2016

Interactive Watershed Model

THE A TEAM

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1. Problem Formulation

1.1 Introduction

The A Team chose to design a watershed model for Mrs. Crandell's middle school class because of a common understanding between ourselves and the client of the importance of the watershed cycle in today's youth. In Phase I, the A Team will formulate a black box and objective for our watershed model design project. A simplified illustration for the world, pre and post project completion, is shown in our black box in Figure 1-1.

1.2 Objective

The objective of this project is to construct an interactive watershed model for students between the ages of 8-13 that demonstrates the components of Humboldt's watershed and how pollutants are distributed throughout each area. The interactive watershed will be built on a 3ft by 2.5ft platform, which usually fits on a typical countertop.

1.3 Black Box

Figure 1-1: Our black box demonstrating the objective of the design project.

2. Problem Analysis and Literature Review

2.1 Problem Analysis Introduction

The problem analysis classifies the client's expectations and constraints we may have for the interactive watershed for the 7th and 8th graders. For the problem analysis we will discuss the specifications, considerations, and usage of our project.

2.1.1 Specifications and considerations

The specifications of this project are factors that must be considered for the design process. The following three specifications will be considered during the design process: water should flow smoothly and not make a mess, the reuse water in the watershed for multiple uses, and low maintenance.

2.2 Literature Review

2.2.1 General Watersheds

2.2.1.1 General Watersheds

Watersheds deals with all the surface, subsurface, and groundwater that drain to a common channel and then to another water body. Watersheds can range in size. Hydrology is the study of the principles and processes of water movement and storage in its natural environment. Hydrology is important to understand when dealing with watersheds because watersheds deal with a dynamic and changeable area dependent on water. Watershed hydrology is the study of the movement and storage of water in the watersheds. The hydrologic cycle starts in the atmosphere where the water condenses to precipitation (i.e. rain, and snow). Precipitation is captured by natural vegetative cover and distributed to runoff or the precipitation evaporated back to the atmosphere. The water captured by natural vegetative cover infiltrates the soil and percolates to a detention storage that temporary hold water and if the water is held longer this would be retention storage. Water that moves back to the atmosphere from the ground is evapotranspiration which is a combination of evaporation and transpiration. Evaporation happens when the water moves from the surface to the atmosphere by moving phases to vapor. Transpiration happens when water moves from the soil and roots to the atmosphere. If the water does not go through evapotranspiration, then the water become streamflow, runoff or discharge. Water that is in the stream often come from different storage and sources such as ground water, channel, soil storage and etc. The types of storage are Depression, Channel, Detention, Ground water, Retention, and Vegetation. Storage of water is the quantity of water that is temporary out of the hydraulic cycle.

2.2.1.2 Watershed models

Watershed models help show the impact of human activities on natural processes of the watershed such as the flow of water, sediment, chemicals, nutrients, and microbial organisms.

Watershed models are tools that demonstrate and solve water resource and environmental problems. The strengths of Watershed models are the diversity of problems that can be applied to the model and closely mimic the given areas hydrologic processes. The weakness of watershed models is that most are not user-friendly and some cannot contain the social, political and environmental systems. Watershed models need data that includes hydro-meteorological, geomorphologic, agricultural, pedologic, geologic, hydraulic, and hydrologic.

2.2.1.3 Humboldt watersheds

Humboldt Bay is a natural bay located in Humboldt County in northern California. Water carried by four main creeks and rivers pour into the bay and each of these are fed by their corresponding watersheds. The main watershed in Humboldt are the Jacoby Creek Watershed, Freshwater Creek watershed, Elk River Watershed, and Salmon Creek Watershed, each named for the creek or river that each watershed feeds. Each of these watersheds extends miles inland to the river and creeks' headwaters and incorporate numerous smaller streams, creeks, and tributaries. They extend down towards the bay where the mouth of each watershed is located (Natural resources services 2005). The wetlands and marshes around Humboldt Bay are also recognized as part of the watersheds.

2.2.1.4 Tributaries

A tributary is a smaller body of moving water that feeds into a larger creek or river known as a main stem. Tributaries are usually located high in the watershed near the headwaters and do not flow directly into a lake or ocean. They are categorized into "left-bank tributaries" and "right-bank tributaries" depending on which side of the main stem they are located on when looking downstream. (National Geographic 2013). Tributaries are often formed from snowmelt and precipitation at higher elevations and become very prone to changes in flow and water level with variations in temperature and precipitation. (Van Kirk 2008)

Figure 2-1: Upper Yangtze River and a tributary *(Nature Conservancy 2010)*

2.2.2 Building Materials

2.2.2.1 Clay

Clay has been around for thousands of years as a building material. Clay is non-toxic, affordable and recyclable. The benefits of clay as a material is that it is durable, and healthy. Clay is often mixed with straw and used as a top layer of structures. On the bottom layer of the structure is the frame that is held together with things like wood and other base materials.

2.2.2.2 3D Printing

3D printing is a desktop fabrication where a real object is created from a 3D design. 3D printing works by printing the real object layer by layer. This process is beneficial because it makes it possible to get an exact part in relative short time.

2.2.2.3 Plastics (polymers)

Plastics are slightly flexible and lightweight. There are plastics that cannot be reformed once hardened. These include epoxy resins, polyester resins, Bakelite, melamine, Ural. The plastics that can be reformed are polyethylene, acrylic, ABS, nylon and PVC. Epoxy resin is used often to make a material stronger and more durable.

2.2.2.4 Styrofoam

Styrofoam material is very easy to shape by hand. Sharp knives or hot wire cutter can shape the Styrofoam with ease. Two different forms of Styrofoam are extruded polystyrene and expanded polystyrene. Expanded polystyrene is more fragile than extruded polystyrene. Polystyrene is used in many products to make them lightweight such as surfboards. Polystyrene is made by polymerizing styrene.

2.2.3 Tidal Areas

Tidal areas or tidal zones are the shoreline areas that experience changes in low and high tides. These areas are divided into the spray or splash zone, upper or high intertidal zone, mid intertidal zone, low intertidal zone, and subtidal zone. Splash or spray zones are the highest area. They are usually dry and only covered by the highest tides. High intertidal zones are covered by average high tides. Mid intertidal zones are at the uppermost edge of the average daily high tides and exposed during daily low tides. Low intertidal zones are exposed only during extreme low tides. Subtidal zones are almost always submerged. All of these areas are home to numerous species of invertebrates, algae, and seaweeds (Oregon State Parks 2014). The magnitude and frequency of tidal changes are largely dependent on the shape of the coastal area and the solar and lunar times. Tides are a result of the moon's orbit around the earth. However, the positions of the continents affect the frequency of these tides restricting the movement of water to ocean basins and seas. This results in semidiurnal tide, where a coastline experiences two high and two low tides a day, diurnal tides which are once daily high and low tides, and mixed semidiurnal tides which have two high tides of differing size and two low tides of different size (Groen 2008). Most of the US West Coast experience mixed semidiurnal tides (NOAA 2008). The shape of the tidal area also affects the tidal magnitude with narrow or shallow bay or estuary openings lessening the effects of tides and wide openings amplifying them.

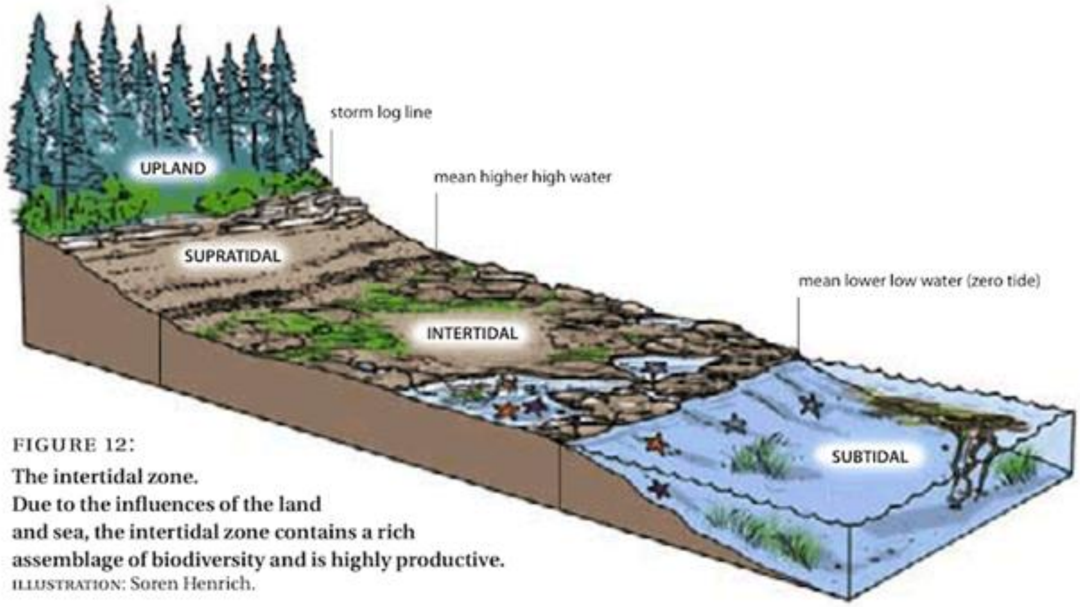


Figure 2-2: Intertidal area illustration *(biodiversitybc.org 2007)*

2.2.3 Wetlands

2.2.3.1 General

Wetlands are complex and play a large role in watershed systems and the corresponding ecosystems. “Wetlands are the transitional zones between terrestrial and aquatic ecosystems which experience seasonal or permanent above surface water” (Klemas, V., 2013). These areas are typically dense in vegetation and act as important habitats for many plants and animals. “Wetlands also provide protection from storm flooding, water quality improvement through filtering of agricultural and industrial waste, and recharge of aquifers” (Klemas, V., 2013). They are able to protect from flooding by acting as sponges and soak up much of the excess water being brought in by the storm. Many of these coastal wetlands are within feet of being lost due to the rising sea levels causing a major concern to protecting wetlands.

