IOWA STORM WATER MANAGEMENT MANUAL

9.03 STORAGE ROUTING FOR FINAL DESIGN

IOWA DEPARTMENT OF NATURAL RESOURCES

TABLE OF CONTENTS

CONTENTS

Refer to the glossary for words in **bold black text**.
Some items of emphasis are in **bold blue text.**

9.03-1 OVERVIEW

Section 9.01 reviews the need for stormwater detention and the types of best management practices (BMPs) that meet those goals.

Section 9.02 reviews methods to develop initial estimates of detention storage needed to provide desired rate reductions. Those methods can be used to start the design process with a better idea of how much area will be required to meet project goals. This can be done before valuable design time is spent developing site-specific grading and utility plans.

This section is dedicated to the methods to be used during creation of more detailed design plans. These methods validate the preliminary storage volume estimates and determine the actual performance of the proposed stormwater detention facility.

> Stormwater detention is a **rate–based** standard. That is, compliance is demonstrated by showing the post–project release rate is below a maximum value established to meet project requirements.

NOTE

Methods to determine allowable release rates are described in Section 2.05, 3.02 and 9.02.

9.03-2 USE OF MODELING SOFTWARE

A. GENERAL INFORMATION

Given the variety of available software packages capable of performing calculations consistent with the TR-55 methodology, it is assumed that designers will rarely use techniques to manually develop runoff hydrographs in the methods described. This section is intended to review the required inputs and assumptions that typical software packages use.

B. MODEL TYPES

Designers are not limited to use of Win-TR55 or any specific software package. Any software running the TR-20 or TR-55 calculations may be used. Many newer software packages have incorporated options that facilitate the design process and provide output reports in formats that are easier to read. The designer should be familiar with the basis of such calculations, which are described in detail in Sections 9.03-4 and 9.04.

C. INPUT PARAMETERS

To properly size a detention practice, it is critical that the characteristics of the watershed that are input into the model reflect real-world conditions as closely as possible. Prior to this step, the designer should prepare a map of the watershed to define the various parameters that will need to be input into the model. `ESSENTIAL`

1. **Watershed size:** Perhaps the most basic parameter, defining the areas of land draining to each practice or conveyance to be studied.

2. **Curve Number:** The curve number is the parameter that determines the portion of rainfall that is converted to runoff from a given landscape. To define this number, site soils and land cover need to be defined for the watershed area being reviewed.

   a. **Hydrologic Soil Group (HSG):** A measure of soil types ranging from A (lowest runoff potential) to D (highest runoff potential). These parameters can be determined from soil maps prepared by the USDA for any county, or through use of the NRCS Web Soil Survey website.

   b. **Land Cover:** The guidance manual for NRCS TR-55 (as well as the related section of ISWMM) includes curve numbers for various land cover types, based on HSG. The curve numbers for these land uses depend on assumptions of impervious cover and the condition of open spaces within those land uses. For this reason, curve numbers should not be selected based on land type. They should be **determined for each subarea based on the current (and/or future) impervious cover and the condition of the open spaces within the given area (depth of topsoil and/or soil quality restoration).** The conditions used for this analysis should be based on the fully developed condition of the area the BMP is intended to serve. If the exact future impervious cover is not known for a given area, the designer should use an assumed value and provide supporting evidence for such assumptions. `ESSENTIAL`

NOTE

Selection of Curve Numbers is discussed in greater detail in Section 2.05.

3. **Time of concentration (Tc):** This parameter is a measure of the shape and length of the watershed. It defines the time expected for runoff to pass from the most hydraulically distant point in a given subarea to the outfall point of that area. **Calculation of time of concentration should be done with great care.** Underestimation of Tc can lead to a higher expected flow rate. If a shorter Tc is used in calculating the natural or existing flows (often used to determine the allowable release rate from a practice), this could result in allowing water out of the practice too quickly. If a longer Tc is used, the peak flow rates might be underestimated, resulting in undersizing of detention storage or conveyance structures.

4. **Time step for modeling:** Models will compute flow rates and volumes for each time step as defined by the user. In smaller watersheds (< 10 acres), a shorter interval is important, as the true peak flow rate might be missed if a longer step interval is used. Under most conditions, a calculation time step interval of 1 minute is preferred. For practices with watersheds greater than 10 acres in size, a time interval of 2 minutes may be used. ESSENTIAL

Figure 9.03-2-1: An example of a watershed data entry screen for a stormwater modeling software program.

