

7. STORAGE FACILITIES

7.1 Overview

As communities grow and change through new construction, development or redevelopment, modifications in land use can affect the amounts of permeable and impermeable surfacing in a drainage basin. Increases in impermeable surface areas from roofs or pavement in streets and parking lots, for example, can affect the rate of stormwater runoff. New construction or reconstruction in a basin often increases the amount of impermeable surfacing in the basin and also peak flow downstream. These increased flows may overwhelm an existing downstream storm sewer system or cause downstream flooding.

In addition to reducing or maintaining downstream peak flows, storage of stormwater runoff provides a water quality benefit as well. Slowing and temporarily storing runoff can allow sediment and other pollutants to settle out before being discharged to a stream or other water feature.

Storage facilities can range in size from small facilities contained in parking lots or other on-site facilities to large regional facilities, lakes, and reservoirs. Unless the master planning process or regional analysis has shown that the detention requirements can be transferred to a regional facility approved by the City, on-site storage facilities to maintain or reduce existing peak flows are required. Any approved transfer or combining of detention requirements must occur within the same watershed as defined by the City's master plan. Even if detention requirements can be transferred to a regional facility, on-site facilities may still be necessary to maintain receiving stream channel stability, maintenance, and water quality.

The location of storage facilities must be carefully considered. The designer must keep in mind how the facility controls runoff within a defined basin as well as its effect on other drainage features and infrastructure within the larger urban environment. Consideration may also be given to larger stormwater storage basins being multi-use facilities. Some basins may function as sports fields when dry or ponds for parks and urban areas if they are designed to maintain a permanent pool of water.

In addition to guidance outlined in the following sections, methods and procedures for design of stormwater detention facilities can be found in Hydraulic Engineering Circular No. 22, Urban Drainage Design Manual.

7.2 Detention and Retention

Stormwater storage facilities may be referred to as detention facilities or retention facilities. Detention basins are stormwater runoff storage facilities that usually have a dry bottom except during and for a temporary period after a storm event. A detention basin may be a swale, ditch, dry pond, hard-surfaced basin, or underground facility.

Retention basins are stormwater runoff storage facilities that have a permanent pool of water and have capacity to store additional runoff when required. Retention basins are often ponds or small lakes.

Some stormwater storage basins function as water quality sedimentation basins to separate pollutants, suspended solids, and debris from stormwater. Sedimentation basins can be incorporated into the design of detention or retention basins. Chapter 8 of this manual provides guidance on sedimentation basins.

Since design principles are primarily the same for detention and retention basins, the term "storage facilities" in this manual will refer to both. The specific terms "detention" or "retention" will be used in the case where one or the other is specifically indicated.

7.2.1 Computer Programs

Routing calculations for design of storage facilities can be time-consuming and repetitive. To assist with these calculations, reservoir routing computer programs such as Hydraflow Hydrographs or the U.S. Army Corps of Engineers HEC-HMS are available. Storage facilities shall be designed and analyzed using the NRCS Curve Number method for inflow hydrograph development and Storage Indication or modified Puls method for reservoir routing calculations.

7.2.2 Plan Review

If required, the owner shall submit storage facility construction plans to the Nebraska Department of Natural Resources (NeDNR) for approval. See Section 7.5 for dam classification and requirements.

Plan submittal to the City for review and approval shall include:

- Supporting calculations for hydrologic and hydraulic analysis and design. At a minimum, supporting calculations shall include design storm inflow and outflow hydrographs, stage-storage-discharge curves, and cumulative inflow and outflow elevation curves for the design storms.
- Appropriate soil investigation (i.e., suitability for water storage, settlement potential, slope stability, and influence of groundwater) for the structure hazard classification.
- Construction plans for storage, including the outlet structure.

At the end of construction, a licensed surveyor or engineer shall submit a separate written statement to the City documenting that the grading and construction of storage facilities has been completed in conformance with the approved construction plans.

7.2.3 Ownership and Maintenance of Storage Facilities

Storage facilities in a development, along with all inlet and outlet structures and/or channels, are to be owned and maintained by the developer or a property-owners' association unless the City has approved an alternative ownership/maintenance arrangement. Because the downstream storm sewer drainage system will be designed assuming detention storage upstream, a storage facility in the storm sewer drainage system shall remain permanently functional as a storage facility site unless or until the City relieves the owner of such responsibility in writing. Documentation of the storage facility and owner maintenance responsibility will be made in permanent records such as a plat, agreement, or other record acceptable to the City.

7.3 Design Criteria

7.3.1 General Criteria

As described in Section 7.1, storage of stormwater runoff may be concentrated in regional facilities or distributed in on-site facilities throughout an urban drainage system. Regardless of their location, storage facilities shall be designed to attenuate the post-project runoff peak flow rate so that it is equal to or less than the existing 2-year, 10-year, and 100-year peak flow rates of the project. When storage of stormwater runoff is required, detention facilities should be used to attenuate the peak flow rate from developed areas. Retention may be considered case by case with prior approval by the City. The design criteria for storage facilities shall include the following:

- Release rate
- Grading and depth
- Location and downstream analysis
- Storage volume
- Outlet works

7.3.2 Release Rate

Release rates from the outlet of a storage facility shall be such that the runoff peak flow rate at the downstream property line or downstream limit of a proposed project is equal to or less than the existing peak flow rate for the 2-year, 10-year, and 100-year discharges. Upon meeting these criteria, runoff from intermediate storm return periods can be assumed to be adequately controlled.