2.2.3.2 Pollution deterrence

Wetlands fight against variety of pollution that infiltrate our water systems. “Wetlands remove these pollutants by trapping the sediments and holding them. The slow velocity of water in wetlands allows the sediments to settle to the bottom where wetland plants hold the accumulated sediments in place” (Washington State Department of Ecology, 2016). Runoff is one of the most prominent ways that excess nutrients and contaminants get carried through the ecosystems, often times originating with industrial or individual production.

Figure 2-3: Arcata Wetlands *(Humboldt.edu)*

2.2.4 Ground Water

2.2.4.1 General

Groundwater is Part of an earthly water cycle that has no beginning or end, meaning that water is constantly changing location and form. When liquid water comes into contact with the earth, it will either stay on the surface, or it will be absorbed into the ground. “Some of the infiltrated water will be transpired by plants and returned to the atmosphere, while some will cling to particles surrounding the pore spaces in the subsurface, remaining in the unsaturated zone. The rest of the infiltrated water will move gradually, driven by gravity, into the saturated zone of the subsurface, becoming groundwater. From here, groundwater will flow toward points of discharge such as rivers, lakes, or the ocean to begin the cycle anew” (State of California, 2016). Groundwater plays a huge role in supplying the nation with adequate water supply.

2.2.4.2 Impact of Groundwater

“Some 2.78 million trillion gallons of groundwater, 30.1 percent of the world's freshwater, are estimated for the entire planet of Earth” (NGWA, 2010). With nearly one third of the world’s fresh water residing underground, groundwater plays a large role in supplying water. Even though a large percentage of our water supply comes from groundwater, the vast majority moves very slowly until discharged in some surface water source. “Hydrologists estimate, according to the National Geographic Society, U.S. groundwater reserves to be at least 33,000 trillion gallons — equal to the amount discharged into the Gulf of Mexico by the Mississippi River in the past 200 years” (NGWA, 2010).

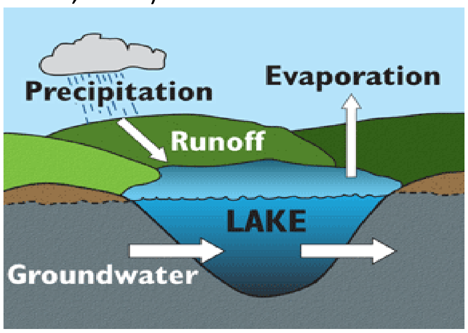


Figure 2-4: Groundwater illustration (Jim Buchholz 2016)

2.2.5 Seasonal River Flow

River flow varies from year to year and season to season. The water flow through the rivers is responsible for land erosion that we see. “All streams carry sediment and most of this sediment has been washed into a channel from surface runoff. Channel beds and banks is also a contributor of sediment. The quantity of sediment in a stream varies temporally due to changes in discharge. Normally, as discharge and velocity increase, the amount of sediment being carried by the stream rises correspondingly” (Michael Pidwirny, 2009). On a normal year in northern California, fall will produce a decent amount of scattered precipitation which will turn into consistent rain and snowfall in the mountains during winter. When spring comes around rain will continue to fall but slow down as summer comes into effect and rain is a rare sight. This has a direct correlation to the level of water flow in river and tributary systems. Rain is a constant supplier to the water flow while the snow melt from high mountains keeps the rivers flowing through the dry season. As pictured in figure__, the Klamath River is in full flow as summer approaches. “In some parts of the world, such as in Washington State in the Pacific Northwest of the United States, annual springtime flood events occur when rain falls on existing snow packs known as a "rain-on-snow event."” (Perlman, 2015)

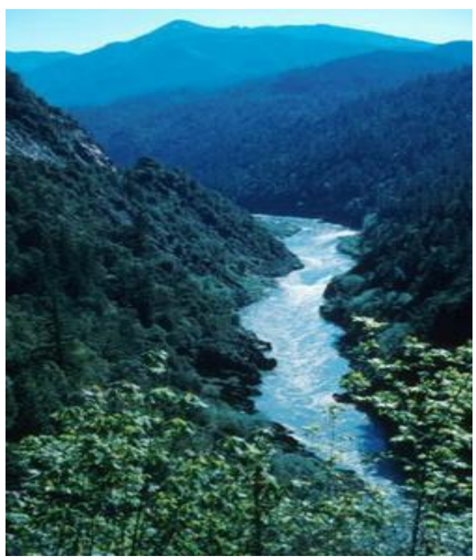


Figure 2-5: Klamath River (U.S. Fish and Wildlife Service 2016)

2.2.6 Point and Nonpoint Pollution Sources

No matter the source, there is always pollution that enters our watershed and into our water system due to human activity. Point source pollutions are an identifiable source, which are usually drainage pipes from factories. The origins of nonpoint source pollution cannot be identified; this type of pollution is usually urban or agricultural run-offs that pick up any type of pollution off the streets and into our waterways. (Harvey 2016)

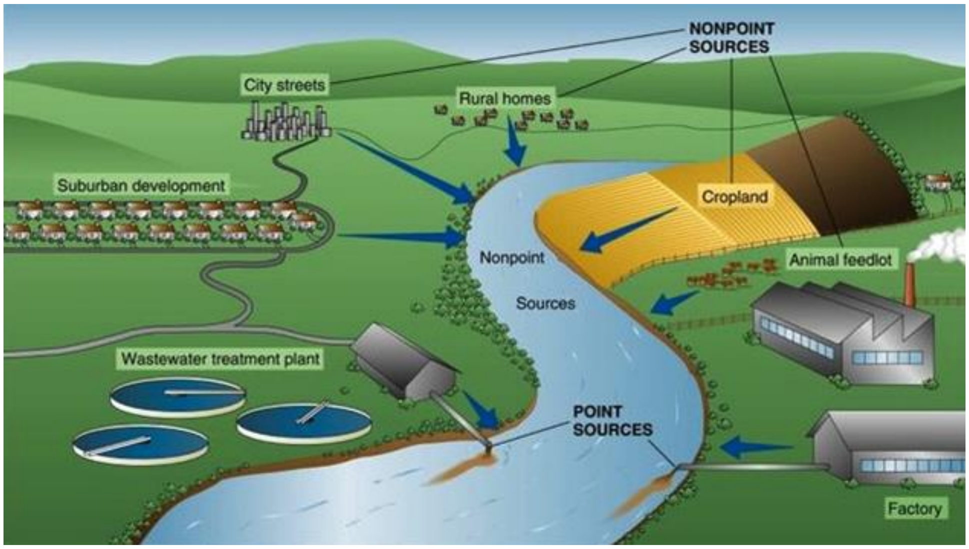


Figure 2-6: Point source pollution and nonpoint source pollution. (Standrige, 2016)

2.2.6.1 Point Source Pollution

"Point-source pollutants in surface water and groundwater are usually found in a plume that has the highest concentrations of the pollutant nearest the source and diminishing concentrations farther away from the source." (Harvey, 2016). Point-source pollutants are found from various sources that can be found in waters that are dispersed by businesses, urban areas, agricultural, and factories (Harvey, 2016).

Everyday many of the factories discharge various wastes, like petroleum, into our water from their factory through the pipes. Agricultural point source pollutions are usually animal feeding operations, or animal waste. (Harvey, 2016)

Many of these point-source pollutions can reach our ground water through infiltrating rainwater beneath the ground. Surface water can also be affected due to airborne pollution, or liquid pollution. (Harvey, 2016)

2.2.6.2Non-Point Source Pollution

Nonpoint-source pollution occurs as water moves across land and picks up any type of pollutants, and the water will carry these pollutants to our waterways. Most of the pollutants do not have a known origin as the water has probably carried it far from its source. Therefore, much of the nonpoint-source pollution spread throughout the land by rainfall or water flowing through the land. (Harvey, 2016)

2.2.6.3 Clean Water Act

The Clean Water Act in 1972 was put into place when people began noticing that our waterways were being polluted by human pollutions, mainly from big businesses and factories. Our waterways are now cleaner and less pollutants are entering our waterways due to the Clean Water Act. (Adreen, 2008)

2.2.6.4 Water Quality Standards

Due to the Clean Water Act, water standards have increased as well. The EPA will review these standards every three years and change anything according to current issues that have to do with our water ways. (Adreen, 2008)

