DETENTION BASIN DESIGN

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CTC 260
Project #: 4

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1. INTRODUCTION

In this report, we present the steps followed to design a detention basin for the proposed tract. The site is located near St. Paul, Minnesota. The TR-55 graphical peak discharge method, described in [1], is used in the runoff computations.

To design the detention basin for the proposed plan, we first calculate the peak runoff for two site conditions: Pre-development phase (present) and Post-development phase (developed).

By trial and error, we design a detention basin and route the inflow hydrograph through the basin. The peak rate of runoff entering the natural stream after development will be attenuated so that it will not exceed the pre-development peak runoff rate for a 100-year frequency storm.

2. SITE INFORMATION AND WATERSHED PARAMETERS

2.1. Site Information

The provided site information and watershed parameters are,

a. Site location: Near St. Paul, Minnesota
b. Type II rainfall distribution (from Figure B-2 in [1])
c. Hydrologic Soil group: B
d. Cover Description:
   Predevelopment:
     Woods, good condition
   Postdevelopment:
     Impervious (parking lots, roads and roofs)
     Lawns, good condition
     Woods, fair condition

2.2. Watershed Delineation and Drainage area calculation

The drainage area tributary to the proposed detention basin is delineated as shown in Figure A.1. Note that the drainage area includes land uphill of the tract that drains onto the tract. This area is used to compute both predevelopment and postdevelopment runoff for detention design because it best represents total runoff leaving the tract.

The area is measured using Autocad software and the value found is:

Area = 631500 ft²
      = 14.5 acres
      = 0.023 square mile
3. PEAK DISCHARGE AND HYDROGRAPH COMPUTATION

3.1. Method

The peak runoff is calculated using the graphical peak discharge method, described in TR-55 report [1]. The hydrograph is determined using the exhibits which are also provided in the TR-55 report [1].
The following steps are followed in determining the peak runoff in the graphical peak discharge method:

a) Total drainage area, \( A_m \), in square miles
b) Time of concentration, \( T_c \), in hours
c) Weighted curve number, \( CN \)
d) Appropriate rainfall distribution (I, IA, II, or III)
e) Total runoff, \( Q \), in inches computed from \( CN \) and rainfall
f) 24-hour rainfall, \( P \), in inches
g) Initial abstraction, \( I_a \) (in). From Table 5-1 of [1].
h) Ratio of \( I_a/P \)

The peak discharge, \( q_p \), is computed using the following equation,

\[
q_p = q_u A_m Q F_p
\]

(Equation 1)

where, \( q_p \) is the peak discharge (cfs), \( q_u \) is the unit peak discharge from exhibit 4 (csm/in), \( A_m \) is the drainage area (mi\(^2\)), \( Q \) is the runoff (in), and \( F_p \) is pond and swamp adjustment factor (In our case, we assume that there is no pond or swamp so \( F_p = 1 \))

The computation of the hydrograph coordinates for selected \( T_c, T_t \) (Note here that \( T_t = 0 \) because the flow is running directly to the outlet) and \( I_a/P \) is carried out using the appropriate sheets in Exhibit 5-II [1]. The flow at any time of the hydrograph is

\[
q = q_t A_m Q
\]

(Equation 2)

where, \( q \) is the hydrograph coordinate (cfs) at hydrograph time \( t \), \( q_t \) is the tabular hydrograph unit discharge from exhibit 5 (csm/in), \( A_m \) is the drainage area (mi\(^2\)), and \( Q \) is the runoff (in).

3.2. Predevelopment

3.2.1. Time of Concentration

The hydraulic path used to calculate the time of concentration is shown in Figure 2. Segmentation of the hydraulic path is also shown in Figure 2. Note that it is assumed that there is no open channel in the watershed and only two segments are considered. Segment AB corresponds to the sheet flow and Segment BC corresponds to the shallow concentrated flow.
The two segments have the following parameters:

Sheet flow: Grass
   Length, L = 100 ft
   Slope, s = 10%
   Manning’s roughness coefficient, n=0.40

Shallow concentrated flow:
   Length, L = 1180 ft
   Slope, s = 10%
The time of concentration is found to be: (For details, see Table 1)

Sheet flow: \( T_1 = 0.20 \) hr
Shallow concentrated flow: \( T_2 = 0.07 \) hr
Time of concentration, \( T_c = T_1 + T_2 \)
\[
T_c = 0.20 + 0.07 = 0.27 \text{ hr} = 16 \text{ min}
\]

Note: the Manning’s roughness coefficient for the sheet flow is assumed to be equal to 0.40 because the surface is wooded.

