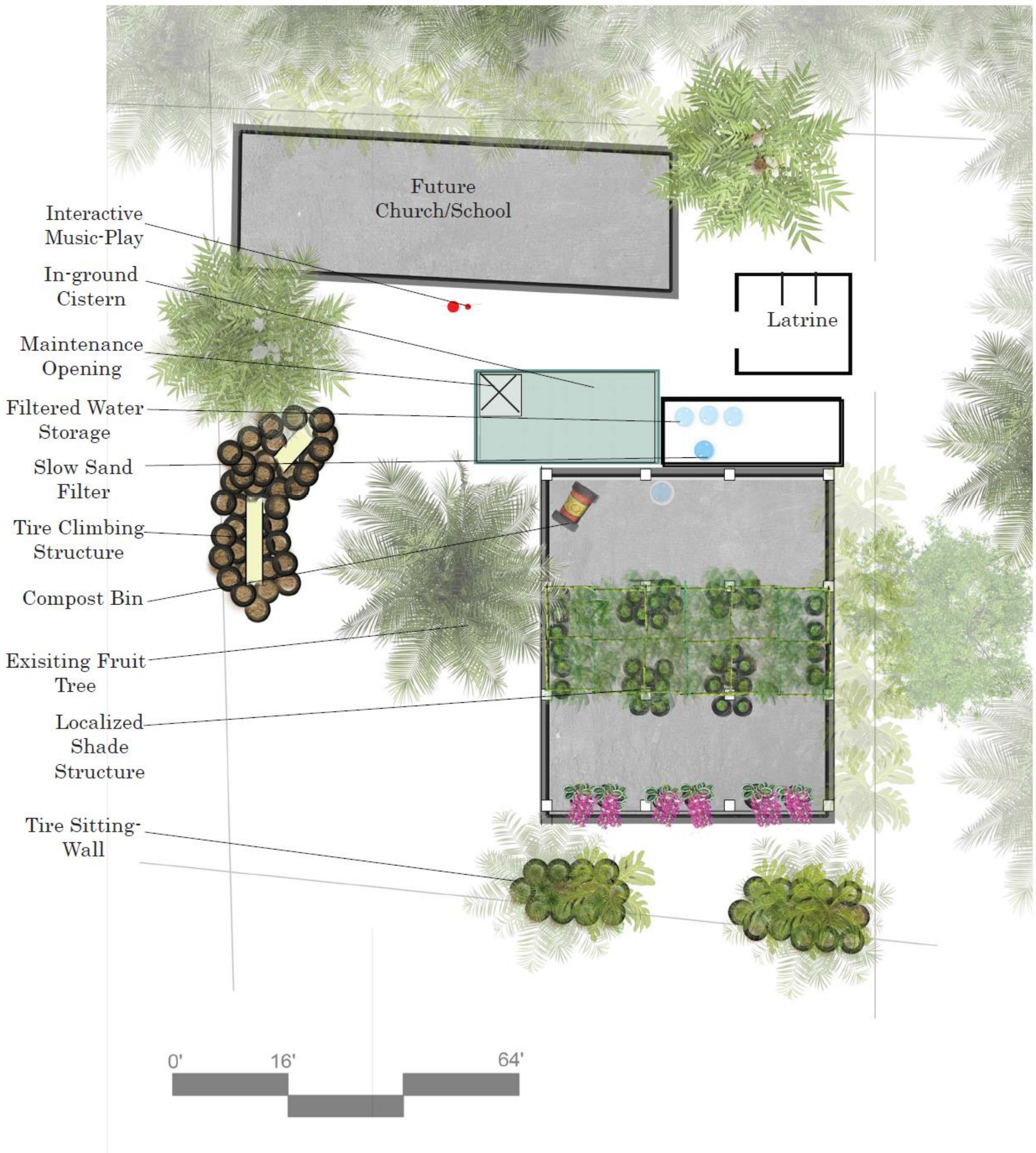

Figure 62: Proposed Plan New Covenant School- Haiti (Author)

Test Filter

In the spirit of repurposing most of the materials for testing the water system in a lab were found scraps and recycles. Collaborating with the recycling department of the University of Maryland (3) repurposed barrels were secured. Additionally, some PVC scraps were found in a warehouse of the university. Some minor parts such as pipefittings, a float valve, and hose clamps. Figures 63 and 64 display the underdrain and the top diffuser for the assembly. The water flow was the main concern tested in the barrel.

Figure 63: Underdrain Assembly Lab Testing (Author)

Figure 64: Diffuser Assembly Lab Testing (Author)

Chapter 7: Implementation

Figure 65: Engagement in the Implementation of the Project (Author)

In early March 2015, a team traveled to Haiti to help oversee the implementation of a community health project. Figure 66 shows the packed truck traveling to the site.

Collaboration

The students of the school were asked to draw pictures of what they wanted in their playground. An overwhelming amount of students wanted soccer. This is not surprising since riots in Haiti soccer matches have paused outbreaks. Soccer is loved by the children and adults of Haiti. Due to the limited space, a full soccer field is not possible on the site. However since the field would be for elementary school children a scaled field is possible.

