4.4.7 Temporary Sediment Basin

Source: City of Franklin

Definition and Purpose

A sediment basin is a temporary impoundment structure, typically constructed by excavating a depression or building a compacted embankment, designed to intercept and detain sediment-laden stormwater runoff from active construction sites. The primary components of a sediment basin include a forebay, an earthen embankment, sediment storage, live storage, surface dewatering mechanism, principal spillway, and emergency spillway. These basins slow the velocity of stormwater, allowing suspended particles time to settle out before being discharged offsite. Beyond sediment control, these basins can function as temporary peak flow attenuation systems to mitigate downstream erosion. While intended to be temporary measures, sediment basins can be converted into permanent stormwater controls with proper planning and design (Section 7).

Appropriate Applications

Sediment basins, or their engineered equivalents (Section 5), are to be used where treatment of sediment-laden runoff is necessary, as specified by the Tennessee CGP. They are most appropriately located at the lowest parts of the site, typically along the perimeter of an area to be disturbed, where flows concentrate before discharging offsite. For drainage areas less than (approximately) five to 10 acres, other sediment control measures are likely more economical and effective. Typically, sediment basins are used when the contributing drainage area is less than 100 acres. (USEPA, 2021).

Limitations and Maintenance

Sediment basins may be difficult to construct or less effective when a construction site has steep slopes, shallow bedrock, or other site constraints. Site conditions may determine that alternatives to sediment basins are better suited and more effective. Further, multiple, less extensive measures can be implemented in series to obtain the same, or greater, sediment removal capacity (Section 5) than a sediment basin. Equivalent control justification should be provided in the EPSC plans when applying for coverage under the CGP. See Chapter 5 for additional details on equivalent measures.

When inspecting sediment basins, assess the structural integrity, sediment accumulation, and the condition of spillways, embankments, and outlet structures. When 50% of the sediment storage capacity of the sediment basin is filled, accumulated sediment must be removed and disposed of properly or stabilized onsite. Such maintenance requires equipment access to the basin and dewatering operations. To ease sediment removal operations, forebays are used as a form of pretreatment that captures larger sediment particles and reduces maintenance to a localized area. Forebays also require sediment removal maintenance once 50% of the sediment storage capacity has been reached; however, they are designed to completely dewater through gravity, making sediment removal operations more efficient compared to the main basin. Routine maintenance tasks for sediment basins, in addition to sediment removal, include removing debris from risers, dewatering devices, and spillways, repairing erosion or piping along the embankment and outlet pipe, inspecting for signs of structural failure, such as subsidence, cracking, or bulging, and visual observation of the quality of water discharging from the basin during and/or after storm events.

Lastly, sediment basins are subjected to the regulations of the Tennessee Safe Dam Act of 1973 if either the embankment is 20 feet or more in height (measured from its crest down to the lowest point of natural grade, which is the downstream toe of the embankment) or if the impoundment will have a capacity, at maximum water storage elevation, of 30 acre-feet (48,400 cubic yards) or more. When either condition is met, refer to Section 1.3.2 for appropriate permitting. Limiting sediment basin drainage areas to less than 25 acres and diverting unpolluted runoff around the construction site are ideal means to lessen the likelihood of meeting the criteria of the Tennessee Safe Dam Act.

Planning and Design Considerations

Planning Considerations

Sediment basins need to be designed with proper planning to ensure effectiveness, regulatory compliance, and economic installation. First, the location of a sediment basin is critical to its effectiveness. Not only does its location impact sediment removal capabilities, but sediment basins must be located such that sudden failures do not result in loss of life or serious property damage. For maximum effectiveness, sediment basins should be located to intercept the largest possible amount of sediment-laden runoff from the area that is to be disturbed (ALSWCC, 2018; TDOT). Further, sediment basin locations impact the basin design dimensions, orientation, and accessibility. Basins are not to be located in wetlands, streams, buffer zones, or on steep, unstable slopes, as these conditions compromise effectiveness and increase risk of failure (VDEQ, 2024). Second, sediment basins are commonly converted to permanent (i.e., post-construction) stormwater control measures such as detention basins (Section 7.3) and retention basins (Section 7.4), because many of the design principles complement one another. In such cases, to ensure regulatory compliance, both construction *and* post-construction regulations (local and state) are to be incorporated into the design. When the sediment basin is not to be converted to a permanent stormwater control, the embankment and resulting sediment deposits are to be leveled (and stabilized) or otherwise disposed of properly. Third, to ensure an economic and effective design, diverting runoff (Section 4.2.2) from undisturbed areas reduces the volume of runoff a sediment basin must treat. Furthermore, when a sediment basin is to be converted to a permanent post-construction stormwater control measure, consider a design that will overlap the design components and earthwork, such that they meet both construction and post-construction regulations. Because many of the design considerations overlap, construction of a separate, permanent basin is likely unnecessary and can be achieved through a simple conversion of the temporary sediment basin.

All state and local health and safety requirements shall be met concerning fencing and signs warning the public of the hazards of soft, saturated sediment and flood water. The designer and developer should be aware of the potential hazards that a temporary sediment basin represents to the health and safety of a neighborhood. Sediment basins can be attractive to children and can be dangerous to those who may accidentally slip into the water and soft mud or who may become entrapped at flowing inlets. The basin area should, therefore, be fenced or otherwise made inaccessible, unless this is deemed unnecessary due to the remoteness of the site. Strategically placed signs around the impoundment should also be installed.

Special consideration may need to be given in design, operation and maintenance in areas of the state where health hazards stemming from mosquito breeding and West Nile Virus have occurred. In any case, local ordinances and regulations regarding health and safety must be followed. Setting the sediment storage depth (i.e., permanent pool) greater than four feet helps limit mosquito breeding (Zawarus, 2022). Further, ensuring the criteria of live storage dewatering between 48 and 72 hours also helps prevent mosquito breeding (Henn et al., 2008; Zawarus, 2022).

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Design Considerations

Sediment basins have various design components and are to be installed before any upgradient earth-disturbing activities commence. Sediment basin design components include a forebay, an earthen embankment, sediment storage, live storage, a surface dewatering mechanism, a principal spillway system, and an emergency spillway (Figure 4.4.7.1-A). The following are shortened definitions and functions of each component:

- *Forebay* – pretreatment mechanism meant to settle the majority of coarse sediments, thereby reducing the sediment removal frequency of the basin. The forebay is most commonly attached to the basin; however, it can be detached and positioned upgradient of the basin;
- *Embankment* – an earthen structure, either excavated or built and compacted. It functions to detain runoff;
- *Sediment storage* - bottom layer within the primary basin footprint. It is often referred to as wet storage, dead storage, or permanent pool, and is where soil particles settle and accumulate. A dewatering mechanism sets the height below which water is pooled, unless dry weather conditions or infiltration lower the water level;
- *Live storage* – a zone in between the sediment storage and top of principal spillway that is sometimes referred to as dry storage. The live storage zone is sized hydrologically to capture and slowly release runoff from the design storm;
- *Dewatering mechanism* – a mechanism, such as a perforated riser (Section 4.4.12.2.1) or a skimmer (Section 4.4.12.2.2), that slowly releases water from the live storage zone. The controlled outflow of water allows time for soil particles to settle out and reduces peak flows. This mechanism sets the top elevation of the sediment storage zone and the beginning elevation of the live storage zone;
- *Principal spillway* – a component in which the dewatering mechanism is either built into or attached to. The spillway conveys water from the basin to the downstream side of the embankment through a pipe (barrel);

- *Emergency spillway* – a bypass spillway designed to safely convey the 25-year, 24-hour storm event. It provides a safe pathway for larger storms to bypass the embankment and principal spillway, thus ensuring resiliency of the basin. Some local jurisdictions may require the emergency spillway to convey a peak flow rate associated with a larger design storm.

