Table of Contents

Figures

Tables

1 Problem Formulation

1.1 Introduction

Section 1 of this document broadly outlines the background of the problem presented by Six Rivers Charter High School (abbrev. Six Rivers) and the objective for solving it. The Black-Box model in Section 1.3 illustrates the present and future states of the project site as of the beginning of the Fall 2019 semester.

1.2 Background

Six Rivers is a dependent charter high school located in Arcata, CA, that shares property with Arcata High School. Part of Six Rivers' mission statement acknowledges the importance of an outdoor education experience. The school currently has a space designated for a garden and outdoor learning space, but it has been out of use for a considerable amount of time. A failing staircase is the primary access point from the school parking lot, and although still usable, it is unsightly and a relatively unsafe structure for use at a school. Figure 1-1 is an aerial view of the project site taken when the outdoor learning space and original staircase were newly constructed. It is not an accurate representation of the site as of September 2019.

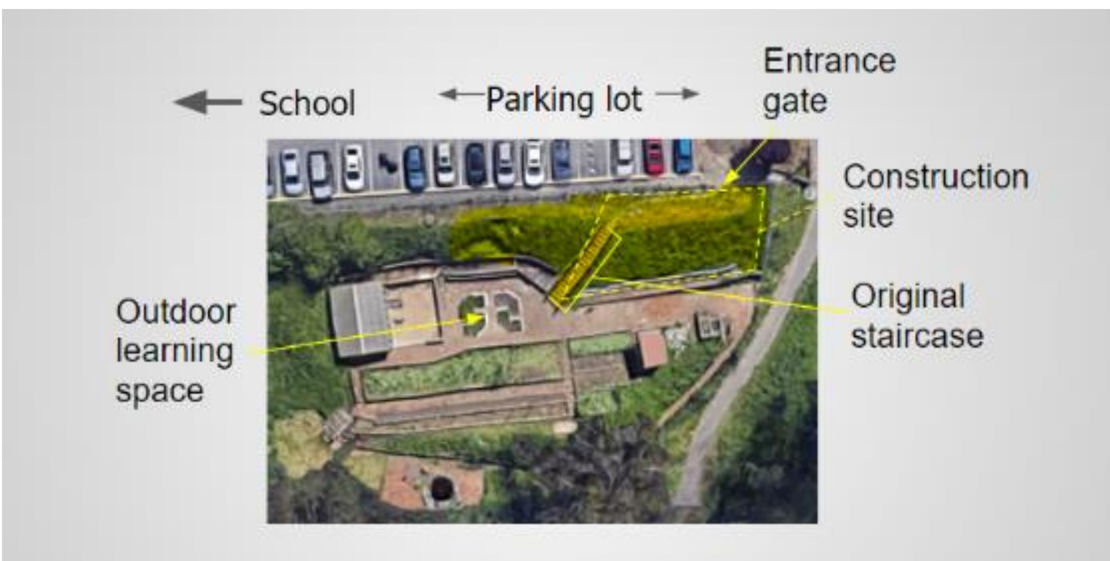


Figure 1-1 Top down view of the project site and surrounding area (Google Maps 2019)

Six Rivers wants to make use of the outdoor learning space that has been underutilized for a long time, and an undertaking of this size is a perfect opportunity to involve the high school students in hands-on experience with engineering, landscaping, design, and problem solving. Renovating the entire overgrown space into a usable area will require more work than Team AZDC alone can provide, so while Team AZDC designs and constructs a means of access two other teams are working to turn the flat area at the base of the stairs into a safe and functional space that will be utilized by students and faculty for years to come.

1.3 Objective

The objective of this project is to develop a safe, cost-effective, wheelbarrow accessible means of access to the garden and outdoor learning space. It is necessary for the final design to withstand the substantial rainfall and erosion endemic to the region without compromising structural integrity.

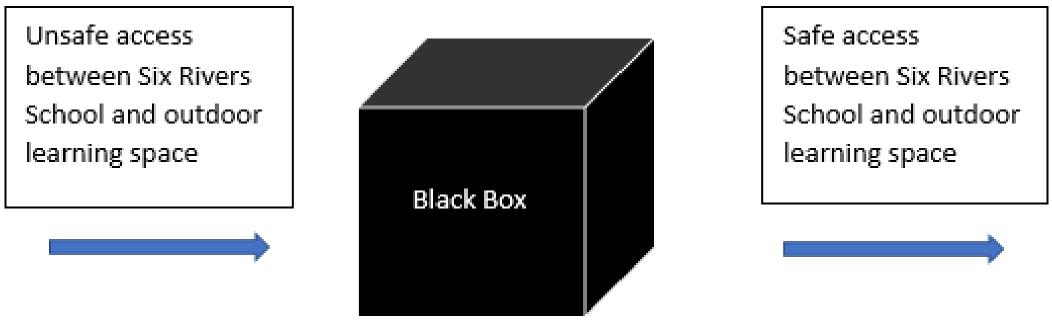


Figure 1-2 Black Box diagram outlining the state of the project before and after the design process (Kamaal and White 2019)

Figure 1-2 is a visual representation of the project. The diagram's input is the current state of the staircase in disrepair and the output is the state of the newly designed access route after completion.

2 Problem Analysis

2.1 Introduction

Section 2, Problem Analysis, organizes and defines parameters provided by the client into a structure that guides the design process. This section of the document details the project's specifications, considerations, criteria, constraints, and anticipated usage of the final design.

2.2 Specifications

Specifications are necessary or explicitly requested components which must be incorporated into the final design. The specifications designated by the client are:

- The final product must be safe to use in every respect.
- The pathway must be wider than 36".
- The pathway must enable ascending and descending wheelbarrow access.

- The pathway and its supportive structure must be maintainable by students.
- The design must create space for planting in the surrounding area.

2.3 Considerations

Considerations are defined as unspecified environmental and user factors which have the capacity to negatively affect the safety and functionality of the design. Considerations also examine design aesthetics and future maintenance.

Considerations for this project are:

- High volume and long durations of rainfall throughout the year.
- Water flow which could cause washout of pathway surface material.
- Slope failure both above and below the pathway and it's retaining walls.
- Pathway grade with respect to wheelbarrow accessibility.
- Pathway should be able to be maintained by the students with faculty direction.
- Space on each side of the pathway should be easily plantable.
- Incorporation of upcycled building materials for financial restrictions and educational value.

2.4 Criteria and Constraints

Criteria and constraints discuss which individual elements AZDC and the client intend to incorporate in the design with respect to the constraint provided by each criterion. Table 2-1 lists criteria and its respective constraints.

Table 2-1 Criteria and constraints

Criteria:	Constraint:
Safety and Accessibility	Must have strong reinforcement
	A high schooler of average strength must be able to move a loaded wheelbarrow up and down pathway
Labor Intensity	Overall design must not be so labor intensive that the project is unable to be completed by Dec. 20, 2019
Cost	Total expenses must not exceed $400 budget ($75 per team member and $100 from Six Rivers)

Plantability	The design must allow for a variety of planting options in the areas surrounding the pathway
Ecology	Repurposed or upcycled building materials must be used unless newly sourced materials are absolutely necessary
Maintenance	The pathway must be maintainable by high school students and not require so much work that it falls upon Six Rivers faculty
Educational Value	Each component of the design must have an educational aspect
Aesthetics	Must have higher visual appeal than the current structure

2.5 Usage

This subsection evaluates the anticipated amount of usage the design will encounter and how it may affect structural integrity over time. The amount of traffic the pathway will experience will vary heavily by time of year, time of day, and class-specific activity. If there is a maximum class size of 35 students and six periods in every school day, then there is an estimated maximum of 210 students that would use the path in a single day. The pathway will have to withstand:

- Daily use by students during roughly 168 regular school days (CA Department of Education 2019) and potentially additional days of fewer students in the summer.
- Random use by trespassers.

3 Literature Review

3.1 Introduction

Section 3, Literature Review, is the preliminary research stage of the pathway design process. Compiled in this section is research gathered on client criteria, Humboldt County's environment and climate, surface and subsurface drainage, retaining structures, trail construction, and educational standards.

3.2 Client Criteria

The client for this design project, Six Rivers, is represented by their Principal Ron Perry, agriculture teacher Kelly Miller, landscaping teacher Dorian Koczera, and Mr. Koczera's students. The client request is for us to design and construct a pathway that tackles the steep incline and provide safe access to the learning garden space that is located at the foot of a steep hill. The garden area will hold up to 30 students per class so it is necessary for the pathway to be wheelbarrow accessible and support a load of 30 students (Koczera 2019). Many students from the landscaping class expressed their desire for a pathway that addresses mud generation during and after heavy rainfall. The students also are requesting a pathway design that is reliable and upgradeable (Lancaster 2019). The client also requests that the pathway be low maintenance and require no extra care during the summer months when school is not in session (Koczera 2019). The client aims for a design that mitigates the dangers of the natural hillside in a cost effective and highly educational manner (Perry 2019).

3.3 Climate, Soil Types, and Plants of Coastal Humboldt County

3.3.1 Introduction

This section details the different environmental aspects of the region in which the project site exists.

3.3.2 Erosion Control: A Biotechnical Engineering Approach

In nature the main factor that mitigates soil and hillside erosion is vegetation (Morgan and Rickson 1995). The lack of vegetation increases the risk of slope failure because the soil is more prone to erosion (Morgan and Rickson 1995). Biotechnical engineering is a method of using biological and non-biological components in a hybrid system to effectively tackle the issue of erosion (Morgan and Rickson 1995). Field studies indicate that the best soil binders are fine roots between 1-20mm in diameter such as grasses, legumes and small shrubs. Some of the main benefits of such root systems are given by the illustration in Figure 3-1 (Morgan and Rickson 1995).

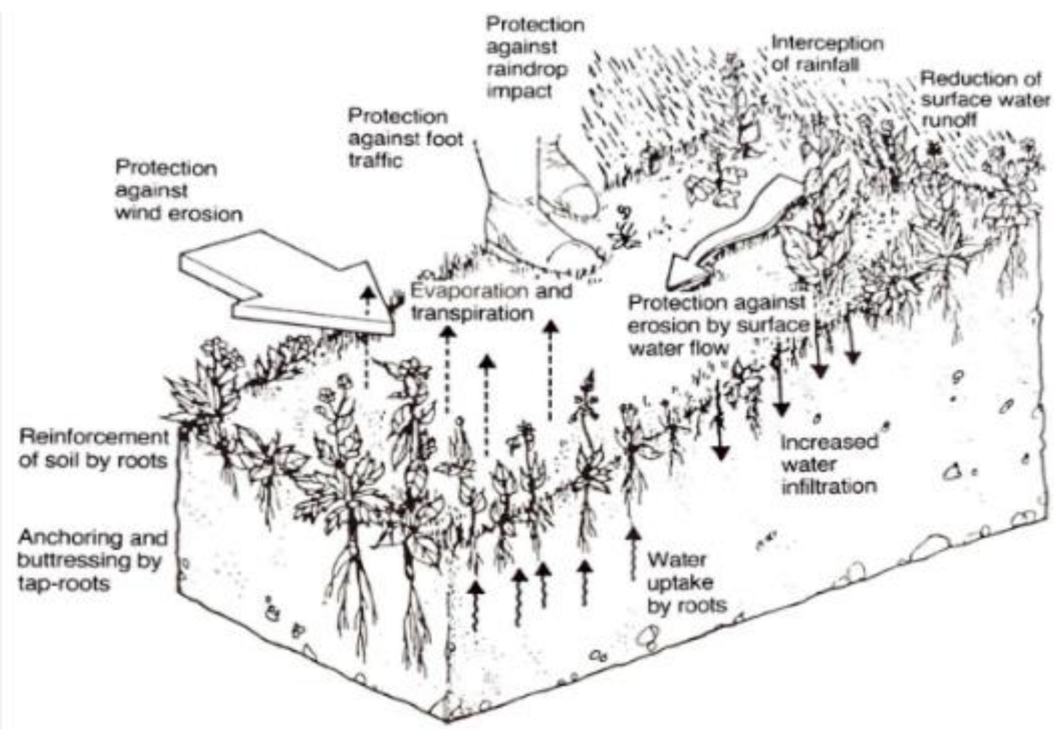


Figure 3-1 Bioengineered erosion control (Morgan and Rickson 1995)

3.3.3 Soil Type

From observation, the soil on site appears to be largely composed of gravel, topsoil, sand, and clay.