Key Provisions and Proposed Reforms

Section of Act	Statutory Reference	Description	Proposed Reform	Reform Result
End-of-pipe Controls Plus Water Quality Standards				
402	33 U.S.C. § 1342	**NPDES Permit Program.** In order to discharge a pollutant into our waters, every point source discharger must obtain a permit and comply with its terms. Permits incorporate effluent limitations unless more stringent permit limitations are necessary to meet water quality standards.		
		Long Term Control Plans. Combined sewer systems must implement certain controls and develop a Long Term Control Plan (LTCP) to meet state water quality standards as part of their NPDES permits.	Section 402(q) should be amended to require communities with combined sewer systems to incorporate green infrastructure into their Long Term Control Plans.	Prevent pollution caused by sewage overflows and save money on storm-water management costs.
301	33 U.S.C. § 1311	**Effluent Limitations.** Effluent limitations are industry-wide regulations established by EPA that set performance limits for pollution discharge. Existing industrial discharges must meet the following: Best Conventional Pollutant Control Technology (BCT) and Best Available Technology (BAT). POTWs must implement "secondary treatment."	Section 301(b) should be amended to require BAT for conventional pollutants.	Force technological innovation and reduce the level of conventional pollutants in the nation's waters.
			Section 301(d) should be amended to make clear that EPA has a mandatory duty to revise BAT limitations whenever technological improvements meet guideline factors set forth in § 304(b).	Require polluters to keep pace with technological improvements.
304	33 U.S.C. § 1314	**Effluent Guidelines.** Effluent limitations are established by reference to the effluent guidelines which are promulgated under § 304. Section 304 references factors that EPA is to consider in setting effluent limitations.	Section 304(b) should be amended to hold conventional pollutants to the same effluent guidelines as apply to toxic and nonconventional pollutants (BAT).	Force technological innovation and reduce the level of conventional pollutants in the nation's waters.
303	33 U.S.C. § 1313	**Water Quality Standards & TMDLs.** Every three years, states must review water quality standards subject to EPA approval. States must also identify which waters will remain polluted after technology-based standards are implemented, prioritize these waters, and establish "total maximum daily loads" (TMDLs) so that the waters meet applicable water quality standards.	Section 303(d) should be amended to ensure impaired waters are identified in comprehensive fashion. Section 303(d) should clarify that a waterbody is impaired not just when particular chemical criteria are violated, but whenever it cannot meet a designated use.	Protect wildlife and aquatic ecosystems, not just water chemistry.
			Section 303(c) should be amended to include biological criteria and minimum flows so that wildlife and aquatic ecosystems are protected.	Make it clear that TMDLs must address waters whose biological or physical integrity is impaired by hydrological modifications.
			Section 303 should be amended to directly address waters that are impaired, in whole or in part, due to climate change.	Respond to climate change.
			Section 303 should be amended to set reasonable deadlines for the establishment of TMDLs.	Insert accountability into the TMDL program

Figure 2-7: Clean Water Act reform by the EPA, changing certain standards that pertain to current political issues. (Adreen 2008)

2.2.7 Effects of Development on Watershed

Development on a watershed can greatly increase the quality of our waterways in a negative way. Naturally our waters will run down from the mountains to sea level and into the very waters that we use to drink from. With natural occurrences mixed with human development, water can carry human pollutants into our waterways. (Palanisami, 2009)

Figure 2-8: Watershed without human development (Parishad) v. a watershed with human development (City Of Columbia)

3. Alternative Solutions

3.1 introduction

Section 3 describes the alternative solutions for building the watershed model. In this section will cover our brainstorming session that helped us produce six alternative solutions. These alternative solutions meet the design criteria in Section 2 with an emphasis on safety, portability, and general structure.

3.2 Brainstorming

The A Team conducted a trio of brainstorming sessions that led to the proposals for the alternative solutions. One session was a free flowing unstructured meeting the ideas of quantity over quality. The second session branched off the ideas of the unstructured meeting to get a deeper understanding of each alternative solution. The third session developed the six best ideas that honed in from our first and second brainstorming session. In these sessions, there was the use of whiteboards, paper, computer, and our imaginations (refer to appendix).

3.3 Alternative Solutions

Alternative solutions are design ideas that are based upon our brainstorming sessions and the literature review. Section 3.3.1-3.3.6 includes descriptions of the following solutions: Build Yo' Own Dough, Own the Foam, SimCity, One Mountain One Love, Clay All Day, and Now You See Me.
In addition, each solution includes a base material, water resistant material, water usage, food coloring, and dimensions of 3 by 2.5 feet. Food coloring will demonstrate the pollution that is carried by the water. Water resistant material will make the materials water resistant and durable. The dimensions for our watershed model are required for the classroom setting.

3.3.1 Build Yo' Own Dough

Build Yo' Own Dough is the interactive model that has been proposed through the brainstorming session. Build Yo’ Own Dough allows the students to construct their own version of a watershed model with suggested guidance. Water compatible playdoh will be the foundation for the students to build their own version. This alternative solution will come with a base and the components required to build a watershed model. The model will have its own base with a type of casting that the students will build upon. The casting will show a suggested watershed, but the students have the power to create with their own imagination.

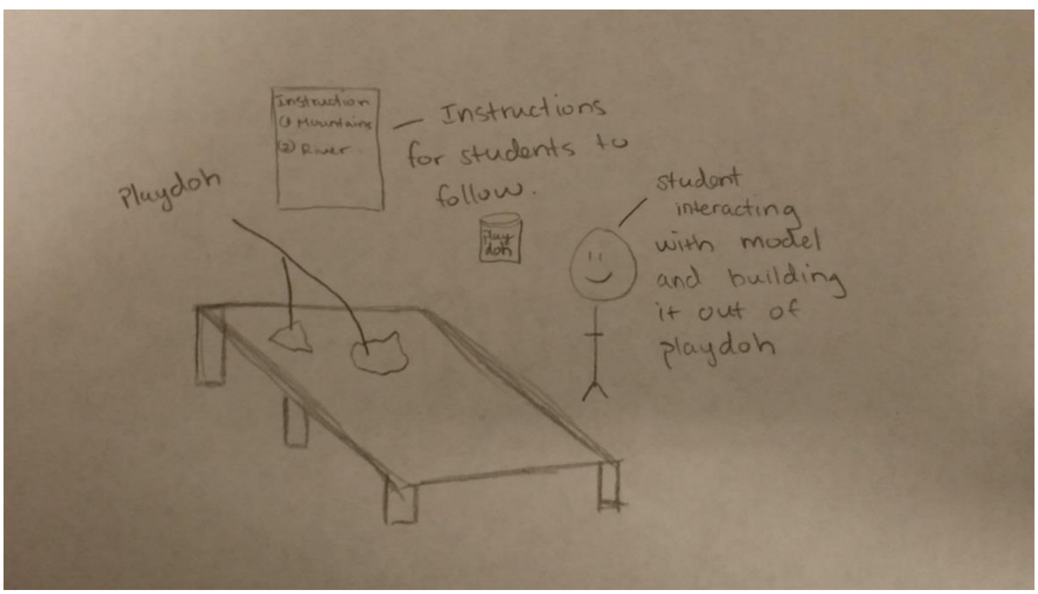


Figure 3-1: Build Yo’ Own Doh’ (Photo by Tran Huyen Pham)

3.3.2 Own the Foam

Own the Foam will be a detailed form of a watershed model with the plastic coating to make it water resistant. There will be a wood base for the model with recyclable Styrofoam that will be cut into desirable shapes to build our watershed. Appropriate indentations will allow for the multiple uses of different structures to show a range of watersheds. A type of water resistant coating will be applied to the model to allow for durability and easy water runoff. The model will most detailed due to the fact that Styrofoam is easy to carve into desirable structures. The Styrofoam will be a solid foundation once the protective coating is implemented so that water runoff is fluid. This design will be eco-friendly because it is recyclable material that is gathered from environmentally conscious companies.

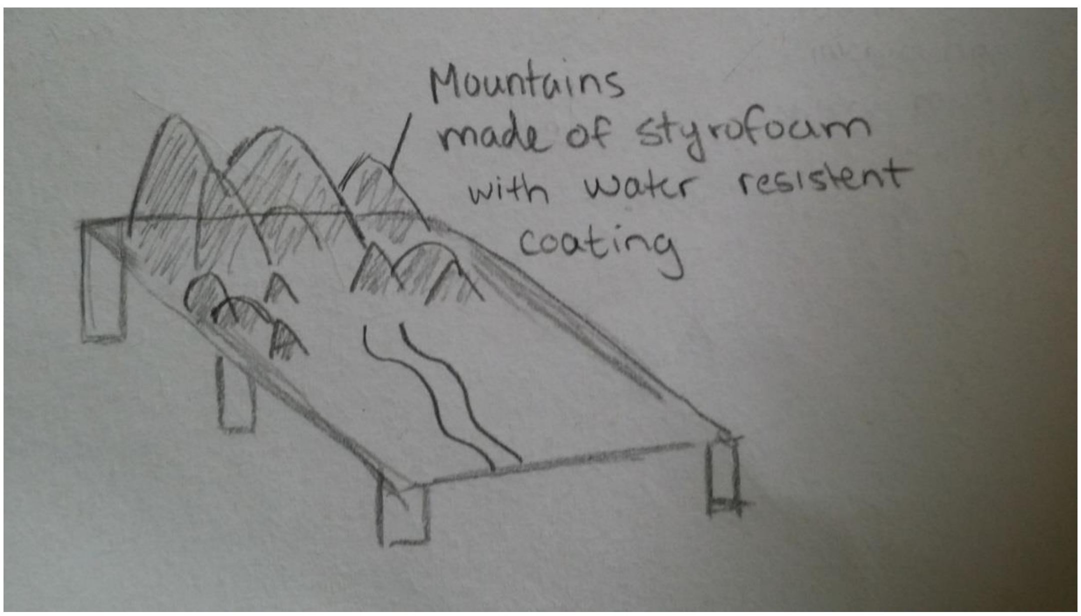


Figure 3-2: Own the Foam (Photo by Tran Huyen Pham)

3.3.3 SimCity

SimCity is an alternative solution that will demonstrate the urban setting within the watershed model. This watershed model will implement the ideas of how human development can affect the watershed. The solution illustrates more manufacture point source pollution and nonpoint source pollution. This model will have detachable buildings so the students can compare undeveloped parts of a watershed to a parts that have human development.
This model will have more urban settings in the flat lands of the watershed system to illustrate human development. The general idea of water runoff is the same as previously mentioned alternative solutions, but demonstrates a more detailed model of urban development.

