General Information for Detention Practices

A. Introduction

Storm runoff detention is considered a viable method to reduce runoff impacts. Temporarily detaining a specified volume of runoff can significantly reduce downstream flooding, as well as pipe and channel requirements in urban areas. The main purpose of a detention facility is to store the excess storm runoff associated with increased basin imperviousness and discharge this excess at a rate similar to the rate experienced from the basin without development.

1. Excess storm runoff will be judged in comparison to the site in its pre-developed condition and should include all increases in stormwater resulting from any of the following:

    a. An increase in the impervious surface of the site, including all additions of buildings, roads and parking lots.

    b. Changes in soil absorption caused by compaction during development.

    c. Modifications in contours, including the filling or draining of small depressional areas, alterations of drainageways, or regrading of slopes.

    d. Site clearing.

    e. Alteration of drainageways or installation of collection systems to intercept street flows or to replace swales or other drainageways.

    f. Alteration of subsurface flows, including any groundwater dewatering or diversion practices such as curtain drains.

    g. Any increase in runoff that occurs by piping building downspouts that previously discharged to splash blocks.

2. Pre-developed condition means those hydraulic and hydrologic site characteristics existing prior to the development being proposed and includes all the natural storage areas and drainageways plus existing farm drainage tiles and highway drainage structures. The Jurisdictional Engineer may require the pre-developed condition to be considered in a natural state (without any man-made development) if drainage problems are occurring down stream due to existing development at the proposed site or in the basin.

3. Developed condition means those hydraulic and hydrologic site characteristics that occur following the completion of the proposed development that may result in excess runoff.

4. Post-developed peak runoff is expected to exceed pre-developed runoff from a similar storm event. Even if calculated time of concentration or curve number tables suggest lower post-developed runoff, developed sites generally have more impervious areas, compacted soils, change in soil horizon, and differing vegetation from undeveloped conditions. There may be exceptions, but careful consideration of the hydrologic method and sufficient engineering judgment are necessary to ensure calculated results meet reasonable expectations.

B. Storm Detention Regulations

The developer, subdivider, or applicant should construct stormwater detention facilities designed by a Professional Engineer licensed in the State of Iowa that meets the criteria of this section. Storm basins will follow Iowa Department of Natural Resources Rules and Regulations as described in the Iowa Administrative Code, Title V, Chapter 70.

1. Conditions that Require an Iowa DNR Permit:

a. Dams: Approval by the department for construction, operation, or maintenance of a dam in the floodway or floodplain of any water source will be required when the dimensions and effects of such dams exceed the thresholds established by this rule:

1) Any dam designed to provide a sum of permanent and temporary storage exceeding 50 acre-feet at the top of dam elevation, or 25 acre-feet if the dam does not have an emergency spillway, and which has height of 5 feet or more.
2) Any dam designed to provide permanent storage in excess of 18 acre-feet and has a height of 5 feet or more.
3) Any dam across a stream draining more than 10 square miles (rural only).
4) Any dam located within one mile of an incorporated municipality, if the dam has a height of 10 feet or more, stores 10 acre-feet or more at the top of the dam elevation, and is situated such that the discharge from the dam will flow through the incorporated areas.

b. Low Head Dams: Any low head dam on a stream draining two or more square miles in an urban area, or 10 or more square miles in a rural area.

c. Levees or Dikes: Approval by the department for construction, operation, and maintenance of levees or dikes will be required in the following instances:

1) Rural Areas: In rural areas, any levees or dikes located on the floodplain or floodway of any stream or river draining more than 10 square miles.
2) Urban Areas: In urban areas, any levee or dike along any river or stream draining more than two square miles.

2. Design Storm: The design storm is the rainfall event having a return frequency of 100 years, unless higher frequencies are required by the Department of Natural Resources or the Jurisdiction. Design storm duration is that critical duration of rainfall requiring the greatest detention volume, or, based on the nature of the watershed, the critical duration would be the storm that causes the greatest downstream impact.

3. Release Requirements:

a. Release Rate: In an effort to mimic the pre-developed hydrology of a drainage area, maximum post-development release rates have been established based upon pre-developed conditions. These restrictions aid in the reduction of down-stream flooding and reduce the cost of downstream storm conveyance infrastructure.

