Worksheet 2: Runoff curve number and runoff

Project ________________________________ By ______ Date ______
Location ________________________________ Checked ______ Date ______
Circle one: Present Developed ________________________________

1. Runoff curve number (CN)

<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 1/ Area</th>
<th>Product of CN % area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Table 2-2</td>
<td>Fig. 2-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>Totals =</td>
</tr>
</tbody>
</table>

1/ Use only one CN source per line

CN (weighted) = total product/total area = ______=______ ; Use CN = __________

2. Runoff

Frequency ...........................................yr
Rainfall, P (24-hour) ....................................in
Runoff, Q ..............................................in
(Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)

Storm #1 | Storm #2 | Storm #3 |
-----------|----------|----------|

Appendix A – Exhibit II (2 of 8)
Worksheet 3: Time of concentration ($T_c$) or travel time ($T_t$)

Project ________________________________ By ______ Date ______

Location ________________________________ Checked ______ Date ______

Circle one: Present Developed ________________________________

Circle one: $T_c$ $T_t$ ________________________________

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

<table>
<thead>
<tr>
<th>Sheet flow (applicable to $T_t$ only)</th>
<th>Segment ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Surface description (table 3-1)</td>
<td></td>
</tr>
<tr>
<td>2. Manning's roughness coeff., $n$ (table 3-1)</td>
<td></td>
</tr>
<tr>
<td>3. Flow length, $L$ (total $L \leq 300$ ft)</td>
<td>ft</td>
</tr>
<tr>
<td>4. Two-yr 24-hr rainfall, $P_2$</td>
<td>in</td>
</tr>
<tr>
<td>5. Land slope, $s$</td>
<td>ft/ft</td>
</tr>
<tr>
<td>6. $T_t = 0.007(nL)^{0.4}/P_2^{0.6}s^{0.4}$</td>
<td>Compute $T_t$, hr</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shallow concentrated flow</th>
<th>Segment ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Surface description. (paved or unpaved)</td>
<td></td>
</tr>
<tr>
<td>8. Flow length, $L$</td>
<td>ft</td>
</tr>
<tr>
<td>9. Watercourse slope, $s$</td>
<td>ft/ft</td>
</tr>
<tr>
<td>10. Average velocity $V$ (figure 3-1)</td>
<td>ft/s</td>
</tr>
<tr>
<td>11. $T_t = L/3600V$</td>
<td>Compute $T_t$, hr</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Channel flow</th>
<th>Segment ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Cross sectional flow area, $a$</td>
<td>ft$^2$</td>
</tr>
<tr>
<td>13. Wetted perimeter, $P_w$</td>
<td>ft</td>
</tr>
<tr>
<td>14. Hydraulic radius, $r = a/P_w$</td>
<td>Compute $r$, ft</td>
</tr>
<tr>
<td>15. Channel slope, $s$</td>
<td>ft/ft</td>
</tr>
<tr>
<td>16. Manning's roughness coeff., $n$</td>
<td></td>
</tr>
<tr>
<td>17. $V = 1.49 t^{0.4} s^{0.4}/n$</td>
<td>Compute $V$, ft/s</td>
</tr>
<tr>
<td>18. Flow length, $L$</td>
<td>ft</td>
</tr>
<tr>
<td>19. $T_t = L/3600V$</td>
<td>Compute $T_t$, hr</td>
</tr>
<tr>
<td>20. Watershed or subarea $T_t$ or $T_c$ (add $T_t$ in steps 6, 11 and 19)</td>
<td>hr</td>
</tr>
</tbody>
</table>

Appendix A – Exhibit II (3 of 8)
Worksheet 4: Graphical Peak Discharge method

Project _________________________________________ By ______ Date ______

Location _______________________________ Checked ______ Date ______

Circle one: Present Developed ________________________________

1. Data:
   - Drainage area \( A_m \) = _______ mi\(^2\) (acres/640)
   - Runoff curve number, \( CN \) = _______ (From worksheet 2)
   - Time of concentration \( T_c \) = _______ hr (From worksheet 3)
   - Rainfall distribution type = _______ (I, II, III)
   - Pond and swamp areas spread throughout watershed = _______ percent of \( A_m \) (____ acres or mi\(^2\) covered)

<table>
<thead>
<tr>
<th>Storm #1</th>
<th>Storm #2</th>
<th>Storm #3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Frequency ____________________________ yr

3. Rainfall, \( P \) (24-hour) _____________ in

4. Initial abstraction, \( I_a \) ____________ in
   (Use \( CN \) with table 4-1.)

5. Compute \( I_a /P \) ________________________

6. Unit peak discharge, \( q_u \) _____________ csm/in
   (Use \( T_c \) and \( I_a /P \) with exhibit 4-___)

7. Runoff, \( Q \) ___________________________ in
   (From worksheet 2.)

8. Pond and swamp adjustment factor, \( F_p \) ______________
   (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond and swamp area.)