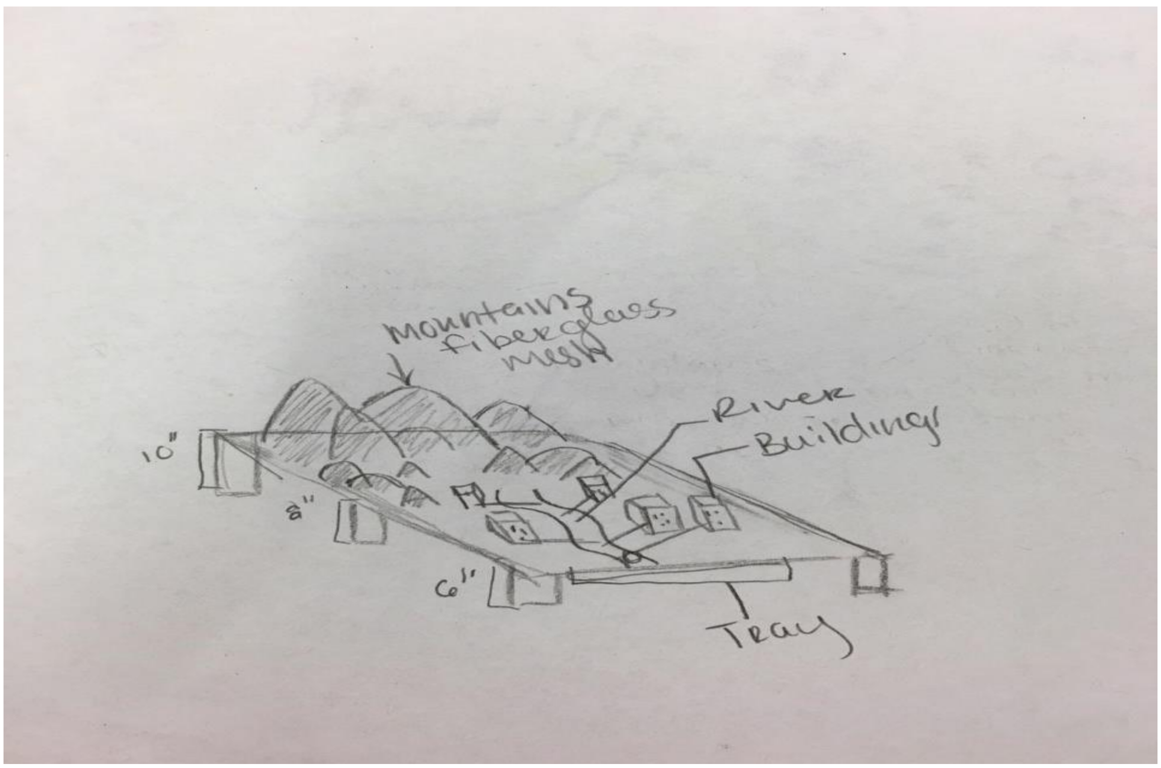


Figure 3-3: SimCity (Photo by Jessica Ramirez)

3.3.4 One Mountain One Love

One Mountain One Love is an alternative solution that will demonstrate natural water flow coming straight off of one mountain. The mountain range is detachable and fixed to a slanted wood platform that promotes the natural flow of water. The model will show how water enters mountain streams and flows to the ocean. This model is simple to design and construct while effectively demonstrating a basic watershed. It will include more details in the rivers, meandering stream, and tributaries within the watershed. The confluence of water is important for the students understanding of how pollution travels through a water system.

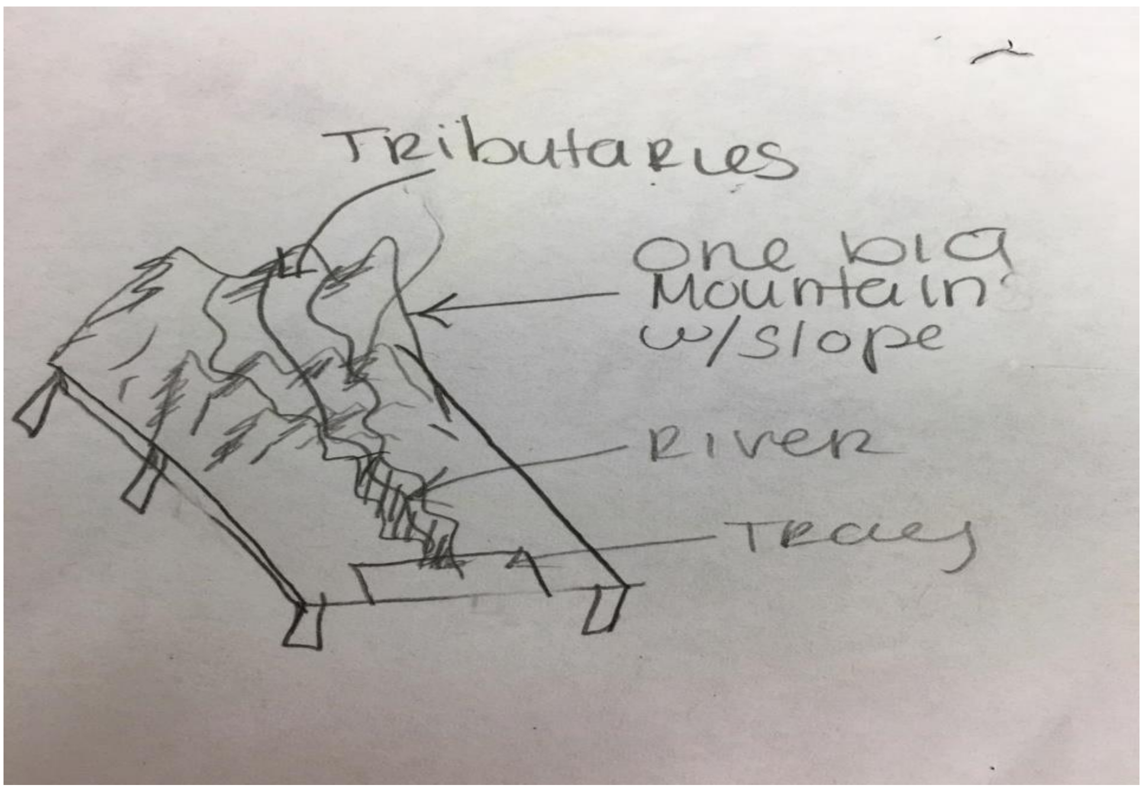


Figure 3-4: One Mountain One Love (Photo by Jessica Ramirez)

3.3.5 Clay All Day

Clay All Day is constructed from a mixture of clay and other natural materials. These materials are eco-friendly, cost effective, and easy to obtain. It implements natural geology of watersheds into a miniature structure. Clay can be made durable through natural remedies such the addition of lime or by simply firing it. Clay is also easy to mold into a desirable shape. The model will be constructed on a wood base. The solid foundation will support the final form of the hardened clay, ensuring stability and durability. It will include a mountains that resemble those around Humboldt and will flatten into the wetlands on the coast.

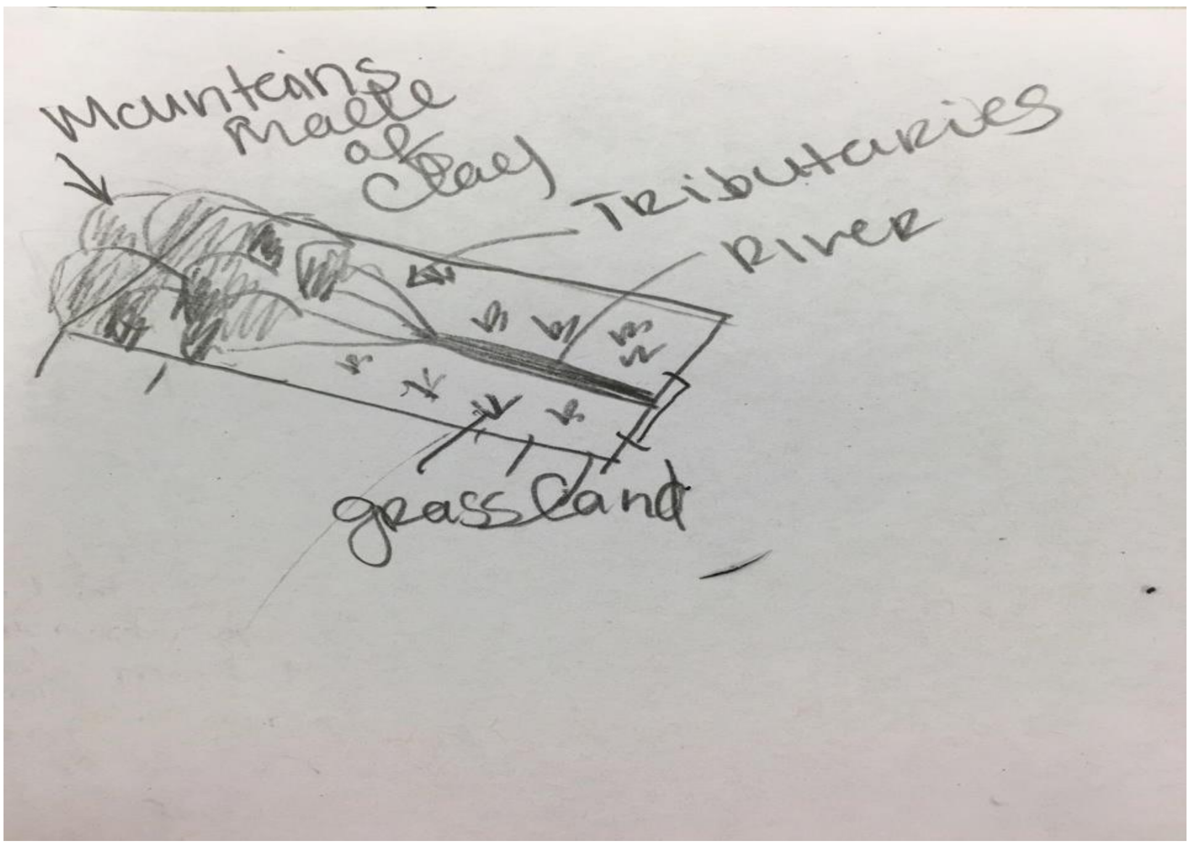


Figure 3-5: Clay All Day (Photo by Jessica Ramirez)

