BYU ENGINEERING
Civil & Construction Engineering

CAPSTONE

BLUFFDALE CITY – 1690 WEST DRAINAGE STUDY
Project ID: CEEn_CPST_011

by

JE² Engineering
Emily Blanchard
Jonah Dundas
Eva-Marie Hamill

A Capstone Project Report

Submitted to

Addison Mitton
City of Bluffdale, Utah

Department of Civil and Construction Engineering
Brigham Young University

April 17th, 2023

Executive Summary

PROJECT TITLE: Bluffdale City – 1690 West Drainage Study
PROJECT ID: CEEn_CPST_11
PROJECT SPONSOR: City of Bluffdale, Utah
TEAM NAME: JE^2 Engineering

Our project aimed to provide a more permanent drainage solution for 1690 West in Bluffdale, which has historically had issues with flooding. The project followed the City of Bluffdale Standards and was completed with the assistance and supervision of Addison Mitton, P.E. from the City of Bluffdale and Dr. Rollin Hotchkiss, P.E. from Brigham Young University. The deliverables for the project included a report, a poster, and a presentation to the sponsor.

Our tasks for the project included evaluating the site, determining the design storm, calculating peak runoff, and comparing alternatives. Maintaining a schedule was crucial for the success of completing the tasks in an appropriate amount of time as well as the overall completion of the project.

In the analysis and design of our drainage solution, we considered social, environmental, economic, and safety impacts. The most significant unintended consequence of our project would be the impact on the neighborhood during the construction. To minimize the effects of this unintended consequence we recommended coordinating the construction of our project with construction on W 14600 S.

We are comfortable with the assumptions that we made to define our catchment and determine the design storm hydrology. We do not anticipate they will have a significant impact on our conservative design. We determined that given a 10-year design storm the intensity would be 2.28 in/hr and the duration would be 12 minutes. Because of the necessary segmentation of the watershed, we used a catchment area of 2.3 acres and a composite C-value of 0.627. The resulting design flow was 3.24 cfs.

We brainstormed four alternatives and chose two feasible alternatives. These alternatives were designed and priced. We recommend that the City of Bluffdale implement the first alternative which is to wait to install a permanent drainage solution on 1690 W until construction begins on W 14600 S. The construction of this alternative would cost $68,275.50. This is the most cost and time effective solution.

Table of Contents

List of Figures

List of Tables

Introduction

Our capstone project was to design drainage solution alternatives for 1690 West in Bluffdale. Historically, this section of road has had flooding issues during heavy rain. A slight dip in the road allowed water to pool and created a safety hazard for vehicles. The city has installed a temporary drain next to the curb on the east side of the road, but the road needs a more permanent solution. The objective of this project is to design a more permanent drainage solution from the existing inlet that outfalls into the Jordan River.

The section of road is about 750 feet long and intersects with a newly paved road. The road runs north and south with the Jordan river a few blocks to the east and a canal a few hundred feet to the west. The west side of the road has curb and gutter while the east side does not. Figure 1 labels the most important features of the site.

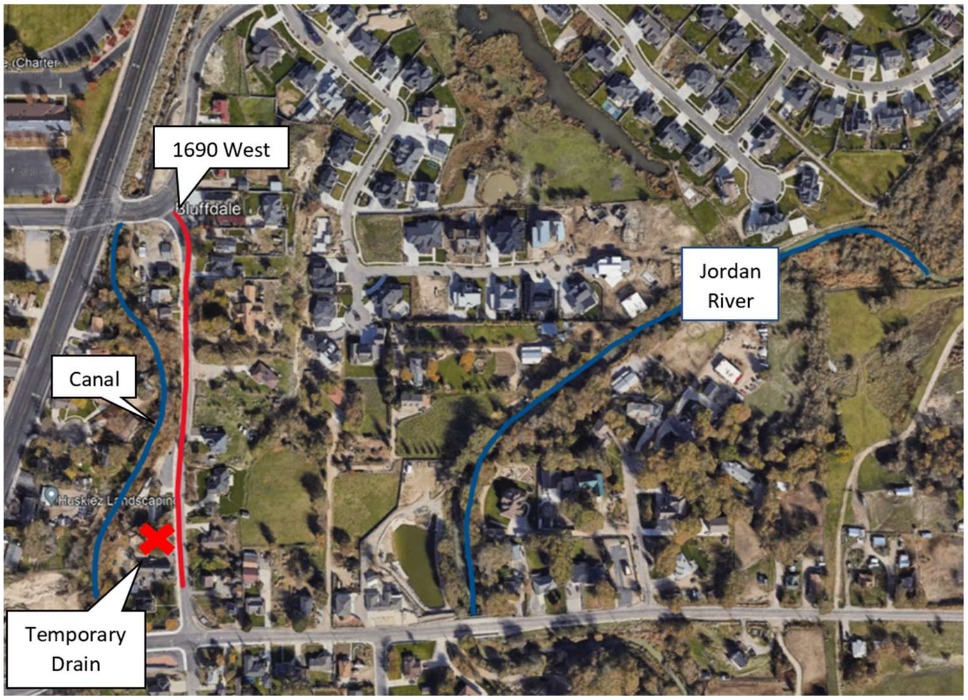

Figure 1 Project Site with the Most Important Features Labeled

Our design must comply with the City of Bluffdale Standards. Additionally, our sponsor asked that we avoid cutting into the new street if possible. Our design recommendations will also consider any social, environmental, financial, and safety impacts of our solutions. Our team also complied with the expectation of meeting with our sponsor and faculty member often and completing all assignments associated with the capstone course.

The major tasks associated with our project are evaluating the site, delineating the watershed, determining the design storm, calculating peak runoff, and comparing the alternatives. Our project was completed during the 2022-2023 school year. The deliverables for our project include this report, a poster, and a presentation to our sponsors.

Schedule

Maintaining a schedule was crucial for the success of our project. Breaking the project down into smaller tasks and allocating time to complete those tasks helped us remain accountable. This project helped us develop our time management skills and learn to avoid procrastination. Table 1 lists the anticipated completion date of each milestone from our proposed work plan in addition to the actual completion date. This schedule ensured that our team stayed on track to complete our final report on time.

We did face challenges along the way but had many great accomplishments. Some of the challenges that we faced affected our schedule. For example, we initially struggled to view the elevation LiDAR data of our area which slowed down our watershed delineation, and in turn, the design storm runoff. We took advantage of many resources on campus and were very proud of ourselves when we successfully extracted the surface data to view in ArcGIS Pro.

In addition, analyzing the costs and impact of alternatives took more time than we anticipated. This was not a problem because we had allotted extra time in our schedule. The extra time that we spent considering alternatives and unexpected consequences was beneficial to the project and was not detrimental to our ability to finish the project and final report on time.

Table 1 Schedule Milestones with Planned and Actual Completion Dates

Milestone	Planned Completion Date	Actual Completion Date
Visit the Site	10/7/2022	10/7/2022
Delineate the Watershed	1/22/2023	2/1/2023
Determine Design Storm Runoff	2/5/2023	2/16/2023
Brainstorm Alternatives	2/19/2023	2/27/2023
Compare Alternatives	3/5/2023	3/23/2023
Write a Final Report	3/26/2023	4/7/2023
Summarize Findings on a Poster	4/9/2023	4/5/2023
Prepare Presentation	4/9/2023	4/7/2023

Assumptions & Limitations

In all engineering projects, we make assumptions that place limitations on our designs. It is important to state those assumptions. In our project, we made assumptions in defining our catchment area and in determining the design hydrology.

