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Site Development at the Corner of Drake and Stadium

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Site Development – Corner at Drake and Stadium

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Submitted to—
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ACKNOWLEDGMENTS

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1. EXECUTIVE SUMMARY

1.1. ABSTRACT

This report presents the site layout alternatives for the development located at the corner of Drake and Stadium in Kalamazoo, Michigan. In the report four different layouts are suggested and followed by best management practices for grading and earthwork plans, porous asphalt pavement design, storm water retention design for the proposed site, and storm sewer pipe design. The redesign of the Costco Development Site aims to maximize efficiency of the development area through the warehouse and gas station location, parking lot layout, and trucking routes. Grading design is developed based on the existing site conditions before construction took place. The storm water retention design for the Costco watershed is utilized for an onsite retention basin, bioinfiltration systems, porous asphalt pavement, and an oil separator in order to minimize cost and maximize sustainability.
2. INTRODUCTION

2.1. DESCRIPTION OF PROJECT AND BACKGROUND

The Corner at Drake and Stadium is a site development project located at the northeast quadrant of the U.S. 131 and Stadium Drive interchange in Kalamazoo as shown in Figures 1 and 2. The construction on the 40-acre development began in November, 2013. The mixed-used commercial center is anchored by a Costco warehouse and has the potential to include two hotels, a bank, restaurants, and some retail stores.

Costco Wholesale Corporation built a 150,000-square-foot warehouse club store and a gasoline station on the northeast corner of Stadium and Drake. Out of the initially owned 39.2-acre property by AVB, almost half, approximately 16.3 acres, was purchased by Costco Wholesale Corp. In addition, Costco’s development has been estimated to account for about one-third of the $70 million overall costs of the retail center. Therefore, Costco’s site development criterion was a major factor in the development of the property.

Initially Drake and Stadium Road Intersection was zoned for residential use only. Thirty-two houses and acres of trees were demolished in the Century-Highfield area in order to make way for the Corner at Drake and Stadium project. The demolition of the original residential zone induced positive changes in the community.

After numerous negotiations and discussions between MDOT, the Kalamazoo County Road Commission, AVB and Costco Wholesale Corporation, a thorough design was submitted by Hurley & Stewart, which included, but not limited to, the following parameters:

- Site Planning and Layout
Site Development – Corner at Drake and Stadium

- Site Grading/Earth Balancing
- Regional Storm Water Management
- Site Utility Design
- Traffic Engineering Solution
- Sanitary and Waste Water Plan

When Hurley & Stewart performed engineering work for the site development, they designed the project based on Costco’s site development criterion. The goal of this report is to develop two site layouts without Costco’s limitations, and then analyze it with the current property layout. Also, two different alternatives are suggested for this property that consider Costco’s limitation. All four alternatives are compared to the current property layout.

![Figure 1 Site Location (Source: Google Maps)](image-url)
2.2. SCOPE OF WORK

The goal of this project is to improve and provide alternative design solutions for the Site Development - Corner at Drake and Stadium in Kalamazoo, Michigan. SJMB & Associates have developed four alternative site layout plans. Based on the approximate cost, sustainability, site aesthetics, and site efficiency one of the alternatives is selected and the final scope of the project is designed. The chosen alternative has a grading plan for the cut and fill volumes, porous asphalt pavement design, and storm water retention design, storm sewer pipe design, and project cost.
2.3. IMPACTS AND CONSTRAINTS

The Site Development – Corner at Drake and Stadium is one of those unique projects where the constraints are not only from engineering perspective but also from the client. For this project, the engineering constraint was the existing site elevation. The elevation difference from North-South Drake is a concern to Costco, as shown in Figure 3. They were concerned that their warehouse will not be visible to their customers.

The project was recently completed after long negotiations with Costco Wholesale Corporation. During the construction and delivery of the project, Costco played a major role towards establishing parameters for the parties involved. They played a key role in the layout of the project, which restricted some of the companies such as Hurley & Stewart from delivering their desired designs.

Due to Costco’s exceptionally high investment in the development of the property, they incessantly insisted their warehouse to be placed in the center of the property. The location of Costco’s warehouse and their gas station played a major role in the layout of the site. They wanted their costumers to have easy access to the store and the gas station. Taking in consideration Costco’s restrictions, two alternatives are designed in order to meet Costco’s needs.
2.4. PROJECT DELIVERABLES

2.4.1. COMPUTER AIDED DESIGN DRAWINGS

The CAD or design drawings provide the proposed engineering solutions for the property. The drawings also include the following items:

- Overall Site Layout
- Site Grading Plan
- Porous Asphalt Design
- Storm Water Retention Design for Costco Watershed
- Storm Sewer Pipe Design and Layout

2.4.2. ANALYSIS OF ALTERNATIVES

The analysis portion of the report thoroughly delineates the specific elements of the proposed solution for the development. The four alternatives are compared later in Section 3.1.2.6 based on cost, sustainability, site aesthetic, and site efficiency.
2.4.2.1. ALTERNATIVE 1: COSTCO AT THE NORTH CORNER #1

This alternative presents a site layout considering Costco’s limitations. A brief description of the alternative’s cost, sustainability aspects, site aesthetics, and site efficiency are discussed in further detail in Section 3.1.2.2.

2.4.2.2. ALTERNATIVE 2: COSTCO AT THE SOUTH CORNER

Unlike the alternatives 1, this alternative does not consider any of the Costco’s limitations. Although, a similar analysis is performed for this alternative in terms of cost, sustainability aspects, site aesthetics, and site efficiency in further detail in Section 3.1.2.3.

2.4.2.3. ALTERNATIVE 3: COSTCO AT THE SOUTH CORNER ROTATED 90°

Similar to Costco at the South Corner, Costco’s limitations are disregarded and its efficiency is measured on the entire site rather than only for Costco warehouse. Cost, sustainability aspects, site aesthetics, and site efficiency are discussed in further detail in Section 3.1.2.4.

2.4.2.4. ALTERNATIVE 4: COSTCO AT THE NORTH CORNER #2

This last alternative is very similar to the existing design except the Costco warehouse is rotated 90 degrees. Cost, sustainability aspects, site aesthetics, and site efficiency are discussed in further detail in Section 3.1.2.5.

2.4.2.5. COMPARISON OF FOUR AT ALTERNATIVES AND THE AS-BUILT SITE LAYOUT

Each of the preliminary alternatives are analyzed based on the following criteria:
Site Development – Corner at Drake and Stadium

- Cost
  - Site Area
  - Asphalt Area

- Sustainability
  - Green Area
  - Parking Space
  - Bioinfiltration Area

- Site Aesthetics
  - Green Area
  - Site Appeal

- Site Efficiency
  - Parking Ratio to the Available Land
  - Future Development Area

The four alternatives are compared in order to select the alternative that meets the above criteria based on the following scoring scale.

Table 1 Scoring Scale for Evaluating the Options

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Acceptable</td>
</tr>
<tr>
<td>2</td>
<td>Good</td>
</tr>
<tr>
<td>3</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
2.4.2.6. FINAL AND CHOSEN SITE LAYOUT

The final alternative carries out the remaining scope of the work as stated below:

- Grading and Earthwork
  - Calculations For Excavation or Cut Volume
  - Calculation For Embankment or Fill Volume
  - Designed Final Grading Plan

- Storm Runoff Analysis

- Storm Water Retention Design
  - Bioinfiltration Systems
  - Porous Asphalt Pavement
  - Retention Pond Basin

- Storm Sewer Pipe Design and Layout

- Project Cost
3. BODY OF REPORT

3.1. ENGINEERING ANALYSIS

3.1.1. METHODS USED

A method of trial and error has been used for designing the alternative layouts for the site. Each team member designed a particular alternative and took the following parameters in consideration: traffic flow for trucks, sustainability, and maximizing the land for the future developments.

After the best alternative has been chosen, the rational method is utilized to calculate the storm runoff volume for the site for a 100-year storm event. The Average End Area Method is then used for sizing the storage of the retention pond. For the grading work for the chosen alternative, AutoCAD Civil3D is used to grade the proposed site in order to have the collected runoff water naturally flow to the catch basins. The building is also built at an elevation that meets Costco’s desire for the store to be seen from the highway. The existing site elevation differences are blended across the entire site. Civil3D is also used to calculate the amount of cut and fill in the site.

