TEAM 13: HUDSONVILLE HYDRAULIC OPERATION

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1 - Problem Statement

Hudsonville Hydraulic Operation is assessing two locations of flooding within the City of Hudsonville. The City of Hudsonville, located in Western Michigan south west of Grand Rapids, can be located on the map displayed in Figure 1. The first location concerns a model to eliminate flooding problems along Buttermilk Creek, which flows through Summergreen Golf Links, flooding the course and the backyards of several apartment buildings. A number of options for detention are being considered in the area near Holland Drive, just North of I-196 along Buttermilk Creek. The city of Hudsonville is looking to expand into this golf course area, making it a residential neighborhood and eliminating floodplain property. This area is indicated by the number 1 on the map in Figure 2. The second location is just west of 36th Avenue and south of Chicago Drive involving an onion farm that drains into the backyards and sometimes basements of several homes. This flooding sometimes flows straight over 36th Avenue and into Summergreen Golf Links creating more flooding problems. This area is indicated by the number 2 on the map in Figure 2. Team 13 will analyze rainfall data and soil types of these two sites to create a harmonious proposal to the City of Hudsonville to alleviate the flooding problems in these two locations.

Figure 1: The City of Hudsonville Relative to the City of Grand Rapids
2 - Background and History

2.1 - Introduction

The City of Hudsonville covers an area of 5 square miles in Ottawa County located in the Southwest Lower Section 8 in the state of Michigan. The City is nicknamed “Michigan’s Salad Bowl” due to the city’s deep agricultural history. Because of the city’s small size and growing population, many areas for residential expansion are being considered including building in a flood zone previously owned by a golf course. This area currently floods dangerous close to several existing apartment buildings and over several pedestrian bridges. A nearby onion farm also floods into the backyard of several homes along 36th street.

2.2 - Buttermilk Creek and Summergreen Golf Links

Buttermilk Creek flows through Summergreen Golf Links which is located within the 100 year flood plain. Recently, several large storms have flooded the golf course to the very edge of the 100 year flood plain putting water levels dangerously close to several apartment buildings located adjacent to the
course. In addition, plans are currently being made to turn the golf course into residential areas which would be located in the 100 year flood plain. This is an issue because if a 100 year storm should come and the flood plain is not rebuilt then all the new residencies on the golf course and the existing apartments will be flooded out. New detention areas will be required for the new development and are being designed by the developer but even more urgent are the current flooding dangers. An aerial photograph of the creek’s entrance to the golf course can be seen in Figure 3.

![Figure 3: Aerial Photograph Buttermilk Creek and Summergreen Golf Links](image)

**2.3 - 36th Avenue and Onion Farm**

There are several homes along 36th Avenue that are at a much lower elevation than the onion farm which is adjacent to their properties. The property backyards are regularly flooded by the runoff from the farm and several basements have received up to a foot of water regularly for the past several years. Some of the residents have expressed to the city an interest in constructing a berm to hold back the flow from the farm. The city has had neither the time nor the resources to look into this problem so Team 13 is evaluating alternatives to alleviate the flooding problems. An aerial photo can be seen in Figure 4.

![Figure 4: Aerial Photograph Onion Farm Flooding 36th Avenue Homes](image)
3 - Existing Conditions

3.1 – Buttermilk Creek Site Conditions

The approximate area of the upper portion of the Buttermilk Creek watershed is 935 acres as seen in Figure 5. The design point is where flooding occurs and is located in the north where the star is shown.

The soils in this area are more diversified due to the expanse of the area. The exact types and the cover area of each of the soils types will be included later when the watershed is more clearly defined. The approximate types of land use can be seen in Table 1 and Figure 6. The highest point in this watershed is 730 feet and the lowest point, which is also the design point, is 645 feet.