Always 484 for central Iowa

Source: Hydraflow Hydrographs Extension

5. **Stage vs. storage relationship of the detention area:** Most software programs include a table to enter these properties. At specific elevations, the area available for temporary water storage is defined. This is most typically done in increments of 0.5 or 1.0 foot of elevation change. This information needs to be entered starting at the lowest elevation used for temporary storage. For a dry or dry ED basin, this would be the elevation of the lowest surface inlet. For wet ponds or stormwater wetlands, this would be the normal water surface elevation (permanent pool). Grading plans or contour maps are used to gather the data for this stage vs. storage relationship.
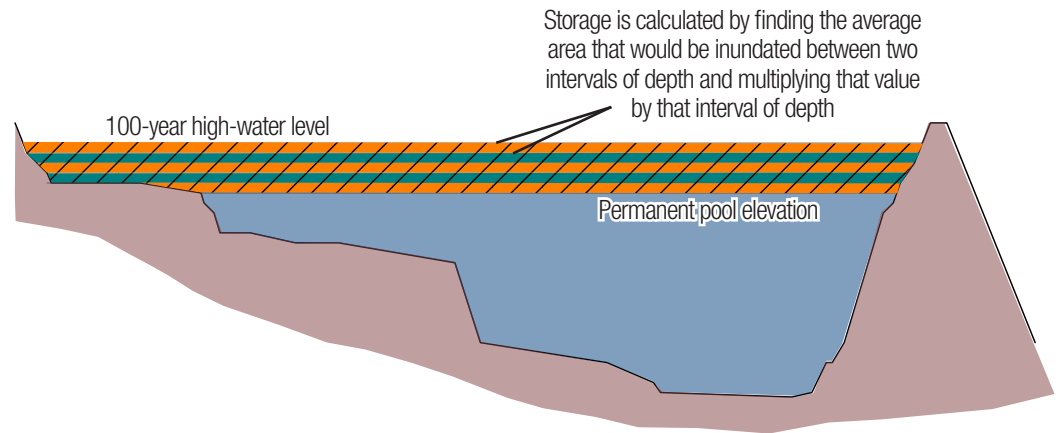
Storage is calculated by finding the average area that would be inundated between two intervals of depth and multiplying that value by that interval of depth

100-year high-water level

Permanent pool elevation

Figure 9.03-2-2: An illustration of how temporary detention storage is calculated for a wet detention pond.

Row	Stage	Elevation	Contour Area	Incremental Storage	Total Storage	Total Discharge
	(ft)	(ft)	(sqft)	(cuft)	(cuft)	(cfs)
0	0.00	100.00	125,900	0.000	0.000	0.000
1	1.00	101.00	144,500	135,200	135,200	2.127
2	2.00	102.00	163,500	154,000	289,200	3.008
3	3.00	103.00	210,600	187,050	476,250	17.00
4	4.00	104.00	249,300	229,950	706,200	41.93
5	5.00	105.00	261,400	255,350	961,550	90.65
6	6.00	106.00	273,700	267,550	1,229,100	124.49
7	7.00	107.00	286,300	280,000	1,509,100	244.63

Pond Name: POND FINAL DESIGN

Figure 9.03-2-3: An example of a stage-storage data entry screen for a stormwater modeling software program.

Source: Hydraflow Hydrographs Extension

6. **Stage vs. discharge relationship of the outfall structure:** This information is used in the routing calculations to determine the expected release rate as water levels within the practice change during a storm event. These outflow rates are typically computed by software. In more unique cases, the outfall rates may need to be computed manually or using a spreadsheet program and then input into a model.