Another computer software known as Minimal Impact Development Standards (MIDS) Calculator is used in this project to calculate the effective usage of bioinfiltration cells and porous asphalt pavement on the site. The runoff value and the contributing drainage area for each cell are entered in the MIDS Calculator. The software performs calculations on the areas where porous asphalt pavement will be placed.
3.1.2. OPTIONS ANALYZED

3.1.2.1. SITE LAYOUT SOLUTION BY HURLEY & STEWART

Hurley & Stewart designed and provided the layout shown in Figure 4 to Costco and AVB as a final design layout for the site. Due to the elevation and steep slope on the site, the entire site was brought down three feet from the existing conditions. The soil from the site was sold to MDOT for the construction of the new on and off ramps for the US 131 and Stadium interchange. During the
demolition stage of this project, hundreds of trees were cut down in order to make the development on this site possible. The city did not consider sustainability impacts of the site due to the disturbance of the site. This layout does not meet the sustainability aspects of this site.

The flow of traffic for the existing site is smooth and safe. The trucks and consumer vehicles are diverged as soon as they enter from the North Drake Road. The traffic flow for trucks is the largest plus in this layout. The location of the gas station allows customers to enter with ease. The layout also meets the client’s visibility requirements.

Despite the lack of sustainable features in this design, the project re-used all the crushed concrete gathered during the demolition of the houses. The crushed concrete was used as a sub base for the Century Road, the ring road built on site.
3.1.2.2. ALTERNATIVE 1: COSTCO AT THE NORTH CORNER #1

The layout in Figure 5 meets Costco’s and MDOT’s needs in terms of the placement of the Costco warehouse, and it provides effective traffic flow for trucks and consumer vehicles. The site also utilizes the use of bioinfiltration systems and porous asphalt to attenuate the cost and design values for the retention basin for Costco’s development.

As shown in the figure above, the Costco warehouse has been rotated 90 degrees from its original design and three bioinfiltration cells are placed. One of the cells is parallel to Drake Road, and it is to the West of the building entrance. The other two are parallel to the West Michigan Avenue. Porous asphalt is also
utilized on this site. This aided in reducing the number of catch basins needed to drain the water from the runoff. Refer to Section 5.1.1 for bioinfiltration system and Section 5.1.2 for porous asphalt for this alternative.

Looking at Table 2 below, the site will use a minimum of 5 alternatives for the site area. It will provide a 21.7 acres of land for the future development. It has the lowest of five alternatives in terms of impervious area of 8.01. The site also meets the requirements for the minimum parking spaces. It provides 721 parking spaces for the potential customers.

| Table 2 Alternative 1: Costco at the North Corner #1 |
|---------------------------------|--------|--------|
| Future Development Area | 21.7 | Acres |
| Total Site Area | 15.8 | Acres |
| Green Area | 90,525 | S.F |
| Proposed Pond | 29,765 | S.F |
| Concrete Curb | 48,470 | S.F |
| Asphalt Area | 8.01 | Acres |
| 3 Bio-retention | 16,320 | S.F |
| # Parking | 721 | Spaces |
| Min. Accessible parking required | 15 | Spaces |
| Proposed Accessible Parking | 18 | Spaces |
| Min. Van Accessible Parking | 3 | Spaces |
3.1.2.3. ALTERNATIVE 2: COSTCO AT THE SOUTH CORNER

The alternative shown above in Figure 6 is the best environmental solution for the development. A long bioretention system is suggested for the site with an underdrain to route the filtered water for use by either the city, Costco, or the future developments on site. The site in the above figure also meets all the city standards in term of parking requirements and even exceeds the City’s green area requirements.

As shown in Table 3 below, the site above will use 20.7 acres of land only for Costco’s development. It will have 91,580 square foot of green area. The available parking space for the costumers is 726 if this site is used. The asphalt or
the impervious area on this site is roughly 12.4 acres. Compare to the other site alternatives, this has the highest runoff area. It also leaves the least available land of 16.8 acres for the future developments.

The other downside to this layout is it does not have an efficient traffic flow for the trucks. Another disadvantage for this layout is the maintenance costs needed to maintain the large bioretention system compared to the small bioinfiltration cells in alternative 1.

Table 3 Alternative 2: Costco at the South Corner

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Future Development Area</strong></td>
<td>16.8</td>
<td>Acres</td>
</tr>
<tr>
<td><strong>Total Site Area</strong></td>
<td>20.7</td>
<td>Acres</td>
</tr>
<tr>
<td><strong>Green Area</strong></td>
<td>91,580</td>
<td>S.F</td>
</tr>
<tr>
<td><strong>Proposed Pond</strong></td>
<td>16,500</td>
<td>S.F</td>
</tr>
<tr>
<td><strong>Concrete Curb</strong></td>
<td>63,730</td>
<td>S.F</td>
</tr>
<tr>
<td><strong>Asphalt Area</strong></td>
<td>12.36</td>
<td>Acres</td>
</tr>
<tr>
<td><strong>3 Bioretention</strong></td>
<td>60,722</td>
<td>S.F</td>
</tr>
<tr>
<td><strong># Parking</strong></td>
<td>726</td>
<td>Spaces</td>
</tr>
<tr>
<td><strong>Min. Accessible parking required</strong></td>
<td>15</td>
<td>Spaces</td>
</tr>
<tr>
<td><strong>Proposed Accessible Parking</strong></td>
<td>18</td>
<td>Spaces</td>
</tr>
<tr>
<td><strong>Min. Van Accessible Parking</strong></td>
<td>3</td>
<td>Spaces</td>
</tr>
</tbody>
</table>
3.1.2.4. ALTERNATIVE 3: COSTCO AT THE SOUTH CORNER ROTATED 90°

The alternative in the Figure 7 above provides an aesthetically appealing development for the entire site. It is the best solution for Costco’s visibility concerns because it will be highly visible from almost all angles, especially to those driving down US 131. The location of Costco is placed in an ideal location on the site. It will allow the customers to have an easy access to the gas station as well as the rest of the site. The retention basin will add to the aesthetics of the site.

Table 4 below provides a general site information attributed to this site. This site has the maximum green area compare to the other site alternatives, because it is the second largest total site area of 17.4 acres. While the area is the
second largest, the layout contains the smallest number of parking spaces of 616 spaces. Only 9.34 acres of the land is an impervious area which is still lower than the impervious area of the existing site.

<table>
<thead>
<tr>
<th>Future Development Area</th>
<th>20.1</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Site Area</td>
<td>17.4</td>
<td>Acres</td>
</tr>
<tr>
<td>Green Area</td>
<td>95,017 S.F.</td>
<td></td>
</tr>
<tr>
<td>Proposed Pond</td>
<td>40,727 S.F.</td>
<td></td>
</tr>
<tr>
<td>Concrete Curb</td>
<td>63,250 S.F.</td>
<td></td>
</tr>
<tr>
<td>Asphalt Area</td>
<td>9.3</td>
<td>Acres</td>
</tr>
<tr>
<td># Parking</td>
<td>616</td>
<td>Spaces</td>
</tr>
<tr>
<td>Min. Accessible parking required</td>
<td>13</td>
<td>Spaces</td>
</tr>
<tr>
<td>Proposed Accessible Parking</td>
<td>15</td>
<td>Spaces</td>
</tr>
<tr>
<td>Min. Van Accessible Parking</td>
<td>3</td>
<td>Spaces</td>
</tr>
</tbody>
</table>
3.1.2.5. ALTERNATIVE 4: COSTCO AT THE NORTH CORNER #2

The design illustrated in the Figure 8 is similar to the existing design, except the Costco warehouse is rotated 90 degrees. The goal was to change the angle of the building and notice if the site becomes more efficient in terms of green area, available area for the future developments, and less impervious area for the runoff.

The site utilizes no bioinfiltration systems. Although, it provides the highest available land for the future developments and uses less land for the Costco property, while meeting all the constraints from Costco and the city. If it were to be used, the site will have a green space of 68,133 square feet, which is
still approximately 7,000 square feet more than the existing site. It will have the second lowest impervious area from the chosen alternative. That impervious area will be approximately 8.04 acres.

<table>
<thead>
<tr>
<th>Table 5 Alternative 4: Costco at the North Corner #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future Development Area</td>
</tr>
<tr>
<td>Total Site Area</td>
</tr>
<tr>
<td>Green Area</td>
</tr>
<tr>
<td>Proposed Pond</td>
</tr>
<tr>
<td>Concrete Curb</td>
</tr>
<tr>
<td>Asphalt Area</td>
</tr>
<tr>
<td># Parking</td>
</tr>
<tr>
<td>Min. Accessible parking required</td>
</tr>
<tr>
<td>Proposed Accessible Parking</td>
</tr>
<tr>
<td>Min. Van Accessible Parking</td>
</tr>
</tbody>
</table>

3.1.2.6. COMPARISON OF ALTERNATIVES

The table below serves as a preliminary and generic comparison for the different alternative solutions for the site. The alternatives are compared based on the maximum green area, maximum available land for the future development, and minimum asphalt area.