1) **General:** The major storm drainage system should be designed to reduce the risk of substantial damage to the primary structure from storm runoff expected from the major storm. The effects of the major storm on the minor drainage system should be noted.
   2) **2 Year Pre-developed:** After development, the release rate of runoff for rainfall events having an expected return frequency of two years should not exceed the existing, pre-developed peak runoff rate from that same storm.
   3) **5 Year Pre-developed:** For rainfall events having an expected return frequency of 5, 10, 25, 50, and 100 years, the rate of runoff from the developed site should not exceed the existing, pre-developed peak runoff from a 5 year frequency storm of the same duration. Allowable discharge rate may be restricted due to downstream capacity.
   4) **Upstream Pass-through:** Detention of runoff generated by upstream land is not required on the new development site. Release of runoff generated off-site and routed through the detention basin should not be made in such a manner as to increase the combined off-site and on-site release rate.
   5) **Staged Discharge:** Because the allowable release rate varies depending on the storm frequency, multiple outlets or a multi-stage control structure may be necessary to comply with these requirements. This is especially true for sites with off-site pass-through as demonstrated in the following example.

b. Release Rate Example:

1) A 10 acre site has a critical storm duration of 6 hours after development.
2) The peak rate of runoff generated by the site for the pre-developed 2 year, 6 hour storm is 8.5 cfs.
3) The peak rate of runoff generated by the site for the pre-developed 5 year, 6 hour storm is 12 cfs.
4) The site receives off-site runoff from a 5 acre upstream area. The off-site area has the following runoff properties:

Allowable Runoff, cfs	**Return Period**					
	2 yr	***5 yr***	***10 yr***	***25 yr***	***50 yr***	***100 yr***
Offsite runoff	4.25	6	7	8.5	9.5	11

5) Taking into consideration the offsite contributing area, the maximum release rate for a given storm event is summarized in the following table:

Allowable Runoff, cfs	**Return Period**					
	2 yr	***5 yr***	***10 yr***	***25 yr***	***50 yr***	***100 yr***
Release for on-site runoff	8.5	12	12	12	12	12
Off-site “pass through”	4.25	6	7	8.5	9.5	11
Allowable release rate	12.75	18	19	20.5	21.5	23

4. Detention Volume Methods:

a. Two methods for watershed routing are allowed. The modified rational method may be used for areas up to 5 acres. For larger areas, the Storage Indication or modified Puls method should be utilized. This is the method utilized by WinTR-55 and other hydrology software. These methods are described in the following sections.

The use of other technically proven methods for similar drainage areas needs approval by the Jurisdictional Engineer. For larger drainage areas, the Project Engineer should understand the details of a computerized hydrology program before selection of the program.

b. The Project Engineer will submit the stormwater detention proposal according to the drainage report as described in Section 2A-4. Also required is certification by a licensed Professional Engineer that the stormwater detention facilities design and calculations were performed by the engineer, or under the engineer's supervision, and that the facilities and design meet the criteria of this section.

C. Limitation of Stormwater Runoff

1. No development should cause downstream property owners, water courses, channels, or conduits to receive stormwater runoff from the proposed development site at a higher peak flow rate, or at higher velocities than would have resulted from the same storm event occurring over the site of the proposed development with the land in its natural, pre-developed condition.

2. The Project Engineer can submit to the Jurisdictional Engineer the following factors for consideration in changing storm detention requirements as a condition for approval of development:

   a. Specific elements of the drainage report as outlined in Section 2A-4 and items listed in Section 2G-1, A, 1.

   b. Historical or potential localized drainage or flood problems adjacent to the site.

   c. Historical or potential area wide drainage or flooding problems in the watershed.

   d. Location of the site relative to existing drainageways and/or stormwater conveyances.

   e. Extent of proposed site increase in impervious surface area.

   f. Anticipated future development of the drainage basin.

   g. Existing site features which may facilitate or impede detention design and/or construction.

3. Multiple and contiguous tracts of land of which only part will be initially developed but are contained in the same basin are described below under two conditions:

   a. One Owner: The basin will be considered for stormwater detention for the entire tract. The results of the study, including staged construction of stormwater facilities, will be contained in the drainage report as outlined in Section 2A-4. As a minimum, the developed tract will require detention.

   b. Multiple Owners: Many times, upstream undeveloped discharges occur through the proposed developed property, which cannot be avoided. Possible options for stormwater detention design in a basin with tracts having multiple owners are:
   1) Isolation Detention:
      a) Isolate the proposed development portion from the rest of the basin. Construct a detention control structure on the downstream side of a developed area and outside of a mainline channel where there is no pass-through from upstream undeveloped property. This allows the detention basin to serve only the developed area.
      b) Isolate the stormwater to be bypassed from the developed area by a split-flow structure upstream of the proposed detention basin.