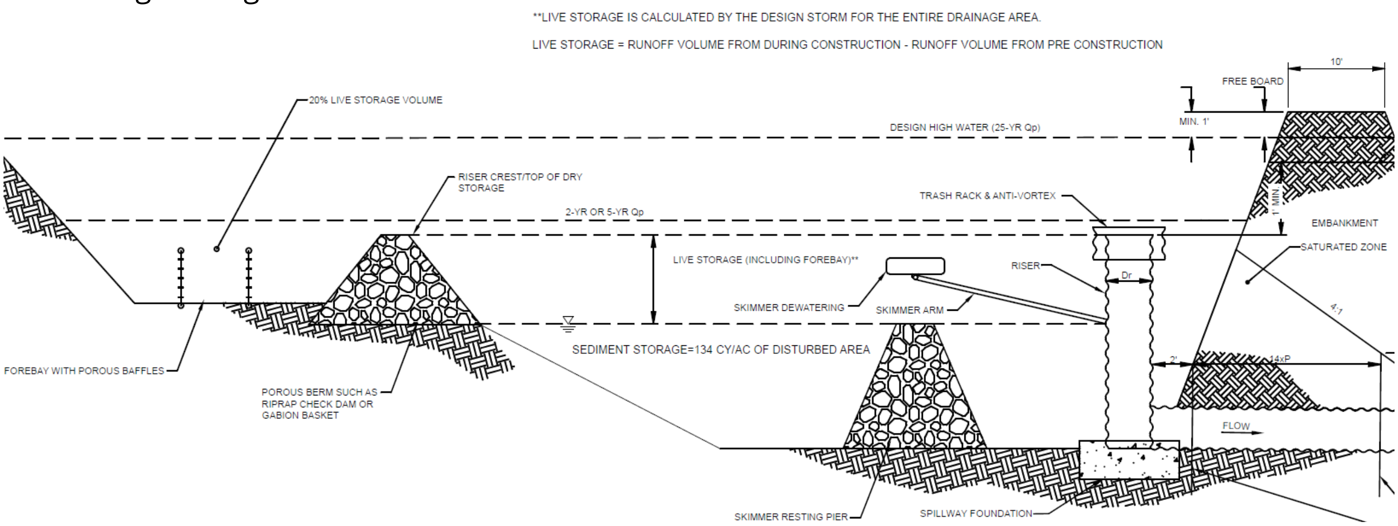


Figure 4.4.7.1-A: Sediment basin components.

Live Storage Design

Volume is one of the most important aspects of sediment basin design. Live storage is the area above the sediment storage that fills with runoff during a storm event and is therefore sized from the site hydrology based on the design storm. At a minimum, live storage volume should have a capacity of the difference in runoff volume between construction conditions (typically assumed as bare soil for the disturbed area and meadow for the areas left undisturbed) and pre-construction conditions (typically assumed as a meadow). Ensure land use (or multi-land use) assumptions accurately reflect site conditions.

The live storage volume will drain through the dewatering mechanism. In its volumetric design, live storage should have a minimum length (L) to width (W) ratio of 2L:1W, which, within reasonable bounds, increases detention time, trapping efficiency, and reduces short-circuiting (Haan et al., 1994). At higher velocities of inflow, short-circuiting or dead space can become an issue. To prevent inflow from this phenomenon, such that influent sediments disperse over the entire surface area, porous baffles (Section 4.4.12.1.1) can be implemented into sediment basin design. Length is defined as the distance between a point of inflow and the principal spillway. Where space limitations do not accommodate the minimum L:W ratio, solid baffles (Section 4.4.12.1.2) can be used to increase flow path lengths. Where there is more than one inflow point and where circumstances preclude this ideal arrangement, any inflow point that conveys more than 30% of the total peak inflow rate should meet the minimum L:W ratio. Embankment side slopes, known as the horizontal (H) to vertical (V) ratio, should not be steeper than 2H:1V for stability. The combination of required live storage volume, L:W ratio, and H:V ratio will help determine the dimensions of the live storage zone and its surface area at capacity. Sediment trapping efficiency is primarily a function of particle size distribution, and thus the design of sediment basins should account for the sizes of influent particulates (Haan et al., 1996). However, such design procedures require complex analyses. To compensate for this, a larger surface area, particularly in terms of surface area to inflow, has been found to promote the settling of particulates. Barfield & Clar (1986) suggest that live storage surface area at capacity (acres) should be at least one one-hundredth times the peak inflow (cubic feet per second). Thus, the following equation is a good design check:

$$A_s \geq 0.01 \times q_p \qquad \text{(Eqn 28)}$$

where A_s is the surface area of the live storage at capacity and q_p is the peak flow rate corresponding to either the 2-year, 24-hour or 5-year, 24-hour storm event and calculated from general engineering methodologies as specified in Section 2.1.3. Sediment trapping efficiencies in the live storage zone can also be improved by incorporating flocculants and polymers (Section 4.4.12.5); however, these technologies should be implemented in pretreatment or upstream of the sediment basin in order for them to take effect and assist in sediment settling in the basin.

Sediment Storage Design

While live storage is calculated hydrologically, sediment storage volume is calculated based on the anticipated sediment yield. To reiterate, the sediment storage zone is often referred to as wet storage, dead storage, or the permanent pool zone in other manuals or design guidance documents; herein, it will be referred to as sediment storage. Minimum sediment storage volume can be calculated via the sediment yield ratio. The sediment yield ratio assumes one inch of erosion and sediment yield over one acre per year, which equates to 3,618 cubic feet per acre per year of sediment. The sediment storage volume should be calculated from the disturbed area within the contributing drainage area. However, site specific calculations should also be checked, especially for larger sites. If these calculations yield greater volumes than the sediment yield ratio, site specific calculations must be followed. If these calculations yield lesser volumes, the sediment yield ratio can be used. Site specific calculations can be evaluated with methods expressed in Section 2.2. It may be beneficial to add physical elevation or height markers within the basin footprint or on the principal spillway to assist in assessing accumulated sediment height in the sediment storage zone. Once the sediment has accumulated to 50% of the sediment storage volume or within one foot of the dewatering mechanism, sediment removal is necessary. The sediment storage volume will have side slopes, which are reflected in H:V ratios, with recommended ratios of 2H:1V or flatter. Since there is a slope on the basin sides, 50% storage capacity will not occur at half the sediment storage height. The sediment storage volume and specified L:W and H:V ratios can help determine the sediment storage height, which will be used to set the elevation of the dewatering mechanism. Overall, the height and volume of sediment storage promote better settling conditions between runoff-producing events and minimize re-suspension of captured sediment. Relatively little research exists specifying a minimum sediment storage depth that substantially reduces or minimizes sediment resuspension due to influent velocities and wind, though it is known that a larger depth will continue to decrease resuspension. IECA (2021), MPCA (2023), and ALSWCC (2022) recommend minimum sediment storage depths of one, one and a half, and two feet, respectively. A Pennsylvania-based study found that a sediment basin with a sediment storage depth of one and a half feet discharged 23.1 kilograms of sediment from two two-year storms. Of the 23.1 kilograms, approximately 13% of the sediment was resuspended and discharged from previously settled sediments (Fennessey & Jarrett, 1997). A sediment storage depth of four feet (or greater) discourages mosquito breeding (Zawarus, 2022) but is rather impractical for construction purposes. A sediment storage depth of four feet would likely yield a vast overdesign in most scenarios. Lastly, if a sediment basin is to be converted to a permanent detention or retention basin, consider over-excavating the sediment storage such that accumulated sediment will bring the bottom of the basin to permanent basin grade. With this method, accumulated sediment will not need to be removed from the basin before conversion to a permanent stormwater control; however, it will require stabilization.