9. Peak discharge, \( q_p \) ________________ cfs
   (Where \( q_p = q_u A_m Q F_p \))
Worksheet 5a: Basic watershed data

<table>
<thead>
<tr>
<th>Subarea name</th>
<th>Drainage area</th>
<th>Time of concentration</th>
<th>Travel time through subarea</th>
<th>Downstream subarea names</th>
<th>Travel time summation to outlet</th>
<th>24-hr Rainfall</th>
<th>Runoff curve number</th>
<th>Runoff</th>
<th>Initial abstraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( A_m )  (mi²)</td>
<td>( T_o ) (hr)</td>
<td>( T_i ) (hr)</td>
<td></td>
<td>( \sum T_i ) (hr)</td>
<td></td>
<td></td>
<td></td>
<td>( A_m Q ) (mi²-in)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( I_a ) (in)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( I_a/P )</td>
</tr>
</tbody>
</table>

- \( A_m \) (mi²): Area of the subarea.
- \( T_o \) (hr): Time of concentration.
- \( T_i \) (hr): Travel time through the subarea.
- \( \sum T_i \) (hr): Summation of travel times.
- 24-hr Rainfall: 24-hour rainfall.
- Runoff curve number:
- Runoff:
- Initial abstraction:

---

Appendix A - Exhibit II (5 of 8)

From worksheet 3

From worksheet 2

From table 5-1
Worksheet 5b: Tabular hydrograph discharge summary

<table>
<thead>
<tr>
<th>Subarea name</th>
<th>Basic watershed data used ( \mu )</th>
<th>Select and enter hydrograph times in hours form exhibit 5 - ( \mu )</th>
<th>Discharges at selected hydrograph times ( 3/ ) (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subarea ( T_e ) (hr)</td>
<td>( \sum T_i ) ((hr))</td>
<td>( I/P )</td>
<td>( A_m Q ) (mi²-in)</td>
</tr>
</tbody>
</table>

Appendix A - Exhibit II (6 of 8)

Composite hydrograph at outlet

1/ Worksheet 5a. Rounded as needed for use with exhibit 5.

2/ Enter rainfall distribution type used.

3/ Hydrograph discharge for selected times in \( A_m Q \) multiplied by tabular discharge from appropriate exhibit 5.
Worksheet 6a: Detention basin storage, peak outflow discharge ($q_o$) known

Project ___________________________ By ___________________________ Date __________

Location ___________________________ Checked _________________ Date __________

Circle one:  Present  Developed ________________________________

![Detention basin storage diagram]

<table>
<thead>
<tr>
<th>Elevation or stage</th>
</tr>
</thead>
</table>

1. Data:
- Drainage area: $A_m = \_\_\_\_\_\_ mi^2$
- Rainfall distribution: Type (I, IA, II, III)
  
<table>
<thead>
<tr>
<th>1st stage</th>
<th>2nd stage</th>
</tr>
</thead>
</table>

2. Frequency: $\_\_\_\_\_\_ yr$

3. Peak inflow discharge: $\_\_\_\_\_\_\_ cfs$
    (from worksheet 4 or 5b)

4. Peak outflow discharge: $\_\_\_\_\_\_\_\_\_ \_ cfs$
    
5. Compute $q_o / q_i$

6. $V_i / V_m$ .................
    (Use $q_o/q_i$ with figure 6.1)

7. Runoff, $Q$ .................
    (From worksheet 2)

8. Runoff volume, $V_r$ .................
    $(V_r = Q A_m = 53.33)$

9. Storage volume, $V_s$ .................
    $(V_s = V_r (V_i/V_m))$

10. Maximum stage, $E_{max}$
    (From plot)

Appendix A – Exhibit II (7 of 8)
Appendix A – Exhibit II (8 of 8)
Worksheet 6b: Detention basin, peak outflow, storage volume \( V_f \) known