Table 1: Buttermilk Creek Watershed Land Use

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Color</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland</td>
<td>Cream</td>
<td>70</td>
</tr>
<tr>
<td>Hardwood Savanna</td>
<td>Light Green</td>
<td>15</td>
</tr>
<tr>
<td>Residential (single-family)</td>
<td>Off White</td>
<td>8</td>
</tr>
<tr>
<td>Industrial Park</td>
<td>Grey</td>
<td>5</td>
</tr>
<tr>
<td>Vacant</td>
<td>Dull Green</td>
<td>1</td>
</tr>
<tr>
<td>Clear-cut</td>
<td>Bright Green</td>
<td>1</td>
</tr>
</tbody>
</table>
3.2 – Onion Farm Site Conditions

The approximate watershed for the onion farm is 16 acres as seen in Figure 7. There are four types of soils in this area; MtC2 (Morley loam with 6 to 12 percent slopes that are eroded), MrC (Montcalm loamy sand with 6 to 12 percent slopes), MrB (Montcalm loamy sand with 2 to 6 percent slopes), and Sh (Shoals loam). Most of these soils have a relatively equal mixture of sand, silt, and clay. The majority of the land is used as cropland with a small section of land that is residential. The highest peak elevation for this watershed is 680 feet and the lowest elevation is 656. The flood prevention structure would be located in the east.
4 - Objectives

The primary goal of the project is to alleviate flooding problems that occur at the golf course and at the low point of the onion farm in Hudsonville. At the onion farm site, the goal will be to design a system that will keep flooding of the houses from occurring for everything less than a 25 year storm. At the golf course along Buttermilk Creek the objective will be to eliminate flood threats for 50 or 100 year storms. The first step will be to assess the current systems and identify the key problem areas. The second step will be to determine optimal solutions to the problems in terms of protection, detention, conveyance, remediation and scale. Secondary objectives will include learning to communicate with a client (the City of Hudsonville), learning to work as a project team and acquiring new understanding of storm water engineering techniques.

5 - Alternative Solutions

Team 13 is considering alternative solutions to alleviate the flooding problems of Buttermilk Creek onto the golf course and for the houses located at the base of the onion farm. These solutions will be weighed on the basis of financial feasibility and the quality of design to relieve the current problems along with the adhering to City of Hudsonville codes and direction from Dan Strikwerda (Planning Administrator).
5.1 - Buttermilk Creek

5.1.1 - Expansion of Existing Detention Pond

There is an existing detention pond with room for expansion southwest of New Holland Street upstream of the golf course flood zone. The volume of the current detention pond is 1.9 acre-ft. The city already owns the surrounding land which is mostly forested.

One advantage of expanding the existing detention pond would be that the amount of material removed would be greatly reduced which would result in greater cost savings. Also, only having one site will reduce space used for flood management.

One disadvantage of this option is that we might be restricted by the surrounding area to expand.
5.1.2 – New Detention

There is an area upstream of the golf course, just North of New Holland Drive where a new detention pond could be located. This new detention pond would work in conjunction with the existing detention pond.

Figure 9: New Detention Pond Site

An advantage of this is that we could design the pond however works best and not have to worry about working around an existing structure. We have to keep in mind though that this might be our only option for this site if the existing pond cannot be expanded.

The disadvantage of this option is that we have to extract all the material from the site and would have to transport it somewhere. This will result in an increase in cost and longer project duration. We would also have to cut down trees and change the surrounding habitat. This would change the ecosystem in the area which would not be desirable for us and for the city because of these reasons.

5.1.3 - Rain garden

The third alternative at this site is a rain garden which will be designed to create a space for large quantities of water to infiltrate into the ground instead of running downstream. A rain garden is composed of 60% sand, 20% compost, and 20% topsoil. This would require that the soil at the base of the onion farm area be removed. This area would be back filled with a fine soil and plants that have roots capable of holding larger than normal amounts of water on top of layers of sand and rock. Figure 10 shows a plan and profile view of a basic rain garden.
A couple advantages of the rain garden are that it is aesthetically pleasing to the public. Plants could be replaced and maintained, and also less water will be sent downstream but infiltrate the ground instead. With the addition of plants and grass, it is more pleasing to the public. When building a detention pond, that area will be open space and only used for detaining water and nothing else. With the addition of plants and trees, the ecosystem can be restored in a way. With more water infiltrating through the ground, less water will be flushed downstream, lessening the chances of flooding. Rain gardens also cut down on the amount of pollution that is discharged back into rivers. The contaminants seep into the ground which prevents them from running downstream.

