

# Unit Nine

## SEDIMENTATION BASINS

---

### INTRODUCTION

Sediment is the product of uncontrolled erosion and is the greatest pollutant by volume affecting Michigan's lakes and streams. Sediment fills in lakes and streams, clogs ditches, increases flooding potential, adversely impacts plant and animal life, and diminishes scenic and recreational values (Figure 9-1).



**Figure 9-1**

A coordinated strategy must be developed for all earth change activities to prevent erosion and control off-site sedimentation. This strategy generally involves developing an overall site plan that consists of various components; one of which is a comprehensive soil erosion and sedimentation control plan. Additional information regarding site plans and a compilation of erosion and sedimentation control measures can be found in the Michigan Department of Environmental Quality's "Guidebook of Best Management Practices for Michigan Watersheds."

The first and primary goal of the soil erosion and sedimentation control plan is to use a combination of controls and techniques to minimize on-site erosion. Common erosion control measures and techniques include staging/phasing construction activities, quickly covering bare soil with mulch, sod, or other erosion resistant materials, diverting water away from the construction area, and installing check dams to reduce runoff velocities.

Erosion control is not 100 percent effective, so sediment control must be used in conjunction with the erosion control efforts. Sediment control can be vegetative and/or structural. Structural controls commonly used include perimeter silt fences, various storm drain inlet filters, aggregate access roads, sedimentation traps, and sedimentation basins. This unit will focus on sedimentation basins.

Sedimentation basins can be very effective for certain soils and site characteristics. Basins are generally ineffective when used for controlling clay-sized particles or when improperly designed or maintained. The purpose of this unit is to provide a

general overview of basin construction, usage, and effectiveness to assist regulatory agencies in reviewing and assessing the adequacy of soil erosion and sedimentation control plans. This unit is not intended to be used for detailed engineering design purposes. For specific design criteria, contact the Natural Resources Conservation Service, local conservation districts, consulting engineers, and other professional experts. Terms used in this unit are defined in Appendix 9A.

## **THE DIFFERENCE BETWEEN STORM WATER BASINS AND SEDIMENTATION BASINS**

It is important to draw a distinction between storm water basins and sedimentation basins. Storm water basins are permanent structures designed to replace the natural water storage of a site and provide some water quality improvement after the site is completed. Historically, the primary purpose of storm water basins was to reduce on-site and downstream flooding by controlling the rate of storm water discharge. Secondary benefits include water quality improvement such as sediment removal, aesthetics, and recreational opportunities. Many of these secondary benefits are now being incorporated into the design of storm water basins. However, it is important to remember that most storm water basins are not designed to remove sediment and they generally do not work well for that purpose.

Sedimentation basins are used during construction and are specifically designed to control off-site migration of sediment. The primary purpose of basins is to trap sediment and other coarse material. Secondary benefits can include controlling runoff and preserving the capacity of downstream reservoirs, ditches, diversions, waterways, and streams. Once construction is completed, sedimentation basins are often filled to match the final site grade or converted to function as storm water basins.

It is imperative that the type of basin to be constructed is identified in the project-planning phase, i.e. sedimentation or storm water. There are distinct design criteria to achieve these different functions. If the intention is for a storm water basin to serve as a temporary sedimentation basin during construction, then the design criteria to maximize sediment settling must be incorporated in the initial design. Some storm water basins control higher design flows and allow smaller design flows to pass through. To be used as sedimentation basins, they would need to control the smaller flows as well. This unit describes sedimentation basin review criteria; other manuals should be consulted for the review and design of storm water basins.

## **REVIEWING SEDIMENTATION BASIN DESIGN COMPONENTS**

A sedimentation basin is a depression in the land surfaces, with a defined surface area and storage volume, which receives sediment-laden runoff. By definition, they are impoundment structures designed to remove the sediment from runoff before it leaves the site and store the sediment.

Sedimentation basins can be designed as retention basins or detention basins. Retention basins are constructed to collect and retain runoff (Figure 9-2). Water leaves the basin through infiltration and evaporation, there are no outlet structures. Detention basins are constructed to collect and temporarily detain runoff (Figure 9-3). Water is discharged from the basin through an outlet structure designed to release the runoff at a reduced rate.



