IOWA STORMWATER MANAGEMENT MANUAL

9.13 UNDERGROUND DETENTION

Department of
Natural Resources

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

9.13-1 LAYOUT AND DESIGN

A. SUMMARY

Underground stormwater detention systems are primarily used to temporarily store runoff where there is limited open space. They are used to capture runoff from a given site area and release it at slower rates.

They may be constructed in various ways including storm sewer pipes, chambers, vaults and/or aggregate layers. Storm structures are provided at key locations to provide access for maintenance. There are several manufacturers that produce proprietary systems.

DESIGN PROCESS OVERVIEW

1. Complete Site Evaluation and Planning
2. Determine the Watershed Area Draining to the Underground Detention System
3. Locate Pretreatment and/or Other Water Quality Practices
4. Develop Maintenance Plan
5. Integrate into Stormwater Plan

MAINTENANCE REQUIREMENTS

1. Designate Responsible Parties for Maintenance
2. Complete Construction Sequencing
3. Remove Accumulated Sediment and Debris Frequently from Pretreatment Area(s) and System
4. Perform Regularly Occurring Maintenance Which is Essential to Maintaining Available Storage

An underground detention chamber system under construction in Davenport.

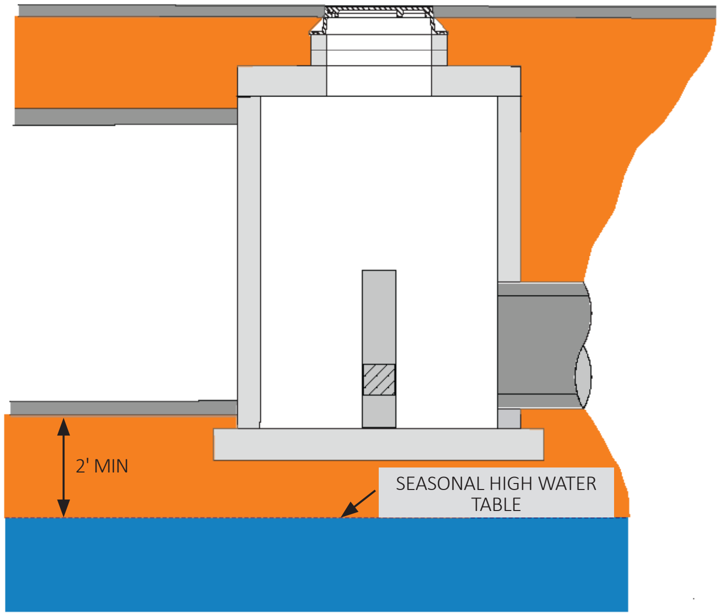
B. APPLICATIONS

Underground detention systems are more expensive than other types of detention practices to construct. While they could be used anywhere, they are usually installed in urban sites where there is insufficient area to excavate a detention basin on the land surface with enough storage to reduce outflow rates to the desired level. They can be constructed below other site features, including parking lots, roadways and even buildings; allowing the development potential of a given site to be maximized.

The elevation difference between the surface and the expected outfall of the system (either to the land surface or a downstream storm sewer) is a limiting factor when considering underground detention systems. Each type of system will need a certain depth of cover over the system and then the height of the system itself. In some cases, that may dictate if an underground system is feasible and the types or sizes of systems that can be used.

SITE FEASIBILITY

- Soils - There are no specific restrictions based on soil type or HSG classification. However, some soil types may require special consideration to stabilize excavations during construction. Also, soil conditions will impact the ability to infiltrate stormwater into the soil layers below the underground detention system, so soil conditions do need to be considered if runoff reduction through infiltration is a project goal. Refer to the recommendations of site-specific geotechnical engineering studies for construction recommendations.
- Depth to water table - To prevent system storage from being reduced by groundwater infiltration, the **seasonal high-water table** should be at least two (2) feet below the lowest elevation (pipe, structure or aggregate layers) used for storage within the underground detention system. An impermeable geotextile or engineering fabric may be used as a water barrier to prevent groundwater infiltration into the system, if the recommended vertical separation can't be provided. For proprietary systems, refer also to the manufacturer's recommendations.
- Tributary area - There are no set minimums or maximums, however the cost of underground systems usually means they are applied to smaller sites and drainage areas.
- Space required – The space required will vary depending on the type and depth of system being proposed. Greater depths allow for a smaller footprint and can be more cost effective, as larger diameter pipes can be used.
- Site topography - There needs to be sufficient elevation difference between the site surface and the outfall elevation to accommodate the desired depth of the system. Underground detention systems are best located below flatter topography, to reduce the potential for deeper excavations and backfill along the uphill end of the system.



NOTE

Refer to Part 9.13-1.D of this section for more information on system depth recommendations.

C. UNIFIED SIZING CRITERIA

The primary use for underground detention systems is providing temporary storage of stormwater runoff. For that purpose they can be used to address the Channel Protection (CPv), Overbank and Extreme Flood Protection criteria as described in the U**nified Sizing Criteria (USC).**

Some underground detention systems include features that allow runoff from the most frequently occurring events to be diverted first into a specific portion of the storage system called isolator rows. When isolator rows are provided, the underground detention system may be able to meet some or all of the **Water Quality volume (WQv)** requirements. However, a better and preferred approach would be to use other water quality **best management practices (BMPs)** installed upstream of the underground detention system to meet WQv requirements. TARGET

For example, runoff could first be directed to permeable paver installations or bioretention cells for WQv treatment. Runoff would then pass into the underground detention system through overflow inlets connected to the system or by runoff being allowed to percolate through those water quality BMPs into aggregate layers within the underground detention system.

Underground detention systems can be designed to address Recharge Volume (Rev) requirements. This can be accomplished by extending the aggregate storage layers below the outflow elevation of the system, forcing captured runoff volume to be infiltrated into subsoil layers. Subsoil conditions would need to be tested to verify the expected percolation rates. Such testing would need to be completed for the soils below the bottom of the excavation for the system. These tests would determine if the captured runoff could be completely drained from the system within 24 hours after a rainfall event. TARGET

Table 9.13-1-1. Potential to Use Underground Detention to Meet USC Requirements

Unified Sizing Criteria	Application
Recharge Volume (Rev)	Potential
Water Quality Volume (WQv)	Potential
Channel Protection Volume (CPv)	Primary
Overbank Flood Protection (Qf)	Primary
Extreme Flood Protection (Qe)	Primary

NOTE

See ISWMM Section 3.01 for more information about the USC.

NOTE

Refer to Part 9.13-1.E of this section for more information on how the Underground Detention Systems can be used to address Rev and WQv requirements.

D. DESIGN ELEMENTS AND CRITERIA

INFLOW CAPACITY

The methods used to direct runoff into the underground detention system need to have the capacity to convey the peak rate of flow from the event to be managed (typically the 100-year storm event) into the underground detention system. The capacity of all flow paths and methods used (storm inlets, pipes, permeable pavers, percolation through aggregate layers, etc.) needs to allow that peak rate of flow into the system. ESSENTIAL

PRETREATMENT

Pretreatment practices should be provided upstream of the underground detention system to reduce the potential for sediment and debris from being washed into the system. The pretreatment volume of 10% of the WQv volume should be provided, but may be reduced under the following conditions: TARGET

Pretreatment is not required for areas that already have passed through an appropriately sized pretreatment or water quality BMP.

- If an isolator row is included in the underground detention system, the isolator row may also act as part of the pretreatment approaches. In that circumstance, the storage within the isolator row should be increased by any pretreatment volume not addressed by upstream practices, to account for the potential of sediment deposition which would reduce available storage within the isolator row. TARGET
- A catch basin sump structure is recommended at the entry point to any isolator row. A minimum sump depth of 24 inches is recommended, but may be different based on manufacturer's requirements or to increase the pretreatment volume provided prior to the isolator row. TARGET
- Any intakes constructed directly into the system should be connected to the isolator row and not the other storage chambers.
- For sites with hotspot land uses, hydrodynamic separators (HDS), filters or inserts may be needed to better capture runoff containing elevated levels of oils, fuels and other similar pollutants. For fueling stations, consider including a gate or valve system that can prevent fuel spills from entering the system.

NOTE

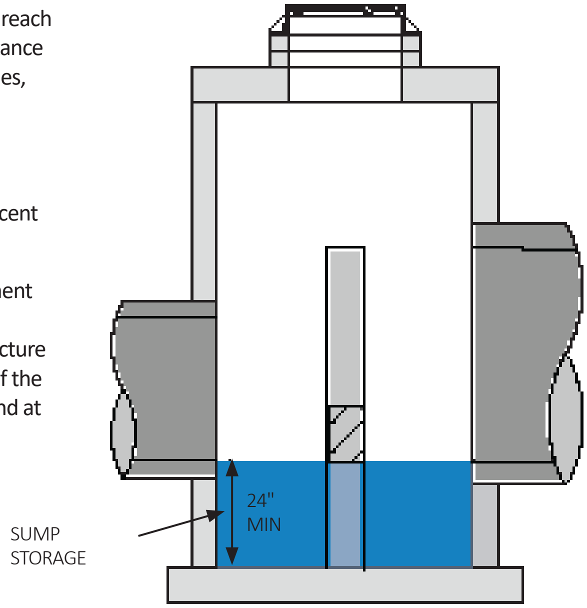
When sump structures are used for pretreatment, check that at least 2 feet of vertical separation is maintained above the seasonal high water table and construct the structure with water tight seals to prevent infiltration.

ACCESS

There needs to be a clear path with legal right of access to allow the party responsible for maintenance to reach the underground detention system. Of key importance is equipment and personnel access to any manholes, intakes or cleanouts that are used for inspection or to remove sediment or debris from the system. ESSENTIAL

In many locations, this access can come from adjacent drives, parking areas or streets.

Vacuum trucks are typically used to remove sediment and debris that collects within the underground detention system. Access by manhole or inlet structure should be provided at inflow and outflow points of the system, the location of any diversion structures, and at each endpoint of any isolator rows. ESSENTIAL

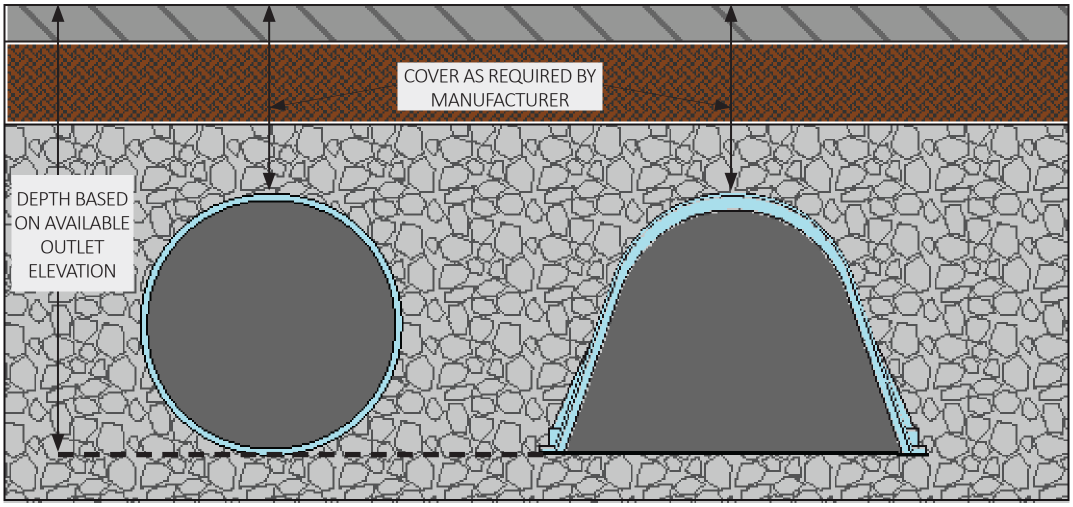


DEPTH

The depth of these systems is variable, depending on several factors.

Cover – There needs to be sufficient cover over the system to protect it from damage and to support any loading from vehicles or equipment that will drive over the system. For proprietary systems, refer to the manufacturer's requirements to determine the required cover over the system. When the system is constructed from storm sewer pipes and structures, refer to the Iowa Statewide Urban Design Standards and Specifications (SUDAS) or other local requirements to determine the required cover over the pipes and structures within the system. ESSENTIAL

- Storage Chambers and/or Pipes – There are various types of pipes and chambers that can be used to provide underground storage. Shallower systems will need a larger footprint area compared to systems that can provide greater depth.
- Aggregate Layers – Aggregate materials are used to backfill above, around and under storm chambers and pipes. The void spaces within these aggregate layers can be used to store water. This can be done if the chambers or pipes are made from perforated materials or have other provisions to allow water to move freely between the chambers, pipes and aggregate materials.
  - Aggregate complying with Iowa DOT Section 4122, Gradation No. 13, Class 2 durability gravel or crushed stone (AASHTO M 43/ASTM D 448, Size 2) is recommended for use as storage aggregate materials.
- Outfall Elevation – Ultimately, the depth of the system will be limited by the difference in elevation between the site surface and where runoff can be discharged from the system. This is often based on the elevation of a downstream storm sewer system or by the elevation of the land surface downstream where a pipe outfall may be able to discharge to the surface.



NOTE

This illustration shows two different examples of shapes used for underground detention chambers. Other shapes and types may be used.

STORAGE

The required storage volume will depend on the inflow rates and volumes being sent to the system and the allowable release rate needed to meet USC requirements. ESSENTIAL

Within the system, the high-water elevation during a 100-year storm event should not extend above the elevation of the bottom of any pavement surface or bedding aggregate layer (for any infiltration based BMP or pavement system) located directly over the underground detention system. TARGET

NOTE

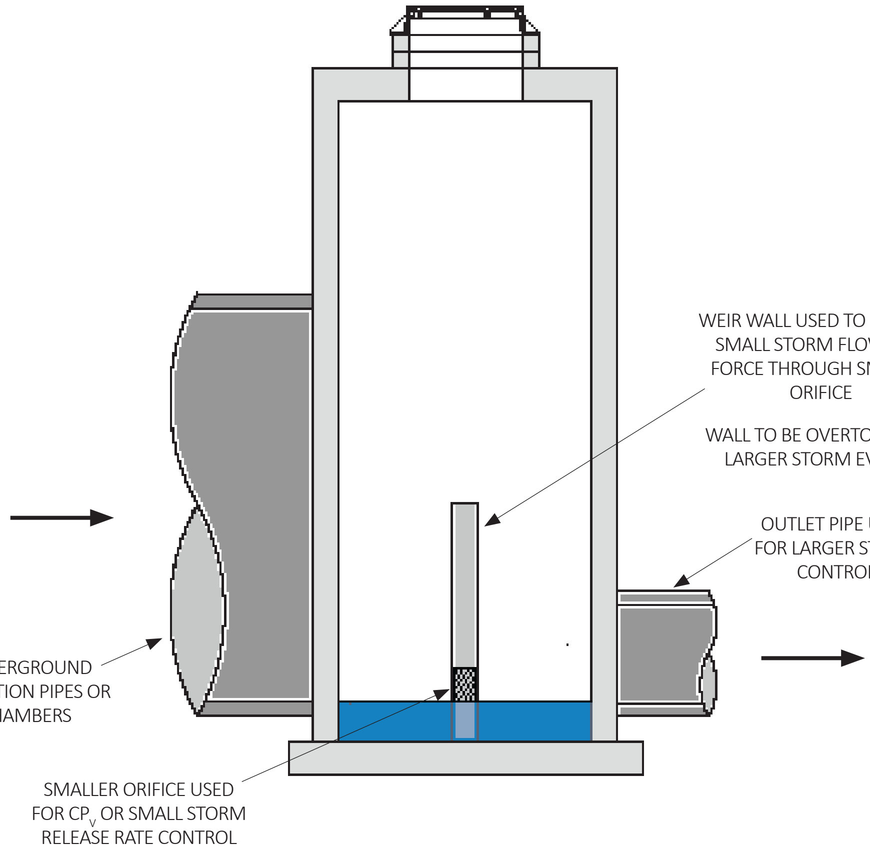
Refer to ISWMM Sections 9.02 to 9.04 for general information about stormwater detention routing, estimation and design of outlet controls.

NOTE

An outlet, junction or cleanout structures, check that at least 2 feet of vertical separation is maintained above the seasonal high water table and construct the structure with water tight seals to prevent infiltration.

