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1 Problem Formulation

1.1 Introduction: This section of our report, problem formulation, contains our group's objective statement and black box model for our design project. The black box model is shown in Figure 1-1. This is a simple examination of the desired changes and outcomes from the implementation of our design.

1.2 Objective: The purpose of our project is to research, design, and implement an effective, useful, and resourceful pathway that traverses the desired location at Zane Middle School.

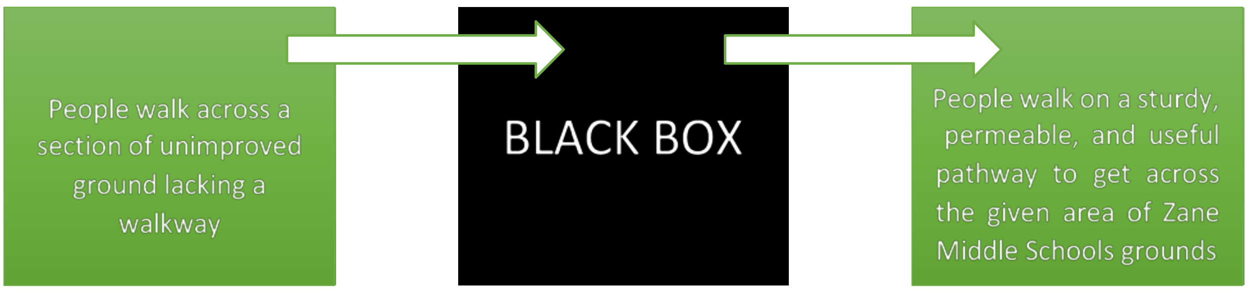

Figure 1-1 Black Box Model

2 Problem Analysis and Literature Review

2.1 Introduction to the Problem Analysis

The Problem Analysis presents the criteria of the client and explains the constraints and specifications for this project. This analysis will cover specifications, considerations, criteria, usage, and the production volume of this project.

2.1.1 Client Criteria

The client criteria are: the path design should be durability, aesthetically pleasing, minimize construction costs, repeatable, resemble an already built permeable pathway, semi permeable, be safe to walk on, and connecting two pathways from pre-determined point's together (Hammons 2016). The previously built semi permeable pathway this team's project must resemble is shown in Figure 2-1. Throughout this document the previously built permeable pathway constructed by past HSU Engineering 215 students is abbreviated and referred to as pbpp. Throughout this document, the pathway constructed by The Eco Team is referred to as the constructed permeable pathway. The constructed permeable pathway must be in a general location connecting two predetermined points, this area is shown in Figure 2-2.

Figure 2-1 Photo Taken by Jack Lisin

Figure 2-2 Photo Taken by Jack Lisin

2.1.1 Specifications

Specifications are the basic requirements that this team must meet and consider when designing this project. These specifications were determined by the client criteria and course instructions and considerations.

This teams specifications for this project are: Connects two existing pathways, resembles the already built permeable concrete pathway, is durable and long lasting, is semi permeable, and the design is chosen by The Eco Team after completing the Design Process.

2.1.2 Considerations

Considerations are guidelines inferred from the specifications and from knowledge of the design process as well as background knowledge of pathway construction and of the proposed location of the pathway.

When designing this pathway and choosing the criteria, this team will consider the following: The price of various materials and different pathway design options, the ability of this team to implement a design, the durability of various materials to withstand middle school student activity, the environmentally friendliness of different materials and how design affects it, and the visual aspect of the pathway since we are constructing on public property.

2.1.3 Criteria

Criteria	Constraints
• Safety	• Cannot be slippery, lifted or taken apart
• Durability	• Must have a strong foundation and solid in nature with minimal maintenance, must be three feet wide like the pbpp
• Sustainability	• Must utilize environmentally friendly and sustainable materials when possible, must be semi permeable
• Price	• Cannot exceed $75 per team member expense limit, or $375 total
• Ease of Implementation	• The Eco Team must be able to successfully design and implement the project without unreasonable or unfeasible hardships and design a project that could be repeated by others
• Aesthetics	• Must maintain the professional and elegant visual aspect of Zane Middle School and the Memorial Garden, must have resemblance to previously built semi permeable pathway

2.1.4 Usage

The design for the pathway will be proposed to the Eureka City Unified School District and will be used as an organized walkway for middle school students, faculty, and pedestrians. The pathway will help people stay on solid pathways and provide a more direct route across the location grounds. The permeable aspect of the pathway will prevent accumulation of large amounts of standing water on the path and will ideally aid and increase the rate of ground water recharge in the immediate area.

2.1.5 Production Volume

One pathway will be produced by the Eco-team for and at Zane Middle School. It will connect an already existing concrete sidewalk and a already existing semi permeable concrete pathway. There are more locations where pathways are needed on campus and this project will ideally be a model for future implementations of this design on the Zane Middle School campus and elsewhere.

2.2 Introduction to Literature Review

The purpose of this literature review is to summarize the background research and current literature required to implement and design a permeable pathway for this team's client at Zane Middle School.

2.2.1 Client Criteria

The client criteria are: the path design should be durability, aesthetically pleasing, minimize construction costs, repeatable, resemble an already built permeable pathway, semi permeable, be safe to walk on, and connecting two pathways from pre-determined point's together (Hammons 2016).

2.2.1.1 Information Regarding Client Criteria

Sustainable Manufacturing is the process of creating products through economically sound processes that minimize the harmful environmental impacts and conserve energy and resources (EPA 2015).

Durability is the ability to last a long time without a Signiant amount of deterioration Durable materials is environmentally friendly as it conserves resources and reduces wastes and limits the environmental impacts of repair and replacement (PCA 2015). A structure is durable if it fulfils its task for the intended and desired time span with minimal maintenance and the intended design life span is often determined by the client. (Perkins 1986).

Permeability is the ability to allow infiltration and penetration through pores and empty voids (Dictionary.com Unabridged 2016).

2.2.2 Potential Pathway Material and Designs

2.2.2.1 Pathway Plants

Woolly Thyme: T. pseudolanuginosus, also known as Woolly thyme, has some leaves that look fuzzy as seen in Figure 2-3. It is a candidate for being used in a pathway because it can handle heavy foot traffic. Woolly thyme grows flat and can grow to be 1-3 inches tall. It does not take much work to maintain. Maintenance includes an annual trim, little water, full sun, and well-drained soil. Woolly thyme grows flowers during the second half of June, and these flowers do attract bees. (Wingate 2003)

Figure 2-3

http://media.highcountrygardens.com/media/catalog/product/cache/3/image/500x/cdd56dd0d7347dc27aa421c918b212c4/w/o/woolly-thyme-emorrissette.jpg

Brass Buttons: Leptinella squalida, also known as Brass Buttons Figure 2-4 is a plant that grows to be around two inches tall and is a creeping plant. Even though it is a creeping plant, having a two inch thick hard paving material as a border will keep the plant contained where it is intended to be. It is forgiving of heavy foot traffic. Brass buttons likes to have part shade and regular watering during dry times (Wingate 2003).

Figure 2-4
https://gardencoachpictures.files.wordpress.com/2011/03/vaipsasik_cotula_sqyalida.jpg

Star Creeper: Pratia pedunculata, also known as blue star creeper, is a pathway plant that can withstand heavy foot traffic. It blooms in early summer with pale-blue blossoms as seen in Figure 2-5. Boundaries are a necessity for this plant because it will spread indefinitely otherwise. Blue star creeper likes full sun or minimal shade unless it is in a hot area. If the winter brings low temperatures then it will loses it leaves because it is a semi-evergreen plant.
(Wingate 2003)

Figure 2-1 http://www.wilsonbroslandscape.com/Blue_Star_Creeper_3x3.jpg

2.2.2.2 Various Types of Lumber

Redwood: Sequoia semperevirens, better known as redwood, is a type of tree and wood that can be found in the coastal northwestern part of the United States of America. Other common names include Sequoia, Coast Redwood, and California Redwood. The heartwood color varies from a light pinkish brown to deep reddish brown as you can see in Figure 2-6. The grain is fairly straight for the majority and the texture is coarse. The tree height ranges from 200-300 feet and its diameter varies from six to twelve feet. The average dried weight is 26 pounds per cubic foot and the Janka hardness is 2000 N. It is easy to work with for the most part, but if the grain is irregular than planer tear out may happen. Some of its common uses include being used for construction, decking, beams, and furniture. The durability of redwood is moderate to great regarding its resistance to decay. Old-growth trees tend to be more durable than the younger second-growth trees (TWD 2015).

Figure 2-2 http://www.buffalo-lumber.com/images/redwood-siding-9.jpg

Hard Maple: Acer saccharum, also known as Hard Maple, is a type of tree and wood. Other common names for Hard Maple include Sugar Maple and Rock Maple. The grain of Hard Maple is fairly straight Figure 2-7 and its texture is fine. This type of wood has low durability and has a higher risk of getting attacked by insects. Hard Maple is fairly easy to work with. This type of wood is not expensive nor cheap, but is fairly priced. As far as sustainability goes it is not listed the IUCN Red list of Threatened Species nor the CITES Appendices. (TWD 2015)

Figure 2-3 http://www.hardwood-lumber.com/store/images/hard%20maple.jpg

White Oak: Quercus alba, also known as white oak, is a type of tree and wood. The white oaks heartwood has a medium brown color as seen I Figure 2-8. Its grain is straight, while the texture is uneven. The trees height range from 65-85 feet, while its diameter ranges from three to four feet. The average dried weight is 47 pounds per cubic foot and its Janka hardness is 5, 990 N. White Oak can react with iron especially when it is wet causing the wood to stain. It is very durable and is used in boatbuilding (TWD 2015).

Figure 2-4 http://fowlerlumber.com/wp-content/uploads/2011/05/DSC_0731.jpg

2.2.3 Permeability, Groundwater, and Local Precipitation

When designing our permeable pathway it will be important to consider what factors contribute to permeability. Aspects of groundwater recharge and the amount and type of precipitation the potential pathway will experience will affect its permeability and durability.

2.2.3.1 Structural and Hydrological Design

Construction of a permeable pathway must have a completed determination of the thickness of the various components that are necessary to support the pathway for the intended traffic to protect the subgrade from any damage. Tests for the correct mixture should be taken in order to obtain the correct formula for construction. Knowing the strength and permeability of the sample with help with the overall performance of the actual pathway. (Hein and Schaus 2013)

It is typical for permeable pavement to replace impermeable surfaces. The best design is one that accommodates for foot traffic and hydrological features that provides accurate water drainage. Hydrological Design governs the key design components required to infiltrate rainwater and runoff through the pavement while filtering the water to meet with the standards of storm water management. An ideal pavement design is one that accommodates the stress of intended foot traffic and has the minimum hydrological features to manage the water flow. Rain is caught in depressions in the ground, goes straight into the soil (depending on the soil makeup), or is limited by ground cover. If the soil comprises clay then little to no water can be absorbed, while sand or arid soils can easily absorb rainwater. As a result of this, the total runoff from rainfall is smaller than the total rainfall itself. The two most important things that must be considered when designing pervious concrete is permeability and storage capacity. The permeability takes into account the flow rate of water through the concrete layer and then into the soil and subgrade soils. The total volume of rain is required to allow for the correct calculation of storage capacity. This includes the capacity of the pervious pavement, the soil and any subbases that are used. The use of a subbase can seriously increase or decrease the storage capacity and drainage of storm water. It is important to build on level ground otherwise, if the pathway were on a slope, the water would collect at the bottom of the angled slope leading to overflow of the subgrade shown in Figure 2-8. For sloped pavements, the angle of the slope must be taken into consideration to solve for the storage capacity calculations, and if the infiltration rate of the subgrade is exceeded. With high flow rates, the pavement can be weakened or washed out if not properly planed for. (Pervious Pavement 2011)

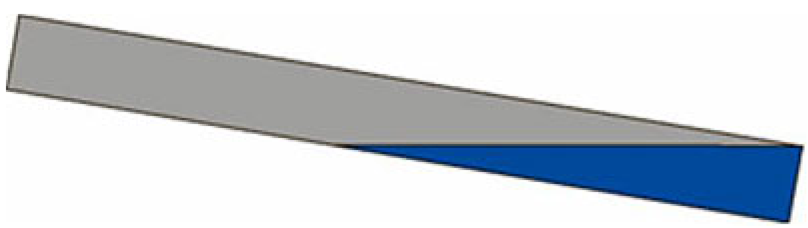

Figure 2-8 http://www.perviouspavement.org/design/hydrological.html

Pervious concrete is a material unlike any other conventional cement concrete that has distinct matrix and behavior features. These features are predictable and measurable even though they are different from normal cement concrete. Projects that have undergone the correct planning and have a life span of 20 to 30 years provide a great deal of experiential evidence associated to quantifiable properties, adequate subgrades, and construction techniques. Studies and Research for each of these areas have only recently commenced. The estimation of the average daily traffic (ATD) is crucial to determine the design for a long lasting pavement. Unless cracking of the surface is acceptable, the pervious concrete should be jointed. A result from the use of minimal water, the pervious concrete has a decrease in the cracking potential so owners normally do not object to the surface fractures. The flexural strength of the concrete in this type of design in very important. The load of the pavement is distributed evenly about the subgrade to account for the correct strength of design.

