As rural areas become urbanized, the resulting increases in peak discharges can adversely affect downstream flood plains. Increasingly, planners, developers, and the public want these downstream areas to be protected. Many local governments are adopting ordinances to control the type of development and its allowable impacts on the watershed. One of the most common controls requires that postdevelopment discharges do not exceed present-condition discharges for one or more storm frequencies at specified points along a channel.

This chapter discusses ways to manage peak discharges by delaying runoff. It also presents a procedure for estimating the storage capacity required to maintain the peaks within a specified level.

Efforts to reduce the effects of increased runoff from urban areas have been innovative and diverse. Many methods have been used effectively, such as infiltration trenches, porous pavement, rooftop storage, and cisterns. But these solutions can be expensive or require site conditions that cannot be provided.

The detention basin is the most widely used measure for controlling peak discharge. It is generally the least expensive and most reliable of the measures that have been considered. It can be designed to fit a wide variety of sites and can accommodate multiple-outlet spillways to meet requirements for multifrequency control of outflow. Measures other than a detention basin may be preferred in some locations; their omission here is not intended to discourage their use. Any device selected, however, should be assessed as to its function, maintenance needs, and impart.

Estimating the effect of storage

When a detention basin is installed, hydrologic routing procedures can be used to estimate the effect on hydrographs. Both the TR-20 (SCS 1983) and DAMS2 (SCS 1982) computer programs provide accurate methods of analysis. Programmable calculator and computer programs are available for routing hydrographs through dams.

This chapter contains a manual method for quick estimates if the effects of temporary detention on peak discharges. The method is based on average storage and routing effects for many structures.

Figure 6-1 relates two ratios: peak outflow to peak inflow discharge \(q_o/q_i\) and storage volume runoff volume \(V_s/V_r\) for all rainfall distributions.

The relationships in figure 6-1 were determined on the basis of single stage outflow devices. Some were controlled by pipe flow, others by weir flow. Verification runs were made using multiple stage outflow devices, and the variance was similar to that in the base data. The method can therefore be used for both single- and multiple-stage outflow devices. The only constraints are that (1) each stage requires a design storm and a computation of the storage required for it and (2) the discharge if the upper stage(s) includes the discharge of the lower stage(s).

The brevity of the procedure allows the planner to examine many combinations of detention basins. When combined with the Tabular Hydrograph method, the procedure’s usefulness is increased. Its principal use is to develop preliminary indications of storage adequacy and to allocate control to a group of detention basins. It is also adequate, however, for final design of small detention basins.
Input requirements and procedures

Use figure 6-1 estimate storage volume ($V_s$) required or peak outflow discharge ($q_o$). The most frequent application is to estimate $V_s$, for which the required inputs are runoff volume ($V_r$), $q_o$, and peak inflow discharge ($q_i$). To estimate $q_o$, the required inputs are $V_r$, $V_s$, and $q_i$.

Estimating $V_s$

Use worksheet 6a to estimate $V_s$, storage volume required, by the following procedure.

1. Determine $q_o$. Many factors may dictate the selection of peak outflow discharge. The most common is to limit downstream discharges to a desired level, such as predevelopment discharge. Another factor may be that the outflow device has already been selected.

2. Estimate $q_i$ by procedures in chapters 4 or 5. Do not use peak discharges developed by other procedure. When using the Tabular Hydrograph method to estimate $q_i$ for a subarea, only use peak discharge associated with $T_t = 0$.

Figure 6-1  Approximate detention basin routing for rainfall types I, IA, II, and III
3. Compute \( q_o/q_i \) and determine \( V_s/V_r \) from figure 6-1.

4. \( Q \) (in inches) was determined when computing \( q_i \) in step 2, but now it must be converted to the units in which \( V_s \) is to be expressed—most likely, acre-feet or cubic feet. The most common conversion of \( Q \) to \( V_r \) is expressed in acre-feet:

\[
V_r = 53.33Q(A_m) \quad \text{[eq. 6-1]}
\]

where
- \( V_r \) = runoff volume (acre-ft)
- \( Q \) = runoff (in)
- \( A_m \) = drainage area (mi\(^2\)), and
- 53.33 = conversion factor from in-mi\(^2\) to acre-ft.

5. Use the results of steps 3 to 4 to compute \( V_s \):

\[
V_s = V_r \left( \frac{V_s}{V_i} \right) \quad \text{[eq. 6-2]}
\]

where
- \( V_s \) = storage volume required (acre-ft).

6. The stage in the detention basin corresponding to \( V_s \) must be equal to the stage used to generate \( q_o \). In most situations a minor modification of the outflow device can be made. If the device has been preselected, repeat the calculations with a modified \( q_o \) value.