OUTLET STRUCTURES

At the downstream end of the system, a multi-stage outlet structure will likely be needed if the system is intended to meet the CPv and larger storm detention requirements. This is typically accomplished by constructing a weir wall within the outfall structure, with a smaller opening to limit the release rate for smaller storms placed within or through the wall. The top of the overflow weir would be set above the high-water elevation of the CPv event (1-year storm), allowing higher rates of flow to leave the system during larger storm events. In some cases, additional weir widths may need to be staggered at higher elevations to provide adequate control between the 1-year and 100-year storm events. TARGET

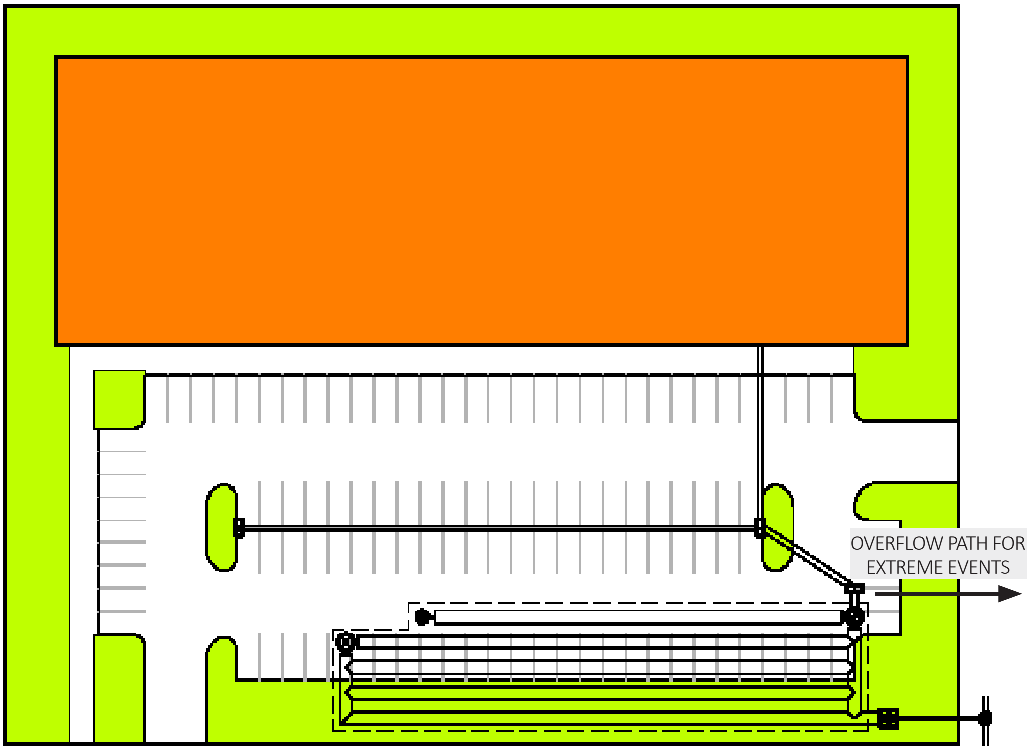


CATASTROPHIC STORM OVERFLOW PATH

The designer should evaluate a path of overflow for storms that are larger than the 100-year storm event. If the underground system is sized to handle the 100-year storm event, any larger storms will not be able to enter the system. Runoff will need to be able to have a safe path out of the site which is not expected to cause damage to property or infrastructure. ESSENTIAL

MANUFACTURER'S RECOMMENDATIONS

Many proprietary systems are designed by the manufacturer. They typically provide a final plan set for shop drawing review prior to construction. These drawings often include specifications and requirements that the project design engineer may need to integrate into the contract documents for the project. Often, these plan sets will designate some items as "As specified by engineer" or "Provided by others". The site designer will need to address such items on their construction documents. ESSENTIAL



ADVISORY ABOUT SUBSOIL INFILTRATION

As mentioned previously, underground detention systems can be designed to promote surface runoff reduction. This is typically accomplished by extending the aggregate layers below the outlet elevation that drains the system to the surface or an adjacent storm sewer network. Since these systems have limited ability to filter, capture or remove certain types of pollutants, caution should be taken if hotspot land uses are expected to drain to the system.

This type of configuration could be classified as an injection well that would be regulated under the Environmental Protection Agency's (EPA) Underground Injection Control (UIC) regulations. This type of configuration may not be classified by the EPA as an injection well as long as the system drains to a surface outlet. However, designers could contact the EPA with specific design arrangements to ensure that they are not subject to the UIC requirements. CAUTION

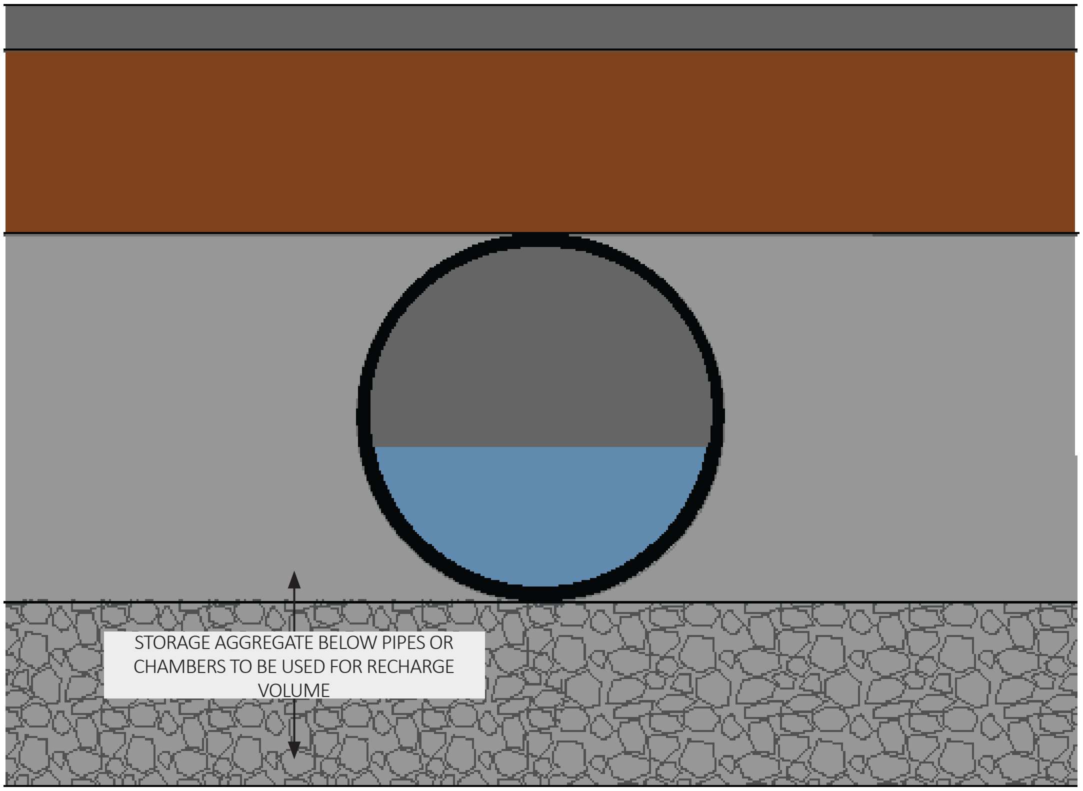
https://www.epa.gov/uic/basic-information-about-class-v-injection-wells

E. SPECIAL CASE ADAPTATIONS

RECHARGE VOLUME

Storage aggregate layers located below any outflow elevation to the storm sewer or surface can be counted toward the Recharge Volume (Rev) requirements. The depth of the storage aggregate used for Rev should be set so that it can be completely drained within 24 hours after a rainfall event. Subsoil layers should be tested to determine the expected percolation rate into the subsoil layers below the underground detention system. ESSENTIAL

For example, if the percolation rate is determined to be one (1) inch per hour, then the depth of storage aggregate below the outflow point of the system credited toward Rev requirements should not be any greater than 24 inches (1 inch per hour x 24 hours = 24 inches).



WATER QUALITY VOLUME

As mentioned previously, the preferred approach would be to have BMPs that meet WQv requirements which are separate from the underground detention system. In this way, pretreatment and WQv management should be provided before runoff enters the underground detention system.

However, WQv requirements may be achieved within an underground detention system if the following parameters are met:

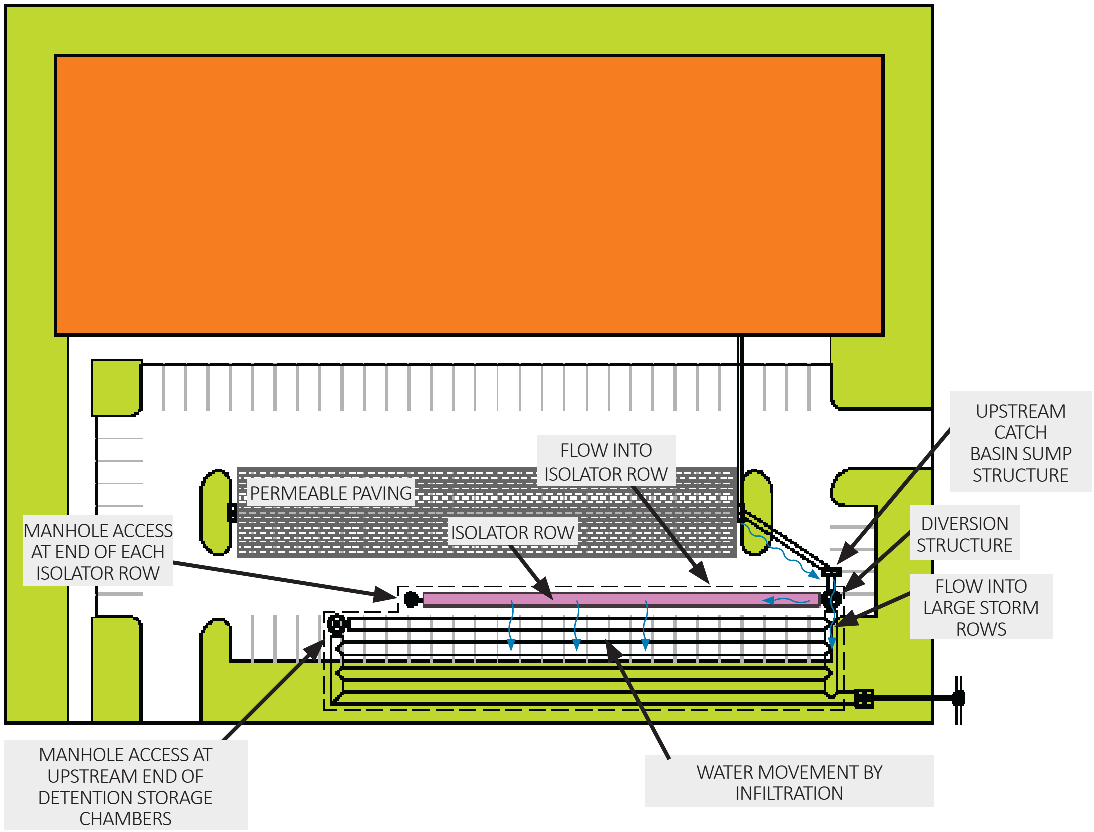
- The system is designed with an isolator row configuration to promote filtration and pollutant removal within the first row of the system. ESSENTIAL

- The entire volume of runoff expected to be generated from the WQv event is directed into the isolator row. In this configuration, a diversion structure would be used to ensure that the WQv runoff is directed into the isolator row, but flow from larger events would be redirected into other storage chambers or pipes. ESSENTIAL
  - The isolator row would be sized to store the entire WQv volume from the upstream area (other than any WQv volume already managed by upstream BMPs) within the pipes or chambers used for the isolator row. Void spaces in aggregate layers outside of the isolator row may be used for detention of larger storm events, but not counted toward WQv treatment volume. ESSENTIAL
- A manhole or inlet structure providing full access is provided at each end of the isolator row. ESSENTIAL
- Flow out of the isolator row can only leave through perforations in the exterior of the isolator row, forcing water to percolate through some portion of storage aggregate before it can enter other storage chambers or pipes and be allowed to leave the system through the outlet. ESSENTIAL
  - With open-bottom chambers, isolator rows are installed on a woven geotextile fabric to add additional stability and protection to the aggregate below during the cleanout process.
  - Other pipe configurations used as isolator rows can also be wrapped in a non-woven geotextile fabric to provide additional particle filtration and removal.

The isolator row configuration is expected to provide water quality benefits through capture of sediments and to some extent phosphorus materials attached to the captured sediments. Some testing has been done of isolator row systems that indicates that TSS reductions of 80% or greater are possible[1 and 2]. Some other reductions in turbidity, ammonia, Total Kjeldahl Nitrogen, phosphorus and zinc are possible.[1]

Sources:
(1) WinSLAMM- Performance Observations. (2) NJCAT Technology Verefication.

Isolator rows may be less effective at removing other types of pollutants (such as nitrates). If targeting a certain pollutant is a project goal, it may be necessary to use other water quality BMPs in place of (or in concert with) the isolator row system to achieve those project goals.



9.13-2 SIZING CALCULATIONS

A. CALCULATION PROCEDURE

1. Determine if the development site and conditions are appropriate for the use of an underground detention system. Consider the Application and Feasibility criteria in Section 9.13-1.

2. Calculate the pretreatment volume or Water Quality volume to be provided (if applicable).

    a. Consider using other practices upstream of the underground detention system to meet these requirements to the greatest degree possible.

3. Develop a stormwater model (TR-55) for the watershed area for the practice. The model should determine peak flow rates and volumes for the proposed conditions. This information may be needed for the natural and existing conditions to determine the allowable release rates, based on local jurisdictional requirements. Refer to Section 9.02-2.A for the events to be studied and Section 9.03 for use of modeling software.

4. Estimate required storage volumes to meet the aspects of the Unified Sizing Criteria to be managed by the practice. For underground detention practices, this is typically the CPv through 100-year storm events. Designers are strongly encouraged to use the procedure in Section 9.02-3 to estimate required storage very early in the planning process for any new development or stormwater facility. Estimated storage values can project the area that should be set aside for stormwater detention, allowing other development goals to be planned around that reserved open space.

5. Determine pre-treatment measures.

    a. The pretreatment volume should be 10% of WQv.

    b. Pretreatment is required even for facilities that aren't managing the WQv.

6. Prepare a preliminary layout of the system to identify preliminary stage-storage relationships that exceed the volumes estimated in Step 4. If an isolator row is used to manage WQv, verify that its capacity exceeds 100% of the WQv to be treated. If it is to provide pretreatment in addition to the WQv volume, verify its capacity exceeds 100% of the WQv to be treated plus the required pretreatment volume. Design the diversion structure for the isolator row, as applicable.

7. Enter the preliminary stage-storage relationships and outlet configurations into a TR-55 software program and route inflow hydrographs through the preliminary detention system design. Identify the projected release rates for each event studied.

8. Review projected release rates from Step 7 for the preliminary design. Verify that the projected rates are less than the allowable rates calculated as part of the estimation procedure referred to in Step 4. Iterate as needed, adjusting staged outlet controls or stage-storage relationships within the software program to meet required release rate restrictions.

9. Check outflow velocities at pipe outfalls and spillways. Adjust sizing or geometry or add erosion protection features as needed for the 100-year, 24-hour event.

    a. From the continuity equation, determine pipe velocity based on flow rate (Q) and area (A) [V = Q/A]

10. Check that a safe overflow path is provided for events larger than the 100-year storm event. Identify the overflow path of the drawings for the proposed site.

Complete design checklists at the end of this section to verify that sizing design criteria have been satisfied. Proceed to development of detailed plans and specifications. After completion of final design, make any adjustments as needed so that final plan information matches the finished calculation report.

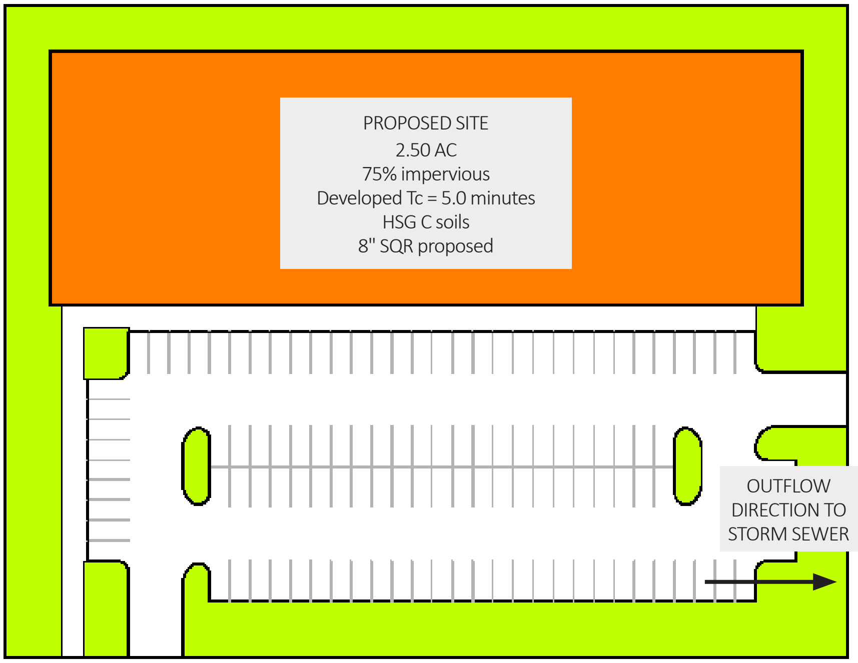
B. DESIGN EXAMPLES

EXAMPLE #1 – NO UPSTREAM WATER QUALITY BMPS PROVIDED

For this example, it is given that a commercial development site will drain to an underground detention system.