Figure 66: Volunteers Traveling to Site in Northern Haiti

Adjusted Design for onsite conditions and Soccer Field

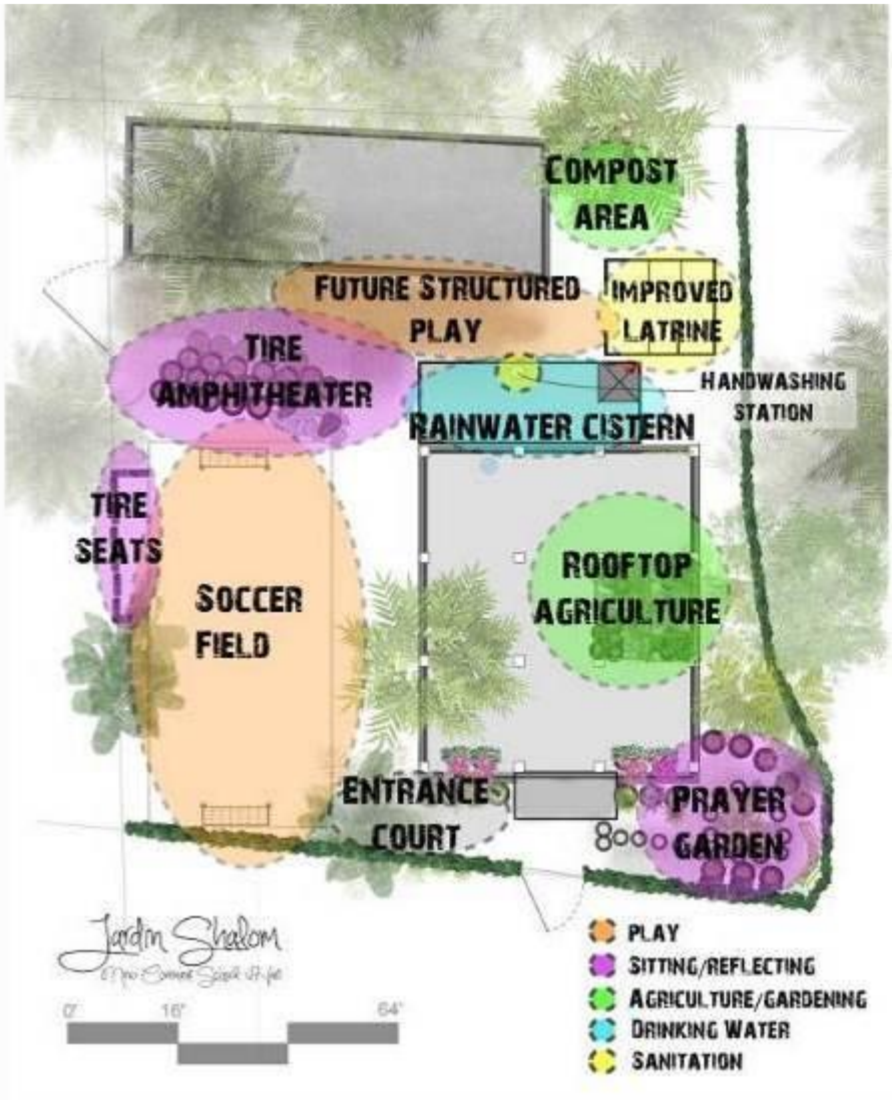

Figure 67: Final Site Layout/Design (Author)

Placement of soccer field

The longest length of land was needed to create the soccer field. For that purpose the soccer field is placed between the two buildings as shown in Figure 67. Additionally it is far enough away from the water system that it will not cause any problems. The field size is small but sufficient enough for school aged children.

Need for a wall

The placement of the field on a 6% slope created an opportunity and need for a wall. Quickly the idea of a tire wall was discussed. Through some brainstorming a collaborative idea of a tire amphitheater came about (Figure 68). While the water system and agriculture are the major impacts on the health the soccer field and amphitheater are the social drivers of the project.

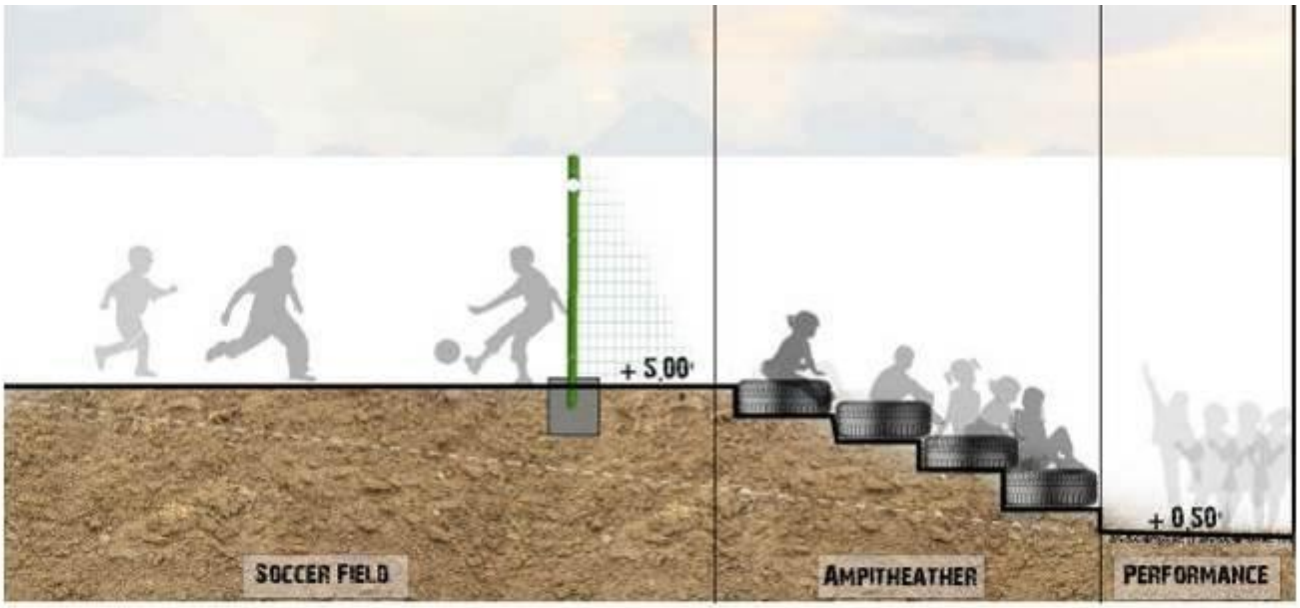

Figure 68: Soccer Field Amphitheater Section Drawing (Author)