The existing design is set as a benchmark for comparing other alternatives with. Comparing the first alternative, Costco at North Corner, with the existing design, the site area has been reduced by 0.56 acres, the future development has been increased by 0.56 acres, the asphalt or impervious area has been reduced by 2.10 acres.
If the maximum green area was the only variable in the comparison of the alternatives then the alternative with Costco at South Corner Rotated 90° would be considered the solution of the choice. Since it is not, an alternative is chosen which meets most of the criteria.

Table 6 Comparison of All Design Alternatives

<table>
<thead>
<tr>
<th>Layout</th>
<th>Site Area (Acres)</th>
<th>Future Development (Acres)</th>
<th>Asphalt Area (Acres)</th>
<th>Green Area (ft³)</th>
<th>Parking Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Design</td>
<td>16.36</td>
<td>21.14</td>
<td>10.11</td>
<td>61,560</td>
<td>788</td>
</tr>
<tr>
<td>Costco at the North Corner #1</td>
<td>15.8</td>
<td>21.7</td>
<td>8.01</td>
<td>90,525</td>
<td>721</td>
</tr>
<tr>
<td>Costco at South Corner</td>
<td>20.7</td>
<td>16.8</td>
<td>12.36</td>
<td>91,580</td>
<td>726</td>
</tr>
<tr>
<td>Costco at South Corner Rotated 90°</td>
<td>17.4</td>
<td>20.1</td>
<td>9.34</td>
<td>95,017</td>
<td>616</td>
</tr>
<tr>
<td>Costco at the North Corner #2</td>
<td>15.1</td>
<td>22.4</td>
<td>8.04</td>
<td>68,133</td>
<td>688</td>
</tr>
</tbody>
</table>

Three of the alternatives from the table above are compared based on cost, sustainability, site aesthetics, and site efficiency. Scoring is set from a scale of 3 to 1. A score of 3 is given for excellent, 2 for good, and 1 for an acceptable performance. The cost is based on the amount area the site is covered by the asphalt. Bioinfiltration cells on the site is also taken into the preliminary cost comparison.

Sustainability criteria is based on the amount of green space the alternative provides and is also depended on bioinfiltration systems. Besides the green space, the number of parking spaces each alternative provides is also considered under sustainability for the site because that is directly related to the
impervious area. In terms of parking spaces, least number of parking spots are considered that will satisfy the minimum requirement for parking spaces.

Site aesthetics is considered as the total amount of green area in the site and how aesthetically pleasing the site appears. In terms of site efficiency, number of parking spaces is considered. A ratio of the total Costco site area and the number of parking spaces was utilized in order to effectively compare the efficiency of the site. The amount of area each alternative provides for future development is also considered. Further on, the scores are added for the final result.

Table 7 Performance Comparison Results

<table>
<thead>
<tr>
<th>Layout</th>
<th>Cost</th>
<th>Sustainability</th>
<th>Site Aesthetics</th>
<th>Site Efficiency</th>
<th>Total</th>
</tr>
</thead>
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<tr>
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<td>2</td>
<td>3</td>
<td>9</td>
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<td>2</td>
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<td>3</td>
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<td>2</td>
<td>2</td>
<td>3</td>
<td>10</td>
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</table>

3.1.3. ELEMENTS OF SUSTAINABILITY

Elements of sustainability in this project starts with the demolition plan. Roughly 30,000 cubic yards of crushed concrete is to be taken out from the street driveways, houses, curbs, and sidewalks. This concrete will be grounded until it is gravel sized and it will be re-used as the sub base for Century Drive.

In the recommended alternative design, the usage of bioinfiltration systems will not only reduce the storm runoff volume, but it will also reduce the amount of pollutant
concentration. Besides that, the bioinfiltration systems will add to the aesthetics and provide an environmentally friendly site development.

As shown in Figure 31 in Appendix D, the bioinfiltration cells reduced the runoff by 7%, which equates to 12,363 cubic feet of volume capacity. In terms of annual pollutant load reductions, the bioinfiltration cells combined will reduce the annual total phosphorus by 21%, which is 2.31 lbs. of particulate phosphorus and 1.88 lbs. of dissolved phosphorus. There has been a reduction in the annual total suspended solids as well. The reduction estimates to roughly 21%, which is 761 lbs. based on 3,547 lbs. received on site.

To further reduce the runoff volume design value, a porous asphalt pavement is recommended in areas where parking lanes and stall is present. In the recommended alternative solution, the area for the parking lanes and stall is roughly 155,610 ft². The porous asphalt is relatively cheaper than conventional asphalt. By incorporating porous asphalt, the total runoff volume is reduced by 71,426 ft³, but it has a storage capacity of 83,640 ft³. A hundred percent of runoff water directed to that area will be infiltrate down to the soil. Adding this to the bioinfiltration system, the total runoff volume is reduced by 91,288 ft³ out of 189,675 ft³ runoff volume, which equates to 49% reduction.

In terms of pollutant load reductions, the porous asphalt pavement has the capacity to filter 3.66 lbs. of particulate phosphorus, 3.00 lbs. of dissolved phosphorus, and 1,209 lbs. of total suspended solids. The porous asphalt combined with bioinfiltration system will reduce the annual total phosphorus by 56% and reduce the total annual total suspended solids (TSS) by 1,985 lbs. out of 3,547 lbs., which is also 56% reduction in total TSS.
The material used for the storm sewer is also sustainable in terms of life cycle and environmental impact. Polypropylene is recommended to be used for sewer pipes on the site. Polypropylene has life cycle of 100 years compared to concrete, which is only 70 years.
4. **EARTHWORK**

A survey of the site before demolition was performed and given to SJMB & Associates from the Hurley & Stewart, the sponsors of this project. In the earthwork section of this project, the team dealt with many constrains. The first constraint in the project is the elevation of the warehouse. Costco wanted to be seen from the US-131, West Michigan Avenue, and Drake Road. Before demolishing and rebuilding the portion of Drake Road, there was a huge elevation change. It was necessary to start from the entrance elevation of Drake Road and downgrade to the site. In order to meet constraints of Costco’s and Drake Road, the building is placed at the elevation of 924.5 feet above the sea level.

The second constraint is from the American with Disabilities Act (ADA). ADA requires a maximum slope of 5% throughout the site. The entrances of all sidewalks and entrances must be flush in order to make all areas wheelchair accessible. The slope of the building and the surrounding areas are sloped at 2%. The third constraint is due to the chosen design. The bioinfiltration systems have a recommended 3 to 1 slope from the overflow surface area to the bottom surface media of the each bioinfiltration cell. The fourth and last constraint is from the storm sewer pipe system that is to be placed on the site. The entire parking lot is graded down at the slope of 1.5 to 2 percent in order for the water to flow to the catch basins.

Taking all these constraints, the grading part of this project is completed using AutoCAD Civil 3D. The proposed grading plan is then overlaid on top of the survey before demolition to obtain cut and fill volumes. The proposed grading plan is shown in Figure 19 in Appendix C.

The results from Civil3D indicate, the project need a cut volume of around 71,191 cubic yards and fill volume of 105,455 cubic yards. This gives a net fill volume of 32,276
cubic yards. A rough cost estimate for the earthwork section of this project is obtained using RsMeans. See Appendix B.
5. STORM WATER RETENTION ANALYSIS

Costco requested for the site to be able to retain a 100 year storm event. The rational method is used to calculate runoff volume in the site. The equation $Q = CiA$ is used to calculate that runoff.

The total project site is divided into five different sections in order to account for the different runoff coefficients across the site. The weighted runoff coefficient is used for the rest of the analysis. See Table 19 in Appendix H for the different runoff coefficients and calculations for the weighted runoff coefficient. As calculated, the weighted runoff coefficient of 0.72 is used for the entire site.

The 100-year intensity values are obtained from the Kalamazoo County Drain Commissioner Site Development Rules in order to calculate the flow for a 24 hour storm. The total area for the chosen alternative is obtained from Table 2 as 15.8 acres. The only outflow from the retention basin is from the infiltration through the bottom base of the pond. The infiltration rate, taken from the sponsors, is used as 3 in./hr. This was converted to cubic feet per second by multiplying by the base area of the pond and using conversion factors. The outflow is further subtracted from the inflow and converted to volume. A maximum volume through a 24 hour storm is used for the design calculations. As shown below in the Table 20 Appendix H, the runoff volume turns out to be 189,675 cubic feet.