The designer needs to input this information carefully to ensure that the model most accurately reflects the intent of the designer. Some key advisory points related to using software programs in multi-stage design:

a. **Orifices/culverts:** Typically software packages provide a space to input a number of orifice or pipe controls. The designer should refer to a given software package's user manual for specific guidance and understanding of the assumptions made by the program.
Often, these packages use "Culvert A" as the primary pipe spillway out of the detention basin. This is most typically the orifice, pipe or culvert that flow must pass through when passing out of the multi-stage control devices and leaving the practice. Other culverts or orifices can be specified that control flow upstream of Culvert A. Such controls are considered to be operating

as "multi-stage" by the program. In such cases, "Yes" should be selected as the multi-stage option in this arrangement. Any control that conveys flow that will bypass Culvert A should have "No" selected in the multi-stage option. (This applies to both culverts and weir design options).
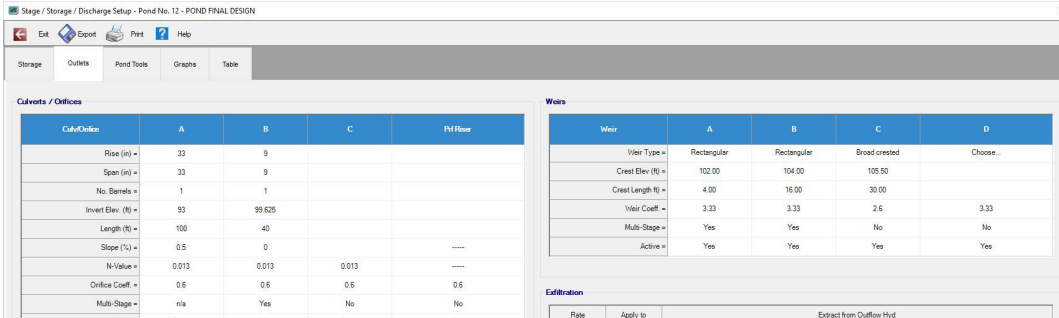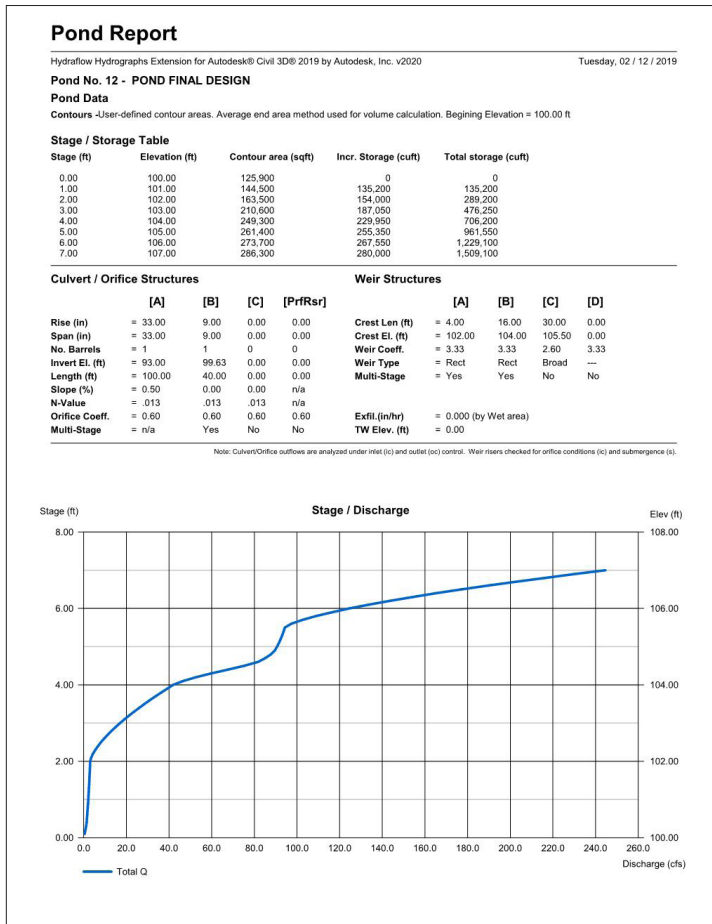

Figure 9.03-2-4: An example of outlet data entry screen for a stormwater modeling software program.
Source: Hydraflow Hydrographs Extension

Figure 9.03-2-5: An example of a pond data and stage-discharge graph generated by a stormwater modeling software program.
*Source: Hydraflow Hydrographs Extension*

The designer must input the correct size, shape and elevation information for each orifice or culvert, along with any required coefficients or constants.

b.   **Weirs/auxiliary spillways:** Software packages usually provide a space to input parameters for weir controls as well. Some weirs might be the top edges of an inlet structure whose outlet is Culvert A. These weirs are most often rectangular or V-notch weirs. Auxiliary spillways usually modeled as broad-crested weirs and usually will bypass Culvert A (hence, "No" should be selected as the multi-stage option).