Project ____________________________ By ____________________________ Date ______

Location ____________________________ Checked ____________________________ Date ______

Circle one: Present Developed ____________________________

Detention basin storage

1. Data:
   Drainage area .......... \( A_w = \) _____ mi\(^2\) 
   Rainfall distribution type (I, IA, II, III)

2. Frequency .......... yr

3. Storage volume, \( V_f \) .......... ac ft

4. Runoff, \( Q \) .......... in
   (From worksheet 2)

5. Runoff volume, \( V_r \) .......... ac ft
   (\( V_r = QA_{53.33} \))

6. Compute \( V_f / V_r \) ..........

7. \( q_1/q_2 \) .......... in
   (Use \( V_f / V_r \), and figure 6-1)

8. Peak inflow discharge, \( q_1 \) .......... cfs
   (From worksheet 4 or 5b)

9. Peak outflow discharge, \( q_o \) .......... cfs
   \( (q_o = q_1 (q_2/q_1)) \)

10. Maximum stage, \( E_{max} \) ..........
    (From plot)

\( 
1/ \) 2\(^{nd} \) stage \( q_o \) includes 1\(^{st} \) stage \( q_1 \)
Appendix A – Exhibit III (1 of 4)

DETENTION BASIN STORAGE DESIGN

I Calculate the peak flow in cfs due to the one (1) year frequency storm under predeveloped conditions.

\[ q_1 = A \times C \times i \quad \text{(allowable detention basin outflow release rate – stage one)} \]

- Area, \( A = \) [_______] acres
- Runoff Coefficient, \( C = \) [_______]
- Intensity, \( i = \) \( a/(t_c+b) = \) [_______] in/hr

Where: \( a = 80 \) (Table IV)

\( b = 14 \) (Table IV)

\( t_c = \) time of concentration (minutes) as determined from Appendix C – Exhibit 1

\[ q_1 = A [_______] \times C [_______] \times i [_______] = [_______] \text{ cfs} \]

II Calculation for the one (1) year frequency storm under postdevelopment conditions.

\[ Q_1 = A \times C \times i \]

- Area, \( A = \) [_______] acres
- Runoff Coefficient, \( C = \) [_______]
- Intensity, \( i = \) \( a/(t_c+b) = \) [_______] in/hr

Where: \( a = 80 \)

\( b = 14 \)

\( t_c = \) time of concentration (minutes)

\[ Q_1 = A [_______] \times C [_______] \times i [_______] = [_______] \text{ cfs} \]

III Critical Storm Calculation.

\[ [(Q_1/q_1) - 1.0] \times 100 = PC \quad \text{PC = [_______]} \] (See Table II on Page 34 for Critical Storm Frequency)

Critical Storm Frequency = [_______]

IV Calculate maximum storm duration, \( T_{\text{cor}} \), for the critical storm frequency (in minutes).

\[ T_{\text{cor}} = \left( \frac{(A \times C \times a \times b)}{(2 \times q_1/3 - [(q_1^2 \times t_c) / (6 \times C \times A \times a)]})^{1/2} - b \right) \]
Appendix A – Exhibit III (2 of 4)

Where: $a = \text{determined from Table IV (for critical storm frequency)}$

$b = \text{determined from Table IV (for critical storm frequency)}$

$C = \text{the one year postdeveloped weighted runoff coefficient}$

$A = \text{area in acres}$

$T_{cor} = [\text{______}] \text{ minutes}$

V \quad \text{Calculate } I_{cr}:

$I_{cr} = \left[ \frac{a}{(T_{cor} + b)} \right] = [\text{______}] \text{ in/hr}$

VI \quad \text{Calculate } Q_{cr}, \text{ flow at maximum duration for the critical storm frequency:}

$Q_{cr} = A \left[ \text{______} \right] \times C \left[ \text{______} \right] \times I_{cr} \left[ \text{______} \right] = [\text{______}] \text{ cfs}$

VII \quad \text{Calculate the required storage volume due to critical storm criteria, } SV_{cr}:

$SV_{cr} = \left[ \left( 60 \times Q_{cr} \times T_{cor} \right) - \left\{ 2 \times q_{1} \times (T_{cor} + t_{c}) \times 60 \right\} / 3 \right]$

$\quad + \left\{ (q_{1}^{2} + t_{c} \times 60) / (6 \times Q_{cr}) \right\}$

$SV_{cr} = [\text{______}] \text{ ft}^{3}$

VIII \quad \text{Calculate the peak flow in cfs due to the one-hundred (100) year frequency storm under predeveloped conditions.}$

$q_{100} = A \times C \times I \quad (\text{allowable detention basin outflow release rate – stages one + two})$

\text{Area, } "A" = [\text{______}] \text{ acres}$

\text{Runoff Coefficient, } "C" = [\text{______}]$

\text{Intensity, } "I" = a/(t_{c} + b) = [\text{______}] \text{ in/hr}$

Where: $a = 290 \text{ (Table IV)}$

$b = 31 \text{ (Table IV)}$

$t_{c} = \text{time of concentration (minutes) as determined from Appendix C – Exhibit 1, for predeveloped}$

$q_{100} = A \times C \times I \times \left[ \text{______} \right] = [\text{______}] \text{ cfs}$

IX \quad \text{Calculate maximum storm duration } T_{c100}, \text{ for the one-hundred year frequency (in minutes) storm under postdeveloped conditions.}
\[ T_{cr} = \left( \frac{(A \cdot C \cdot a \cdot b)}{(2 \cdot q_{100}/3) - [(q_{100}^2 \cdot t_c) / (6 \cdot C \cdot A \cdot a)]} \right)^{1/2} - b \]

Where:
- \( a = 290 \)
- \( b = 31 \)
- \( C = \text{the one-hundred year postdeveloped weighted runoff coefficient} \)
- \( A = \text{area in acres} \)

\[ T_{c100} = [ \underline{______} ] \text{ minutes} \]

X  Calculate \( I_{100} \):

\[ I_{100} = \left[ a / (T_{c100} + b) \right] = [ \underline{______} ] \text{ in/hr} \]

XI  Calculate \( Q_{100} \), flow at maximum duration for the critical storm frequency:

\[ Q_{100} = A [ \underline{______} ] \cdot C [ \underline{______} ] \cdot I_{100} [ \underline{______} ] = [ \underline{______} ] \text{ cfs} \]

XII  Calculate the required storage volume due to critical storm criteria, \( SV_{cr} \):

\[ SV_{100} = [(60 \cdot Q_{100} \cdot T_{c100})] - \{ [2 \cdot q_{l} \cdot (T_{c100} + t_{c}) \cdot 60] / 3 \} + [(q_{100}^2 \cdot t_c \cdot 60) / (6 \cdot Q_{100})] \]

\[ SV_{100} = [ \underline{_______} ] \text{ ft}^3 \]

XIII  Design Notes:

1. Design as a two stage outlet
   a. An iterative process is required since the change in elevation head will cause an increase in the outflow of the stage one opening.
   b. Two detention areas can be used to eliminate the iterative two stage outlet design process.

2. Emergency overflow must be accounted for via a spillway or other means.

General Notes:

1. The formulas used in calculations III through VII assume an orifice controlled outflow.

2. Reference pages 98 and 99, Water and Wastes Engineering, "Estimate Detention and Reservoir Storage". By A.S. Païtal, P.E., Ph.D.
ROCK CHANNEL PROTECTION AT CULVERT AND STORM SEWER OUTLETS

NOTES
Rock size (6", 12", 18") indicates the square opening on which 95% of the material, by weight, will be retained.
The width of protection shall be the width of the headwall, with 4 ft being the minimum.
(Where a stream bed will withstand the calculated velocity without erosion, no rock channel protection will be required.)
CRITICAL AREA PLANTING

1. TEMPORARY AND PERMANENT SEEDING

1.1 SEEDBED PREPARATION

A. **Lime** (in lieu of a soil test recommendation) on acid soil (ph = 5.5 or less) and subsoil at a rate of 100 pounds per 1000 sq. ft. or two (2) tons per acre of agricultural ground limestone.

B. **Fertilizer** (in lieu of soil test recommendation) shall be applied at a rate of 12-15 pounds (25 pounds for permanent seeding) per 1000 sq. ft. of 10-10-10 or 12-12-12 analysis or equivalent.