Table 1: Time of Concentration Computation – Predevelopment

<table>
<thead>
<tr>
<th>Sheet Flow, (Applicable to ( T_c ) only)</th>
<th>Segment ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Surface description (Table 3-1)</td>
<td>AB</td>
</tr>
<tr>
<td>2. Manning’s roughness coeff, ( n ) (Table 3-1)</td>
<td></td>
</tr>
<tr>
<td>3. Flow length, ( L ) (for ( L \leq 100 ) ft)</td>
<td></td>
</tr>
<tr>
<td>4. Two-year 24-hour rainfall, ( P_2 ) (in in)</td>
<td></td>
</tr>
<tr>
<td>5. Land slope, ( s ) (in ft/ft)</td>
<td></td>
</tr>
<tr>
<td>6. ( T_1 = \frac{0.07 \text{ ft/hr}}{0.40^{5/8} \sqrt{L}} ) Compute ( T_1 )</td>
<td>0.20 + = 0.20</td>
</tr>
</tbody>
</table>

Shallow Concentrated Flow

<table>
<thead>
<tr>
<th>Segment ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Channel Flow</th>
<th>Segment ID</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Miscellaneous</th>
<th>Segment ID</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.2. Curve Number and Runoff Computation

As cited in the site information, the surface area is wooded and it is in good condition. The curve number, CN, and the runoff, Q, are calculated using Worksheet 2. The computation of CN and Q are shown in Table 2, and the values are found to be

\[ \text{CN} = 55. \]
\[ \text{Q} = 1.5 \text{ in.} \]

Note here that the runoff, Q, is determined using Table 2-1 of [1] using the appropriate CN and the 24-hours storm rainfall P. The 24-hours storm rainfall, P, is determined from IDF curves developed in this study and listed in Appendix A of this report.

Table 2: Curve Number, C, and Runoff, Q, Computation – Predevelopment

<table>
<thead>
<tr>
<th>Soil name and hydrologic group (Appendix A)</th>
<th>Cover description (Cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)</th>
<th>CN</th>
<th>Area (m²)</th>
<th>Product of CN x area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Name, B</td>
<td>Wooded, Good Condition</td>
<td>55</td>
<td>100.0</td>
<td>5,500.0</td>
</tr>
</tbody>
</table>

3 Use only one CN source per line.

\[ \text{CN (weighted)} = \frac{\text{total product}}{\text{total area}} = \frac{5,500.0}{100.0} = 55 \]

Use CN = 55

2. Runoff

<table>
<thead>
<tr>
<th>Frequency .................................................... years</th>
<th>Storm #1</th>
<th>Storm #2</th>
<th>Storm #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall, P (24 hour) ...................................... in.</td>
<td>5.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Runoff, Q ................................................... in.</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equation 2-3 and 2-4</th>
<th>Storm #1</th>
<th>Storm #2</th>
<th>Storm #3</th>
</tr>
</thead>
</table>


3.2.3. Peak Discharge

The computation of the peak discharge use Equation 1 and the steps followed are detailed in Worksheet 4 as shown in Table 3. The peak discharge of the site before development is found to be

\[ q_{p} = 20 \text{ cfs} \]

Table 3: Peak Discharge Computation - Predevelopment

3.2.4. Discharge Hydrograph

The discharge hydrograph is constructed using Exhibit 5-II for a \( T_{C} = 0.3 \text{hr} \), \( T_{t} = 0.0 \) and \( I_{a}/P = 0.3 \). The flow at any time of the hydrograph is calculated using Equation 2. The discharge hydrograph is illustrated in Figure 3.
3.3. Postdevelopment

3.3.1. Time of concentration

The hydraulic path used to calculate the time of concentration is shown in Figure 4. Segmentation of the hydraulic path is also shown in Figure 4, where Segment AB is the sheet flow, Segment BC is the Shallow concentrated flow, and Segment CD is the pipe flow. Here, I want to note that I assume that a pipe run from the buildings and the parking into the detention basin, as shown in Figure 4. The design of the pipe is beyond the scope of this report. The travel time within the pipe is assumed to be

\[ T_3 = 0.03 \text{ hr} \]

The segments AB and BC have the following parameters:

- **Sheet flow:** Grass
  - Length, \( L = 100 \text{ ft} \)
  - Slope, \( s = 14\% \)
  - Manning’s roughness coefficient, \( n=0.40 \)

- **Shallow concentrated flow:**
  - Length, \( L = 624 \text{ ft} \)
  - Slope, \( s = 14\% \)

The time of concentration is found to be:

- **Sheet flow:** \( T_1 = 0.18 \text{ hr} \)
- **Shallow concentrated flow:** \( T_2 = 0.03 \text{ hr} \)
Time of concentration, Tc: \[ Tc = T1 + T2 + T3 \]
\[ Tc = 0.24 \text{ hr} \]
\[ = 14 \text{ min} \]

Figure 4: Delineated Watershed and Hydraulic Path – Post-development

3.3.2. Curve Number and Runoff Computation

The computation of the curve number is completed using Worksheet 2 [1]. The curve number is weighted because there are different surface types within the drainage area.
Four types exist in the site under study. The hydrologic soil group B, is assumed for the site.