Catchment Area Assumptions:
There is a canal located west of the existing drain. Since the canal is uphill from where our drain is located on the street, we assumed that the canal catches all water west of it. We included the area between the canal and the street in our catchment area. This may be a limitation if there is a large storm event and the canal is unable to hold excess runoff. In this scenario, our drainage solution would be unable to handle canal breach and would result in major flooding. Since this is unlikely and we have no reason to believe the canal will overtop, we are not concerned about this scenario.

In addition to assuming that the canal catches all of the water flowing from the west, we also assumed that the storm drains north of our drain along 1690 West also catch all of the water north of them. This assumption means that we did not include the area north of the storm drains in our catchment area. This may be a limitation because if there is a large storm event and those drains are unable to catch all of the water, then the excess runoff would need to be handled by our drainage solution.

When determining the catchment area, we also included part of W 14600 S located west of our drain but east of the last storm drain. Due to the elevation of the roadway, we assumed that this water would flow down onto 1690 W and contribute to the water that would go into the drain. This assumption may be a limitation if the water from W 14600 S does not contribute to our drainage area, but the amount of water would potentially change the design values that were determined later on.

Our design also assumed that the storm drains would be well-maintained and not clogged. The limitation of this assumption is that if the drains are clogged, then the water will not be able to drain, but will remain on the roadway and the issue of flooding will not be resolved.

Even though we made assumptions when determining the catchment area for our storm drain, we are comfortable that the assumptions we made were reasonable and that the limitations will not have a significant impact on our conservative design.

Hydrologic Assumptions:
Storm drain design involves making several hydrologic assumptions to estimate the expected flow and pipe sizing of the system to manage the runoff during a storm. Some of the assumptions that we made in our design deal with the rainfall intensity, the runoff coefficient, and the time of concentration.

Rainfall intensity is based on historic data about storm frequency. We used an intensity-frequency-distribution (IDF) curve generated by NOAA for the city of Midvale which is located about 10 miles north of our site on 1690 W. This assumption is reasonable since Midvale is not far away from our site and is the closest station to our site. If the rainfall intensities of storms in Midvale differed greatly from those in Bluffdale, that would be a major limitation of our design, but this is very unlikely.

To determine the runoff coefficient, we had to divide the catchment area based on land use and assume C-values associated with each land use. We referenced our hydrology textbook and a short course on the rational method by Dr. Hotchkiss to inform our C-value assumptions. A composite weighted C-value was calculated using these assumed values and our land use maps.

For determining the intensity, we assumed that the duration was equal to the time of concentration. Due to the odd shape of our catchment area, we divided our watershed into two different segments. We also needed to use a compound time of concentration because the land cover changed significantly over the length of our longest hydrologic path. We computed the time of concentration using the kinematic wave equation for each section of the path and then added them together.

These hydrologic assumptions are typical in analysis, so there are no limitations that are cause for concern in our analysis and design.

Design, Analysis & Results

As part of our project, we performed hydrologic analysis, hydraulic design, and the comparison of alternatives. This involved evaluating the site, delineating the watershed, determining the design storm, calculating peak runoff, and comparing the alternatives.

Evaluating the Site:

We began the project by visiting the site. The temporary drain sits at the bottom of the slight vertical sag curve in the road where the water used to pool. The road segment lies between the Jordan River and an irrigation canal. The land slopes down from the canal to the river. The canal acts as a boundary for our catchment area because all water uphill of the canal will flow into the canal as discussed in the Assumptions & Limitations section.

Delineating the Watershed:

Due to the size and shape of our catchment, watershed delineation by hand was the most practical approach. We used topographic LiDAR data from the city and the 7.5-minute USGS quadrangle to map out the catchment. This data is available for reference in Appendix A: Topographic Data. The catchment was bounded by a canal on the western side, the crest of the road on the eastern side, existing storm drains on the north end, and the slope of the road on the south end. ESRI ArcGIS Pro was used to digitize and measure the area. Figure 2 below shows the complete catchment area of roughly 3.5 acres.

Figure 2 Delineated Catchment Area

Determining the Design Storm:

In accordance with City of Bluffdale Standards, we used the Kinematic Wave Equation to determine the intensity and the Rational Method to determine the runoff. The City Standards also call for the use of a 10-yr design storm.

The odd shape of our catchment area made the path of time of concentration unclear. The longest hydrologic path could be:

1. Across the lawns on the south side of the catchment and then north along 1690 West to the storm drain
2. Down 1690 West from the far north side of the catchment to the inlet

Since traveling across the lawns is much slower than along the road, the first scenario would allow the entire area of the watershed to contribute to the peak flow. Whereas, in the second scenario, only the highly impervious areas of the watershed would contribute. Whichever storm scenario produces the highest peak discharge should be used for design.

To determine the time of concentration, intensity, and duration of the storm, we iterated using the Kinematic Wave Equation (eq-1) and the IDF curve (Figure 3) shown below. A tabulated version of the IDF curve is included in Appendix B: Tabulated IDF Curve. This iteration is completed by assuming that the time of concentration is equal to the storm duration.

$$t_c = \frac{0.93\ \ ^{0.6}N^{0.6}}{i^{0.4}S^{0.3}} \qquad \text{(eq-1)}$$

$t_c = time\ of\ concentration$
$L = overland\ flow\ length$
$N = Manning's\ roughness\ coefficient\ for\ overland\ flow$
$i = rainfall\ intensity\ (in/hr)$
$S = average\ slope\ of\ overland\ flow\ path$