<u>*Amphitheater Installation*</u>

Figure 69: Placement of Tires (Author)

Figure 70: String Line Leveling Amphitheater (Author)

A general layout was placed for 3 rows of seating in an inward curve. Volunteers dug the rows of tires similar to a tiered wall system (Figure 69). String was used to gauge the level of across each row (Figure 70). Multiple sizes of tires were used to create comfortable seating for everyone. The tires are filled are backfilled with soil and then the top few inches are filled with large gravel. The filling of tires is shown in Figure 71 and 72. Children engaged in compacting the soil in the tires. This was a fun exercise for them as exposed in Figures 73 and 74.The children also helped move the soil and gravel to the tires.   Eventually the children creatively painted the tires and rocks as presented in Figures 79-81.

Figure 71: Soil Transferred from Ground to the Tires (Author)

Figure 72: Locals Finish Tops of Tires for Sitting (Author)

Figure 73: Girls Jumping on Tires to Compact Soil (Author)

Figure 74: Girls Jumping on Tires to Compact Soil (Author)

Figure 75: Team Picture During Construction of Amphitheater (Author)

Figure 76: Layout of amphitheater during construction (Author)

Figure 77: Children testing seat heights (Author)

Figure 78: Children hanging out on amphitheater (Author)

Figure 79: Above view of volunteers and children painting tires (Author)

Figure 80: Painting tires of amphitheater (Author)

Figure 81: Painted Tires of Amphitheater (Author)

Figure 82: Finished Amphitheater above View (Author)

Figure 83: Children Using the Amphitheater (Author)

Soccer Field

"If you want to do something nice for a child, give them an environment where they can touch things as much as they want" Buckminster Fuller, 1972

Figure 84: Children Helping to Move Soil for Soccer Field (Author)

An estimated three to four yards of fill soil was moved on site to level the grade of the soccer field. The bottom of the amphitheater was excavated and that soil was used as fill for the soccer field as shown in Figure 68. Additional fill was used from the soil excavated for the cistern. Children willingly moved the soil in 5 gallon buckets (Figures 85 and 86). Lollypops helped provide extra incentives for the children to help move the soil. Bamboo with a concrete base serves as goal posts. The horizontal cross piece of the goal is latched through the top of the goal. Figures 87-92 demonstrate the construction of the physical goal post. As soon as the goal went up children moved the soil quicker so they could finish the field and begin play as display in Figure 84.

Children encouraged boundaries be constructed using rocks placed along the length of the field. An old mosquito net serves as the goal net (Figure 92). The children playing on the field helped to fine compact the soil in place. Figures 93-96 shows the children playing the first game on the field. The soccer goal post was replicated by a community member within one day of installation. Vertical tire seats were create along the one edge of the field. The seats become their own little social spaces displayed in Figures 97-99.

Figure 85: Volunteers Moving Soil in 5 gallon buckets (Author)

Figure 86: Children Moving Soil for Field (Author)

Figure 87: Carpenter Cuts Bamboo Lengths (Author)

Figure 88: Haitian Carpenter Latches the Bamboo

Figure 89: Volunteer pours concrete base (Author)

Figure 90: Concrete base of goal post

Figure 91: Volunteers and children install net (Author)

Figure 92: Finished soccer net (Author)

Figure 93: Children Play in new net (Author)

Figure 94: First Soccer Game (Author)

Figure 95: Children Play Soccer (Author)

Figure 96: Children Play Soccer (Author)

Figure 97: Children Sitting on Tire Seats (Author)

Figure 98: Children Congregate Around Seats (Author)

Figure 99: Children Paint Tire Seats (Author)

Figure 100: Above View of Soccer Field and Amphitheater (Author)

Sustainable Gardening

Figure 101: Social Harvest Design (Author)

The new covenant gardens build upon previous research Social Harvest project (Trobman, 2012) which uses intensive green roofs to grow food (Figure 101). The project involved the design and install of a prototype closed-loop food, medicinal and water harvesting system in Port-au-Prince, Haiti. The project grows food for struggling families in need of critical vitamins. The gardens were created using a commonly repurposed oil barrels as planters on flat rooftops. The barrels were welded inexpensively by local craftsman using scrap metal for the bottom of the planters. Soil is created through compost created out of waste materials such as cardboard, and food scraps. Water is harvested from the rooftop into 55 gallon drums at the lower floors of the households.

Several intensive roof gardens were constructed on household sites. Education outreach was conducted jointly by university professors and students. The project cost about 500-600$ per rooftop garden that feeds a four person household. The gardens have mixed success. The oil barrels are valuable items in Haiti's market. From an American perspective they are inexpensive however they are too costly for a Haitian family to implement on their own. The oil barrels also tended to heat up significantly making the crops require extra water. The shade structure similarly was not sustainable due to the use of imported shade cloth and use of wood.

However, overall the project was highly effective from a tactical urbanism standpoint. The ideas of teaching people to garden with locally available materials proved to be fruitful. People were excited and involved in the learning of building, harvesting, and maintaining the gardens. The rooftop gardens make sense due to the limited open space, compacted and non-fertile soils, and flat concrete rooftops. The gardens grow food and engage people which were the goal.