3.3.4 Humboldt County Coastal Climate

Humboldt County is a region of mild temperatures and high precipitation levels due to its proximity to the Pacific Ocean. Along the coast temperatures differ by only about 10 °F between the hottest and coldest times of year, and seldom rise above 80 °F. Rainfall commonly takes place in every month of the year but about 90% of total rainfall occurs in the period from October to April. The wettest parts of the county receive over 100 inches of precipitation annually (Humboldt.gov n.d.).

3.3.5 Edible Berries

Similar characteristics between native and edible plants make it worthwhile to examine a few species that fall into both categories. Some native berry plants are:

- Blue Elderberry
- Red Elderberry
- Red Thimbleberry
- Pacific Blackberry
- Woodland Strawberry
- Twinberry
- Snowberry (Calscape 2019)

Additionally, there is a native species of Blackberry to California as well as the invasive Himalayan species of Blackberry (Armstrong 2019).

3.3.6 Slope Stabilizing Edible Berries

In addition to the similarities between native plants and edible plants, there is also crossover between edible berries and slope stabilizing edible plants. Some notable slope stabilizing plants are:

- Red Thimbleberry
- Pacific Blackberry
- Woodland Strawberry
- Twinberry

Bank stabilizing plants are:

- Two additional varieties of Snowberry (beside the one already listed)
- Three varieties of Coffeeberry
- Bitter Cherry
- A variety of native sedges, grasses, and bushes (Calscape 2019)

Figure 3-2 Snowberry (Calscape 2019)

Snowberries are very low maintenance, easy to plant, and flower in the Spring and Summer. Snowberries are very low maintenance, easy to plant, and flower in the spring and summer. Coffeeberries flower in Spring, however, prefer sandy soil to clay soil. Bitter Cherry blooms in Spring, is relatively easy to maintain, and does well in partial shade as well as moderate to slow drainage (Calscape 2019). Thimbleberries also do well in partial shade (Armstrong 2019).

3.3.7 Native Shade Growing Berries

Thimbleberries as well as Salmonberries grow successfully in partial shade, while huckleberries (shown in Figure 3-3) do well in mostly sun with partial shade (Armstrong 2019).

Figure 3-3 Red and Black Huckleberries. (Armstrong 2019)

3.3.8 Edible Non-Native Plants

Many non-native edible plants thrive in Humboldt county. A few that fall within the criteria of the Six Rivers project are:

- Multiple species of Blueberries
- Aronia
- Goumi Berries
- Chilean Guava
- Chilean Myrtle
- Red Currants
- Gooseberries
- Jostaberry
- Juneberry (Armstrong 2019)

3.4 Trail Construction

3.4.1 Introduction

This section compiles research regarding trail construction.

3.4.2 Trail Base

Trails need to be constructed to be nearly level from side to side and sloped slightly downhill. The two recommended ways to do this are called half-bench and full-bench construction (U.S. Department of Interior 1996). Full-bench construction is considered more stable since the loose soil that is removed from the bank is not used in the trail base (U.S. Department of Interior 1996).

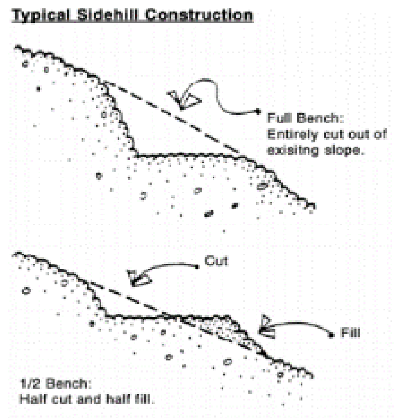


Figure 3-4 Half-bench and full-bench construction (U.S. Department of the Interior 1996)

3.4.3 Slope Locations

In order to prevent erosion on sidehills it is important to construct trails with a moderate grade (U.S. Department of the Interior 1996). Water should not be allowed to flow down the trail. Instead it should cross the trail and disperse downhill (U.S. Department of the Interior 1996). Figure 3-5 shows examples of correct and incorrect sidehill trail placement with respect to control of water flow.

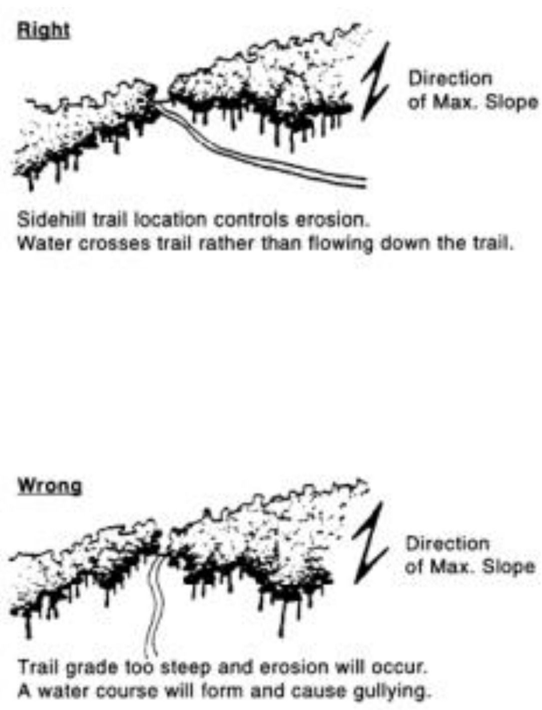


Figure 3-5 Water disbursement on trails (U.S. Department of the Interior 1996)

3.4.4 Slope Stability

Slope failure is commonly caused by geological factors, slope inclination, excessive load pressure on slope head, and the weakening of the slope toe due to erosion (Veder 1981). Geological factors include soil composition, ground movement caused by earthquakes, and temperature changes. Erosion caused by running water is known to cause fissures which contribute to instability by weakening the toe of the slope (Veder 1981). Increased load pressure compacts soil, and when combined with water erosion creates a positive feedback loop which can rapidly deteriorate slopes (Veder 1981). To increase slope stability, it is crucial to address water erosion, provide adequate drainage, and avoid permeable load bearing surfaces on a slope (Veder 1981).

3.4.5 Trail Structures

Figure 3-6 demonstrates technically correct ways to build certain trail structures. These should be used as guides to enhance local creativity, and not to limit it (U.S. Department of the Interior 1996).

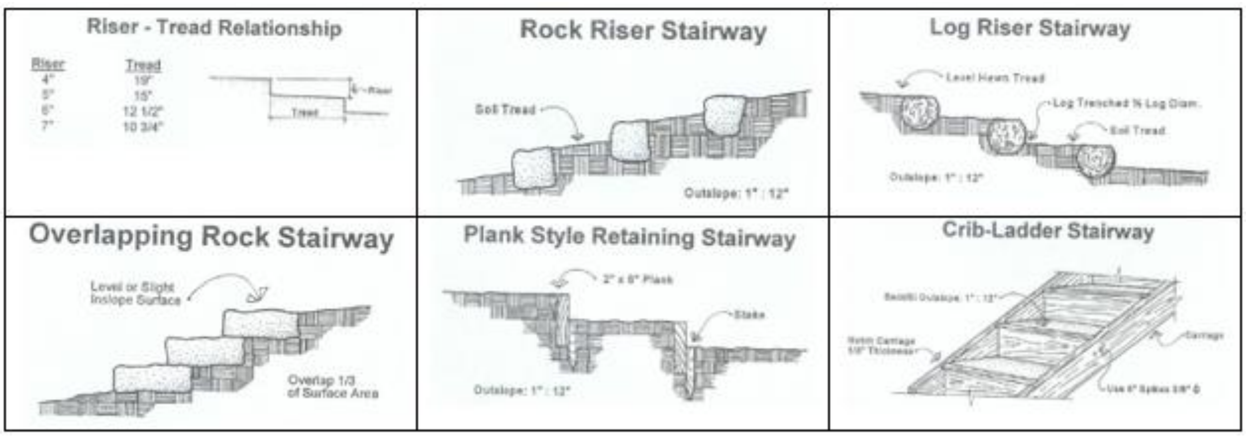


Figure 3-6 Technically correct trail structures (U.S. Department of the Interior 1996)

3.4.6 Coweeta Dips

Coweeta Dips are considered to be one of the most cost-effective and low maintenance drainage techniques for trail construction. As shown in Figure 3-7, a Coweeta Dip is a water catch used to prevent water from flowing down the trail by sending it out slope (U.S. Department of the Interior 1996).

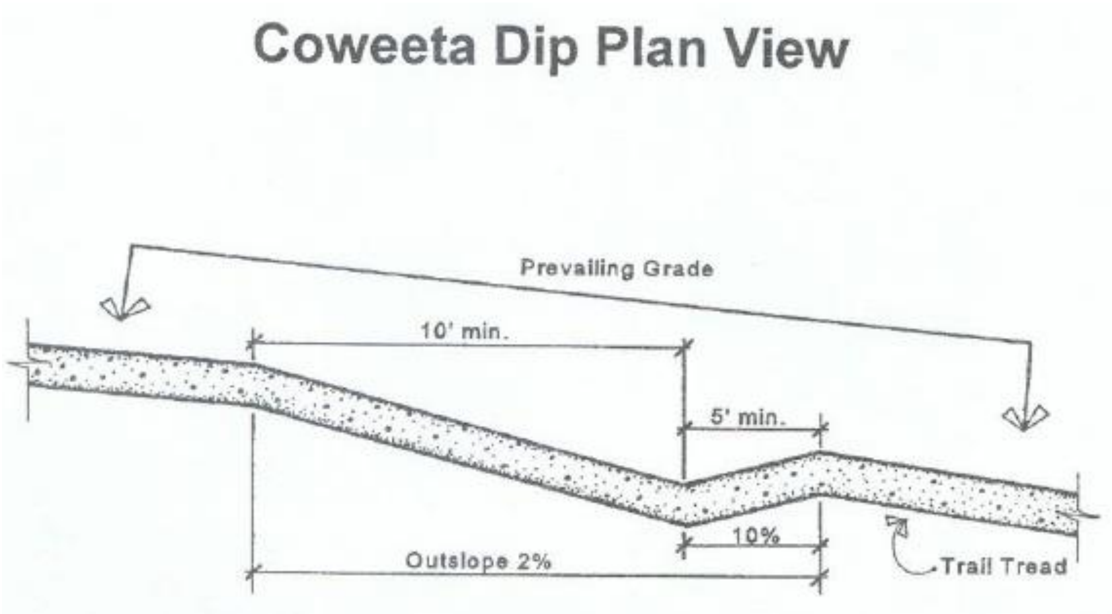


Figure 3-7 Coweeta Dip construction diagram (U.S. Department of the Interior 1996)

3.5 Drainage

3.5.1 Introduction

This section details the methodology of percolation tests and the broad concepts of surface and subsurface drainage.