A combination design for a pervious pavement use will produce an extensive array of strengths and permeability values, reliant on the amount of compaction. Testing before construction should aid in determining the association between compressive or splitting tensile and flexural strength, along with the weight and/or voids appropriate for the materials planned for use (Pervious Pavement 2011).

2.2.3.2 Groundwater and Precipitation

Groundwater comes from precipitated water that must filter down through the vadose zone to reach the zone of saturation, where groundwater flow can occur. The rate of infiltration is a function of soil and rock type, precursor water, and time. The vadose zone contains the materials between the Earth’s surface and the zone of saturation. The water table is located right above the saturated zone and below a layer that varies in thickness called the capillary fringe. Water is pulled up into this layer by capillary action. The vadose, or unsaturated, zone serves as a filter before the water can reach the zone of saturation (DAI 2016).

The movement of groundwater relies on the properties of the rock and sediment and the groundwater’s total flow potential. Permeability is one important properties of groundwater flow. Permeability is the ability of a rock or soil type to allow the infiltration of fluids. Permeability depends on the magnitude of pore gaps and how tightly the gaps are connected. Grain shape, grain packing, and cementation all affect permeability. Figure 2-9 shows the actual pathway of a water molecule as it slows through soil or rock. The water molecules always travel in a downward route. (DAI 2016).

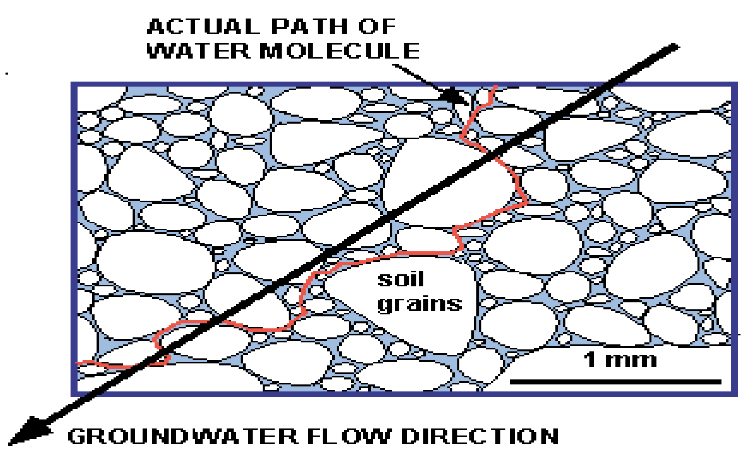

Figure 2-9 http://imnh.isu.edu/digitalatlas/hydr/concepts/gwater/imgs/soil.gif

The volume of precipitation is important to take into consideration when constructing a permeable pathway. According to the National Weather Service Forecast Office, in Eureka, CA, it is shown in Figure 2-10, the weather and amount of precipitation for the year 2016. The amount of rain is shown to be above the average amount (National Weather 2016). With such large amounts of precipitation in 2016, the construction of a permeable pathway is crucial to the consequences of large quantities of storm water. With these large quantities of water, the water will be able to easily infiltrate through permeable concrete without creating large puddles. Therefor resulting in easier groundwater recharge and filtration of the water. With the forecasted amount of rain for the year of 2016, the implementation of a permeable pathway versus a concrete pathway will further assist with ground water recharge.

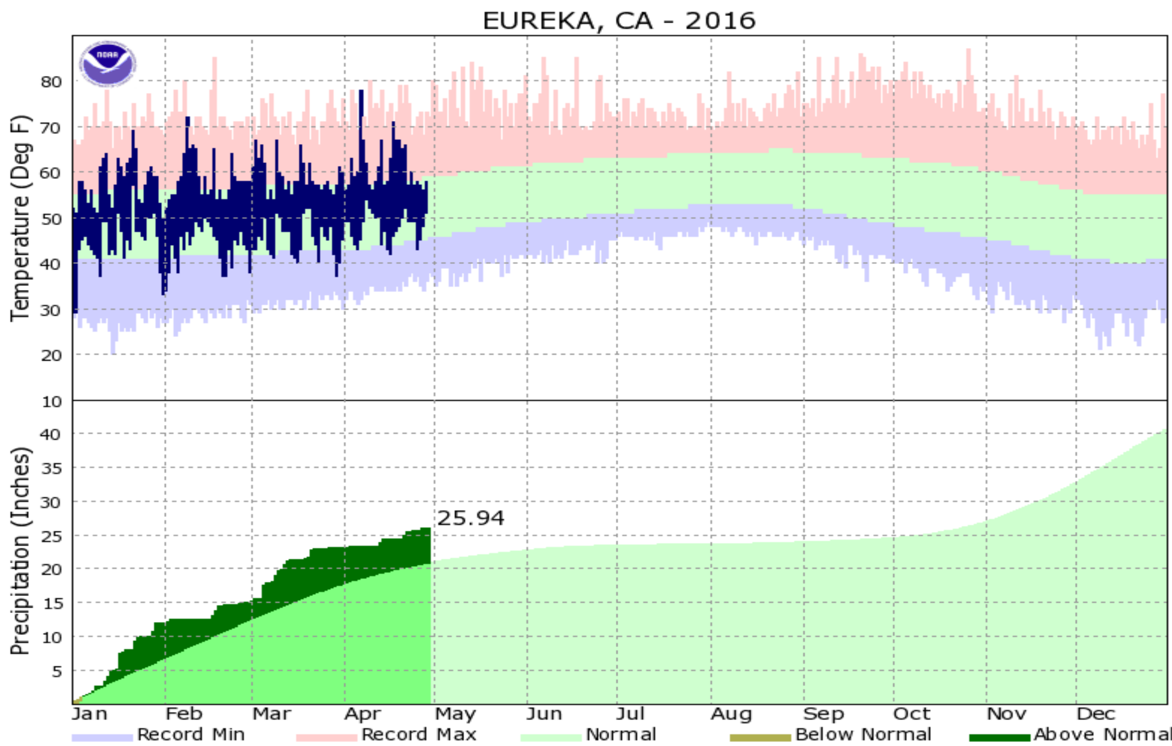

Figure 2-10. Source: http://www.wrh.noaa.gov/images/eka/cliplot/KEKA2016plot.png

2.2.4 Review of Concrete

Concrete is a mixture of paste and aggregates. The paste, comprised of Portland cement and water, coats the surface of the aggregates. This paste undergoes hydration and hardens to the aggregates, creating strong mass rock like structure known as concrete. Concrete is malleable when newly mixed and strong and durable when hardened. Concrete is a material consisting of water, aggregates, chemical admixtures, and cement. The proportions for standard concrete is 6 percent air, eleven percent Portland cement, 41 percent coarse aggregate (gravel), 26 percent fine aggregate (sand), and 16 percent water (PCA 2015).

Aggregates are granular materials such as gravel, sand, and crushed stone. For a successfully concrete mix, aggregates need to be clean and durable particles free of coatings of other fine materials. Fine Aggregates are sand or crushed stone that is less than 3/8 inch in diameter. Coarse aggregates are larger and are typically between 3/8th inch and 1.5 inch in diameter; Gravel is typically used as the coarse aggregate in concrete (PCA 2015).

Chemical admixtures are materials added to the concrete mix other than water, aggregates, and Portland cement. These admixtures are added and used to reduce the cost of production, change the properties of the concrete, and other various specific reasons. Various admixtures include water reducing admixtures, retarding admixtures, accelerating admixtures, superplasticizers, and corrosion inhibiting admixtures (PCA 2015).

Cement is a mixture of aggregates, cement, and water. It is valuable material because it is very strong and durable. Cement is a manmade material created at high temperature comprising of Lime, Silica, and oxides of aluminum and Iron. In the production of Cement, first clinker is made at temperatures of 1400 degrees Celsius, then the clinker is mixed with other minerals to create the powder known as cement. Clinker is made from limestone and smaller quantities of clay, shale and sand. The limestone is used to obtain the calcium while the sand, shale, and clay is used are sources of silica aluminum and iron. New materials that are alternatives to traditional materials for the production of cement include: mill scale, Fly Ash, and Slag. Cement production is either done “wet” or “dry” depending on the water content of the raw materials. The dry process is far less energy intensive than the wet process (WBCSD 2015).

2.2.4.1 Possible Maintenance Requirements to Maintain Concrete Structures

It is unrealistic to expect the structure to maintain it’s as new condition for its intended life span without maintenance. Portland Cement Concrete can have an almost unlimited life unless it is subject of physical degradation or a chemical attack. If there is corrosion damage or cracks within the concrete the concrete is not durable. Often defects in concrete building is the result of corrosion of the reinforcement (inner concrete and material within concrete coating). Thus when designing one must consider and ensure long term protection of the reinforcement. To ensure long term protection of the reinforcement the concrete must be very impermeable (Perkins 1986).

2.2.4.2 Alternatives to Cement in Concrete Mix

There are alternatives to Portland cement that are more sustainable, have been proved and tested as viable, and can be implemented worldwide. Known as High-Volume Fly Ash (HVFA) concrete technology. It is a low cost and low carbon output cement technology. HFVA concrete mixtures are comprised of: A minimum of 50% coal fly ash by mass of cement; a low water content; Total Cementitious material 300 to 400 kg/m^3. Benefits of using HFVA cement technology are: freshly produced HFVA concrete possesses good workability and are easy to pump. Hardened HFVA concrete is resistant to cracking (Mehta 2010).

2.2.4.3 Concrete Safety

Concrete can be a perfectly safe material to work with so long as precautions are taken. Protecting one’s head and eyes while working on a construction site with concrete manufacturing taking place is important. A hard hat and safety goggles are advised. It is important to protect your eyes from dust and splattering materials that may be present when working with concrete. Many of the materials used to create concrete are heavy. When lifting heavy materials, one should have their back straight, legs bent, and the weight centered between your legs and as close to the body as possible. If lifting something creates strain on ones back, they should get assistance. When working with freshly formed concrete, care should be taken to prevent chemical burns from the concrete and skin irritation. Concrete can be abrasive to the skin, can cause chemical burns, and can dry out skin it comes in contact with. Clothing worn when in contact with wet concrete should be kept as dry as possible, wet clothing can transport harmful effects of concrete into the skin. Water proof gloves, long pants, and a long sleeved shirt should be worn when coming in contact with concrete. To avoid skin irritation, wash skin frequently with a neutral soap and clean water (PCA 2015).