2) **Main Channel Detention:** Care should be exercised in not placing a control structure in a mainline channel unless it is designed for development to occur in a progressive manner. The designer needs to simulate the detention and corresponding release rate for only the developed area. A control structure that handles both flows (to be detained and pass through) has to be designed to retain the difference between the pre-developed and post-developed runoff rate from the developed area only and bypass the remaining upstream discharge. This can result in a complicated outlet control structure and routing system that has to split the flows within the detention basin.
3) **Regional Detention:** Develop a regional detention system within the watershed that handles logical segments of the watershed or the entire watershed.

D. Detention Basin Design Methods

A detention basin is to be designed to reduce the peak inflow by temporarily storing the excess stormwater and then releasing the water volume at allowable rates over an extended period. The main objective of this section is to outline the design procedure in order to determine the detention basin storage volume required. The design of a stormwater detention basin requires both hydrologic and hydraulic information. The basic hydrologic data includes the inflow hydrograph and the allowable release. In order to determine the volume required, the inflow hydrograph needs to be developed first. The hydraulic information of a basin requires prior knowledge of the basin geometry and outlet structures. Two common methods for determining the detention basin size are the Modified Rational Method and the TR-55 Method.

1. Modified Rational Method:

a. Theory: The simplest but least accurate detention routing method is the Modified Rational Method. The Modified Rational method uses the peak flow calculating capability of the Rational method, paired with assumptions about the inflow and outflow hydrographs to compute and approximation of storage volumes for simple detention calculations.

To find the required volume, the Modified Rational Method uses a trial method to find the critical storage for a given drainage area. The basic approach assumes the stormwater runoff hydrograph (detention basin inflow hydrograph) for the design storm is trapezoidal in shape. The peak runoff rate is calculated using the Rational formula:

$$q_{pi} = CiA$$ **Equation 2G-1.01**

where:

q_{pi} = peak runoff from site (peak inflow into detention basin)
C = runoff coefficient
i = rainfall intensity, in/hr
A = drainage area, ac

Note: Refer to Section 2B-4 for additional information on the use of the Rational method.

It is assumed the peak of the outflow hydrograph falls on the recession limb of the inflow hydrograph and the rising limb of the outflow hydrograph can be approximated by a straight line. The storage volume is determined by the critical (inflow) duration, and using a constant outfall release rate. With these assumptions:

$$S_d = q_{pi}t_d - \frac{Q_a(t_d + T_c)}{2}$$ **Equation 2G-1.02**

where:

S_d = detention volume required, ft^3
Q_a = allowable peak outflow rate, cfs
t_d = design storm duration, sec
T_c = time of concentration for the watershed, sec

The design storm duration is the duration that maximizes the detention storage volume, S_d, for a given return period. The storm duration can be found by trial and error using rainfall data from Section 2B-2. This is normally an iterative process done by hand or with a spreadsheet. Downstream analysis is not possible with this method, as only approximate graphical routing takes place.

b. Limitations: Use of the Modified Rational method has limitations. This method makes several assumptions including a constant rainfall over the watershed and a maximum release rate that is constant over the storm duration. Because of these assumptions the Modified Rational method does not produce a true inflow or outflow hydrograph, merely approximations of such. In addition, the Modified Rational method cannot easily account for off-site pass through from upstream drainage areas. For these reasons, the use of the Modified Rational method is limited to sites of 5 acres or less with no off-site pass through.

c. Design Example: Development of a 4.0 acre undeveloped site into an industrial complex is proposed. A detention basin will be used to limit the post-development peak discharge to the Q_5 pre-developed rate. The inflow hydrographs are developed using varying durations multiplied by the discharges for each Q_{100}. The outflow hydrograph for each duration, multiplied by the constant Q_5, is subtracted from the inflow hydrograph. The highest remaining storage volume is selected as the final basin volume.