3.3.6 Now You See Me

Now You See Me is an alternative solution model that will show the effects of pollution as it runs through the ground water. This alternative will possibly a complete watershed system due to the fact that the students can see below the surface. This will implement the essence of nonpoint pollution and how it can reach the groundwater that many people drink from. This model will demonstrate the impact of pollution on groundwater and human use.
This model will have a see through material that will be structured to illustrate the groundwater system. The model will be built in a similar fashion to previously mentioned models but is different in the fact that there is the aspect of ground water. This could be beneficial in the structure because the drainage of water from the model can be more effective.

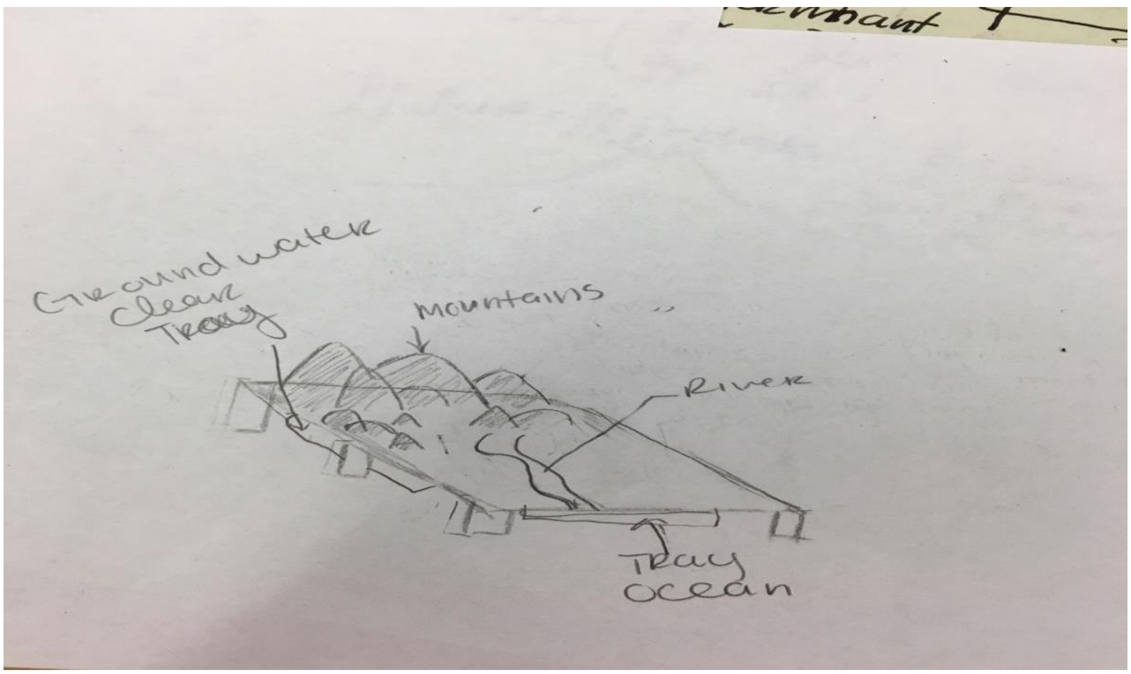


Figure 3-6: Now You See Me (Photo by Jessica Ramirez)

4 Decision Process

4.1 Introduction to the Decision Phase

Section 4 outlines the development of the final solution that is chosen from the alternative solutions listed in Section 3. The criteria outlined in Section 2 are used to decide the top quality solution.

4.2 Criteria definition

Listed below is the criteria that were decided in Section 2.

- **Cost**- The cost shall not exceed $300 dollars.
- **Durability**- The model shall maintain its structural reliability and functionality over time.
- **Ease of Use**- The model will need to be able to be understood and used by students age 10 and above.
- **Consistency**- The model will need to perform consistently.
- **Educational**- The model will be interactive in showing watershed features and pollution within watersheds.

4.3 Solutions

The alternative solutions listed below are detailed and diagrammed in Section 3:
- Build Yo' Own Dough
- Own the Foam
- SimCity
- One Mountain One Love
- Clay All Day
- Now You See Me

4.4 Decision Process

The method used in facilitating the decision process was the Delphi method. In the Delphi Method, The A Team determined the weight of each criterion showing the ranking of the criteria. The higher the weight the more important, and higher, the rank of the individual criterion. The list of criteria with weights are shown in Table 4-1.
After the criteria weights were determined, The A Team scored each alternative solution ranging from one to thirty according how each solution meets each criterion. A high score will demonstrate the solution’s ability to adequately fulfill a criterion. A low score will demonstrate the solution's inability to adequately fulfill a criterion. The scores of each alternative solution are shown in the Delphi Matrix. After each solution is scored for each criteria, the solutions are multiplied by the weight of the criteria resulting in a final overall score for each alternative.

Table 4-1: Design Criteria and weights

Criteria	Weight
Educational	10
Durability	10
Cost	6
Consistency	9
Ease of use	7

Table 4-2: Delphi Decision Matrix

Criteria		***Solution***											
List	**Weight**	**Build Yo' Own Doh**		**Own the Foam**		**SimCity**		**One Mountain One Love**		**Clay All Day**		**Now You See Me**	
Cost	6	30	180	35	210	40	240	25	150	35	210	10	60
Durability	10	10	100	35	350	35	350	40	400	30	300	40	400
Ease of Use	7	40	280	45	315	40	280	50	350	35	245	40	280
Consistency	9	10	90	25	225	25	225	35	315	35	315	35	315
Educational	10	50	500	30	300	35	350	10	100	30	300	40	400
Total		1150		1400		1445		1315		1370		1455	

4.5 Final Decision Justification

Based on the Delphi Method results, the alternate solution SimCity had the second highest score next to Now You See Me. Although it was close in score to Now You See Me, it was decided that the educational value, ease of use, and buildability of SimCity made it the better option. This is due to the inclusion of an urban setting in the flatlands which can illustrate human pollution in a watershed system. It is important to the client and to the A team that the watershed model be informative and educational. SimCity also scored highly in the Delphi method criteria of durability, cost, and consistency.

5. Specifications

5.1 Introduction

Section 5 is a detailed description of the final design for the interactive watershed model chosen in Section 4. This description includes CAD drawings illustrating the model's components and the functions, a cost overview with details on the design cost in hours, implementation cost, and maintenance cost, instructions on its use and implementation, and results from testing.

5.2 Description of Solution

SimCity is an alternative solution that will demonstrate the urban setting within the watershed model. This watershed model will implement the ideas of how human development affects the watershed such as point source pollution, nonpoint source pollution and removing natural filter system like the marsh. This model will have an urban setting in the flat lands of the watershed system showing water runoff polluting the main river line. The mountains at the top will show the basic watershed features such as tributaries that form to a mandarin that runs to the main body of water. The main river will go through two parts after coming down the mountain. The first part will be a group of buildings that can be shown as either houses or industrial buildings. These buildings will have a tube section that will flow to the river. The tube section will have the ability to indicate point source pollution by placing dye in the tube section. The second part the river will run through will be a marsh. The marsh will be a filtering system for the dye in the water before the water reaches the final destination, a clear tray. The marsh will be a removable part so that the watershed model will show the negative impact when the marsh is removed. The main part of the body of water will be the final destination implemented with a clear tray that will show the results of pollution indicated by food dye or colored gelatin. The movement of water and pollutants through the model can be viewed in Figure 5-1.