The major disadvantage of this would be the cost. The plants would cost extra and also the soil that would have to be backfilled into the area. This soil would have to be a much more absorbent soil which will cost more.

### 5.2- 36th Avenue and Onion Farm

#### 5.2.1 Berm with a spillway

In this alternative a berm with a spillway would be designed. This would require that a berm be built between the houses and the onion farm. The berm would be capable of holding back water of a specific volume. When this maximum volume is reached, water would be allowed to flow at a controlled rate over the spill way. The material to build up the berm could come from dredging out the unused farm land and grading the land to flow towards 36th Avenue. The owner of the farm, as well as the residents of the affected houses, have all consented to the design of some structure such as a berm to hold back the flooding and have made requests to the City of Hudsonville. Small shrubs and trees could be planted on top as well as grass throughout to maintain the stability of the soil. The design height and slopes will not be great enough to warrant any kind of geotextile bank stabilization.
Some of the advantages to this design are that it would be simple and consistent with the area. There are several other houses in the area that have similar berms in their backyards but those are more landscaping than engineered. It will also allow for settling of sediments in the pond. This will make the effluent over the spillway of much higher quality. A design like this will be relatively simple in that the spillway will be designed for certain storm event that the residents and city decide, which will most likely be a 25 year storm.

A disadvantage of this alternative is that it will create constant pooling of water behind the berm which will be rather dirty from the soil runoff. This will be unsightly and be a place where diseases, mosquitoes, and other insects will more than likely breed. However, the soil in this area is very loamy because it is farmland and has a fairly high rate of infiltration, so large pooling should be limited to only after very large storms.

5.2.2 - Berm with an orifice

This option would yield similar results to a berm with a spillway, except that there would be culvert in the berm to allow flow to pass between two houses and into the street or a pipe leading underground to the existing storm sewer in 36th Avenue. This would require a much smaller berm, but more grading work. Examples of what this proposal would look like are shown in Figure 12.
This alternative would still be consistent with the surrounding area and meet with the expectations of the residents. However, there would be no pooling of water on the upstream side of the berm after a storm event and most of the water would exit the grounds though the orifice. The orifice could be set at a level to allow a controlled flow of water out at a designed elevation allowing the pond to drain at a slower rate than if the water were to wash through the site as it currently does. Another advantage of this alternative is that if the orifice is connected to the 36th street storm sewer, then the residents do not need to be concerned about a channel flowing in their side yards and possibly causing problems.

A disadvantage of this alternative is that the water is still flowing into the yards of the residents houses and although it will be at a controlled rate and location, there still will be flow through the channel into 36th Avenue. If there were a pipe buried from the orifice to the existing storm sewer for 36th street an easement will need to be obtained from the residents who have been very cooperative thus far. This alternative will also be much more costly than any other alternative, especially if a pipe were to be buried and connected to the 36th Avenue storm sewer.

5.2.3 - Open channel between two houses

There is a slight slope where the side yards in between two adjacent houses meet. If these slight swells are reinforced the runoff from the onion farm could be directed between the houses and allowed to flow over 36th Avenue, into the storm sewer there and into the part of Buttermilk Creek that is located on the golf course. Some regrading of the area owned by the farmer just before the properties of the homeowners will need to be done.
The greatest advantage of this alternative is that it is the cheapest and easiest alternative with only some minor regrading. It will be quick and noninvasive for the homeowners and the farmer. However, this alternative will only be successful if there is little flow into the area and will most likely not correct the flooding but only direct it in a semi controlled area.