**Figure 9-2**



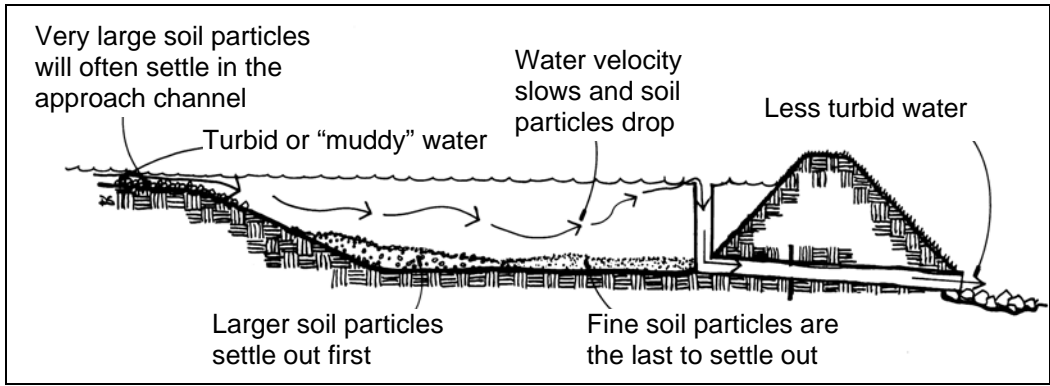
**Figure 9-3**

Sedimentation basins that are retention basins may be used in areas that have rapid infiltration rates, such as sandy soils. They should never be used in areas that are predominantly clay or silt with limited infiltration rates. Retention basins in sandy areas will become less and less effective with prolonged use. The clay and silt sized particles mixed with the sand will eventually seal the bottom of the basin and will greatly impede or stop the infiltration which is required for retention basins to be effective.

Sedimentation basins are generally designed to function as detention basins. The basic components of a sedimentation basin include an inlet, a storage area, and an outlet. An effective sedimentation basin detains runoff long enough for sediment to settle out of the water (Figure 9-4). The amount of settling is dependent upon the following characteristics:

- rate of inflow
- surface area of the basin
- velocity of flow through the basin
- particle size
- volume and/or detention time

To ensure maximum performance, each of the following design components must be carefully reviewed during the planning phase: the building site conditions and the sedimentation basin location, size, configuration, and structures, as well other design considerations. In addition to proper design, adequate maintenance is critical in achieving peak performance.



**Figure 9-4: Sedimentation basin operation.**

## Building Site Conditions

Soil type and expected runoff must be considered when assessing if a sedimentation basin is appropriate and feasible. The soils at a site play a critical role in determining runoff potential, erodibility, and settling rate. In general, the higher the rate of infiltration and transmission through the soil, the smaller the volume of runoff. For example, fine textured soils, such as clay, produce a higher runoff volume than do coarse textured soils, such as sand.

The effectiveness of sedimentation basins is primarily dependent upon the particle size(s) of the incoming sediment and the velocity that the sediment-laden water passes through the basin. In theory, sediment deposition increases as the water velocity decreases. Sedimentation basins are very effective in removing coarse-grained particles, such as sand, from the runoff water, but ineffective in removing very fine soil particles, such as clay.

Table 9-1 provides a general overview of the runoff potential, settling rate, and the effectiveness of sedimentation basins for a number of soil types. Generally, sedimentation basin effectiveness can be surmised based on soil type. It is important to remember that, due to glacial action in Michigan, many of the building sites include a variety of soil types. Each site should be carefully reviewed to identify the appropriate soil type and particle size from which to base the sedimentation basin design.

**Table 9-1: Soil Types and Sedimentation Basin Effectiveness.**

Soil Type	Runoff Potential	Settling Rate	Sedimentation Basin Effectiveness
Sand	Low	High	High
Sandy Loam	Low	High	High
Sandy Silt Loam	Moderate	Moderate	Moderate
Silt Loam	Moderate	Moderate	Moderate
Silty Clay Loam	Moderate	Low	Low
Clay Loam	Great	Low	Low
Clay	Great	Low	Low

## Sedimentation Basin Location

The location of the basin will be determined by the topography of the site (Figure 9-5), the size of the basin required, and land availability. Sedimentation basins must be placed to receive runoff prior to discharge off-site. Space must be identified on the development site to accommodate the necessary surface area of the basin. Ideally, this space will not impinge upon buildable land and will be obtained with the least amount of earthwork.