Figure 9.03-2-6: An example of a multi-stage outlet used for flow control at a wet detention pond.
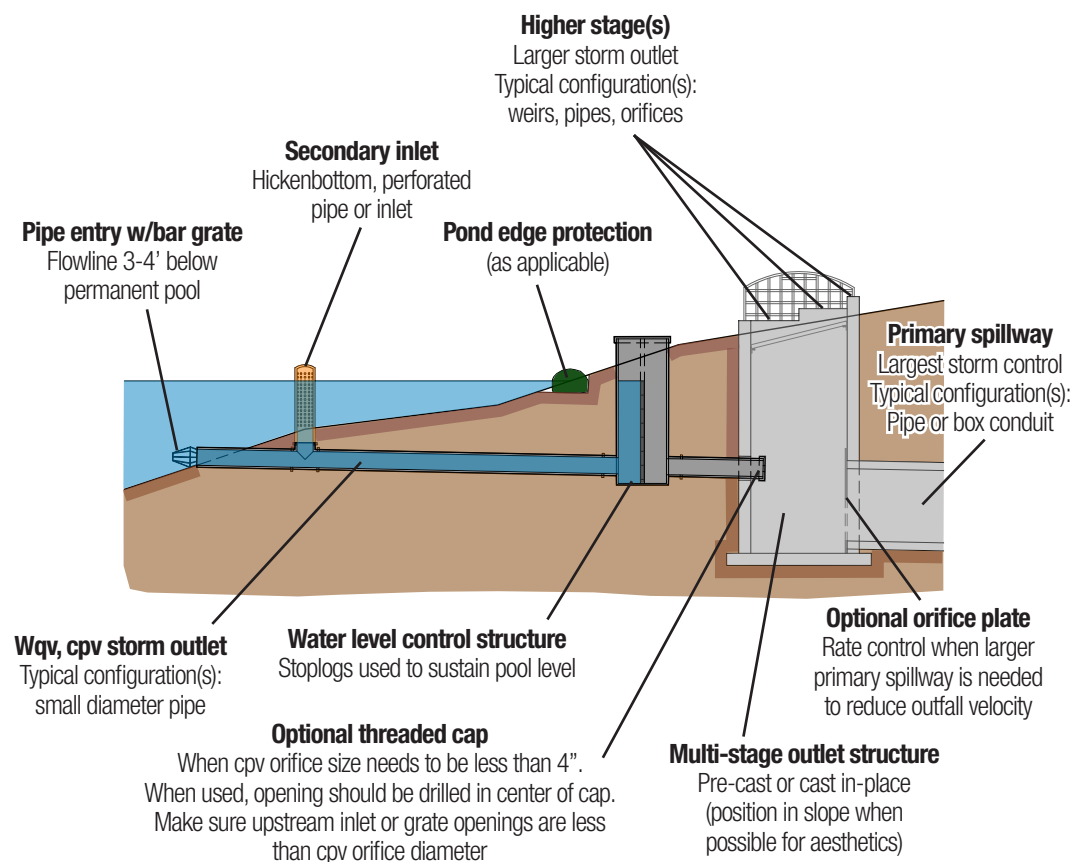
7.   **Watershed routing path:** The designer must input the way that subareas are added or routed to the detention practice. All areas that will drain through the detention area should be added together. In some cases, channel reaches need to be input into the model to simulate the time it takes for flow from an upstream area to pass through a downstream area. Once added, the total inflow hydrograph is selected as the input flow to be routed through the correct basin.

D. MODEL OUTPUTS

Most software programs will provide output in tabular or graphical form. Graphical output is most useful for reviewing inflow/outflow vs. highwater elevation vs. time relationships for key storm events to understand the expected operation of the detention basin. Other summary data such as runoff volumes and peak flow rates from different subwatershed areas is often presented in tabular form.