Using the Average End Area Method described in the Kalamazoo County Drain Commissioner Site Development Rules, the capacity of the retention pond was developed. The first step to size the pond required to find the top elevation of the pond from the grading plan. This elevation ended up being 913 feet above sea level. According to the Kalamazoo County Drain Commissioner Site Development Rules, all dry retention basins must have a 4 to one
slope in order to allow regular maintenance of the pond. For every one foot in elevation change
the surface areas were extracted from Civil3D and inserted into Table 21. The volume was
calculated using the following formula,

\[
Volume \ 1 = \left( \frac{A_1 + A_2}{2} \right) \times Change \ in \ Elevation
\]

The volume was calculated for each change in elevation. Each volume was summed in order
to get an accumulative volume, which equaled 103,515 ft\(^3\). Please refer to Table 21 for detailed
calculations.
6. STORM WATER CONSIDERATIONS

6.1. CHOSEN ALTERNATIVE: STORM WATER RETENTION DESIGN

5.1.1 BIOINfiltrATION SYSTEM DESIGN

Figure 9 Location of Bioinfiltration Cells and Drainage Area

The bioinfiltration cells are to be installed in three different places over the site in order to guide runoff toward the cells. The first bioinfiltration cell is located by the first entrance to the site from South Drake Road. The grading in Civil3D is done in such a way that the water in the highlighted areas shown in Figure 9 will drain to the center of each bioinfiltration cells.

The bioinfiltration cell 1 has contributed drainage area of 55,497 ft². This number was taken from Civil3D by drawing polyline around the contributed drainage area. Similar approach is taken to calculate the drainage area for the remaining bioinfiltration cells. The
calculations in Appendix D for bioinfiltration cell 1 indicate the runoff volume as 25,277 ft³. A bioinfiltration cell of 20 ft. by 256 ft. is designed to retain some portion of that volume. The drainage capacity for bioinfiltration 1 as shown in Figure 20 is 4,781 ft³. That amount is calculated by taken the average of overflow surface area \(A_o\) 6,400 ft² and bottom surface area \(A_M\) 5,120 ft² and multiplied by the overflow depth of 10 in. or 0.83 ft. See the Figure 10 and Figure 11 below for cross-section and plan views.

The volume received, 25,277 ft³, is calculated using the runoff depth equation

\[
\frac{(P - 0.2 + S)^2}{P + 0.8 + S}
\]

from the Natural Resources Conservation Services (NRCS) under the United States Department of Agriculture (USDA). A 5.7 in./hr. precipitation, about a 1 in/hr. less than 100 year storm, is used and assumed for the calculation. The coefficient \(S\) is calculated using the equation \(S = \frac{1000}{CN} - 10\) (NRCS). The term \(CN\) is the curve number, which is taken from USDA. The \(CN\) is an indicative of how much water will infiltrate during a storm given the surface area conditions. A conservative \(CN\) of 98 is used for the calculation. See Table 10. Finally, the runoff volume is calculated by multiplying the runoff depth and the drainage area. A similar approach for the calculation of total runoff volume is used for the remaining bioinfiltration cells.

MIDS Calculator software is also used to confirm the runoff volume, bioinfiltration capacity, and the volume overflow. As shown in Figure 20 in Appendix D, the volume capacity of bioinfiltration cell 1 will not accommodate for the total runoff volume directed towards it, the volume overflow of 20,496 ft³ is directed to catch basin (CB) 5 through a 12 in diameter pipe as shown in Figure 16. Also see Figure 18 for the location of CB 5.
The bioinfiltration cell 2 has contributed drainage area of 16,922.7 ft$^2$. The calculations in Appendix D for bioinfiltration cell 2 indicate the runoff volume as 7,700 ft$^3$. A bioinfiltration cell of 20 ft. by 188 ft. is designed to retain some portion of that volume. The drainage capacity for bioinfiltration 2 as shown in Figure 21 in Appendix D is 3,511 ft$^3$. That amount is calculated by taking the average of overflow surface area ($A_o$)
4,700 ft\(^2\) and bottom surface area (A_M) 3,760 ft\(^2\) and multiplied by the overflow depth of 10 in. or 0.83 ft. See the Figure 12 and Figure 13 for cross-section and plan views.

As shown in Figure 21 in Appendix D, the volume capacity of bioinfiltration cell 2 will not accommodate for the total runoff volume directed towards it, the volume overflow of 4,197 ft\(^3\) is directed to catch basin (CB) 8 through a 12 in diameter pipe as shown in Figure 16. Also see Figure 18 for the location of CB 8.

---

4,700 ft\(^2\) and bottom surface area (A_M) 3,760 ft\(^2\) and multiplied by the overflow depth of 10 in. or 0.83 ft. See the Figure 12 and Figure 13 for cross-section and plan views.

As shown in Figure 21 in Appendix D, the volume capacity of bioinfiltration cell 2 will not accommodate for the total runoff volume directed towards it, the volume overflow of 4,197 ft\(^3\) is directed to catch basin (CB) 8 through a 12 in diameter pipe as shown in Figure 16. Also see Figure 18 for the location of CB 8.
The bioinfiltration cell 3 has contributed drainage area of 28,682 ft². The calculations in Appendix D for bioinfiltration cell 3 indicate the runoff volume as 13,064 ft³. A bioinfiltration cell of 20 by 188 ft. is designed to retain some portion of that volume. The drainage capacity for bioinfiltration 3 as shown in Figure 22 is 4,071 ft³. That amount is calculated by taken the average of overflow surface area (A_o) 5,450 ft² and bottom surface area (A_M) 4,360 ft² and multiplied by the overflow depth of 10 in. or 0.83 ft. See the Figure 14 and Figure 15 for cross-section.

As shown in Figure 22 in Appendix D, the volume capacity of bioinfiltration cell 3 will not accommodate for the total runoff volume directed towards it, the volume overflow of 8,993 ft³ is directed to catch basin (CB-10) through a 12 in diameter pipe as shown in Figure 16. Also see Figure 18 for the location of (CB-10).

![Figure 14 Cross Section of Bioinfiltration Cell 3](image-url)
5.1.2 POROUS ASPHALT PAVEMENT

Due to the material properties of the porous asphalt, it is recommended to be used in the site to attenuate the runoff volume the site will receive annually. It forms fewer cracks and potholes compare to conventional asphalt because of its well-draining stone bed and deep structural bed. It also has 15 years higher of lifespan than conventional asphalt because of reduced freeze and thaw stresses that develop from the water in the
base and sub base layers. Due to the rapid drainage of the surface, there is less occurrence of freeze puddles and black ice. Also, it is roughly cheaper than conventional asphalt. It also costs around fifty cents to a dollar per square foot. Despite these advantages, it has poor structural capacity. It is not appropriate for high traffic volume and where commercial trucks are routed. It also has tendency to clog when excessive salt is used. In that case during every spring following winter, a general vacuum sweeping should be applied to clear off the surface of the pavement from clogging.

In the chosen alternative design, porous asphalt is recommended for parking lanes and stall with top surface area and drainage area of 155,610 ft². Figure 17 shows the cross section of the porous asphalt with different layers. In order to design for the layers, design parameters are taken from Environmental Protection Agency (EPA) shown in Table 14.

The top layer of the pavement consists of 3 inches open-graded porous asphalt with 40 percent voids. The choker course layer includes half inch crush granules with thickness equal to 2 inches. 3/4 – 3/16 inch stone is suggested for the 5 inch open-graded base reservoir. The storage is further increased in the 5 inch open-graded sub base layer of bigger stone aggregates. 3/4 – 2 ½ inch stone is required for the last layer. The water will further infiltrate down to the uncompact sandy soil with infiltration rate of 0.8 in./hr. The total depth of the pavement is calculated as 15 inches or 1.25 feet.

The capacity of the porous asphalt is calculated using the following equation: \( \text{Top Surface Area} \times \text{Depth} \times \text{Porosity} \). The porosity of the sandy soil is taken from Table 15. The total capacity of the porous asphalt turns out to be 83,640 cubic feet. The amount of water directed to the porous asphalt from the contributed drainage area is only
72,802 cubic feet. A more detailed calculation is shown in Appendix E. Minimal Impact Development Standards (MIDS) software is also used to confirm the capacity of the porous asphalt. See Figure 26, Appendix E.

Figure 17 Cross Section of Porous Asphalt Pavement
7. STORM SEWER PIPE DESIGN AND LAYOUT

7.1. STORM SEWER PIPE PRODUCT

For this project, polypropylene is chosen because the product has 30 years higher lifespan as concrete. It also costs cheaper than concrete. The product comes into 19 feet, 8 inches length with variety of diameters. Due to the durability and stiff outer walls of the plastic pipe, it is chosen to be used as sewer pipes.