3.5.2 Percolation Test

A home percolation test can be used to test how long it takes water to penetrate soil. The test is conducted by digging a 6" to 12" hole in the ground and filling it several times to fully saturate the soil. A ruler is then placed in the hole and the hole is filled with water once more. By measuring the initial height of the water in the hole and the duration between when the hole is full and empty, the percolation time can be calculated. Table 3-1 is then used to find out how much area is needed to absorb certain amounts of water (Greywater Action n.d.).

Table 3-1 Soil percolation chart

Infiltration Rate (min/inch)	**Area Needed** (sq.ft/gal/day)	***Example:*** *After filling the hole four times, the water level dropped 6 inches in 75 minutes. 75 divided by 6 is about 13 minutes/ inch.*	***Example:*** *Now we multiply our greywater flow (14 gallons per day) by the area needed (0.4). 14 X 0.4= 5.6, so we need about 6 square feet of ground to absorb our daily greywater flow.*
0-30	0.4	*13 min/inch is between 0 and 30, so we use this line.*	*We need **6 sq. feet for 14 gallons/day***
40-45	0.7		
46-60	1.0		*If we were in this line we'd need 1.0 X 14 or **14 sq. feet.***
61-120	2		

3.5.3 Surface Drainage

Two of the most common ways to improve surface drainage on slopes is with graded banks or levees. Other notable methods include ditches, open drains, grassed waterways, humps, and hollows (Mickan and Ellinbank 2019).

3.5.4 Subsurface Drainage

Typical subsurface drainage systems contain a network of underground pipes which connect like that of a river system. Smaller lateral pipes collect water below the surface, feeding into main pipes which output into a designated site such as a natural river or lake. It is imperative that the outlet component have the capacity to receive the maximum flow from all lateral pipes and main pipes. Pumps must be installed in situations where there is not a suitable outlet to handle the total flow of the system. It is equally important that all pipes function properly, which means protecting them against fracture, clogging, rodent inhabitation, erosion, and in some regions freezing (University of Illinois n.d.).

3.6 Retaining Walls

3.6.1 Introduction

This section compiles research of different retaining wall designs, case studies, and details about various ecological building materials.

3.6.2 Mechanically Stabilized Earth Retaining Walls

Introduction

Mechanically Stabilized Earth (MSE) retaining walls utilize an alternating combination of compacted soil layers and reinforcing components which backfill behind an exterior wall face. The MSE design is based on the interdependent combination of backfills and soil reinforcements, and the relationship between friction and tension (Reinforced Earth 2018).

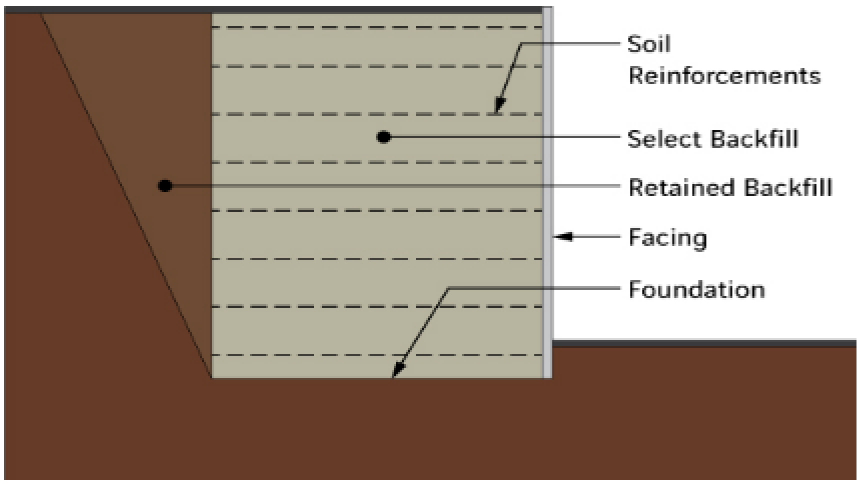


Figure 3-8 Cross section view of basic MSE wall components (Reinforced Earth 2018)

Case Studies

Seattle - Tacoma International Airport

In the early 2000s the Seattle-Tacoma International Airport built a third runway which required the construction of a multi-tiered MSE wall. The design team analyzed more than 60 retaining wall designs before landing on the final decision of a steel-reinforced MSE wall. It has a maximum height of 148 feet and 15 years later is in stable condition (Reinforced Earth 2019).

Figure 3-9 Seattle - Tacoma International Airport MSE Wall (Reinforced Earth 2019)

US 97: Modoc Point - Hagelstein Park Project

This project, produced for the Oregon Department of Transportation, created more than 100,000 square feet of Reinforced Soil Slope (a form of MSE) and nearly 20,000 square feet of earth retaining structures. The total height of this project exceeds 170 feet (Hilfiker Retaining Walls 2015).

Figure 3-10 Before/after of US 97: Modoc Point - Hagelstein Park Project (Hilfiker Retaining Walls 2015)

Facing Elements

The wall face has varying degrees of functionality, sometimes designed to be purely cosmetic and other times to prevent erosion and restrain structural backfill. In larger projects it is imperative that the facing elements be equipped to uphold horizontal forces (Berg, Christopher and Samtani 2009). Flexible wall facings such as welded wire or geosynthetics are often covered by concrete or shotcrete to protect them from UV exposure.

Reinforced Fill Soil

Salvaged materials used to backfill must be chosen with consideration. Repurposed asphalt tends to creep out of place which over time causes wall deformation and weakening of reinforcement components. Repurposed concrete is also potentially problematic as it has the capacity to produce tufa precipitate, a form of limestone which is very porous and percolates a white, gelatinous substance which can clog drains or ooze out of the wall face (Berg, Christopher and Samtani 2009).

Reinforcing Elements

Reinforced soil is principally similar to reinforced concrete in that reinforcing materials and structures are placed parallel to the dominant direction of strain to enhance the mechanical characteristics of mass, making up for pure soil's deficient tensile resistance. Reinforcements should be evenly distributed throughout the backfill space and allow consistent, unbroken stress transfer between soil and reinforcement structure (Berg, Christopher and Samtani 2009). Two predominant types of reinforcement are steel strips, bars, or grids, and geotextiles and geogrids.

Advantages

MSE retaining walls are known for their ability to manage high differential soil settlement and distribute bearing pressure across a wide foundation area. The nature of the design allows for a wide range of flexibility for different reinforcing geometries and a relatively rapid construction compared to other retaining wall designs (Reinforced Earth 2018). Potential water drainage systems in MSE designs are variable, particularly in smaller scale projects. MSE walls are resistant against seismic activity, and because they do not require permanent, solid foundational support they are tolerant of malformations (Berg, Christopher and Samtani 2009).

Limitations

Distribution of responsibilities for the design and construction of this type of wall have been at the root of problems for failed projects. Separate design teams not seeing geotechnical reports or design criteria specific to the construction site is a common disconnect. Unreported or insufficiently collected data of any number of factors such as soil strength parameters, minimum global stability, soil bearing capacity, or soil weight units can lead to a variety of failures in the structure (Harpstead and Schmidt n.d.).

3.6.3 Gravity Walls

Introduction

Gravity walls, typically constructed of concrete or stone, gain stability through the sum weight of the structure and a tongue-and-groove locking system. They are typically built on a gravel base and do not require much engineering or a permit to build if they are under four feet high (Brooks and Nielsen 2013).

Gravity Wall Case Studies

Retention Pond, Plymouth, MN

An office complex replaced a failing retaining wall in their parking lot that served a second purpose as a stormwater retention pond. The wall was erected without taking the parking lot out of service and the concrete is an optimal building material for Minnesota's freeze/thaw conditions (ReCon n.d.).

Figure 3-11 Gravity Wall Retention Pond, Plymouth, MN (ReCon Retaining Walls, n.d.)

Blair Quarry, Blair, WI

A 36-foot tall tongue and groove gravity wall was built into a sandstone cliff with the capacity to support large mining trucks that would put approximately 2000 pounds per square foot of pressure on the structure. The wall is "near-vertical" and the soil it retains is reinforced by Strata geogrids. It was constructed in eight days from the arrival of the first blocks it was built with (ReCon n.d.).

Figure 3-12 Blair Quarry Reinforced Gravity Retaining Wall, Blair, WI (ReCon Retaining Walls 2011)

Advantages of Gravity Retaining Walls

Gravity walls have a wide variety of shapes of block and ways that they can be stacked to fit the needs of the environment and the desires of the person for whom it is being built. The separate blocks make them easier to adjust if something were to fall out of place or change during the design process, as opposed to preset concrete which is much more difficult to change once set into place (Stonetree 2019).

Limitations of Gravity Retaining Walls

Gravity walls rely on mass for their strength, so large blocks are often used which are difficult to maneuver without a second pair of hands or heavy machinery. In addition, some find the lack of decoration and uniform style throughout the wall that is inherent to this building style to be boring (Stonetree 2019).

3.6.4 Tires

Introduction

Used tires have become an increasingly popular component in earth-footed support structures across the world for their overabundance, inexpensive nature, wide accessibility, and rugged durability. The details of this section are with respect to constructing designs using tires with a diameter of approximately 26" and a wheel width of approximately 9".

Tire Composition

Modern tires are commonly composed of a variety of synthetic rubber compounds, synthetic polymers, natural rubber, steel wire, fabric textiles, fillers, antioxidants and antiozonants, and curing elements (zinc oxide and sulfur) (US Tires, n.d.). There is some variation in the proportion of ingredients between passenger car tires and truck tires. Passenger car tire composition is about 24% synthetic rubber compounds, primarily butadiene rubber and styrene butadiene rubber. Natural tree rubber makes up about 19% of the tire (US Tires, n.d.). About 26% of passenger tires is made up of reinforcing fillers such as carbon black and amorphous precipitated silica, added to improve tear resistivity, tensile strength, and abrasion resistivity. Antioxidants, antiozonants, and curing elements make up 14% of passenger vehicle tires. Antioxidants and antiozonants such as OCTAMINE®, NAUGARD® 445, and DURAZONE® 37 are added to keep the rubber on the surface from degrading due to temperature, oxygen, and ozone exposure (US Tires, n.d.). Curing elements such as zinc oxide and sulfur are essential additions which harden rubber into a solid during the vulcanization process (Addivant n.d.).

Tire-faced Retaining Wall Case Study

Plumas National Forest

The U.S. Department of Agriculture has built numerous tire-faced earth retaining walls in Plumas National Forest, up to 3.1m (10-ft) high. The design staggers the tires of each row horizontally by half the diameter of a tire on each subsequent layer to prevent backfill soil from emerging through the holes between each tire. This placement creates planting space in the center hole of each tire, supplying the face with the added reinforcement of the planted vegetation's root systems. The backfilled earth in this design is reinforced with slit-film woven geotextile (Hossain, 2000).