Figure 102: Garden Sign Made by Student (Author)

<u>Jardine Shalom</u>

Jardine Shalom translates to ‘the Peace Garden’. The hope is for the garden to be a welcoming and reinforcing element of the community by providing green to an area that has so much greys and brown. The garden includes customized tire planters, soil created on site, compost area and a shade structure created out of localized materials. Students participated in the creation of the tires gardens including the creation of the soil mixture, planting seeds, and painting the tires. Figure 102 shows the garden sign created by a school student.

Tire gardens are not a new idea. It is common to grow vegetables and crops in the tires. There are tons of old abandoned tires. Flat tires are a frequent event in Haiti due to the poor road conditions. Tires are a durable and portable material. Repurposing them as planters makes sense for those aims.

Tire Cutting

Figure 103: Haitian Volunteer Cutting Tires (Author)

Tire gardens were created by cutting the sidewall of one side of the tire to increase planting area (Figure 103). Small slits were notched into the tire for aesthetic purposes. After the tires were cut they workers inverted them to create final planters (Figure 104). Truck tires were used for the planters because they were widely available in Haiti. This provided a bigger planting area, but was somewhat difficult to cut and invert. The locals proved to have better technique at inverting tires as seen in Figures 104 and 106.

Figure 104: Inverting a tire (Author)

Figure 105: Stack of finished tire planters (Author)

Figure 106: Volunteers work to invert tire (Author)

Figure 107: Placement of tires (Author)

Tire Planter Placement

Children's arm lengths are short, making it difficult for them to reach over another tire. The planters were placed in clusters of 4 or 5 to provide for access to the planters

Figure 108: Concrete block placement (Author)

Figure 109: Children carry sifting equipment (Author)

for maintenance (Figure 107). The tires were placed on four cinderblocks. Three blocks adjoining and then 1 block placed perpendicular shown in Figures 108. All the blocks were placed on their sides to reduce the holes at the bottom of the planter. Clusters of tires also keep the gardens cooler, reducing the need for water and increasing production.

Soil Mixing

Students and volunteers were led in mixing soil for the garden. Rooftop gardening soil is tricky due to weight constraints. The soils need to be lightweight, yet still provide nutrients to the plant. It also needs to retain enough water so that the vegetables will grow without constant watering.

Figure 110: Clumps of Soil and Manure (Author)

Figure 111: Sack of Manure (Author)

Figure 112: Volunteers break clumps (Author)

Figure 113: Volunteers sift soil mixture (Author)

Figure 114: Children search for garden worms (Author)

Figure 115: Haitian child holds garden worm (Author)

Figure 116: Children dig for garden worms (Author)

Some fine top soil (clay loam) was found on site. Children and volunteers carried buckets of the soil onto the rooftop for mixing. Children brought sacks of manure (shown in Figure 111) in exchange for $1 US. The mixture was created at two parts top soil/one part manure (Figure 110). The big chunks were broken by hand and placed through a fine sifting (Figures 112 and 113). This resulted in very fine potting soil. Finally, students searched for worms and added them to the mixture. For most of the students, this was their first exposure to worms. Figures 114-116 show the students' fascination to worms.

Planter Components

First, a layer of a couple rice sacks are placed on top of the cinderblocks at the bottom of the planter. Second, a layer of plastic bottles are placed on top of the planters. The plastic bottles help reduce the weight of the planter and help with drainage. They act as rock would but only lighter. Third, a layer of soil consisting of clumps that could not pass through the sifter is added. Fourth, a layer of river sand is them added. Fifth, the mix of top soil and manure is added to the very top layer of the planter. Figures 117-126 show the various membrane layers of the planter.

Figure 117: Rice sack (Author)

Figure 118: Rice sack (Author)

1

Figure 119: Plastic bottles

Figure 120: Plastic bottles (Author)

2

Figure 121: Clump soil mix

Figure 122: Clump soil mix

3

Figure 123: River sand (Author)

Figure 124: River sand (Author)

4

Figure 125: Top Soil Mix (Author)

Figure 126: Top Soil Mix (Author)

5

Shade Structure


Figure 127: Coconut weave sample (Author)

Due to the intense sunlight in the Caribbean, a shade structure is needed to grow vegetables on the rooftop. A specialized structure was created on site using local materials. The locals refer to the structure as the “house”.

A local craftsman weaved coconut leaves to create a shade cloth (Figures 127- 130). The leaves will break down over time and then get added to the compost bin. Furthermore, the site is very prone to tropical storms and high winds. A structure must be mobile enough that it can collapse during a storm. Heavy duty PVC was used as the support columns Figure 131. Bamboo columns proved to be ineffective for support due to the wind. Bamboo is used for the cross supports for the coconut mat as displayed in Figures 132, 136, and 137. Figure 138 shows the immediate use of the structure for shade by locals.

Figure 128: Local craftsman weaving coconut leaves (Author

Figure 129: Coconut leaves weaving (Author)

Figure 130: Coconut leaf woven (Author)

Figure 131: PVC Support column (Author)

Figure 132: Bamboo cross support (Author)

Figure 133: Cutting bamboo (Author)

Figure 134: Assembling cross support (Author)

Figure 135: Attaching supports and coconut mat (Author)

Figure 136: Attaching coconut mat (Author)

Figure 137: Structure supports (Author)

Figure 138: Enjoying the shade (Author)

Figure 139: Finished shade structure (Author)

The children took control over painting the tire planters. Figures 142-147 show the students involvement in painting the tires. Hand prints of the students outline the outside of the planters (Figures 140-141). The children's engagement helps to build ownership of the project.