There are three steps in the Modified Rational Method as follows:

1) **Step 1:** The first step is to collect the physical data for the drainage area. This is the drainage area, the time of concentration, the runoff coefficient, pre-developed peak discharge, etc.
   - Existing 4.0 acre undeveloped site
   - Soil Group D
   - C = 0.22 for Q_5 pre-developed condition
   - C = 0.9 for post-developed (industrial)
   - T_c = 15 min.
   - Q_a = 10.0 cfs (pre-developed Q_5 = 0.22x3.8x4.0 = 3.3 cfs)
2) **Step 2:** The second step is to establish the peak runoff rate from the developed site for various intensity-duration relationships at the design frequency (Q_{100}), beginning with the time of concentration and continuing with other increased storm durations.

Table 2G-1.01: Peak Basin Inflow for Various Durations

Duration (hour)	**C_{100}**	**Intensity (inches/hour)**	**Area (acres)**	**Inflow, q_{pi} (cfs)**
0.25	0.9	7.48	4.0	26.9
0.50	0.9	5.12	4.0	18.4
1.00	0.9	3.25	4.0	11.7
2.00	0.9	2.01	4.0	7.2
3.00	0.9	1.48	4.0	5.3
6.00	0.9	0.87	4.0	3.1

3) **Step 3:** The third step is to calculate the release volume and required storage until the maximum or critical storage is found. The allowable release rate for this detention basin needs to remain below 10 cfs as determined in Step 1 above. Table 2G-1.02 below outlines the process of calculating the required storage for each storm duration.

Table 2G-1.02: Storage Duration Values

(1) **Duration (hour)**	(2) **Q_{100} Intensity (inches/hour)**	(3) **Q_{100} Inflow (cfs)**	(4) **Q_{100} Volume (cubic feet)**	(5) **Release Vol. Q_5 (cubic feet)**	(6) **Storage (cubic feet)**
0.25	7.48	26.9	24,200	3,000	21,200
0.50	5.12	18.4	33,100	5,900	27,200
1.00	3.25	11.7	42,100	11,900	30,200
2.00	2.01	7.2	51,800	23,800	28,000
3.00	1.48	5.3	57,200	35,600	21,600
6.00	0.87	3.1	67,000	71,300	0

Column (3) Peak Flow = Q = CIA (take from Table 2G-1.01 above)
Example: 0.9 x 7.48 x 4.0 = 26.9 cfs
Column (4) Runoff Volume = Q (Col 3) x Duration of Storm (Col 1) x 3600
Example: 26.9 cfs x 0.25 hrs x 3600 s/hr = 24,200 cu. ft.
Column (5) Release Volume = 3.3 cfs x Duration of Storm (Col 1) x 3600
Example: 3.3 x 0.25 x 3600 s/hr = 3,000 cu. ft.
Column (6) Required Storage = Runoff Volume (Col 4) – Release Volume (Col 5)
Example: 24,200 – 3,000 = 21,200 cu. ft.

As Table 2G-1.02 shows, the critical duration is one hour, since it produces the largest detention volume of 30,200 cubic feet. Therefore, the detention basin needs to be designed to accommodate the 30,200 cubic feet of storage with at least a 1 foot freeboard for the detention dike. The basin emergency spillway release rate should be determined based on the onsite discharge greater than the 100 year post-developed peak discharge.

A second analysis must still be completed for the 2 year pre/post developed condition. When storage volumes are known for the 2 year and 100 year storms, a suitable outlet control structure can be designed.

2. **Flood Routing:** The most commonly used method for calculating detention basin volume is to route an inflow hydrograph through a detention pond utilizing the Storage Indication or modified Puls method. This method compares the difference in the average values of two closely spaced inflows and outflows, yielding the change in storage over a given time period. By continuing this process for the duration of the storm and beyond, the total required storage for the basin can be determined.

This is the methodology utilized by WinTR-55 and other hydrology software and can also be completed through the use of a spreadsheet. A detailed description of the manual process for routing a storm through a detention basin is presented in Chapter 8 of FHWA's HEC-22.

E. Estimating Storage Volume

TR-55 indicates that the method presented should not be used for final design. The final design should be verified by routing the inflow hydrograph and determining if the proposed volume is adequate

The volume of the basin is determined by developing a hydrograph and routing the design storm through the basin. If the design storm can be routed through the basin without overtopping or exceeding the freeboard requirements, the basin volume is adequate. If the routing procedure indicates the storage elevation of the basin exceeds the freeboard requirements or overtops the basin, additional volume in the basin is required.