Batam, Indonesia Microwave Transmission Tower

In 1992 an MSE retaining wall with a tire wall-face was built in Batam, Indonesia to uphold the deteriorating hill below a 100m (328-ft) high microwave transmission tower. The 54m (177-ft) long wall cost less than 40% of the quote for a reinforced-concrete retaining wall and was built in approximately 50 days by 10-12 unskilled laborers using only simple hand tools. The wall-face was composed of 1,400 old tires sourced from a local dump, and slightly less than one 5.5 x 100-m (18 x 328-ft) roll of woven geofabric for reinforcement was used to counter the horizontal earth pressure. Filler for the tires was a combination of granite aggregate and quarry waste (Broms and Poh 1995).

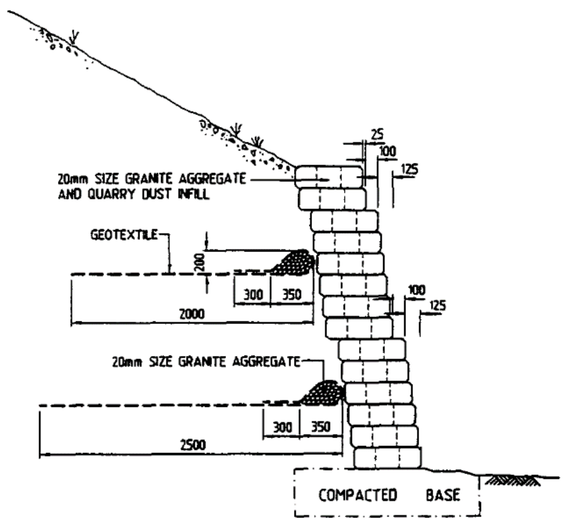


Figure 3-13 Cross section of rubber tire wall, Batam, Indonesia (Broms and Poh 1995)

3.6.5 Earthbag Construction

Introduction

"Earthbag" (also known as "rammed earth in a bag" or "reinforced rammed earth") is a general term not referring to a single product from an individual manufacturer. Earthbags are most often made of polypropylene fabric and filled with ordinary soil found at the worksite. Polypropylene is a highly durable synthetic fabric with a half-life of 500+ years and has the capacity to endure vertical circumferential pressures (Geiger and Zemskova 2015).

Earthbag Structure Case Studies

2015 Gorkha Earthquake

In 2015 a 7.8 magnitude earthquake rattled Nepal. The 55 Earthbag structures in the country were all reported to have endured the earthquake with no structural damage (Geiger and Zemskova 2015).

SuperAdobe

SuperAdobe is a patented form of earthbag technology. This technique utilizes polypropylene tubes rather than bags, four-point, two strand galvanized barbed wire, and basic tools. The classic design is the arch, regarded for centuries as the strongest architectural form. Structures typically top off at 4 meters in diameter, are easy to assemble with unskilled labor, and are accessible to any part of the earth with enough soil to fill the tubes required. SuperAdobe domes satisfy California earthquake code tests. Additionally, many of the structures in the aforementioned 2015 Gorkha earthquake were built with the SuperAdobe design (CalEarth n.d.).

Figure 3-14 SuperAdobe structure in construction (CalEarth n.d.)

Filler

Most soil types are sufficient for use in Earthbag structures and there is no standardized ratio of soil composition for this application. That being said, the most common soil type contains 25%-30% clay, 70%-75% sandy soil, and 10% moisture. It takes approximately 2-3 months for the soil to naturally harden, after which it is solid like a brick (Geiger and Zemskova 2015).

Benefits of Earthbag Structures

The traditional Earthbag constructed design is staggering the bags flat like bricks. Additional reinforcing measures can be taken to strengthen the structure, such as lining the top of each row with 14-gauge 4-point barbed wire to hook the top and bottom of each layer to one another, but extra measures such as this are not imperative to the durability of the structure. Earthbag structures are inexpensive, environmentally sustainable, and widely accessible because they do not require timber, steel, concrete, cement, or transportation of materials to the worksite (save for the empty polypropylene bags themselves). Earthbag structures can also be built with simple tools and unskilled labor (Geiger and Zemskova 2015).

Limitations of Earthbag Structures

The physical labor demands of Earthbag construction are not to be ignored. Depending on size, projects can require many strong hands for many hours (Windrich 2009). Like any architectural project it can be difficult to construct safe and effective structures without prior experience, and because the technology is not commonly taught in engineering schools many professionals are unfamiliar with the relationship between natural forces (earthquakes, etc.) and this material (Structure1 2019).

3.7 Educational Standards

Section 3.7, Educational Standards, details content standards released by the California Board of Education relevant to the design of this project.

3.7.1 Outdoor Learning

Outdoor learning has been shown to decrease ethnocentrism and increase self-esteem (Hoffman 2007). Students who participate in a social gardening activity for 4 hours per week for just 3 weeks had more favorable scores on an Ethnocentrism test and a Self-Esteem test (Hoffman 2007). The test results are shown in Table 3-2.

Table 3-2 Ethnocentrism vs. self-esteem scores (Hoffman 2007)

Overall Mean Scores of Gardening and Nongardening Students

	Ethnocentrism	Self-Esteem
Gardeners	2.32	3.64
Nongardeners	3.71	2.16

3.7.2 Mathematics Standards

The Standards for Mathematical Practices state that students will be able to solve problems arising in everyday life (CA Board of Education 2019). By high school, students may be able to use geometry to solve design problems (CA Board of Education 2019).

3.7.3 Agricultural Standards

The Career Technical Education Standards for Agricultural and Natural Resources state that high school agriculture students develop the skills needed to find careers in agriculture. The standards include pathways to specific career areas like Agricultural Mechanics and Ornamental Horticulture (CA Board of Education 2005).

The Agricultural Mechanics pathway trains students for careers such as Agriculture Equipment Operators. Construction skills like measuring board dimensions, identifying wood products, and working with concrete are covered. Safe and appropriate equipment use is also part of the standard (CA Board of Education 2005).

3.7.4 Linking Design of School Facilities to Educational Standards

The design of school facilities should support educational objectives. All school facilities should be safe, clean, and up to date technologically. Further, they should reflect the importance that society puts on education (CA Department of Education 1997). Ideally designed school facilities come from specific educational specifications derived from high priority educational goals (CA Department of Education 1997).

Educational specifications tell a designer what is required to meet the needs of specific educational programs (CA Department of Education 1997). A process of developing educational specifications is detailed in Table 3-3 (CA Department of Education 1997).

Table 3-3 Process and phases for developing educational specifications (CA Department of Education 1997)

Educational Specifications Schedule

Phase	*Start*	*Review*	*Approvals*	*Completion*
1. Data collection				
2. Development of educational specifications				
3. Community input				
4. Evaluations and revisions				
5. Approvals				
6. Other				

Specifications are only one part of an iterative process for designing facilities. The process is a continuum, detailed in Figure 3-15 (CA Department of Education 1997).

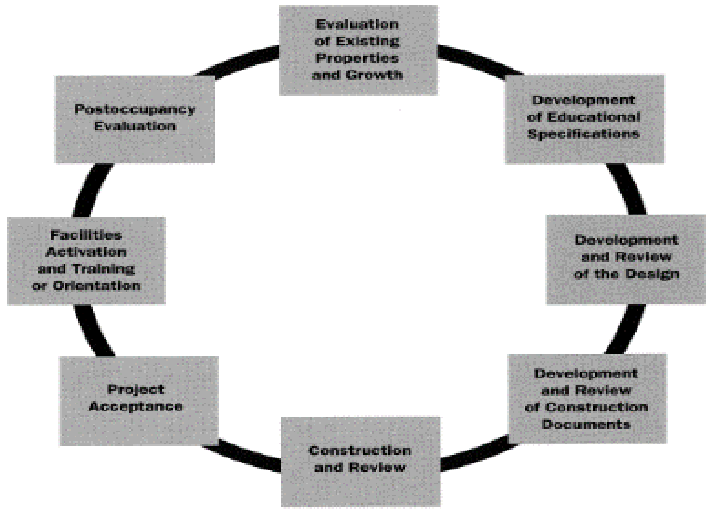


Figure 3-15 Educational specifications continuum (CA Department of Education 1997)

4 Search for Alternative Solutions and Decision

4.1 Introduction

Section 4 outlines the six solutions developed based on the criteria, structured and unstructured brainstorming sessions, and the results determined using the Delphi Matrix method (Table 4-2). The values returned by the Delphi Matrix and the research compiled in Section 2 and Section 3 informed the final decision.

4.2 Criteria

AZDC met with the client to establish the following set of criteria in order to inform the design process.

Safety: No one can injure themselves on the final design.

Accessibility: Accessibility is measured by the ease of access the pathway provides throughout the year, considering the varying abilities of students and the design's functionality for use with a wheelbarrow.

Labor Intensity: Labor intensity considers the physical aspects of each structural component. This includes labor involved in moving materials from their source to the construction site and the different aspects of labor involved in building with a specific material.

Plantability: Plantability refers to how easy it is to plant in the space above and below the pathway, as well as which plants are most appropriate for the site in terms of slope stabilization, edibility, and regional nativity.

Ecology: Ecology focuses on the sustainability of materials used. Newly purchased materials will rank lower in this criterion than upcycled or repurposed materials.

Cost: Cost is defined by the total amount of money spent by the design team and Six Rivers. No donations will be considered as part of the overall cost of the project. Designs that cost less out of pocket rank higher in this category.

Maintainability: Maintenance refers to the quantity and difficulty of upkeep that a design option requires with respect to both short and long-term use.

Educational Value: Educational value of a design is quantified by answering the question: what benefit do the students at Six Rivers Charter gain from having the pathway? This can be measured in terms of agricultural and horticultural education, or simply providing improved access to an alternative education space.

Aesthetic: Aesthetic is the visual appeal held by materials individually and their combined appearance in the complete design.

4.3 Brainstorming and Alternative Solutions

Our team held two structured brainstorming sessions and many unstructured sessions throughout the design process. Our structured sessions focused on producing options for different pathway components that suit our criteria. The components we developed options for were pathway material, drainage options, retaining wall type, plant species, switchback placement, and pathway layout. We focused on one category at a time and came up with as many ideas as we could for 10 minutes. Following that we reduced our list by eliminating options that were not feasible with respect to cost, time constraint, client desire, and practical application. Pictures showing some of our brainstorming notes from the above process can be found in Appendix A.

Unstructured sessions took place as the project required it. For example, during our preliminary brainstorming sessions we did not anticipate having large areas of bare hillside, but during construction we cleared out all vegetation below the urbanite and earth tire retaining walls. We were concerned about the bare hill eroding below our unfinished retaining walls, so we held an unstructured brainstorming session at the construction site focusing on ways to stabilize the slope.

Using the options developed through our brainstorming sessions we arranged six alternative solutions, listed in Table 4-1.