6 - Feasibility Study

There are no foreseeable feasibility issues. Each alternative solution will be analyzed and the effectiveness will be assessed. Rainfall history and watershed data has been obtained through GIS as well as access to Hudsonville's public infrastructure. After collecting data and a layout is replicated, modeling will be completed through HEC-HMS and HEC-RAS. The models will be tested against real storm events with tabulated rainfall data. The City of Hudsonville has this information and we will inquire for it when it is needed. Hudsonville has also agreed to a reasonable budget to aid us in our design of an optimal solution.

All foreseeable feasibility studies and data has been gathered during the fall semester and a basic design will be formed including all feasible alternatives. During the spring semester a detailed design will be created that will alleviate the flooding problems in Hudsonville. The HEC-HMS and HEC-RAS models of existing conditions and models of feasible design alternatives will be created. Through this modeling we will be able to determine the optimal solution for each site based on cost, environmental factors and appropriate land use. All designs are coordinated through and approved Dan Strikwerda (City Planner), Pauline Luben (City Manager) and Phil Leerar (City Counsel and Civil Engineer for Access Business Group) adhering to the city codes and the needs of the city.
7 - Preliminary Design

7.1 – HEC-HMS Storm Event Modeling

The primary work will be in the modeling of the watershed and the various sub-basins to determine a hydrograph for several different storm events. The first step is to delineate the watershed for the area of Buttermilk Creek that is being studied and divide it into sub-basins based on topography. The sub-basins are divided into land use and soil type to find the curve number and the time of concentration for a 25 and 50 year storm event. The curve number is calculated by taking an area-weighted average of initial abstraction, infiltration rate, soil type, soil cover, land use, hydrologic conditions and moisture conditions of the area. Time of concentration refers to the time it takes for a raindrop at the furthest edge of the watershed to reach the furthest downstream end. A curve number is calculated for each sub-basin of the watershed to be put into the HEC-HMS watershed modeling program. HEC-HMS (Hydrologic Modeling System) is a program that models a watershed and its various sub-basins, along with stream and reservoir elements, to determine hydrographs at each location within the watershed. From the hydrograph a peak outflow can be estimated which will be the design flow in the HEC-RAS models.

7.1.1 – HEC-HMS Modeling of Buttermilk Creek Watershed

For the golf course, HEC-HMS is used to model the large watershed area and delineate it into its many sub-basins including the existing detention ponds. Once the model of the existing conditions is completed, a peak flow into the golf course area will be the output. This peak flow will be taken to the HEC-RAS modeling software which will model Buttermilk Creek in the area of the flooding to determine peak flood levels. After this model is complete and consistent with actual storm events the different design alternatives can be included into the HEC-HMS model. The alternatives will be adjusted until a peak outflow is found that can be put into the HEC-RAS model of Buttermilk Creek in the golf course area that limits flooding to an acceptable level.

7.1.2 – HEC-HMS Modeling of Onion Farm

Most of the modeling for the onion farm can be completed within HEC-HMS since there is no stream present there. The watershed will include only one sub-basin since the whole area that drains to the flooding zone behind the houses is all farmland of the same soil type and not very large and the peak flow into the area will be determined. Then each of the alternatives can be modeled. The two berm alternatives can be modeled as reservoirs with the appropriate outlet structures and the sizes can be adjusted until flood levels are limited to appropriate levels. A small HEC-RAS model will need to be created for the open channel alternative and adjusted to hold and convey the design volume through to 36th street.
7.2 – HEC-RAS Modeling

The intermediate step will be to take the peak flows computed in the HEC-HMS modeling and put them into a HEC-RAS (River Analysis System) model. HEC-RAS is a program that models a river using several measured and interpolated cross sections to create the entire length of the river body. It is not a dynamic system because only the peak flows need to be studied to determine the maximum extent of flooding. A HEC-2 (predecessor of HEC-RAS) model will be obtained from Bruce Menerey of FEMA that will help to better articulate the HEC-RAS cross sectional data.