The final design of a detention facility requires three items:
- an inflow hydrograph
- a stage vs. storage curve
- a stage vs. discharge curve

1. To check the capacity of a basin with a known volume, use the methods described in the previous sections.

    a. Develop an inflow hydrograph for the storm in question.

    b. Develop the stage-storage and stage-discharge curves for the basin.

    c. Route the storm through the basin to determine the outflow hydrograph. Check the peak of the outflow hydrograph to ensure that it does not exceed the allowable value. Also, check the peak storage volume to ensure that it does not exceed the capacity of the basin.

2. Analyzing a known basin utilizing the methods developed in the previous sections is relatively straightforward. However, determining the required size of a proposed basin is an iterative process, and can be quite time consuming without a method to develop a preliminary volume estimate. Fortunately, TR-55 provides a method for determining quick estimates of detention basin volumes.

    a. Figure 2G-1.01 relates two ratios: peak outflow to peak inflow (q_o/q_i) and storage volume to runoff volume (V_s/V_r). The value for q_i is determined by the peak of the inflow hydrograph. The value for q_o is normally dictated by the allowable release rate. The volume of runoff can be calculated by the Rational method or tabular hydrograph method.

       The relationships in Figure 2G-1.01 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.

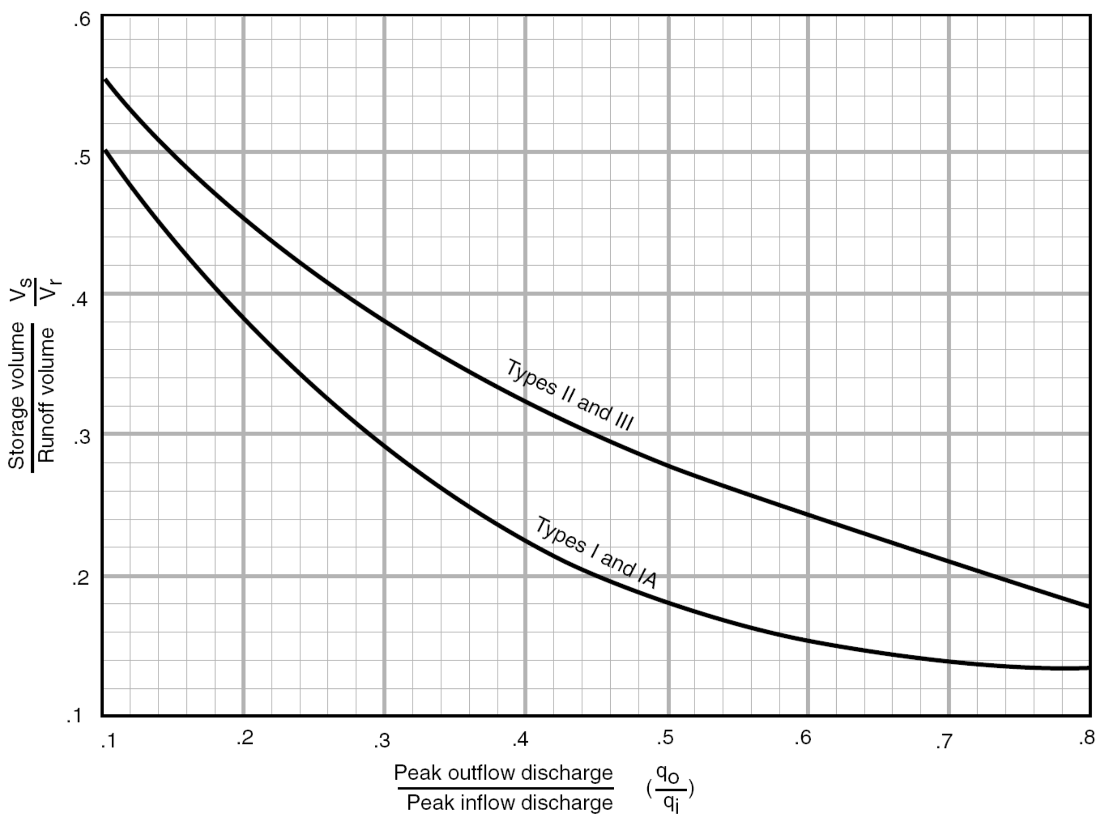
    b. The method can therefore be used for both single- and multiple-stage outflow devices. The only constraints are that:
       1) Each stage requires a design storm and a computation of the storage required for it.
       2) The discharge of the upper stage(s) includes the discharge of the lower stage(s).

c. The brevity of the procedure allows the designer 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.