Forebay Design

The forebay is most effective when positioned at the primary inlet of the sediment basin, where it serves to intercept incoming flow and facilitate the settling of larger particles prior to entering the main basin. To maximize performance, the forebay should comprise at least 20% of the live storage volume. Its bottom elevation should match the top of sediment storage elevation in the primary basin, such that the forebay does not have a permanent pool, and should be separated from the main basin by a porous barrier, such as a rock berm, check dam, etc. This barrier promotes sedimentation of larger particles and diffuses incoming flow, reducing the risk of short-circuiting. The crest of the berm

must not exceed the elevation of the principal spillway riser crest and be designed to convey the 2-year or 5-year, 24-hour peak flow rate via a designated spillway. To prevent re-suspension of accumulated sediment and minimize scour during high flow events, influent energy must be controlled through the use of an energy dissipator such as plunge pools, conventional riprap, or other appropriate measures (Section 4.3.4). Additionally, the forebay must be easily accessible for routine maintenance, as it will accumulate sediment at a faster rate than the rest of the sediment basin. Accumulated sediment must be removed and disposed of properly once 50% of the forebay capacity has been reached.

The forebay may also be completely disconnected from the main basin and in the influent channel. Emmett (2022) compared sediment basin performance between three design configurations: 1) 2012 TDEC recommendations (which included a constructed 20% live storage forebay volume, 2) TDOT recommendations without a forebay, and 3) TDOT recommendations with a rock check dam placed in an influent channel. While all three designs exceeded the 80% sediment removal criteria within Tennessee, the influent channel check dam improved the performance of the standard TDOT sediment basin by removing an additional 3% total mass of sediments, making it nearly as effective as the standard 20% live storage forebay. The rock check dam acting as a forebay configuration removed between 63 and 75 percent of the total sediments (before entering the main basin), which was similar to the 68 to 80% of the 2012 TDEC forebay, demonstrating the impact of forebays in reducing sediment removal maintenance from the main basin. Additionally, the rock check dam forebay was credited with further reducing effluent peak flow rates and achieved the 80% sediment removal criteria quicker than when it was not implemented. In all regards of the study, the rock check dam forebay performed nearly as well as a typical forebay design, while decreasing the forebay footprint (Emmett, 2022).

Principal Spillway Design

The principal spillway consists of a vertical riser, typically constructed from corrugated metal or reinforced concrete, connected to a horizontal drainpipe (barrel) that extends through the embankment and discharges beyond the downstream toe. The recommended minimum temporary riser diameter for a circular riser pipe is 18 inches or equivalent cross-sectional area for other shapes. The minimum dimensions are recommended for ease of maintenance. Further, a trash rack and anti-vortex device may be necessary to reduce clogging in the riser. The foundation base of the principal spillway should be firmly anchored to prevent floating due to buoyancy. Computations, with a minimum factor of safety of 1.25 (downward forces = 1.25 × upward forces), to determine anchoring specifications should be completed. For risers 10 feet or less in height, the anchoring may be a concrete base or a square steel plate. The concrete base needs to be at least 18 inches thick, with the edge of the concrete base extending past the riser a distance equal to (or greater than) the diameter divided by two (Figure 4.4.7-B). When using a rectangular riser structure, replace diameter with the width of the box. Also, the riser should be embedded into the concrete at least six inches for stability. The square steel plate, which is used for a metal riser, should have a minimum thickness of one-fourth inch, a width equal to twice the diameter of the riser, and be welded to the riser pipe. The plate is to be covered in at least two and a half feet of stone, gravel, or compacted soil to counteract buoyancy. If compacted soil is the chosen method, it should be compacted to 95% maximum proctor density. If a steel plate is employed, ensure that material over the plate is not removed during maintenance activities.

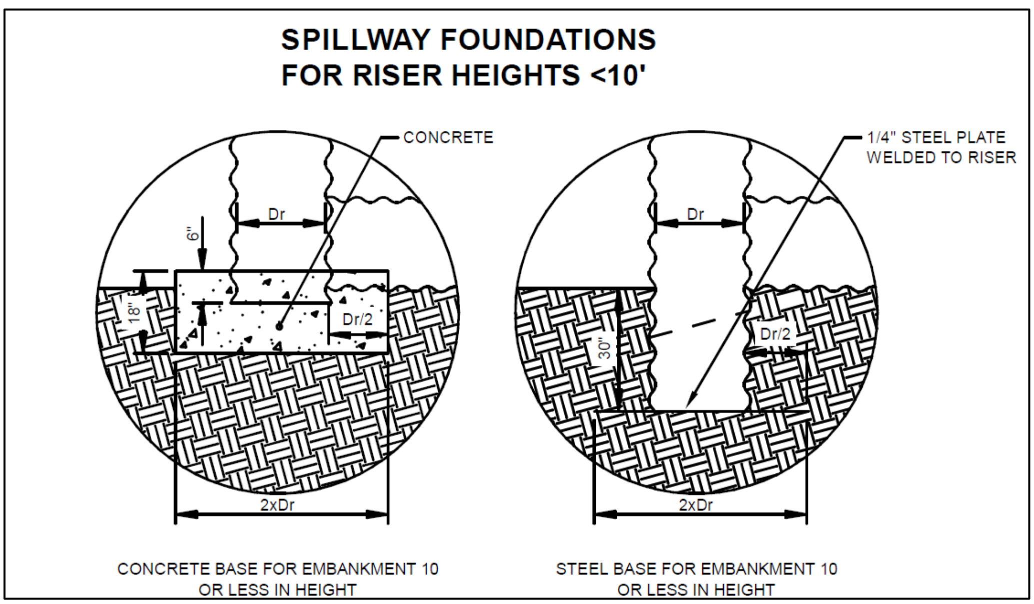


Figure 4.4.7-B: Riser pipe details.

Sizing of the barrel, which extends through the embankment to an outlet, can be computed utilizing Eqn 15 (a reformulated version of Manning's Equation) and methodology from Section 3.3.2.4. However, at a minimum, the barrel should be 12 inches in diameter to minimize clogging and allow maintenance. The riser and all pipe connections shall be mechanically sound and completely watertight and not have any other holes, leaks, gashes, or perforations other than designed openings for dewatering. Do not use dimple (mechanical) connectors as they are not watertight. The use of plastic pipe through the embankment should be approached with caution due to the potential for deflection, long-term creep, and separation from the surrounding soil. The outlet of the barrel must be adequately protected or fitted with energy dissipation measures [e.g., riprap aprons (Section 4.3.6), stilling basin (Section 4.3.7), baffles (Section 4.3.4), etc.] to prevent erosion. Where discharge occurs at or near property boundaries, appropriate drainage easements should be obtained in compliance with local ordinances. Additionally, it is best when outlet flows from the impoundment are directed into a natural receiving watercourse to preserve existing flow paths and avoid adverse impacts to downstream or adjacent offsite properties.