7.2.1 - HEC-RAS Modeling of Buttermilk Creek at Golf Course

The next step is to determine the capacity of Buttermilk Creek. Several cross sections of the creek at the flooding area will need to be modeled. Some of these cross sections will come from the FEMA Floodplain Study done previously but other cross sections may be necessary. For this model, paired elevations and offsets from the stream center will need to be measured, in addition to left and right overbanks. Manning’s n, which is a friction factor, for the stream bottom and overbanks was also included in the FEMA Floodplain Study. The peak flow of the existing HMS model will be run through the model of the creek and compared with previously recorded flood levels to make sure that the model is accurate. Then, the peak flows from each of the alternative designs will be run through the model and adjusted until flood levels are decreased to the desired level. These alternatives can then be compared and a cost for each can be determined based on the amount of work required. Finally an optimal solution can be determined.

7.2.2 – HEC-RAS Modeling of Onion Farm Alternatives

The only HEC-RAS modeling that will need to be done for the onion farm flood area will be to model the channel alternative. A few cross sections will need to be taken and the regrading of the land modeled to an appropriate level to allow conveyance of the peak flow from the HEC-HMS model. This alternative can then be compared with the two detention alternatives to determine which best meets the needs of the residents and keeps costs to a minimum.

8 - Christian Perspective

The final project designs will be completed with regard to the best interest of the City of Hudsonville and its residents as it pertains to their current flooding issues. The design will have environmental impacts in both the present and the future and Team 13 will take these impacts into account throughout the design process. Team 13 will communicate honestly about any problems that might arise and act with integrity. It is important to this project and Team 13 that Christian perspective is not simply an item that can be crossed off a check list. As Christian engineers Team 13 wants our faith to be reflective in every aspect of our project from the actual design to our attitude in carrying out the design, from the way we make presentations to the way we interact with City of Hudsonville officials and residents.
9 - Task Breakdown

- **Research Meeting with Glen Remelts**: Thursday, **October 16, 2008 @ 4:00pm in the library**

- **Meeting** Friday, **October 17, 2008** with The Planning Director/Zoning Administrator (Dan Strikwerda), The City Manager (Pauline Luben), and Civil, Central Engineer of Access Business Group (Phil Leerar)

- **Web site design**: Monday, **October 20, 2008**

- **Oral presentation to ENGR 339 class**: Friday, **October 24, 2008**

- **Industrial Consultant Meeting**: **October 29, 2008**

- **Site walk through with Dan Strikwerda**: **November 7, 2008**

- **PPFS draft**: Monday, **November 17, 2008**

- **Meeting with Professor Hoeksema to obtain modeling information**: **November 20, 2008**

- **Preliminary design models**: **November 24-December 12, 2008**

- **Model Construction**: **November 24-December 12, 2008**

- **Final web site design**: Friday **December 12, 2008**

- **Preliminary Design Memo**: Friday **December 12, 2008**
10 - Cost Estimates

These equipment and operating costs will be used similarly in both sites.

Table 2: Equipment Costs

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Daily Cost</th>
<th>Weekly Cost</th>
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<tbody>
<tr>
<td>Bobcat</td>
<td>$350.00</td>
<td>$1,400.00</td>
</tr>
<tr>
<td>Mini Excavator</td>
<td>$800.00</td>
<td>$3,200.00</td>
</tr>
<tr>
<td>Backhoe</td>
<td>$600.00</td>
<td>$2,400.00</td>
</tr>
<tr>
<td>Bulldozer</td>
<td>$900.00</td>
<td>$3,600.00</td>
</tr>
<tr>
<td>Dump Trailer</td>
<td>$650.00</td>
<td>$2,600.00</td>
</tr>
<tr>
<td>Single Axle Dump Truck</td>
<td>$400.00</td>
<td>$1,600.00</td>
</tr>
<tr>
<td>Portable Generator</td>
<td>$175.00</td>
<td>$700.00</td>
</tr>
</tbody>
</table>