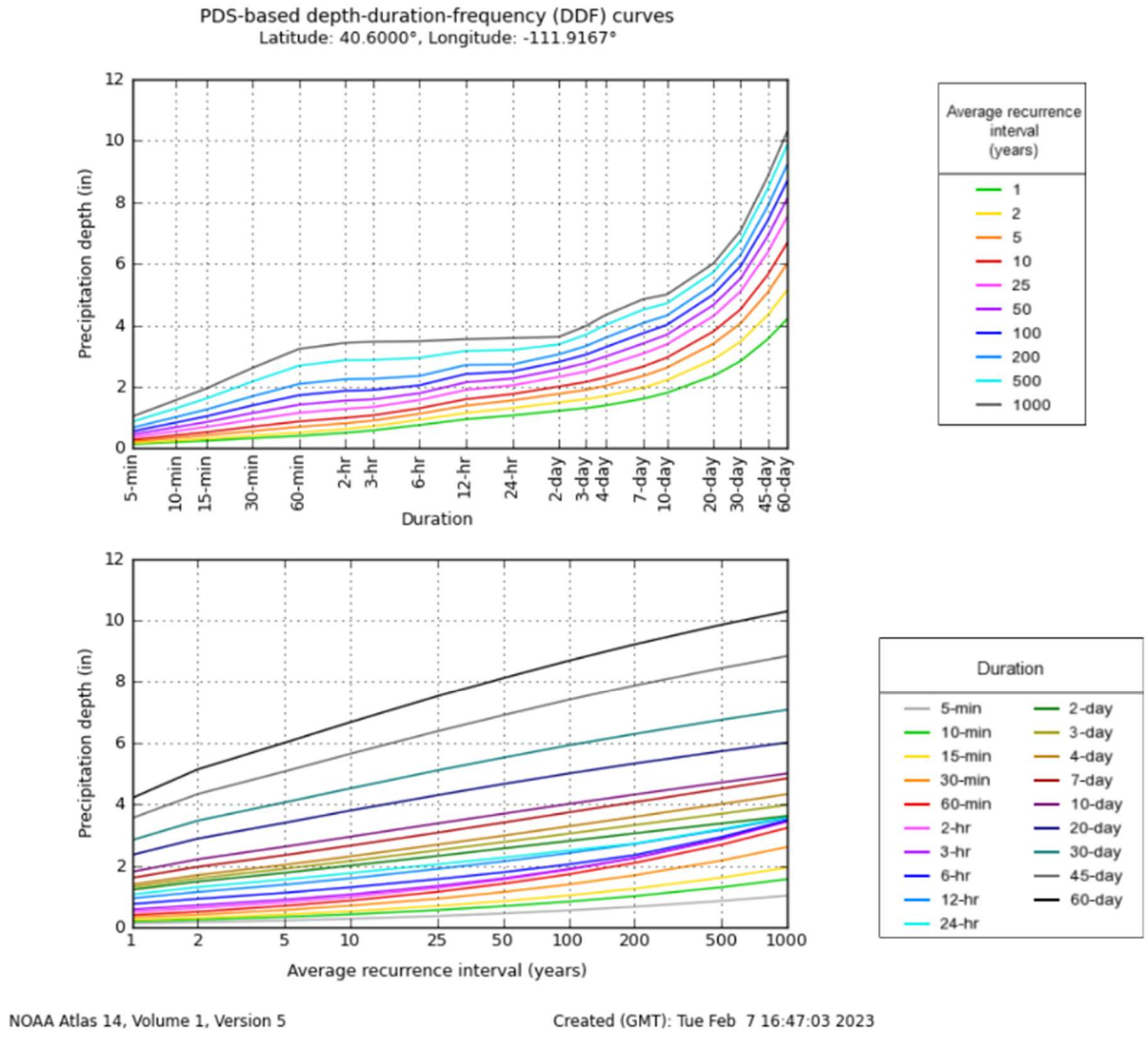

Figure 3 NOAA IDF Curve for the City of Midvale

For scenario 1, the iteration process yielded a time of concentration of 48 minutes and an intensity of 1.02 inches/hour. For scenario 2, the iteration process yielded a time of concentration of 12 minutes and an intensity of 2.28 inches/hour.

Calculating Peak Runoff:

To calculate the maximum discharge, we had to calculate the composite C-value for each of these scenarios as well. Using ArcGIS Pro, we broke the watershed up into 6 different land uses. Figure 4 shows the land uses within the catchment. For scenario 1, we calculated a composite C-value of 0.525 over an area of 3.5 acres. For scenario 2, we calculated a composite C-value of 0.627 with an area of 2.3 acres.

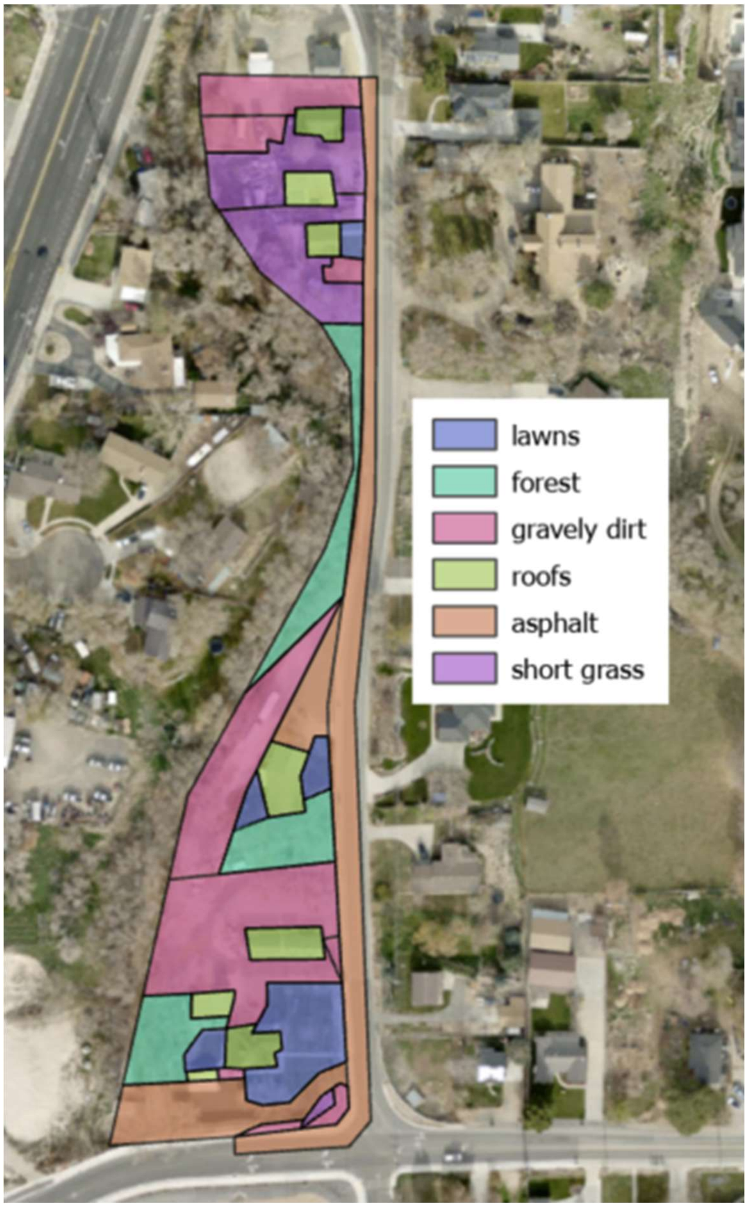

Figure 4 Land Uses within Catchment Area

The information we have calculated regarding the two scenarios is summarized in Table 2. This information can be plugged into the Rational Equation (eq-2) and used to calculate the maximum flow for each scenario.

$$Q_{max} = CiA \qquad \text{(eq-2)}$$

Table 2 Hydrologic Data Used to Calculate Maximum Flow Using the Rational Method

Scenario	Composite C-Value	Rainfall Intensity (in/hr)	Catchment Area (acres)	Maximum Flow (cfs)
1 - across lawns	0.525	1.02	3.5	1.86
2 - along road	0.627	2.28	2.3	3.24

You can see in the table above that Scenario 2 produces the larger maximum peak flow. So, we will use 3.24 cfs as the design flow.

Potential Alternatives:

We came up with four potential alternatives.

1. Waiting to install permanent drainage solution until construction begins on W 14600 S
2. Installing permanent drainage solution now
3. Doing nothing
4. Purchasing easements

For reasons discussed in the Related Issues section of this report, we decided not to move forward with the easement alternative. Before we can accurately compare the alternatives, the hydraulic design of alternatives 1 and 2 must be determined. The do nothing alternative does not require any design work but will be included in our comparison of alternatives.

Hydraulic Design:

In this step we will determine the hydraulic design of the alternatives 1 and 2. Our design must be compliant with Bluffdale City Standards. The most relevant standards are:

1. there should be manholes every 500 ft
2. the design velocity should be between 3 and 15 fps
3. the minimum pipe size is 15”
4. pipes need to be buried at least 1 ft deep

Figure 5 is a map of the two alternatives for reference. The placement of the manholes is in compliance with the minimum distances between manholes.

Figure 5 Map of Alternatives 1 and 2

The first pipe segment in both of the alternatives is the same. The second alternative has three additional pipe segments. The surface elevation of each manhole was taken from the LiDAR data and used to calculate the slopes for each segment. The depth of the pipes was adjusted to meet the minimum design velocity of 3 fps and the minimum burial depth of 1 ft. The characteristics of each node between the pipe segments is shown in Table 3.

Table 3 Characteristics of Nodes between Pipe Segments

	ground surface elevation (ft)	depth (ft)	pipe burial elevation (ft)	distance from previous node (ft)	slope between (ft/ft)
node 1	4426.23	1	4425.23		
node 2	4427.78	4	4423.78	231	0.00628
node 3	4414.79	4	4410.79	331	0.03924
node 4	4401.64	4	4397.64	332	0.03961
node 5	4396.14	4.77	4391.37	118	0.05314

We confirmed this design by using Hydraulic Toolbox to calculate flow characteristics of each pipe. The results from this analysis are shown in Table 4.