In the project-planning phase, the location and number of sedimentation basins to be used on-site will be determined. Several small basins at strategic locations provide greater flexibility in site design and greater environmental protection. The loss of sediment will be much greater if there is a failure from a single large basin than from one of a number of smaller basins. Several small basins may be effective for removing sand, but are ineffective for removing silt and clay-sized particles.

The basin(s) should be located where, if a failure of the embankment occurs, resource or property damage would be minimal. Sedimentation basins should not be located in or immediately adjacent to lakes, streams, or wetlands.



Figure 9-5

## Sedimentation Basin Size

The soil type and runoff volume will dictate the size of the basin required. There are a number of methods used for designing sedimentation basins which take one or both of these factors into consideration. Each method has limitations, however, and those limitations should be thoroughly reviewed prior to selecting a particular method. Another point to remember is that, regardless of what method is selected, clay and some silt-sized particles will not settle out in basins so the discharge will be turbid. The following are four commonly used methods:

Revised Universal Soil Loss Equation (RUSLE): Some individuals inappropriately use the RUSLE to determine the size of sedimentation basins. The RUSLE is an erosion model designed to compute longtime average soil loss from sheet and rill erosion; it does not predict soil loss from gully erosion. More importantly, it does not predict deposition rates. The volume of sediment generated on a site is relatively small when compared to the runoff volume from the site. Expected runoff must be

taken into account when sizing sedimentation basins. A basin sized to only accommodate the estimated sediment generated from a site would be substantially undersized. The RUSLE should only be used to determine the additional storage volume in the basin after the runoff volume has been determined.

Water Surface Area Method: This method assumes that a particular sized particle settles at a uniform velocity and that settling is independent of depth. The basin size is a function of the surface area, not the volume of the basin. The rate of settling is dependent on the rate of inflow, the surface area of the basin, the flow velocity through the basin, and the settling velocity of the individual particles. The settling velocity is determined by an equation known as Stoke's Law. To use this method, the designer must decide what design storm frequency should be used, such as a 1-, 2-, 5-, or 10-year storm, and what sized particle they want to capture, such as clay, silt, or sand. Once those decisions are made, calculations can be made to determine the basin surface area necessary to settle out the selected particle size. Detailed information on this method can be found in the Oakland County Drain Commissioner's Erosion Control Manual. It is questionable as to how valid Stoke's Law is for this type of application. This method was developed for designing clarifiers; the flow hydraulics in sedimentation basins varies considerably from those in clarifiers.

Detention Method: This method is based on the theory that the rate of sediment removal is dependent on the length of time that the runoff water and sediment is detained in the basin. Sediment deposition increases as detention time increases. Detention time in the basin is influenced by the storage volume in the basin and the discharge capacity of the outlet structure. Typically, a riser pipe with orifices is used to dewater sedimentation basins. The number and diameter of orifices in the riser pipe controls the quantity of water discharged. Detailed information on this method can be found in the Oakland County Drain Commissioner's Erosion Control Manual. This method is more applicable for controlling peak discharge rates than for determining sediment deposition. Based on any given storm frequency and peak discharge rate, calculations can be made to determine the appropriate riser pipe design. However, it is not clear how the specified detention relates to sediment deposition.

Storage Per Contributing Area Method - This method relies on a simple relationship between the storage volume and the size of the contributing drainage area of the basin. Using this method, the minimum storage volume should be based on 3,600 cubic feet per acre of contributing drainage area. The 3,600 cubic feet per acre is equivalent to one inch of runoff per acre. The sedimentation basin storage volume should be divided equally into "dry" or dewatered detention storage and "wet" or retention storage.

## Sedimentation Basin Configuration

The shape of the basin plays an important role in determining the effectiveness for removing sediment. Length to width ratios should be a minimum of 4:1 to maximize the flow path length within the basin. Length is the distance between the inlet and outlet structures. Instead of being a perfect rectangular shape, it is advisable to have the basin wedge-shaped, with the inlet at the narrow end. When physical site constraints prevent construction of basins with a length/width ratio of 4:1, consideration should be given to using baffles to increase the flow path length within the basin.