7.2. STORM SEWER PIPE LAYOUT

As shown on the figure above, there are 10 catch basin’s (CB) used on the entire site to drain the storm water. The reason of this is because the large contributions from the
bioinfiltration and porous asphalt. By routing the storm sewers in one direction, the runoff water is reduced by 49% because of the combined effects of the bioinfiltration and porous asphalt. Also, if a two way system was designed, it would have resulted in a more expensive design because of the added inlet control structure that would have been added, which included sediment control devices.

7.3. STORM SEWER PIPE DESIGN

According to the Kalamazoo County Drain Commissioner Site Development Rules, the diameter of the storm sewer pipes must sustain a 10 year 24 hour storm event. Also, it was specified that all storm pipes must have a minimum pipe diameter of 12 inches. The velocity of the water must be designed within the parameters specified in order to deter settling of particles, the required slopes are given in Table 19, Appendix G. These slopes will provide the required minimum velocity of 3.0 feet per second or greater, but the velocities must not exceed the maximum of 16 feet per second.

After determining all design parameters, the first step was to use the rational method, $Q = CiA$, in order to calculate the flow for each drainage area. The runoff coefficient for the impervious area is taken is 0.95. Once the flow for each drainage area is known, the flows are used to calculate the required diameters using the Manning’s equation, which resulted in the use of four 12” pipes, two 18” pipes, and four 24” pipes. Detailed calculations can be seen in Table 17.
8. SUMMARY AND CONCLUSIONS

8.1. DELIVERABLES ACCOMPLISHED

This project aimed to propose an alternative design that optimized cost, sustainability, site aesthetics, and site efficiency. This was accomplished by developing several alternative site layouts, and selecting the layout that has the highest score in the decision matrix described in Section 3.1.2.6. A detailed Earthwork Plan, Storm Water Retention Design Plan, Storm Sewer Plan, and Sustainability Plan were delivered for the analysis of The Site Development – Corner at Drake and Stadium.

8.2. RECOMMENDATIONS AND CONCLUSIONS

The Costco at the North Corner #1 design is recommended for this site because the site provides more green space, future development area, and is an environmentally friendly design. It also minimizes the storm water runoff by infiltrating the water down to the soil through bioinfiltration cells and porous asphalt pavement. The design also utilizes best management practices to reduce the amounts of pollutants. It significantly reduced the annual total phosphorus and annual total suspended solids. The proposed layout design supports sustainability in the community and could be an inspiration for the future development projects in the city of Kalamazoo. The proposed alternative could also qualify for the LEED Accreditations for controlling quantity of runoff water and improving runoff water quality.
9. REFERENCES

9.1. CODES AND SPECIFICATIONS

- American Association of State Highway and Transportation Officials (AASHTO)
- Manual on Uniform Control Traffic Conservation Device (MUCTD)
- United States Geological Survey – Topographical Maps

9.2. TEXTBOOKS AND OTHER REFERENCES

Below are the texts that will be used in order to complete design aspect of the project:

Site Development – Corner at Drake and Stadium


9.3. SOFTWARE

Following are list of software that will be utilized in this project:

- Civil 3D
- AutoCAD
- Minimal Impact Development Standards (MIDS) Calculator
- Microsoft Office (Excel, Word, Microsoft Project, and PowerPoint)
- Google Maps
10. APPENDICES

10.1. APPENDIX A – PERFORMANCE COMPARISON DETAILED TABLE

Table 8 Performance Based Comparison

<table>
<thead>
<tr>
<th>Layout</th>
<th>Cost</th>
<th>Sustainability</th>
<th>Site Aesthetic</th>
<th>Site Efficiency</th>
<th>Total</th>
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</thead>
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<tr>
<td></td>
<td>Site Area</td>
<td>Asphalt</td>
<td>Green Area</td>
<td>Parking</td>
<td>Bio</td>
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<td>2</td>
<td>3</td>
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### APPENDIX B – COST ESTIMATE

#### Table 9 Project Cost

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<th>UNIT PRICE</th>
<th>QUANTITY</th>
<th>TOTAL</th>
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</thead>
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<td>WATER PIPES</td>
<td>DIAMETER</td>
<td>UNIT PRICE</td>
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<td>LOCATION/TYPE</td>
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<td>BIOIFILTRATION</td>
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<td>$ 76,800.00</td>
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<td>B</td>
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<td>3760</td>
<td>$ 56,400.00</td>
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<td>C</td>
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<td>4360</td>
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<td>CUT&amp;FILL</td>
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<td>71190.52</td>
<td>$ 208,588.22</td>
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<td>FILL</td>
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<td>LCY</td>
<td>$ 1.75</td>
<td>105466.37</td>
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$ 1,090,574.96
10.3. APPENDIX C – EARTHWORK DESIGN CALCULATIONS

![Figure 19 Earthwork Using Civil3D](image)

The figure shows the earthwork design calculations using Civil3D software, with a color scheme indicating cut and fill areas.
Bio-infiltration Cell 1:

Runoff Depth (in) = \(\frac{(P-0.2S)^2}{P+0.8S}\) (USDA – NRCS: Source)

\[ S = \frac{1000}{CN} - 10 \]

\[ P = \text{Precipitation (Use 5.7 inch)} \]

\[ \text{CN = Curve Number (measure of how much water will infiltrate during a storm. See Table 1 below)} \]

Use CN = 98 Soil Group A or B for sandy soil

\[ S = \frac{1000}{98} - 10 = 0.204 \]

Runoff Depth = \(\frac{(5.7-0.2+0.204)^2}{5.7+0.8+0.204}\) = 5.462 in or 0.455 ft

Runoff Volume (ft\(^3\)) = Drainage Area (ft\(^2\)) * Runoff Depth (ft.) = 55,497 * 0.455 = 25,277 ft\(^3\)

Designed Surface Area: 20 x 256 ft. = 5120 sq. ft.

Designed Storage Capacity: 5,120 * \(\frac{10}{12}\) = 4,781 ft\(^3\)

Design Okay! The remaining 20,496 cubic foot water directed to the catch basin via 12 in. diameter overflow pipe
Table 10 NRCS curve numbers in urban areas. (Source: USDA-NRCS, 1986)

<table>
<thead>
<tr>
<th>Land Use/Cover</th>
<th>Soil Group A</th>
<th>Soil Group B</th>
<th>Soil Group C</th>
<th>Soil Group D</th>
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</thead>
<tbody>
<tr>
<td>100% Impervious (parking lots, rooftops, paved sidewalks)</td>
<td>98</td>
<td>98</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Open space (lawns and golf courses) with grass cover &lt; 50%</td>
<td>68</td>
<td>79</td>
<td>86</td>
<td>89</td>
</tr>
<tr>
<td>Open space with grass cover 50% to 75%</td>
<td>49</td>
<td>69</td>
<td>79</td>
<td>84</td>
</tr>
<tr>
<td>Open space with grass cover &gt; 75%</td>
<td>39</td>
<td>61</td>
<td>74</td>
<td>80</td>
</tr>
<tr>
<td>Woods in fair hydrologic condition</td>
<td>36</td>
<td>60</td>
<td>73</td>
<td>79</td>
</tr>
</tbody>
</table>

Bio-infiltration Cell 2:

Runoff Depth (in) = \( \frac{(P - 0.2 + S)^2}{P + 0.8 + S} \) (USDA – NRCS: Source)

\[ S = \frac{1000}{CN} - 10 \]

\( P \) = Precipitation (typically use 1 inch)
\( CN \) = Curve Number (measure of how much water will infiltrate during a storm. See Table 1 above.

Use \( CN = 98 \) Soil Group A or B for sandy soil

\[ S = \frac{1000}{98} - 10 = 0.204 \]

Runoff Depth = \( \frac{(5.7 - 0.2 + 0.204)^2}{5.7 + 0.8 + 0.204} \) = 5.462 in or 0.455 ft
Runoff Volume ($ft^3$) = Drainage Area ($ft^2$) * Runoff Depth (ft.) = $16,922.7 \times 0.455 = 7,700 \, ft^3$

Designed Surface Area: 20 x 188 ft. = 3,760 sq. ft.