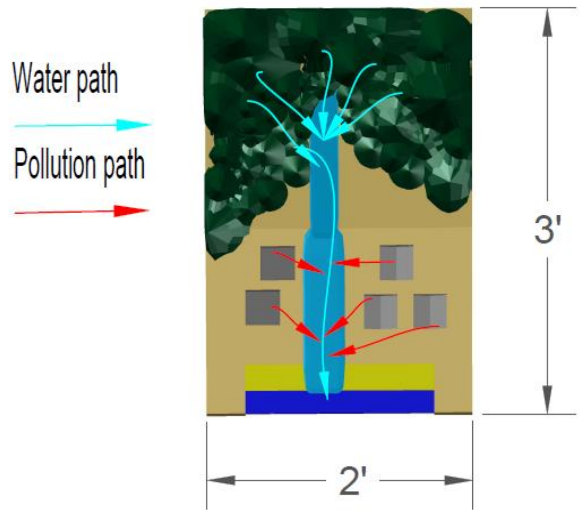


Figure 5-1: Top View CAD Drawing of water and pollutant paths

5.2.1 Base

The base of the watershed model is constructed from plywood and two by fours. The surface on which the mountains and structures are built on is formed from two pieces of plywood both 2 feet by 1.5 feet. The first piece of plywood at the back end of the model is angled downward at about 6°. The second is angled at about 3°.These are supported by three sets of legs constructed from two by fours with each set of legs measuring 10”, 8’’, and 7’’. The two different inclines help to facilitates quicker water flow at the top of the model in the mountains and headwaters and slower flow through the urban area. A depression is carved into the top piece of plywood to direct water flow into a main river. The base was then painted and lacquered to provide a water resistant surface for the water to flow over and to help prevent possible water damage.

5.2.2 Mountains

The mountains are constructed from chicken wire and fiber glass. The general shape of the mountains are formed out of chicken wire. The fiberglass is mixed with paint to give the mountains color. The chicken wire frames are then coated in the fiberglass and allowed to harden.

Figure 5-2: Completed Model Mountains

5.2.3 Buildings

Model structures are located at the lower, flatter end of the watershed. These buildings are made from upcycled plastic milk cartons. They are painted and affixed with droppers connected to straws protruding from each container. Simulating point-source pollutants, the droppers can be filled with food coloring which will then flow out through the straws and on to the model's surface. As water flows through this area of the watershed, pollutants will accumulate and be carried towards the collection container with the rest of the water.

5.3 Costs

5.3.1 Design Cost (hours)

Design cost is the total amount of hours that were spent on each phase of the design process. A total of 113 hours were spent on the design project. The figure below illustrates the design cost in hours spent per phase. The majority of the time spent was on the solution implementation in phase V.

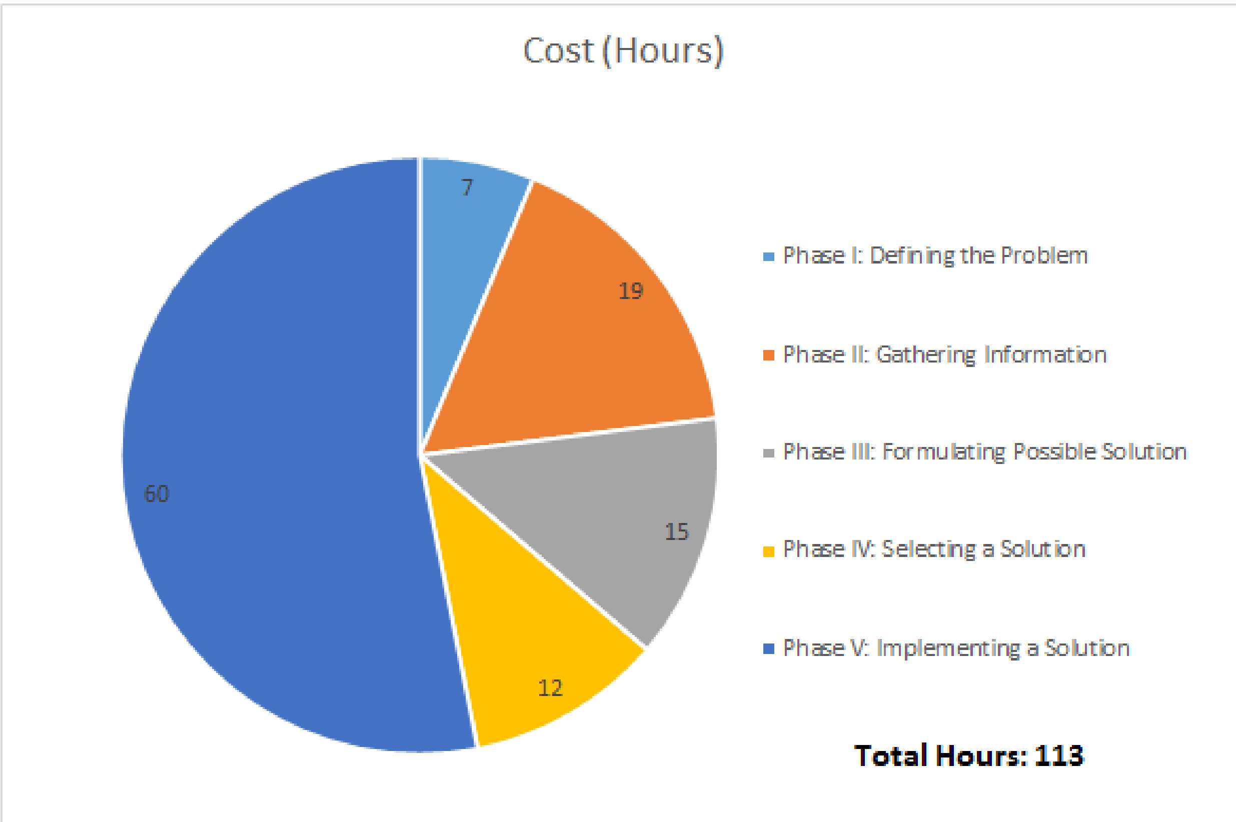


Figure 5-3: Design Cost per Phase

5.3.2 Implementation Cost ($)

Implementation cost is the total cost that went into the construction of the interactive watershed model. Table 1-1 shows the individual cost of each material used in the project. The materials that were repurposed or up-cycled are listed as free. The total implementation cost was approximately $105.

Table 5-1: Material Costs

Materials	**Cost**
Chicken Wire	$15
Lacquer	$9
Milk Carton	Free
Glue	$10
Paint	$10
Straw	Free
Tray	$5
Sponge	$1
Wood	$25
Fiberglass	$30
Total	$105

5.3.3 Maintenance Cost ($)

The operation and maintenance cost for the watershed model are relatively low and dependent on the frequency of use. The maintenance includes cleaning residue left over from food dye and water after every use, replacing the sponge after every 50 uses or whenever necessary, and purchasing food dye when out. The total operation and maintenance cost is estimated to be no more than $17 annually.

Table 5-2: Operation and Maintenance Costs

Task	Frequency	Cost(Minutes)	Cost($)
Clean Residue	After every use	5	0
Purchase Food Dye	When it runs out	2	5

5.4 Instructions for Implementation and Use of Model

The model is to be set up and operated in a classroom. Water and food coloring will be used in the model. The user will place desired amounts of food coloring along the path of water flow either on the model's surface or in designated buildings. The sponge will be placed at the end of the model to simulate a wetland or marsh if the user wish to do so. The sponge does not have to be used so that it may show the environmental effects that occur in its absence. Water will be poured from a watering can or sprayed from a spray bottle on to the model. The incline and watercourse will direct the water downstream through the mountains, urban area, and into the collection container. The user will be able to see the effects that the simulated pollutants have on the water quality throughout the model.

5.5 Results

The testing of the watershed model went well, but we have found some minor flaws as to the water being poured onto the mountains. We realized that if the students were to pour too fast, it would overflow the rivers and tributaries and push the water out to the sides. This is something we don't want as it can get the classroom messy, especially if there is food dye in the water. We only want it to go to one destination, which is the tray. Overall, the model works very well and all we need to do is to fix this minor flaw and our model is ready to go.

References

Adreen, William L., and Shana Campbell Jones 2008. *The Clean Water Act: A Blueprint for Reform*. Carbondale, IL: Council, 1991. Center of Progressive Reform, July 2008. Web. 22 Feb.2016.

Andresen, Frank. "An Introduction to Traditional and Modern German Clay Building." *Natural Building Colloquium*. NetWorks, 2016. Web. 23 Feb. 2016.

Black, P.(1996). Watershed Hydrology. Chelsea, Mich.: Ann Arbor Press

Chemical, Staff. "What Is Polystyrene?" *Chemical Safety Facts*. ChemicalSafetyFacts.org, 01 May 2014. Web. 24 Feb 2016.

Fish, Water 4. "The Klamath River." *Water4Fish*. Water4Fish, 2012. Web. 02 May 2016.

Groen, Pier, 2016. "Tide | Physics." *Encyclopedia Britannica Online*. Encyclopedia Britannica, Web. 23 Feb. 2016.

Harvey, Julie K. "Pollution Sources: Point and Nonpoint." *Water Encyclopedia*. Advameg, Inc., n.d. Web. 22 Feb. 2016.

Hirsch, Robert M. United States Geological Survey, 2016. "Groundwater and Surface Water Interaction." Feb 10, 2016. Web. 23 Feb. 2016.

Humboldt State University Engineering 115. "Arcata Wastewater Treatment Plant & Arcata Marsh and Wildlife Sanctuary." Web. 23 Feb. 2016.

Jim Buchholz 2016, “Central Wisconsin Essentials: The basics of Geology and Natural landscapes”. University of Wisconsin Stevens Point, 2016

Klemas, Victor. "Remote Sensing of Coastal Wetland Biomass: An Overview." (n.d.): n. pag. *Ebscohost*. Web.

National Geographic Society, 18 Apr. 2013"Tributary." *National Geographic Education*.. Web. 21 Feb. 2016.

Natural resources services 21 Mar. 2005"Current NRS Projects: Humboldt Bay Watershed Enhancement Program." *Current NRS Projects: Humboldt Bay Watershed Enhancement Program*. Web. 20 Feb. 2016.