Figure 140: Decorated tire garden (Author)

Figure 141: Handprint Tire Garden (Author)

Figure 142: Child decorate tires (Author)

Figure 143: Children decorate tires (Author)

Figure 144: Child paints tire (Author)

Figure 145: Child places hand on paint (Author)

Figure 146: Child paints garden entrance sign (Author)

Figure 147: Children sit behind decorated tires (Author)

Planting Seeds and Compost Bins

Children and volunteers helped plant seeds and cuttings in the tire gardens (Figures 148, 151,153,154). The seeds and cuttings included Tomato, Seminole Pumpkin, Okra, Amaranth, Ethiopian Kale, Winged Bean, Collards, Maringa Tree, Chaya, Pepper, Marigolds, and Onions. In addition to planting in tires, banana stalks were hollowed for planting. Bananas retain a lot of moisture making them very suitable to grow in. A map was created by the school to identify the plants seeds in each container (Figure 146). Figures 148- 150 demonstrate the banana stalk planting. About a 4" wide hole was cut into the stalk. Compost bins were created as shown in Figure 152.

Figure 148: Hollowing banana stalk (Author)

Figure 149: Banana stalk planters (Author)

Figure 150: Volunteer plants banana stalk (Author)

Figure 151: Volunteer Plants Seeds (Author)

Figure 152: Compost bins (Author)

Figure 153: Children plant seeds (Author)

Figure 154: Child places seed into soil (Author)

Figure 155: Community members gather to learn about plants (Author)

Figure 156: Plan View of Planters (New Covenant School)

Jardine Shalom uses similar ideas as the Social Harvest of containerized gardens on the rooftop. However Jardine Shalom (New Covenant Site) uses all free and found materials to build the gardens making it accessible to even the poorest communities. The tires also create a larger growing space then the oil barrels. The placement of the gardens on community rooftops exposes a larger audience to gardening, rather than an in individual family. This also integrates into the children's daily school routines. While the ideas are similar Jardine Shalom is more accessible and integrated then Social Harvest projects.

Rainwater Harvesting and Slow Sand Filtration

PVC pipes collect rainwater from the flat rooftops and stores the rainwater from the rooftop. An electric pump brings the water from the cistern to the rooftop storage barrel. The barrel then provides pressure for the slow sand filter float valve.

Electric pump

An electric pump was chosen over the option of a hand pump. An electric pump is widely available in Haiti. It also is significantly less expensive and cheaper to repair then a hand pump. Electricity is very common skill trade in Haiti. People understand Electricity and can find the parts to repair it.

A hand pump was very hard and very expensive to find in Haiti. It is even more difficult to find repair parts for them.

Cistern

The cistern is composed of a concrete form with a concrete top. It has a large maintenance access metal cover shown in Figures 157 and 158.

Figure 157: Cistern maintenance access (Author)

Figure 158: Cistern concrete top (Author)

Slow Sand Filter Assembly

A barrel on the roof provides pressure for the slow sand filter (Figure 160). The slow sand filter is controlled through a float valve that maintains a two inch height of water above the sand. The float valve assembly is shown in Figures 161-164. Figure 163 show the water flowing into the system through the diffuser. The slow sand filter is located about the height of a barrel above the storage containers (see figure 159). This is so the slow sand filter can fill the two storage barrels through gravity. The system will eventually be enclosed with cinderblock storage room.

Figure 159: Slow sand filter system (Author)

Figure 160: Pressure Barrel and Drain Pipes (Author)

Figure 161: Examining Float Valve (Author)

Figure 162: Above View of Float Valve and top diffuser (Author)

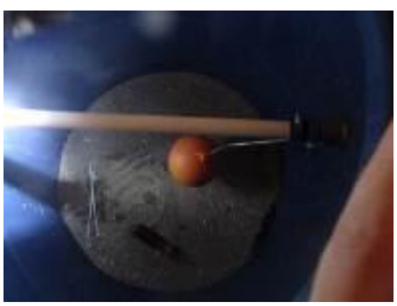

Figure 163: Float Valve Assembly (Author)

Figure 164: Float Valve (Author)

Figure 165: Sifting of Sand and Gravel (Author)

All the materials for the membrane of the filter can be obtained from the river. River gravel was sifted and separated in size orders of small sand, small gravel, and large gravel (Figure 165). Sand was placed in the sun for several weeks so that it would be cleaned (Figure 166). It is important to get most of the silt out of the sand. This can be done by turning the sand in the wind so that the fine silt will blow away. Large and small gravel is rinsed in buckets to remove sand and dirt Figure 168.

The underdrain and top diffuser are created with ½" PVC pipe. Holes were drilled in the underdrain and diffuser holes with a 1/16" drill bit about a thumb width apart Figure 173. The holes are drilled on one side of the pipe with the exception of the input and output ends of the pipes. The underdrain holes were placed down to prevent dirt from clogging the holes. The diffuser holes were placed upwards to reduce flow rate. A simple rectangular shape is efficient design for both the underdrain and top diffuser. An extra middle pipe was added to the bottom collector for extra water outflow. Turnoff valves were added at the bottom of each of the storage barrels (Figure 170).

Figure 166: Pile of Unseparated River Sand and Gravel (Author)

Figure 167: Sifting of Sand (Author)

Figure 168: Washing Gravel (Author)

Figure 169: Adding Gravel to Filter (Author)

Figure 170: Volunteers Install Flow Valve (Author)

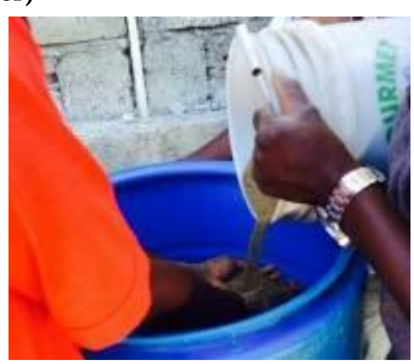

Figure 171: Adding Sand Layer (Author)

Figure 172: Large Gravel (Author)

Figure 173: Underdrain and Large Gravel (Author)

Large Gravel

Figure 174: Small Gravel (Author)

Figure 175: Small Gravel (Author)

Mediu
m

Figure 176: Fine Sand (Author)

Figure 177: Fine Sand (Author)

Fine SAND

The filter was created by adding two 5 gallon buckets of large gravel; two 5 gallon buckets of small gravel; and six 5 gallon buckets of fine sand. The filter is composed from top to bottom of smallest grain to largest grain at the bottom (Figures 172-177).