Table 4 Flow Characteristics in Each Pipe Segment

Pipe Characteristics	1	2	3	4	Units
Flow	3.237	3.237	3.237	3.237	cfs
Depth	0.686	0.411	0.41	0.38	ft
Area of Flow	0.69	0.351	0.315	0.315	sq ft
Wetted Perimeter	2.086	1.527	1.524	1.46	ft
Hydraulic Radius	0.331	0.23	0.23	0.216	ft
Average Velocity	4.692	9.213	9.245	10.273	fps
Top Width (T)	1.244	1.174	1.174	1.15	ft
Froude Number	1.11	2.968	2.983	3.458	
Critical Depth	0.725	0.725	0.725	0.725	ft
Critical Velocity	4.386	4.386	4.386	4.386	fps
Critical Slope	0.00526	0.00526	0.00526	0.00526	ft/ft
Critical Top Width	1.234	1.234	1.234	1.234	ft
Max Shear Stress	0.269	1.006	1.013	1.259	lb/ft^2
Avg Shear Stress	0.13	0.564	0.568	0.716	lb/ft^2

The average velocity in each pipe falls between the required 3 and 15 fps. We do not need to consider the formation of pressurized flow backing up and out of the storm drain because the flow is supercritical, and the normal depth is less than the height of the pipe.

Comparing Alternatives:

One of the easiest comparisons to make between the alternatives is the building cost. We used information from the Fairfax County, Virginia Land Development Services and Utah Department of Transportation (UDOT) for unit price estimations (Appendix C: Price References). The final pricing estimates for each alternative are shown in Table 5. A more detailed breakdown of these estimates is included in Appendix D: Price Breakdown.

Table 5 Building Cost of Each Alternative

Alternatives	Building Cost
1. Wait to Tie into Construction on 14600	$68,275.50
2. Complete Entire Project Now	$213,258.30
3. Do Nothing	$0
4. Easements	Not considered due to related issues

While the do nothing alternative is the cheapest we do not recommend this solution because the temporary solution does not meet all the city's design standards and under extreme flooding scenarios could prove insufficient. Alternative 1 is the next cheapest option.

We acknowledge that the cost of building a project should not be the only consideration. A thorough analysis of the other pertinent issues is provided in the Related Issues section. One major advantage of alternative 1, is that it minimizes disruption to the residents by avoiding multiple construction projects. One disadvantage is the risk the city assumes by leaving the temporary drain in place while waiting for construction on the neighboring road to occur. This risk can be minimized by properly maintaining and cleaning the temporary inlet.

Taking into account all foreseeable impacts, we recommend alternative 1. This is the cheapest build alternative, it has major advantages for the neighboring residents, and the disadvantages can be easily minimized.

Related Issues

While our proposed drainage solution will effectively solve flooding issues on 1690 West, it's important to consider other unexpected consequences that may result from the implementation of our proposed solutions. This includes environmental, social, safety, and economic factors.

Installing a permanent drainage solution with an outlet directly to the Jordan River could have negative environmental impacts. Pollutants, garbage, and other hazards are commonly collected in stormwater runoff. If these items enter the river, they could be harmful to the water quality and ecology of the river. In extreme circumstances, this could lead to the loss of habitat for native species and may impact biodiversity. While there is no plan to formally treat the stormwater before it reaches the river, there are several elements of our design that will help prevent pollution. Our inlet has a grate that can help catch trash and large debris. There is also an inlet box that will allow sediment and debris to settle out before entering the pipe. We have also budgeted for a Stormwater Pollution Prevention Plan (SWPP) which will help reduce the impact to the river during construction. The details of this plan are specified by the city standards included in Appendix E: City of Bluffdale Standards. Lastly, we recommend that a fish is either stamped or painted onto the inlet to discourage people from dumping chemicals into the inlet. With these measures in place, we feel that the environmental impacts of our project have been properly mitigated.

Our proposed solutions will have temporary, negative impacts on the lives of residents in the area that will have to be planned for, particularly during the construction phase of the project. This has social impacts as well as safety impacts. 1690 West is located in a highly residential area. To install a permanent stormwater drainage solution, roads will have to be closed. Closing roads and creating alternate routes for drivers will drastically affect residents since road closures often cause significant traffic disruption, which can lead to delays, increased travel times, and congestion. This can be particularly problematic in urban areas with limited alternate routes. This will affect the flow of traffic as well as the accessibility of homes in the neighborhood. In addition to the traffic delays, road closures can create safety concerns for pedestrians, cyclists, and drivers who are forced to take alternate routes. This can be especially dangerous if the alternate routes are not well-maintained or are not designed to handle increased traffic volumes. We have included in our project budget funds for traffic control which should allow for safe navigation and accessibility in the area during the construction phase. Other issues that could affect the residents such as noise and cleanliness will have to be considered by the construction teams themselves. If construction is limited to daytime hours, traffic and noise complaints likely will be lessened.

In addition, as part of our drainage solution, we include the removal and replacement of the asphalt road. Replacing only part of an asphalt road can be problematic because it can create an uneven surface that can be hazardous for drivers as well as pedestrians. If only a section of the road is replaced, it may not properly adhere to the surrounding pavement which can result in failure. While replacing one section of the road may seem more cost effective than replacing the entire roadway in the short term, it can lead to overall higher maintenance costs in the long run if the section fails or needs additional repairs. Where possible in our design we replace entire lanes as opposed to partial lanes, in order to minimize these consequences.

We had initially intended on providing a fourth possible solution which involved purchasing easements, but after considering the social implications and financial cost of this option, we didn't consider it feasible. Since 1690 West is not far from the Jordan River, we thought about piping the water straight to the river. While this would have used less material and spanned a shorter distance, all the work would be done on private property. Installing and maintaining public infrastructure on private land is difficult. There are few roads or other means of accessing the land where the pipe would need to be installed which would make, at best, the construction process burdensome and, at worst, cause unacceptable damage to the properties through which the pipe would be laid. This would continue to be an issue throughout the life of the pipe during its regular maintenance. Given these issues, we decided this could not be considered a feasible solution.

It is important as engineers to consider all the impacts of our projects. We have tried our best to anticipate all the impacts of our project but acknowledge that sometimes there are unforeseeable consequences of a project. We hope that the city will watch for and address additional concerns associated with this project.

Lessons Learned

Communication was challenging at times for our team. We had to coordinate with Bluffdale's city engineer, our faculty advisor, and with our fellow teammates. We all have very different schedules, so we learned to communicate early and often. If we weren't quick to reach out when we needed help, or if we didn't anticipate when we would need help and reach out in advance, we would find our progress halted until we received a response.

When we got stuck or were waiting on a response from our sponsor or advisor, we searched for answers to our questions using the resources available to us. We learned the importance of being proactive and searching for our own solutions instead of relying wholly on the help of our sponsor or faculty advisor. There were several occasions that we were able to find answers to our questions through the internet, textbooks, the city design standards manual, or other professors.

We also learned the value of utilizing different forms of communication. At the beginning of our project, we relied solely on emails to ask questions. After meeting in person with our sponsor about half-way through the semester, we realized how powerful a conversation could be in answering our questions quickly and promptly. From that point on, we started calling and texting our sponsor when appropriate, and this helped us to work more efficiently throughout the remainder of the semester.

On many occasions we faced technical problems that we didn't have the knowledge or experience to solve. In these instances, we approached professors that had the knowledge and experience we were lacking. We met with Professor Jeremy Dye with AutoCAD questions, Dr. Dan Ames with GIS questions, and Dr. Rollin Hotchkiss with hydrology questions. Even though there wasn't a single professor that had all the answers to all of our questions, each professor was able to help us with a specific issue we were facing, and piece by piece we were able to complete our project. This was a satisfying process for us, and we gained a new appreciation for the wealth of information and resources available to us as college students.