2.2.4.4 Environmental Impact of Concrete:

Production of Concrete does have an effect on global CO_2 and other greenhouse gas emissions. Global cement production, where much of the pollutants from the production of concrete comes from, accounts for roughly seven percent of global CO_2 output into our atmosphere. Portland cement manufacturing is an extremely energy intensive process, producing a ton of Portland cement requires four giga joules of energy. Further negative environmental impacts from the production of concrete come from the extraction of other necessary raw materials. Mining for clay and limestone and other materials often result in deforestation and a loss of top soil. Global annual concrete production consumes large amounts of aggregate, roughly ten billion tons of sand, gravel, and crushed rock. Extraction of this aggregate is an energy intensive process often has many negative environmental impacts on the ecosystems it is taken from. Massive amounts of fresh water is used as well, around 1 trillion liters of water annually. The entire construction process tends to be energy intensive as well. Transportation of materials and workers, mixing, and batching all tend to be energy intensive. The typical life of concrete structures is around fifty years, but concrete structures near the coast tend to have service lives of twenty to thirty years. Possible ways to decrease the negative environmental impacts from concrete construction are decreasing the amount of aggregate, water, and cement needed and used (Mheta 2001).

2.2.4.5 Permeable Concrete

Permeability is the rate at which a gas or liquid passes through a test structure. Concrete is made up a pore structure. The pore structure allows water under pressure to pass slowly through the concrete. The rate through high quality dense concrete is extremely slow. The permeability of concrete is determined by: The quality of the cement and aggregate; quality of the cement paste; bond development between paste and aggregate; degree of compaction of the concrete; presence or absence of cracking; standard of curing; characteristics of any admixtures used in the paste (Perkins 1986).

Pervious concrete is a special type of concrete that allows for water to be able to fully penetrate through. This type of concrete is a distinctive and sustainable way to deal with storm water by allowing it to seep into the ground and reduce any runoff from precipitation or other means. The water that is allowed to seep through the concrete into the soil below permits for a naturally occurring water treatment. Regular pavement would allow for pollutants on the surface to runoff into drains to pollute nearby bodies of water. Pervious concrete consists of a specially formulated combination of typical cementitious materials and uniformed open graded coarse aggregate. Proper designs will contain high percentages of void spaces to accommodate storm water from any source (ACPA 2006). This leads to faster groundwater recharge and also meets the U.S. Environmental Protection Agency (EPA) regulations for storm water. Its void content ranges from 18 to 35% with compressive strengths of 400 to 4000 psi (28 to 281 kg/m^3). The infiltration rate of pervious concrete will fall into the range of 2 to 18 gallons per minute per square foot (80 to 720 liters per minute per square meter) (Obla 2010). Applications of permeable pavement can be applied to most provinces but does face some challenges with freezing temperatures. Proper care is required to ensure the life span of the pavement. Studies show that although it may be difficult to implement in cold temperatures, snow-covered pervious concrete may melt quicker than regular pavement, resulting in less snow plowing and refreezing or ponding (ACPA 2006). Figure 2-11 shows an example of how water passes through a pervious concrete cylinder.

Figure 2-11 http://secement.org/pervious_concrete.htm

2.2.4.6 Types of Permeable Pavement

Dry-Laid Pavers is a method of installing pavers or stones over sand and gravel. This allows for the water to pass by the openings and through the sand and gravel. Sometimes grass or other plant life can grow in between these pavers creating a living environment in the pathway. Brick can be used as a permeable paver when space or cracks are left in between the bricks. The material of the brick will allow for water to flow to open spaces. Crushed Stone or Gravel is the cheapest material to use and is simply placed and packed on top of leveled out soil. Stone can be used as pavers with gravel in between or plant life. Flagstone and slate are the most common stone that is used in this process. Ground Reinforcement Grids create a structure that assists in planting or filling in spaces with paving material. The end result looks like a grid and can be different combinations of plant and paving material, whether one is the fill or one is the outline. Plastic Mats with Cells are circular cells that allow for planting or permeable material to be implemented created small areas that are gaps for water to go. Grass Pavers closely resembles the look of a regular lawn, but it gives the reinforcement and structure to the pathway. Open cells are filled with dirt and then the grass seed is planted. This type is really strong and designed to carry heavy loads. (LandscapingNetwork 2016)

3 Alternative Solutions

3.1 Introduction

Section 3 details the alternative solutions that have been discussed and established during brainstorming sessions. A total of ten alternative designs were developed.

3.2 Brainstorming

Two Brainstorming sessions were held, during each session the team sketched ideas on both paper and white board in an empty classroom in Science-D (engineering department) at Humboldt State University. These brainstorming sessions were used in order to build off of each individual's ideas to create stronger alternatives. Multiple building techniques and design ideas were thrown into the air such as well as different locations of how the pathway could be laid out. Permeability was the main factor included in our ideas. Notes and sketches of from these brainstorming sessions can be found in Appendix A.

3.3 Alternative Solutions

The ten alternative solutions that have been developed and are detailed below. A sketch of each design is included to help deliver a visual aid and provide further detail of each alternative. These alternatives will be evaluated against each other and the best fit will be chosen for our final design.

3.3.1 Woodyboo

Woodyboo is a pathway that is constructed of wooden planks and wood stakes to raise the pathway up a 1.5 inches off the ground as shown in Figure 3-1. There are small gaps between each wooden plank to allow water to drain through and seep back into the ground. The wood stakes are driven into the ground and then sleepers are installed. These are then fastened with treated deck screws driven through the stakes. Where the two sleepers join, it is strengthening at the joint with plywood on either side, supported with a stake. The wooden planks are attached to the sleepers with screws and spacers are used to keep the planks evenly spaced apart.

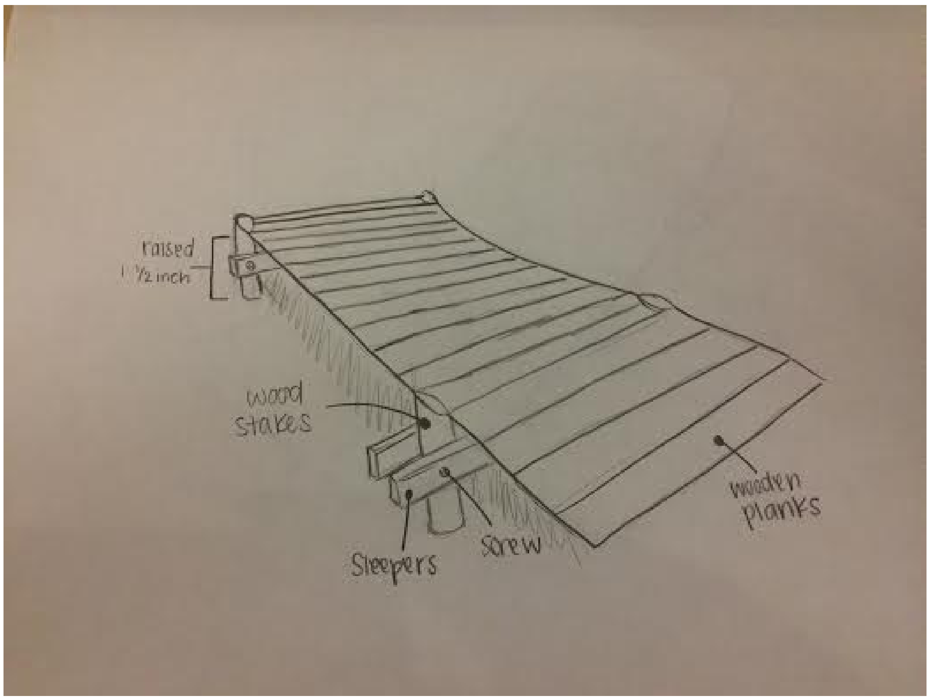

Figure 3-1 Woodyboo (photo drawn by McKenna Rayburn)

3.3.2 Brickleberry

The design for Brickleberry consists of both permeable gravel with brick pavers as seen in Figure 3-2. The soil on the site of the path is dug up, compacted and then geotextile is laid down so the gravel and soil do not mix. Wooden or hard plastic edging is used in order to keep the gravel and pavers from shifting. The brick pavers are then set on the bedding layer, side by side, with pea gravel then swept in between all the joints. The depth at which the soil needs to be removed depends on the traffic that the path will undergo and the soil type.

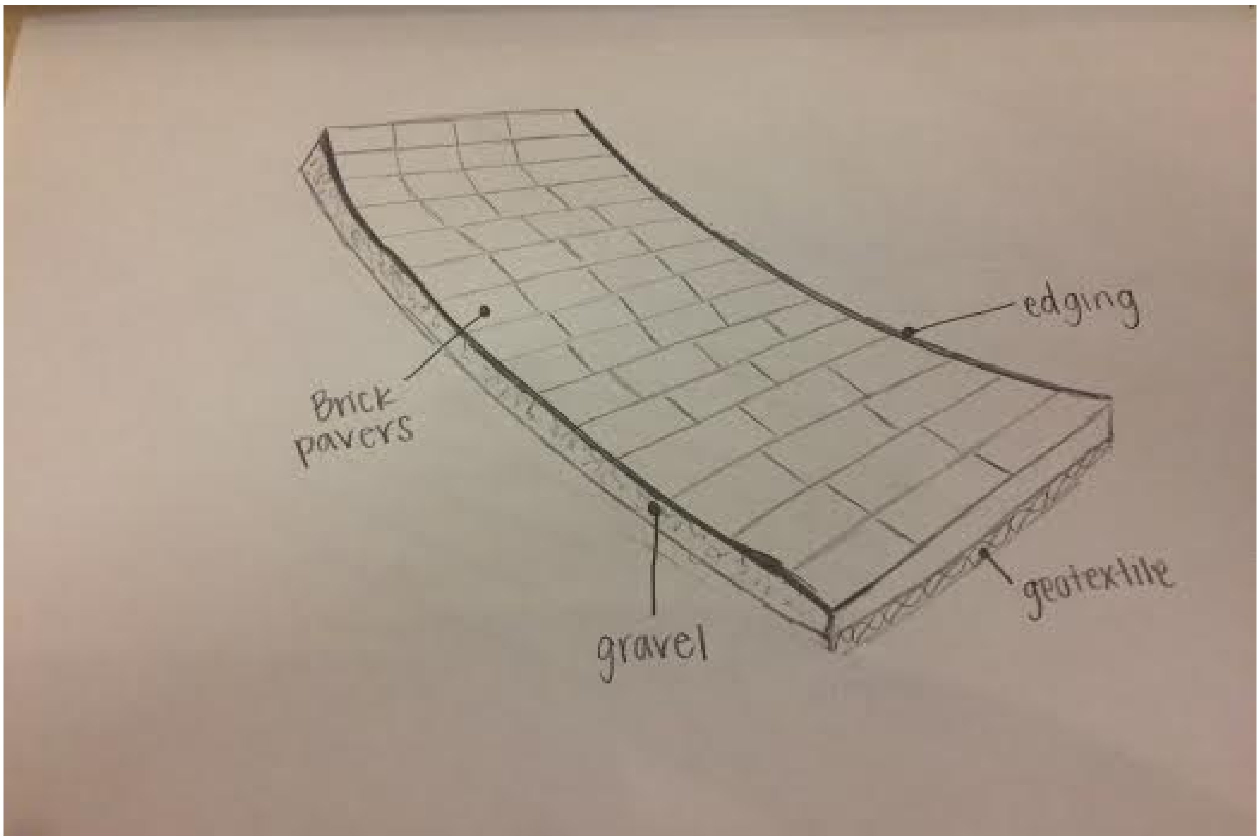

Figure 3-2 Brickleberry (Photo drawn by McKenna Rayburn)

3.3.3 Recycled Bottle Pathway

The Recycled Bottle Pathway as seen below in Figure 3-3 would be made out of recycled bottles. They would be packed down tightly with a natural permeable material that would also secure the bottles in the ground. This design could have the pathway hug the curb or weave through the woodchip area. Recycled bottles come in many different colors, so there could be an aesthetic benefit. When students see such a large volume of single use bottles in one place, they may think about wastefulness and how single use products impact our environment.