In order to prevent internal erosion in the embankment, the fill must be carefully compacted around the drainpipe barrel. If good compaction methods are difficult to implement, anti-seep collars can be used to form structurally sound, watertight connections. Anti-seep collars help reduce uncontrolled seepage and prevent internal erosion or piping inside the embankment and along the drainpipe barrel. Unfortunately, poor compaction and construction techniques are common, and therefore some localities require anti-seep collars instead of allowing the alternative of quality compaction around the drainpipe. When used, they are to be placed on the drainpipe barrel of the principal spillway within the normal saturation zone of the embankment to increase the seepage length by at least 10%, under either of the following conditions:

- The settled height of the embankment exceeds 10 feet; or
- The embankment has a low silt-clay content (Unified Soil Classes SM or GM), and the barrel is greater than 10 inches in diameter.

Since the anti-seep collars are to be installed within the saturated zone, the assumed normal saturation zone is determined by projecting a 4H:1V sloped line from the point where the normal water elevation (can be assumed to be the top of the principal spillway) meets the upstream slope to a point where this line intersects the invert of the barrel pipe or bottom of the cradle, whichever is lower. The collars should extend a minimum of two feet around the barrel. The maximum spacing between collars should be 14 times the projection of the collars above the barrel and not closer than two feet to a pipe joint. Collars should be placed sufficiently far apart to allow space for hauling and compacting equipment. Precautions should be taken to ensure that 95% compaction is achieved around the collars. Connections between the collars and the barrel shall be watertight. Plans should specify the method of compaction around the pipe barrel to ensure adequacy and to prevent damage to the anti-seep collars and joints. Follow compaction specifications provided by the project engineer to ensure adequacy and to prevent damage to the anti-seep collars and joints.

Dewatering Mechanism

A dewatering mechanism is typically either a perforated riser pipe or a skimmer attached to the principal spillway. Dewatering openings should be sized to drain the live storage volume within 48 to 72 hours, thereby allowing ample time for settling of soil particles but draining before another storm. Furthermore, as previously mentioned, dewatering within this timeframe (i.e., a constantly changing water surface elevation) discourages mosquito breeding (Henn et al., 2008; Zawarus, 2022). Design guidance for dewatering mechanisms can be found in Section 4.4.12.2. Pumps can also be a means to dewater a basin. When using a portable pump, the inlet hose connected to the pump should be secured so that it only draws down water from the basin surface and cannot sink below the surface. Adequate energy dissipators are also to be in place at the outlet end of the discharge hose to prevent scouring and erosion. Treatment when pumping can be placed at the inlet or outlet of the system, such as a skimmer (Section 4.4.12.2.2) or a sediment filter bag (Section 4.4.12.6).

Emergency Spillway

The emergency spillway serves as a critical safety mechanism for a sediment basin by conveying flows from storm events exceeding the design storm. The spillway should be sized to pass the peak flow from the 25-year, 24-hour storm, without overtopping or compromising the integrity of the embankment. Thus, no flow should leave the basin through the emergency spillway during the design (2-year or 5-year, 24-hour) storm. It also functions as an emergency outlet in the event of excessive sediment accumulation, reducing the storage of the basin, blockage of the principal spillway, or failure of the dewatering mechanism, which would prevent proper dewatering times. An evaluation of the site and downstream conditions must be made to determine the location of an emergency spillway. In some cases, the site topography does not allow a spillway to be constructed in undisturbed material. A minimum of one foot of vertical height is needed between the top of the principal spillway and the emergency spillway elevation. There should also be one foot of freeboard between the 25-year, 24-hour high-water elevation and the embankment crest elevation. Emergency spillways should be constructed on undisturbed ground or well-consolidated soil in order to reduce the risk of settlement,

Source: City of Franklin

decreased freeboard, and scouring during the design storm. Emergency spillways should be lined with non-erodible material appropriate to withstand the calculated shear stress within the channel from the 25-year, 24-hour storm event and over-excavated to compensate for the thickness of linings such as conventional riprap in order to preserve its intended design flow capacity. A professional engineer is responsible for the design of the emergency spillway.

Embankment

Embankments are earthen structures that are built up and compacted. It provides the total storage, which is comprised of the sediment storage zone, live storage zone, and all additional freeboard requirements. In addition to the required one foot of vertical elevation between the top of the principal spillway and the bottom of the emergency spillway, one foot of freeboard should be provided from the 25-year, 24-hour highwater elevation and the embankment crest. The top width of the embankment is dependent on embankment height (Table 4.4.7.1-A) and should not be less than 10 feet wide if the embankment is used for maintenance access. All components of the embankment must be stabilized upon construction completion and before it becomes operational. Trees and/or shrubs should not be allowed to grow upon the embankment due to the ability of the roots of such vegetation to destabilize the embankment and/or encourage piping.

Table 4.4.7.1-A: Embankment with specifications. Source: USDA (2022).

Embankment Height (ft)	Embankment Width (ft)
< 10	6
10 - 14	8
15 - 19	10
20 - 24	12
25 - 34	15

For earth-fill embankments, a cutoff trench should be along the embankment centerline to minimize seepage and reduce the risk of internal erosion. This trench is to extend a minimum of one foot into a stable, impervious soil layer and be at least two feet deep. It should also extend up both abutments to the elevation of the riser crest. The minimum width of the trench is four feet, or wider as necessary to accommodate compaction equipment. Side slopes should not be steeper than 2H:1V. Compaction of the trench must meet the same standards as those specified for the embankment. During backfilling and compaction, the trench should be adequately drained.

Embankment fill material should be clean mineral soil taken from borrow areas and free of roots, woody vegetation, stumps, sod, oversized stones, rocks, or other perishable or objectionable material. The fill material selected must have enough strength for the dam to remain stable and be cohesive when properly compacted, to prevent excessive percolation of water through the dam. Any embankment material should contain approximately 20% clay particles by weight. Using the Unified Soil Classification System, SC (Clayey sand), GC (clayey gravel), and CL ("low liquid limit" clay) are among the preferred types of embankment soils. Areas on which fill is to be placed shall be scarified prior to placement of fill. The fill material should contain the amount of moisture needed to ensure that at least 95% compaction will be achieved, and must be placed in six-inch lifts over the entire length of the fill. Loosely placed embankment soil is subject to excessive settlement, severe erosion, and slope failure. Compaction can be obtained by routing the hauling equipment over the fill so that the entire surface of the fill is traversed by at least one wheel or tread track of the equipment, or by using a compactor. Note that the spillway barrel must be installed in the embankment as it is being constructed in lifts and proper compaction is occurring around the barrel, especially under the haunches. If used, special care shall be taken in compacting around the anti-seep collars (compact by hand, if necessary) to avoid damage and achieve the desired compaction. The embankment should be constructed to an elevation 10% higher than the design height to allow for settlement. If compaction equipment is used, the overbuild may be reduced to not less than 5%. Areas under the proposed embankment (or any structural works related to the sediment basin) shall first be cleared, grubbed, and stripped of topsoil. All trees, vegetation, roots, and/or other objectionable or inappropriate materials should be removed and disposed of by appropriate methods.