7.3.3 Storage Volume

The storage volume of a facility shall be adequate to attenuate the runoff peak flow rate at the downstream property line or downstream limit of the proposed project so that it is equal to or less than the existing peak flow rate for the 2-year, 10-year, and 100-year storms. Routing calculations must be provided to demonstrate that the storage volume is adequate. If the storage facility will also be used for water quality, the storage volume required to attenuate the runoff peak flow rate shall be provided in addition to the water quality control volume (WQCV). See Chapter 9 of this manual for additional information on treatment of the WQCV. If sedimentation during construction causes loss of storage volume, design dimensions shall be restored before completion of the project.

7.3.4 Grading and Depth

Storage facilities shall be designed and constructed to meet the following grading and depth criteria.

- Side slopes shall be no steeper than 4:1 (horizontal to vertical).
- The top width of any embankment shall be no narrower than 14 feet.
- Traversable vehicle access for maintenance purposes shall be provided from public right-of-way.
- The bottom area of storage facilities shall be sloped at a minimum of 1% to a centralized low flow channel. The low flow channel shall be sloped at a minimum of 0.5% from the inlet to the outlet of the storage facility.
- Storage facilities that fall under the jurisdiction of the Nebraska Dam Safety Program shall be reviewed and permitted by NeDNR.

7.3.5 Outlet Works

Outlet works selected for storage facilities shall include a principal spillway and an emergency overflow. The discharge from a principal spillway must be released in a nonerosive manner and can be controlled through a combination of drop inlets, pipes, weirs, orifices, chutes, and channels. Slotted-riser-pipe outlets are sometimes used (typically for water quality treatment) but may be prone to clogging problems if not properly designed and protected. Storage facilities shall be designed to pass all required design storms without allowing flow to enter the emergency overflow. Outlet works that provide control for a range of stormwater runoff events, including those smaller than the 2-year design storm, are preferred.

The emergency overflow crest elevation shall be set a minimum of one foot above the maximum water surface elevation for the 100-year design storm being conveyed through the primary spillway. The emergency overflow shall, at minimum, be designed to convey the 100-year discharge with one foot of freeboard above the maximum water surface elevation for the 100-year design storm being conveyed entirely through the emergency overflow. For large storage facilities, selecting a flood magnitude for sizing the emergency overflow shall be consistent with the potential threat to downstream life and property if the basin embankment were to fail. Large storage facilities that fall under the jurisdiction of the Nebraska Dam Safety Program may also have more stringent requirements for the emergency overflow. The emergency overflow for a storage facility shall be armored or protected from erosion to prevent failure of the facility during large events.

Outlet works must operate without requiring attendance or operation. The outlet works for storage facilities shall be designed to drain temporarily stored runoff within 72 hours. If the storage facility will also be used for water quality, minimum time requirements to drain the WQCV from Chapters 8 and 9 of this manual shall be adhered to.

7.3.6 Location and Downstream Analysis

Although storage facilities are designed to control the discharge of stormwater runoff at the outlet works, consideration of the timing of these discharges from the proposed facility and other facilities in the same basin can be critical to the function of the overall stormwater system. The City may require the discharges of the proposed facility to be routed through the downstream stormwater system to ensure that peak discharges from the storage basin do not cause adverse effects downstream.

For developments that discharge directly into or very near major receiving waters (e.g., major rivers), delaying the peak and extending the receding limb of the hydrograph may result in a higher peak on the major drainageway or receiving water. If a routing analysis of the entire drainage basin shows that a storage facility would have adverse effects on the overall stormwater system and all downstream stormwater infrastructure is sized appropriately to convey runoff for the 100-year storm from the proposed project conditions, and all areas in the basin will have similar runoff timing, the City may consider an exemption of these storage facility requirements.

7.4 General Hydraulic Procedure

For the design of storage facilities, a stage-storage-discharge analysis is used, routing the inflow hydrograph through the facility with different basin and outlet geometry until the desired outflow hydrograph is achieved. A general procedure for the design of storage facilities follows. Additional information on this procedure, preliminary storage estimates, detailed hydraulic principles for outlet works, stage/storage and stage/discharge relationships can be found in the most recent edition of the Hydraulic Engineering Circular No. 22: Urban Drainage Design Manual.