Nature Conservancy, 2010. “This is a tribute”, mother nature network. Mmn, 20 July. 2010.

NGWA. "Groundwater Facts - National Groundwater Association." *National Groundwater Association*. National Ground Water Association, 18 Oct. 2010. Web. 02 May 2016.

NOAA 2008, "Tides and Water Levels." *NOAA National Ocean Service Education:*. NOAA, 25 Mar. 2008. Web. 21 Feb. 2016.

Oregon State Parks, 2014"Tidal Zones." *Tidal Zones*. Oregon State Parks, n.d. Web. 21 Feb. 2016.

Palanisamia, K., and D. Suresh Kumar 2009."Impacts of Watershed Development Programmes: Experiences and Evidences from Tamil Nadu." Agricultural Economics Research Review, 2009. Web. 23 Feb. 2016.

Parishad, Malvanchal Vikas 1997. "Watershed Development for Milli Watershed." *WordPress*. WordPress, 10 July 1997. Web. 23 Feb. 2016.

Perlman, Howard. "Snowmelt - The Water Cycle." *USGS-Science for a Changing World*. U.S Geological Survey, 7 Aug. 2015. Web. 23 Feb. 2016.

Singh, V., & Frevert, D. (2006). Watershed Models. Boca Raton: Taylor & Francis.

Staff, Columbia. "Do You Know Your Shed?" *City Of Columbia*. City Of Columbia, n.d. Web. 23 Feb. 2016.

Standrige, Karla. "Pollution -." *Mission Resource Conservation District*. MRCD, 9 July 2015. Web. 23 Feb. 2016.

Van Kirk, Robert W., and Seth W. Naman, 2008. "RELATIVE EFFECTS OF CLIMATE AND WATER USE ON BASE-FLOW TRENDS IN THE LOWER KLAMATH BASIN." *Journal of the American Water Resources Association* 44.4 (2008): 1035-052. *Ebscohost*. Web. 23 Feb. 2016.

Warren, Staff. "Material Properties." *Material Properties*. Warren School, 2016. Web. 23 Feb. 2016.

Washington State Department of Ecology, "Functions and Values of Wetlands | Washington State Department of Ecology." *Functions and Values of Wetlands*. n.d. Web. 23 Feb. 2016.

6 Appendix

6.1 Group Members Project Hours

Tanner Sakurai 12-week project hours for ENGR 215.

Tanner Sakurai						
All Time in Hours						
Date	Task Description	General Course Time		Project Time		Total Time Course
		Task	Total	Task	Total	
2/12/2016	Meeting with client	0	0	1	1	1
2/14/2016	section I group meeting	0	0	1	2	2
2/18/2016	section II group meeting	0	0	1	3	3
2/21/2016	group meeting	0	0	1	4	4
2/23/2016	lit review	0	0	2	6	6
2/24/2016	lit review	0	0	2	8	8
2/25/2016	Group meeting	0	0	1	9	9
3/6/2016	group eval	0	0	1	10	10
3/9/2016	problem analysis	0	0	3	13	13
3/15/2016	section III	0	0	2	15	15
3/16/2016	section III	0	0	1	16	16
3/20/2016	AutoCAD model	3	3	3	19	22
4/1/2016	team meeting	0	3	1	20	23
4/9/2016	project building	0	3	2	22	25
4/15/2016	project building	0	3	2	24	27
4/19/2016	Document edits	0	3	2	26	29
4/20/2016	presentation rehersal	0	3	1	27	30
4/21/2016	presentation rehersal	0	3	1	28	31
4/25/2016	section 5 revisions	0	3	2	30	33
4/29/2016	document edits	0	3	1	31	34
4/30/2016	document edits	0	3	2	33	36
5/1/2016	model tests	0	3	1	34	37

Scott Harrison 12-week project hours for ENGR 215.

Scott Harrison						
All time in hours						
Date	Task Description	General Course Time		Project Time		Total Course Time
		Task	Total	Task	Total	
2/12/2016	Meeting with Client	0	0	1	1	1
2/14/2016	Meeting with Team	0	0	1	2	2
2/14/2016	Timesheet	1	1	0	2	3
2/18/2016	Team Meeting	0	1	1	3	4
2/21/2016	Team Meeting	0	1	1	4	5
2/23/2016	Literature Review	0	1	4	8	9
2/24/2016	CAD Practice	2	3	0	8	11
2/26/2016	Section II work	0	3	2	10	13
2/28/2016	CAD Practice	2	5	0	10	15
3/4/2016	Formatting Word	0	5	2	12	17
3/5/2016	Team Evals	0	5	2	14	19
3/9/2016	Brainstorming/prob anal	0	5	3	17	22
3/15/2016	Section III work	0	5	1	18	23
3/16/2016	Section III work	0	5	2	20	25
3/22/2016	AutoCad Model	0	5	2	22	27
3/27/2016	Document edits	0	5	1	23	28
3/27/2016	Individual Refrences	0	5	1	24	29
3/29/2016	Excel Practice	1	6	0	24	30
4/1/2016	Team Meeting	0	6	1	25	31
4/9/2016	Project Building	0	6	2	27	33
4/16/2016	Project Building	0	6	2	29	35
4/17/2016	Project Building	0	6	1	30	36
4/20/2016	Presentation Rehersal	0	6	2	32	38
4/21/2016	Presentation Rehersal	0	6	1	33	39
4/25/2016	Buying Supplies	0	6	1	34	40
4/30/2016	Document Edits	0	6	3	35	41

4/30/2016	Project Building	0	6	3	38	44	
5/1/2016	Project Trial	0	6	1	39	45	
5/2/2016	Document Touch-ups	0	6	2	41	47	

Jessica Ramirez 12-week project hours for ENGR 215.

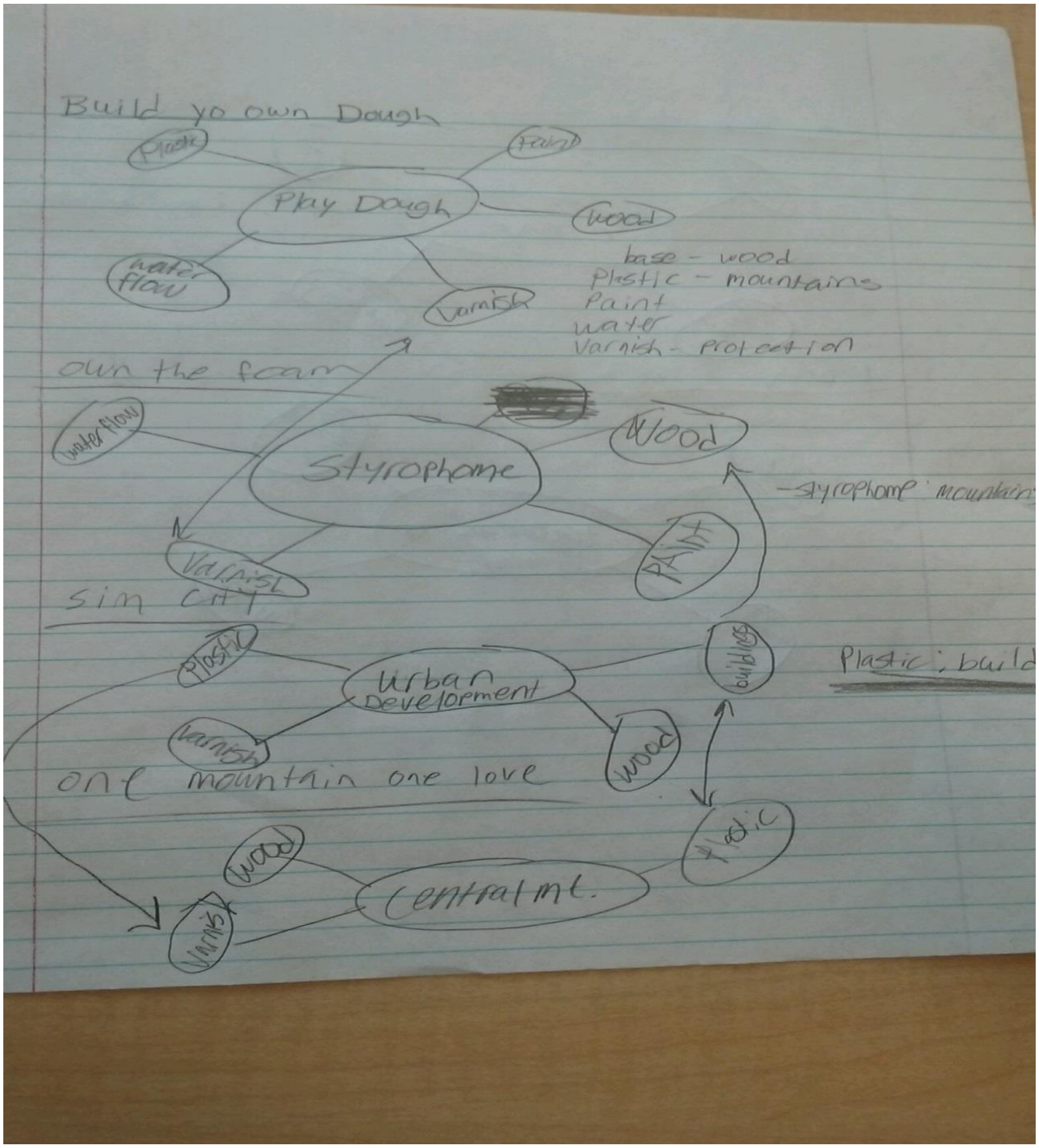
Jessica Ramirez Engr215 Lab Thursday 2pm-5pm						
All time in hours						
Date	**Task Description**	**General Course Time**		**Project Time**		**Total Course Time**
		Task	**Total**	**Task**	**Total**	
2/12/2016	Meeting with client	0.0	0.0	1.0	1.0	1.0
2/13/2016	Time sheet	1.0	1.0	0.0	1.0	2.0
2/14/2016	Team Meeting	0.0	1.0	1.5	2.5	3.5
2/14/2016	Section 1 writing	1.0	2.0	0.0	2.5	4.5
2/19/2016	Team meeting	0.0	2.0	1.0	3.5	5.5
2/23/2016	section II writing	0.0	2.0	6.0	9.5	11.5
2/24/2016	Peer Editing	0.0	2.0	2.0	11.5	13.5
2/24/2016	CAD #2	2.0	4.0	0.0	11.5	15.5
2/27/2016	2nd sec II writing	0.0	4.0	1.0	12.5	16.5
3/7/2016	word #2	1.0	5.0	0.0	12.5	17.5
3/7/0206	Team evaluation	0.0	5.0	2.0	14.5	19.5
3/10/2016	Team meeting	0.0	5.0	2.0	16.5	21.5
3/14/2016	section editing	0.0	5.0	3.0	19.5	24.5
3/16/2016	section 3	0.0	5.0	2.0	21.5	26.5
3/23/2016	autocad drawing	1.0	6.0	2.0	23.5	29.5
4/1/2016	Team meeting	0.0	6.0	1.0	24.5	30.5
4/5/2016	Poster draft	0.0	6.0	2.0	26.5	32.5
4/7/2016	appropedia	0.0	6.0	1.0	27.5	33.5
4/8/2016	final autocad	0.0	6.0	2.0	29.5	35.5
4/9/2016	email client	0.0	6.0	0.5	30.0	36.0
4/9/2016	section V	0.0	6.0	2.0	32.0	38.0
4/9/2016	building	0.0	6.0	3.0	35.0	41.0
4/15/2016	building	0.0	6.0	2.1	37.1	43.1
4/25/2016	Mountains build	0.0	6.0	4.0	41.1	47.1
4/26/2016	Mountains fiberglassed	0.0	6.0	5.0	46.1	52.1
4/27/2016	Practice presentation	0.0	6.0	2.0	48.1	54.1
4/28/2016	Practice presentation	0.0	6.0	1.0	49.1	55.1
4/29/2016	Poster	0.0	6.0	2.0	48.1	54.1