Type 1: Impervious (Parking lots, Paved roads, and Roofs): 2.76 acres with CN = 98
Type 2: Lawn, Good Condition: 4.49 acres with CN = 61
Type 3: Woods, Fair Condition: 2.9 acres with CN = 60
Type 4: Woods, Good Condition (Part outside the tract): 4.35 acres with CN = 55

The computation of CN and Q are shown in Table 2, and the values are found to be

\[
\begin{align*}
\text{CN} & = 66. \\
\text{Q} & = 2.4 \text{ in.}
\end{align*}
\]

Table 4: Curve Number, CN, and Runoff, Q, Computation – Post-development

<table>
<thead>
<tr>
<th>Soil name and hydrologic group (Appendix A)</th>
<th>Cover description</th>
<th>CN</th>
<th>Area (acres)</th>
<th>Product of CN x area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impervious</td>
<td></td>
<td>98</td>
<td>19.0</td>
<td>1,662.0</td>
</tr>
<tr>
<td>Soil Name, B Lawn, Good Condition</td>
<td></td>
<td>61</td>
<td>31.0</td>
<td>1,891.0</td>
</tr>
<tr>
<td>Soil Name, B Woods, Fair Condition</td>
<td></td>
<td>60</td>
<td>20.0</td>
<td>1,200.0</td>
</tr>
<tr>
<td>Soil Name, B Woods, Good Condition</td>
<td></td>
<td>55</td>
<td>30.0</td>
<td>1,650.0</td>
</tr>
</tbody>
</table>

Use only one CN source per line.

CN (weighted) = total product \( \frac{6,603.0}{100.0} = 66 \)

Use CN = 66

2. Runoff

<table>
<thead>
<tr>
<th>Storm #1</th>
<th>Storm #2</th>
<th>Storm #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (number of years)</td>
<td>100</td>
<td>5.9</td>
</tr>
<tr>
<td>Rainfall (24 hour) (in.)</td>
<td>5.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Runoff (in.)</td>
<td>2.4</td>
<td>2.4</td>
</tr>
</tbody>
</table>

(Use P and CN with Table 2-1, Figure 2-1, or equations 2-3 and 2-4.)
3.3.3. Peak Discharge

The computation of the peak discharge use Equation 1 and the steps followed are detailed in Worksheet 4 as shown in Table 5. The peak discharge of the site after development is found to be

\[ q_p = 39 \text{ cfs} \]

Table 5: Peak Discharge Computation – Post-development

<table>
<thead>
<tr>
<th>Data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td></td>
</tr>
<tr>
<td>Drainage area</td>
<td>( A_m = 0.02 \text{ m}^2 ) (acres/640)</td>
</tr>
<tr>
<td>Runoff curve number</td>
<td>( CN = 66 ) (From Worksheet 2)</td>
</tr>
<tr>
<td>Time of concentration</td>
<td>( T_c = 0.24 \text{ hr} ) (From Worksheet 3)</td>
</tr>
<tr>
<td>Rainfall distribution type</td>
<td>II (II, III, DMVII)</td>
</tr>
<tr>
<td>Pond and swamp areas spread throughout watershed</td>
<td>0 percent of ( A_m ) (acres or m² covered)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Storm 1</th>
<th>Storm 2</th>
<th>Storm 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.030</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.3.4. Discharge Hydrograph

The discharge hydrograph is constructed using Exhibit 5-II for a \( T_C = 0.2 \text{ hr} \), \( T_I = 0.0 \) and \( I_a/P = 0.1 \) and Equation 2. The discharge hydrograph is illustrated in Figure 5.
3.4. Peak Discharge Comparison

The peak discharge of the site before and after development is shown in Figure 6. As seen, the peak discharge increased from 20.00 cfs to 39.00 cfs after development and it occurred in an earlier time. To attenuate the peak runoff to a level equal to less than the predevelopment peak, a detention basin has to be built. The design of the detention basin for this site is given in the following section.
4. DETENTION BASIN DESIGN

The steps followed for designing the detention basin are:

Step 1: Locate proper site for construction of the basin
Step 2: Determine the required volume and dimensions of detention basin
Step 3: Design outlet structure
Step 4: Route the outflow
Step 5: Check if the design requirements are met. If the design requirements are not met repeat step 2 to step 4 until design requirements are met.