This output information should be presented to the local jurisdictional review authority along with the stormwater management plan (as described within Section 3.01). Details of the information to be provided, related to stormwater detention design is included in Section 9.03-3.
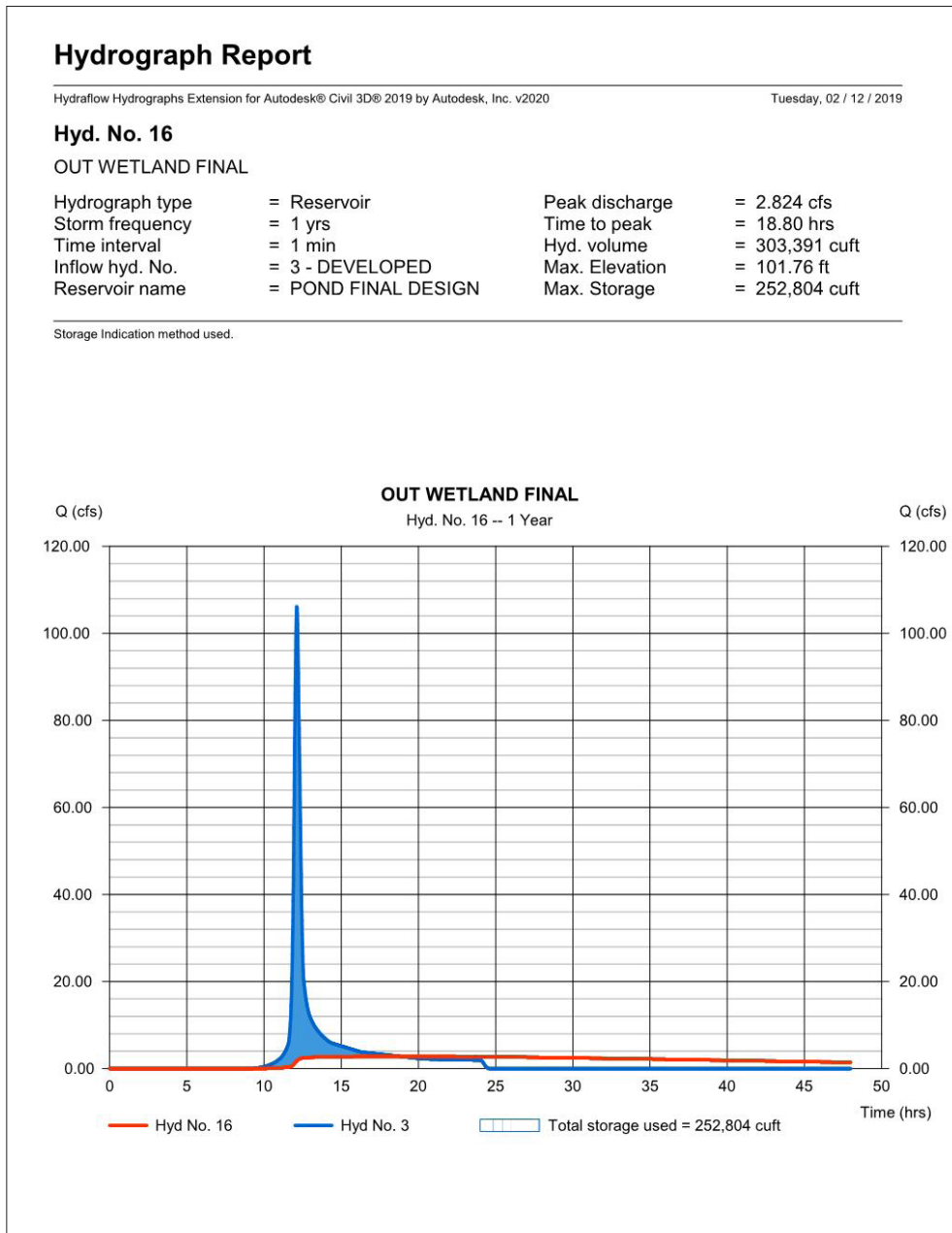

Figure 9.03-2-7: An example of inflow-outflow hydrographs generated by a stormwater modeling software program.