The surface area of the basin is more important than the depth in regards to sediment removal. Increasing the basin depth will provide additional storage; however, it will not significantly increase the rate of sediment removal. The basin depth should be a minimum of two feet and no shallower than the average distance from the inlet to the outlet (length) divided by 200.

To meet the above design criteria, all basins constructed to store less than 80,000 cubic feet (400 feet x 100 feet x 2 feet) of water must have a depth of 2 feet and all basins constructed to store more than 80,000 cubic feet of water must have a depth greater than 2 feet. The depth is dependent on the length of the basin. For example, a basin that is 600 feet long must have a depth of 3 feet (600 feet divided by 200 = 3 feet).

Basin dimensions can be determined using the following equations:

1. Volume = Length x Width x Depth
2. Basins with volumes less than 80,000 cubic feet  
Width =  $\sqrt{\text{Volume}/8}$   
Length = 4 x Width  
Depth = 2 feet (a constant)
3. Basins with volumes more that 80,000 cubic feet  
Width =  $\sqrt[3]{12.5 \times \text{Volume}}$   
Length = 4 x Width  
Depth = Length/200

Calculations used to derive equations 2 and 3 are presented in Appendix 9B.

## Sedimentation Basin Structures

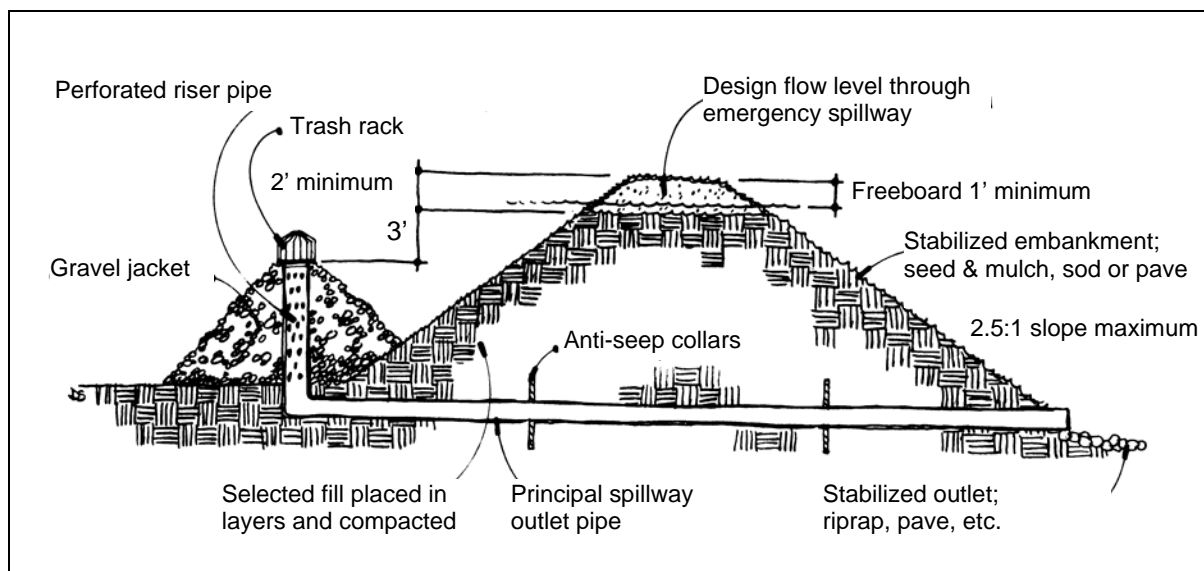
In addition to the sedimentation basin size, the inlet structure, principal outlet structure, and emergency spillway must be appropriately designed to ensure proper performance.

Inlet Structure - To minimize short-circuiting, the inlet and outlet structures should be at opposite ends of the sedimentation basin. Slopes of the inlet channel should be minimized to reduce velocities and potential inlet erosion.