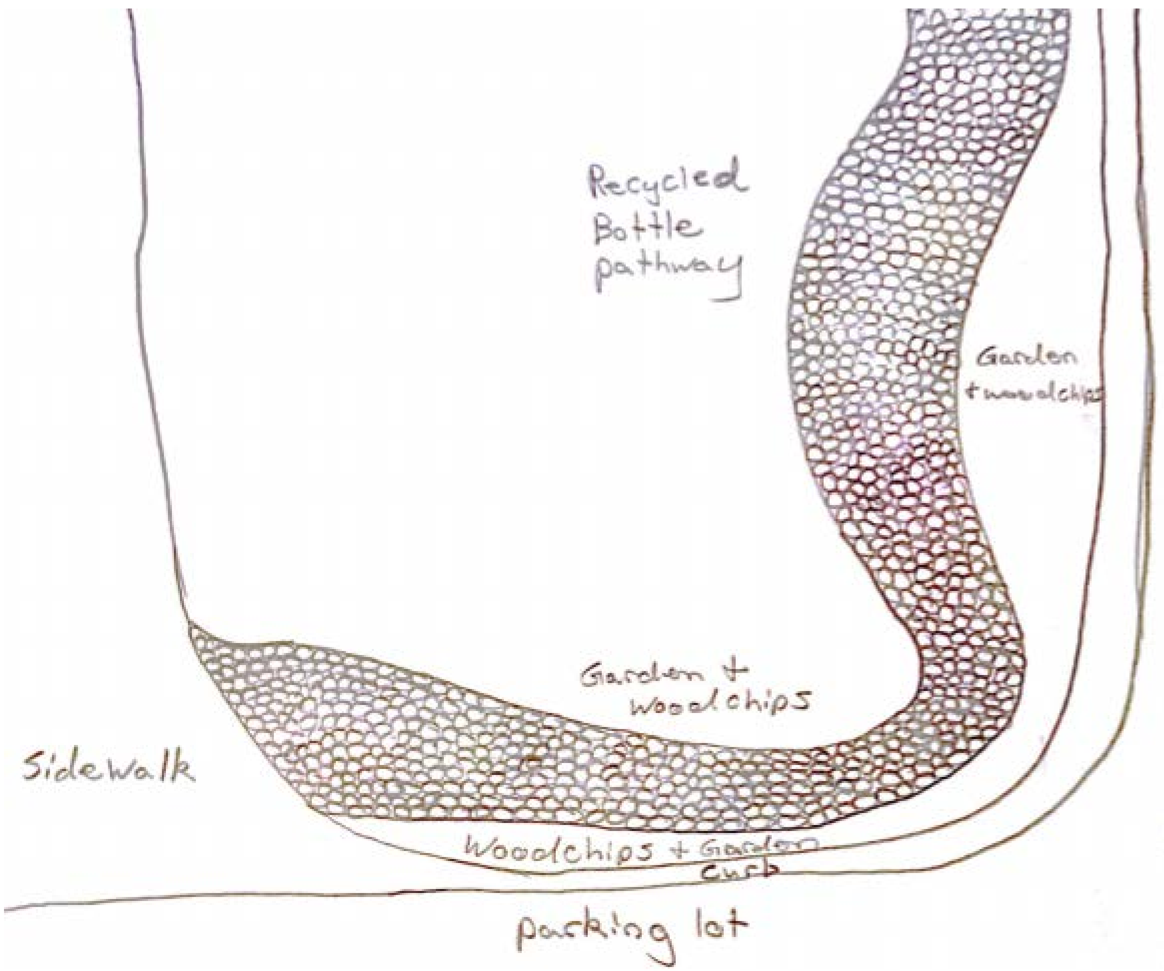

Figure 3-3 Recycled Bottle Pathway (drawing by Natalie Rynne)

3.3.4 Grid Pathway with Plants

The Grid Pathway with Plants design consists of concrete, gravel, and plant life as shown in Figure 3-4 below. This design is named the Grid Pathway with Plants because of the squares of plant life in between the concrete make it permeable. The plant squares help reduce puddles forming on the surface by absorbing the water. The concrete is usually set over a leveled gravel base that acts as the second permeable material in this design. This second layer assures permeability by assuring the plants will not be swamped.

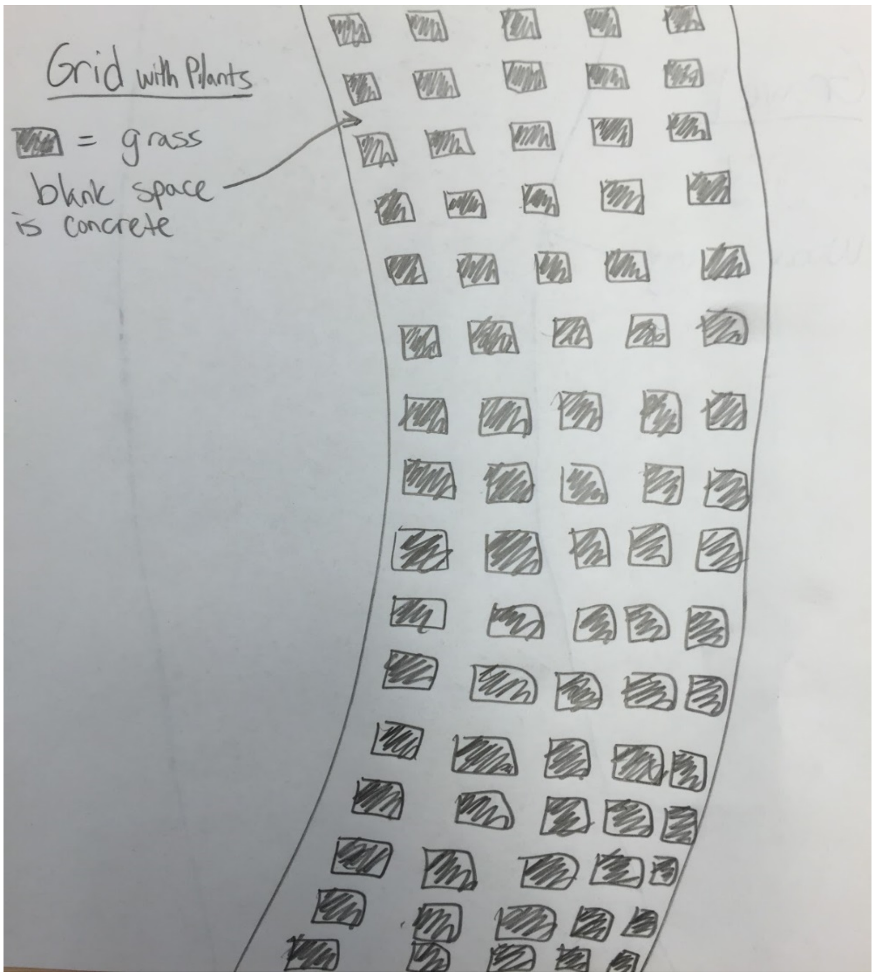

Figure 3-4 Grid Pathway (Drawn by Shane Dotterer)

3.3.5 Gravel Pathway

The Gravel Pathway is a simple design that uses tiny pieces of gravel as the permeable surface as shown in Figure 3-5. The bottom layer of this design is a bed of sand which acts as the final permeable material in the pathway. A fabric or mesh could be placed in between the sand and the gravel. Then gravel or small stone will be used as the top layer because the tiny separation of the gravel is all that is needed for a permeable walkway. Water can flow through all the cracks and then down into the sand layer. The bottom layer of the gravel pathway will be comprised of larger in diameter gravel, and the upper layers will be comprised of smaller in diameter gravel.

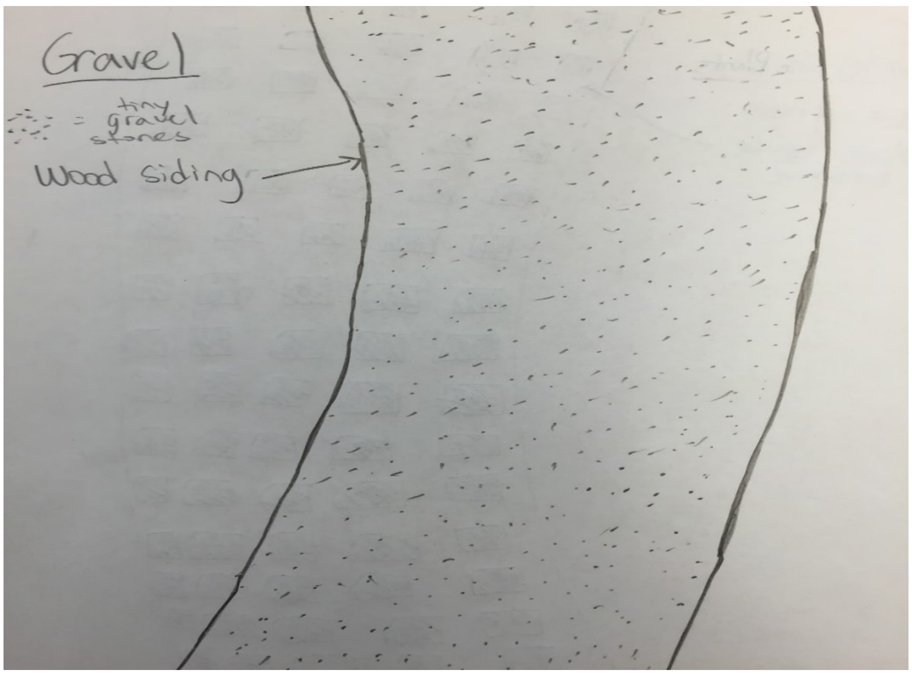

*Figure 3-5 Gravel Pathway (*Drawn by Shane Dotterer)

3.3.6 Organi-Striped Pathway

The Organi-Striped Pathway as shown in Figure 3-6 has alternating lines of nature and stone. The lines using stone, or brick, or pavers are there to help make the path more obvious and gives the children an option to step over the nature lines if wanted. The other type of line called a “nature line” is the space between the stone and it is filled with plants like grass or some other low plant that can withstand heavy foot traffic. The nature line is the permeable part of the walkway.