There were moments during our project that our data wasn't making sense to us or our faculty advisor. Instead of ignoring these concerns and pressing on, we would spend the time necessary to clear up any confusions. This meant that we visited the site more often than we had initially planned for, and we met with our faculty advisor and sponsor more often than we originally anticipated. Meeting more often helped us avoid mistakes and improve our confidence in the validity of our analysis.

The lessons we learned during our capstone experience have given us a glimpse into what it will be like to work in industry. The skills we developed in this process will be valuable in our future careers. We have become better problem solvers, communicators, and engineers.

Conclusions

Our team was able to meet all of our sponsor's needs. We found the runoff quantity for the watershed, two possible drainage solutions, drainage collection, conveyance, and outfall designs. We have provided ample maps and exhibits in this report. We believe the two alternatives we've outlined in this report are the most feasible solutions to the flooding issues for 1690 West.

To calculate the runoff quantity, we used the rational equation. The area of the watershed was confirmed in Esri's ArcGIS Pro after we manually delineated the watershed. The intensity was computed iteratively using the kinematic wave equation and an IDF curve from NOAA for the City of Midvale. We computed an area-weighted, composite C-value using ArcGIS Pro.

The design storm was a 10-year storm with an intensity of 2.28 in/hr and a duration of 12 minutes. Because of the necessary segmentation of the watershed, we used a catchment area of 2.3 acres and a composite C-value of 0.627. The resulting design flow was 3.24 cfs.

In addition to the design analysis performed in determining the design flow and pipe sizing, we also considered the unexpected consequences of implementing our project. We considered environmental, social, safety, and economic factors. We are confident that our design mitigates these unexpected consequences and are confident in the conclusions that we have reached in our analysis.

Recommendations

Waiting to tie into the planned construction on W 14600 S is the preferred alternative but we recommend the City of Bluffdale investigate how urgent the flooding situation currently is before deciding on this alternative. If the city is confident in the performance of the temporary drain, then the preferred alternative is the best option. The preferred alternative would cost $68,275.50 to install. However, if the temporary drain is not adequately mitigating flood issues, then we recommend installing a permanent solution sooner. In this case, our second alternative would be the best option. The second alternative would cost $213,258.30 to install. The second alternative would cost the City of Bluffdale significantly more to install, so it is important for the city to keep the current temporary drain well-maintained to help prevent the need to choose the more expensive, second alternative.

Figure 6 is a map of the preferred alternative. The system installed would mirror Figure 7 below from the city design manual. The only difference being that the pipe would only leave the inlet box in one direction.

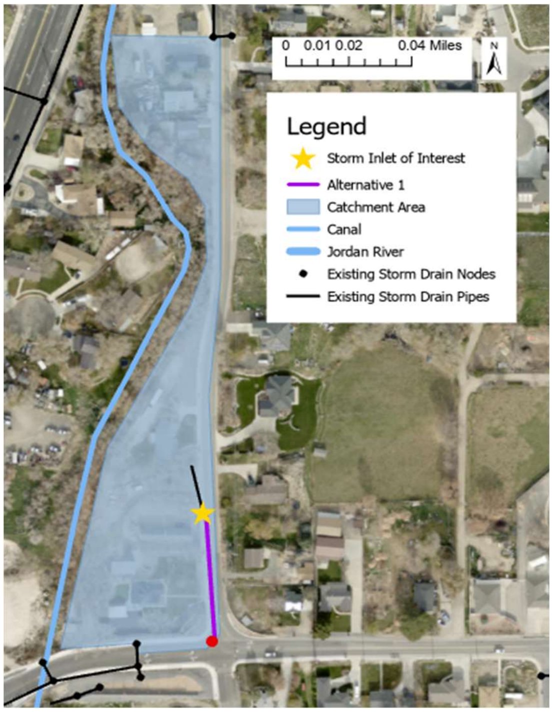

Figure 6 Map of Preferred Alternative 1

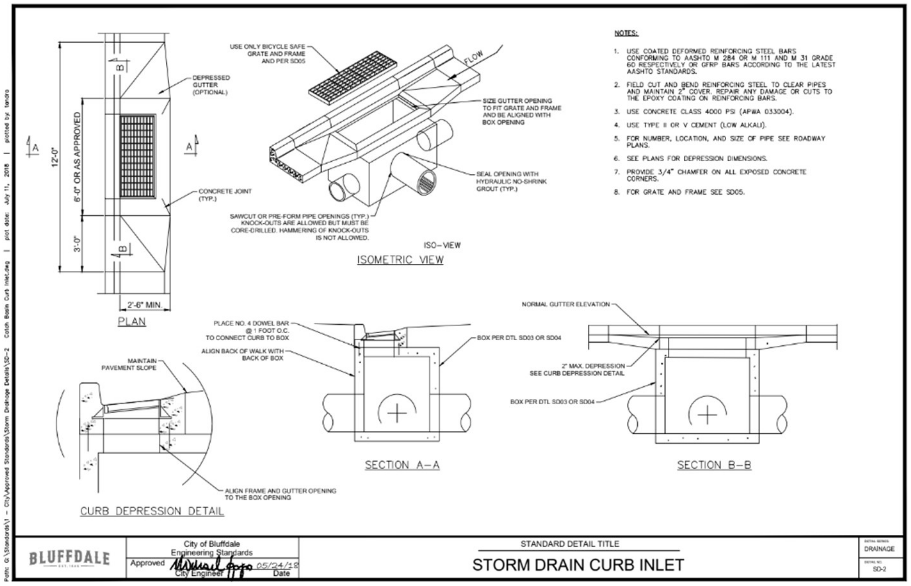

Figure 7 Sample CAD Drawing of Inlet Box from City Design Manual

When the city moves forward with the implementation and construction, we encourage them to keep in mind the following:

- Coordinating this project with the scheduled construction on W 14600 S to minimize disruption to residents
- Complying with the SWPP plan in the city standards
- Painting or stamping a fish on inlet to discourage dumping of chemicals and pollutants

Keeping these things in mind will ensure that the project implementation comes with the fewest negative consequences possible.