This estimating technique becomes less accurate as the q_o/q_I ratio approaches the limits shown in Figure 2G-1.01. The curves in Figure 2G-1.01 depend on the relationship among available storage, outflow device, inflow volume, and shape of the inflow hydrograph. When the 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 inflow (q_i), the 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% cannot be tolerated. Figure 2G-1.01 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.

Figure 2G-1.01: Approximate Detention Basin Routing for All Rainfall Types



Source: FHWA, HEC-22

d. The purpose of Figure 2G-1.01 is to provide a starting point for the size of the basin. The process may have to be repeated several times to achieve a basin that has sufficient volume and meets specific inlet and outlet controls.

F. Detention Facilities Requirements

1. Earthen Detention:

a. Slopes on embankments should be at least 4:1 or flatter and should have appropriate temporary and permanent erosion control stabilization.

b. Detention bottom cross-slopes to the main detention swale or channel will be 2% minimum. Concrete paved swale or channel bottom (cunette) and subsurface drains is required for slopes less than 1.5%. The Jurisdictional Engineer may require a pilot channel in the detention basin bottom.

c. The embankment top should be at least 6 feet wide.

d. Freeboard should be a minimum of 1 foot above the controlled emergency spillway discharge. If there is not room for an emergency spillway, the minimum freeboard above the 100 year surface elevation of the structure should be increased to 2 feet.

e. The embankment should be protected from catastrophic failure due to overtopping following Iowa DNR requirements where applicable. Overtopping can occur when the pond outlets become obstructed or when a larger than 100 year storm occurs. Failure protection for the embankment may be provided in the form of a buried, heavy rip rap layer on the entire downstream face of the embankment or a separate emergency spillway having a minimum capacity of twice the maximum developed inflow rate for the 100 year storm. The spillway is also needed to control the release point of the overflows. Structures should not be permitted in the path of the emergency spillway or overflow, and easements should be considered. The flowline of the emergency spillway should be set equal to or above the 100 year water surface elevation. Stormwater easements need to be considered downstream of the emergency spillway.

2. Parking Lot Storage:

a. Paved parking lots may be designed to provide temporary detention storage of stormwater on a portion of their surfaces not to exceed 25%.

b. Outlets should be designed to empty the stored waters slowly, and depths of storage must be limited to 9 inches so as to prevent damage to parked vehicles. The minimum pipe size for the outlet is 12 inches in diameter where a drop inlet is used to discharge to a storm sewer or drainageway.

   Where a weir and a small diameter outlet through a curb are used, the size and shape are dependent on the discharge/storage requirements. A minimum pipe size of 6 inches in diameter is recommended.

c. To assure that the detention facility performs as designed, maintenance access should be provided. The outlet should be designed to minimize unauthorized modifications that affect function. Any repaving of the parking lot will be evaluated for impact on volume and release rates and are subject to approval.

d. Storage areas should be posted with warning signs.

3. **Multipurpose Basins:** Dry bottom basins may be designed to serve secondary purposes for recreation, open space, or other types of use which will not be adversely affected by occasional or intermittent flooding.

4. **Maintenance:** The owner of the detention basin may be the developer, homeowner, homeowner's association, or Jurisdiction. The method of ownership and maintenance responsibility of the detention basin including easements, should be defined in the Jurisdiction's ordinance or in a developer's agreement with the Jurisdiction.

   Maintenance of the detention area must be performed on a regular basis to ensure the basin will operate as designed when needed. Maintenance should include:
   - Mowing to control trees and weeds. No trees should be permitted in the impoundment dam.
   - Checking for the integrity of the dam, including repair of varmint holes, and low places in the dam other than the emergency spillway.
   - Ensuring the emergency spillway is operating properly and at the proper elevation.
   - Ensuring all valves and gates are exercised regularly and in operating order.
   - Inspecting outlet orifices to ensure proper operation, including the proper operation of any orifice plates.
   - Ensuring the inlet to the basin allows proper flow to the detention area.
   - Ensuring inlet, outlet, and emergency spillways are free from obstructions.
   - Inspecting any related signs are in place and legible.
   - Inspect fence, if any, for continuity.
   - Inspect erosion control to ensure it is adequate.

G. References

Flood Plain Development. Iowa Administrative Code. Title V. Chapter 70.

U.S. Department of Transportation. *Urban Drainage Design Manual*. Hydraulic Engineering Circular No. 22. Third Ed. 2009.