It will take approximately two weeks of use for the schmutzdecke to form. The top 2" of sand will be removed for cleaning purposes every July when school is not in session. Water was tested using the present absent powder kit shown in Figure 178.

Figure 178: Haiti Health and Agriculture Workers Test Water (Author)

Handwashing Station

A handwashing station was created using simple, quick, and inexpensive materials (Figures 179 and 180). The station will use 55 gallon drums to collect water from an overhang roof that is not hooked up to the cistern. A 5 gallon bucket with an on/off valve functions for water. The bucket is filled with water and a chlorine/disinfection mixture. A black plastic pan is used to collect the water with a small hole to fill into a 5 gallon bucket for reuse for laundry. The hand washing station helps reduce infection and overall improve the health of the children.

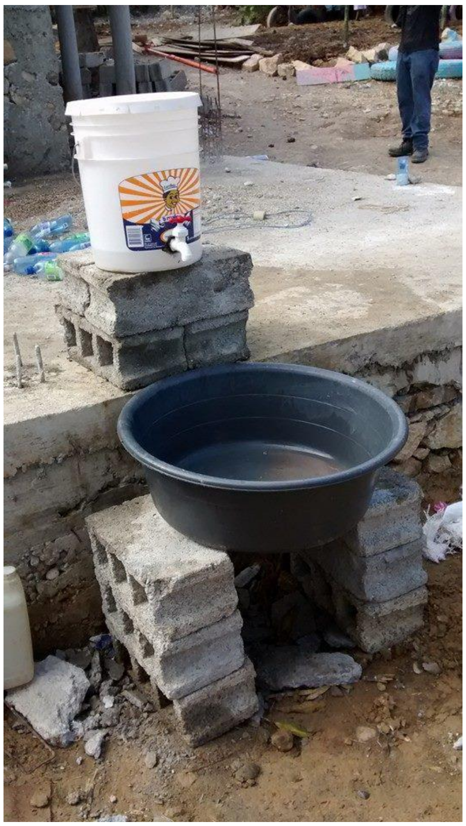

Figure 179: Hand washing Station (Author)

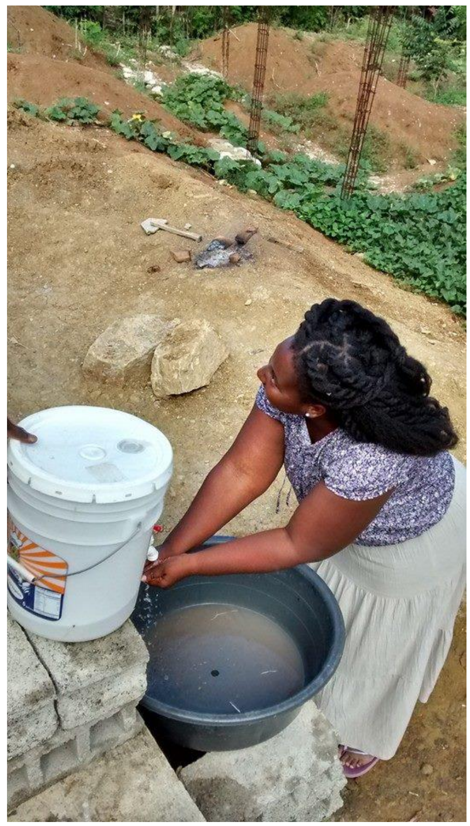

Figure 180: Volunteer Uses Hand washing Station (Author)

The prayer garden was a last minute design idea. The idea is that it would be a place where people can come and reflect in the shade of the garden. An underutilized corner space was selected for the prayer garden. Figure 185 shows the laying of tire seats to help enclose the space. The scrap outer rims of the tires from the gardens were used as stepping stones (Figures 181 and 182.) The rims were filled with gravel. Tire lounge seats and a custom bamboo bench were created. Lounge seats were created with the tires as shown in Figures 183 and 184. A special scented plant was purchased for the garden shown in Figure 186. The space can function as a gathering place, mediation, reflection, and even an extra classroom.

Figure 181: Jumping Around on Stepping Stone (Author)

Figure 182: Stepping Stone (Author)

Figure 183: Volunteer Use Tire Chair/Lounge (Author)

Figure 184: Children Use Tire Lounge (Author)

Figure 185: Prayer Garden During Construction (Author)

Figure 186: Scented Plant (Author)

Plastic Bottle Wind Chime

Plastic bottles and cans that otherwise would be burnt or wind up in the ocean were reused for a wind chime (Figures 188 and 189). The finished wind chime is demonstrated in Figure 187. Children instantly helped with the task without any encouragement or instructions. Figures 190 and 191 demonstrate children's curiosity for the project. There was a curiosity for using the ubiquitous plastic bottles. The children helped weave the metal through the bottles as well as add small pebbles to the bottles for sound effects. Figure 190 shows volunteers helping to hang the bottles on the rooftop for decoration.