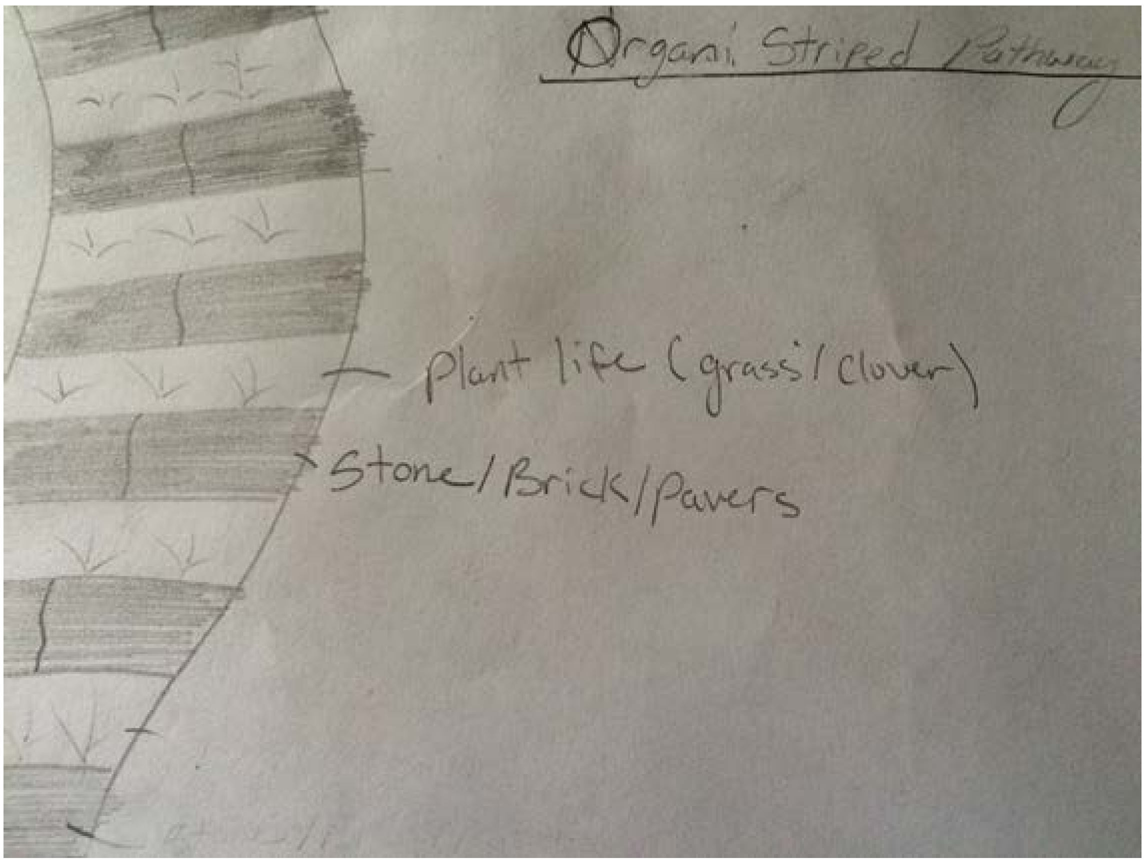

Figure 3-6 Organi-striped Pathway (Drawn by Makyle Harman)

3.3.7 Rocky Road Walkway

The Rocky Road Walkway shown below in Figure 3-7 consists of two main parts; gravel in the middle and the stones lining the walkway. The gravel in the middle of the pathway is permeable, thus the children will not have to worry about the pathway flooding. The stone lining the pathway makes the path more appealing to the eyes, and also helps to keep the gravel within the pathway. This is constructed by digging out the pathway to be around five inches deep. Once this is done a weed barrier is laid at the bottom of the pathway. After this put a small layer of sand that is about one inch deep on top of the weed barrier. Then put the gravel in the pathway filling it to ground level. Finally put rocks alongside the pathway.

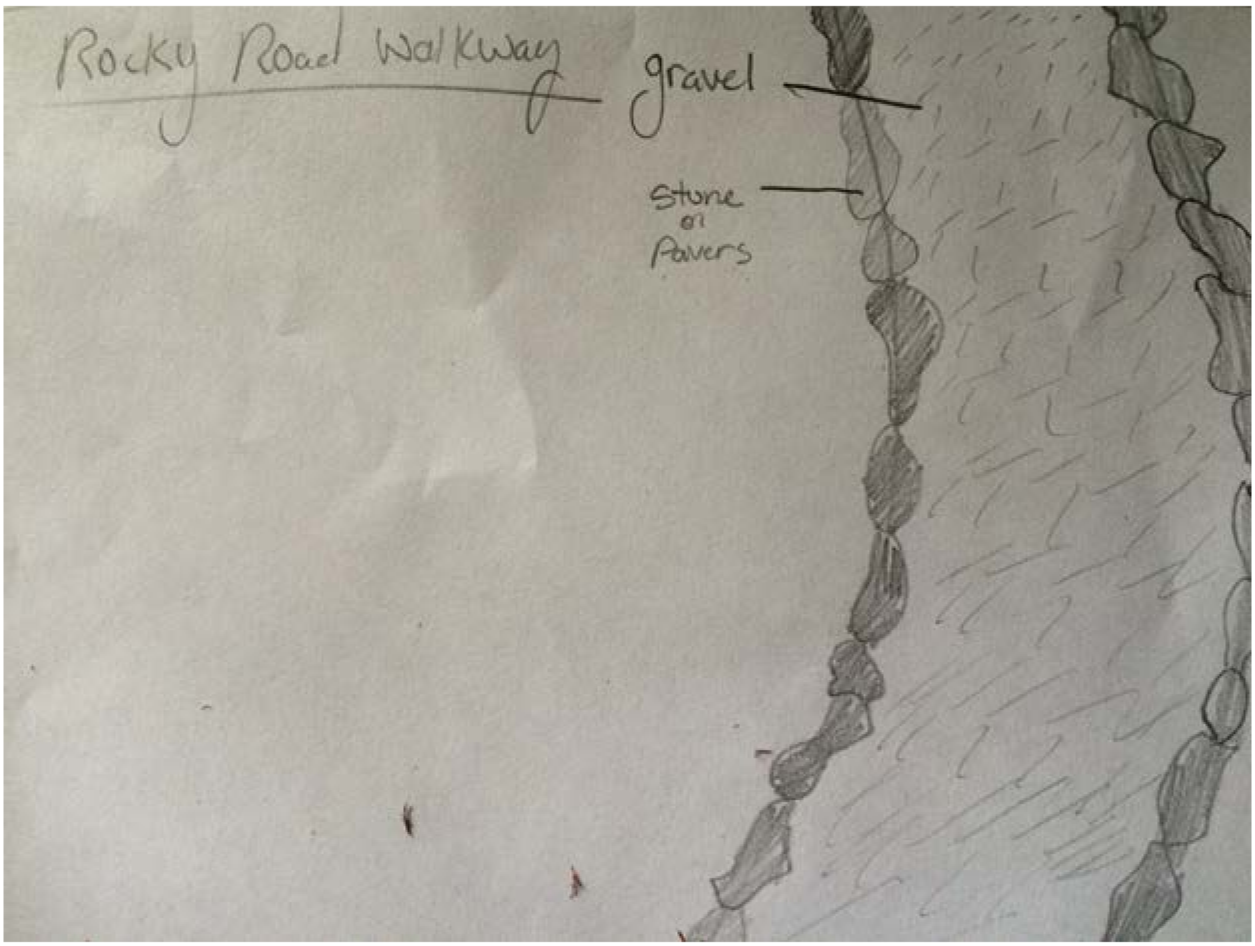

Figure 3-6 Rocky Road Walkway (Drawn by Makyle Harman)

3.3.8 Permeable Concrete Pathway

Figure 3-9 shows what a constructed permeable pathway utilizing the techniques used by previous Humboldt State Engineering 215 students could look like. The potential pathway is the vertical outline of a path in Figure 3-8. The pathway almost resembles gravel that has been tightly held together by glue. This gives the pathway permeable characteristics allowing for greater speed and ease at which water will run off the pathway. The white specks and roughness of the shading of the pathway attempts to illustrate this characteristic. This drawing shows the pathway in the option two location shown in figure one. This shows the pathway going directly from the sidewalk to the pbpp.

The pathway starts to the left, away from the road, because between the sidewalk and the grass to the left of the walkway in the drawing is a height gap. This could be a potential tripping hazard so our pathway cannot go there and must meet with the sidewalk on level ground. The pathway avoids going to close to the rock pile, because the ground is slightly slanted there which could result in a non-level pathway. This path would ideally meet with both the sidewalk and pbpp on level ground. This pathway has dividers on all edges of the path in the ground between the dirt (earth) and the concrete. The horizontal pathway near the top of Figure 3-8 is the pbpp, in the top right corner of Figure 3-8 it hits the curb of the road and stops.

Figure 3-8 Permeable Concrete Pathway (drawing by Jack Lisin)

3.3.9 The Artistic Match

Figure 3-9 shows a semi permeable pathway that matches the one build by previous Engineering 215 students, but adding broken pieces of pottery and other recycled materials to add color and design to the pathway. This pathway would be build the same way as permeable concrete pathway alternative, but adding other materials for artistic value. This pathway would have edges and dividers between layers.

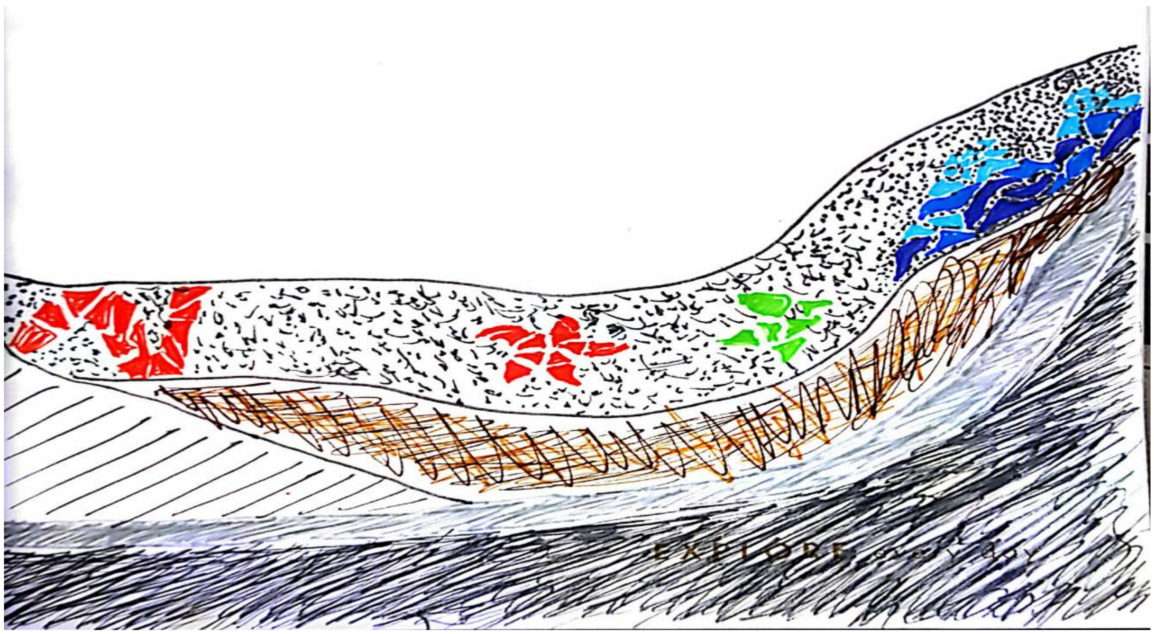

Figure 3-9 The Artistic Match (drawing by Natalie Rynne)

4 Decision Process

4.1 Introduction

Section 4 details the decision process to decide which solution would be the best to implement at Zane Middle School. The Delphi Method produces a solution based on how well each alternative solution best fits the criteria discussed in Section 2.

4.2 Criteria

The material shown below are this teams definitions of the criteria that needs to be met. These definitions give a complete summary of each criteria, which is used to judge how well each alternative solution fits the criteria. Below is also a short justification for the reasoning behind our team including and upholding the given criteria in our design considerations.

- **Safety:** The pathway should not harm anyone who walks on it. Impediments to safety include sharp edges, slippery surface, etc. This pathway is on public property and is at a middle school where kids will be walking on it. Safety must be stringently up help and considered throughout the design process.
- **Cost:** The cost for all materials used in constructing our solution for this project should not exceed the predetermined budget of $75 per person and $375 per team. Minimizing cost is an important factor in this project as this team has limited financial resources and the lower the cost the more likely this design will and can be replicated in the future. This team would like to create a design that can be fairly easily reproduced with similar results by others.
- **Durability:** The structure should be able to withstand weathering, and require little to no continuous upkeep. The pathway must be able to withstand continues use by middle school students.
- **Ease of Implementation:** The pathway should be simple to build and replace. The client discussed the possibility of themselves replicating this design in the future at Zane Middle School and we would like to make this as easy as possible for that to happen.
- **Sustainability:** The materials used in the building process should be from recycled material or sustainable resources in an effort to maintain a low carbon footprint and demonstrate appropriate technology. This team is comprised of environmental resource engineering students and resource use minimization and appropriate technology implementation are relevant and important aspects of the design process to our team.
- **Aesthetics:** Project should be visually appealing to children and staff as well as visiting adults. This pathway is being built on a professional and important public property grounds that sees plenty of users and visitors and should look nice.