Designed Storage Capacity: $3,760 \times \frac{10}{12} = 3,111 \, ft^3$

*Design Okay!* The remaining 4,197 cubic foot water directed to the catch basin via 12 in. diameter overflow pipe

**Bio-infiltration Cell 3:**

![Bio-retention basin (no underdrain) diagram](image)

**Figure 22 Bioinfiltration / Bioretention 3 Storage Capacity**

- Runoff Depth (in) = \(\frac{(P-0.2S)^2}{P+0.8S}\) (USDA – NRCS: Source)
  
  \[S = \frac{1000}{CN} - 10\]
  
  \[P = \text{Precipitation (typically use 1 inch)}\]
  
  \[CN = \text{Curve Number (measure of how much water will infiltrate during a storm. See Table 1 above.} \]
  
  Use CN = 98 Soil Group A or B for sandy soil

  \[S = \frac{1000}{98} - 10 = 0.204\]
  
  Runoff Depth = \(\frac{(5.7-0.2\times0.204)^2}{5.7+0.8\times0.204} = 5.462 \, \text{in or 0.455 ft}\)

  Runoff Volume ($ft^3$) = Drainage Area ($ft^2$) * Runoff Depth (ft.) = $28,682 \times 0.455 = 13,064 \, ft^3$

  Designed Surface Area: 20 x 218 ft. = 4,360 sq. ft.

  Designed Storage Capacity: $4,360 \times \frac{10}{12} = 4,071 \, ft^3$
Design Okay! The remaining 8,993 cubic foot water directed to the catch basin via 12 in. diameter overflow pipe

Table 11 Performance of Only BioInfiltration Cells

<table>
<thead>
<tr>
<th>Summary Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Goal Requirement</td>
</tr>
<tr>
<td>Performance goal volume retention requirement: 189675 ft³</td>
</tr>
<tr>
<td>Volume removed by BMPs towards performance goal: 12383 ft³</td>
</tr>
<tr>
<td>Percent volume removed towards performance goal: 7 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual Volume and Pollutant Load Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post development annual runoff volume: 23,9251 acre-ft</td>
</tr>
<tr>
<td>Annual runoff volume removed by BMPs: 5,1388 acre-ft</td>
</tr>
<tr>
<td>Percent annual runoff volume removed: 21 %</td>
</tr>
<tr>
<td>Post development annual particulate P load: 10.74 lbs</td>
</tr>
<tr>
<td>Annual particulate P removed by BMPs: 2.31 lbs</td>
</tr>
<tr>
<td>Post development annual dissolved P load: 8.79 lbs</td>
</tr>
<tr>
<td>Annual dissolved P removed by BMPs: 1.88 lbs</td>
</tr>
<tr>
<td>Percent annual total phosphorus removed: 21 %</td>
</tr>
<tr>
<td>Post development annual TSS load: 3547 lbs</td>
</tr>
<tr>
<td>Annual TSS removed by BMPs: 761 lbs</td>
</tr>
<tr>
<td>Percent annual TSS removed: 21 %</td>
</tr>
</tbody>
</table>

Table 12 Bioinfiltration / Bioretention Volume Capacity Overflow From MIDS

<table>
<thead>
<tr>
<th>BMP Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Goal Summary</td>
</tr>
<tr>
<td>BMP Name</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>1 - Bioretention basin (w/o underdrain)</td>
</tr>
<tr>
<td>2 - Bioretention basin (w/o underdrain)</td>
</tr>
<tr>
<td>3 - Bioretention basin (w/o underdrain)</td>
</tr>
</tbody>
</table>
### Table 13 Bioinfiltration System Pollutant Reduction Summary from MIDS

#### Particulate Phosphorus Summary

<table>
<thead>
<tr>
<th>BMP Name</th>
<th>Load From Direct Watershed (lbs)</th>
<th>Load From Upstream BMPs (lbs)</th>
<th>Load Retained (lbs)</th>
<th>Outflow Load (lbs)</th>
<th>Percent Retained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Bioretention basin (w/o underdrain)</td>
<td>13</td>
<td>0</td>
<td>1.25</td>
<td>0.05</td>
<td>96</td>
</tr>
<tr>
<td>2 - Bioretention basin (w/o underdrain)</td>
<td>0.4</td>
<td>0</td>
<td>0.4</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3 - Bioretention basin (w/o underdrain)</td>
<td>0.67</td>
<td>0</td>
<td>0.68</td>
<td>0.01</td>
<td>99</td>
</tr>
</tbody>
</table>

#### Dissolved Phosphorus Summary

<table>
<thead>
<tr>
<th>BMP Name</th>
<th>Load From Direct Watershed (lbs)</th>
<th>Load From Upstream BMPs (lbs)</th>
<th>Load Retained (lbs)</th>
<th>Outflow Load (lbs)</th>
<th>Percent Retained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Bioretention basin (w/o underdrain)</td>
<td>1.06</td>
<td>0</td>
<td>1.02</td>
<td>0.04</td>
<td>96</td>
</tr>
<tr>
<td>2 - Bioretention basin (w/o underdrain)</td>
<td>0.32</td>
<td>0</td>
<td>0.32</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3 - Bioretention basin (w/o underdrain)</td>
<td>0.55</td>
<td>0</td>
<td>0.54</td>
<td>0.01</td>
<td>99</td>
</tr>
</tbody>
</table>

#### TSS Summary

<table>
<thead>
<tr>
<th>BMP Name</th>
<th>Load From Direct Watershed (lbs)</th>
<th>Load From Upstream BMPs (lbs)</th>
<th>Load Retained (lbs)</th>
<th>Outflow Load (lbs)</th>
<th>Percent Retained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Bioretention basin (w/o underdrain)</td>
<td>428</td>
<td>0</td>
<td>412</td>
<td>16</td>
<td>96</td>
</tr>
<tr>
<td>2 - Bioretention basin (w/o underdrain)</td>
<td>130</td>
<td>0</td>
<td>130</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3 - Bioretention basin (w/o underdrain)</td>
<td>221</td>
<td>0</td>
<td>219</td>
<td>2</td>
<td>99</td>
</tr>
</tbody>
</table>
10.5. APPENDIX E – POROUS ASPHALT DESIGN CALCULATIONS AND DETAILS

Drainage Area: 155,610 ft² ~ 3.57 acres
Top Surface Area (Au): 155,610 ft²
Depth (Du): 1.25 ft. ~ 15 in.

Design Capacity (V): \[155,610 \times 1.25 \times 0.43 = 83,640 \text{ ft}^3\]
Underlying Soil (SP) Infiltration Rate: 0.8 in. /hr.
Porosity of Sand (SP): 0.43

Figure 23 Porous Asphalt Capacity Calculation Using MIDS
Table 14 Porous Asphalt Design Parameters (Source: EPA)

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedding/choker layer</td>
<td>• Pervious concrete: None</td>
<td>Washed free of fines</td>
</tr>
<tr>
<td></td>
<td>• Porous asphalt: 1 inch of AASHTO No. 57 stone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• PICP: 2 inches of AASHTO No. 8 stone (MnDOT 3127FA-3)</td>
<td></td>
</tr>
<tr>
<td>Reservoir Layer</td>
<td>• Pervious concrete: AASHTO No. 57 stone or per hydraulic design</td>
<td>Stone layer thickness based on the pavement structural</td>
</tr>
<tr>
<td></td>
<td>• Porous asphalt:AASHTO No. 2, 3, or 5 stone</td>
<td>and hydraulic requirements. Stonewashed and free of</td>
</tr>
<tr>
<td></td>
<td>• PICP: 4 inches of AASHTO No. 57 base and AASHTO No.2, 3 or 4 stone subbase</td>
<td>fines. Recommended minimum void ratio = 0.4.</td>
</tr>
<tr>
<td>Underdrain (optional)</td>
<td>Use 4 to 6 inch diameter perforated PVC (AASHTO M-252) pipe or corrugated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>polyethylene pipe. Perforated pipe installed for the full length of the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>permeable pavement cell, and non-perforated pipe, as needed, connected to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>storm drainage system.</td>
<td></td>
</tr>
<tr>
<td>Filter Layer (optional)</td>
<td>Sand filter layers separated from base above and native soils with geotextile.</td>
<td>The sand layer may require a choker layer on surface to</td>
</tr>
<tr>
<td></td>
<td>Sand layer typically ASTM C33 gradation, 6 to 12 inches thick.</td>
<td>provide transition to base layerstone.</td>
</tr>
<tr>
<td></td>
<td>for Highway Applications; drainage and separation applications. Class I or II.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Porous asphalt industry recommends non-woven geotextile.</td>
<td></td>
</tr>
<tr>
<td>Impermeable Liner</td>
<td>Use a minimum 30mil PVC liner covered by 12 ounce/square yard non-woven</td>
<td></td>
</tr>
<tr>
<td></td>
<td>geotextile. EPDM and HDPE liner material is also acceptable.</td>
<td></td>
</tr>
<tr>
<td>Observation Well</td>
<td>Use a perforated 4 to 6 inch vertical PVC pipe (AASHTO M-252) with a lockable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cap, installed flush with the surface (or under pavers).</td>
<td></td>
</tr>
</tbody>
</table>