Figure 187: Finished Wind Chime

Figure 188: Repurposed Plastic Bottle (Author)

Figure 189: Repurposed Plastic Bottles

Figure 190: Volunteer Helps Hang Wind Chime (Author)

Figure 191: Children Help Assemble Wind Chime (Author)

Figure 192: Children Help Move Wind Chime (Author)

Chapter 7: Afterthoughts

<u>As Built Layout and Next Steps</u>

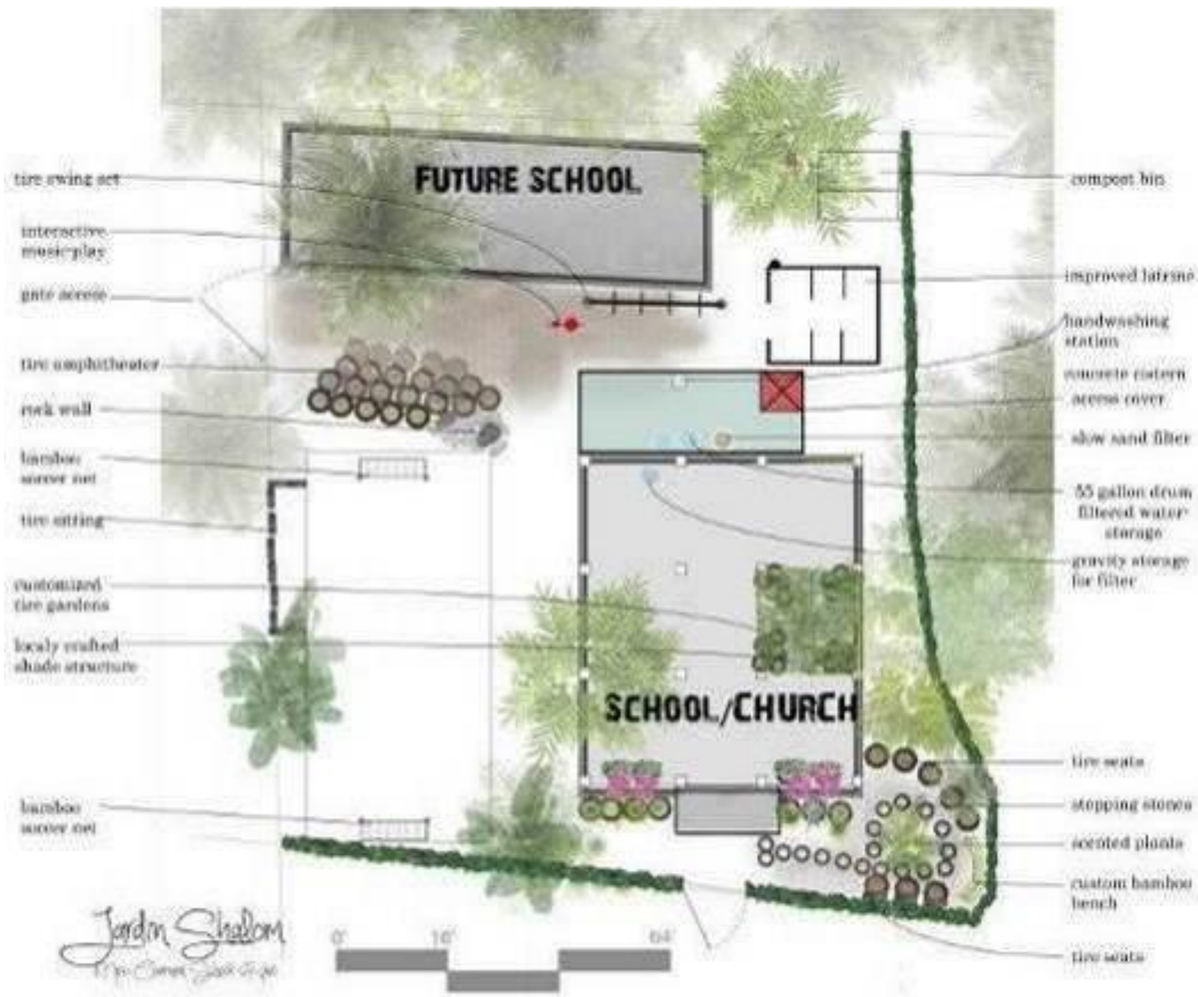

Figure 193: Post Construction Plan (Author)

Continued evaluation and oversight will be provided to New Covenant School as the system continues to be used. It is anticipated that questions of maintenance will arise. There is a local Health and Agriculture staff that will oversee the project. They have extensive experience working with communities and organizing participation. The staff has been trained on the operation and maintenance of the water system. Additionally, all of the staff has strong knowledge in gardening.

The second building will be completed in August 2015. After completion of the second building the next phase of this project will include a swing set, climbing structure, and musical play instruments. Figure 193 shows the as built plan for the site. The kitchen is also being planned to be constructed on part of the roof next to the garden. There is excitement from the seeds sprouting shown in Figures 194-196.

Figure 194: Jardin Shalom One Month After Planting (Author)

Figure 195: Seeds Sprouting (Author)

Figure 196: Seeds Sprouting (Author)

<u>Long Term Sustainability of the Project</u>

The focus of the project is desirable for any community (potable water, gardening, education, and improved community health). The project uses resources that are accessible and relatively easy to construct and maintain. The principles behind the project's use and construction are easy to transfer with others. Also, the scale of the project can be adjusted to fit any community. The project has long term health benefits for the community (potable water, sustainable gardening, education, and social space).

Diffusion of Technologies

Principles of tactical urbanism show a theoretical way of small scale actions serving a larger purpose. It is envisioned that this project will be diffused similarly. The intent of the project is to provide a prototype that can scaled, adjusted, and specified for residential site, church, school, or larger community. The intent is to continue to test and implement the technologies at the local community level (schools, community centers, religious centers, and recreation hubs). The intent is to expand partnerships with other nonprofits and funding agencies to help create systematic implementation of local community scale projects. This will teach locals how to build, operate, and maintain a system. As a result the hope is that locals will implement the technology on their own at the residential scale.