Additional Sediment Basin Enhancements

A valve to close the dewatering mechanism or principal spillway can be used to prevent the basin from discharging, so that it provides additional settling time. The longer the residence time, the more sediment will fall out of the water due to gravity. For further enhancement, flocculants and polymers (Section 4.4.12.5) can be applied to the water. Chemical application can be applied directly to the water in the sediment basin or in a channel leading to the sediment basin. If it is applied directly to the water, it needs to be properly agitated to ensure appropriate mixing. If this is incorporated, the SWPPP is to specify that the gate valve is to remain closed (i.e., holding back all the water in the live storage zone) until it has been chemically treated, the water agitated, and sufficient time has passed to allow sediment to settle (Figure 4.4.7.2-C). Typically, this is at least 24 hours or per manufacturer recommendations. The live storage should be able to dewater within a time frame of 48 to 72 hours when the valve is open.

Figure 4.4.7.-C: Visible differences of the turbidity upon initial chemical application (left) and 24 hours after chemical application (right).

Example Application

Given:

A project site discharges to a stream that has unavailable parameters due to siltation and the following site conditions:

- Drainage area of 10 acres;
- Disturbed area of 7 acres;
- Rainfall of the 5-year, 24-hour storm is 4.08 inches;
- Assume disturbed areas have a curve number of 91;
- Assume undisturbed areas have a curve number of 71;
- Time of concentration during construction of 7.4 minutes;
- Time of concentration pre-construction of 12 minutes;
- Incoming 5-year, 24-hour peak flow rate during construction of 41 cfs; and
- Incoming 25-year, 24-hour peak flow rate during construction of 58 cfs.

Determine:

The design of a sediment basin utilizes the following assumptions:

- Uniform basin geometry - trapezoidal volume and a flat rectangular bottom surface;
- Forebay storage is to be 20% of the live storage;
- Sediment yield of 3,618 ft^3/ac of disturbed area (or 134 yd^3/ac);
- Total live storage provided must capture the increased volume of runoff between pre-construction conditions and during construction conditions; and
- The volume of a trapezoid is approximated by:

$$V = \frac{(A_t + A_b) \times d}{2}$$

where V is the volume of the basin, A_t is the basin top surface area, A_b is the basin bottom surface area, and d is the incremental or total depth.

Solution:

Step 1 – Determine the required sediment storage volume: Sediment storage volume is computed using the sediment yield ratio of 3,618 ft^3/ac of disturbed land, which was based on the assumption of sediment clean out at least every six months.

$$\text{Sediment storage} = 3{,}618 \times 7 = 25{,}326 \text{ ft}^3$$

Step 2 – Determine the required live storage volume: The required live storage volume is computed by the difference in runoff volume between construction and pre-construction conditions. Using the NRCS methodology to compute runoff volume (i.e., Eqns 1-3 in Chapter 2) and a total drainage area of 10 acres, runoff volume can be computed for both scenarios as shown below (refer to Section 2.1.1 for nomenclature). The composite curve number approach (Eqn 4) was used for the construction scenario where seven acres of land were disturbed and the three acres were left undisturbed.

Scenario	CN_{comp}	S (in)	λ	I_a (in)	Q_{CN} (in)	Runoff (cf)
Pre-Construction	71	4.085	0.2	0.817	1.449	52,599
Construction	85	1.765	0.2	0.353	2.529	91,803

The required live storage volume is the difference between the two, which equates to 39,204 ft^3.

Step 3 – Determine the forebay storage volume: The forebay storage volume is assumed to be 20% of the live storage volume or 7,841 ft^3.

Step 4 – Determine the total basin storage volume: The total basin volume is the sum of sediment storage volume and live storage volume, or 64,530 ft^3.

Step 5 – Determine the minimum surface area at the riser elevation, A_s: The minimum surface area can be computed from Eqn 28

$$A_s \geq 0.01 \times q_p = 0.01 \times 41 = 0.41 \text{ ac} = 17{,}860 \text{ ft}^2.$$

Therefore, the surface area of live storage at the riser elevation should be 17,860 ft^2 or larger.

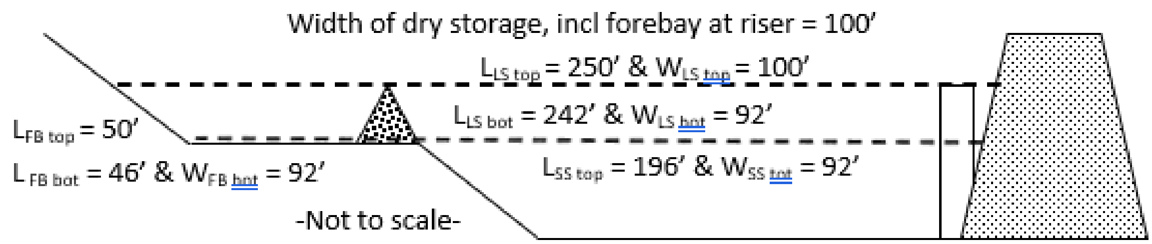
Step 6 – Determine the geometry of the live storage zone: Once the required volumes and surface area are known, the dimensions and depths are variable depending on site constraints (available area and depth). In order to get the required volume, the basin can have a larger surface area and be shallow or deep with less surface area. There is room for the engineer to design what is best for the site. The following is an example methodology for a basin to meet the calculated volumes and best practices.

Step 6a:

The live storage geometry is a trial-and-error approach by first assuming a depth. Trialing a depth of 2 feet, ensure the surface area condition is met:

$$S.A. = Volume/Depth = 39{,}204\ ft^3/2\ ft = 19{,}602\ ft^2$$

The calculated surface area based on the assumed depth is larger than the minimum surface area of 17,860 ft^2 and therefore passes the first check. Next, assume a basin shape with a L:W ratio of 2. First, assume a length of 250 feet and a width of 100 feet at the top of live storage, which equates to a surface area of 25,000 ft^2 as shown below.



Calculate the live storage volume to see if it provides more than the required storage volume.

$$V= [(250 \times 100) + (242 \times 92)] \times 2 /2 = 47{,}264\ ft^3$$

The surface area for the bottom of live storage was calculated by using a slope of 2H:1V. If the depth of the live storage is 2 ft, then the slope of the embankment will taper to the bottom of the live storage over 4 ft on one side. Since there are two sides, each at a 2H:1V grade, that means the bottom of live storage length is 8 ft less than the top of live storage length, which is where 242 ft originated. A similar calculation was done for the width. The forebay dimensions were approximately 20% of the live storage dimensions; however, the length of the forebay at the bottom only decreased from one side as the forebay barrier dimensions were assumed to be negligible (i.e., the forebay did not contribute to an H:V ratio). The calculated volume is greater than the required 39,204 ft^3 of live storage, and therefore, the proposed geometries are acceptable.