Source: Hydraflow Hydrographs Extension

9

Hydrograph Summary Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® 2019 by Autodesk, Inc. v2020

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	5.339	1	740	33,932	------	------	------	1 (commercial, pre-settle)
2	SCS Runoff	4.659	1	738	27,921	------	------	------	2 (commercial, pre-settle)
3	SCS Runoff	6.678	1	744	46,272	------	------	------	3 (multifamily, pre-settle)
4	SCS Runoff	9.604	1	750	77,119	------	------	------	4 (single family, pre-settle)
5	SCS Runoff	8.051	1	748	61,944	------	------	------	5 (single family, pre-settle)
7	Combine	33.30	1	747	247,189	1, 2, 3, 4, 5,	------	------	Pre-settle
9	SCS Runoff	28.11	1	725	87,939	------	------	------	1 (commercial, eg)
10	SCS Runoff	24.00	1	724	71,132	------	------	------	2 (commercial, eg
11	SCS Runoff	36.76	1	726	121,069	------	------	------	3 (multifamily, eg)
12	SCS Runoff	53.89	1	729	201,422	------	------	------	4 (single family, eg)
13	SCS Runoff	44.78	1	728	159,888	------	------	------	5 (single family, eg)
15	Combine	183.58	1	727	641,449	9, 10, 11, 12, 13,	------	------	existing (row crop ag)
17	SCS Runoff	59.83	1	718	136,074	------	------	------	1 (commercial, prop)
18	SCS Runoff	48.95	1	718	111,334	------	------	------	2 (commercial, prop)
19	SCS Runoff	58.87	1	721	150,567	------	------	------	3 (multifamily, prop)
20	SCS Runoff	54.21	1	726	179,998	------	------	------	4 (single family, prop)
21	SCS Runoff	45.27	1	725	142,627	------	------	------	5 (single family, prop)
23	Combine	239.38	1	720	720,598	17, 18, 19, 20, 21,	------	------	proposed conditions

Estimate_Storage.gpw	Return Period: 10 Year	Monday, 07 / 29 / 2019

Figure 9.03-2-8: An example of summary pages generated by a stormwater modeling software program.

Source: Hydraflow Hydrographs Extension

9.03-3 DOCUMENTATION FOR REVIEW

The basis of design for a given stormwater detention BMP should be included in a Stormwater Management Plan (SWMP) prepared for local jurisdictional review (and other agencies with project interest). The following information should be highlighted within the narrative section of that report, and details incorporated into its appendices. **ESSENTIAL**

1. **Subwatershed properties (or Land Use Calculations)** in tabular form identifying the soil type, impervious cover and land uses in each subwatershed area (for both existing and post-developed conditions). This should include properties for off-site, upstream watershed areas (SWMP, Appendix A).

2. **Details of calculation of curve numbers (or other rainfall loss parameters)** as the basis of their selection consistent with preferred design assumptions listed within Section 2.05. Include software input/output, spreadsheets or other calculations used in an appendix to the Stormwater Management Plan (SWMP, Appendix A).

3. **Details of calculations of time of concentration,** consistent with preferred design assumptions. Include software input/output, spreadsheets or other calculations used for Tc in an appendix to the Stormwater Management Plan (SWMP, Appendix A or C).

4. **Include calculations of Recharge Volume (Rev) and Water Quality Volume (WQv)** as applicable (SWMP, Appendix B).

5. **Rainfall depths for reviewed storms** (WQv, 1-, 5-, 10-, 25-, 50- and 100-year events) consistent with prescribed values for the site location. Use values for the appropriate region of the state as listed within Section 2.02. Models for 24-hour storms should indicate that a Type-II rainfall distribution was used (SWMP, Appendix C).

6. Provide **documentation of model inputs and outputs** (SWMP, Appendix C). This should include the following information, for natural, existing and post-developed conditions:

   a. **A summary of volumes and peak rates of flow for all events** listed in item #5 above. These summaries should include this information for each watershed area that feeds into the detention area(s) and the routing output of flows leaving each basin.

   b. **Watershed model input** documenting the following for each subwatershed area for each condition:

      i. Watershed area (in acres)

      ii. Curve number

      iii. Time of concentration (in minutes)

   c. Graphical versions of **the inflow hydrographs for the 1–, 5–, 10– and 100–year storm event should be provided. For other events modeled, a tabular summary of volumes and peak flow rates listed in item #6a above is sufficient detail for review.**

NOTE

What is included with the SWMP should demonstrate the "chain of information" for model inputs and outputs that shows that confirms the assumed watershed properties were input into the model and that the actual output from the model matches the values reported in the SWMP.

d. For each detention practice, document **stormwater detention area properties,** including the following:

    i. **BMP characteristics (pond, wetland, basin, etc.):**

        01. **Stage–storage volume relationship** of the BMP area. No less than 1-foot intervals. More frequent intervals may be required for some BMP types (refer to applicable ISWMM section).