Slow Sand Filter

The slow sand filter is a very flexible and simple technology that has been used for centuries. The filter can be locally fabricated using available materials. A filter can container can be formed through found and bought material such a 5 gallon buckets, plastic drums, bricks, concrete, and metal. The membrane components can all be obtained from a local river. It is intended to be adapted to the site specific conditions. The size of the filter is dependent on the source of the water and the water volume scale. A household system for instance can be constructed using 5 gallon buckets. The source of the water can be also 5 gallon buckets from a local stream. However, this project uses rainwater harvesting due to the large need of water. If the cistern runs dry, river or truck water can be used in the system.

Sustainable Gardening

Raised garden can be translated to both the rooftop and the on the ground. In Haiti space constraints and eroded soils make it difficult to have a traditional garden in Haiti. Raised gardens using available materials can be scaled to fit the condition and scale of the site. A household could start off with a few tires on their back of their house. Again this is dependent on the site. For the New Covenant site the flat rooftop was perfect for gardening. Tires were an available material that can be changed to fit what is available.

Education-Principles of Science Class

The school's curriculum will tie to the sustainable food and water systems of the school. A new class 'Principles of Science' will be offered to 3rd to 4th graders. Students in the class will be exposed to the techniques and science of growing sustainable food and filtering clean water. Students will also gain exposer to the major environmental issues effecting Haiti. Additional workshops for the students will be held with the Community Health and Agriculture team. Students will participate in the maintenance of gardens including watering and harvesting of the plants.

Empowerment

Haitians are capable of solving their problems and are capable of great things. What they need is to be empowered to achieve their potential through education and training. It was important that the local community understood that we are not coming in to build something for them but rather to work with them so that they can learn to do it for themselves. This project was about relationships and people. The technology exists to do anything but it must be right for the context.

Life Cycle of Materials and Maintenance

Continued maintenance strategies will be coordinated with the agricultural support team in Haiti. Since this is a new system the maintenance strategies will have to be figured out over time.

As tires break down they will have to be replaced to avoid contamination. The old tires may be able to be used for a different purpose such as for the playground. It is anticipated that the shade material will last about 6 months and then will be replaced. The old materials will be composted. Continual changing of soil will happen after each growing season. Compost is constantly being created using organic scraps, animal manure, worms, cardboard, and the integration of previous season's soil mixture. Ideally a closed loop system will take place including compost, seed harvesting, and food.

Role of Landscape Architecture in Providing for World Needs

Scale

Today's global challenges are immense in scale and severity. These issues include radically altered global environments, declining environmental resources, Post-industrial cities in physical, social, and economic decline and the looming cloud of climate change. Furthermore, these issues are coupled with much of the world struggling to address basic human needs. All of these issues represent an immense large scale challenge affecting global, regional, and personal health of people. With such immense challenges and rising debts worldwide, it is difficult to even know where to begin.

Smaller grounds up decentralized approaches can create big impacts on the health of people and the environment. In a time of world economic debt, it is even more important that small scale project create more function and interwoven solutions to the challenges. Locally in cities such as Washington DC billions of dollars are being spent on infrastructural water sewage projects that provide very little social or human health benefits. The stormwater pipe in DC will undoubtedly help clean up the Chesapeake Bay but the large scale thinking reduced impactful opportunities of weaving community, ecology, and infrastructure into a beautiful design. This is the result of large scale centralized approaches that have proven ineffective, expensive, and socially unresponsive. For instance, Philadelphia and San Francisco decentralized approaches have cost less and provided far more reaching benefits to other systems.

One project is not going to change the world but many projects have the capacity to create large change. In the developing world there are lots of not for profits working separately to try to achieve the same basic goals. Landscape architecture's rich skill set positions it as a potential molder of these nonprofits in research based strategies. These types of strategies could help to better realize the resources.

Landscape architect's like painters and artists can mold a physical change or transformation in the landscape. This thesis project deals with providing solutions to some of the world needs that have an immediate need. Due to the critical nature of the work, people's lives are immediately impacted by the implementation of a project. Landscape architecture has this potential to be a powerful instrument for social change. But we must create partnerships that can help us realize these relationships. Nonprofits have trusted relations in the communities where they work. However, many of the nonprofits lack the design skills to implement technology.

Practice of Landscape Architecture and Social Impact Design

A commitment to the land and in particular the public realm is fundamental to the practice of Landscape Architecture. Fredrick Law Olmsted defined the profession of landscape architecture through his public interest design. His work sought to enhance the livability of cities for humans and increase the health and welfare for the public. Social impact design is based on the notion that everyone, regardless of income level should benefit from power of design to shape how we live. Designers have the skills, expertise, and experience to help solve the complex imperatives the world is facing. Design is about change and creating change. So it makes sense that the practice of design should respond to the tremendous need of the rest of the world and all the social and environmental issues that loom over the planet.

Recently, the profession of landscape architecture has not taken a prominent role in the social impact design. Landscape architecture is uniquely suited to reengage in public interest design. The disciplines broad skills set makes it well suited to engage and process the complex environmental and social world problems. In doing so the profession can raise awareness and the conversation about social impact design,

However, one critical factor is the economic factors of practice. Most social impact projects do not pay well or at all. Social impact design would require a commitment from firms to do pro-bono work. As this thesis demonstrates this may be a perfect intersection for research/academia and practice to intersect. The discipline of Landscape architecture can align its practice towards the world's challenges and help to better shape people and the environments health. A student experiencing building a project is an invaluable experience. More importantly it can increases stewardship of the land worldwide.

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