Appendix A: Topographic Data

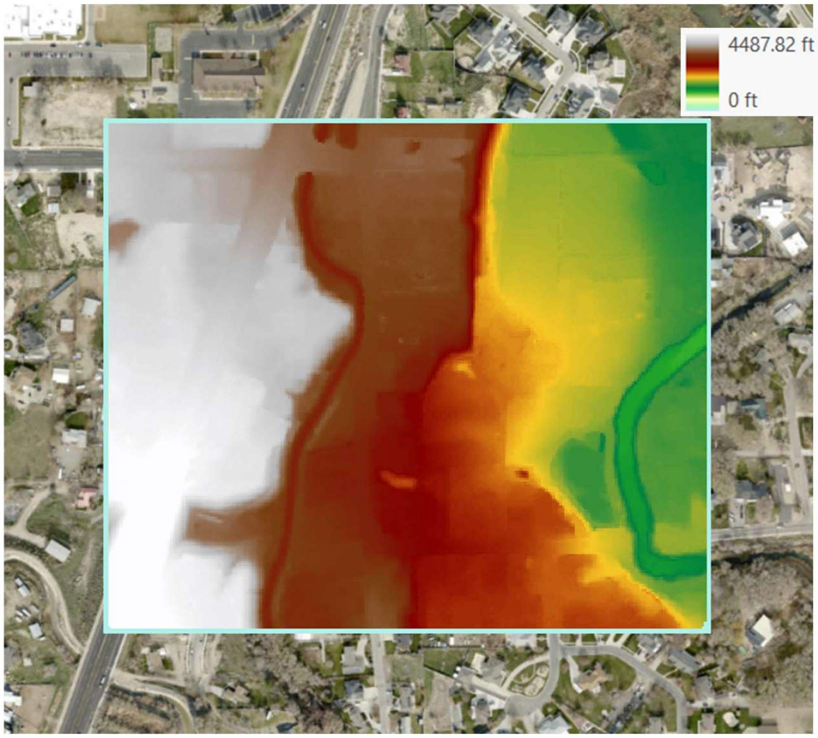

Figure 8 LiDAR data provided by the City of Bluffdale

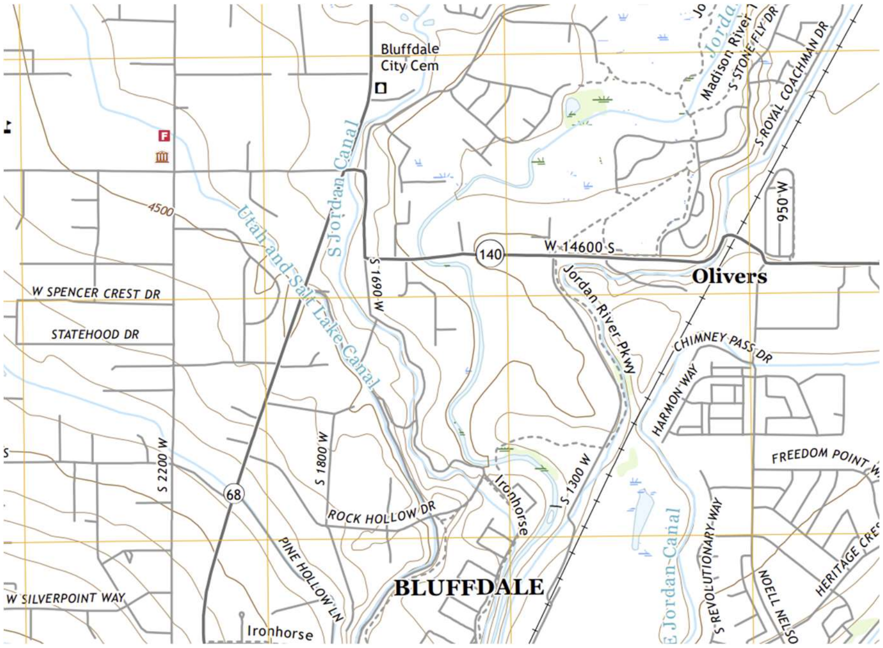

Figure 9 Portion of USGS 7.5-minute Quadrangle

Appendix B: Tabulated IDF Curve

Table 6 Tabulated IDF Curve from NOAA for the City of Midvale, UT

2/7/23, 9:47 AM Precipitation Frequency Data Server

NOAA Atlas 14, Volume 1, Version 5 MIDVALE
Station ID: 42-5610
Location name: Midvale, Utah, USA*
Latitude: 40.6°, Longitude: -111.9167°
Elevation:
Elevation (station metadata): 4344 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.127 (0.112-0.147)	0.161 (0.142-0.186)	0.220 (0.193-0.256)	0.276 (0.238-0.321)	0.365 (0.307-0.429)	0.450 (0.367-0.533)	0.548 (0.432-0.658)	0.665 (0.503-0.815)	0.854 (0.611-1.07)	1.03 (0.702-1.32)
10-min	0.194 (0.170-0.224)	0.245 (0.215-0.284)	0.335 (0.294-0.389)	0.420 (0.362-0.489)	0.556 (0.468-0.653)	0.684 (0.558-0.811)	0.834 (0.658-1.00)	1.01 (0.766-1.24)	1.30 (0.930-1.64)	1.56 (1.07-2.02)
15-min	0.240 (0.211-0.278)	0.304 (0.267-0.352)	0.416 (0.364-0.482)	0.521 (0.449-0.606)	0.689 (0.579-0.809)	0.848 (0.692-1.01)	1.03 (0.816-1.24)	1.25 (0.949-1.54)	1.61 (1.15-2.03)	1.94 (1.32-2.50)
30-min	0.323 (0.284-0.374)	0.409 (0.360-0.473)	0.560 (0.490-0.650)	0.701 (0.604-0.816)	0.928 (0.780-1.09)	1.14 (0.931-1.35)	1.39 (1.10-1.67)	1.69 (1.28-2.07)	2.17 (1.55-2.73)	2.61 (1.78-3.36)
60-min	0.400 (0.351-0.463)	0.506 (0.445-0.586)	0.693 (0.606-0.804)	0.868 (0.748-1.01)	1.15 (0.966-1.35)	1.41 (1.15-1.68)	1.72 (1.36-2.07)	2.09 (1.58-2.56)	2.68 (1.92-3.38)	3.23 (2.21-4.16)
2-hr	0.500 (0.451-0.565)	0.624 (0.560-0.703)	0.810 (0.724-0.916)	0.988 (0.873-1.12)	1.28 (1.10-1.46)	1.55 (1.29-1.79)	1.87 (1.51-2.19)	2.24 (1.74-2.70)	2.86 (2.10-3.54)	3.43 (2.40-4.35)
3-hr	0.579 (0.528-0.644)	0.713 (0.650-0.791)	0.897 (0.813-0.997)	1.07 (0.960-1.19)	1.34 (1.18-1.51)	1.59 (1.36-1.80)	1.89 (1.58-2.22)	2.26 (1.82-2.72)	2.87 (2.21-3.58)	3.46 (2.53-4.39)
6-hr	0.753 (0.698-0.819)	0.923 (0.852-1.00)	1.12 (1.03-1.22)	1.30 (1.19-1.42)	1.56 (1.41-1.72)	1.79 (1.59-1.99)	2.04 (1.78-2.30)	2.35 (1.99-2.75)	2.94 (2.41-3.61)	3.48 (2.76-4.44)
12-hr	0.940 (0.869-1.02)	1.15 (1.06-1.25)	1.38 (1.28-1.52)	1.59 (1.46-1.74)	1.90 (1.71-2.09)	2.14 (1.91-2.39)	2.41 (2.11-2.72)	2.71 (2.32-3.10)	3.17 (2.63-3.72)	3.55 (2.88-4.48)
24-hr	1.06 (0.992-1.14)	1.30 (1.22-1.40)	1.55 (1.45-1.67)	1.76 (1.64-1.89)	2.04 (1.90-2.20)	2.27 (2.10-2.44)	2.50 (2.30-2.75)	2.72 (2.49-3.13)	3.20 (2.75-3.75)	3.58 (2.94-4.53)
2-day	1.22 (1.14-1.31)	1.49 (1.39-1.60)	1.77 (1.65-1.90)	2.01 (1.87-2.15)	2.32 (2.15-2.49)	2.56 (2.37-2.75)	2.81 (2.59-3.02)	3.05 (2.80-3.30)	3.38 (3.08-3.79)	3.62 (3.27-4.57)
3-day	1.30 (1.22-1.39)	1.59 (1.50-1.71)	1.90 (1.78-2.03)	2.15 (2.02-2.30)	2.50 (2.34-2.67)	2.77 (2.58-2.96)	3.04 (2.82-3.27)	3.32 (3.06-3.57)	3.69 (3.37-4.06)	3.98 (3.60-4.63)
4-day	1.39 (1.31-1.48)	1.70 (1.60-1.81)	2.03 (1.91-2.16)	2.30 (2.17-2.45)	2.69 (2.52-2.86)	2.98 (2.78-3.17)	3.28 (3.05-3.51)	3.59 (3.32-3.85)	4.01 (3.66-4.32)	4.33 (3.93-4.69)
7-day	1.61 (1.52-1.71)	1.97 (1.86-2.09)	2.34 (2.22-2.49)	2.65 (2.52-2.81)	3.07 (2.91-3.25)	3.40 (3.21-3.60)	3.74 (3.50-3.96)	4.07 (3.79-4.32)	4.51 (4.16-4.82)	4.84 (4.43-5.20)
10-day	1.80 (1.70-1.91)	2.21 (2.09-2.35)	2.62 (2.48-2.78)	2.95 (2.79-3.12)	3.38 (3.19-3.57)	3.69 (3.48-3.91)	4.01 (3.76-4.25)	4.32 (4.04-4.58)	4.71 (4.38-5.02)	5.00 (4.62-5.35)
20-day	2.35 (2.22-2.48)	2.88 (2.72-3.05)	3.40 (3.22-3.59)	3.80 (3.60-4.00)	4.30 (4.07-4.52)	4.66 (4.40-4.91)	5.00 (4.72-5.27)	5.33 (5.00-5.63)	5.73 (5.36-6.07)	6.01 (5.60-6.39)
30-day	2.83 (2.68-2.99)	3.47 (3.27-3.67)	4.06 (3.84-4.29)	4.52 (4.27-4.77)	5.10 (4.82-5.39)	5.52 (5.21-5.83)	5.92 (5.57-6.26)	6.29 (5.91-6.67)	6.75 (6.30-7.19)	7.07 (6.58-7.56)
45-day	3.55 (3.36-3.75)	4.33 (4.10-4.59)	5.07 (4.80-5.35)	5.64 (5.34-5.95)	6.38 (6.03-6.72)	6.90 (6.51-7.27)	7.40 (6.96-7.80)	7.87 (7.38-8.32)	8.44 (7.89-8.94)	8.84 (8.23-9.39)
60-day	4.20 (3.97-4.45)	5.14 (4.85-5.44)	6.00 (5.68-6.35)	6.67 (6.31-7.07)	7.52 (7.10-7.96)	8.12 (7.64-8.60)	8.68 (8.16-9.22)	9.22 (8.64-9.82)	9.86 (9.21-10.5)	10.3 (9.58-11.0)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Back to Top