        02. **Stage–discharge relationship of BMP outlet.** Calculations should identify all stages of outflow design (riser pipe, orifice, weir, discharge pipe, overflow spillway, etc.) and include characteristics of each (elevation, size, etc.) that match plan dimensions.

          • Calculations should include either detailed calculations of flow through each outlet stage, or graphical representation of stage-discharge relationship from calculation output from the software package used.

          • The calculations should note whether the flow from a given stage is routed through the primary spillway (multi-stage) or a secondary overflow.

        03. **Weir and/or orifice coefficients** that account for energy loss (resistance to flow).

        04. Include information related to sub-items 01 though 03 above for assumptions about existing stormwater management facilities that are expected to have flow passing through the proposed site or practice(s).

        05. If performing routing calculations manually or via spreadsheet tools, refer to Section 9.04. Methods, assumptions and calculations used in routing should be consistent with these sections, except as amended by local jurisdictions.

    ii. **Target allowable peak discharge** from the reservoir (for each event to be considered).

    iii. Routing output results:

        01. **Outflow hydrograph** from routing output identifying flow rate (in cfs) versus time, the peak flow rate, time of occurrence of peak flow in relation to the rainfall event. For analyses involving the 1-, 10- and 100-year events identified in this report, provide a numeric or graphic representation of the entire outlet hydrograph through the duration of the storm event.

        02. **A graph of storage volume or elevation versus time** for the 1-, 10- and 100-year {design} events. Review drawdown for extended detention of small storms (minimum 24-hour drawdown after storm event, maximum 72-hour drawdown).

        03. **Identify maximum storage volume and water surface elevation** for each event reviewed.

        04. For each event, calculate the **maximum storage volume in watershed–inches** (equivalent depth of water over the area served by the basin) and as a **percentage of total runoff** (maximum storage volume divided by total runoff volume).

Equation 9.03-3-1

$$\text{Max Storage Volume (watershed-inches)} = \frac{\text{High Water Storage Volume (CF)}}{\text{Watershed Area (AC) x 43,560 (SF/AC)}} \times \frac{\text{12 inches}}{\text{1 foot}}$$

7.   **Drainage maps identifying watershed (and subwatersheds) areas.** Flow paths and land uses for both **natural**, existing and post-development conditions should be identified. Clearly identify drainage boundaries, areas and flowpaths on the drainage maps. Label subwatershed areas clearly with numbers or letters that correspond to identification of subareas. This naming system should be reflected in other calculations and data so that the design assumptions are easily reviewed (SWMP, Appendix E).

8.   **Soil maps or geotechnical reports** supporting selection of hydrologic soil group (HSG) categories (A through D). The NRCS Web Soil Survey website is the preferred source for initial soil information. This site starts by site selection at the state and county level, then allows you to focus down to an individual site area. The specific site boundary can be selected, allowing the user to navigate through a variety of soils information.

The soil map data is based on general assumptions of soil properties based on local observations. If soil borings are completed during the design process, the geotechnical report should be used to address whether the soil types listed on the Web Soil Survey site are accurate for a given site. This information should be used to adjust the HSG groups used for final design, as appropriate. In addition, geotechnical reports may be needed to support design of pond liner elements.

9.   For models with multiple subareas, where hydrographs are to be combined with or routed through downstream areas or basins, **provide a flow chart, schematic plan or map that identifies how separate hydrographs have been routed or combined**. This will help clarify how models were built to route flows from various areas through proposed management practices.

NOTE

Older county soil maps and other sources of information may not be updated as frequently as the NRCS Web Soil Survey website:

websoilsurvey.nrcs.usda.gov

Where soils are listed as "urban" assume:

HSG B soil for natural
HSG D soil for developed
—OR—
Conduct geotechnical explorations to classify soil types based on soil samples collected from the site.