*costs include fuel but does not include operator

Table 3: Labor Costs

<table>
<thead>
<tr>
<th>Labor</th>
<th>Hourly Cost</th>
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<tbody>
<tr>
<td>General Laborer</td>
<td>$48.00</td>
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<tr>
<td>Equipment Laborer</td>
<td>$54.00</td>
</tr>
<tr>
<td>Bobcat and Mini Excavator Operator</td>
<td>$60.00</td>
</tr>
<tr>
<td>Backhoe Operator</td>
<td>$65.00</td>
</tr>
<tr>
<td>Dump Truck Operator</td>
<td>$54.00</td>
</tr>
</tbody>
</table>

To construct a new detention pond the following equation is a general guideline:

\[ C = 12.4V^{0.760} \]

Where:

\( C = \) Construction, Design and Permitting Cost
\( V = \) Volume needed to control the 10-year storm (cubic feet)

Using this equation, typical construction costs are:

- $ 41,600 for a 1 acre-foot pond
- $ 239,000 for a 10 acre-foot pond
- $ 1,380,000 for a 100 acre-foot pond

For example, to install a new detention pond of the same size as the existing one, 1.9 acre feet, the cost would be $83,200. In addition, detention ponds have an estimated cost for maintenance of about 3% to
5% of the initial construction costs. Detention ponds normally do not have to be replaced. For a typical detention pond the life time will be about 20 years. This brings an estimated cost for construction and maintenance of a new detention pond to $87,400.

To expand the existing detention pond similar construction costs will be incurred except that the pond’s volume will already partially exist so the volume used in the equation should be around the total volume of the new detention pond minus the volume of the existing.

The construction of a rain garden will be different than the detention pond alternatives. The rain garden will include the following materials and supplies:

**Materials**

- 2x12 #1 treated pine - about $15.00 for one eight-foot board
- Ten two-foot long sections of steel reinforcing bar (rebar)—about $10.00
- Two stainless steel elbow brackets with four 1.5
- Inch stainless steel wood screws—about $15.00
- Topsoil (how many bags we will need depends on the size of your rain garden)—about $3.00 for a 40 lb. bag
- Mulch or straw—about $3.00 for a 40 lb. bag or $5.00 for a bale of straw
- Sand—about $5.00 for a 20 lb. Bag
- Plants—native plants, be ones that can withstand both heavy moisture and very dry periods
- Material for killing existing vegetation (round up)

These estimates are based on a smaller scale model, so for our purposes these quantities will need to be multiplied many times to meet the needs of our model.
11 - Business Plan

H2O Incorporated is a small civil engineering firm located in western Michigan that specializes in flood management. This includes issues that pertain to modifying and fixing current structures as well as establishing new flood prevention structures. The methods used to solve flooding problems range from the design of new detention ponds to increasing capacity of old detention ponds to designing small and large scale rain gardens. Services also include the design and construction of berm structures. H2O Incorporated is licensed to provide consulting and contracting services throughout the state of Michigan.

The services provided by H2O Incorporated are aimed primarily at an industrial market. This includes private and public, residential and commercial properties. All projects that H2O Inc. receives via the bidding process or private contact will be drafted in a preliminary contract. This contract will include an assessment of the current flooding situation and source of flooding, a proposed design to address the flooding problems, and a labor and equipment pricing sheet.

Private property owners are expected to pay in full upon completion of a project as stipulated in a prior signed contract. Public property falls under the jurisdiction of the individual township and each township is expected to pay in full upon completion of a project as stipulated in a prior signed contract. An interest of 6% will be added to all outstanding bills on a monthly basis until the full amount is paid for services rendered.
12 - Appendices

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