PF graphical

Appendix C: Price References

Since many suppliers will not offer price estimates without some indication of serious intent to purchase, we had to get creative when finding price estimates. The following two references are what we used to price out our alternatives.

- The 2023 Unit Price Schedule from Fairfax County, Virginia Land Development Services
  - https://www.fairfaxcounty.gov/landdevelopment/sites/landdevelopment/files/assets/documents/pdf/publications/unit-price-schedule.pdf

- UDOT's Estimator Corner
  - https://drive.google.com/open?id=1u4orc1VFiHbtAg8mfSZmbon2JZx4eay8

Appendix D: Price Breakdown

Table 7 Detailed Price Breakdowns for Alternatives 1 and 2

Item	Description	Unit Cost	units	Al1 Quantity	Alt1 cost	Alt2 Quantity	Alt 2 cost
15" reinforced concrete pipe	RCP Class III to V, 12" to 30" $ 120 LF	$120.00	LF	231	$27,720.00	1012	$121,440.00
inlet box	Curb Drop Inlets, Precast, 12"-30" Pipes $ 8,808 EA	$8,808.00	EA	1	$8,808.00	1	$8,808.00
manhole	Standard Frame and Cover (MH-2) 4 FT ID, 6' depth with frame and cover $ 5,574 EA	$5,574.00	EA	1	$5,574.00	3	$16,722.00
replace side walk	Sidewalk, Concrete 4" - no reinforcement and no base & Concrete 4" with WWF & no base $ 62 SY	$62.00	SY	141	$8,742.00	141	$8,742.00
replace curb and gutter	Concrete Curb & Gutter (CG-2, CG-3, CG-6 & CG-7) $ 33 LF	$33.00	LF	210	$6,930.00	210	$6,930.00
asphalt repair	Bituminous Concrete, Subbase, Base Course, Top Course & Coat per Square Yard $ 76 SY	$76.00	SY	21	$1,596.00	300	$22,800.00
				Alt 1 Subtotal:	**$59,370.00**	**Alt 2 Subtotal:**	**$185,442.00**
SWPP	2% of construction costs	2%	Lump	1	$1,187.40	1	$3,708.84
Traffic Control	3%-5% of construction costs	4%	Lump	1	$2,374.80	1	$7,417.68
Maintenance of Traffic	1% of construction costs	1%	Lump	1	$593.70	1	$1,854.42
Mobilization	7%-10% of construction costs	8%	Lump	1	$4,749.60	1	$14,835.36
				Alt 1 Total:	**$68,275.50**	**Alt 2 Total:**	**$213,258.30**

Appendix E: City of Bluffdale Standards

The City of Bluffdale Design Manuals are extensive and cover a wide variety of project types. A complete list of the available manuals is available here:

- Standard, Specifications, and Manuals
  - https://www.bluffdale.com/234/Standards-Specifications-Manuals

The most relevant manuals in our project were:

- Storm Water Design Standards Manual August 2021
  - https://www.bluffdale.com/DocumentCenter/View/4243/Storm-Water-Design-Standards--Manual-August-2021
- SWPP Details June 2019
  - https://www.bluffdale.com/DocumentCenter/View/4247/SWPP-Details-June-2019
- Storm Drainage Details - Dec 2022
  - https://www.bluffdale.com/DocumentCenter/View/5411/Storm-Drainage-Details---Dec-2022

Appendix F: Team Resumes

Eva-Marie Hamill

(509) 901-5166 · e.hamelaswood@gmail.com · www.linkedin.com/in/EvaMarieHamill

EDUCATION

Brigham Young University, Ira A. Fulton College of Engineering — Apr 2023
Civil and Environmental Engineering Major with Environmental Science Minor — Provo, UT

- Society of Woman Engineers BYU student chapter secretary
- Competed in ASCE 2021 Blue Sky Innovation and placed 2nd at the Rocky Mountain Conference
- Member of ASCE National and BYU Student Chapter
- Relevant Coursework: Aquatic Policies and Laws, Environmental Engineering, Hydrology, Hydraulic Structure Design, Advance Engineering Applications of GIS, History of City Planning, and Technical Writing

WORK EXPERIENCE

Brigham Young University, Hydroinformatics Laboratory — Dec 2021-Present
Research Assistant: Groundwater data processing and mapping — Heber, UT

- Developed a Google Colab Notebook for groundwater visualization and provided a live demonstrated for a group of 30 stakeholders in the West African Region during a series of workshops
- Documented two web apps that use remote sensing and in situ measurements to map groundwater for stakeholders
- Tested machine learning algorithms using skills learned through an online course
- Learned about the complexities of groundwater modeling using GMS software

Central Utah Water Conservancy District — Feb 2021-Aug 2022
Intern at Wasatch County Water Efficiency Project Office — Heber, UT

- Developed a web app that updates automatically to reflect the current water schedule to help our staff and local irrigation companies monitor scheduled water use
- Optimized an existing spreadsheet for scheduling and visualizing use of ditch water by adding VBA which reduced the run time from 5-10 minutes to under 10 seconds
- Scheduled water for urban and agricultural users, updated GIS maps, maintained and troubleshooted a large database using skills in VBA
- Monitored water use, visited construction sites, and inspected condition of infrastructure in the field

Brigham Young University, Department of Civil and Environmental Engineering — Aug 2020-Apr 2021
Teaching Assistant Statics — Provo, UT

- Worked on practice problems with students individually to help them understand basic engineering concepts
- Conducted and taught exam reviews for a class of 60 students
- Interacted professionally over Zoom