Tran Huyen Pham 12-week project hours for ENGR 215.

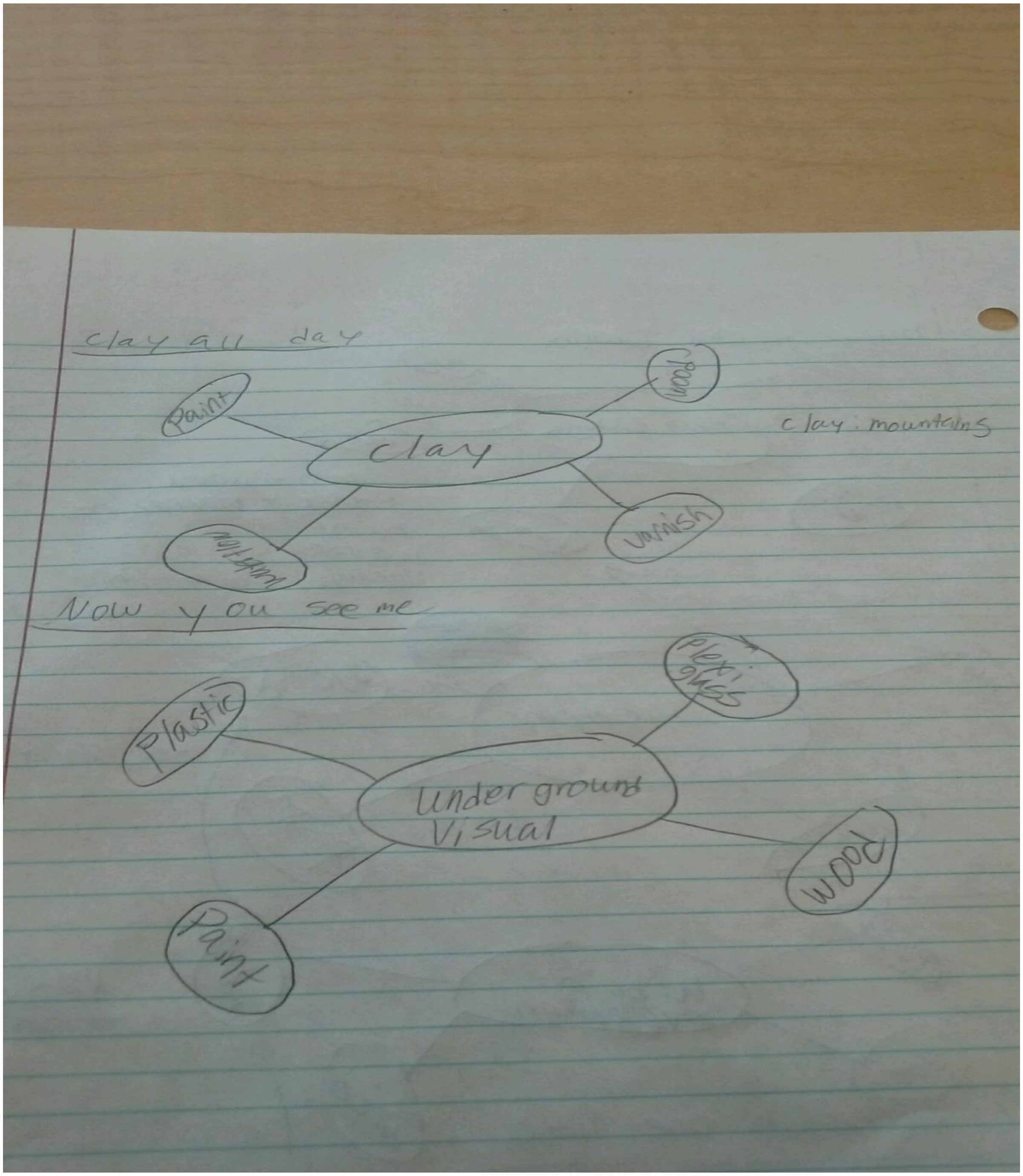
Tran Huyen Pham						
All times are in Hours						
Date	Task Description	General Course Time		Project Time		Total Course Time
		Task	Total	Task	Total	
2/14/2016	Team Meeting	0.0	0.0	0.5	0.5	0.5
2/14/2016	Section 1 Writing	0.0	0.0	0.5	1.0	1.0
2/14/2016	Time Sheet	1.0	1.0	0.0	1.0	2.0
2/19/2016	ACAD #2	2.0	3.0	0.0	1.0	4.0
2/21/2016	Excel #2	2.0	5.0	0.0	1.0	6.0
2/21/2016	Team Meeting	0.0	5.0	1.0	2.0	7.0
2/21/2016	Section 2 Writing	0.0	5.0	2.0	4.0	9.0
2/23/2016	Literature Review	0.0	5.0	3.0	7.0	12.0
2/24/2016	Literature Review	0.0	5.0	1.0	8.0	13.0
2/25/2016	Team Meeting	0.0	5.0	0.5	8.5	13.5
2/25/2016	ACAD #2	0.8	5.8	0.0	8.5	14.3
3/6/2016	Brainstorm	0.0	5.8	0.4	8.9	14.7
3/6/2016	Formatting with Word #2	0.3	6.1	0.0	8.9	15.0
3/7/2016	Brainstorm	0.0	6.1	0.3	9.2	15.3
3/7/2016	Midterm Evaluations	0.5	6.6	0.0	9.2	15.8
3/9/2016	Brainstorm	0.0	6.6	0.5	9.7	16.3
3/9/2016	Section 3 Writing	0.0	6.6	1.5	11.2	17.8
3/10/2016	Finalizing sectionIII draft	0.0	6.6	0.5	11.7	18.3
3/10/2016	Meeting with Professor	0.0	6.6	0.5	12.2	18.8
3/21/2016	Section 4	0.0	6.6	4.0	16.2	22.8
3/23/2016	CAD #3	2.0	8.6	0.0	16.2	24.8
3/27/2016	Individual References	0.8	9.4	0.0	16.2	25.6
4/1/2016	Team Meeting	0.0	9.4	1.2	17.4	26.8
4/9/2016	Team Project Building	0.0	9.4	2.4	19.8	29.2
4/11/2015	Section 5	0.5	9.9	1.0	20.8	30.7
4/15/2016	Team Project Building	0.0	9.9	2.1	22.9	32.8

4/17/2016	Presentation Practice	0.0	9.9	1.3	24.2	34.1
4/20/2016	Presentation Practice	0.0	9.9	1.0	25.2	35.1
4/22/2016	Team Project Building	0.0	9.9	2.0	27.2	37.1
4/30/2016	Team Project Building	0.0	9.9	2.1	29.3	39.2
5/1/2016	Apropedia Page	0.0	9.9	4.0	33.3	43.2
5/1/2016	Model Testing	0.0	9.9	0.9	34.2	44.1

Appendix A: Brainstorm Session (1)



Appendix B: Brainstorming Session (2)



Appendix C: Brainstorming Session (3)