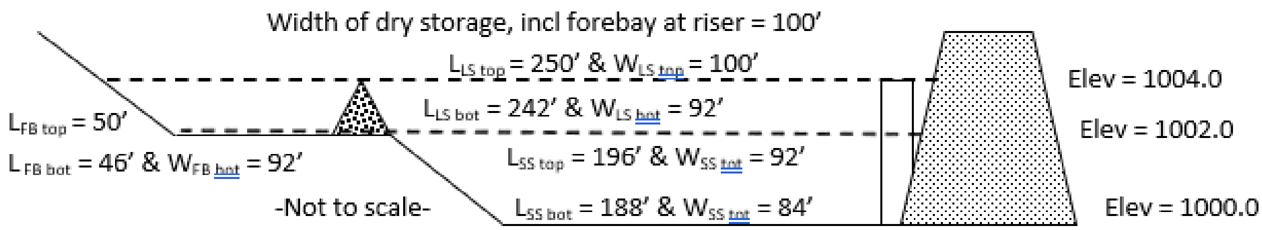
Step 6b:

If the volume calculated in step 6a was not greater than the required, the engineer can amend the depth or L:W or H:V ratios as a best fit. Ensure the minimum surface area recommendation is still met. Then repeat the calculations until the calculated volume is greater than the required. Avoid large overdesign.

Step 7 – Determine the geometry of the sediment storage zone: The sediment storage geometry is also trial and error approach by first assuming a depth. Trialing a lesser depth initially is recommended as the footprint will be minimized, and excess excavation is avoided. Trialing a depth of 2 ft with sediment storage width consistent with the rest of the sediment basin, as it continues down 2 more feet and a side slope of 2H:1V, ensure the geometry provides adequate sediment storage capacity. A depth of 2 ft at a 2H:1V slope is 4 ft on each side, so the bottom width of the sediment storage is 84 ft. If using a 2L:1W ratio, it can be calculated that the length is 188 ft. Therefore, the sediment storage volume can be calculated.

$$V= [(196 \times 92) + (188 \times 84)] \times 2 / 2 = 33{,}824 \text{ ft}^3$$

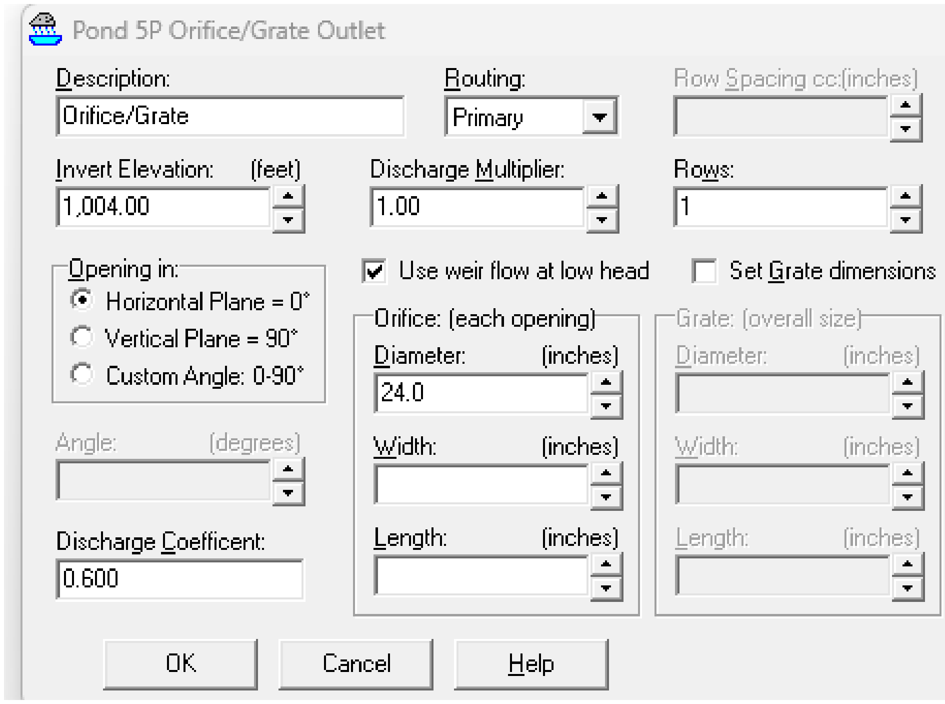
The calculated sediment storage volume is greater than 25,326 ft^3, the required volume; therefore, these dimensions are acceptable.



Step 8 – Summary: With the calculated dimensions, it can be assumed the following are acceptable:

- Riser height = 4 ft;
- Bottom basin elevation = 1000.0 ft;
- Top of sediment storage elevation = 1002.0 ft; and
- Top of riser elevation = 1004.0 ft.

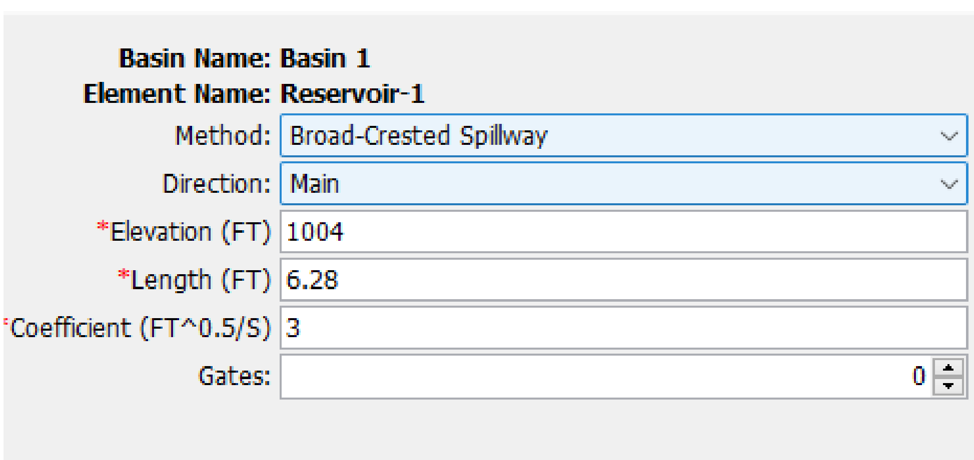
Step 9 – Design of the principal spillway: Establish the principal spillway elevation of 1004.0 ft and assume a riser diameter of 24 inches. The coefficient can be found in Eqn 29 in Section 4.4.12.2.1. For a standpipe in HydroCAD, select the outlet as an orifice/grate in the horizontal plane, as shown below. HydroCAD gives an elevation of 1004.12 ft for the 5-year, 24-hour storm with a 24-inch riser pipe. This is acceptable. If desired, a smaller pipe size could be modeled and selected.



*Disclaimer – Common commercial software is not endorsed by the state, but may be and is commonly used by designers throughout the state.