1. Compute the inflow hydrograph for stormwater runoff for the 2-year, 10-year, and 100-year design storms using the NRCS Unit Hydrograph method described in Chapter 2: Hydrology. Both existing and post-development hydrographs are required.
2. Perform preliminary calculations to estimate storage requirements for the hydrographs from Step 1.
3. Determine the physical dimensions necessary to hold the estimated storage volume from Step 2, including freeboard. The maximum storage requirement calculated from Step 2 shall be used.
4. Size the outlet works. The estimated peak stage will occur for the estimated volume from Step 2; the outlet works shall be sized to convey the allowable discharge at this stage.
5. Perform routing calculations using inflow hydrographs from Step 1 to check the preliminary design using storage routing equations or an appropriate computer program. If any of the routed post-development runoff peak discharges from the 2-year, 10-year, or 100-year design storms exceed the corresponding existing runoff peak discharges or if the peak stage varies from the estimated peak stage from Step 4, revise the estimated volume and basin geometry and return to Step 3.
6. Design the emergency overflow with established freeboard requirements.
7. Evaluate the downstream effects of storage facility releases to ensure that the routed hydrograph does not cause downstream flooding.
8. Evaluate the outlet works and emergency overflow exit velocities and provide channel and bank stabilization as needed to prevent erosion downstream.

7.5 Safe Dams Act

National responsibility for the promotion and coordination of dam safety lies with the Federal Emergency Management Agency (FEMA). The provisions of the Federal Dam Safety Act are administered by NeDNR through the Nebraska Dam Safety Program.

State of Nebraska regulations define a dam as an artificial barrier with the ability to impound water that a) is 25 feet or greater in height from the maximum storage elevation to the downstream toe of the embankment or b) has a maximum storage volume of 50 acre-feet or more (including surcharge storage). Further information on embankments that may function as a dam should be obtained from NeDNR.

NeDNR classifies dams as indicated below:

- High Hazard Dam: A dam located in areas where failure or misoperation would likely result in the loss of human life. Failure may cause serious damage to homes, industrial or commercial buildings, four-lane highways, or major railroads. Failure may cause shallow flooding of hospitals, nursing homes, or schools.
- Significant Hazard Dam: A dam located in areas where failure or misoperation of the dam would result in no probable loss of human life but could result in major economic loss, environmental damage, or disruption of lifeline facilities. Failure may result in shallow flooding of homes and commercial buildings or damage to main highways, minor railroads, or important public utilities.
- Low Hazard Dam: A dam located in areas where failure would likely result in no probable loss of human life and in low economic loss. Failure may damage storage buildings, agricultural land, and county roads.
- Minimal Hazard Dam: A dam located in areas where failure or misoperation would likely result in no economic loss beyond the cost of the structure itself and losses would be principally limited to the owner's property.

Storage facilities that fall under the jurisdiction of the NeDNR must be designed, reviewed, permitted, and constructed in accordance with the Nebraska Dam Safety Program. An owner proposing a storage facility shall submit documentation of compliance with the Nebraska Dam Safety Program or documentation why the facility does not fall under NDNR jurisdiction.

7.6 Maintenance Considerations

Proper design of storage facilities must take long-term maintenance requirements into account. To provide for acceptable performance and function, storage facilities shall be designed to minimize maintenance problems typical of urban detention facilities and address:

- Weed growth
- Sedimentation control and removal
- Protection from blockage of outlet structures
- Litter accumulation
- Maintenance vehicle access
- Grass and vegetation overgrowth
- Bank stabilization
- Provisions for outlet structures allowing complete drainage of retention basins for maintenance or inspection
- Maintenance of fences and perimeter plantings

7.7 Protective Treatment

Protective treatment may be required to prevent entry to facilities that present a hazard to children or others. Fences and/or a safety bench may be required where one or more of the following conditions exist:

- Rapid stage increases would limit possibility of escape.
- Water depths either exceed 2.5 ft for more than 24 hours or are permanently wet.
- Large and/or deep facilities.
- A low-flow watercourse or ditch passing through the detention area has a depth greater than 5 feet or a flow velocity greater than 5 feet per second.

In some cases, it may be advisable to fence the watercourse or ditch rather than the detention area. Fencing should be considered for normally dry storage facilities with design depths in excess of 2.5 ft for 24 hours, unless the area is within a fenced, limited access facility.

7.8 Trash Racks and Safety Grates

Trash racks and safety grates may be required for large storage facilities. Trash racks trap large debris well away from the entrance to the outlet works so that they will not clog the critical portions of the outlet. They also trap debris in such a way that simplifies removal. Well-designed trash racks serve these purposes without interfering significantly with the hydraulic capacity of the system.

Safety grates at inlets keep people and large animals out of confined conveyance structures. Their use should be evaluated, along with hydraulic forces and clogging potential, to assure that effective flow is maintained. Grating should not be installed at the outlet of a confined conveyance structure as it may cause clogging or hamper rescue efforts.

Further information on trash racks and safety grates can be found in the Mile High Flood District's *Urban Storm Drainage Criteria Manual*.

7.9 References

- City of Lincoln Public Works and Utilities Department, 2004. *Drainage Criteria Manual*.
- City of Omaha Environmental Quality Control Division, 2014. *Omaha Regional Stormwater Design Manual*.
- Federal Highway Administration, 2009. *Hydraulic Engineering Circular No. 22, Third Edition, Urban Drainage Design Manual*.
- Nebraska Department of Transportation, 2006. *Drainage and Erosion Control Manual*.
- Mile High Flood District (formerly the Urban Drainage Flood Control District), 2016. *Urban Storm Drainage Criteria Manual*.