Table 15 Porosity of Sand (Source: EPA)

<table>
<thead>
<tr>
<th>Soil texture</th>
<th>Corresponding Unified Soil Classification</th>
<th>Corresponding hydrologic soil group (HSG)</th>
<th>Design Infiltration Rate (in/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel, sandy gravel, and</td>
<td>GW - Well graded gravel or well-graded</td>
<td>A</td>
<td>1.63</td>
</tr>
<tr>
<td>silty gravels</td>
<td>gravel with sand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand, loamy sand, and</td>
<td>GM - Silty gravel or silty gravel with</td>
<td>A</td>
<td>0.8</td>
</tr>
<tr>
<td>sandy loam</td>
<td>sand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silty sand</td>
<td>SM - Silty sand or silty sand with</td>
<td>B</td>
<td>0.45</td>
</tr>
<tr>
<td>Silt loam, loam</td>
<td>ML - Silt</td>
<td>B</td>
<td>0.3</td>
</tr>
<tr>
<td>Sandy clay loam</td>
<td>GC - Clayey gravel or clayey gravel with</td>
<td>C</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>sand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay, clay loam, silty</td>
<td>CL - Lean clay or lean clay with sand or</td>
<td>D</td>
<td>0.06</td>
</tr>
<tr>
<td>clay, sandy clay, and</td>
<td>gravel or gravelly clay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>silty clay</td>
<td>CH - Fat clay or fat clay with sand or</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>gravel or gravelly fat clay</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MN - Elastic silt or elastic silt with</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>sand or gravel</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
10.6. APPENDIX F – COMBINED IMPACT OF BIOINFILTRATION SYSTEM AND POROUS ASPHALT PAVEMENT

Table 16 Summary Information on Effective Impact of All BMPs

Summary Information

Performance Goal Requirement

| Performance goal volume retention requirement | 189675 ft³ |
| Volume removed by BMPs towards performance goal | 92288 ft³ |
| Percent volume removed towards performance goal | 49 % |

Annual Volume and Pollutant Load Reductions

| Post development annual runoff volume | 23.9251 acre-ft |
| Annual runoff volume removed by BMPs | 13.3915 acre-ft |
| Percent annual runoff volume removed | 56 % |

| Post development annual particulate P load | 10.74 lbs |
| Annual particulate P removed by BMPs | 6.01 lbs |
| Post development annual dissolved P load | 8.79 lbs |
| Annual dissolved P removed by BMPs | 4.92 lbs |
| Percent annual total phosphorus removed | 56 % |

| Post development annual TSS load | 3547 lbs |
| Annual TSS removed by BMPs | 1985 lbs |
| Percent annual TSS removed | 56 % |

Table 17 BMPs Volume Capacity and Overflow Amount from MIDS

BMP Summary

<table>
<thead>
<tr>
<th>BMP Name</th>
<th>BMP Volume Capacity (ft³)</th>
<th>Volume Received (ft³)</th>
<th>Volume Retained (ft³)</th>
<th>Volume Outflow (ft³)</th>
<th>Percent Retained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Bioretention basin (w/o underdrain)</td>
<td>13260</td>
<td>25197</td>
<td>13280</td>
<td>11917</td>
<td>53</td>
</tr>
<tr>
<td>2 - Bioretention basin (w/o underdrain)</td>
<td>3511</td>
<td>7708</td>
<td>3511</td>
<td>4197</td>
<td>46</td>
</tr>
<tr>
<td>3 - Bioretention basin (w/o underdrain)</td>
<td>4071</td>
<td>13064</td>
<td>4071</td>
<td>8993</td>
<td>31</td>
</tr>
<tr>
<td>4 - Permeable pavement</td>
<td>83640</td>
<td>71426</td>
<td>71426</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 18 BMPs Pollutant Reduction Summary from MIDS

### Particulate Phosphorus Summary

<table>
<thead>
<tr>
<th>BMP Name</th>
<th>Load From Direct Watershed (lbs)</th>
<th>Load From Upstream BMPs (lbs)</th>
<th>Load Retained (lbs)</th>
<th>Outflow Load (lbs)</th>
<th>Percent Retained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Bioretention basin (w/o underdrain)</td>
<td>1.29</td>
<td>0</td>
<td>1.29</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2 - Bioretention basin (w/o underdrain)</td>
<td>0.4</td>
<td>0</td>
<td>0.4</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3 - Bioretention basin (w/o underdrain)</td>
<td>0.67</td>
<td>0</td>
<td>0.66</td>
<td>0.01</td>
<td>99</td>
</tr>
<tr>
<td>1 - Permeable pavement</td>
<td>3.66</td>
<td>0</td>
<td>3.66</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

### Dissolved Phosphorus Summary

<table>
<thead>
<tr>
<th>BMP Name</th>
<th>Load From Direct Watershed (lbs)</th>
<th>Load From Upstream BMPs (lbs)</th>
<th>Load Retained (lbs)</th>
<th>Outflow Load (lbs)</th>
<th>Percent Retained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Bioretention basin (w/o underdrain)</td>
<td>1.06</td>
<td>0</td>
<td>1.06</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2 - Bioretention basin (w/o underdrain)</td>
<td>0.32</td>
<td>0</td>
<td>0.32</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3 - Bioretention basin (w/o underdrain)</td>
<td>0.35</td>
<td>0</td>
<td>0.34</td>
<td>0.01</td>
<td>99</td>
</tr>
<tr>
<td>1 - Permeable pavement</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

### TSS Summary

<table>
<thead>
<tr>
<th>BMP Name</th>
<th>Load From Direct Watershed (lbs)</th>
<th>Load From Upstream BMPs (lbs)</th>
<th>Load Retained (lbs)</th>
<th>Outflow Load (lbs)</th>
<th>Percent Retained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Bioretention basin (w/o underdrain)</td>
<td>427</td>
<td>0</td>
<td>427</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2 - Bioretention basin (w/o underdrain)</td>
<td>130</td>
<td>0</td>
<td>130</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3 - Bioretention basin (w/o underdrain)</td>
<td>221</td>
<td>0</td>
<td>221</td>
<td>2</td>
<td>99</td>
</tr>
<tr>
<td>1 - Permeable pavement</td>
<td>1209</td>
<td>0</td>
<td>1209</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>
### 10.7. APPENDIX G – STORM SEWER PIPE DESIGN

#### Table 19 STORM SEWER PIPE DESIGN

<table>
<thead>
<tr>
<th>Pipeline Start</th>
<th>Pipeline End</th>
<th>Area [acres]</th>
<th>C [in/hr.]</th>
<th>i [in]</th>
<th>Q(_{\text{design}}) [ft(^3)/s]</th>
<th>D(_{\text{calculated}}) [in]</th>
<th>D(_{\text{design}}) [in]</th>
<th>r</th>
<th>V(_{\text{design}}) [ft./s]</th>
<th>Grade%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB-1</td>
<td>CB-2</td>
<td>0.232</td>
<td>0.72</td>
<td>3.52</td>
<td>0.588</td>
<td>7.330</td>
<td>12</td>
<td>6</td>
<td>3.15</td>
<td>0.48%</td>
</tr>
<tr>
<td>CB-2</td>
<td>CB-3</td>
<td>0.300</td>
<td>0.72</td>
<td>3.52</td>
<td>1.348</td>
<td>10.006</td>
<td>12</td>
<td>6</td>
<td>3.15</td>
<td>0.48%</td>
</tr>
<tr>
<td>CB-3</td>
<td>CB-4</td>
<td>1.022</td>
<td>0.72</td>
<td>3.52</td>
<td>3.938</td>
<td>14.957</td>
<td>18</td>
<td>9</td>
<td>3.15</td>
<td>0.28%</td>
</tr>
<tr>
<td>CB-4</td>
<td>CB-5</td>
<td>0.799</td>
<td>0.72</td>
<td>3.52</td>
<td>5.963</td>
<td>17.475</td>
<td>18</td>
<td>9</td>
<td>3.15</td>
<td>0.28%</td>
</tr>
<tr>
<td>CB-5</td>
<td>CB-6</td>
<td>0.471</td>
<td>0.72</td>
<td>3.52</td>
<td>1.194</td>
<td>9.559</td>
<td>12</td>
<td>6</td>
<td>3.15</td>
<td>0.48%</td>
</tr>
<tr>
<td>CB-6</td>
<td>CB-7</td>
<td>0.496</td>
<td>0.72</td>
<td>3.52</td>
<td>7.157</td>
<td>18.712</td>
<td>24</td>
<td>12</td>
<td>2.98</td>
<td>0.17%</td>
</tr>
<tr>
<td>CB-7</td>
<td>CB-8</td>
<td>0.570</td>
<td>0.72</td>
<td>3.52</td>
<td>8.602</td>
<td>20.048</td>
<td>24</td>
<td>12</td>
<td>2.98</td>
<td>0.17%</td>
</tr>
<tr>
<td>CB-8</td>
<td>CB-9</td>
<td>0.246</td>
<td>0.72</td>
<td>3.52</td>
<td>0.623</td>
<td>7.493</td>
<td>12</td>
<td>6</td>
<td>3.15</td>
<td>0.48%</td>
</tr>
<tr>
<td>CB-9</td>
<td>CB-10</td>
<td>0.278</td>
<td>0.72</td>
<td>3.52</td>
<td>9.930</td>
<td>21.157</td>
<td>24</td>
<td>12</td>
<td>2.98</td>
<td>0.17%</td>
</tr>
<tr>
<td>CB-10</td>
<td>POND</td>
<td>0.555</td>
<td>0.72</td>
<td>3.52</td>
<td>11.336</td>
<td>22.234</td>
<td>24</td>
<td>12</td>
<td>2.98</td>
<td>0.17%</td>
</tr>
</tbody>
</table>