4.1. Design Requirements

The detention basin requirements are:

- The peak runoff leaving the tract after development is equal to or less than the peak runoff leaving the tract before development.
- Runoff and basin routing computations are to be by NRCS Method.
- Basin side slopes are 3:1 (horizontal to vertical).

4.2. Detention Basin Type and Location

In this project, a dry open-cut basin is proposed. The location of the basin is chosen to be along the south-east boundary of the tract as shown in Figure 4 because this is the lowest point on the site and is adjacent the natural stream that flows south of the tract.

Note here that a grading at the southerly border of the tract may be required in order to flow all runoff toward the detention basin.

4.3. Detention Basin Dimensions

The schematic illustration of the proposed detention basin is shown in Figure 7. The dimensions of the basin and the storage volume versus elevation are listed in Table 6. The storage volume versus water elevation level is depicted in Figure 8.

<table>
<thead>
<tr>
<th>Elevation (ft)</th>
<th>Area (sq. ft)</th>
<th>Incremental Volume (c.f.)</th>
<th>Cumulative Volume (c.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>181.50</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>182.50</td>
<td>7200</td>
<td>3600</td>
<td>3600</td>
</tr>
<tr>
<td>183.50</td>
<td>8652</td>
<td>7926</td>
<td>11526</td>
</tr>
<tr>
<td>184.50</td>
<td>10176</td>
<td>9414</td>
<td>20940</td>
</tr>
<tr>
<td>185.50</td>
<td>12208</td>
<td>11192</td>
<td>32132</td>
</tr>
<tr>
<td>186.50</td>
<td>13888</td>
<td>13048</td>
<td>45180</td>
</tr>
</tbody>
</table>
4.4. Outlet Structure and Outflow Computation

The detention basin outflow structure is illustrated in Figure 9. As shown in the sketch, two-stage structure is suggested. The parameters of the outflow structure are as the following:
Orifice
Orifice diameter (ft) : 1.00
Area of orifice (sq. ft) : 0.785
Invert elevation (ft) : 181.50
Discharge Coefficient, c : 0.62

Weir
Crest length (ft): 1.50
Wall thickness (ft): 0.50
Crest elevation (ft): 183.50

Figure 9: Outflow Structure of Detention Basin

The outflow computation is shown in Table 7, and the discharge rating versus water elevation level is plotted in Figure 10.

Table 7: Outflow Computation

<table>
<thead>
<tr>
<th>Water Level Elevation (ft)</th>
<th>Orifice</th>
<th>Weir</th>
<th>Total Discharge (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Head, h (ft)</td>
<td>Discharge, Q (cfs)</td>
<td>Head, H (ft)</td>
</tr>
<tr>
<td>181.50</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>182.50</td>
<td>0.50</td>
<td>2.76</td>
<td>0.00</td>
</tr>
<tr>
<td>183.50</td>
<td>1.50</td>
<td>4.79</td>
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<td>184.50</td>
<td>2.50</td>
<td>6.18</td>
<td>1.00</td>
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<td>185.50</td>
<td>3.00</td>
<td>6.77</td>
<td>2.00</td>
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<tr>
<td>186.50</td>
<td>4.00</td>
<td>7.82</td>
<td>3.00</td>
</tr>
</tbody>
</table>

Figure 10: Outflow Discharge versus Water Elevation Level
4.5. Outflow Routing

Now that the detention basin size and the outflow structure are selected, we compute the outflow routings to determine the peak outflow. The routing hydrograph is computed using the routing method which relies on continuity equation [2].

First, we create a table of values of $2S/\Delta t - O$ and $2S/\Delta t + O$ versus outflow, $O$. For this purpose, the storage volume and discharge rating, determined in the previous steps, are used. The incremental time period was chosen as $\Delta t = 0.20$ hour which is equal to 720 seconds. The results are depicted in Table 8 and the graph is shown in Figure 11.