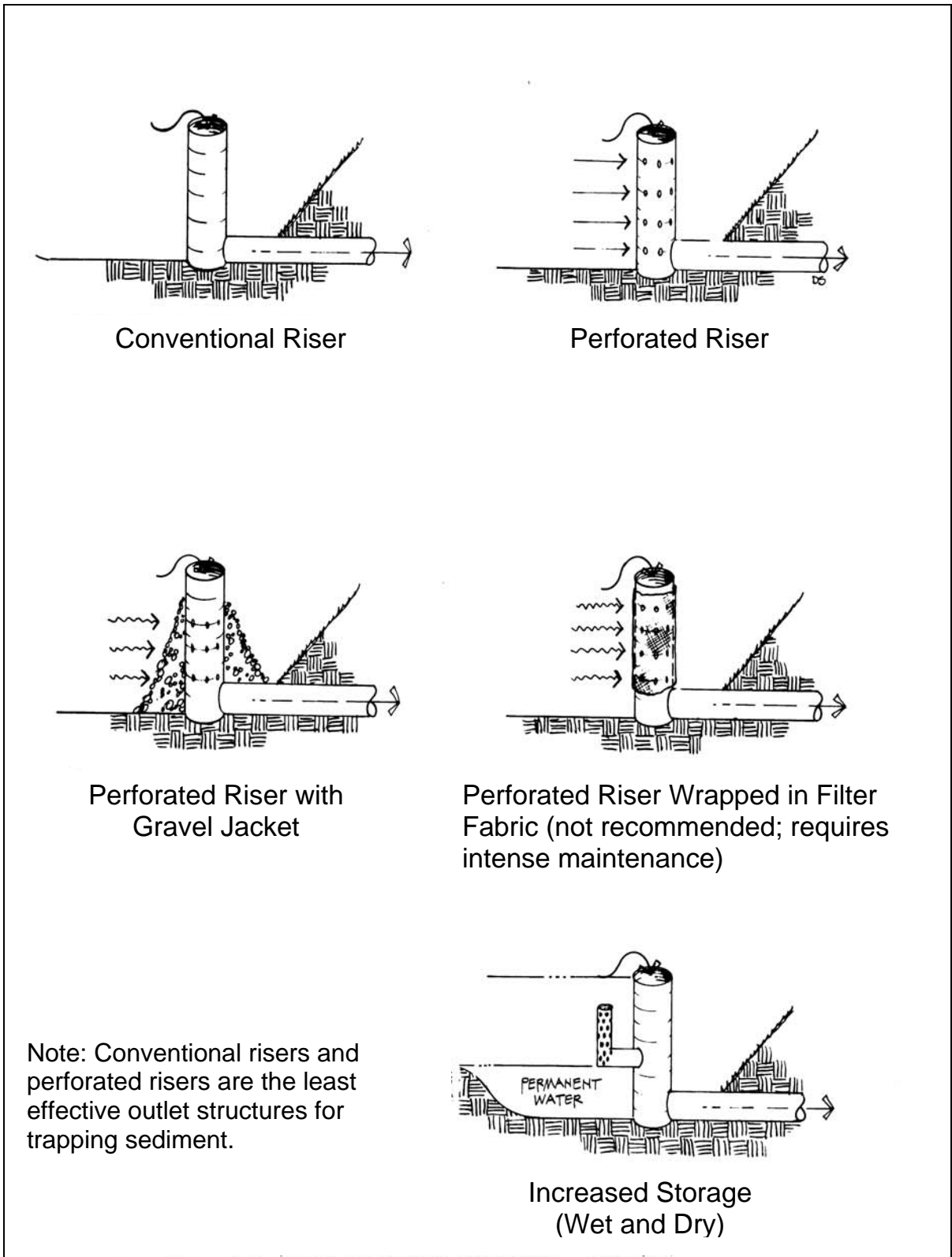
Principal Outlet Structure - Dewatering by a perforated riser pipe remains the least expensive and most widely used outlet structure. Minor changes in pipe perforation diameters or spacing can significantly alter basin discharge hydraulics and water detention times. An increase in sediment retention can be achieved if the perforated riser is encased in a gravel jacket (Figure 9-6). Figure 9-7 illustrates a number of options for outlet structures; each providing varying sediment removal efficiencies. The riser pipe should never be wrapped with filter fabric due to rapid clogging and intense maintenance requirements.

In the design of the outlet structure, the following elements must be addressed to ensure its effectiveness: design discharge, allowable head on the riser, diameter of the riser pipe, diameter of the barrel, and the size based on dewatering design. In addition, riprap, or other suitable material must be used to reduce erosion at the end of the outlet.