For this example, it is given that the watershed to the inlet has the following parameters:

- Central Iowa Location (Region 5)
- Drainage Area = 2.50 acres
- Impervious surfaces = 1.875 acres (75%)
- **Time of concentration** (Tc):
  - Natural Condition = 18.1 minutes
    - » Based on Lag Equation, Curve Number = 71, Watershed Slope = 2%, Flow length = 550 feet
  - Existing Condition = 14.3 minutes
    - » Based on NRCS Velocity Equation
    - » Sheet Flow Length = 100 feet, Slope 2%, 2-year storm rainfall = 3.08 inches
    - » Shallow Concentrated Flow = 450 feet, Slope 2%, unpaved surface
  - Developed Condition = 5.0 minutes
    - » Very short sheet flow paths are expected, and flow is directed to inlets within the parking lot of the commercial development
    - » Tc is given for this example, but should be calculated in practice
- Soils:
  - **Hydrologic Soil Group** C
  - 8" of **soil quality restoration (SQR)** is proposed



NOTE

Level of SQR applied to open spaces impacts Curve Number and WQv calculations. Refer to the Soil Quality Management and Restoration Section of ISWMM for more information.

NOTE

A reminder that the preferred approach would be to locate water quality and/or pretreatment practices upstream of the underground detention system.

1. Determine if the development site and conditions are appropriate for the use of a underground detention system. Consider the Application and Feasibility criteria in Section 9.13-1.

   For this example, it is given that the site conditions are appropriate for an underground detention system.

2. Calculate the pretreatment volume or Water Quality volume to be provided (if applicable).

   Consider using other practices upstream of the underground detention system to meet these requirements to the greatest degree possible. For this example, it is given that no upstream water BMPs are proposed.

   (Example #2 is included to show how calculations are performed if upstream BMPs are proposed.)

Water Quality volume calculations:

- Runoff coefficient (Rv) = 0.05 + 0.009 (I)   I = impervious cover (%)   Equation 9.13-2-1
  - Rv = 0.05 + 0.009 (75) = 0.725
- Water Quality volume (WQv) = Rv x P   Equation 9.13-2-2
  - P = WQv precipitation (1.25 inches)
  - WQv = Rv x P = 0.725 x 1.25 inches = 0.906 watershed-inches

    = 0.906 watershed-inches x 2.50 acres x 43,560 (square feet / acre) / 12 (inches / foot)

    = 8,224 CF (cubic feet)
- Required pretreatment volume = 10% of Water Quality volume (WQv)
  - Pretreatment volume = WQv x 10% = 8,224 CF x 10% = 822 CF

3. Develop a stormwater model (TR-55) for the watershed area for the practice. The model should determine peak flow rates and volumes for the proposed conditions. This information may be needed for the natural and existing conditions to determine the allowable release rates, based on local jurisdictional requirements. Refer to Section 9.02-2.A for the events to be studied and Section 9.03 for use of modeling software.

- Natural Condition Curve Number (CN):
  - Meadow = 71
- Existing Condition Curve Number:
  - Row Crop Agriculture, contoured with crop residue in good condition = 81
- Developed CN for most storm events:
  - CN for impervious areas = 98
  - CN for open space areas = 74
  - **Weighted Curve Number (CNw)** = (98 x 75%) + (74 x 25%) = 92
- Curve Numbers above were selected based on HSG and SQR conditions given for this project example
- The Hydraflow Hydraulics software program was used to prepare the TR-55 stormwater model for this example (other third party software programs may also be used). Based on the CNs listed above, the time of concentrations previously noted, the site area of 2.50 acres the following results were calculated:
  - Also note Type II rainfall distribution, time interval of 1 minute and shape factor of 484 were used.

Table 9.13-2-1: Summary of TR-55 Results for This Example.

		Natural		Existing		Developed	
	Rainfall	Peak Rate	Volume	Peak Rate	Volume	Peak Rate	Volume
Storm Event	Inches	cfs	CF	cfs	CF	cfs	CF
1	2.67	1.5	5,200	3.5	9,700	8.2	17,300
2	3.08	2.2	7,200	4.6	12,500	9.8	20,900
5	3.81	3.7	11,400	6.6	17,800	13	27,500
10	4.46	5.1	15,400	8.5	22,800	15	33,300
25	5.44	7.4	22,000	11	30,600	19	42,300
50	6.26	9.4	27,900	14	37,400	22	49,800
100	7.12	12	34,300	16	44,600	25	57,800

- For this example, assume that the designer is choosing to follow recommendations within the Unified Sizing Criteria, which would be in excess of local jurisdictional requirements, with the events larger than the CPv event required to restrict outflow rates to the peak flow rate for the same storm event for natural conditions (based on local site soils), or the peak flow rate for the 5-year storm event based on existing conditions, whichever is less.

Table 9.13-2-2: Summary of Allowable Release Rates for This Example

Storm Event	Allowable Release Rate (cfs)	Condition Based On
2-year	2.2	natural, same event
5-year	3.7	natural, same event
10-year	5.1	natural, same event
25-year	6.6	existing, 5-year event
50-year	6.6	existing, 5-year event
100-year	6.6	existing, 5-year event

Sidebar discussion:

For this example, it is given that there is no off-site area expected to pass through the site and none of the site bypasses the underground detention system (direct discharge).

- If there were off-site areas to route through the system, the allowable release rate could be increased by the peak rate expected from the off-site area in its existing (or currently developed condition) for the same storm event.
- If there were direct discharge areas, the peak rate from those direct discharge areas under the proposed developed conditions would need to be subtracted from the allowable release rate from the site, for each event.
  - In some cases, the amount of direct discharge may make it infeasible to meet the allowable release rate requirement (especially for smaller storm events).
  - Designers should work to minimize direct discharge areas (particularly those that are covered by impervious surfaces).

Refer to ISWMM Section 3.01 (Unified Sizing Criteria) for additional guidance and information about adjusting allowable release rates based on off-site flows or direct discharge areas.

4. Estimate required storage volumes to meet the aspects of the Unified Sizing Criteria to be managed by the practice. For underground detention practices, this is typically the CPv through 100-year storm events. Designers are strongly encouraged to use the procedure in Section 9.02-3 to estimate required storage very early in the planning process for any new development or stormwater facility. Estimated storage values can project the area that should be set aside for stormwater detention, allowing other development goals to be planned around that reserved open space.

   To estimate the amount of storage required to meet the CPv requirements, the procedure listed in the Small Storms Section of ISWMM should be followed. These steps are summarized below:

   a. Convert the runoff volume for the CPv event to watershed inches.

   Qa = Runoff Volume (CF) x (1 acre / 43,560 SF) x (1 watershed / area [in acres]) x (12 inches / 1 foot)

   Equation 9.13-2-3

   Runoff volume can be taken from the TR-55 output (see Table 9.13-2-1). For this example, the runoff volume for the developed site for the CPv event (1-year storm) is 17,300 CF.

   Qa = 17,300 CF x (1 acre / 43,560 SF) x (1 watershed / 2.5 acres) x (12 inches / 1 foot)

   Qa = 1.91 watershed-inches

   b. Find the unit peak discharge, qu.

   qu = (peak runoff rate in cfs) x [(640 ac/mi2) / (watershed area [in acres])] x [1 / (Qa in watershed inches)]

   Equation 9.13-2-4

Peak runoff rate can be taken from the TR-55 output (see Table 9.13-2-1). For this example, the runoff volume for the developed site for the CPv event (1-year storm) is 8.2 cubic feet per second (cfs).

qu = 8.2 cfs x [(640 ac/mi2) / 2.5 acres] x [1 / 1.91 watershed-inches] = 1,101 cfs / mi2-inch (csm/in)

c. Use Figure C3-S6-1 (from the Small Storm Hydrology ISWMM Section) to find the allowable outflow – inflow ratio (qo/qi).

Using the value for qu calculated in the previous step (1,101 csm/in), draw up to the 24-hour curve and then over to the left axis. The value is off the chart, so a qo/qi value of 0.02 can be used for this example.

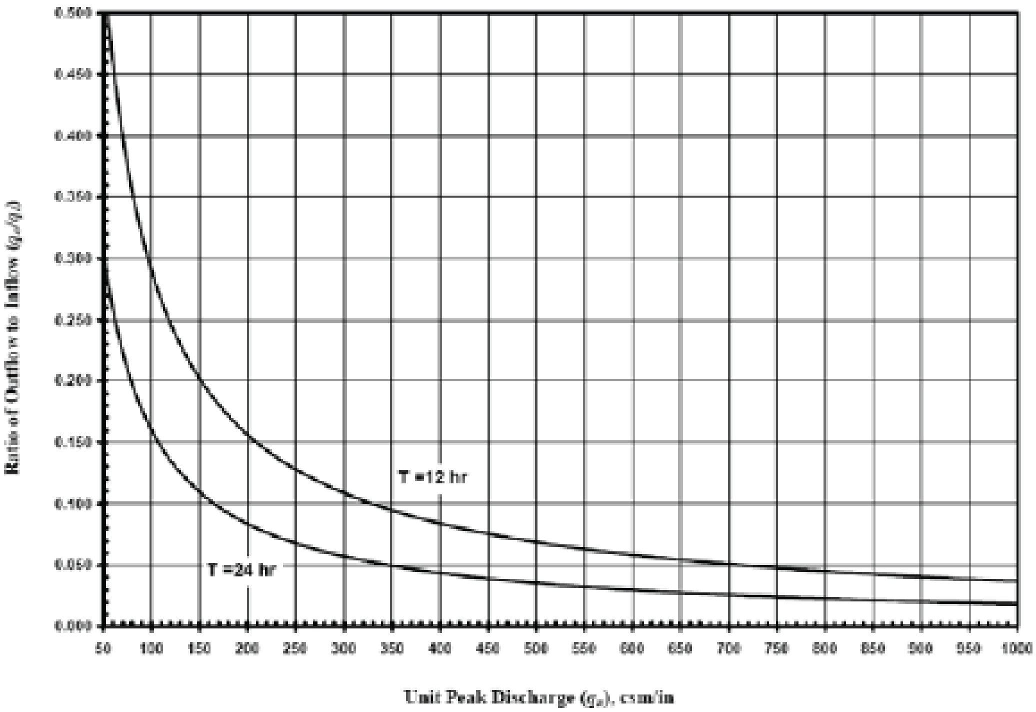


Figure 9.13-2-1. Example of Figure C3-S6-1 Used to Calculate Inflow – Outflow Ratio.

Peak runoff rate (qi) can be taken from the TR-55 output (see Table 9.13-2-1). For this example, the runoff volume for the developed site for the CPv event (1-year storm) is 8.2 cubic feet per second (cfs) (see model output from Step 3). Solving for peak allowable release rate, qo:

qo = (qo / qi) x qi = 0.02 x 8.2 = 0.16 cfs

d. The estimated storage required can be calculated using the equation below:

$$\frac{Vs}{Vr} = 0.683 - 1.43\left(\frac{qo}{qi}\right) + 1.64\left(\frac{qo}{qi}\right)^2 - 0.804\left(\frac{qo}{qi}\right)^3 \quad \text{Equation 9.13-2-5}$$

Solving this equation, with the volume of runoff Vr taken from the TR-55 output (17,300 CF) and the qo/qi ratio found to be 0.02 for this example:

$Vs / Vr = 0.683 – 1.43 (0.02) + 1.64 (0.02)^2 – 0.804 (0.02)^3 = 0.6550$

Vs = (Vs / Vr) x Vr = 0.6550 x 17,300 CF = 11,332 CF

This procedure can be repeated for the larger storm events. The results of the calculations for the larger storm events are summarized below. It is recommended to multiply the estimated storage (Vs) by at least 15% to provide a factor of safety to be used in preliminary sizing of the underground detention system. However, this may need to be increased to 30 or 40% in some cases (see page 25).

Table 9.13-2-3: Summary of Detention Storage Estimation for This Example.

	qo	qi	qo/qi	Vs/Vr	Vr	Vs	Vs *1.15
Storm Event	cfs	cfs			CF	CF	CF
1	0.16	8.2	0.02	0.655	17,300	11,332	13,000
2	2.2	9.8	0.22	0.436	20,900	9,103	10,500
5	3.7	13	0.28	0.390	27,500	10,734	12,300
10	5.1	15	0.34	0.355	33,300	11,814	13,600
25	6.6	19	0.35	0.350	42,300	14,824	17,000
50	6.6	22	0.30	0.380	49,800	18,919	21,800
100	6.6	25	0.26	0.405	57,800	23,408	26,900

5. Determine pre-treatment measures.

   – The pretreatment volume should be 10% of WQv.
   – Pretreatment is required even for facilities that aren't managing the WQv.

Several alternatives for pretreatment could be implemented. If upstream water quality BMPs are proposed to be used to meet WQv requirements upstream of the underground detention system, pretreatment may already be satisfied for those areas, provided that the WQv BMPs are sized to meet the WQv requirements for the areas draining to those practices. Pretreatment does not need to be provided again for areas where those requirements have already been met by another pretreatment or WQv practice. For those cases, refer to the appropriate section of ISWMM to make sure that pretreatment or WQv practices have been appropriately sized.

For this example, we are going to assume that no other upstream practices have been provided to meet the pretreatment requirements.

A preferred approach would be to use some type of pretreatment practice where runoff enters the underground detention system.

For example, a hydrodynamic separator system (HDS) could be used upstream of the underground detention system. Review the Hydrodynamic Separators Section of ISWMM for more information on how to properly select and size an HDS system. In this example, the adjusted CN for the Water Quality event would be found to be 97.

Completing the TR-55 calculation for the 2.5-acre site, with a Tc of 5 minutes and a WQv rainfall event of 1.25 inches, the peak rate of inflow from the site would be found to be 4.1 cfs. That value would need to be used to select a HDS system that could be used as a pretreatment device.

6. Prepare a preliminary layout of the system to identify preliminary stage-storage relationships that exceed the volumes estimated in Step 4. If an isolator row is used to manage WQv, verify that its capacity exceeds 100% of the WQv to be treated. If it is to provide pretreatment in addition to the WQv volume, the capacity should exceed 100% of the WQv to be treated, plus any pretreatment volume to be provided. Design the diversion structure for the isolator row, as applicable.

If upstream pretreatment is provided, the isolator row would need to be sized to contain 8,224 CF (the WQv volume for this example, calculated in Step 2) of runoff. That value could be reduced if upstream water quality BMPs are used to manage part or all of the WQv requirements.

For this example, we will assume that no upstream pretreatment is provided, so the isolator row would need to be able to store 100% of the WQv, plus the pretreatment volume (9,046 CF). The size and shape of the isolator row will depend on the type of system being proposed.

Three options are reviewed here:

Table 9.13-2-4: Isolator Row Options – Trial 1

Option	Height	Storage per Linear Foot (LF)	Target Length for WQv + pretreatment*
StormTech® SC-740 Chamber	30”	6.4 CF/LF	1,414 LF
ChamberMax® Chamber	30”	6.2 CF/LF	1,459 LF
30” Corrugated Metal Pipe (CMP)	30”	4.9 CF/LF	1,846 LF

* Example calculation- 9,046 CF / 6.4 (CF/LF) = 1,414 LF

NOTE

Upstream water quality BMPs can only meet the WQv requirements for the areas draining to those practices. They can't be oversized to earn credit against areas that don't drain to the practice.

Those options were compared because each of these systems are of similar height. However, you can see that there is considerable length of each of these systems required to meet the WQv requirements (and pretreatment requirements in this case). If feasible, using taller chambers would reduce the length of pipe or chambers needed to meet these requirements.