Table 4-1 Alternative solutions

Direct Path with Gravel and Gutter
• Gravel pathway with compacted dirt
• Direct path
• Earthbag retaining structure
• Recycled Concrete wall face
• Wattle Drainage
• Plants
  o Blueberries
  o Snowberries
  o Red Thimbleberry
  o Elderberries
	Direct Path with Compact Earth Tires
	• Gravel pathway with compacted dirt
	• Direct path
	• Compact earth tire retaining structure
	• Vegetative wall face (tire planters)
	• Gutter drainage
	• Plants
	  o Blueberries
	  o Snowberries
	  o Huckleberries

High Switchback with Recycled Concrete
• Gravel pathway with compacted dirt
• High Switchback
• Recycled concrete retaining structure
• Recycled concrete wall face
• Wattle drainage
• Plants
  o Blueberries
  o Snowberries
  o Red Thimbleberry
  o Elderberries
	High Switchback with Compact Earth Tires
	• Gravel pathway with compacted dirt
	• High Switchback
	• Compact earth tire retaining structure
	• Vegetative wall face (tire planters)
	• Gutter drainage
	• Plants
	  o Blueberries
	  o Snowberries
	  o Huckleberries
	  o Salmonberries

Low Switchback with Recycled Concrete
• Gravel pathway with compacted dirt
• Low Switchback
• Recycled concrete retaining structure
• Recycled concrete wall face
• Wattle Drainage
• Plants
  o Blueberries
  o Snowberries
  o Red Thimbleberry
  o Elderberries
	Low Switchback with Compact Earth Tires
	• Gravel pathway with compacted dirt
	• Low Switchback
	• Compact earth tire retaining structure
	• Vegetative wall face (tire planters)
	• Gutter Drainage
	• Plants
	  o Blueberries
	  o Snowberries
	  o Huckleberries
	  o Salmonberries

Option 1: Direct Path with Gravel and Gutter

The direct path placement does not suitably address the client criteria of wheelbarrow accessibility because the elevation change relative to horizontal distance change is too great. If there is doubt that a high schooler will be able to traverse the slope hauling a wheelbarrow, then that grade is too steep. The direct path also is not as open for planting as the switchback options. The gravel and compacted dirt pathway surface combination is financially and ecologically sound because the materials are already on site. Earthbags meet the criteria of safety and are estimated to be approximately as labor intensive as compact earth tires, but because they require the purchase of new polypropylene bags they are not financially or ecologically favorable. The recycled concrete wall face is ecologically and financially preferable, but the material cannot be planted in and the labor intensity is high. Wattle drainage is safe, ecologically and financially viable, low labor, and low maintenance. Snowberries provide slope stabilization, are easy to maintain, and are low cost. Blueberries are edible, but extremely high maintenance. Red Thimbleberries are native and edible. Elderberries, Huckleberries, and Salmonberries are native and edible.

Option 2: Direct Path with Compact Earth Tires

The direct path placement does not suitably address the client criteria of wheelbarrow accessibility because the elevation change relative to horizontal distance change is too great. If there is doubt that a high schooler will be able to traverse the slope hauling a wheelbarrow, then that grade is excessive. The direct path also is not as open for planting as the switchback options. The gravel and compacted dirt pathway surface combination is financially and ecologically sound because the materials are already on site. A compact earth tire retaining wall is very safe, ecologically favorable, plantable, cost effective, low maintenance, and aesthetically pleasing, but are very labor intensive. Gutter drainage is safe, financially neutral, and ecological to build, but requires maintenance and are relatively laborious to install. Snowberries provide slope stabilization, are easy to maintain, and are low cost. Blueberries are edible, but extremely high maintenance. Huckleberries and Salmonberries are native and edible.

Option 3: High Switchback with Recycled Concrete

The high switchback layout addresses the client request for wheelbarrow accessibility, safety, and plantability. The gravel and compacted dirt pathway surface combination is financially and ecologically sound because the materials are already on site. A recycled concrete retaining wall is safe, ecologically and financially highly favorable, relatively labor intensive, and low maintenance. Wattle drainage is safe, ecologically and financially viable, low labor, and low maintenance. Snowberries provide slope stabilization, are easy to maintain, and are low cost. Blueberries are edible, but extremely high maintenance. Red Thimbleberries and Elderberries are native and edible.

Option 4: High Switchback with Compact Earth Tires

The high switchback layout addresses the client request for wheelbarrow accessibility, safety, and plantability. The gravel and compacted dirt pathway surface combination is financially and ecologically sound because the materials are already on site. A compact earth tire retaining wall is very safe, ecologically favorable, plantable, cost effective, low maintenance, and aesthetically pleasing, but are very labor intensive. Gutter drainage is safe, financially neutral, and ecological to build, but requires maintenance and are relatively laborious to install. Snowberries provide slope stabilization, are easy to maintain, and are low cost. Blueberries are edible, but extremely high maintenance. Huckleberries and Salmonberries are native and edible.

Option 5: Low Switchback with Recycled Concrete

The low switchback layout addresses the client request for wheelbarrow accessibility, but brings with it a steeper grade than the high switchback option which is not favorable. The gravel and compacted dirt pathway surface combination is financially and ecologically sound because the materials are already on site. A recycled concrete retaining wall is safe, ecologically and financially highly favorable, relatively labor intensive, and low maintenance. The recycled concrete wall face is ecologically and financially preferable, but the material cannot be planted in and the labor intensity is high. Wattle drainage is safe, ecologically and financially viable, low labor, and low maintenance. Snowberries provide slope stabilization, are easy to maintain, and are low cost. Blueberries are edible, but extremely high maintenance. Red Thimbleberries and Elderberries are native and edible.

Option 6: Low Switchback with Compact Earth Tires

The low switchback layout addresses the client request for wheelbarrow accessibility, but brings with it a steeper grade than the high switchback option which is not favorable. The gravel and compacted dirt pathway surface combination is financially and ecologically sound because the materials are already on site. A compact earth tire retaining wall is very safe, ecologically favorable, plantable, cost effective, low maintenance, and aesthetically pleasing, but are very labor intensive. Gutter drainage is safe, financially neutral, and ecological to build, but requires maintenance and are relatively laborious to install. Snowberries provide slope stabilization, are easy to maintain, and are low cost. Blueberries are edible, but extremely high maintenance. Huckleberries and Salmonberries are native and edible.

4.4 Decision Process

The team reached a final design after analyzing the Delphi Matrix, shown in Table 4-2. A Delphi Matrix is used to weigh the value of the established criteria with respect to each design solution based on the team and client's priorities. Each of the individual components of the design, their possible combinations, what each specific combination would entail relative to the construction site and anticipated usage were considered. After brainstorming ideas, the team reduced the list of potential designs based on time constraints, financial constraints, client criteria, and safety. The team then used the Delphi Matrix method to individually and collectively evaluate each individual component of the designs on a 0-50 scale. Next, the team created a second Delphi Matrix to analyze complete design options based on a list of weighted criteria scaled 0-10. Further, the ratings of the individual design aspects were reevaluated after completing the first Delphi Matrix. The client's input was incorporated to adjust the weights of the criteria in the final Delphi Matrix (Table 4-2). Plant types were chosen based on research pertaining to ease of planting, maintenance, edibility, slope stabilization, and nativity.

Table 4-2 Delphi Matrix used to make final decision

		Alternative Solutions (0-50 high)					
		Direct Path		High Switchback		Low Switchback	
		Solution 1	Solution 2	Solution 3	Solution 4	Solution 5	Solution 6
Criteria	Weight (0-10 high)	Earth Bag Recyc. Concrete Wattle	Tire Tire Planters Gutter	Recyc. Concrete Wattle	Tire Tire Planters Gutter	Recyc. Concrete Wattle	Tire Tire Planters Gutter
Accessibility	10	42 / 418	44 / 438	31 / 313	30 / 300	39 / 393	38 / 383
Labor Intensity	9	26 / 236	25 / 225	24 / 214	21 / 191	31 / 275	25 / 221
Plantability	7	34 / 236	36 / 249	38 / 263	45 / 315	38 / 266	47 / 327
Ecology	6	37 / 221	45 / 270	40 / 240	41 / 248	42 / 249	43 / 260
Cost	7	33 / 228	43 / 298	34 / 236	35 / 245	41 / 284	43 / 298
Maintenance	5	36 / 181	38 / 188	29 / 144	34 / 169	32 / 160	38 / 191
Educational Value	4	20 / 80	24 / 97	24 / 95	28 / 113	25 / 100	30 / 120
Aesthetic	4	28 / 110	26 / 105	35 / 140	35 / 140	34 / 135	35 / 139
		1709	1868	1644	1721	1861	1938

4.5 Final Decision Justification

After reviewing the final Delphi Matrix, the team settled on the sixth design solution, featuring low switchback pathway placement, a compacted earth tires retaining wall, and gutters for drainage. As the top three criteria from the Delphi matrix are accessibility, labor intensity, and plantability, this option stood out as an appropriate mix of all three. Accessibility is enhanced by the even slope that results from a longer switchback, and labor intensity is optimized by taking advantage of the natural slope of the hill to avoid unnecessary digging. The low switch back option elicits a longer trail naturally creating more space for planting. Unlike the other two pathway options, the low switchback design creates access to the lower section of the hill for additional planting. Despite the fact that this solution did not score highest for any of the top three criteria, it was the design which most widely appropriately addressed the criteria.

5 Specifications

5.1 Introduction

After the final decision was made on what components would be incorporated, the physical design and construction process began. The chosen pathway placement evolved out of an initial layout that is shown in Figure 5-1. This section provides instructions on how the design in Figure 5-1 was implemented.

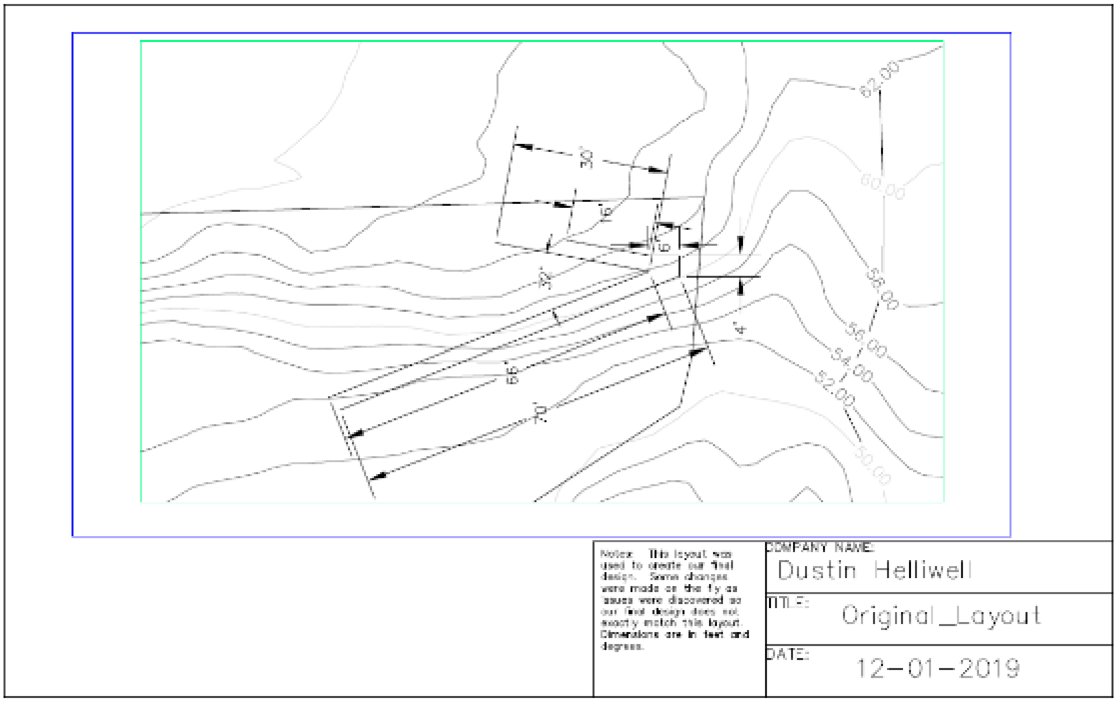


Figure 5-1 Initial layout (Helliwell 2019)

5.2 Description of Solution

The actual manifestation of the final solution involved a combination of the solution alternatives in Table 4-1. The full length of the pathway is approximately 90' and the area of the landing is approximately 35 square feet. The bottom of the pathway to the landing is supported by a 66' urbanite retaining wall that expands upon a pre-existing concrete block retaining wall. The landing is supported by a compact earth tire retaining wall measuring approximately 54" high by 13' wide, and comprised of 24 tires arranged hexagonally. The portion of the pathway between the top of the pathway and the landing does not require reinforcement because the downhill slope has sufficient vegetation to maintain integrity. The pathway surface is composed of three layers: tamped earth as the base, a mixture of soil and gravel in the middle, and mulch on top. Out sloping of the pathway and Coweeta dips are used for drainage. Ripraps, straw, and grass seed are utilized as temporary and lasting erosion control for the remaining bare slopes. Figure 5-2 shows an east facing perspective of the final trail design. Figure 5-3 shows a vertical perspective of the final trail design.