#### Table 20 MDOT PARAMETERS (SOURCE: MDOT DRAINAGE MANUAL)

<table>
<thead>
<tr>
<th>MDOT Parameter</th>
<th>A</th>
<th>R</th>
<th>GRADE</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0.785</td>
<td>0.25</td>
<td>0.48%</td>
<td>0.013</td>
</tr>
<tr>
<td>18</td>
<td>1.767</td>
<td>0.375</td>
<td>0.28%</td>
<td>0.013</td>
</tr>
<tr>
<td>24</td>
<td>3.142</td>
<td>0.5</td>
<td>0.17%</td>
<td>0.013</td>
</tr>
<tr>
<td>30</td>
<td>4.909</td>
<td>0.625</td>
<td>0.15%</td>
<td>0.013</td>
</tr>
</tbody>
</table>
Figure 24 Location of Catch Basins
Figure 25 Storm Sewer Cross-Section (TYP.)
10.8. APPENDIX H – STORM RUNOFF ANALYSIS

Table 21 Contributing Areas and Associated Runoff Coefficients

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Area [ft²]</th>
<th>Area [Acres]</th>
<th>Runoff Coefficient, 'C'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Space</td>
<td>74,208</td>
<td>1.70</td>
<td>0.30</td>
</tr>
<tr>
<td>Building (Roof)</td>
<td>153,269</td>
<td>3.52</td>
<td>0.95</td>
</tr>
<tr>
<td>Impervious Area</td>
<td>263,110</td>
<td>6.04</td>
<td>0.95</td>
</tr>
<tr>
<td>Porous Asphalt</td>
<td>155,610</td>
<td>3.57</td>
<td>0.35</td>
</tr>
<tr>
<td>Bioretention</td>
<td>16,320</td>
<td>0.37</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>662,517</strong></td>
<td><strong>15.2</strong></td>
<td><strong>0.72</strong></td>
</tr>
</tbody>
</table>

Table 22 Storm Runoff Volume Spreadsheet

<table>
<thead>
<tr>
<th>Time (hr.)</th>
<th>Infiltration Rate of 3 in/hr. for the SF of bottom of the basin</th>
<th>0.935</th>
<th>cfs</th>
<th>Storage Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>i₁₀₀ (in/hr. )</td>
<td>Cumulative Rainfall (in)</td>
<td>Q_{inflow} (cfs)</td>
<td>V_{inflow} (ft³)</td>
</tr>
<tr>
<td>0.08</td>
<td>8.880</td>
<td>0.710</td>
<td>97.28</td>
<td>28,016</td>
</tr>
<tr>
<td>0.167</td>
<td>7.740</td>
<td>1.293</td>
<td>84.79</td>
<td>50,975</td>
</tr>
<tr>
<td>0.25</td>
<td>6.640</td>
<td>1.660</td>
<td>72.74</td>
<td>65,465</td>
</tr>
<tr>
<td>0.333</td>
<td>5.752</td>
<td>1.915</td>
<td>63.01</td>
<td>75,537</td>
</tr>
<tr>
<td>0.5</td>
<td>4.560</td>
<td>2.280</td>
<td>49.95</td>
<td>89,915</td>
</tr>
<tr>
<td>0.667</td>
<td>3.800</td>
<td>2.535</td>
<td>41.63</td>
<td>99,956</td>
</tr>
<tr>
<td>0.75</td>
<td>3.516</td>
<td>2.637</td>
<td>38.52</td>
<td>103,994</td>
</tr>
<tr>
<td>0.833</td>
<td>3.275</td>
<td>2.728</td>
<td>35.88</td>
<td>107,586</td>
</tr>
<tr>
<td>1</td>
<td>2.890</td>
<td>2.890</td>
<td>31.66</td>
<td>113,972</td>
</tr>
<tr>
<td>2</td>
<td>1.785</td>
<td>3.570</td>
<td>19.55</td>
<td>140,788</td>
</tr>
<tr>
<td>3</td>
<td>1.313</td>
<td>3.939</td>
<td>14.38</td>
<td>155,340</td>
</tr>
<tr>
<td>4</td>
<td>1.055</td>
<td>4.220</td>
<td>11.56</td>
<td>166,422</td>
</tr>
<tr>
<td>5</td>
<td>0.887</td>
<td>4.435</td>
<td>9.72</td>
<td>174,901</td>
</tr>
<tr>
<td>6</td>
<td>0.887</td>
<td>5.322</td>
<td>9.72</td>
<td>209,881</td>
</tr>
<tr>
<td>7</td>
<td>0.768</td>
<td>5.376</td>
<td>8.41</td>
<td>212,011</td>
</tr>
<tr>
<td>8</td>
<td>0.682</td>
<td>5.456</td>
<td>7.47</td>
<td>215,166</td>
</tr>
<tr>
<td>9</td>
<td>0.615</td>
<td>5.535</td>
<td>6.74</td>
<td>218,281</td>
</tr>
<tr>
<td>10</td>
<td>0.560</td>
<td>5.600</td>
<td>6.13</td>
<td>220,845</td>
</tr>
<tr>
<td>11</td>
<td>0.516</td>
<td>5.676</td>
<td>5.65</td>
<td>223,842</td>
</tr>
<tr>
<td>12</td>
<td>0.446</td>
<td>5.352</td>
<td>4.89</td>
<td>211,064</td>
</tr>
<tr>
<td>18</td>
<td>0.321</td>
<td>5.778</td>
<td>3.52</td>
<td>227,864</td>
</tr>
<tr>
<td>24</td>
<td>0.256</td>
<td>6.144</td>
<td>2.80</td>
<td>242,298</td>
</tr>
<tr>
<td>48</td>
<td>0.140</td>
<td>6.720</td>
<td>1.53</td>
<td>265,013</td>
</tr>
</tbody>
</table>
Table 23 Retention Pond Volume Capacity

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Area (ft²)</th>
<th>Volume (ft³)</th>
<th>Accl. Volume (ft³)</th>
<th>Accl. Vol. (ac-ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>906</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>907</td>
<td>2,324</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>908</td>
<td>9,649</td>
<td>5,987</td>
<td>5,987</td>
<td>0.137</td>
</tr>
<tr>
<td>909</td>
<td>13,471</td>
<td>11,560</td>
<td>17,547</td>
<td>0.403</td>
</tr>
<tr>
<td>910</td>
<td>17,394</td>
<td>15,433</td>
<td>32,979</td>
<td>0.757</td>
</tr>
<tr>
<td>911</td>
<td>21,417</td>
<td>19,405</td>
<td>52,384</td>
<td>1.203</td>
</tr>
<tr>
<td>912</td>
<td>25,541</td>
<td>23,479</td>
<td>75,863</td>
<td>1.742</td>
</tr>
<tr>
<td>913</td>
<td>29,764</td>
<td>27,652</td>
<td>103,515</td>
<td>2.376</td>
</tr>
</tbody>
</table>
10.9. APPENDIX I – CAD DRAWINGS