Table 9.13-2-5: Isolator Row Options – Trial 2

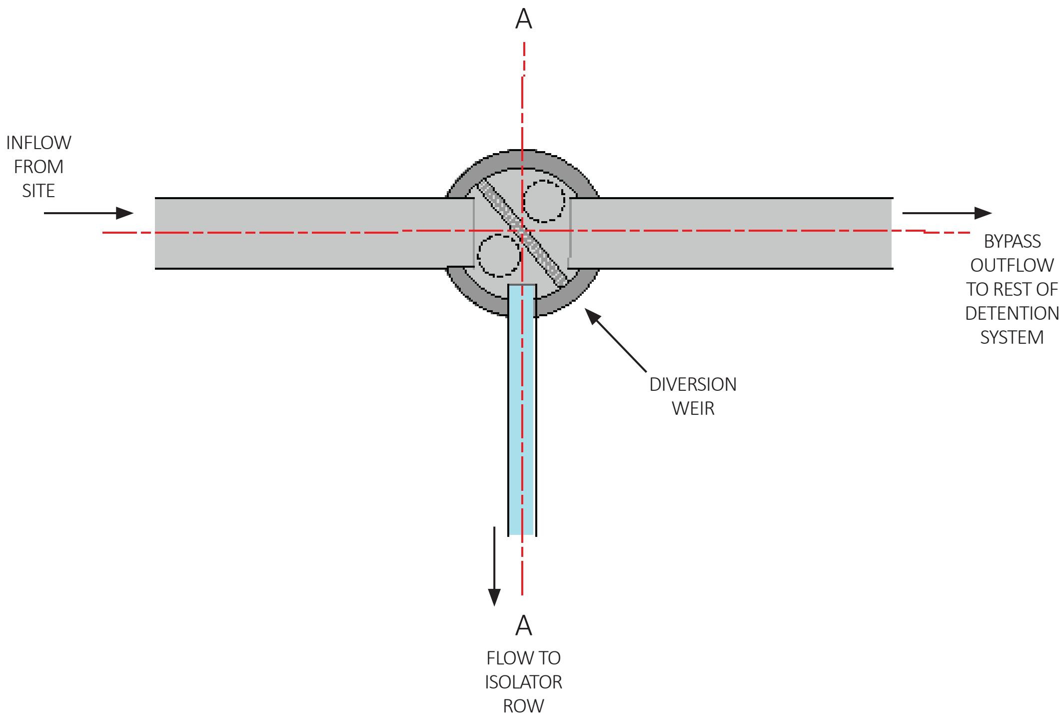
Option	Height	Storage per Linear Foot (LF)	Target Length for WQv + pretreatment*
StormTech® MC-4500 Chamber	60"	24.5 CF/LF	369 LF
60" Corrugated Metal Pipe (CMP)	60"	19.6 CF/LF	461 LF

* Example calculation – 9,046 CF / 24.5 (CF/LF) = 369 LF

Even with these larger sizes, the amount of pipe or chambers required to provide the WQv storage is significant. This is another reason it may be a better approach to use other water quality BMPs upstream of the underground detention system to reduce or eliminate the WQv volume to be addressed by the isolator row.

Design the diversion structure for the isolator row, as applicable.

The diversion structure needs to be designed to direct the entire WQv flow into the isolator row. However, flows from larger events need to be allowed to bypass the isolator row to the rest of the underground detention system.



a. Size the opening to the isolator, using the orifice equation.

$$Q = CA\,(2gh)^{1/2}$$ Equation 9.13-2-6

Where:

Q = WQv peak flow rate to route to the isolator row. For this example, the WQv event peak runoff rate was found in Step 4 as being 4.1 cfs.

C = orifice coefficient (0.60)

A = cross-sectional area of the orifice or pipe opening (square feet)

g = gravitational acceleration constant (32.2 ft/s2)

h = head, which is the elevation difference between the expected elevation of the diversion wall and the center of the orifice or pipe opening to the isolator row (feet)

To make sure the isolator row can be completely filled before flow is diverted to the other parts of the underground detention system, the head should be no less than the height of the isolator row minus the radius of the orifice or pipe that controls flow into the isolator row.

This may require some iteration or trial and error to find the right balance between the desired orifice or pipe opening size and the elevation of the diversion weir.

If we were planning to use a 60-inch tall pipe or chamber system for the isolator row, we could try a 12-inch orifice or pipe opening controlling flow into the isolator row.

This would be a head (h) of 60 inches – 12 inches x (1/2) = 60 inches – 6 inches = 54 inches = 4.5 feet:

The cross-sectional area of a circular opening would be found from the formula:

$$A = \frac{\pi d^2}{4}$$ Equation 9.13-2-7

Where:

A = cross-sectional area of the orifice or pipe opening (square feet)

d = opening diameter (feet)

$$A = \frac{\pi(1\,foot)^2}{4}$$

A= 0.785 square feet

Use that value of A to solve for the capacity of the opening, with "h" chosen to be 4.5 feet as noted above:

$$Q = CA\,(2gh)^{1/2}$$

$$Q = (0.60)(0.785)\,(2 * 32.2 * 4.5)^{1/2}$$

$$Q = 8.0\ cfs$$

Since the capacity of the opening (8.0 cfs) is greater than the WQv peak flow event (4.1 cfs), this design will work. In this case, a higher flow rate into the isolator row is not too concerning, as it only has the volume capacity to capture the WQv event. Once the chamber is full, flow will have to divert over the weir wall into the rest of the underground detention system.

b. Size the length of the weir needed to convey the bypass flow. The weir should be wide enough that the design flow being directed to the underground detention system can physically pass over the weir within the structure and not cause significant backflow in the upstream storm system.

Flow over a weir can be solved by the following equation:

$$Q = C\,L\,H^{3/2}$$

Equation 9.13-2-8

Where:

Q = Flow to pass over the weir (cfs)

C = weir coefficient (3.3 for a sharp-crested weir)

L = length of the weir, measured perpendicular to flow over the wall (feet)

H = head, which is the elevation difference between the expected high-water elevation of water immediately upstream of the weir and the top elevation of the weir (feet)

For this example, the peak rate for the 100-year storm event needs to be diverted into the underground detention system. From the TR-55 model, the peak flow from the developed site was found to be 25 cfs.

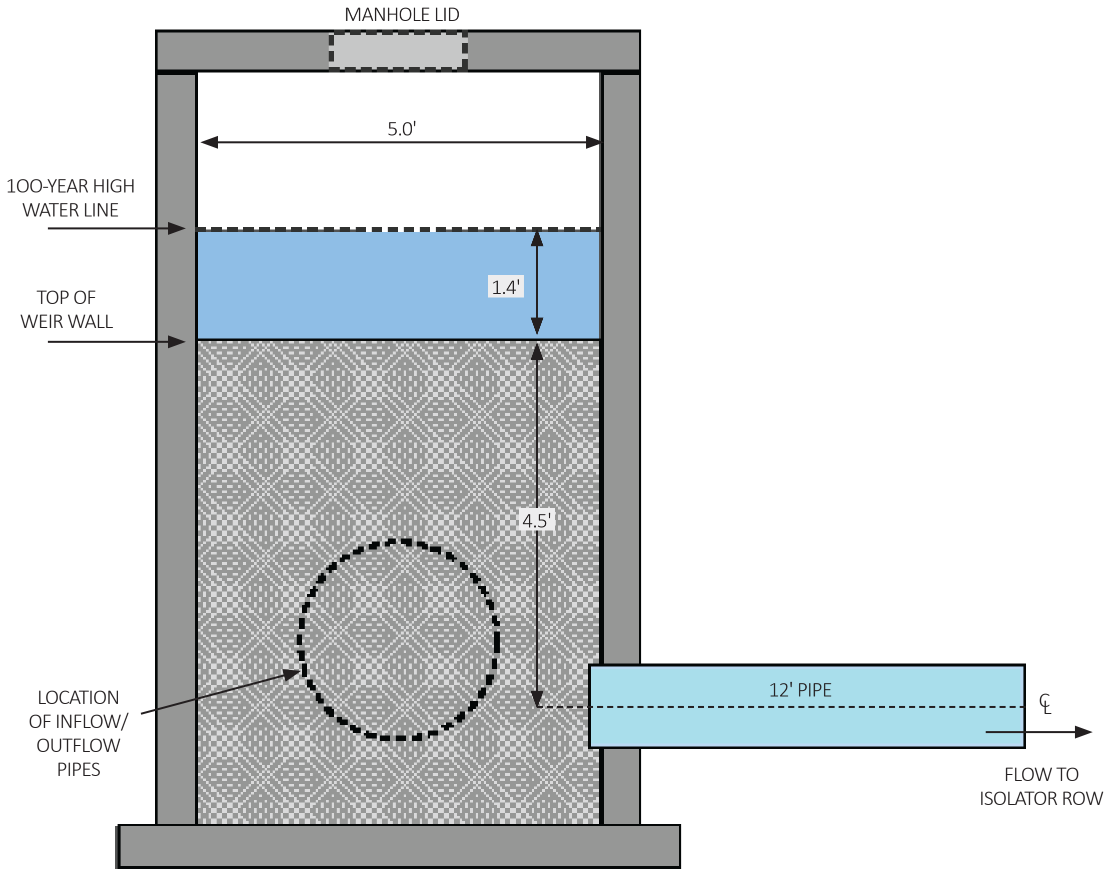
If the designer were to try a 5-foot long weir, with a head of 1.4 feet:

$$Q = (3.3)\,(5\,ft)(1.4\,ft)^{3/2}$$

$$Q = 27.3\ cf$$

Since the capacity of over the weir (27.3 cfs) is greater than the 100-year peak flow (25 cfs), this design will work. The designer should also recheck that this design high-water level will not create a **tailwater** condition for the upstream storm network that would prevent it from being able to convey the design storm event.

SECTION A-A



7. Enter the preliminary stage-storage relationships and outlet configurations into a TR-55 software program and route inflow hydrographs through the preliminary detention system design. Identify the projected release rates for each event studied.

- The stage-storage relationships will vary considerably depending on the type of pipe or chamber system used.
- When a proprietary system is selected, use the manufacturer's guidelines to determine the specific stage-storage relationships.
- Storage should be evaluated at frequent intervals, at least at 0.5 foot intervals, measured vertically. Detailed calculations of storage should be provided for review.
- Aggregate storage outside of the pipes or chambers may be counted as long as there are perforations or an open bottom to the chamber allowing the free movement of water between the pipes / chambers and the aggregate layers. Aggregate materials as recommended by this section have an assumed porosity of 0.35.

NOTE

The pipe to the isolator row may be designed to be larger than the minimum size needed to allow flow into the isolator row.

Table 9.13-2-6: Stage-Storage Relationship for This Example.

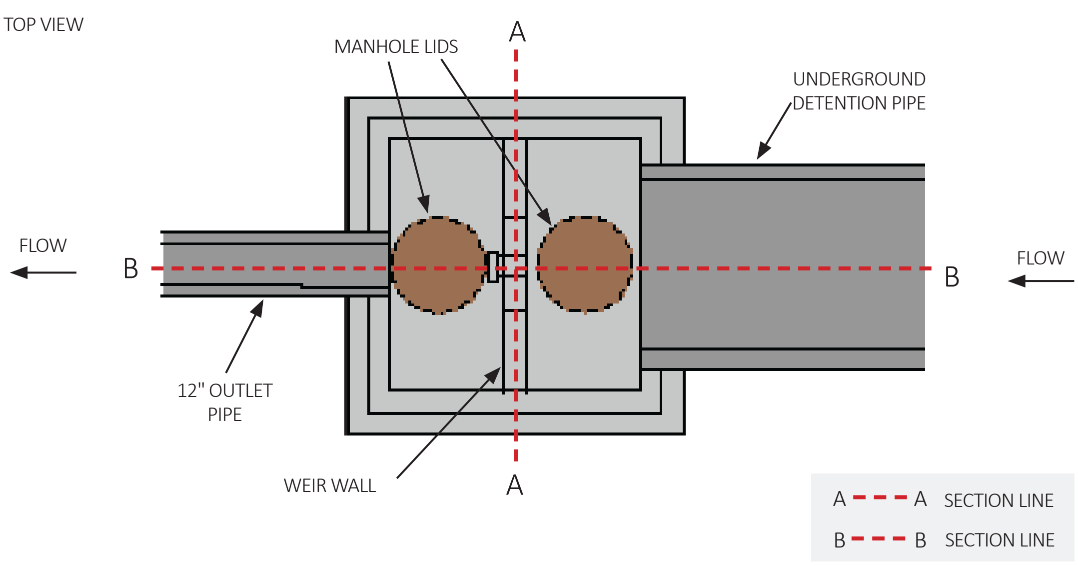
Row	Stage	Elevation	Contour Area	Incremental Storage	Total Storage	Total Discharge
	(ft)	(ft)	(sq ft)	(cu ft)	(cu ft)	(cfs)
0	0.00	100.00	n/a	0.0000	0.0000	0.0000
1	0.50	100.50	n/a	1,739	1,739	0.134
2	1.00	101.00	n/a	2,091	3,830	0.208
3	1.50	101.50	n/a	2,271	6,101	0.264
4	2.00	102.00	n/a	2,374	8,474	3.854
5	2.50	102.50	n/a	2,423	10,898	4.519
6	3.00	103.00	n/a	2,423	13,321	5.048
7	3.50	103.50	n/a	2,373	15,694	5.489
8	4.00	104.00	n/a	2,271	17,965	5.911
9	4.50	104.50	n/a	2,091	20,056	6.246
10	5.00	105.00	n/a	1,738	21,794	6.652

For this example, the outlet is configured as follows:

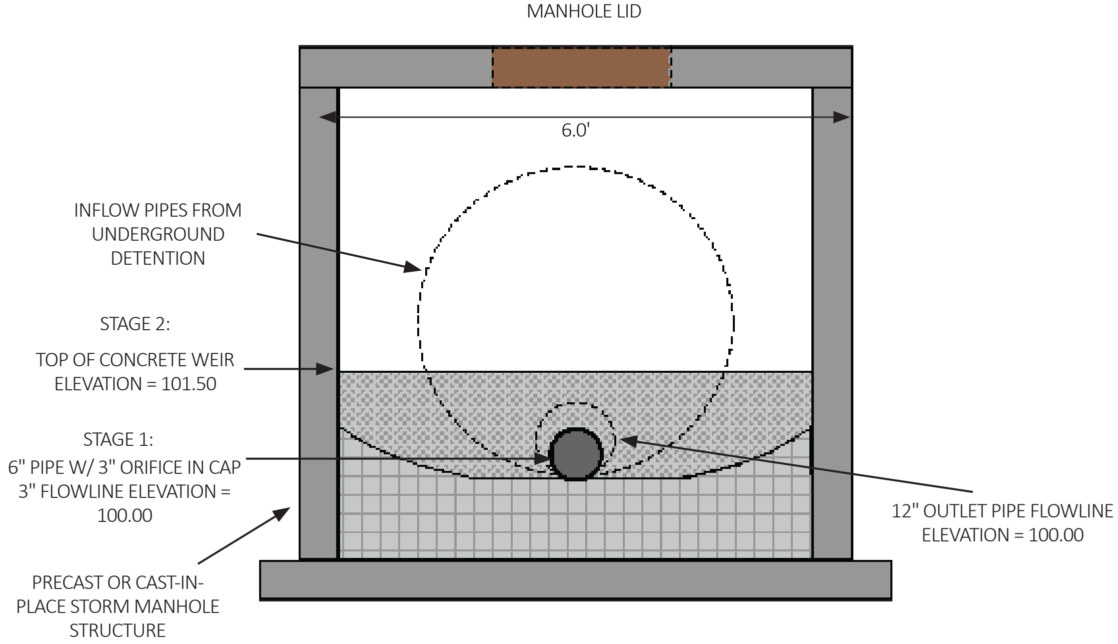
- Stage 1: 3" orifice at end of 6" pipe set in weir wall at bottom of underground detention system (elevation 100.0)
- Stage 2: 6' wide weir wall at elevation 101.5 (set to be above the expected high-water elevation for the Channel Protection volume (CPv) or 1-year storm event.)
- Stage 3: Principal spillway out of outfall structure (downstream of weir wall), protected with 11" orifice in plate over pipe opening (elevation 100.0)

8. Review projected release rates from Step 7 for the preliminary design. Verify that the projected rates are less

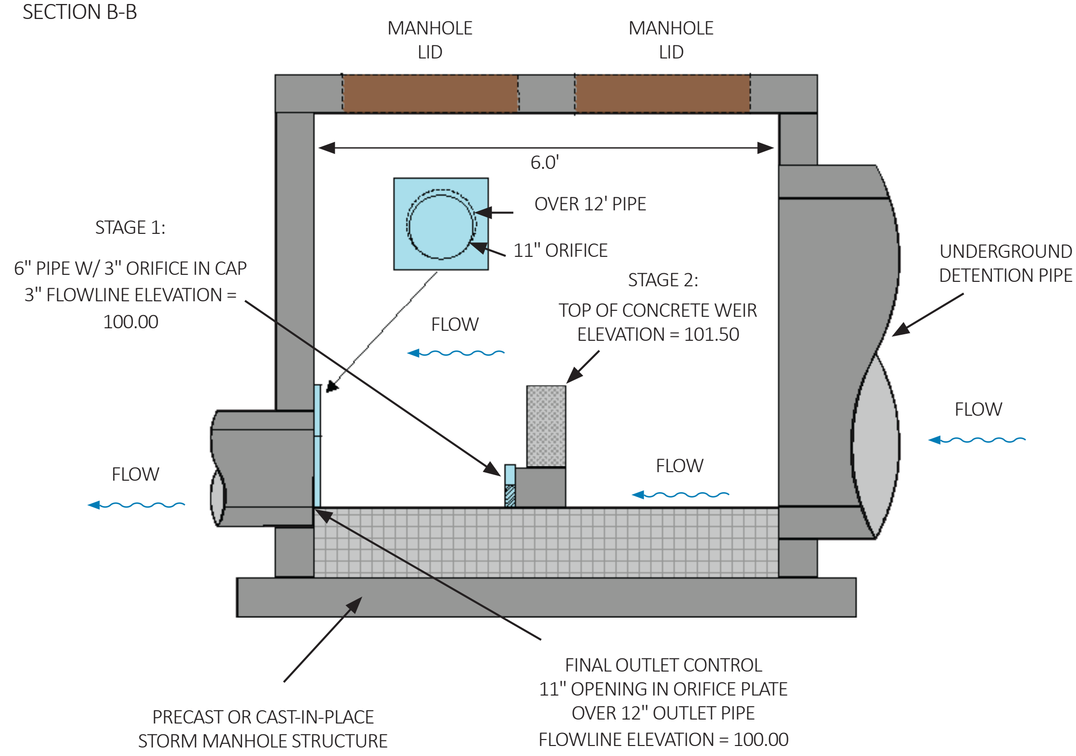
ILLUSTRATIONS OF OUTLET STRUCTURE
DESIGN FOR THIS EXAMPLE



SECTION A-A



SECTION B-B



than the allowable rates calculated as part of the estimation procedure referred to in Step 4. Iterate as needed, adjusting staged outlet controls or stage-storage relationships within the software program to meet required release rate restrictions.