4.3 Solutions

The following list is comprised of the nine alternative solutions from Section 3. Details of each alternative solution are given in Section 3.

- The Artistic Match
- Permeable Concrete Pathway
- Organi-Striped pathway
- Rocky Road Pathway
- Grid Pathway with Plants
- Gravel Pathway
- Brickleberry
- Woodyboo
- Recycled Bottle

4.4 Decision Process

The decision process known as the Delphi Method was used to determine the final solution. To complete a Delphi Matrix, we first had to assign a weighting for each criterion. Each principal was rated on a scale from 1-10, with 10 being the highest shown in Table 4-1. The Eco team concluded that each criterion should be given its rating by providing reasonable justifications for why one should be of higher rank than another. These justifications were based on the client criteria, knowledge of the location and client needs, and an understanding the basics of building a pathway. The second step for the process is to assign a rating on a 0-50 scale for each alternative solution shown in Table 4-2. A low score correlated to a solutions inability to fulfill the given criterion. A high score is given to the solution that best meets the criterion. The final step was to multiply each alternative solution rating by each criterion rating; the sum of the multiplied scores are added and used to determine a final solution. The solution with the highest weighted sum is the one that best fits the project criteria.

Table 4-1

Criteria	**Weight**
Safety	10
Durability	9
Sustainability	9
Price	7
Ease of implementation	6
Aesthetics	5

Table 4-2

Critera		solutions								
List	Weight	The artistic match	Permeable Concrete Pathway	Organi-striped pathway	Rocky Road pathway	Grid Pathway with Plants	Gravel Pathway	Brickleberry	Woodyboo	Recycled Bottle
Price	8	10 / 80	10 / 80	30 / 240	30 / 240	15 / 120	40 / 320	15 / 120	25 / 200	45 / 360
Safety	10	40 / 400	40 / 400	26 / 260	35 / 350	30 / 300	35 / 350	40 / 400	10 / 100	20 / 200
Durability	9	40 / 360	40 / 360	30 / 270	30 / 270	20 / 180	25 / 225	40 / 360	15 / 135	20 / 180
Aesthetics	5	50 / 250	30 / 150	35 / 175	35 / 175	45 / 225	25 / 125	35 / 175	40 / 200	20 / 100
Ease of implementation	8	25 / 200	25 / 200	17 / 136	40 / 320	15 / 120	40 / 320	20 / 160	10 / 80	20 / 160
Sustainability	9	25 / 225	25 / 225	25 / 225	40 / 360	34 / 306	40 / 360	25 / 225	30 / 270	15 / 135
Total		1515	1415	1306	1715	1251	1700	1440	985	1135

4.5 Final Decision

Based upon the results of the Delphi Matrix, the design solution labeled, “The Artistic Match” is the best solution for the Eco Team to pursue. This design takes into account each criteria and would provide a durable walkway for the faculty and students of Zane Middle School. Once the pathway is constructed minimal upkeep is required.

5 Specification of Solution

5.1 Introduction

The purpose of Section five of this document is to provide a detailed plan of how this team created a permeable concrete pathway. It provides a description of the final product, an examination of the costs of different aspects of this project, instructions on how to make a product of similar character, and a summary of the results of this project.

5.2 Solution Description

This team’s final pathway solution is the permeable concrete pathway. The permeable concrete pathway is a design of a durable but pervious concrete pathway that allows water to infiltrate through it. The final pathway is a structure of rocks held together by a cement paste to form a semi permeable concrete structure. This structure of rock aggregate and cement paste has an interconnected open system of air voids between the aggregate that allows for the passage of water. This structure is achieved by decreasing the amount of paste material added while still coating all the aggregate to create a strong but permeable structure. The pathway connects the locations (the two already built improved walkways) predetermined by the client. The constructed pathway connects level with both the sidewalk and the pbpp. The concrete material is placed in the ground with earth surrounding it. Separating the sides of the concrete pathway from the earth surrounding it is a plastic barrier.

5.2.1 Creating Permeable Concrete

The process of creating permeable concrete is similar to that of traditional concrete. The main difference is the proportion of materials added. The amount of water and cement is cut when mixing permeable concrete. These differences are shown in Table 5-1.

Table 5-1

Traditional Concrete	Pervious Concrete
Coarse Aggregate	Coarse Aggregate
Portland Cement	Less Portland Cement
Fine Aggregate	No Fine Aggregate
Lots of Water	Not Much Water

From limited background knowledge of the proportioning of permeable concrete, experimental testing of different material proportions to create permeable concrete block samples was conducted. Testing resulted in 0.004 cubic yards of permeable concrete material being created from 0.0027 cubic yards 3/8th inch pea gravel, 0.0009 cubic yards type II Portland cement, and 0.0003 cubic yards water. This sample block of permeable concrete is shown in figure 5-1.

Figure 5-1

Through trial and error the correct material proportions were discovered to create a durable but pervious concrete material. Table 5-2 shows the material proportions that were determined by testing to create a durable and permeable concrete material. These proportions were used in the overall implementation of this project and are the approximate proportions of the concrete material that makes up the finished pathway.

Table 5-2

Material	**Amount by Volume**
Coarse Aggregate	9 Parts
Type II Portland Cement	3 Parts
Fresh Water	1 Part

The following are the basic steps required to create permeable concrete:

- Step 1: Mix Portland cement and coarse aggregate together
- Step 2: Add water and thoroughly mix to create unity binding paste distribution throughout material
- Step 3: Pour concrete into a moist mold and allow to air dry for a weak
- Step 4: Prevent additional rain or sunlight from hitting the permeable concrete when drying

5.2.2 Our Design Specifics

Our design connects the sidewalk with the already build permeable pathway in a manner that minimizes the total length of the pathway and thus the total amount of materials required for its implementation. A bird's eye view of the general location of the pathway is shown in the schematic in Figure 5-2.

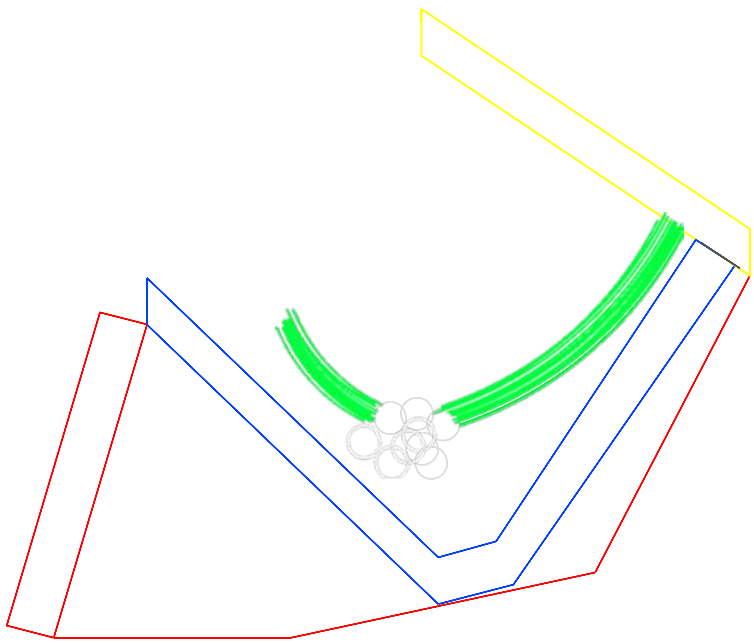

Figure 5-2 Auto Cad Drawing by Jack Lisin

Schematic (Figure 5-2) Key: Yellow Outline: Pbpp. Green Lines: Vegetation barrier line. Grey Circles: Rock Pile and Drainage Pit. Red Outline: Sidewalk Red Line: Street Curb. Blue Outline: This teams constructed pathway general location.

Figure 5-2 shows the general obstacles that will need to be avoided and the general direction our path will follow. The main obstacles need to be avoided are the vegetation, the rock pile, and the sprinkler system which is right up next to the curb (the red lines). Constructing the pathway in this location gave The Eco Team two possible options for exact locations of the pathway. Figure 3-8 illustrates from a bird's eye view the possible locations for the constructed pathway at Zane

Middle School. It shows two possible locations for the pathway, option one (shown with a red arrow) and option two (shown with a blue arrow).

Option one shows how the constructed pathway could go from the sidewalk to the edge where the grass meets the curb of the road and then follow the curb to the previously built pathway. Option two shows how the path could go around the rock pile and memorial garden, and across the ground between the curb and the vegetation to meet up with the pbpp. Implementing option one may result in a less muddy grassy area as pedestrians who go over the curb and across the grass will meet up with the pathway before going onto bare ground. However, next to the curb is a sprinkler system and constructing the pathway immediately next to the curb would cause issues with the sprinkler system. Option two puts the pathway closer to the water drainage “hole” in the ground where the rock pile is, and this could result in better water runoff speed then option one. Less water on and in the pathway is favorable for the safety of those using the pathway and its long term durability. Option two also results in the total length of the pathway being shorter than option one. Due to these factors the Eco Team chose to implement option two in order to increase the drainage speed, cut the total distance (and thus cost) of the pathway, and avoid causing issues with the sprinkler system.

The pathway constructed by The Eco Team follows the general direction that option two (the blue arrow) in figure follows. It meets with the curb, arches around the rock pile and vegetation line then goes through the center of the grounds between the vegetation and the curb to meet up with the pbpp. The pathway does not meet up with or touch the curb in any location because next to the curb is a sprinkler system that was avoided.

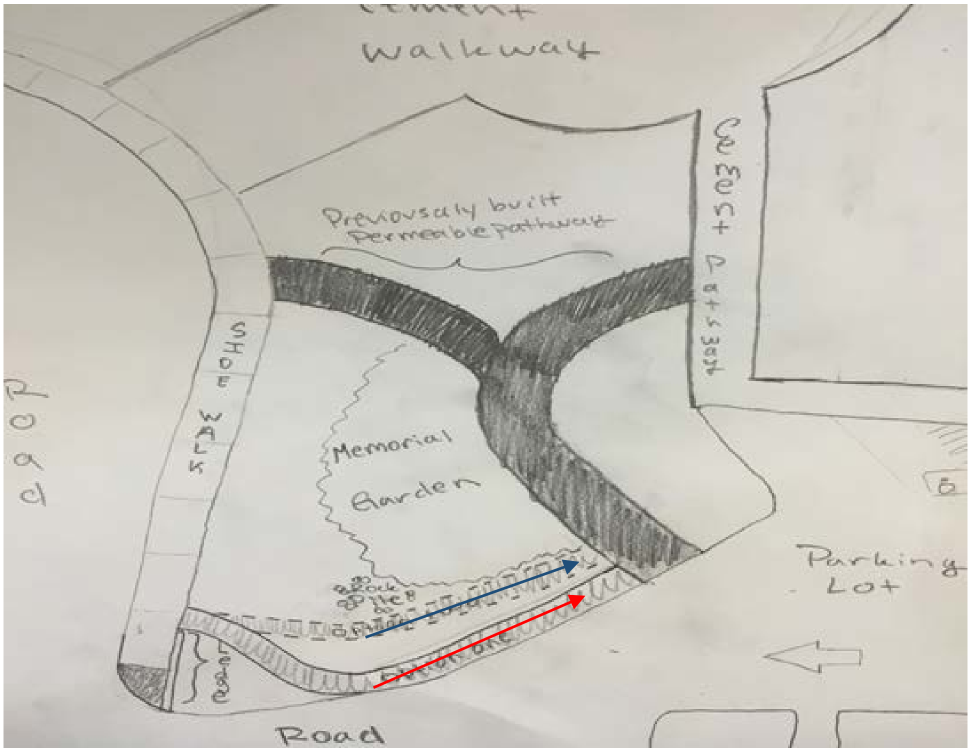

Figure 5-3 Drawn by Jack Lisin

Figure 5-2 shows the curb and vegetation that were avoided in the construction and design of this team's pathway. The pathway in figure 5-2 is the previously built permeable concrete pathway created by past HSU engineering students.