Table 8: Routing Computation Parameters

<table>
<thead>
<tr>
<th>Cu. Volume (c.f.)</th>
<th>Outflow (cfs)</th>
<th>$2S/\Delta t - O$ (cfs)</th>
<th>$2S/\Delta t + O$ (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3600</td>
<td>2.76</td>
<td>7.2</td>
<td>12.8</td>
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<td>4.79</td>
<td>27.2</td>
<td>36.8</td>
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<td>69.3</td>
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<td>45180</td>
<td>33.69</td>
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<td>159.2</td>
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</tbody>
</table>

Figure 11: Graph of $2S/\Delta t + O$ versus $O$, and $2S/\Delta t - O$ versus $O$

The detention basin routing table is listed in Table 9. The inflow and outflow hydrographs are plotted in Figure 12. As seen in Table 9, by routing through the detention basin, the runoff rate was attenuated to rate below predevelopment runoff value. The
resulting peak outflow rate is 19.90 cfs, which is less than the peak runoff of the site before development, and hence the detention basin design was accepted.

Table 9: Detention Basin Routing Table

<table>
<thead>
<tr>
<th>Time (hr)</th>
<th>$I_1$ (cfs)</th>
<th>$I_1+I_2$ (cfs)</th>
<th>$2S/\Delta t - O$ (cfs)</th>
<th>$2S/\Delta t + O$ (cfs)</th>
<th>$O_2$ (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>0</td>
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<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
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<td>0.35</td>
<td>1.44</td>
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<td>0.42</td>
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</tr>
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<td>1.50</td>
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<td>2.20</td>
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<td>5.57</td>
<td>1.27</td>
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</tbody>
</table>

Figure 12: Inflow and Outflow Hydrographs
5. SUMMARY AND CONCLUSION

The values of peak runoff of the site before and after development (with and without detention basin) are listed in Table 10. The hydrographs are plotted in Figure 13. As seen, the peak discharge increased from 20 cfs to 39 cfs after development. The designed detention basin has attenuated the postdevelopment peak runoff to a rate less than the predevelopment rate. The outflow peak 19.90 cfs correspond to a maximum water level of 185.40 ft.

To complete the detention basin design other tasks should be considered. These tasks include emergency spillway, erosion control, and maintenance and safety of the detention basin. However and due to time limitation these tasks will not be discussed in this report.

Table 10: Peak runoff rate summary

<table>
<thead>
<tr>
<th></th>
<th>Peak runoff (cfs)</th>
</tr>
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<tbody>
<tr>
<td>predevelopment</td>
<td>20.00</td>
</tr>
<tr>
<td>Postdevelopment</td>
<td></td>
</tr>
<tr>
<td>without detention</td>
<td>39.00</td>
</tr>
<tr>
<td>basin</td>
<td></td>
</tr>
<tr>
<td>Postdevelopment</td>
<td></td>
</tr>
<tr>
<td>with detention basin</td>
<td>19.90</td>
</tr>
</tbody>
</table>

Figure 13: Discharge Hydrographs
The rainfall Intensity-Duration-Frequency (IDF) curves for St. Paul Minnesota were constructed using the precipitation data generated from the precipitation maps provided in HYDRO-35 [3] and NOAA Atlas 2 [4].

Table A.1 and Table A.2 list the rainfall intensity for storm duration of 5, 10, 15, 30 and 60 minutes and for storm duration of 2, 3, 6, 12 and 24 hours, respectively. The values for 2-year and 100-year frequencies are listed. Figure A.1 and Figure A.2 show the IDF curves for storm duration of 5, 10, 15, 30 and 60 minutes and for storm duration of 2, 3, 6, 12 and 24 hours, respectively.

Table A.1: Rainfall intensity for storm duration of 5, 10, 15, 30, and 60 minutes.

<table>
<thead>
<tr>
<th>Duration (Minutes)</th>
<th>2-Year</th>
<th>100-Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5.04</td>
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<td>60</td>
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<td>3.15</td>
</tr>
</tbody>
</table>

Table A.2: Rainfall intensity for storm duration of 2, 3, 6, 12, and 12 hours.

<table>
<thead>
<tr>
<th>Duration (Hours)</th>
<th>2-Year</th>
<th>100-Year</th>
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</thead>
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<td>2</td>
<td>0.83</td>
<td>1.75</td>
</tr>
<tr>
<td>3</td>
<td>0.57</td>
<td>1.25</td>
</tr>
<tr>
<td>6</td>
<td>0.34</td>
<td>0.70</td>
</tr>
<tr>
<td>12</td>
<td>0.21</td>
<td>0.43</td>
</tr>
<tr>
<td>24</td>
<td>0.11</td>
<td>0.25</td>
</tr>
</tbody>
</table>
Figure A.1: Rainfall intensity for storm duration of 5, 10, 15, 30, and 60 minutes.

Figure A.2: Rainfall IDF curves for storm duration of 2, 3, 6, 12, and 12 hours.
References:


4. Precipitation Frequency Atlas Maps (Central and Eastern U.S.),