Table 9.13-2-7: Modeling Results for This Example.

Storm Event	Allowed	Out	High Water Elevation	Max. Temp. Storage	Max. Temp. Storage
	(cfs)	(cfs)	(feet)	(CF)	(watershed-inches)
1-year (CPv)	0.2	0.2	101.3	14,100	1.6
2-year	2.2	0.7	101.6	15,600	1.7
5-year	3.7	3.7	102.0	17,300	1.9
10-year	5.1	4.5	102.5	19,900	2.2
25-year	6.6	5.3	103.4	24,100	2.7
50-year	6.6	6.0	104.1	27,500	3.0
100-year	6.6	6.6	105.0	30,900	3.4

Table 9.13-2-8: Additional Modeling Results for This Example.

	Max Rainfall Volume Stored	Peak Delay In vs. Out	Peak Flow Reduction In Vs. Out Reduction	Initial Storage Estimate*	Final Storage Routing Result	Final/ Estimate
Storm Event	%	In vs. Out (min)	In vs. Out (%)	(CF)	(CF)	
CPv (1-year)	58.2%	125	97.6%	11,332	14,100	1.24
2-year	55.8%	36	92.9%	9,103	15,600	1.71
5-year	50.0%	8	71.5%	10,734	17,300	1.61
10-year	49.2%	8	70.0%	11,814	19,900	1.68
25-year	48.8%	8	72.1%	14,824	24,100	1.63
50-year	48.4%	8	72.7%	18,919	27,500	1.45
100-year	47.8%	8	73.6%	23,408	30,900	1.32

*Original "Vs" Storage Estimate Without Safety Factor

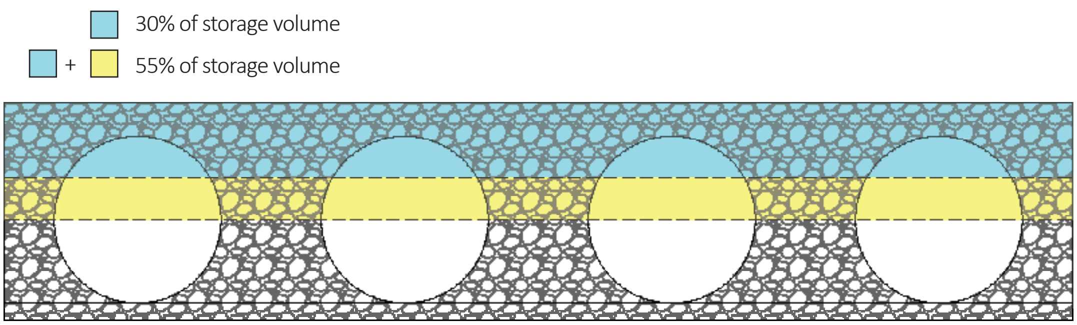
For each storm event, the proposed release rate is less than or the same as the allowable value, so this design example works. In most cases it is necessary to iterate options for outlet configurations and storage to meet project goals and to make the system as efficient as it can be.

The storage volumes noted above include the storage in both the isolator row and the rest of the detention system. The isolator row fills first, spilling over into the rest of the system once it is full.

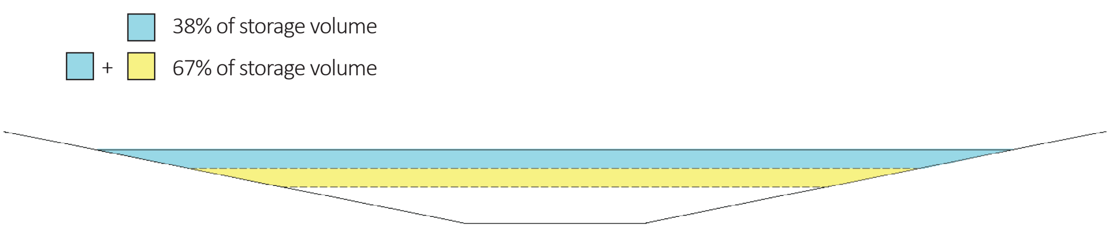
Note that in the final column of Table 9.13-2-8, the final storage volume found in this example is 32% higher than the original estimate (without the 15% factor of safety recommended for other stormwater detention systems).

Underground systems constructed from pipes or other structures with curved tops don't provide as much storage near the top of the system. The top of the system is where the outlet can release more runoff, since the head pressure on the outlet is greater, allowing more flow to pass through.

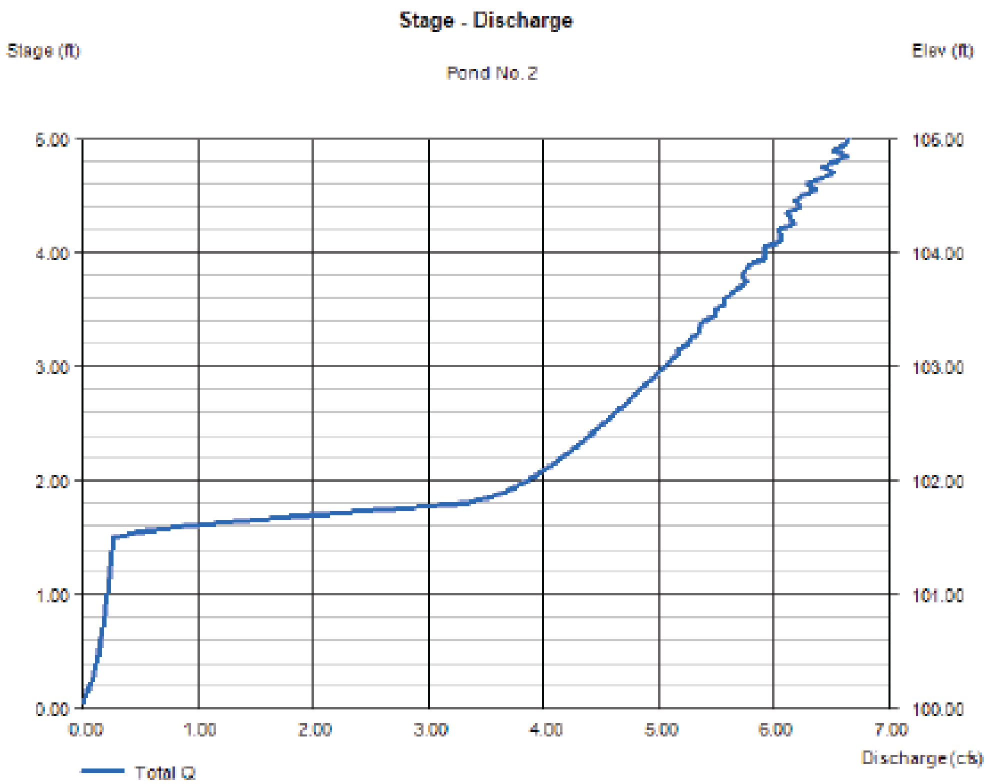
UNDERGROUND DETENTION SYSTEM



DRY DETENTION BASIN



The total storage of each of these detention practices is essentially the same, but more of the storage in the dry basin is held in the shaded areas in the top of the basin, where there is more elevation head available to push water through the outlet. This makes underground detention systems less efficient and may require more storage volume to achieve the same release rate reductions for larger storm events.



This is different than above ground systems which usually have larger incremental increases in volume as you get to the top of the basin. So, when designing underground detention systems, it may be wise to use a factor of safety of 30-40% when using the method in Step 4 to estimate required storage.

NOTE

Some jurisdictions in Iowa have more specific outlet velocity requirements.

9. Check outflow velocities at pipe outfalls and spillways. Adjust sizing or geometry, or add erosion protection features as needed for the 100-year, 24-hour event.

- From the continuity equation, determine pipe velocity based on flow rate (Q) and area (A) [V = Q/A]
- The expected release rate during the 100-year event is 6.6 cfs.
- If a 12-inch pipe is used downstream of the 11-inch orifice the velocity can be solved as:

  A = π r2 = π (0.5 foot)2 = 0.785 square feet (SF)

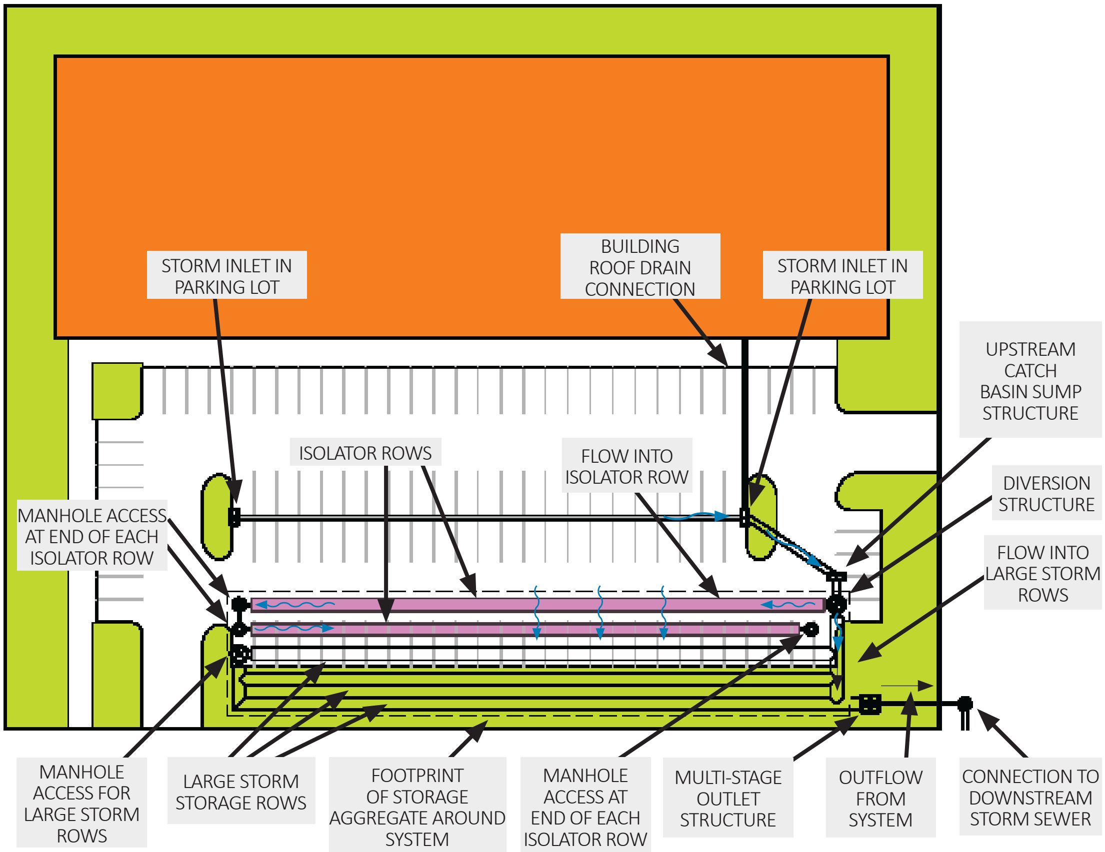
  V = Q / A = 6.6 cfs / 0.785 SF = 8.4 feet per second (fps)

If the 12-inch pipe discharges to the surface, appropriate scour protection would need to be provided to protect the surface at that location. If velocity (V) was found to be greater than 10 fps, the designer may wish to increase the outlet pipe size to reduce the velocity within the pipe, while maintaining the orifice size upstream.

10. Check that a safe overflow path is provided for events larger than the 100-year storm event. Identify the overflow path of the drawings for the proposed site.

The site grading plan would need to be reviewed for this step. The catastrophic overflow path should be designated to makes sure no structures or other property might be damaged if storms larger than the 100-year storm event occur or if the system inlet or outlet points were blocked.

Complete design checklists at the end of this section to verify that sizing design criteria have been satisfied. Proceed to development of detailed plans and specifications. After completion of final design, make any adjustments as needed so that final plan information matches the finished calculation report.



NOTE

This example needs two isolator rows, to be able to store the WQv, since no upstream BMPs are planned.

EXAMPLE #2 – UPSTREAM WATER QUALITY / PRETREATMENT PROVIDED

For the same site conditions used in the previous example, let us assume that the other water quality BMPs (bioretention cells, permeable pavers, etc.) are being used to address 80% of the pretreatment and 60% of the water quality volume requirements for the area that is draining to the underground detention system.

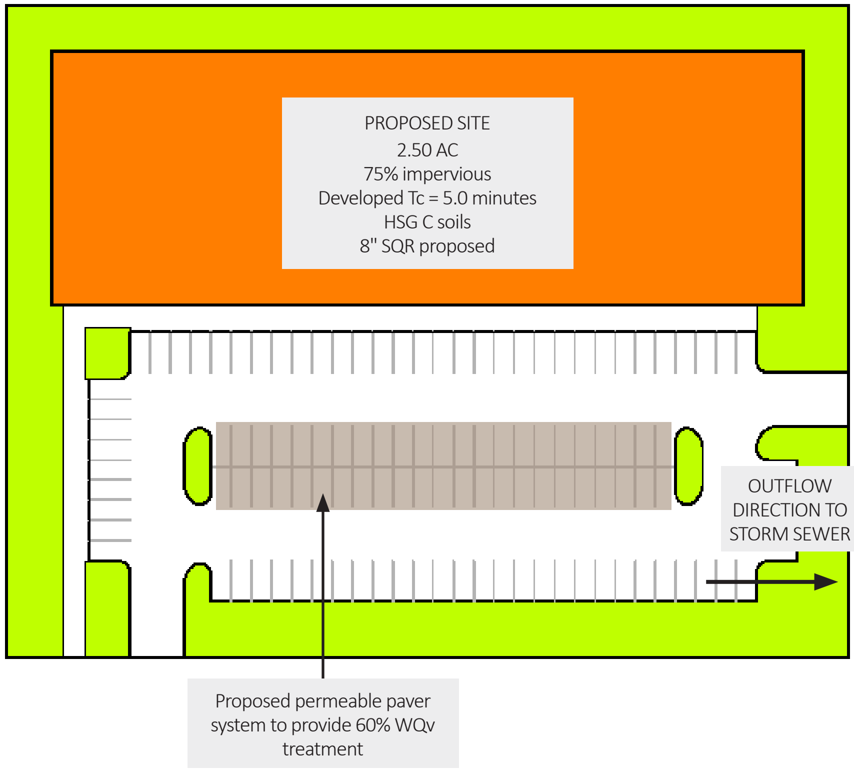
1. Determine if the development site and conditions are appropriate for the use of a underground detention system. Consider the Application and Feasibility criteria in Section 9.13-1.

   For this example, it is given that the site conditions are appropriate for an underground detention system.

2. Calculate the pretreatment volume or Water Quality volume to be provided (if applicable).

Water Quality volume calculations:

- Runoff coefficient (Rv) = 0.05 + 0.009 (I) I = **impervious cover** (%) Equation 9.13-2-1
  - Rv = 0.05 + 0.009 (75) = 0.725
- Water Quality volume (WQv) = Rv x P Equation 9.13-2-2
  - P = WQv precipitation (1.25 inches)
  - WQv = Rv x P = 0.725 x 1.25 inches = 0.906 watershed-inches (site total)
    - » = 0.906 watershed-inches x 2.50 acres x 43,560 (square feet / acre) / 12 (inches / foot)
    - » = 8,224 CF (cubic feet)
  - If 60% of WQv is managed upstream:
  - WQv to treat in isolator row = (100% - 60%) x 8,224 CF = 3,290 CF
- Required pretreatment volume = 10% of Water Quality volume (WQv)
  - Pretreatment volume = WQv x 10% = 8,224 CF x 10% = 822 CF (site total)
  - If 80% of pretreatment is provided upstream:
  - Pretreatment required in isolator row = (100% - 80%) x 822 CF = 165 CF



3. Develop a stormwater model (TR-55) for the watershed area for the practice. The model should determine peak flow rates and volumes for the proposed conditions, as well as the natural and existing conditions as needed to determine the allowable release rates, based on local jurisdictional requirements. Refer to Section 9.02-2.A for the events to be studied and Section 9.03 for use of modeling software.