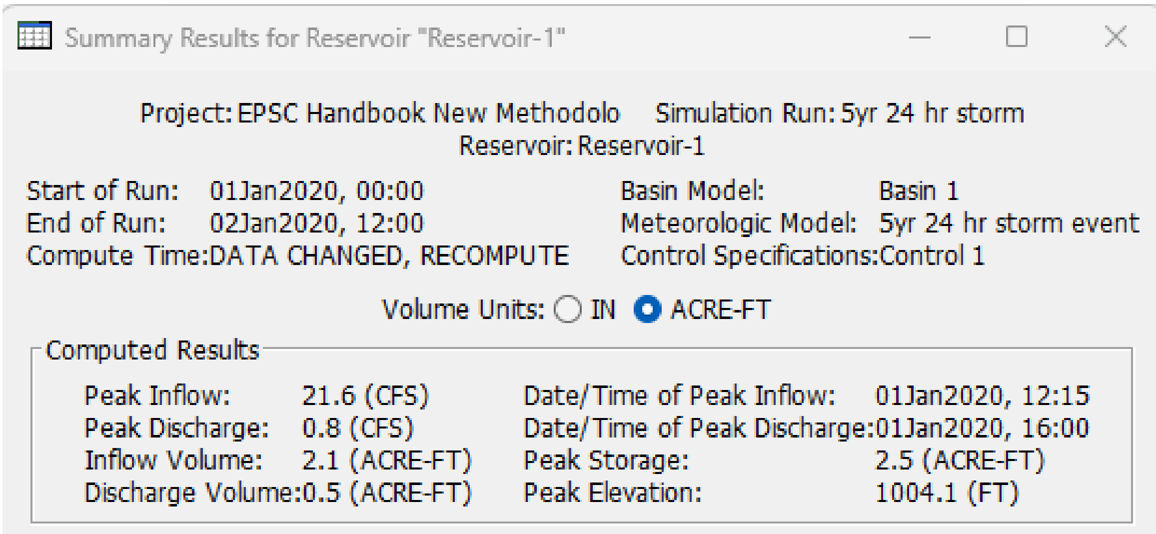
An outlet pipe of 24 inches has adequate capacity.

HEC-HMS is also shown as an example software for calculations below.



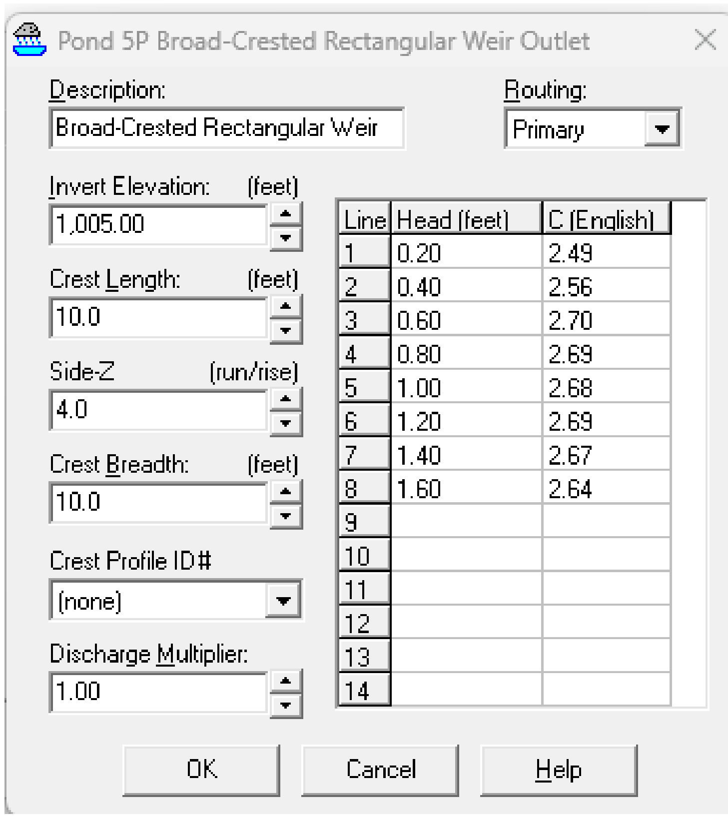
The length provided for the spillway equates to the perimeter of the riser pipe that acts as a weir/spillway. The pipe size being proposed for the riser is 24 inches in diameter.

$$\text{Length of Spillway} = \text{Perimeter} = \pi \times \text{diameter} = \pi \times 2 \text{ ft} = 6.28 \text{ ft}$$



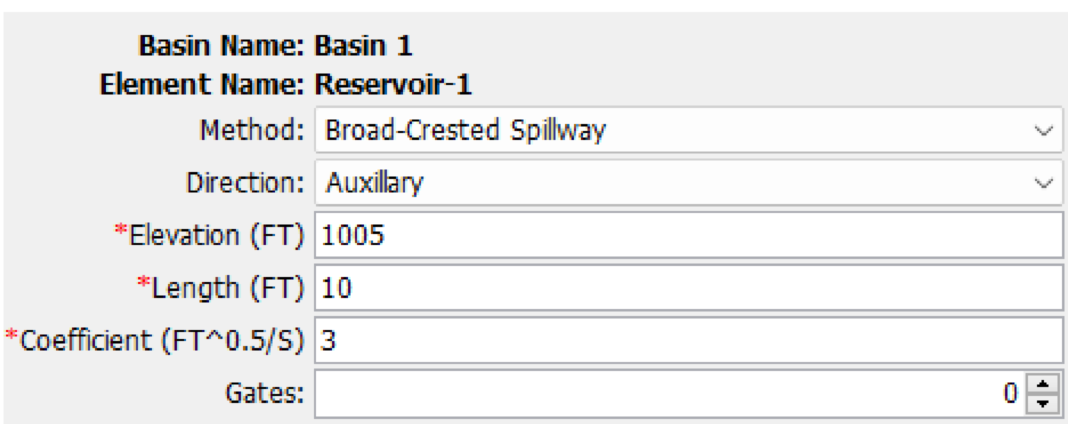
Step 10 – Design of the emergency spillway: Flow credit is given to the principal spillway but not the dewatering device. A minimum freeboard of 1 ft from the top of the principal spillway to the emergency spillway is necessary. Therefore, first try the emergency spillway at an elevation of 1005 ft. The emergency spillway will need to be checked with the 25-year, 24-hour design storm, as it is used to convey larger storm events. Use the following assumptions in HydroCAD as shown below:

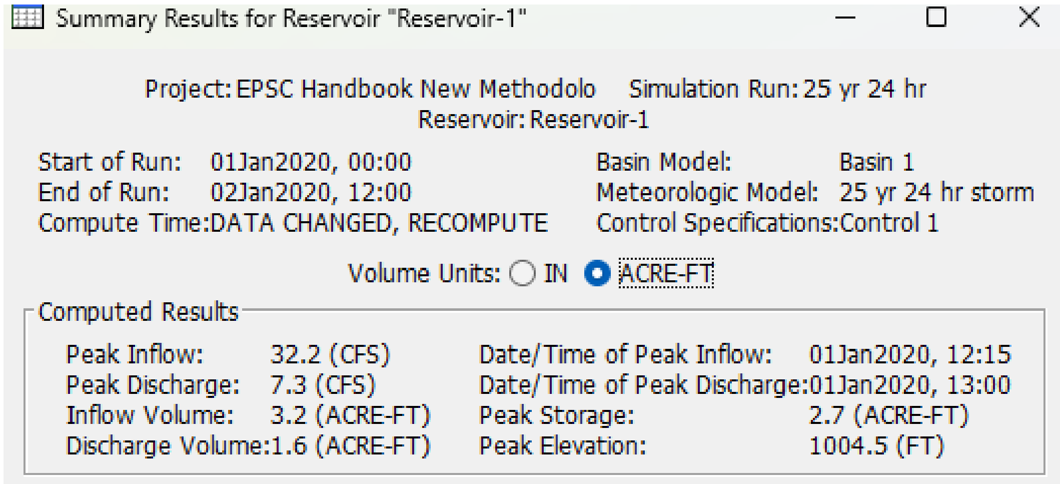
- Emergency spillway elevation = 1004.0' (Principal Elevation) + 1' (minimum freeboard) = 1005.0 ft;
- Emergency Spillway Side slopes = 4H:1V; and
- Assume a weir length = 10 ft.