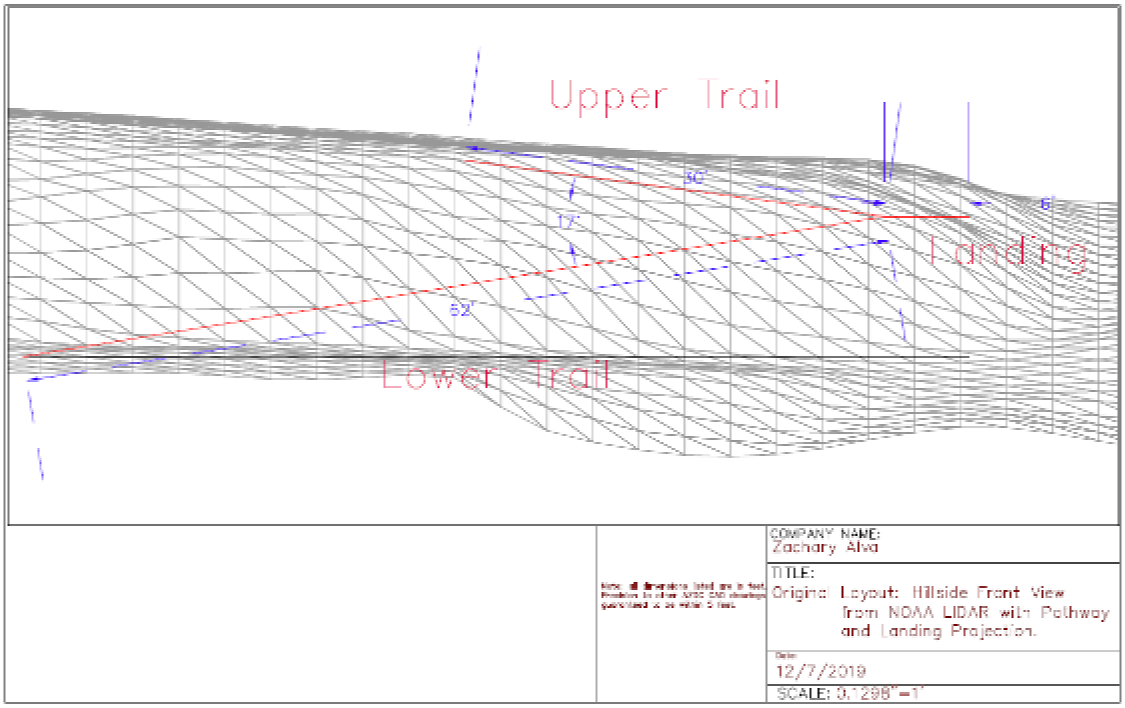


Figure 5-2 Final trail design - east facing view (Alva 2019)

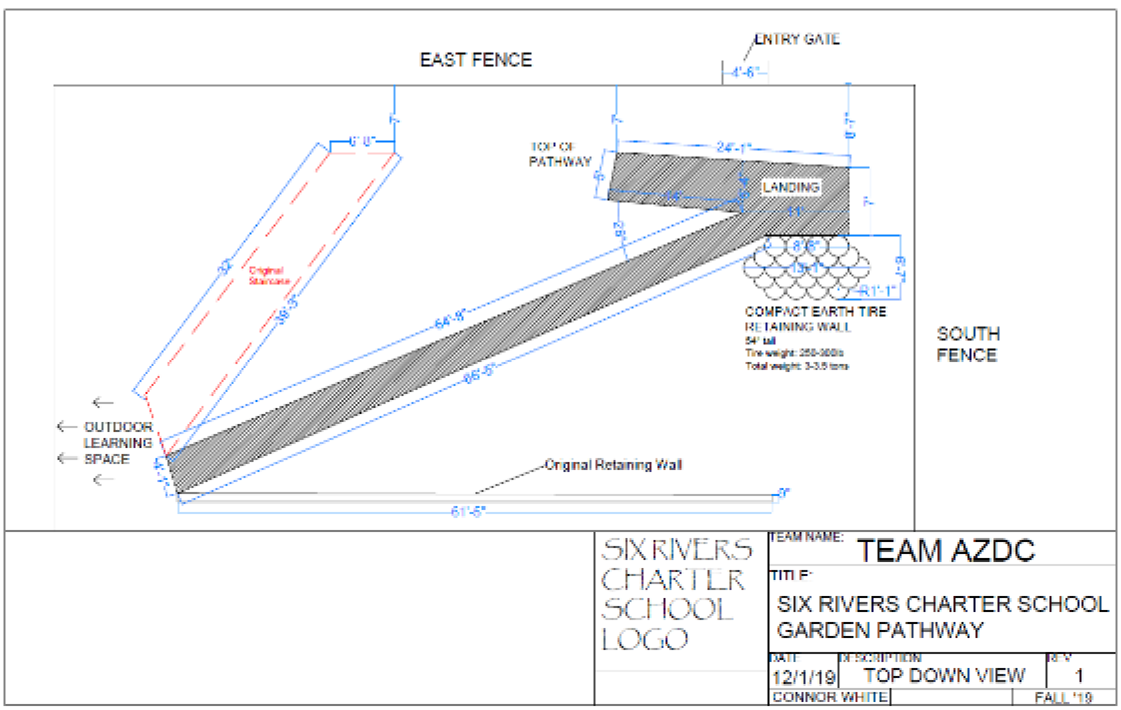


Figure 5-3 Final trail design - top view (White 2019)

5.2.1 Pathway and Drainage

Drainage along the pathway is addressed through a combination of techniques. Based on the literature review above, out sloping and Coweeta dips were utilized to move water off the pathway. This minimizes erosion caused by fast moving water and reduces the total amount of water flowing on the path surface. Wood chips were also used along the path surface. The chips slow down water, cover up mud, and provide an easy walking surface.

Erosion above and below the path was addressed through spreading straw and grass seed. The straw slows down the flow of water and holds the dirt in place. As the straw breaks down the grass seed sprouts and replaces the function of the straw in a more permanent way.

5.2.2 Compact Earth Tire Retaining Wall

The compact earth tire retaining wall consists of 24 tires, packed with soil taken out of the hillside. Each fully compacted tire is estimated to weigh between 250-300 pounds. The tire wall has 5 rows: the bottom and top rows are 4 tires across, the middle row is 6 tires across, and the remaining two rows are each 5 tires across. The orientation of the is geometrically symmetrical about the center row, as shown in Figure 5-3. The tire wall is one of the primary features that meets the plantability criteria, as each tire can hold a plant without compromising the structural integrity of the wall.

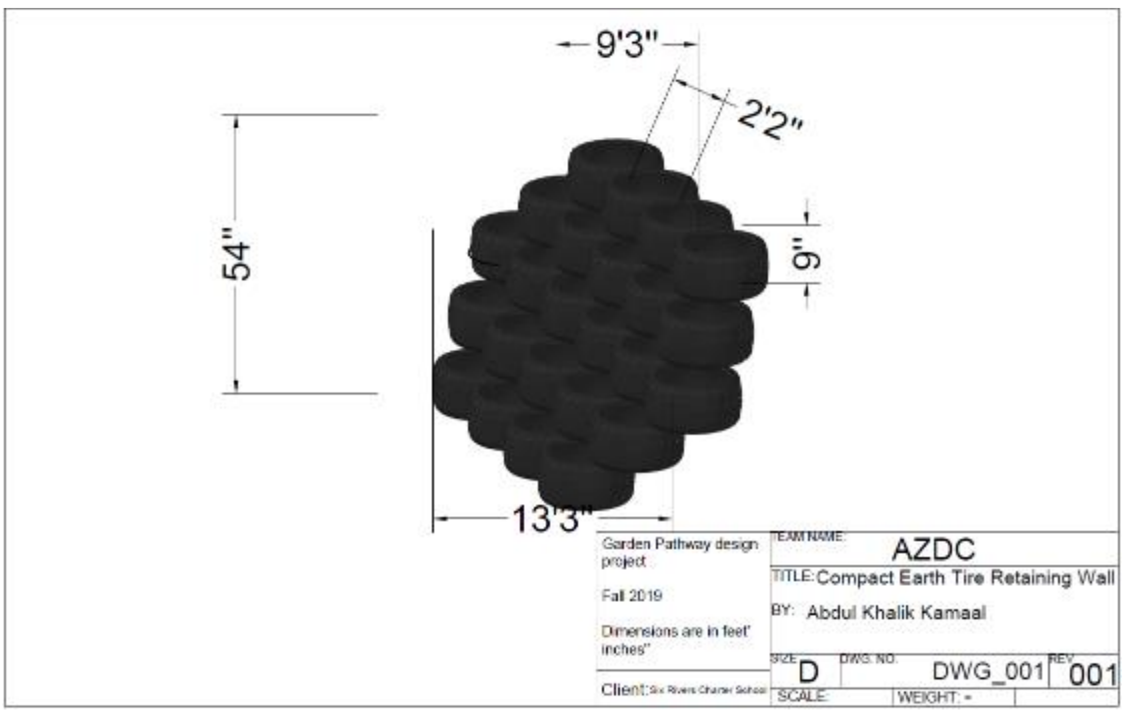


Figure 5-4 AutoCAD rendering of earth tire retaining wall (Kamaal 2019)

5.2.3 Urbanite Retaining Wall

The majority of urbanite used in this project was recycled concrete, more specifically former sidewalk, donated by Figas Construction in Arcata, CA. Two truckloads were sourced from Figas Construction and the remainder was provided by Six Rivers. The urbanite retaining wall runs approximately 66' long and steadily rises in height from 6" at the bottom end to approximately 3.5' where it meets the earth tire retaining wall. The blocks in the bottom row are the largest, estimated to be between 150-300lbs. Each subsequent row is comprised of blocks slightly smaller than the previous row. The blocks are side and backfilled with a combination of soil, sand, gravel, and small concrete chunks.

5.3 Costs

5.3.1 Design Cost in Human Hours

The project took a total of 406 hours distributed between four people (Figure 5-5). Out of the total, the problem formulation phase took 24 hours, the literature review and problem analysis phase took 67 hours, the brainstorming and formulation phase of alternative solutions took 35 hours, the prototyping and formulating the final decision phase took 32 hours, and construction of the design took 248 hours.