VOLUNTEER EXPERIENCE

BYU Global Engineering Outreach Club — Mar 2018-May 2022
Paso Nuevo Prosthetics Team Member and Navajo Nations Trip Volunteer — Provo, UT

- Worked on interdisciplinary team to design and manufacture prosthetic liners for 1/20th of the cost of commercial liners distributed in Ecuador
- Trained technicians in Ecuador to manufacture our liners and fit two patients with test liners
- Preformed systematic testing to determine the bonding properties of medical grade silicones
- Assisted in the construction of a community kitchen and rain catch structure in the Navajo Nations
- Demonstrated the ability to work well in a team and quickly learn new skills like mixing and pouring concrete, fire-treating wood, and installing siding

BYU Low Head Dam Project — Sept 2020-Dec 2020
Member of Volunteer Search Team — Provo, UT

- Utilized Google Earth Pro to find, identify, and mark all the low head dams in Fond Du Lac County, WI
- Contributed to a larger effort by a national committee to prevent likely drownings at these locations

The Church of Jesus Christ of Latter-day Saints — Jul 2018-Jan 2020
Full-time Spanish-Speaking Representative — Milwaukee, WI

- Applied principles of goal setting, accountability, and organization
- Improved public speaking skills through daily practice in both Spanish and English
- Led initiative to start group English classes in three cities, and trained three other teachers

TECHNICAL SKILLS

- Experienced with ArcPRO, ArcGIS online, Model Builder tools, and ESRI field data collection apps
- Coding Experience in Python, VBA, and HTML
- Experienced with WMS and GMS water modeling programs
- Conversational Spanish

Emily K. Blanchard

ekblnchrd@gmail.com // (949) 379-9209 // www.linkedin.com/in/emily-blanchard-byu

EDUCATION

Brigham Young University June 2023
Major: Civil Engineering // GPA: 3.99 Provo, UT
Relevant Coursework: Engineering Applications of GIS, Traffic Engineering, and Hydraulics and Fluid Flow Theory
Involvement and Leadership:

- Society of Women Engineers (SWE) BYU Chapter President and National Member
- Tau Beta Pi Honor Society BYU Chapter Alumni Relations Chair and Member
- Institute of Transportation Engineers (ITE) BYU Chapter Member
- American Society of Civil Engineers (ASCE) National Member and ASCE BYU Chapter Member

RELEVANT EXPERIENCE

Anderson Engineering Company Inc. May 2022-Present
Engineering Technician Saratoga Springs, UT

- Collected and examined more than 150 soil samples in 2 months to determine concentrations of lead and arsenic
- Presented 3 QC project updates regarding sample collection and results to maintain the project timeline
- Analyzed the feasibility of 6 sites for septic systems by investigating soil types and slopes from DEMs

Brigham Young University, Department of Civil Engineering Apr 2021-May 2022
Hydroinformatics Research Assistant Provo, UT

- Researched remote sensing to map flood extent and impact for community leaders to take informed precautions
- Executed Python algorithms to process satellite imagery to analyze flood extent, depth, and duration in 3 locations

Brigham Young University, Department of Civil Engineering Aug 2020-Apr 2021
Teaching Assistant for Statics Provo, UT

- Interacted weekly with the teaching professor to ensure a high-quality engineering course
- Evaluated over 50 assignments and tests weekly to improve student performance growing their success
- Developed problem sets for 4 review sessions to provide students an opportunity to practice class material

Accurate Laminated Products Inc. Feb 2020-Aug 2020
Estimating Coordinator Fullerton, CA

- Customized and streamlined process of receiving and processing bid invitations saving 2 hours per project
- Monitored more than 40 project proposals ranging in size and scope and assisted project managers
- Nurtured relationships with over 15 general contractors to build trust and confidence in our superb service

VOLUNTEER EXPERIENCE

Ira A. Fulton College Engineering, Global Engineering Outreach Mar 2018, Aug 2021-May 2022
Navajo Nation Trip Contributor and Group Member Blanding, UT and Peru

- Built a community kitchen and water conservation shed on the Navajo Reservation
- Collaborated across engineering disciplines for 2 semesters to meet project constraints and community vision
- Designed and implemented a motor-powered quinoa washer improving productivity by 85%

The Church of Jesus Christ of Latter-day Saints Aug 2018-Feb 2020
Full-Time Volunteer Representative Siberia, Russia

- Led discussions with over 30 individuals in one-on-one settings to spread awareness of the organization
- Trained over 50 individuals in teamwork, leadership, Russian language skills, communication, and organization
- Developed strong work ethic by working more than 80 hours per week to meet specific goals

SKILLS AND TECHNICAL SOFTWARES

- Google Earth Engine: analyzed satellite images
- Python: implemented code to model water maps
- Civil3D: analyzed feasibility of sites for septic systems
- Excel: experienced with VBA, VLOOKUP, charts, and graphs
- Synchro: modeled a critical corridor with signal timing and traffic volumes
- Zoho: monitored customer relationships and project timelines and to enrich customer relations
- ArcGIS Pro: built ModelBuilder models and tool interfaces as part of data analysis and map development

Jonah Dundas
(530) 210-1423 · JonahBDundas@gmail.com

EDUCATION

Brigham Young University June 2023
Bachelor of Science/Arts: Civil Engineering Provo, UT

- GPA 3.97
- Co-Author of "SABER: A Model-Agnostic Postprocessor for Bias Correcting Discharge from Large Hydrologic Models" Hydrology 9, no. 7: 113
- Awarded the California Statewide Law Enforcement Association Scholarship, the California Public Safety Administrators Scholarship, a Geneva Rock scholarship, the Pete & Arline Harman Scholarship, the Brigham Young Grant, the Norris Hill Maddock Scholarship, and the Robert R. & Vera S. Cederlof Scholarship while at BYU
- Made the Dean's List in Fall 2020, Fall 2021, and Winter 2022 in the BYU College of Engineering

EXPERIENCE

Brigham Young University Apr 2021-present
Hydroinformatics Lab Research Assistant Provo, UT

- Assisting a PhD student with his python code for bias correction with the lab's global water model
- Developing a Tethys web application using JavaScript and CSS to illustrate the bias correction data
- Reformatted lab trainings into restructured text and published them on a Read the Docs website through GitHub

RB&G Engineering Apr 2022-Aug 2022
Intern Provo, UT

- Lab and field testing of soils, asphalt, and concrete
- Reviewed pile drive reports for the SLC International Airport North Concourse project
- Assisted with geotechnical explorations on drill rig and sample collection

West Desert Roofing Apr 2021-Aug 2021
Roof Installer Provo, UT

- Residential roof demolition and installation

Brigham Young University Aug 2020-April 2021
Statics Mechanics Teaching Assistant Provo, UT

- Responsible for helping about 90 students a semester with their questions regarding the material, their homework, and test preparation
- Aided the professor in editing and publishing online lectures due to COVID restrictions

Cullumber Engineering and Design Inc Jun 2020-Aug 2020
Intern Rocklin, CA

- Designed AutoCAD drawings for residential projects
- Performed basic load calculations for residential projects using the firm's excel spreadsheets
- Reformatted AutoCAD templates to match the firm's style

VOLUNTEER EXPERIENCE

The Church of Jesus Christ of Latter-day Saints Oct 2017-Oct 2019
Full-time Volunteer Representative Guadalajara, Mexico

- Assisted families and individuals in making lifestyle changes that were congruent with the Christian principles I taught
- Participated in service projects such as painting and laying concrete for homes
- Led about 10 other volunteers in weekly meetings and trainings where we set goals and created weekly progress reports
- Taught English as a second language on a weekly basis for months of my service

ACHIEVEMENTS

- Professional working Spanish
- Eagle Scout