Emergency Spillway - The emergency spillway is designed to protect the embankment by providing a second outlet from the basin to accommodate runoff volumes that exceed the design capacity of the principal outlet structure. It also provides a safeguard in case the principal outlet structure becomes obstructed or blocked. The emergency spillway must be able to safely convey the excess runoff to a stabilized or protected area downstream of the embankment.



**Figure 9-6: Perforated riser pipe with gravel jacket.**



Conventional Riser

Perforated Riser

Perforated Riser with Gravel Jacket

Perforated Riser Wrapped in Filter Fabric (not recommended; requires intense maintenance)

Note: Conventional risers and perforated risers are the least effective outlet structures for trapping sediment.

Increased Storage (Wet and Dry)

**Figure 9-7: Principal outlet structures.**  
Adapted From: Watershed Protection Techniques – February 1997

## Other Design Considerations

To assist in achieving proper performance of the sedimentation basin, the following additional design considerations should be reviewed:

- Side slopes should be no greater than 3:1 (horizontal to vertical).
- Vegetation should be established on the side slopes prior to use (Figure 9-8).
- Water table depth should be determined to ensure full or partial dewatering based on design.
- Baffles may be added to increase the length of the water travel path.
- The outlet structure should be located in or near the embankment to allow for safe and easy access for cleaning.



**Figure 9-8**

## Sedimentation Basin Maintenance

Sedimentation basins need to be maintained regularly to achieve peak performance. Site personnel should examine the sedimentation basin when performing routine soil erosion and sedimentation control inspections. This inspection should include reviewing the basin embankments for subsidence, seepage, and erosion, as well as inspecting the integrity of the inlet, outlet, and emergency spillway. Any damage should be repaired daily.

Sediment should be removed when it has accumulated to no more than 50 percent of the basin design wet depth. If sediment is not removed regularly, the sedimentation basin may become a source of sediment to the receiving stream. Instead of trapping the sediment, the basin will temporarily detain it. The removed sediment should be disposed of at locations identified on the plan and contained and/or stabilized per the plan specifications.

## SAMPLE PROBLEMS

A developer is proposing to develop a 40-acre shopping center on a parcel of land with a total drainage area of 120 acres (Figure 9-9). Using the Storage Per Contributing Area Method (3600 ft<sup>3</sup>/acre), calculate the size and dimensions of the sedimentation basins required for the following scenarios:

Problem A: Runoff from the entire 120 acres drains through the sedimentation basin.

Problem B: Runoff from only the 40 acres being developed drains through the sedimentation basin. Runoff from the remaining undisturbed 80 acres is diverted around the construction site.

Problem C: Runoff from the undisturbed 80 acres is diverted around the construction site. Two sedimentation basins are constructed within the construction area; one basin collects runoff from 12 acres and the other basin collects runoff from 28 acres. (Calculate size and dimensions collecting water from the 12 acres.)

### **Problem A** (120 acres drain into the basin)

Step 1: Determine the total storage volume of the basin.

$$\text{Volume} = 120 \text{ acres} \times 3600 \text{ ft}^3 \text{ per acre} = 432,000 \text{ ft}^3$$

Step 2: Determine the width of the basin. (Basin is greater than 80,000 ft<sup>3</sup>)

$$\text{Width} = \sqrt[3]{12.5 \times \text{Volume}} = \sqrt[3]{12.5 \times 432,000 \text{ ft}^3} = \sqrt[3]{5,400,000 \text{ ft}^3} = 175.4 \text{ ft}$$

Step 3: Determine the length of the basin.

$$\text{Length} = 4 \times \text{Width} = 4 \times 175.4 \text{ ft} = 701.6 \text{ ft}$$

Step 4: Determine the depth of the basin.

$$\text{Depth} = \text{Length}/200 = 701.6 \text{ ft}/200 = 3.5 \text{ ft}$$

Step 5: Check to see if the above dimensions are correct.

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Depth} = 701.6 \text{ ft} \times 175.4 \text{ ft} \times 3.5 \text{ ft} = 430,712 \text{ ft}^3$$

(Answer is very close to volume calculated in Step 1; difference is due to rounding off numbers.)