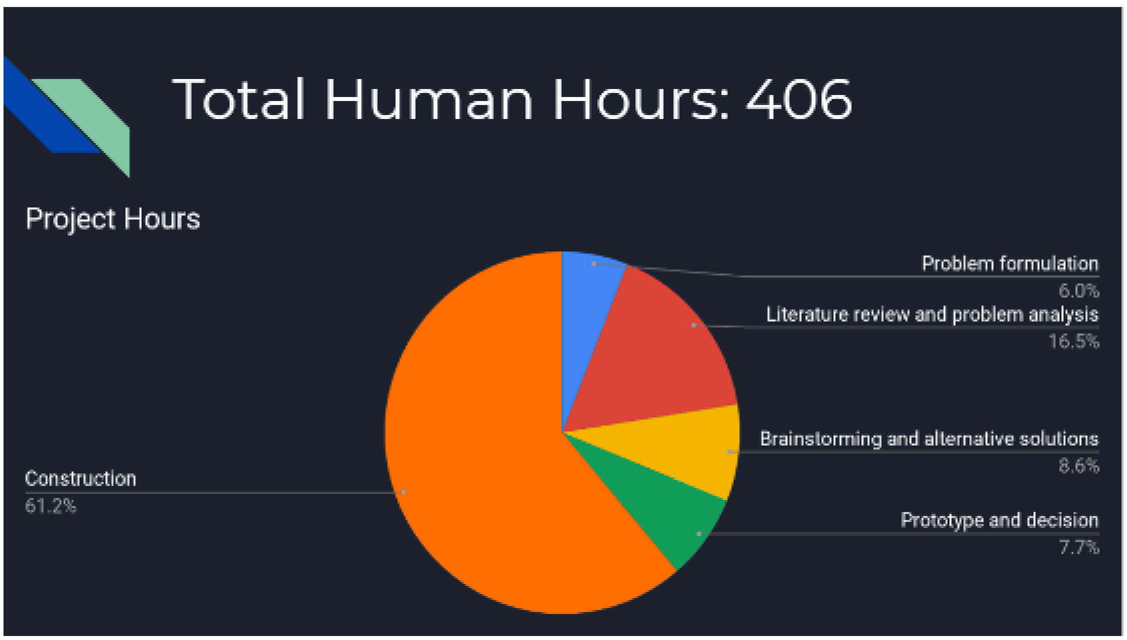


Figure 5-5 Total design hours as of 12/5/2019

5.3.2 Implementation Financial Cost

The financial costs of implementing the trail are outlined in Table 5-1. Expenses were reduced by using upcycled materials, which proved to be eco-friendly and cost effective. Most of the finances went towards the gas required to transport the urbanite and used tires. The remaining amount spent was for a bale of straw and a bag of grass seed.

Table 5-1 Costs

Item	Costs
Materials transportation	$46.91
Straw	$8.62
Grass seed	$3.76
Recycled concrete (donated by Figas Construction)	$0.00
Tires (Anonymous donation)	$0.00
Wood chips	$0.00
Total	**$59.29**

5.3.3 Future Maintenance Financial Cost

The pathway is designed to keep maintenance costs minimal. Short-term maintenance of the path surface may entail addition of wood chips to replace those lost by washout and usage. Wood chips can be obtained in Humboldt County from various free piles scattered throughout the region. It is also possible to have local tree clearing companies deliver chips for free.

Long term maintenance may require more gravel. There is a significant amount of surplus gravel on site that can be used for maintenance. Once this gravel runs out more can be purchased for between $15 and $75 per yard (Homeguide n.d.). Only one cubic yard of gravel was needed to cover the path surface during construction. Based on the above price and anticipated gravel loss, maintenance expenses are expected to be under $20 per year.

5.4 Prototyping

5.4.1 Prototype 1

The first prototype, Figure 5-6, was developed to test the design for potential points of failure. The prototype is constructed of chicken wire as the base, drywall plaster to imitate soil, foam pieces to represent urbanite blocks, and slices of wine corks to represent tires. The prototype was tested by showing it to Humboldt State University engineering students who gave their opinions of what could be improved on and what could be potentially problematic or unsafe.

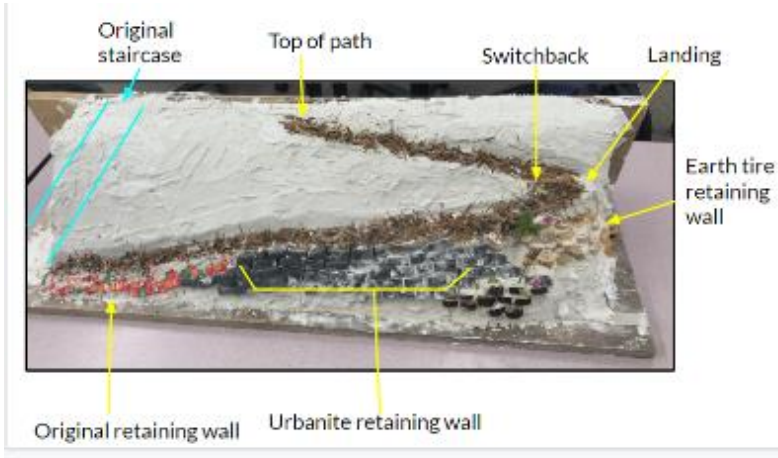


Figure 5-6 Prototype 1

5.4.2 Prototype 2

The second prototype was constructed on site. The purpose of the second prototype was to get live feedback on the design decision made in the classroom and to gauge the structural integrity of the soil making up the hill. After laying down guidelines, the team dug lightly into the hillside to get a sense of the actual scope of the pathway, how easy it was to remove soil from the hillside, and to draw rough outlines for the urbanite retaining wall. The team then showed the prototype to the client (Figure 5-7). The second prototype confirmed a problem faced in constructing the first prototype: the inside angle of the switchback is too tight for the hill to be able to support the upper trail.

Figure 5-7 Discussing prototype 2 with client representative Ron Perry

5.5 Instructions for Implementation, Maintenance, and Use

This section provides step by step instructions of how each component of the final design was constructed, anticipated maintenance of the pathway, and recommended usage.

5.5.1 Implementation Instructions: Pathway

The first step in creating the pathway was to decide on a layout. The first layouts were roughly sketched on black and white photos of the trail (Figure 5-8). Next, the team pulled string on the project site to approximate the edge of the path surface. Then, a rough narrow pathway was cut inside of the strings. After each of these steps the client was consulted to ensure the pathway placement was appropriate.

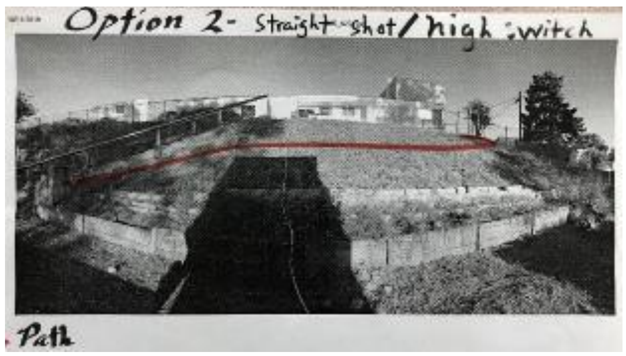


Figure 5-8 Example of layout sketch

The retaining walls needed to be installed before the pathway could be cut into its final shape. The best way to proceed was to rotate between working on the retaining walls and the trail surface. Sometimes the path surface required development to create access to the retaining wall construction area, and sometimes the retaining walls needed to be completed before the trail level and width could be finalized.

The final stage of pathway construction was to tamp down gravel and add a top layer of wood chips. The tamped gravel adds strength to the path surface and reduces the trail's vulnerability to erosion. The wood chip layer provides a comfortable walking surface, prevents mud from gathering on shoes, and mitigates erosion by slowing the flow of surface water.

Figure 5-9 Implementation of the pathway

5.5.2 Implementation Instructions: Compact Earth Tire Retaining Wall

The first step to constructing the compacted earth tire wall is to gather materials. 24 used tires, 24 pieces of upcycled cardboard, about 50 screws, and soil for filling the tires make up the entire list of materials. The most useful tools for creating the tire wall are a shovel, tamper, sledge hammer, mallet, level, and impact driver. The first step is to level and tamp the ground at the base of where the tire wall is to be placed. Next, the first row of tires is laid out and leveled. Soil is prevented from falling out the bottom of the tires by inserting a piece of cardboard into the tire to cover the hole in the bottom. Packing the tires is the most critical step to ensure the success of the tire wall. The tamper, sledge hammer, and mallet are used to ensure that the entire tire, particularly the outer ring of the tire, is compacted such that when the tire bears weight from above it holds firm and does not shift.

Once the first layer of tires is set and completely filled, the next layer is laid in an alternating fashion on top of the first layer so that the center of the tire on the second row is lined up with the outside edges of the tires below it, and shifted back into the hill the same distance as the radius of the tire(Figure 5-10). The new layer of tires is then screwed into the layer below it using the impact driver at four points to ensure that it does not fall out of place during tamping. Then, the packing process repeats until the entire wall is constructed. After each row is completed it is necessary to dig into the hill, creating space for the following row. Finally, the last row of the tire wall is constructed to cleanly connect with the urbanite retaining wall. Backfill and tamp all remaining gaps with a combination of soil and recycled concrete bits.

Figure 5-10 Placement of second row of tires.

5.5.3 Implementation Instructions: Urbanite Retaining Wall

The first step of constructing the urbanite retaining wall is to acquire building materials and tools. This wall uses 3 truckloads of urbanite, about 0.5 cubic meters of mixed soil, sand and gravel for filler, a shovel, a tamper, a level, as well as both a handheld rubber mallet and metal sledgehammer.

The first step is to create a stable foundation layer by digging out all loose dirt, tamping firm the earth that the first layer of urbanite will be placed on, and levelling it. Starting at the lower end, the heaviest blocks are set one at a time. Using the most massive pieces on the bottom row gives the greatest structural integrity. Moving along the line of the pathway, place blocks sequentially by nestling them together such that they "lock" into place. Fill in gaps between the blocks using a combination of soil and gravel. The fill is then massaged into place using tools before packing firmly, so that fill reaches the innermost gaps.

Figure 5-11 Massaging gravel and soil backfill into place

The stability of each block needs to be checked by stepping on it. If it wiggles in place then that means it has not been set firmly enough and requires additional side/backfilling, or increased lateral support by adjusting the placement of adjacent blocks. This is difficult to do once the entire row is completed because adjusting the placement of any one piece alters the placement of the surrounding blocks. Once the first row is firmly placed and stabilized, the second row is constructed with the heaviest remaining blocks following the methods used to construct the first row. This process is repeated until the height of the retaining wall meets the height of the pathway, then it is additionally backfilled and tamped.

5.6 Results

The final product meets all of the criteria outlined by the team and the client. The pathway is a safe way to get up and down the hill at Six Rivers, featuring a gentle slope and wide landing that makes for an easy turn at the switchback. It is wheelbarrow accessible, it’s maintenance is within the capacity of high school students, and has already withstood large amounts of wind and rain without deforming. The pathway, landing, and tire retaining wall are all viable locations for planting any combination of plants described throughout the document.

References:

Addivant (n.d.) “Tire and Rubber Compounding” <https://www.addivant.com/tire-rubber-compounding> (Sept. 30, 2019)

Armstrong, Sean. (2019). “Fruits of the Humboldt Bay: A Community Sourced Planting Guide.” 17th ed. Print.