Figure 5-4 Photo Taken by Jack Lisin

5.2.2.1 Pathway Dimensions

The location of the pathway was chosen in a manner to avoid obstacles and minimize the total length of the pathway. The dimensions of the constructed pathway are shown in table 5-3. The path is sixty feet in length because it is the minimum possible length of the path to ensure it generously avoided all obstacles and connected the pre-determined locations. Its width is three feet because that is the width of the pbpp. Its height is four inches creating a solid and durable block of concrete. Almost all of the concrete is placed below the level of the earth with only a small amount of concrete placed above the level of the earth.

Table 5-3

Dimension	Value
Length	60 Feet
Width	3 Feet
Height	4 Inches
Cubic Yards of Concrete Material	2.22
Cubic Feet of Pathway	60

The approximate dimensions of the pathway are: 60 feet long, 3 feet wide, and 4 inches deep. This means the total volume of the pathway is approximately 60 cubic feet, or 2.2 cubic yards. Since a good portion of the permeable concrete pathway is comprised of air voids between the coarse aggregate, less than 2.2 cubic yards of coarse aggregate was used to construct this pathway.

5.2.2.2 Material Composition of Pathway

The constructed pathway contains the following materials (and their amounts) in its structure:

- Type II Portland Cement
- 3/8th Inch Pea Gravel
- Fresh Water
- Pressure Treated Pine Wood (1x4s)
- Plastic Pathway Liner
- Plastic Stakes

- Approximately 752 lbs., .5 yd^3 used
- Approximately 1.5 yd^3 used
- Approximately .17 yd^3 used
- Ten 3 foot length sections used
- 120 feet used
- 20 used

5.2.3 Brief Construction Procedure

- Gather materials on site
- Dig out proposed location of pathway four inches deep into ground
- Use wood two by fours to section off six foot sections of the path
- Place plastic sheet dividers on entire edge of dug out ground
- Mix materials thoroughly to make permeable concrete, dry first then add water
- Ensure ground is moist before laying, and lay concrete within 1 hour of mixing
- Fill six foot sections of the path at a time
- Clean cement mixer with water in an appropriate manner every 5 batches of concrete
- Protect from elements and direct sunlight for at least two days
- Do not walk on pathway for at least 1 weak after laying concrete
- Properly dispose of concrete waste
- Clean top layer of concrete yearly

5.2.4 Detailed Construction Procedure

This is the procedure The Eco Team generally followed and implemented throughout the construction process.

5.2.4.1 Pre Construction Conditions

Before construction of the permeable concrete pathway began The Eco Team ensured the following conditions had been met. Construction only was permitted to happen on dry days with little or no precipitation. Construction was put off if there was too much rain or if there was rain forecasted for the immediate aftermath of the completion of the pathway. Construction days and times were planned ahead and committed to by team members to ensure all available hands were on site when construction was happening. Efficiency was vital to the completion of the pathway due to the time frame of when construction happened. Team members were committed to the construction process and dedicated hard work and time to the completion of the pathway. Before construction began all tools and materials expected to be needed for the construction process were gathered on site. The outline of the pathway location was outlined in preparation for digging.

5.2.4.2 The Eco Teams Construction Process

The Eco Team began the implementation process by digging out the pathway outline. The outline of the path was dug roughly 3.5 inches down into the ground and 3 feet wide across the outlines entire surface area. The top inch of earth material, which sits about even with the top layer of the constructed pathway, is redwood mulch which was cleared away. The outline of the pathway with the redwood mulch cleared is shown in figure 5-5.

Figure 5-5 Photo by Natalie Rynne

Under the redwood mulch was a weed barrier which had to be cleared off and removed from the outlined path area. The subgrade earth was mostly dirt with some clay which was dug out using shovels. The dug up dirt and clay was transported in wheel barrels to an onsite location at Zane Middle School for storage and future usage by the client. This digging process is shown in figure 5-6 and figure 5-7.

Figure 5-6 Photo by Natalie Rynne

Figure 5-7 Photo by Natalie Rynne

Once the path outline was dug up and cleared of earth, dirt, and clay, the path perimeter was lined with a plastic lining material. The lining material wraps along the edge of the pathway and once the concrete is installed it separates the edges of the concrete from the dirt surrounding it. Ten six foot sections of the dug up path were separated from one another with pressure treated pine wood one by fours. These sections of the path are separated to have separate molds to poor the concrete into and ensure that it is laid out evenly and correctly. These sections of the path are shown in Figure 5-8.

Figure 5-8 Photo by Natalie Rynne

The subgrade within the dug up path outline was removed of loose dirt and was a fairly compact and level surface.

Once the path outline was removed of earth, is lined with plastic lining, and has six foot sections separated out, concrete preparation began. The Eco Team used a borrowed cement mixer from the HSU Engineering Department to mix the concrete in. Materials were prepped and proportioned out in buckets supplied by Zane Middle Schools Maintenance team. The proportions used were roughly two buckets filled with 3/8th" pea gravel, two thirds of a bucket filled with Portland cement mix, and roughly one fifth of a bucket filled with fresh water. These material proportions are shown in figure 5-9.

Figure 5-9 Photo by Natalie Rynne

After the materials were measured and proportioned out in the buckets, the materials were transferred to the cement mixer for mixing. The gravel was added first, followed by the cement and then the fresh water. Each mixture was thoroughly mixed in the cement mixer for roughly three minutes. Once the mixture was thoroughly mixed it was transferred to the wheel barrel for transport to the pathway molds. The concrete was transferred from the wheel barrel to the molds and spread out so it was even with the level of the ground. This is shown in figure 5-10.

Figure 5-10 Picture by Natalie Rynne

Often when mixing, the concrete would clump together and harden to the side of the cement mixer. Effort was given to keep the concrete mixing when in the cement mixer and to get all of the concrete out of the mixer between batches', however clumping still happened. When this happened it was necessary to clean out the cement mixer. This was done by adding water and scraping the inside of the cement mixer with a shovel to remove the hardened on concrete. This is shown in figure 5-11.

Figure 5-11 Photo by Natalie Rynne

The Eco Team went pathway mold to pathway mold filling each one and ensuring the top level of the concrete was level with the ground. After 13 hours of hard work the permeable concrete pathway was successfully installed at Zane middle school. The completed pathway is shown in Figure 5-12.

Figure 5-12 Photo by Natalie Rynne

The pathway was marked to warn pedestrians to keep off while the concrete dried. The immediate days following implementation were dry so it was not necessary to cover the pathway. It was also found that covering the finished pathway resulted in condensation occurring on the tarp and the top layer of the permeable concrete pathway, which could affect the drying process. Once the pathway was installed the ground surrounding the pathway was cleaned up and the redwood mulch made even with the top layer of the pathway again.

5.3.1 Design Cost

The cost required to design this project and complete each aspect of the design stage make up the majority of the cost of this section, and that cost is time. The majority of the design aspect of this project simply required time and human work and effort to complete. Figure 5-13 shows the amount of time our team has devoted to this project.

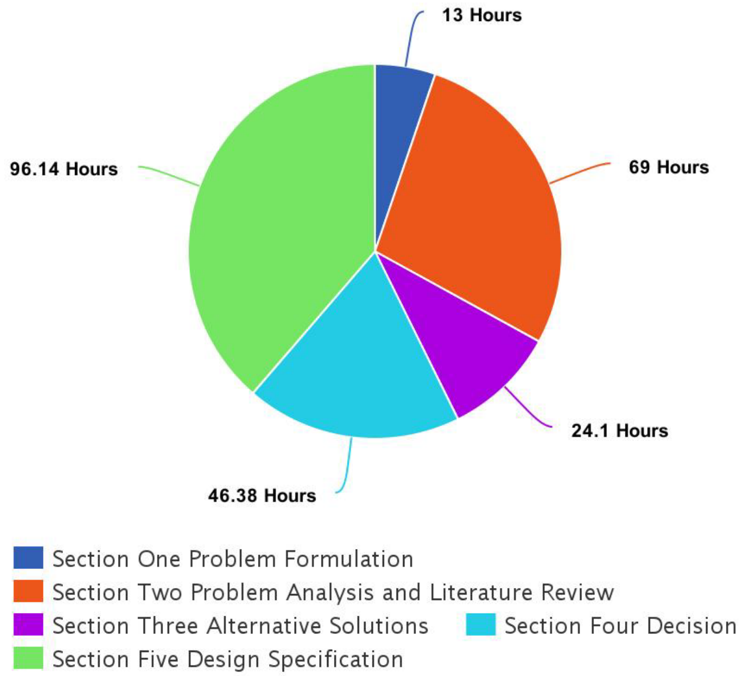

Figure 5-13

5.3.2 Implementation Costs

This part of the design stage is costly, both in money for materials and time and effort to implement the desired design. This portion of the cost analysis includes the time required to acquire materials and get them to the site, getting ourselves to the site, dig out the outline for the pathway, mix the cement, lay the forms and lay the cement. Table 1-5 outlines the monetary cost of the materials required to complete this project.

Table 5-4

Material	Quantity	Cost	Total
Pea Gravel	$2\ cubic\ yd^3$	$13 per ton	$36.00
Buckets	4	Donated	$0.00
Cement	20	$6.74 per 47lb bag	$134.80
Tarps	2	Donated	$0.00
Plastic Liner	3	$20.49	$61.47
Shovel	5	Donated	$0.00
Wheel Barrel	1	Donated	$0.00

Cement Mixer	1	Donated	$0.00
Working Gloves	5	Donated	$0.00
Stakes	2	$11.99	$23.98
Pressure Treated Wood	10	$1.50	$14.91
Total Cost			**$271.16**

5.3.3 Maintenance Costs

There should be no monetary costs required to maintain the pathway after completion. The only maintenance cost required is time, which is needed to sweep and vacuum the pathway. This required probably twenty minutes a weak to sweep and a half our every six months to vacuum the pathway.

5.4 Results

The permeable concrete pathway was constructed over the final weekend of April in 2016. It was a long and hard process that required team work, collaboration, and effort from every member of the team. The Eco Team successfully completed the construction of the pathway in approximately thirteen hours. The Eco Team worked all day on Friday the 29th of April and four hours on the morning of Saturday, April 30th. Thanks to the maintenance crew for getting up early on Saturday morning and letting us into the school so we could power the cement mixer.

5.4.1 Constructed Pathway Specifics

The constructed pathway successfully connects the two desired locations together with a strong and permeable concrete pathway. The finished pathway material, the permeable concrete, can be seen in figure 5-14. Both the top of the sidewalk and the top of the pbpp are raised above the level of the ground. The constructed permeable pathway is level with the ground. There is a very gradual decline as one moves from the intersection of the pathways down the newly constructed pathway. The constructed pathway becomes level with the ground after about four feet. Every point where the pathways merge has a very gradual incline.

Initial examination of the created permeable concrete material reveals a durable structure that holds together relatively well, and appears to have an open air void structure, indicating it will be permeable. The created permeable concrete material used to construct the pathway is very similar in composition to the sample blocks of permeable concrete material created by The Eco Team. Those sample blocks were tested and confirmed to be permeable so the constructed pathway is expected to be permeable as well.

Figure 5-14 Photo by Natalie Rynne

Initial examination of the created permeable concrete material reveals a durable structure that holds together relatively well, and appears to have an open air void structure indicating it will be permeable. The created permeable concrete material used to construct the pathway is very similar in composition to the sample blocks of permeable concrete material created by The Eco Team. Those sample blocks were confirmed to be permeable so the constructed permeable pathway is expected to be permeable as well. A sample block of the created permeable concrete is shown in figure 5-15.