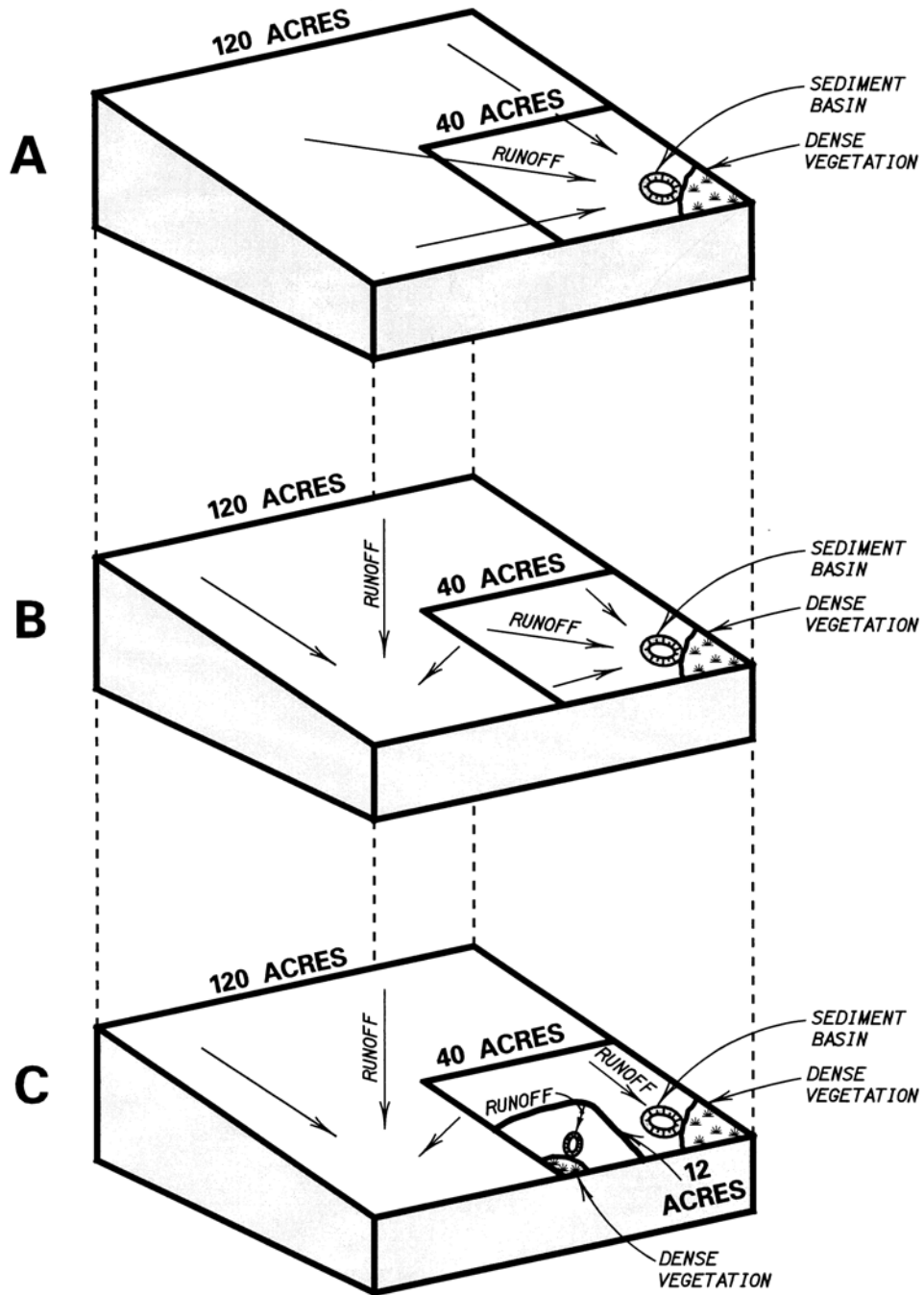


Figure 9-9: Sample problem drainage areas.