These results would be unchanged from the previous example, unless the upstream BMPs provide some level of flow reduction through detention storage. In such a case, the results of detention routing might impact the developed values for inflow rate or volume in the table below.

Table 9.13-2-9: Summary of TR-55 Results for This Example

		Natural		Existing		Developed	
	Rainfall	Peak Rate	Volume	Peak Rate	Volume	Peak Rate	Volume
Storm Event	Inches	cfs	CF	cfs	CF	cfs	CF
1	2.67	1.5	5,200	3.5	9,700	8.2	17,300
2	3.08	2.2	7,200	4.6	12,500	9.8	20,900
5	3.81	3.7	11,400	6.6	17,800	13	27,500
10	4.46	5.1	15,400	8.5	22,800	15	33,300
25	5.44	7.4	22,000	11	30,600	19	42,300
50	6.26	9.4	27,900	14	37,400	22	49,800
100	7.12	12	34,300	16	44,600	25	57,800

- For this example, assume that local requirements are to meet the Unified Sizing Criteria requirements, with the events larger than the CPv event required to restrict outflow rates to the peak flow rate for the same storm event for natural conditions, or the peak flow rate for the 5-year storm event based on existing conditions, whichever is less.

Table 9.13-2-10: Summary of Allowable Release Rates for This Example

Storm Event	Allowable Release Rate (cfs)	Condition Based On
2-year	2.2	natural, same event
5-year	3.7	natural, same event
10-year	5.1	natural, same event
25-year	6.6	existing, 5-year event
50-year	6.6	existing, 5-year event
100-year	6.6	existing, 5-year event

4. Estimate required storage volumes to meet the aspects of the Unified Sizing Criteria to be managed by the practice.

These results would be unchanged from the previous example, unless the upstream BMPs provide some level of flow reduction through detention storage of the CPv event. In such a case, the results of detention routing might impact the developed values for inflow rate or volume in the table below.

a. Convert the runoff volume for the CPv event to watershed inches.

Qa = 17,300 CF x (1 acre / 43,560 SF) x (1 watershed / 2.5 acres) x (12 inches / 1 foot)

Qa = 1.91 watershed-inches

b. Find the unit peak discharge, qu.

qu = 8.2 cfs x [(640 ac/mi2) / 2.5 acres] x [1 / 1.91 watershed-inches] = 1,101 cfs / mi2-inch (csm/in)

c. Use Figure C3-S6-1 (from the Small Storm Hydrology ISWMM Section) to find the allowable outflow – inflow ratio (qo/qi).

As solved previously, the qo/qi ratio for this example was 0.02.

qo = (qo / qi) x qi = 0.02 x 8.2 = 0.16 cfs

d. The estimated storage required can be calculated using the equation below:

$$\frac{Vs}{Vr} = 0.683 - 1.43\left(\frac{qo}{qi}\right) + 1.64\left(\frac{qo}{qi}\right)^2 - 0.804\left(\frac{qo}{qi}\right)^3 \quad \text{Equation 9.13-2-5}$$

Solving this equation, with the volume of runoff Vr taken from the TR-55 output (17,300 CF) and the qo/qi ratio found to be 0.02 for this example:

Vs / Vr = 0.683 – 1.43 (0.02) + 1.64 (0.02)2 – 0.804 (0.02)3 = 0.6550

Vs = (Vs / Vr) x Vr = 0.6550 x 17,300 CF = 11,332 CF

This procedure can be repeated for the larger storm events. The results of the calculations for the larger storm events are summarized below. It is recommended to multiply the estimated storage (Vs) by 15% to provide a factor of safety to be used in preliminary sizing of the underground detention system.

Table 9.13-2-11: Summary of Detention Storage Estimation for This Example.

	qo	qi	qo/qi	Vs/Vr	Vr	Vs	Vs *1.15
Storm Event	cfs	cfs			CF	CF	CF
1	0.16	8.2	0.02	0.655	17,300	11,332	13,000
2	2.2	9.8	0.22	0.436	20,900	9,103	10,500
5	3.7	13	0.28	0.390	27,500	10,734	12,300
10	5.1	15	0.34	0.355	33,300	11,814	13,600
25	6.6	19	0.35	0.350	42,300	14,824	17,000
50	6.6	22	0.30	0.380	49,800	18,919	21,800
100	6.6	25	0.26	0.405	57,800	23,408	26,900

5. Determine pre-treatment measures.

- The pretreatment volume should be 10% of WQv.
- Pretreatment is required even for facilities that aren't managing the WQv.

For this example, it is given that 80% of the pretreatment volume is addressed by upstream practices, and 60% of the WQv volume is being addressed by upstream water quality BMPs.

6. Prepare a preliminary layout of the system to identify preliminary stage-storage relationships that exceed the volumes estimated in Step 4. If an isolator row is used to manage WQv, verify that its capacity exceeds 100% of the WQv to be treated. If it is to provide pretreatment in addition to the WQv volume, the capacity should exceed 100% of the WQv to be treated, plus any pretreatment volume to be provided. Design the diversion structure for the isolator row, as applicable.

For this example, the remaining water quality volume to be treated is 3,290 CF and the pretreatment volume is 165 CF (both values are found in Step 2 of this example), so the total volume to include in the isolator row is 3,455 CF.

Two options are reviewed here:

Table 9.13-2-12: Isolator Row Options

Option	Height	Storage per Linear Foot (LF)	Target Length for WQv + pretreatment*
StormTech® MC-4500 Chamber	60”	24.5 CF/LF	142 LF
60” Corrugated Metal Pipe (CMP)	60”	19.6 CF/LF	177 LF

*Example calculation - 3,455 CF / 24.5 (CF/LF) = 142 LF

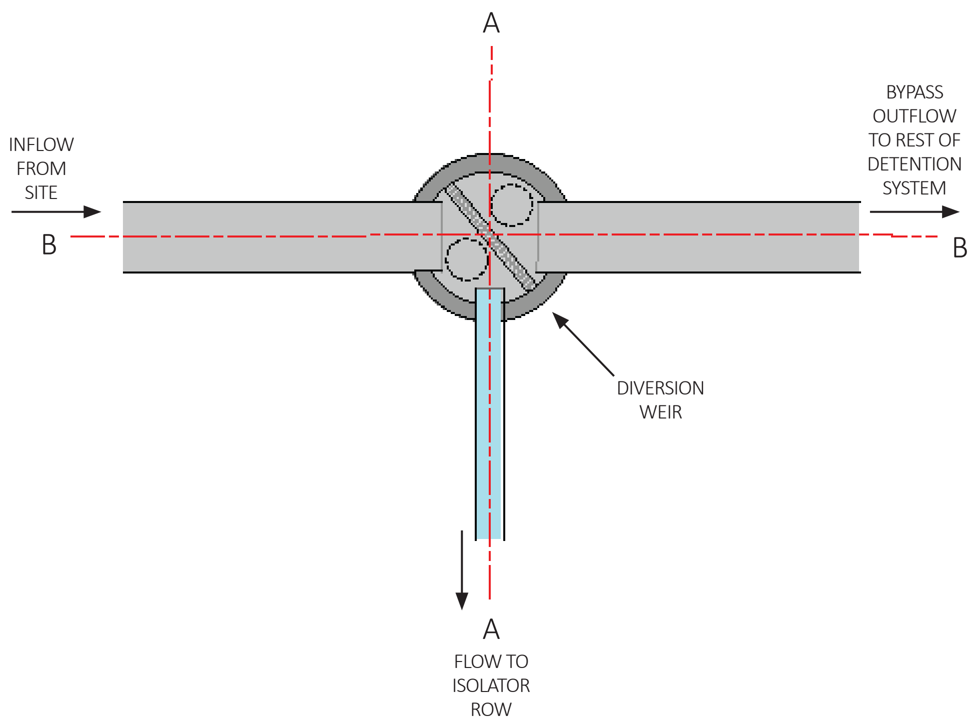
NOTE

This example has been the same as example #1 up to Step 5.

This example includes upstream practices, which reduce the required pretreatment and WQv volumes.

Design the diversion structure for the isolator row, as applicable.

The diversion structure needs to be designed to direct the entire WQv flow into the isolator row. However, flows from larger events need to be allowed to bypass the isolator row to the rest of the underground detention system.



Completing the TR-55 calculation for the 2.5-acre site, with a Tc of 5 minutes and a WQv rainfall event of 1.25 inches, the peak rate of inflow from the site would be found to be 4.1 cfs. The upstream water quality BMPs are given as managing 60% of the WQv volume requirements for this example. There would be assumed to be no direct surface runoff from those areas during the WQv event.

Therefore, the WQv peak rate to the isolator row can be solved by:

WQv peak rate (site total, cfs) x (100% - % WQv treated upstream) = remaining WQv peak rate (cfs)

Equation 9.13-2-9

Remaining WQv peak rate (cfs) = 4.1 cfs x (100% - 60%) = 1.64 cfs

a. Size the opening to the isolator, using the orifice equation.

$$Q = CA\,(2gh)^{1/2}$$

Equation 9.13-2-6

Where:

Q = WQv peak flow rate to route to the isolator row. For this example, the WQv event peak runoff rate was found in Step 6 as being 1.6 cfs.

C = orifice coefficient (0.60)

A = cross-sectional area of the orifice or pipe opening (square feet)

g = gravitational acceleration constant (32.2 ft/s2)

h = head, which is the elevation difference between the expected elevation of the diversion wall and the center of the orifice or pipe opening to the isolator row (feet)

If we were planning to use a 60-inch tall pipe or chamber system for the isolator row, we could try a 12-inch orifice or pipe opening controlling flow into the isolator row.

This would be a head (h) of 60 inches – 12 inches x (1/2) = 60 inches – 6 inches = 54 inches = 4.5 feet:

The cross-sectional area of a circular opening would be found from the formula:

$$A = \frac{\pi d^2}{4}$$

Equation 9.13-2-7

Where:

A = cross-sectional area of the orifice or pipe opening (square feet)

d = opening diameter (feet)

$$A = \frac{\pi\,(1\ feet)^2}{4}$$

$$A = 0.785\ square\ feet$$

Use that value of A to solve for the capacity of the opening, with “h” chosen to be 4.5 feet as noted above:

$$Q = CA\,(2gh)^{1/2}$$

$$Q = (0.60)(0.785)\,(2 * 32.2 * 4.5)^{1/2}$$

$$Q = 8.0\ cfs$$

Since the capacity of the opening (8.0 cfs) is greater than the WQv peak flow event (1.64 cfs), this design will work. In this case, a higher flow rate into the isolator row is not too concerning, as it only has the volume capacity to capture the WQv event. Once the chamber is full, flow will have to divert over the weir wall into the rest of the underground detention system.

b. Size the length of the weir needed to convey the bypass flow. The weir should be wide enough that the design flow for the storm sewer that exceeds the flow being directed to the underground detention system can physically pass over the weir within the structure and not cause significant backflow in the upstream storm system.

These results would be unchanged from the previous example, unless the upstream BMPs provide some level of flow reduction through detention storage of the 10-year storm event. In such a case, the results of detention routing might impact the value for inflow rate used in the design process below.

Flow over a weir can be solved by the following equation:

$$Q = C\,L\,H^{3/2}$$

Equation 9.13-2-8

For this example, the peak rate for the 100-year storm event needs to be diverted into the underground detention system. From the TR-55 model, the peak flow from the developed site was found to be 25 cfs.

If the designer were to try a 5-foot long weir, with a head of 1.4 feet:

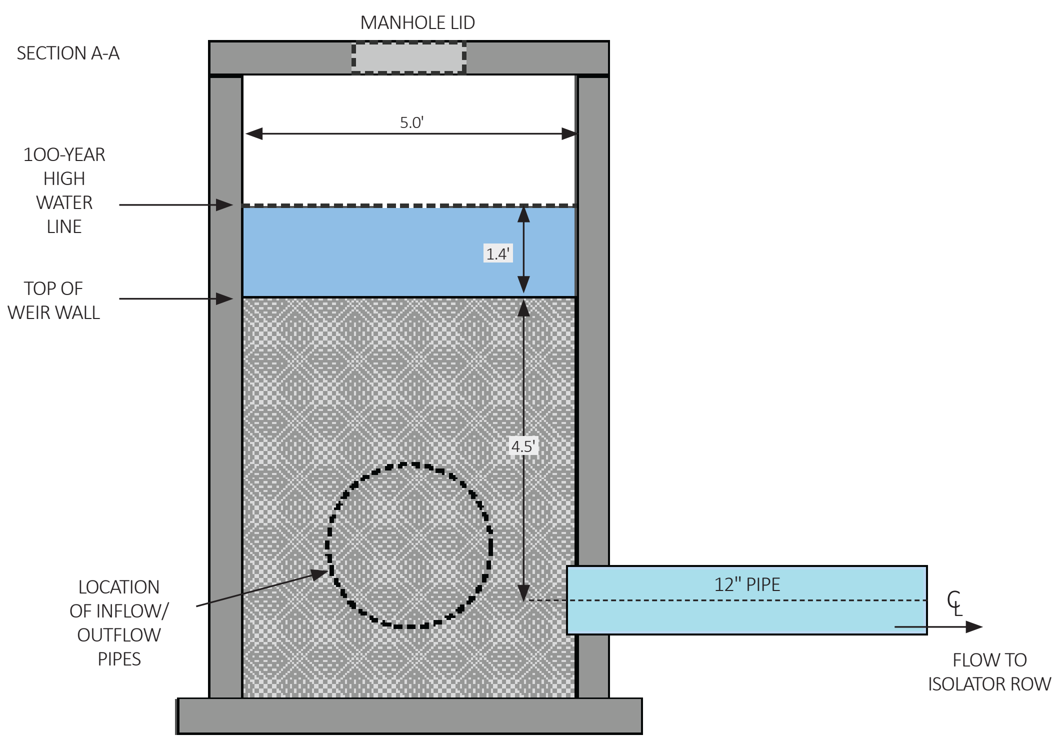
$$Q = (3.3)(5\,ft)(1.4\,ft)^{3/2}$$

$$Q = 27.3\,cf$$

Since the capacity of over the weir (27.3 cfs) is greater than the 100-year peak flow (25 cfs), this design will work. The designer should also recheck that this design high-water level will not create a tailwater condition for the upstream storm network that would prevent it from being able to convey the design storm event.

NOTE

The pipe to the isolator row may be designed to be larger than the minimum size needed to allow flow into the isolator row.



7. Enter the preliminary stage-storage relationships and outlet configurations into a TR-55 software program and route inflow hydrographs through the preliminary detention system design. Identify the projected release rates for each event studied.

- The stage-storage relationships will vary considerably depending on the type of pipe or chamber system used.
- When a proprietary system is selected, use the manufacturer's guidelines to determine the specific stage-storage relationships.
- Storage should be evaluated at frequent intervals, at least at 0.5 foot intervals, measured vertically. Detailed calculations of storage should be provided for review.
- Aggregate storage outside of the pipes or chambers may be counted as long as there are perforations or an open bottom to the chamber allowing the free movement of water between the pipes / chambers and the aggregate layers. Aggregate materials as recommended by this section have an assumed porosity of 0.35.

Table 9.13-2-13: Stage-Storage Relationship for This Example (Adjusted from Example #1).