Figure 5-15 Photo by Jack Lisin

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6 Appendices

Appendix A Group Member Time Sheets

Makyle Harman's Hours

Makyle Harman						
All Time In Hours						
Date	Task	Course Time		Project Time		total time
		Task	Total	Task	Total	
14 Feb. 2016	Trello	0	0	0.1	0.1	0.1
14 Feb. 2016	Timeshet #1	0.3	0.3	0	0.1	0.4
16 Feb. 2016	Group meeting	0	0.3	1	1.1	1.4
17 Feb. 2016	Group meeting	0	0.3	1	2.1	2.4
21 Feb. 2016	Excel #2	0.5	0.8	0	2.1	2.9
forgoten	lit. review research	0	0.8	3	5.1	5.9
forgoten	cost table	0	0.8	2	7.1	7.9
forgoten	alternate designs	0	0.8	4	11.1	11.9
forgoten	cad design for project	0	0.8	3	14.1	14.9
forgoten	revising lit review	0	0.8	1	15.1	15.9
forgoten	gettting supplies	0	0.8	1.5	16.6	17.4
forgoten	presentation	0	0.8	2	18.6	19.4
forgoten	prsentation	0	0.8	2	20.6	21.4
forgoten	getting supplies	0	0.8	1	21.6	22.4
forgoten	moving cement	0	0.8	1	22.6	23.4
forgoten	moving cement	0	0.8	3	25.6	26.4
29 Apr. 2016	building pathway	0	0.8	10	35.6	36.4
30 Apr. 2016	building pathway	0	0.8	4	39.6	40.4
30 Apr. 2016	final doc	0	0.8	3	42.6	43.4
1 May. 2016	time sheet update	0	0.8	0.8	43.4	44.2

Natalie Rynne's Hours

Natalie Rynne						
All Time in hours						
Date	Task Description	General Corse time		Project Time		Total Corse Time
		Task (hours)	Total (hours)	Task (hours)	Total (hours)	Time in hours
2/14/2016	Excell #1	2.0	2.0			2.0
2/14/2016	Time Sheet #1	1.0	3.0	0.0	0.0	3.0
2/14/2016	Design Brainstorming	0.0	4.0	0.5	0.5	4.5
2/14/2016	Trello	0.5	4.0	0.0	0.5	4.5
2/16/2016	Literature reivew Brainstorming	0.5	4.5	1.0	1.5	6.0
2/19/2016	Literature Research	0.0	5.0	1.0	2.5	7.5
2/23/2016	Literature Review Edit	0.0	5.0	1.0	3.5	8.5
2/24/2016	Literature Review Combination/Edits	0.0	5.0	1.0	4.5	9.5
2/27/2016	Visit Zane Middle School	0.0	5.0	1.0	5.5	10.5
2/28/2016	Problem Analysis	0.0	5.0	2.0	7.5	12.5
2/29/2016	Problem Analysis	0.0	5.0	1.0	8.5	13.5
3/6/2016	Formatting with word #2	1.5	5.0	0.0	8.5	13.5
3/7/2016	Team Evaluations	0.0	6.5	3.0	11.5	18.0
3/8/2016	Alternative Design	0.0	6.5	2.0	13.5	20.0
3/10/2016	Section 3	0.0	6.5	2.0	15.5	22.0
3/20/2016	Section 4	0.0	6.5	1.5	17.0	23.5
4/3/2016	Time Sheet #4 Update	0.3	6.5	0.0	17.0	23.5
4/7/2016	Poster Draft	0.0	6.8	1.5	18.5	25.0
4/10/2016	Appropedia	0.0	6.8	3.5	22.0	28.5
4/14/2016	Appropedia	0.0	6.8	2.0	24.0	30.5
4/17/2016	Appropedia	0.0	6.8	2.5	26.5	33.0
4/18/2016	Presentation	0.0	6.8	1.0	27.5	34.0
4/20/2016	Finding Materials	0.0	6.8	3.0	30.5	37.0
4/21/2016	Get Project Materials	0.0	6.8	4.0	34.5	41.0
4/21/2016	Presentation Practice	0.0	6.8	1.0	35.5	42.0
4/25/2016	Dig pathway	0.0	6.8	2.0	37.5	44.0
4/25/2016	Transport Cement Mixer	0.0	6.8	1.0	38.5	45.0
4/28/2016	Appropedia and Documents	0.0	6.8	2.0	40.5	47.0
4/29/2016	Build Pathway	0.0	6.8	10.0	50.5	57.0
4/30/2016	Build Pathway	0.0	6.8	4.0	54.5	61.0
4/30/2016	Final Document	0.0	6.8	3.0	57.5	64.0
5/1/2016	Appropedia	0.0	6.8	6.0	63.5	70.0
5/1/2016	Video on Youtube	0.0	6.8	1.0	64.5	71.0
5/2/2016	Final Edits	0.0	6.8	3.0	67.5	74.0

McKenna Rayburn's Hours

McKenna Rayburn						
All Time in hours						
Date	Task Description	General Corse time		Project Time		Total Corse Time
		Task	Total	Task	Total	
2/14/2016	Time Sheet #1	0.5	0.5	0.0	0.0	0.5
2/14/2016	Design Brainstorming	0.0	0.5	0.5	0.5	1.0
2/14/2016	Trello	0.2	0.7	0.0	0.5	1.2
2/16/2016	Literature reivew Brainstorming	0.0	0.7	1.0	1.5	2.2
2/19/2016	Literature Research	1.0	1.7	1.0	2.5	4.2
2/23/2016	Literature Review Edit	0.0	1.7	1.0	3.5	5.2
2/24/2016	Literature Review Combination/Edits	0.0	1.7	1.0	4.5	6.2
2/27/2016	Visit Zane Middle School	0.0	1.7	1.0	5.5	7.2
2/28/2016	Problem Analysis	0.0	1.7	2.0	7.5	9.2
2/29/2016	Problem Analysis	0.0	1.7	0.5	8.0	9.7
3/6/2016	Formatting with word #2	0.5	2.2	0.0	8.0	10.2
3/7/2016	Team Evaluations	0.5	2.7	0.0	8.0	10.7
3/8/2016	Alternative Design	0.0	2.7	1.0	9.0	11.7
3/10/2016	Section 3	0.0	2.7	0.5	9.5	12.2
3/20/2016	Section 4	0.0	2.7	1.0	10.5	13.2
3/29/2016	Section 5	0.0	2.7	1.0	11.5	14.2
4/4/2016	Poster draft	0.5	3.2	1.0	12.5	15.7
4/5/2015	Pick up gravel	0.0	3.2	0.5	13.0	16.2
4/6/2015	Make sample	0.0	3.2	0.5	13.5	16.7
4/13/2016	Make sample	0.0	3.2	1.0	14.5	17.7
4/14/2016	Practice Presentations	0.0	3.2	1.0	15.5	18.7
4/15/2016	Edit Document	1.5	4.7	0.0	15.5	20.2
4/17/2016	Edit power point	0.0	4.7	1.5	17.0	21.7
4/18/2016	Meet with Trevor	1.0	5.7	1.5	18.5	24.2
4/20/2016	Practice Presentation	0.0	5.7	1.0	19.5	25.2
4/25/2016	Dig & drop off supplies	0.0	5.7	2.0	21.5	27.2
4/28/2016	Work on Document	2.0	7.7	0.0	21.5	29.2
4/29/2016	Build	0.0	7.7	9.0	30.5	38.2
4/29/2016	Edit Lit review	4.0	11.7	0.0	30.5	42.2
4/30/2016	Finish Buliding	0.0	11.7	4.0	34.5	46.2
4/30/2016	Edit Document	0.0	11.7	5.0	39.5	51.2

Shane Dotterer's Hours

		Shane Dotterer				
		57 Hours Total				
Date	**Task Description**	**Course Time**		**Project Time**		Total Time
		Task	Total	Task	Total	
2/14/2016	Trello acoount	0	0	1	1	1
2/14/2016	Timesheet #1	1	1	0	1	2
2/16/2016	Group Meeting	0	1	1	2	3
2/17/2016	Group Meeting	0	1	1	3	4
2/21/2016	Excel #2	1	2	0	3	5
2/24/2016	Literature Review	0	2	3	6	8
2/24/2016	Group Meeting	0	2	1	7	9
2/25/2016	Gantt Chart	0	2	1	8	10
2/28/2016	Group Meeting	0	2	2	10	12
2/29/2016	Problem Analysis	0	2	2	12	14
3/6/2016	Formatting with Word	2	4	0	12	16
3/8/2016	Design Process	0	4	2	14	18
3/10/2016	Section 3	0	4	1	15	19
3/19/2016	Section 4	0	4	3	18	22
4/7/2016	Presentation draft	0	4	5	23	27
4/11/2016	Appropedia	0	4	1	24	28
4/18/2016	Presentation	0	4	2	26	30
4/21/2016	Practice Presentations	0	4	1	27	31
4/22/2016	Gathered Materials	0	4	2	29	33
4/27/2016	Prepared for building	0	4	1	30	34
4/29/2016	Built pathway	0	4	12	42	46
4/30/2016	Built pathway	0	4	5	47	51
4/30/2016	Final Document	0	4	5	52	56
5/1/2016	Time Log	1	5	0	52	57

Jack Lisin’s Hours

Jack Lisin

All time is in hours

Date	Task Description	General Course Time		Project Time		Total Course Time
		Task	Total	Task	Total	
2/12/2016	Trip to Zane Middle	0	0	2.5	2.5	2.5
2/14/2016	timesheet one	1	1	0	2.5	3.5
2/14/2016	individual trello	1	2	0	2.5	4.5
2/21/2016	finished CAD 2	1	3	0	2.5	5.5
2/21/2016	literature review	0	3	3	5.5	8.5
2/21/2016	Formating with word 1	1	4	0	5.5	14
2/21/2016	Excel2	1	5	0	5.5	10.5
2/24/2016	met group/complied litrev	0	5	1	6.5	11.5
2/28/2016	complied section II	0	5	2	8.5	13.5
2/28/2016	Gant Chart	1	6	0	8.5	14.5
3/6/2016	Formating with word 2	1	7	0	8.5	15.5
3/8/2016	alternative designs	0	7	1	9.5	16.5
3/6/2016	midterm team evals	0	7	2	11.5	18.5
3/5/2016	formation with word II	1	8	0	11.5	19.5
3/10/2016	worked on lit review	0	8	1	12.5	20.5
3/10/2016	complied section III	0	8	1	13.5	21.5
3/20/2016	complied section IIII	0	8	1	14.5	22.5
3/23/2016	went to zane middle school to get measurments for project design	0	8	2.5	17	25
3/23/2016	autocad III drawing	2	10	2.5	19.5	29.5
3/29/2016	group brainstorming/desiging of final project and section V	0	10	1	20.5	30.5
4/3/2016	researching for final design project/planning design	0	10	1	21.5	31.5
4/10/2016	Complied Section V	0	10	4	25.5	35.5
4/10/2016	Sample Block Concrete Expirimentation	0	10	4	29.5	39.5
4/12/2016	Complied Pratice Presentation, Practiced Presentation	0	10	1	30.5	40.5
4/15/2016	email corospondance with trevor	0	10	1	31.5	41.5
4/17/2016	revised autocad drawing for sec v and presentation	0	10	1	32.5	42.5
4/20/2016	revised powerpoint for presentation	0	10	3	35.5	45.5
4/20/2016	practiced presentation with group	0	10	1	36.5	46.5
4/25/2016	Trip To Zane for meeting with Trevor and to get spigate key and ec	0	10	3	39.5	49.5
4/29/2016	Implemetation of Design. Construction of Pathway at Zane	0	10	9	48.5	58.5
4/30/2016	Construction at Zane Continued	0	10	4	52.5	62.5
4/30/2016	Compiling and Working on Final Document	0	10	5	57.5	67.5
5/1/2016	Compiling and Working on Final Document	0	10	12	69.5	79.5

Appendix B: Brain storming Session (1)