*Disclaimer – Common commercial software is not endorsed by the state, but may be and is commonly used by designers throughout the state.

HEC-HMS is also shown as an example software for calculations below.





The emergency spillway elevation of 1005 ft is adequate. The 25-year, 24-hour storm event reaches an elevation of 1004.5 ft in the HydroCAD model. Therefore, the freeboard controls this elevation. The top of the berm elevation is 1006 ft, which is adequate since it exceeds the elevation of the emergency spillway elevation plus 1 ft of freeboard. The 50-year and 100-year, 24-hour storm events are checked with these elevations, and they are able to pass through the emergency spillway without overtopping.

Step 11 – Design of a skimmer: To understand the methodology when designing a skimmer or perforated riser, refer to Sections 4.4.12.2.1 or 4.4.12.2.2, respectively. However, for completeness, the example is continued here. The live storage volume of 47,264 ft^3 needs to be dewatered between 48 and 72 hours. Assume a dewatering time closer to 72 hours is ideal for the provided example. Determine the head on the skimmer orifice. The head will vary depending upon the manufacturer's design depth of submergence for a given orifice diameter. Use the following Skimmer size vs. orifice head table based on the Faircloth® skimmer as an example.

Skimmer Size (in)	Head (H) on Orifice (ft)
1.5	0.125
2	0.167
2.5	0.208
3	0.25
4	0.333
5	0.333
6	0.417
8	0.5

The flow through an orifice can be computed via Eqn 29 (Section 4.4.12.2.1), trying a 5-inch skimmer that has a driving head of 0.333 ft.

$$Q = N \times C_d \times A \times (2 \times g \times H)^{1/2}$$

$$47{,}264\,\frac{\text{ft}^3}{72\text{ hours}} = 1 \times 0.6 \times \frac{\pi \times d^2}{4} \times (2 \times 32.2\,\frac{\text{ft}}{\text{s}^2} \times 0.333\text{ ft})^{1/2}$$

$$0.18\,\frac{\text{ft}^3}{\text{s}} = 1 \times 0.6 \times \frac{\pi \times d^2}{4} \times (2 \times 32.2\,\frac{\text{ft}}{\text{s}^2} \times 0.333\text{ ft})^{1/2}$$

$$0.18\frac{\text{ft}^3}{\text{s}} = 2.18 \text{ x } d^2$$

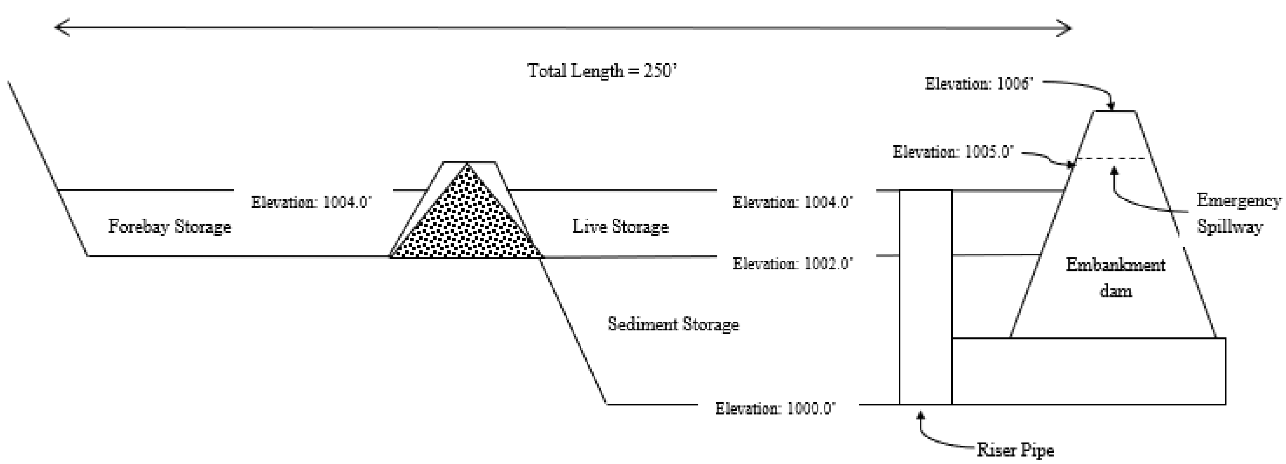
$$d = 0.287 \text{ ft} = 3.45 \text{ inch}$$

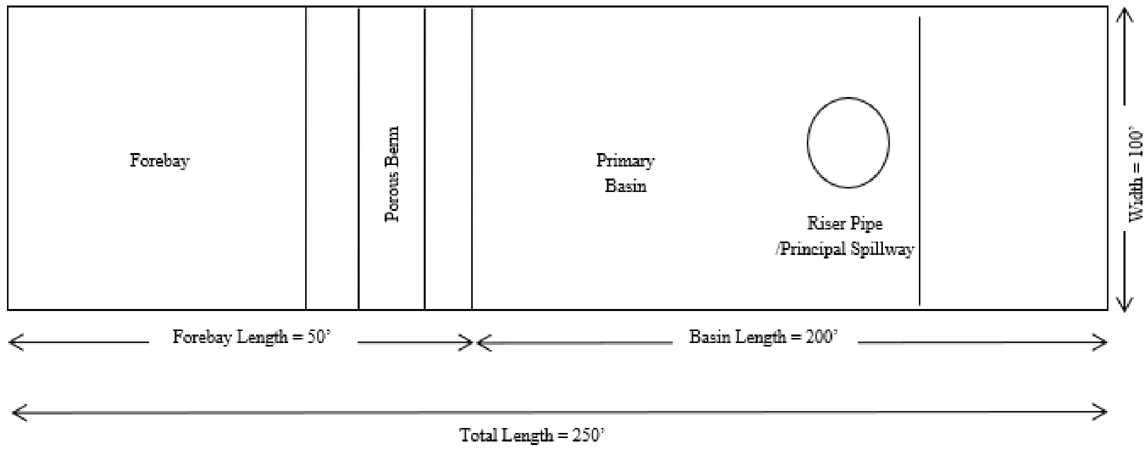
Therefore, a 5-inch skimmer with an orifice of 3.45 inches (or round up to 3.5 inches) is sufficient to dewater the 47,264 ft^3 in 72 hours.

Option: The above parameters can be entered into hydraulic routing software to refine the design.

Note: This sediment basin design example does not include emergency spillway lining calculations and design, nor does it include principal spillway outlet structure apron design and calculations. Examples regarding the lining of the emergency spillway can be found in Section 4.2.6.1, and outlet protection can be found in Sections 4.3.4, 4.36, and 4.3.7. Furthermore, the sediment basin design example does not discuss the anti-buoyancy pad of the principal spillway, anti-vortex and trash rack, anti-seep collars, details of surface skimmer connection to riser & skimmer base pad, or forebay berm design.

Below are schematics of the basin.





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