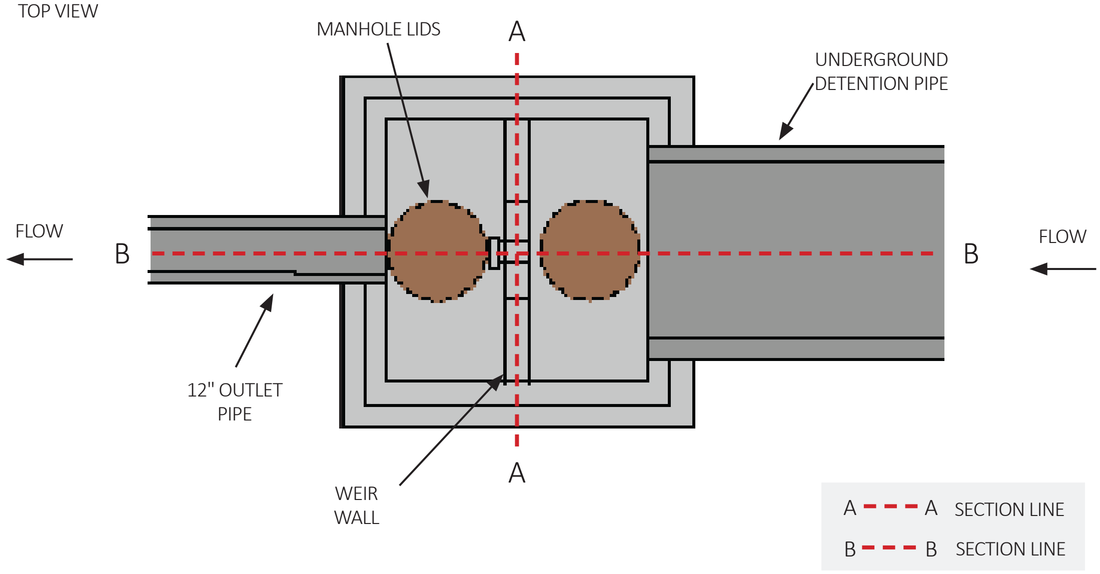
Row	Stage	Elevation	Contour Area	Incremental Storage	Total Storage	Total Discharge
	(ft)	(ft)	(sq ft)	(cu ft)	(cu ft)	(cfs)
0	0.00	100.00	n/a	0.0000	0.0000	0.0000
1	0.50	100.50	n/a	1,932	1,932	0.134
2	1.00	101.00	n/a	2,324	4,255	0.208
3	1.50	101.50	n/a	2,523	6,779	0.264
4	2.00	102.00	n/a	2,637	9,416	1.216
5	2.50	102.50	n/a	2,693	12,109	4.140
6	3.00	103.00	n/a	2,693	14,801	5.024
7	3.50	103.50	n/a	2,637	17,438	5.519
8	4.00	104.00	n/a	2,523	19,961	5.952
9	4.50	104.50	n/a	2,323	22,284	6.352
10	5.00	105.00	n/a	1,931	24,215	6.643

For this example, the outlet is configured as follows:

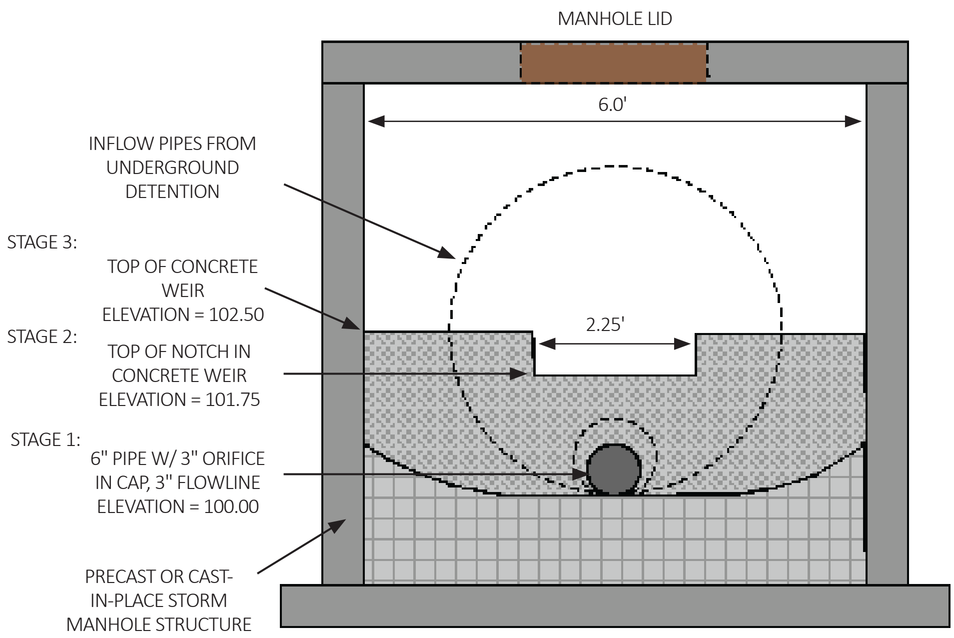
- Stage 1: 3" orifice at end of 6" pipe set in weir wall at bottom of underground detention system (elevation 100.0)
- Stage 2: 2.25-ft wide weir wall at elevation 101.75 (set to be above the expected high-water elevation for the Channel Protection volume (CPv) or 1-year storm event.)
- Stage 3: 3.75-ft wide weir wall at elevation 102.5
- Stage 4: Principal spillway out of outfall structure (downstream of weir wall), protected with 11" orifice in plate over pipe opening at elevation 100.0

ILLUSTRATIONS OF OUTLET STRUCTURE DESIGN FOR THIS EXAMPLE

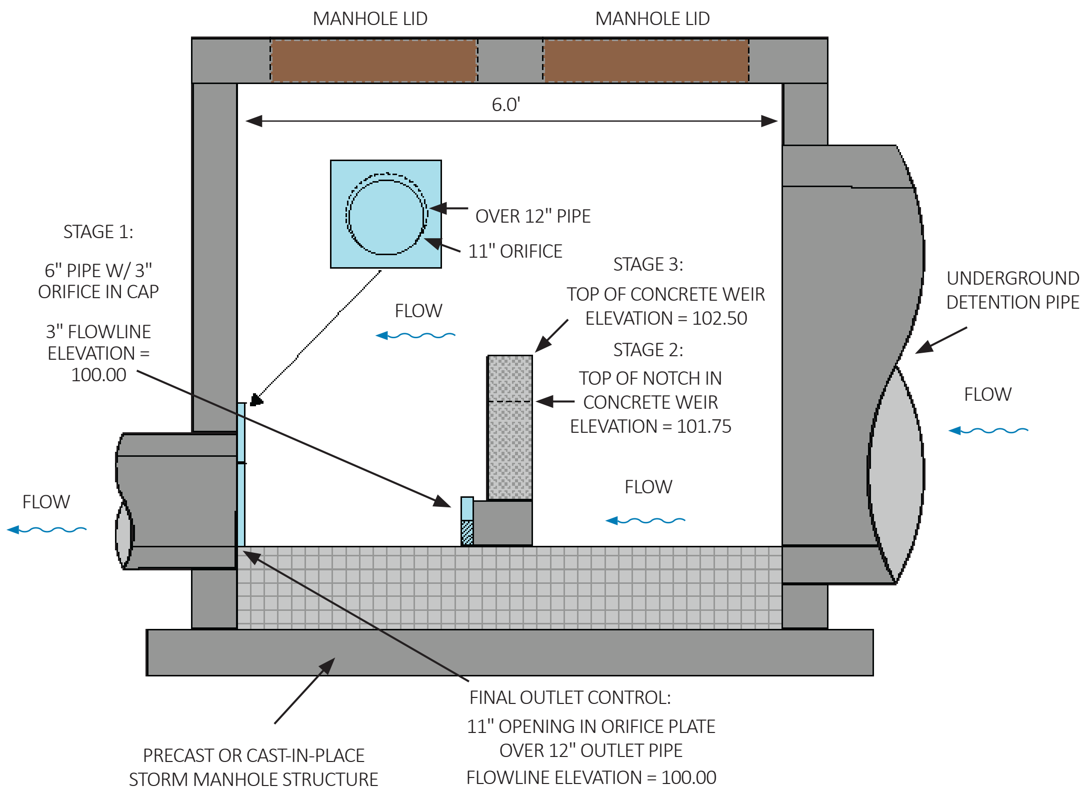
TOP VIEW

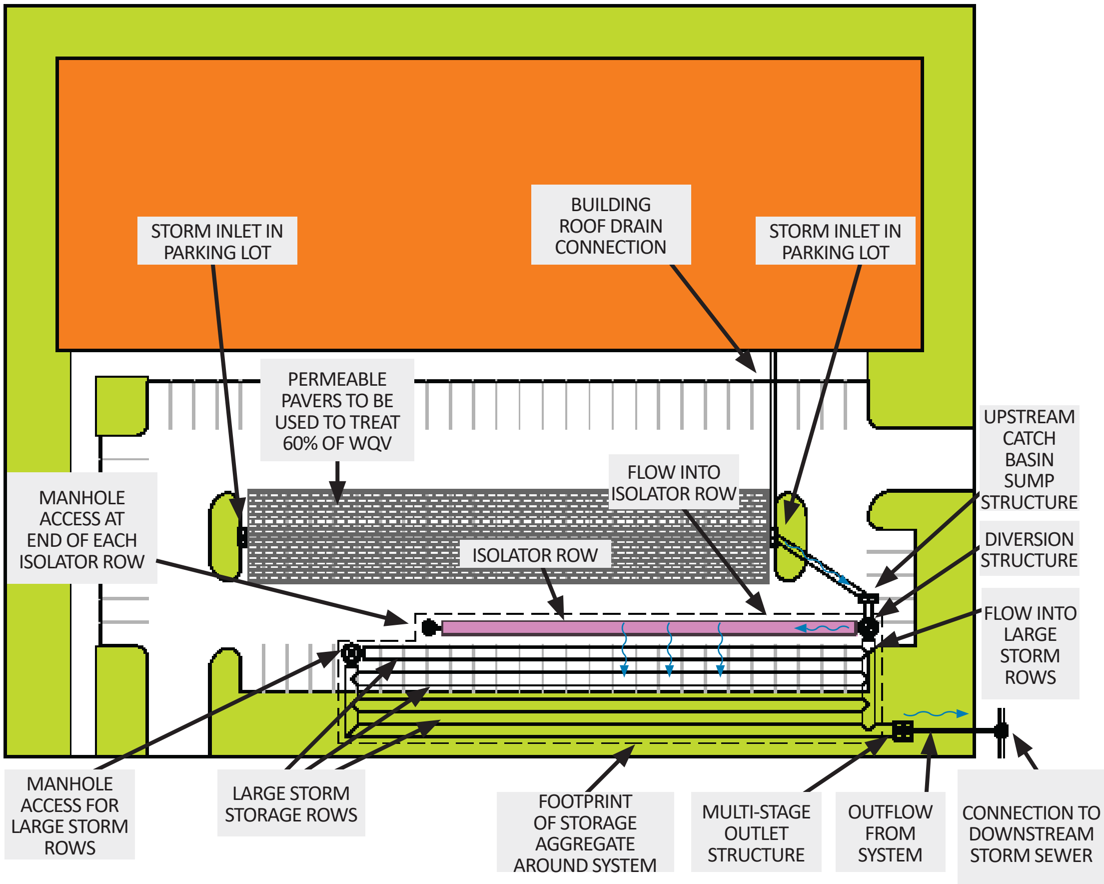


SECTION A-A



SECTION B-B


MANHOLE LID
MANHOLE LID
6.0'
OVER 12" PIPE
11" ORIFICE
STAGE 1:
6" PIPE W/ 3" ORIFICE IN CAP
3" FLOWLINE ELEVATION = 100.00
FLOW
STAGE 3:
TOP OF CONCRETE WEIR ELEVATION = 102.50
STAGE 2:
TOP OF NOTCH IN CONCRETE WEIR ELEVATION = 101.75
UNDERGROUND DETENTION PIPE
FLOW
FLOW
FLOW
FINAL OUTLET CONTROL:
11" OPENING IN ORIFICE PLATE OVER 12" OUTLET PIPE
FLOWLINE ELEVATION = 100.00
PRECAST OR CAST-IN-PLACE STORM MANHOLE STRUCTURE



8. Review projected release rates from Step 7 for the preliminary design. Verify that the projected rates are less than the allowable rates calculated as part of the estimation procedure referred to in Step 4. Iterate as needed, adjusting staged outlet controls or stage-storage relationships within the software program to meet required release rate restrictions.

Table 9.13-2-14: Modeling Results for This Example.

Storm Event	Allowed	Out	High Water Elevation	Max. Temp. Storage	Max. Temp. Storage
	(cfs)	(cfs)	(feet)	(CF)	(watershed-inches)
1-year (CPv)	0.2	0.3*	101.7	11,100	1.2
2-year	2.2	0.8	101.9	12,500	1.4
5-year	3.7	3.5	102.3	14,700	1.6
10-year	5.1	4.7	102.8	17,100	1.9
25-year	6.6	5.5	103.5	21,000	2.3
50-year	6.6	6.1	104.2	24,300	2.7
100-year	6.6	6.6	104.9	27,700	3.1

* In this example, the proposed release rate exceeds the allowable rate for the CPv event. However, since the minimum 3-inch diameter orifice is being proposed to control that event, the flow exceedance is acceptable. See the Small Storms Hydrology Section of ISWMM for more information.

Table 9.13-2-15: Additional Modeling Results for This Example.

	Max Rainfall Volume Stored	Peak Delay In vs. Out	Peak Flow Reduction In Vs. Out Reduction	Initial Storage Estimate*	Final Storage Routing Result	Final/ Estimate
Storm Event	%	In vs. Out (min)	In vs. Out (%)	(CF)	(CF)	
CPv (1-year)	45.8%	106	96.3%	11,332	11,100	1.0
2-year	44.7%	32	91.8%	9,103	12,500	1.4
5-year	42.5%	8	73.1%	10,734	14,700	1.4
10-year	42.2%	8	68.7%	11,814	17,100	1.5
25-year	42.5%	8	71.1%	14,824	21,000	1.4
50-year	42.8%	8	72.3%	18,919	24,300	1.3
100-year	42.9%	8	73.6%	23,408	27,700	1.2

*Original "Vs" Storage Estimate Without Safety Factor

For each storm event, the proposed release rate is less than the allowable value, so this design example works.

The storage volumes noted above include the storage in both the isolator row and the rest of the detention system. The isolator row fills first, spilling over into the rest of the system once it is full.

Using upstream BMPs to manage water quality significantly reduced the storage required in the isolator row. This resulted in a net reduction of isolator row storage of about 60% compared to the design in Example #1.

Note that in the final column of Table 9.13-2-15, the final storage volume is 18% higher than the original estimate, which is much closer to the 15% factor of safety discussed previously.

9. Check outflow velocities at pipe outfalls and spillways. Adjust sizing or geometry, or add erosion protection features as needed for the 100-year, 24-hour event.

- From the continuity equation, determine pipe velocity based on flow rate (Q) and area (A) [V = Q/A]
- The expected release rate during the 100-year event is 6.6 cfs. (unchanged from Example #1)
- If a 12-inch pipe is used downstream of the 11-inch orifice the velocity can be solved as:

$A = \pi r^2 = \pi (0.5 \text{ foot})^2 = 0.785$ square feet (SF)

$V = Q / A = 6.6 \text{ cfs} / 0.785 \text{ SF} = 8.4$ feet per second (fps)

If the 12-inch pipe discharges to the surface, appropriate scour protection would need to be provided to protect the surface at that location. If velocity (V) was found to be greater than 10 fps, the designer may wish to increase the outlet pipe size to reduce the velocity within the pipe, while maintaining the orifice size upstream.

10. Check that a safe overflow path is provided for events larger than the 100-year storm event. Identify the overflow path of the drawings for the proposed site.

The site grading plan would need to be reviewed for this step. The catastrophic overflow path should be designated to makes sure no structures or other property might be damaged if storms larger than the 100-year storm event occur or if the system inlet or outlet points were blocked.

NOTE

Some jurisdictions in Iowa have more specific outlet velocity requirements.

Complete design checklists at the end of this section to verify that sizing design criteria have been satisfied. Proceed to development of detailed plans and specifications. After completion of final design, make any adjustments as needed so that final plan information matches the finished calculation report.

EXAMPLE #3 – RECHARGE VOLUME

For the previous example, assume that the project is intended to treat a recharge volume (Rev). The local standard for Rev is based on a 1.0-inch rainfall event.

Recharge volume calculations:

- Runoff coefficient (Rv) = 0.725 (Solved in Step #2 of Example #1)
- Rechage volume (Rev) = Rv x P Equation 9.13-2-10
  - P = Rev precipitation (1.00 inches)
  - WQv = Rv x P = 0.725 x 1.00 inches = 0.725 watershed-inches

    = 0.725 watershed-inches x 2.50 acres x 43,560 (square feet / acre) / 12 (inches / foot)

    = 6,579 CF (cubic feet)

The footprint area of the aggregate storage around the underground storage system needs to be calculated to calculate the ability to infiltrate the Recharge Volume. The actual footprint will vary based on the pipe and chamber system being used. For these calculations, it is given that the footprint of the aggregate storage layers (including those under the pipes or chambers) is 12,000 SF.

The storage for Recharge Volume will be the storage within aggregate layers that are below the outfall elevation from the system. This can be calculated as:

Storage (CF) = Area (SF) x Depth (feet) x porosity (n) Equation 9.13-2-11

Solving for Depth and using Rev volume for Storage:

Depth (feet) = Rev Storage (CF) / [Area (SF) x porosity (n)] Equation 9.13-2-12

Depth (feet) = 6,579 CF / [12,000 SF x 0.35] = 1.57 feet

So 1.57 feet of aggregate depth is needed to contain the Rev runoff volume. Now we need to check the required percolation rate to drain the aggregate storage within 24 hours.