### Estimating \( q_o \)

Use worksheet 6b to estimate \( q_o \), required peak outflow discharge, by the following procedure.

1. Determine \( V_s \). If the maximum stage in the detention basin is constrained, set \( V_s \) by the maximum permissible stage.

2. Compute \( Q \) (in inches) by the procedures in chapter 2, and convert it to the same units as \( V_s \) (see step 4 in “estimating \( V_s \”).

3. Compute \( V_s/V_r \) and determine \( q_o/q_i \) from figure 6-1.

4. Estimate \( q_i \) by the procedures in chapters 4 or 5. Do not use discharges developed by any other method. When using Tabular method to estimate \( q_i \) for a subarea, use only the peak discharge associated with \( T_t = 0 \).

5. From steps 3 to 4, compute \( q_o \):

\[
q_o = q_i \left( \frac{q_o}{q_i} \right) \quad \text{[eq. 6-3]}
\]

6. Proportion the outflow device so that the stage at \( q_o \) is equal to the stage corresponding to \( V_s \). If \( q_o \) cannot be calibrated except in discrete steps (i.e., pipe sizes), repeat the procedure until the stages for \( q_o \) and \( V_s \) are approximately equal.

### Limitations

- This routing method is less accurate as the \( q_o/q_i \) ratio approaches the limits shown in figure 6-1. The curves in figure 6-1 depend on the relationship between available storage, outflow device, inflow volume, and shape of the inflow hydrograph. When storage volume \( (V_s) \) required is small, the shape of the outflow hydrograph is sensitive to the rate of the inflow hydrograph. Conversely, when \( V_s \) is large, the inflow hydrograph shape has little effect on the outflow hydrograph. In such instances, the outflow hydrograph is controlled by the hydraulics of the outflow device and the procedure therefore yields consistent results. When the peak outflow discharge \( (q_o) \) approaches the peak flow discharge \( (q_i) \) parameters that affect the rate of rise of a hydrograph, such as rainfall volume, curve number, and time of concentration, become especially significant.

- The procedure should not be used to perform final design if an error in storage of 25 percent cannot be tolerated. Figure 6-1 is biased to prevent undersizing of outflow devices, but it may significantly overestimate the required storage capacity. More detailed hydrograph development and routing will often pay for itself through reduced construction costs.
Examples

Four examples illustrate the use of figure 6-1. Examples 6-1 through 6-4, respectively, show estimation of $V_s$ of a two-stage structure, estimation of $q_o$, and use the Tabular Hydrograph method.

**Example 6-1: Estimating $V_s$, single-stage structure**

A development is being planned in a 75-acre (0.1170 mi$^2$) watershed that outlets into an existing concrete-lined channel designed for present conditions. If the channel capacity is exceeded, damages will be substantial. The watershed is in the type II storm distribution region. The present channel capacity, 180 cfs, was established by computing discharge for the 25-year-frequency storm by the Graphical Peak Discharge method (chapter 4).

The developed-condition peak discharge ($q_i$) computed by the same method is 360 cfs, and runoff ($Q$) is 3.4 inches. Since outflow must be held to 180 cfs, a detention basin having that maximum outflow discharge ($q_o$) will be built at the watershed outlet.

How much storage ($V_s$) will be required to meet the maximum outflow discharge ($q_o$) of 180 cfs, and what will be the approximate dimensions of a rectangular weir outflow structure? Figure 6-2 shows how worksheet 6a is used to estimate required storage ($V_s = 5.9$ acre-ft) and maximum stage ($E_{max} = 105.7$ ft).

The rectangular weir equation is

$$q_o = 3.2L_w H_w^{1.5}$$  \[eq. 6-4\]

where

$q_o = \text{peak outflow discharge (cfs)}$
$L_w = \text{weir crest length (ft)}$
$H_w = \text{head over weir crest (ft)}$

$H_w$ and $q_o$ are computed as follows:

$$H_w = E_{max} - \text{weir crest elevation}$$

$$= 105.7 - 100.0 = 5.7 \text{ ft}.$$

Since $q_o$ is known to be 180 cfs, solving equation 6-4 for $L_w$ yields

$$L_w = \frac{q_o}{3.2H_w^{1.5}}$$

$$= \frac{180}{3.2(5.7)^{1.5}}$$

$$= 4.1 \text{ ft}$$

In summary, the outlet structure is a rectangular weir with crest length of 4.1 ft, $H_w = 5.7$ ft, and $q_o = 180$ cfs corresponding to a $V_s = 5.9$ acre-ft.