Berg, R. R., Christopher, B. T., and Samtani, N. C. (2009). “Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes.” National Highway Institute Courses, US Department of Transportation, FHWA-NHI-10-024 FHWA GEC 011-Vol I (Sept. 30, 2019)

Broms, Bengt, Poh, Paul (1995) “Slope Stabilization Using Old Rubber Tires and Geotextiles”. Journal of Performance of Constructed Facilities - J PERFORM CONSTR FACIL. 9 10.1061/(ASCE)0887-3828(1995)9:1(76)

Brooks, Hugh, and Nielsen, John P., (2013) Basics of Retaining Wall Design: A Design Guide for Earth Retaining Structures. 10th ed., HBA Publications

CalEarth (n.d.). “What is SuperAdobe?” <https://www.calearth.org/intro-superadobe> (Oct. 2, 2019)

California Department of Education (1997). “Linking Design of School Facilities to Educational Program” < https://www.cde.ca.gov/ls/fa/sf/documents/edspecs.pdf > (3 Oct. 2019)

California Native Plant Society (CNPS). (2019). California Native Plant Society.2019. “Flora: A Publication of the California Native Plant Society”. <https://www.cnps.org/wp-content/uploads/2019/08/Flora_V2N3-Spring-2019-4Ref-LR.pdf> (3 Oct. 2019)

California State Board of Education (2005). “California Career Technical Education Model Curriculum Standards Grades Seven Through Twelve”

Calscape (2019). “California Native Plant Society (CNPS)”. < https://calscape.org/loc-California/cat-Bank_stabilization/ord-popular?srchcr=sc5dec888da25fc> (3 Oct. 2019)

Connecticut Department of Environmental Protection, Connecticut. (2010). “Artificial Turf Study: Leachate and Stormwater Characteristics” <https://www.ct.gov/deep/lib/deep/artificialturf/dep_artificial_turf_report.pdf > (Oct. 2, 2019),

Geiger, O., and Zemskova, K., (2015). “Earthbag Technology - Simple, Safe and Sustainable” *Nepal Engineers’ Association Technical Journal*, 43-EC30()1, 78-89.

Google Maps (n.d.) < https://www.google.com/maps/@40.8760549,-124.0901789,50m/data=!3m1!1e3> (Oct. 2, 2019)

Greywater Action (n.d.). “How to do a Soil Percolation Test.”, <https://greywateraction.org/how-do-percolation-test/> (Oct. 3, 2019).

Hoffman, A. J., Knight, L. F. M., and Wallach, J. (2007). “Gardening Activities, Education, and Self-Esteem: Learning Outside the Classroom.” Urban Education, 42(5), 403–411.

Homeguide (n.d.). < https://homeguide.com/costs/gravel-prices> (Dec. 8, 2019)

Hossain, Sadique, and Priyantha W. Jayawickrama. (2000). “Use of Whole Tires in Earth Retaining Structures”. CENTER FOR MULTIDISCIPLNARY RESEARCH IN TRANSPORTATION, 2000, *Use of Whole Tires in Earth Retaining Structures*

Humboldt County General Plan (HCGP). (n.d.) “*Geology and Soils”.* <https://humboldtgov.org/DocumentCenter/View/58837/Section-38-Geology-and-Soils-Revised-DEIR-PDF > (3 Oct. 2019)

County of Humboldt (2019). *Climate | Humboldt County, CA - Official Website*. <https://humboldtgov.org/1217/Climate> (Oct. 2019)

Harpstead, D. L. and Schmidt, J. M., (n.d.). “MSE Wall Engineering – A New Look at Contracting, Design, and Construction.”

Journal of the Department of Agriculture, Victoria, Australia. (2019). *Surface Drainage.* Mickan, Ellinbank. < http://agriculture.vic.gov.au/agriculture/dairy/managing-wet-soils/surface-drainage > (3 Oct. 2019)

Kim, D., Baek, K. and Park, K. (2018). Analysis of the Bearing Capacity of Helical Pile with Hexagonal Joints. *Materials*, [online] 11(10), p.1890. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6213753/> (Sept. 30, 2019).

Koczera, D. (2019). “Client interview”. Six Rivers Charter School.

Lancaster, E. (2019). “Student interview” Six Rivers Charter School.

Mays, David C., Ren, Zhiyong, and Rhodes, Emily P. (2012). “Zinc leaching from tire crumb rubber.” *Env. Sci. and Tech.* 46 (23), 12856–12863.

Morgan, R., and Rickson, R. (1995). Slope stabilization and erosion control. E & FN Spon, London [etc.], 1-52.

Perry, R. (2019). “Client interview”. Six Rivers Charter School.

PSE Consulting Engineers (n.d.). “Pros and Cons of Sustainable Building Methods.” <https://www.structure1.com/pros-cons-popular-natural-building-methods/> (Oct. 1, 2019)

ReCon Retaining Walls “Gravity Retaining Walls - Commercial” (n.d.). *ReCon Retaining Walls* “Gravity Retaining Walls - Commercial”, < https://www.reconwalls.com/retaining-wall-case-studies.html> (Sept. 30, 2019)

Reinforced Earth (2018) “Mechanically Stabilized Earth (MSE) Retaining Walls” <https://reinforcedearth.com/products/retaining-walls/mechanically-stabilized-earth-mse- retaining-walls/> (Oct. 1, 2019)

Reinforced Earth. (2019). “Seattle-Tacoma International Airport Third Runway - Reinforced Earth”. Available at: <https://reinforcedearth.com/project/seattle-tacoma-international-airport-third-runway/> (Accessed Oct. 1, 2019).

Stonetree Landscaping, (2019). “Pros and Cons of Block Retaining Walls” <https://stonetreestg.com/pros-and-cons-of-block-retaining-walls/https://stonetreestg.com/pros-and-cons-of-block-retaining-walls/> (Oct. 2, 2019)

TIRE Act (2007). < www.congress.gov/bill/110th-congress/house-bill/5103/tex> (Octwww.congress.gov/bill/110th-congress/house-bill/5103/text. 2, 2019)

University of Illinois at Urbana-Champaign Water Quality (n.d.). "Illinois Drainage Guide.", <http://www.wq.illinois.edu/DG/subsurface.htmhttp://www.wq.illinois.edu/DG/subsurface.htm#targetText=A%20subsurface%20drainage%20system%20consists,main%20drain%20to%20collect%20water.> (Oct. 2, 2019).

U.S. Department of the Interior (1996). “A Handbook for Trail Design, Construction, and Maintenance” < https://www.nps.gov/noco/learn/management/upload/Handbook-complete-2.pdf> (Oct. 2, 2019)

U.S. Environmental Protection Agency (n.d.). "Durable Goods: Product-Specific Data" <https://www.epa.gov/facts-and-figures-about- materials-waste-and-recycling/durable-goods-product-specific-data(n.d.). https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/durable-goods-product-specific-data> (Sept. 30, 2019).

USDA-NRCS Official Soil Series Description. (2019). “*Humboldt Series*”. <http://voyager.humboldt.edu/vwebv/holdingsInfo?bibId=21517> (3 Oct. 2019)

U.S. Tire Manufacturers Association (n.d.). “What’s in a Tire” <https://www.ustires.org/whats-tire-0 > (Sept. 30, 2019)

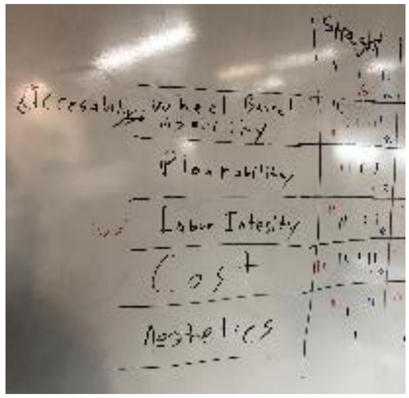
Veder, C. (1981). Landslides and their stabilization. (E. Jahn, tran.), Springer Verlag, New York.

Vegetated Geogrids Prj.geosyntec.com. (2019). Vegetated Geogrids. [online] Available at: <http://prj.geosyntec.com/npsmanual/vegetatedgeogrids.aspx> (2 Oct. 2019).

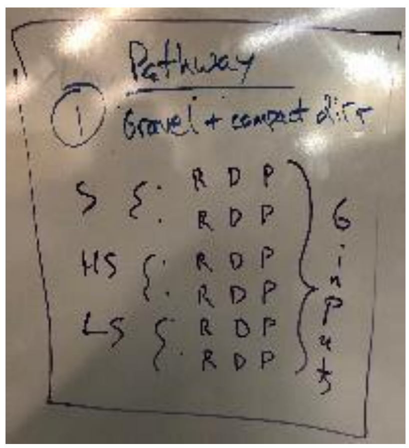
Wellington Road North (n.d.) “Tyre Retaining Walls” <https://www.sites.google.com/site/wellingtonroadnorth/tyre-retaining-walls> (9 Dec. 2019)

Windrich Environmental (n.d.). “Advantages of Using Super Adobe or Earthbag Material” <http://www.windriche.com/superadobe/advantages_and_disadvantages_of_earthbag_construction.htm> (Oct. 1, 2019)

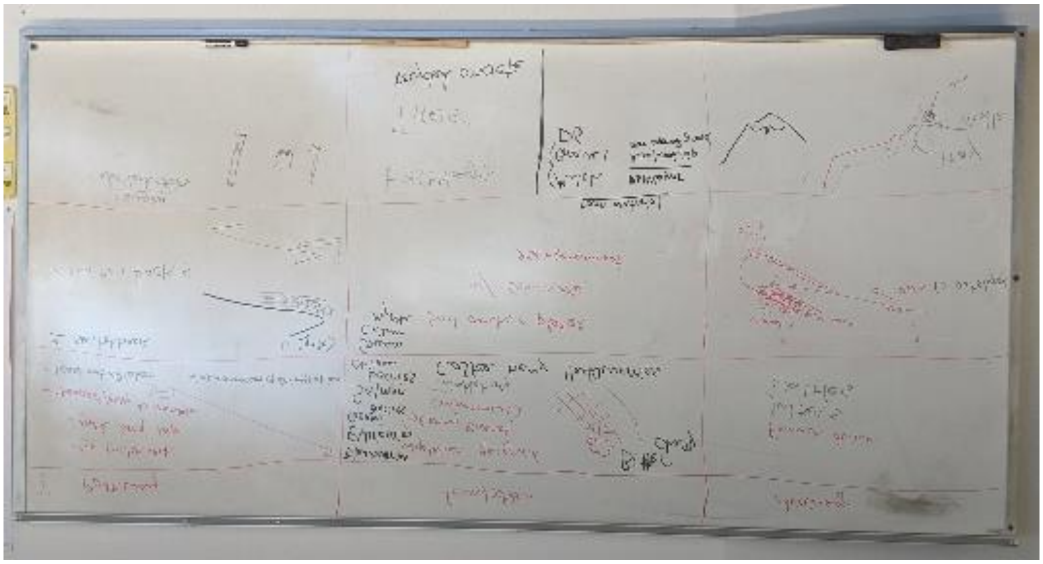
Appendix A: Brainstorming Session Notes



Appendix A 1 Brainstorming notes



Appendix A 2 Brainstorming notes



Appendix A 3 Brainstorming notes

Appendix B: Local Examples of Urbanite Use

Appendix B 1 Local urbanite construction

Appendix B 2 Local urbanite construction