**Problem B** (40 acres drain into the basin)

Step 1: Determine the total storage volume of the basin.

$$\text{Volume} = 40 \text{ acres} \times 3600 \text{ ft}^3 \text{ per acre} = 144,000 \text{ ft}^3$$

Step 2: Determine the width of the basin. (Basin is greater than 80,000 ft<sup>3</sup>)

$$\text{Width} = \sqrt[3]{12.5 \times \text{Volume}} = \sqrt[3]{12.5 \times 144,000 \text{ ft}^3} = \sqrt[3]{1,800,000 \text{ ft}^3} = 121.7 \text{ ft}$$

Step 3: Determine the length of the basin.

$$\text{Length} = 4 \times \text{Width} = 4 \times 121.7 \text{ ft} = 486.8 \text{ ft}$$

Step 4: Determine the depth of the basin.

$$\text{Depth} = \text{Length}/200 = 486.8 \text{ ft}/200 = 2.4 \text{ ft}$$

Step 5: Check to see if the above dimensions are correct.

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Depth} = 486.8 \text{ ft} \times 121.7 \text{ ft} \times 2.4 \text{ ft} = 142,185 \text{ ft}^3$$

**Problem C** (12 acres drain into the basin)

Step 1: Determine the total storage volume of the basin.

$$\text{Volume} = 12 \text{ acres} \times 3600 \text{ ft}^3 \text{ per acre} = 43,200 \text{ ft}^3$$

Step 2: Determine the width of the basin. (Basin is less than 80,000 ft<sup>3</sup>)

$$\text{Width} = \sqrt{\text{Volume}/8} = \sqrt{43,200 \text{ ft}^3/8} = \sqrt{5400 \text{ ft}^3} = 73.5 \text{ ft}$$

Step 3: Determine the length of the basin.

$$\text{Length} = 4 \times \text{Width} = 4 \times 73.5 \text{ ft} = 294 \text{ ft}$$

Step 4: Determine the depth of the basin.

$$\text{Depth} = 2 \text{ ft (Per design criteria on page 6, all basins with a volume less than 80,000 feet must have a minimum depth of 2 feet.)}$$

Step 5: Check to see if the above dimensions are correct.

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Depth} = 294 \text{ ft} \times 73.5 \text{ ft} \times 2 \text{ ft} = 43,218 \text{ ft}^3$$



## **GLOSSARY**

<b><u>Term</u></b>	<b><u>Description</u></b>
Detention	The temporary storage of storm runoff, to control peak discharge rates and provide gravity settling of pollutants.
Detention Time	The amount of time that a volume of water will remain in a detention basin.
Drainage Area	The area of a watershed that contributes runoff.
Emergency Spillway	A depression in the embankment of a pond or basin which is used to pass peak discharges greater than the maximum design storm controlled by the pond.
Erosion	The process by which the land surface is worn away by the action of wind, water, ice, or gravity.
Orifice	An opening in a wall or plate.
Peak Discharge	The maximum rate at which runoff passes a given location in terms of volume per unit of time.
Retention	The holding of runoff in a basin without release, except by means of evaporation or infiltration.
Riser	A vertical pipe extending from the bottom of a basin that is used to control the discharge rate from the basin for a specified design storm.
Runoff	The excess portion of precipitation that does not infiltrate into the ground, but "runs off" and reaches a stream, water body, or storm sewer.
Runoff Coefficient	The ratio of the amount of water that is not absorbed by the land surface to the total amount of water that falls during a rainstorm.
Sediment	Detached soil particles that settle on the land or in a water body.
Sedimentation	The process whereby the detached particles generated by erosion are deposited elsewhere on the land or in a water body.
Time of Concentration	The time required for surface runoff from the most remote part of a drainage basin to reach the basin outlet.
Watershed	An area of land that contributes runoff to a body of water or design point.

## EQUATIONS

### Calculations used to derive equations on page 9-7.\*

1. Basins with volumes less than 80,000 ft<sup>3</sup>

$$V = L \times W \times D \quad (L = 4W \text{ and } D = 2)$$

$$V = 4W \times W \times 2$$

$$V = 8W^2$$

$$V/8 = W^2$$

$$\sqrt{V/8} = W$$

2. Basins with volumes greater than 80,000 ft<sup>3</sup>

$$V = L \times W \times D \quad (L = 4W \text{ and } D = L/200 = 4W/200)$$

$$V = 4W \times W \times (4W/200)$$

$$V = 16W^3/200$$

$$V = W^3/12.5$$

$$12.5V = W^3$$

$$\sqrt[3]{12.5V} = W$$

\* V = volume

W = width

L = length