1.2 SEEDING

A. Species Selection

(1) Temporary Seeding Mixture

<table>
<thead>
<tr>
<th>Seeding Period</th>
<th>Type</th>
<th>Rate (1000 ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring and</td>
<td>1. Oats</td>
<td>3 lbs</td>
</tr>
<tr>
<td>Summer</td>
<td>2. Peren. Ryegrass</td>
<td>1 lbs</td>
</tr>
<tr>
<td></td>
<td>3. Tall Fescue</td>
<td>1 lbs</td>
</tr>
<tr>
<td>Fall</td>
<td>1. Peren. Ryegrass</td>
<td>1 lbs</td>
</tr>
<tr>
<td></td>
<td>2. Rye</td>
<td>3 lbs</td>
</tr>
<tr>
<td></td>
<td>3. Wheat</td>
<td>3 lbs</td>
</tr>
<tr>
<td></td>
<td>4. Tall Fescue</td>
<td>1 lbs</td>
</tr>
</tbody>
</table>

(2) Permanent Seeding Mixture

<table>
<thead>
<tr>
<th>Seeding Period</th>
<th>Type</th>
<th>Rate (1000 ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring,</td>
<td>1. Creeping Red Fescue</td>
<td>0.5 lbs</td>
</tr>
<tr>
<td>Summer, and</td>
<td>Domestic Ryegrass</td>
<td>0.25 lbs</td>
</tr>
<tr>
<td>Fall</td>
<td>Kentucky Bluegrass</td>
<td>0.25 lbs</td>
</tr>
<tr>
<td></td>
<td>2. Tall Fescue</td>
<td>1 lbs</td>
</tr>
<tr>
<td></td>
<td>3. Dwarf Fescue</td>
<td>1 lbs</td>
</tr>
</tbody>
</table>
(2-1) Seedings for Steep Banks or Cuts

Spring,  
1. Tall Fescue  1 lbs
Summer, and
Fall
2. Crownvetch  0.25 lbs
   Tall Fescue  0.50 lbs
3. Flatpea  0.50 lbs
   Tall Fescue  0.50 lbs

(2-2) Seedings for Waterways and Road Ditches

Spring,  
1. Tall Fescue  1 lbs
Summer, and
Fall

B. Apply the seed uniformly with a cyclone seeder, drill, cultipacker seeder, or hydroseeder (slurry may include seed and fertilizer) preferably on a firm, moist seedbed. Seed wheat or rye no deeper than one (1) inch. Seed ryegrass no deeper than one quarter (1/4) of an inch.

C. When feasible, except where a cultipacker type seeder is used, the seedbed should be firmed following seeding operations with a cultipacker, roller, or light drag. On sloping land seeding operations should be on the contour wherever possible.

D. Other seed species may be substituted for these mixtures.

E. These seeding rates need to be increased two to three times if they are to be used as a lawn.

2. DORMANT SEEDING

A. Temporary Seeding - After November 1, use mulch only.

B. Permanent Seeding - Seedings should not be planted from October 1 through November 20. The following methods may be used to make a “dormant seeding”:

   (1) From October 1 through November 20, prepare the seedbed, add the required amounts of lime and fertilizer, then mulch and anchor. After November 20, and before March 15, broadcast the selected seed mixture. Increase the seeding rates by 50 percent for this type of seeding.

   (2) From November 20 through March 15, when soil conditions, permit, prepare the seedbed, lime and fertilize, apply the selected seed mixture, and

   (3) mulch and anchor. Increase the seeding rates by 50 percent for this type of seeding.
3. **MULCHING**

   A. Mulch shall consist of small grain straw (preferably wheat or rye) and shall be applied at the rate of two tons per acre or 100 pounds per 1000 sq. ft.

   B. Spread the mulch uniformly by hand or mechanically so the soil surface is covered.

   C. **Mulch Anchoring Methods**

      (1) **Mechanical** - Use a disk, crimper, or similar type tool set straight to punch or anchor the mulch material into the soil.

      (2) **Asphalt Emulsion** - Apply at the rate of 160 gallons per acre into the mulch as it is being applied.

      (3) **Mulch Netting** - Use according to the manufacturer's recommendations.

4. **IRRIGATION**

   Supply new seedlings with adequate water for plant growth until they are firmly established.