Percolation rate (inches / hour) = Depth (feet) x (12 inches / foot) / (24 hours)

Percolation rate (inches / hour) = 1.57 (feet) x (12 inches / foot) / (24 hours) = 0.79 inches per hour

As long as on-site percolation test taken at an elevation near and just below the bottom of the proposed aggregate layer show a percolation rate of 0.79 inches per hour or more, the system as designed can meet the Rev requirements. If the percolation rate is lower, the system will need to be spread out over a larger area so that the aggregate layers below the outlet can be shallower to store the required Rev volume.

9.13-3 CONSTRUCTION

A. POLLUTION PREVENTION

If the underground detention system is part of a project whose total disturbed area exceeds one acre (including all parts of a common plan of development) a stormwater pollution prevention plan (SWPPP) is required by state and federal law to be prepared.

Prior to construction, coverage under the State of Iowa's NPDES General Permit No. 2 shall be obtained (or, if required, coverage through an individual permit).

The SWPPP document will meet state and local regulatory requirements and will detail the structural and non-structural pollution prevention best management practices (BMPs) that are to be employed at the site.

EXTERIOR PROTECTION

All perimeter and site exit controls should be installed prior to any land-disturbing activities. Such controls may include (but are not limited to) site construction exits, perimeter sediment controls, construction limit fencing, waste collection, sanitary facilities and concrete washout containment systems.

INTERIOR PROTECTION

As construction activities begin, internal controls will be added to prevent erosion and sediment loss from the site area.

Erosion controls (mulches, rolled erosion control products, turf reinforcement mats, etc.) prevent detachment of soil particles from the surface.

Sediment controls (wattles, filter socks, silt fences, sediment basins, etc.) capture sediments after they have become suspended in runoff. Installation of controls may need to be staged to be implemented immediately after construction operations have ceased or are paused in a certain area.

For pollution prevention requirements for other stormwater best management practices associated with the project, refer to the relevant section of ISWMM for more pollution prevention information.

These internal controls are needed to prevent sediment and other debris from being washed into the underground detention system after it has been installed until the area within the site is stabilized with permanent vegetation.

B. CONSTRUCTION SEQUENCING

Underground detention systems are typically designed to be constructed as part of a larger project. They typically will be installed along with the rest of the site storm sewer system.

When used, the isolator row within an underground detention system is sized to capture sediment loadings from areas that are fully stabilized with permanent vegetation post-construction. During construction activities, sediment levels within incoming stormwater runoff will likely be elevated. This means sediment may need to be removed at various intervals during construction. Near the end of project construction, any accumulated sediment should be removed from the isolator row and the underground detention system (as needed) so that it has its full capacity available as the project reaches the post-construction phase.

C. CONSTRUCTION OBSERVATION

A designated representative of the owner should observe construction operations on a frequent basis to confirm the following:

- If the runoff is intended to be bypassed around the underground detention system during construction, make sure the bypass pipes or channels are constructed as designed.
- Storm sewer and pipe structures leading to the system are installed to the dimension, location and elevations specified on the plans and proper installation techniques and trench compaction techniques have been followed.
- The material used to construct the underground detention system are the proper size and design as per the plans. Inspect these materials for damage prior to installation and before they are backfilled with aggregate materials.
- The system is installed to the location and elevation specified on the plans.
- Complete a walk-through with the designer and contractor to identify any items which are not in compliance with project requirements. Document issues in a punch list and confirm when all items are installed or repaired.
- Verify that accumulated sediment or debris is removed from the isolator row and underground detention system prior to final acceptance of the installation.
- As needed by the local jurisdiction, author a letter of acceptance noting either conformance with construction documents, or any allowed deviation thereof.

D. AS-BUILT REQUIREMENTS

During construction, records should be kept by the contractor (and site observer) that will allow record drawings of as-built improvements to be provided to the owner. To demonstrate that the project has complied with contract documents, these records should include, but not be limited to, the following:

- Locate the position and elevation of the rim or lid of any intakes, access manholes, cleanouts or observation ports.
- Document the flowline elevation of each run of pipes or chambers used to construct the underground detention system.
- Verify the sizes and elevations of any orifices, weirs or outflow pipes within the outlet structure.
- If there are significant deviations, adjust the stormwater model prepared for the site based on the collected as-built information to confirm the design remains in compliance with allowable release rates from the site.

An underground detention chamber system under construction in Davenport.

9.13-4 MAINTENANCE

ACCESS PATH

Make sure that an access path is kept clear to allow the required maintenance vehicles (usually a vacuum truck) to access the underground detention system, especially the isolator row and any other pretreatment practices.

ACTIVITIES

During the design process, the entity responsible for routine and long-term maintenance should be identified. These tasks are necessary to maintain the function of the underground detention system. The capacity of the isolator row or other pretreatment practice to intercept suspended sediments and other debris will be reduced if these tasks are not completed. The detention storage capacity of the system may be significantly reduced if regular maintenance is not performed. ESSENTIAL

Table 9.13-4-1

Activity	Schedule
During construction (as applicable)	
Diversion reconnection after construction (if used to bypass practices during construction)	
Throughout construction, remove accumulated sediment within the isolator row, other pretreatment devices and other parts of the underground detention system.	As needed, or at least when 10% of the sediment collection capacity of the isolator row is filled and at completion of major construction activities.
Post-construction	
Inspect the isolator row for sediment collection and/or standing water.	At least four times the first year, and at least twice annually after that, but more frequently as needed if sediment buildup is often observed.
Remove sediment from the isolator row. Check isolator row from each of the access points made available at each end of the isolator row(s).	When 10% of the sediment collection capacity is filled. Typically, it would be expected that sediment may need to be removed from sump collection area at least once or twice each year.
Inspect the underground detention system for sediment collection and/or standing water.	At least two times the first year, and at least once annually after that, but more frequently as needed if sediment buildup is often observed.
Clean and remove debris as necessary.	When observed.
Follow individual manufacturer's O&M requirements.	As applicable.

- Sediments excavated from the isolator row, other pretreatment practices or the underground detention system that are not receiving runoff from designated hotspots are not currently considered toxic or hazardous material and can be safely disposed of by either land application or at a permitted landfill. However, guidance on the related to Per- and Polyfluoroalkyl Substances (PFAS), sometimes referred to as "forever chemicals" is evolving. This guidance may need to be addressed as more federal or state guidance on PFAS is created.
- Sediment testing may be required prior to sediment disposal when a hotspot land use is present.
- Sediment removed from catch basin sumps during construction should be disposed of according to an approved SWPPP.

An underground detention chamber system under construction in Davenport.

9.13-5 SIGNAGE RECOMMENDATIONS

Signage for underground systems is recommended, at least to inform maintenance staff on the location of access points to the underground detention system and its pretreatment practices. Such signage could be used to display maintenance requirements for the system.

Signage could be provided as an educational tool to detail the purpose and function of the underground detention system to the general public.

Illustration of an educational sign.

9.13-6 GLOSSARY

Best Management Practice (BMP)	A feature designed to meet stormwater water quality or quantity management goals.
Floating material	Debris and materials that are buoyant or typically float in stormwater runoff.
Hydrologic Soil Group (HSG)	Categories shown on County Soils Maps that describe the runoff potential of common soil groups. HSG categories range from A to D, with HSG A soils generating the least amount of runoff from rainfall events and HSG D soils generating the most.
Impervious cover	Surfaces on the landscape that do not allow water to pass through, such as roofs and paved surfaces.
Pretreatment	Use of practices or features to capture the heaviest sediment particles, trash or debris out of stormwater flows before it can enter a downstream BMP.
Redevelopment	Construction of site improvements on a parcel of land where buildings, roads, parking areas or other site improvements already exist or previously existed.
Resuspension	When collected sediments or debris that were previously captured by a pretreatment or other water quality BMP are picked up and carried by moving water.
Time of concentration	The length of time it takes stormwater runoff to pass from the farthest upstream point in a drainage area to the outlet after runoff from rainfall has started.
Seasonal high-water table	The highest level of groundwater indicated by soil tests or geotechnical investigations.
Settleable solids	Particles that are large enough to fall out of still or slowly moving water, due to gravitational effects.
Soil Quality Restoration (SQR)	Creating a healthy soil profile through methods of respreading topsoil materials, or using blends of compost and sand to improve soil properties. (See the Soil Quality Management and Restoration Section of ISWMM.)
Tailwater	Elevated water levels at the downstream end of a pipe network or stream which can impede the ability of water to pass through a system.
Unified Sizing Criteria (USC)	The set of stormwater management quality and quantity goals recommended by ISWMM.
Water quality impairments	When the essential functions of rivers, streams or lakes are not supported because of pollutant levels which are measured to be above an accepted allowable standard.
Water Quality Volume (WQv)	One of ISWMM's USC, defined as the runoff generated by a 1.25 inch rainfall event. Over 90% of all rainfall events in Iowa are at or less than this amount of rain.
Weighted Curve Number (CNw)	When multiple land surface covers exist in a drainage area, this value represents the average value of all curve numbers which are weighted by the percentage that each surface cover exists in that specific area.

9.13-7 RESOURCES

R. Pitt and J. Voorhees, ADS Isolator Row and StormTech Infiltration Chambers in WinSLAMM – Performance Observations and Unit Process Descriptions. 2019.

NJCAT TECHNOLOGY VERIFICATION Isolator® Row PLUS StormTech, LLC. 2020.

9.13-8 APPENDIX

KEY DESIGN PARAMETER CHECKLIST

There are important aspects of this manual to consider when jurisdictions seek to create stormwater ordinances or policies that reference or adopt this manual. The Iowa Department of Natural Resources (IDNR) is responsible for the creation and maintenance of this manual, working with a technical committee of local volunteers. However, regulation and enforcement of post-construction stormwater management is primarily left to local jurisdictions.

Therefore, the IDNR does not enforce as requirements, the sizing and design criteria set for this document. For this reason, the language used within this manual has purposefully been written as a guideline, rather than a standard. This means certain language that conveys something is required (i.e. shall, must, etc.) is generally avoided. This has the potential to leave "gray areas" as to what may be interpreted to be required and what is recommended or optional, if this manual is adopted and referenced by local jurisdictions as a standard.

Throughout this section, different design parameters or considerations have been grouped into key categories:

ESSENTIAL

An element of the design of a BMP seen as critical to its proper performance, operation or aesthetics. These aspects should be most important for inclusion and compliance and should rarely be deviated from.

TARGET

An element of the design of a BMP seen as important to its proper performance, operation or aesthetics. These aspects should be included in designs, if at all possible. However, there is more flexibility to allow deviations if it can be demonstrated that it is infeasible to meet the requirement at a given location, or if a certain requirement is in conflict with other requirements. Designers should explain any reason for deviation from targets, for the consideration of the jurisdiction as part of their review.

IDEAL

An element of the design of a BMP seen as the recommended approach for its proper performance, operation or aesthetics. Designers are encouraged to include these in designs as best practice. However, these items are seen as less critical as those noted as essentials or targets.

CAUTION

These are notes or design guidance to highlight items for the designers' careful consideration.

ADVISORY

These are practices, techniques or potential deviations from the design ethic that should be avoided in most circumstances.

ESSENTIAL

1. The methods used to direct runoff into the underground detention system need to have the capacity to convey the peak rate of flow from the event to be managed (typically the 100-year storm event) into the underground detention system. (page 4)
2. The capacity of all flow paths and methods used (storm inlets, pipes, permeable pavers, percolation through aggregate layers, etc.) needs to allow that peak rate of flow into the system. (page 4)
3. There needs to be a clear path with legal right of access to allow the party responsible for maintenance to reach the underground detention system. Of key importance is equipment and personnel access to any manholes, intakes or cleanouts that are used for inspection or to remove sediment or debris from the system. (page 4)
4. Access by manhole or inlet structure should be provided at inflow and outflow points of the system, the location of any diversion structures, and at each endpoint of any isolator rows. (page 4)
5. There needs to be sufficient cover over the system to protect it from damage and to support any loading from vehicles or equipment that will drive over the system. For proprietary systems, refer to the manufacturer's requirements to determine the required cover over the system. When the system is constructed from storm sewer pipes and structures, refer to the Iowa Statewide Urban Design Standards and Specifications (SUDAS) or other local requirements to determine the required cover over the pipes and structures within the system. (page 5)
6. The storage volume within the system will need to be able to contain the inflow rates and volumes being sent to the system while limiting outflow rates to meet USC requirements. (page 5)
7. The designer should evaluate a path of overflow for storms that are larger than the 100-year storm event. If the underground system is sized to handle the 100-year storm event, any larger storms will not be able to enter the system. Runoff will need to be able to have a safe path out of the site which is not expected to cause damage to property or infrastructure. (page 6)
8. Many proprietary systems are designed by the manufacturer. They typically provide a final plan set for shop drawing review prior to construction. These drawings often include specifications and requirements that the project design engineer may need to integrate into the contract documents for the project. Often, these plan sets will designate some items as "As specified by engineer" or "Provided by others". The site designer will need to address such items on their construction documents. (page 7)
9. If the underground detention system is being used to meet Rev requirements:
    a. The depth of the storage aggregate used for Rev should be set so that it can be completely drained within 24 hours after a rainfall event. (page 7)
    b. Subsoil layers should be tested to determine the expected percolation rate into the subsoil layers below the underground detention system. (page 7)
10. If the system is being used to meet WQv requirements:
    a. The system is designed with an isolator row configuration to promote filtration and pollutant removal within the first row of the system. (page 8)
    b. The entire volume of runoff expected to be generated from the WQv event is directed into the isolator row. (page 9)
    c. A diversion structure would be used to ensure that the WQv runoff is directed into the isolator row, but flow from larger events would be redirected into other storage chambers or pipes. (page 9)
    d. The isolator row would be sized to store the entire WQv volume from the upstream area (other than any WQv volume already managed by upstream BMPs) within the pipes or chambers used for the isolator row. (page 9)
    e. Void spaces in aggregate layers outside of the isolator row may be used for detention of larger storm events, but not counted toward WQv treatment volume. (page 9)
    f. A manhole or inlet structure providing full access is provided at each end of the isolator row. (page 9)
    g. Flow that enters the isolator row can only leave through perforations in the exterior of the isolator row, forcing water to percolate through some portion of storage aggregate before it can enter other storage chambers or pipes and be allowed to leave the system through the outlet. (page 9)

11. During the design process, the entity responsible for routine and long-term maintenance should be identified. A maintenance plan is provided to the responsible party for execution. (page 44)

TARGET

1. A preferred approach is to use other water quality best management practices (BMPs) installed upstream of the underground detention system to meet WQv requirements. (page 3)
2. Underground detention systems can be designed to address Recharge Volume (Rev) requirements. This can be accomplished by extending the aggregate storage layers below the outflow elevation of the system, forcing captured runoff volume to be infiltrated into subsoil layers. Subsoil conditions would need to be tested to verify the expected percolation rates. Such testing would need to be completed for the soils below the bottom of the excavation for the system. These tests would determine if he captured runoff could be completely drained from the system within 24 hours after a rainfall event. (page 3)
3. Pretreatment practices should be provided upstream of the underground detention system to reduce the potential for sediment and debris from being washed into the system. The pretreatment volume of 10% of the WQv volume should be provided, but may be reduced under the following conditions:
    a. Pretreatment is not required for areas that already have passed through an appropriately sized pretreatment or water quality BMP. (page 4)
    b. If an isolator row is included in the underground detention system, the isolator row may also act as part of the pretreatment approaches. (page 4)
        i. In that circumstance, the storage within the isolator row should be increased by any pretreatment volume not addressed by upstream practices, to account for the potential of sediment deposition which would reduce available storage within the isolator row.
    c. A catch basin sump structure is recommended at the entry point to any isolator row. A minimum sump depth of 24 inches is recommended, but may be different based on manufacturer's requirements or to increase the pretreatment volume provided prior to the isolator row. (page 4)
4. Within the system, the high-water elevation during a 100-year storm event should not extend above the elevation of the bottom of any pavement surface or bedding aggregate layer (for any infiltration based BMP or permeable pavement system) located directly over the underground detention system. (page 5)
5. At the downstream end of the system, a multi-stage outlet structure will likely be needed if the system is intended to meet the CPv and larger storm detention requirements.
    a. This is typically accomplished by constructing a weir wall within the outfall structure, with a smaller opening to limit the release rate for smaller storms placed within or through the wall. (page 6)
    b. The top of the overflow weir would be set above the high-water elevation of the CPv event (1-year storm), allowing higher rates of flow to leave the system during larger storm events. (page 6)
    c. In some cases, additional weir widths may need to be staggered at higher elevations to provide adequate control between the 1-year and 100-year storm events. (page 6)

CAUTION

1. If they underground detention system is being used to promote runoff reduction by percolation into subsoil layers, verify that the system is not subject to the Environmental Protection Agency's (EPA) Underground Injection Control (UIC) regulations. (page 7)